Hawaii Bioenergy Master Plan

Volume I

Prepared for

State of Hawaii
Department of Business, Economic Development and Tourism

By

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Executive Summary

This Bioenergy Master Plan report was developed in accordance with Act 253, Session Laws of Hawaii (SLH) 2007, which called for a bioenergy master plan to "set the course for the coordination and implementation of policies and procedures to develop a bioenergy industry in Hawaii." The State Department of Business, Economic Development and Tourism (DBEDT), tasked with preparation of the plan, contracted with the University of Hawaii's Hawaii Natural Energy Institute (HNEI) in mid-2008 to achieve the specifications of the legislation.

Importantly, Act 253 Part III states: "**The primary objective of the bioenergy master plan shall [be to] develop a Hawaii renewable biofuels program to manage the State's transition to energy self-sufficiency based in part on biofuels for power generation and transportation**." Thus, the objectives of the legislation - bioenergy industry and bioenergy program development - were overarching considerations in the examination of the specified issues and outcomes. These issues and outcomes were therefore studied in the context of the primary value chain components necessary for a successful bioenergy industry – feedstock production and logistics, conversion, distribution, and end use. Further, the recommendations that comprise the Roadmap are presented to be carried out programmatically, by and through a Hawaii Renewable Biofuels Program.

The report is organized in three volumes as follows:

Volume I includes four parts, reflecting the approach necessary to meet the legislated objectives and guidelines:

- Part 1 – "Overview" provides an overview including Hawaii's energy situation and the role of biofuels in Hawaii's energy mix, background of events leading to Act 253, and the approach to this project. A detailed discussion of the approach is provided to enable the reader to understand the context of this effort.

- Part 2 – "Perspectives on the Bioenergy Industry" provides the executive summaries and recommendations from nine Issue Reports: water and land resources, distribution infrastructure, labor resources, technology, permitting, financial incentives, business partnering, economic impacts, and environmental impacts.

- Part 3 – "Potential and Actions" addresses the five outcomes, further described below, prescribed by Act 253 including "Recommendations for a Hawaii Bioenergy Master Plan".

- Part 4 – "Conclusion" provides closing comments and observations.

Volume II includes the full text of nine separate Issue Reports prepared to meet the requirements of Act 253. To foster stakeholder involvement in the preparation of this report, several stakeholder events were held and a website was established to disseminate information, and to receive input from stakeholders during the project. Input from the breakout session discussions at the April 2009 stakeholder meeting is incorporated in the Issue Reports.

Volume III includes stakeholder review comments on the draft plan and team responses.

The five outcomes that comprise Volume (Vol) I Part 3 are as follows:

OUTCOME I – Does Hawaii Have The Potential To Rely On Biofuels As A Significant Renewable Energy Resource?

Act 253 recognizes the need for commitment of resources in its requirement that the master plan address an "evaluation of Hawaii's potential to rely on biofuels as a significant renewable energy resource". This report responds to this outcome in Section 3.1 (Vol I). For this project, a biofuels production scenario based on 20% displacement of 2007 Hawaii fuel consumption and projected additional bioenergy use was used to define "significant." The analysis indicates that Hawaii does have the potential to meet the production scenario goals.

OUTCOME II – Recommendations for a Hawaii Bioenergy Master Plan

Recommendations for development of a bioenergy industry, from the Issue Reports, are summarized in Section 3.2.1 (Vol I). The recommendations are diverse, reflecting the Legislature's understanding of the far reaching impacts and needs of a bioenergy industry – land and water resources, distribution infrastructure, labor, production and conversion technologies, permitting, financial incentives, business partnering, and economic and environmental impacts.

The industry Roadmap, Section 3.2.2 (Vol I), presented in the table below, identifies priority actions for a Renewable Biofuels Program in alignment with four primary areas of industry concern – availability and use of resources, value chain interdependencies, industry impacts, and program level coordination. These actions are recommended for implementation in the initial three years of the program. The majority of the recommended near-term actions should be continued at least through the mid-term (4 – 9 years) to be responsive to advancements in crop and conversion technologies and changing market conditions. Longer-term (10 – 20 years) actions are those that should be continued as an on-going practice or capability to support the evolution of the industry. These are summarized as follows.

Roadmap Action Item	Near Term			Mid-Term			Long Term		
	2010	2011	2012	2013	2015	2018	2020	2025	2030
Program Level Coordination									
1. Establish a Renewable Biofuels Program: DBEDT shall establish a bioenergy program (Program) to manage the state's transition toward energy self sufficiency based in part on bioenergy for electricity and transportation. The bioenergy program shall receive $1.5 million dollars per year to establish three staff positions using up to $340,000 and the balance shall be used to fund assessments and co-fund demonstration projects as identified in the bioenergy master plan. Assessment and demonstration projects shall be prioritized by bioenergy technical advisory group and stakeholder input. Program personnel shall schedule regular outreach meetings to exchange information with communities on all islands where bioenergy development is proposed. In its first year, the Program shall develop an appropriate tax credit based on green house gas reductions resulting from the displacement of fossil fuels by bioenergy products that accrues to Hawaii bioenergy feedstock producers and bioenergy conversion facilities. Activities of the bioenergy program shall be reported to the legislature annually in December.									
2. Establish Bioenergy Technical Advisory Group that includes one representative each from DBEDT, the Department of Land and Natural Resources (DLNR), the Department of Agriculture (DOA), the Department of Hawaiian Home Lands (DHHL), the Department of Health (DOH), and 18 other members representing the bioenergy industry (3), refiners (2), agricultural producers (4), environmental concerns (3), utilities (3), the Office of Hawaiian Affairs (1), and bioenergy research (2). The advisory group will provide advisory support to the Renewable Biofuels Program.									
3. Involve specific communities through all steps of the process.									
4. Establish Community-Based Bioenergy Working Group.									
5. Maintain an up-to-date list of State and Federal incentives, and provide guidance to prospective bioenergy value-chain business owners on how to apply for incentives (grants, loans, tax credits, etc.).									
6. Synergize the bioenergy master plan with the Hawaii Clean Energy Initiative goals.									
7. Encourage close collaborations among scientists, researchers, policy makers, extension agents, and farmers as a comprehensive link of information dissemination in order to provide the context for informed decision-making.									
8. Establish an independent fact-finding and policy discussion forum, based in science, technology assessment and land use analysis to support programmatic and policy decisions.									

Roadmap Action Item	Near Term			Mid-Term			Long Term		
	2010	2011	2012	2013	2015	2018	2020	2025	2030
9. Provide research, education, and outreach on the role of biofuels.									
10. Act swiftly to capture funding made available through federal programs, especially related to economic stimulus.									
11. Work to promote new workflow processes within State and County permitting agencies as well as efficient interagency cooperation.									
12. Develop and maintain a bioenergy partner database similar to the Bioenergy Partner Catalog in this report.									
13. Facilitate partnerships through a matchmaker. The State can significantly encourage necessary bioenergy partnerships through the creation of a position or program that facilitates such partnerships…and acting as an industry advocate and government liaison.									
14. Position Hawaii's bioenergy strategy in the context of vital State interests such as energy security and greenhouse gas emissions reduction targets.									
15. Clarify whether the State should only attempt to attract those parts of the industry where wages are above manual labor level.									
<u>Availability and Use of Resources</u>									
1. Develop and prepare a single, clear, consistent policy on use and lease of State lands for agriculture, grazing, forestry, and bioenergy feedstock production, in consultation with relevant stakeholders and to promulgate policies of energy and food security. The plan shall include components describing favorable lease terms for bioenergy demonstration projects. Report of this policy shall be submitted to the Legislature by December 2011.									
2. Implement land policy developed in December 2011.									
3. Provide a tax credit of __% of investment to support the refurbishment and continued maintenance of irrigation systems supplying water to agricultural lands of importance to the State of Hawaii that are used for food or bioenergy feedstock production, employ appropriate conservation agriculture practices, and are committed to production agriculture or bioenergy feedstock production for 25 years.									
4. Study the potential effect of bioenergy crop production on drinking water resources. Assess influence of new groundwater resources for biofuel production on aquifer recharge and estimated aquifer sustainable yields.									
5. Conduct a systematic study for cost/benefit analyses of potential reuse of treated water for bioenergy crops.									
6. Increase sustainable water supplies (traditional and non-traditional) for agriculture including bioenergy and biomass crops.									

Roadmap Action Item	Near Term			Mid-Term			Long Term		
	2010	2011	2012	2013	2015	2018	2020	2025	2030
7. Assess the potential for sustainable use of resources for bioenergy crops and other agriculture including ranch lands. Prioritize the use of resources for production of food and fuel.									
8. Encourage appropriate conservation agriculture practices to help reduce water consumption, use of pesticides and fertilizers, and pollution.									
9. Maintain land currently used for agriculture and forestry, and additionally, increase land available for bioenergy use sufficient to support biofuel production.									
10. Conduct research on Hawaii-specific crops and Hawaii-specific crop incentives.									
11. Develop cropping systems that integrate bioenergy crops with current crops for efficient utilization of resources such as land, water, time, and labor.									
12. Develop a decision support system to match biological characteristics of crops to physical characteristics of soil and to environmental and ecological acceptance.									
13. Test water-harvesting technologies in Hawaii to minimize water runoff and maximize water storage.									
<u>Value Chain Interdependencies</u>									
1. Provide a __% tax credit for investments made to convert existing infrastructure to be compatible with bioenergy products or for construction of new infrastructure components for transporting and distributing bioenergy products derived from bioenergy feedstocks that are produced in Hawaii. The credit will be available in the first year that 50% of the total product volume of the infrastructure component is a bioenergy product.									
2. Provide funding for a full-time, tenure track, faculty position in the College of Tropical Agriculture and Human Resources (CTAHR) at the University of Hawaii at Manoa to conduct research and demonstration of appropriate bioenergy feedstock harvesting technologies suitable for Hawaii's conditions.									
3. Fund a continued bioenergy technology assessment activity that can provide updated information on the status of bioenergy conversion pathways and estimates of energy return on investment (EROI) for bioenergy value chain components.									
4. Provide support to industry for preliminary feasibility studies of selected energy crop conversion alternatives to identify the most promising technology pathways and the resource requirements for those pathways.									
5. Develop funding mechanisms to leverage federal and private funds and support demonstration projects.									

Roadmap Action Item	Near Term			Mid-Term			Long Term		
	2010	**2011**	**2012**	**2013**	**2015**	**2018**	**2020**	**2025**	**2030**
6. Establish a bioenergy/biofuel development fund to support research, and technology development and demonstration.									
7. Reconcile investors' concern for exit strategies with biofuels incentives.									
8. Provide incentives for early implementation of bioenergy production.									
9. Implement a purchase program, (targeted at slightly below market rates to avoid competing with private industry) for surplus crops, with restrictions on annual volumes and the duration of the program.									
10. Develop policy to provide benefit streams to bioenergy projects that result in increased State energy resiliency, reduced greenhouse gas emissions, and benefits to rural communities in Hawaii.									
11. Test biofuels under development or in a pre-commercial stage for compatibility with existing petroleum equipment and distribution assets.									
Industry Impacts									
1. Develop a methodology for evaluation of bioenergy projects based on the principles of life cycle assessment (including energy inputs vs. energy outputs and greenhouse gas balances) in consultation with relevant stakeholders.									
2. Establish policy and process whereby State agencies will require life cycle assessments for bioenergy development proposals that seek to use State lands or State funds.									
3. Develop a certification program for biofuels to safeguard Hawaii's unique native eco-systems and culture, and support sustainable biofuels development.									
4. Assess the impacts of rising world oil prices and increasing local production of bioenergy on the two refineries.									
5. Continue assessment of economic impacts of bioenergy production as industry develops and data become available.									
6. Encourage use of existing infrastructure to minimize potential environmental impacts from the development of new infrastructure.									

From the action items in the preceding table, the following items are prioritized for immediate near term action.

1. Establish a Bioenergy Program

To carry out the priority issue area recommendations, a Bioenergy Program must be adequately staffed and funded. The State Department of Business, Economic Development and Tourism (DBEDT) is the most likely location for the program, consistent with the statutory role of the State's Energy Resources Coordinator (ERC).

Program resources should include sufficient personnel and dedicated financial resources commensurate with this industry's vital importance to the economic and energy future of the state. Program staffing of three professionals with bioenergy technical and/or policy experience is recommended. The program term should be no less than 10 years to ensure continuity of industry development, with annual dedicated funding for personnel and program activities. Determination of additional resources to assure the viability of the industry value chain is subject to the assessments recommended as priority actions.

Program activities will include:

- Assessment, research and demonstration projects which will be prioritized by a bioenergy technical advisory group and stakeholder input.
- Community involvement and education and outreach, including conduct of regular outreach meetings to exchange information with communities on all islands where bioenergy development is proposed.
- Support of partnerships including maintenance of partner database.
- Policy and planning activities, in coordination with the bioenergy technical advisory group and stakeholders, including but not limited to the planning and policy requirement items listed in the priority issue area recommendations above.
- In its first year, development of an appropriate tax credit based on green house gas reduction resulting from the displacement of fossil fuels by bioenergy products that accrues to Hawaii bioenergy feedstock producers and bioenergy conversion facilities.
- Industry coordination activities including but not limited to such items listed in the priority issue area recommendations above.
- Annual reports to the legislature.

Responsible party: DBEDT
Implementation date: 2010 - 2020
Funding: $1.5 million annually including $340,000 for 3 full-time equivalent positions

2. **Establish a bioenergy technical advisory group**

A bioenergy technical advisory group should be established and facilitated by DBEDT. The advisory group should include one representative each from DBEDT, the Department of Land and Natural Resources (DLNR), the Department of Agriculture (DOA), the Department of Hawaiian Home Lands (DHHL), the Department of Health (DOH), and 18 other members representing the bioenergy industry (3), refiners (2), agricultural producers (4), environmental concerns (3), utilities (3), the Office of Hawaiian Affairs (1) and bioenergy research (2). The advisory group will provide advisory support to the Renewable Biofuels Program.

Responsible party: DBEDT
Implementation date: 2010 - 2020

3. Develop clear and consistent policy for use of State lands
A single, clear, consistent policy on use and lease of State lands for agriculture, grazing, forestry, and bioenergy feedstock production, in consultation with relevant stakeholders and to promulgate policies of energy and food security should be developed. The policy should include components describing favorable lease terms for bioenergy demonstration projects and lease application and process requirements.

Responsible parties: DBEDT, DLNR, DOA, DHHL
Report date: Due to the Legislature by December 2011.
Policy implementation: 2012

4. Develop methodology for evaluation of bioenergy projects
A methodology for evaluation of bioenergy projects based on the principles of life cycle assessment (including energy return on investment) should be developed in consultation with relevant stakeholders.

Responsible party: DBEDT
Report date: Due to the Legislature by December 2011.

5. Require Life Cycle Analysis for use of State lands or funding support
Establish policy and process whereby State agencies will require life cycle assessments for bioenergy development proposals that seek to use State lands or State funds.

Responsible party: DBEDT
Policy implementation: 2012

6. Provide a tax credit for irrigation systems
The State should provide a tax credit of __% of investment to support the refurbishment and continued maintenance of irrigation systems supplying water to agricultural lands of importance to the State of Hawaii that are used for food or bioenergy feedstock production, employ appropriate conservation agriculture practices, and are committed to production agriculture or bioenergy feedstock production for 25 years. The tax credit may be used over the 25 year period of performance.

Responsible party: Legislature/Administration
Tax credit implementation: 2012

7. Provide a tax credit for infrastructure systems
Provide a __% tax credit for investments made to convert existing infrastructure to be compatible with bioenergy products or for construction of new infrastructure components for

transporting and distributing bioenergy products derived from bioenergy feedstocks that are produced in Hawaii. The credit will be available in the first year that 50% of the total product volume of the infrastructure component is a bioenergy product.

Responsible party: Legislature/Administration
Tax credit implementation: 2012

8. Appropriate funds for a research position

The State shall provide funding for a full-time, tenure track, faculty position in the College of Tropical Agriculture and Human Resources (CTAHR) at the University of Hawaii at Manoa to conduct research and demonstration of appropriate bioenergy feedstock harvesting technologies suitable for Hawaii's conditions.

Responsible party: University of Hawaii - CTAHR
Faculty Hire: 2011

OUTCOME III – Strategic Partnerships for the Research, Development, Testing, and Deployment of Renewable Biofuel Technologies and Production of Biomass Crops

Section 3.3 (Vol I), Strategic Partnerships, identifies partnering arrangements that have arisen from participants identifying a common goal or information gap. Future partnerships to enhance biofuels development can be expected to form among public, private, and nonprofit organizations that leverage funds and or expertise from all parties. In keeping with the value chain approach, partnerships including land owners, biomass (agriculture or forestry) producers, technology providers, bioproduct distributors, major end-users, and investors can be envisioned. Depending on the purpose, partnerships may form vertically across the value chain or horizontally to address needs identified in one industry segment. County, state, and federal entities can be envisioned as participants in the roles of land owners, investors for the public good, and as research providers.

Several entities are already in place to help facilitate strategic partnering at points along the value chain. The Hawaii Clean Energy Initiative, the Hawaii Renewable Energy Development Venture, the Hawaii State Energy Office, University of Hawaii, Hawaii Agriculture Research Center, private companies, and other research institutions all can contribute to partnership building due to their involvement in activities related to bioenergy research, development, testing, and deployment. Coordination between these groups is important and should be fostered.

OUTCOME IV - Biofuels Demonstration Projects

Section 3.4 (Vol I) summarizes demonstration projects that were identified largely from stakeholder input. Candidate projects fell in the categories of feedstock production, conversion technology verification, and transportation/end use demonstration.

Projects designed to demonstrate crop performance/feedstock production included:

- field plantings of a variety of energy crop candidates in key climatic zones on different islands to determine plant response to varied environmental and management factors;
- farmer operated/managed feedstock demonstrations to provide realistic evaluation of production costs and resulting yields;
- feedstock production coupled with technology demonstration to include harvesting and supply logistics.

Projects designed to verify conversion technologies include:

- oil crop production, harvesting, and oil extraction from the crop product with multiple uses for the oil such as biodiesel production via transesterification, hydrotreating for renewable diesel, direct firing, or production of biogases;
- pyrolysis of biomass to produce a bio-oil that can be transported and converted in one of the petroleum refineries for production of fuel substitutes or in direct fired power generation applications;
- gasification or reforming of biomass to produce a syngas for direct use or the production of renewable electricity or biofuels that may include renewable diesel or other synthesis products;
- controlled storage of biofuels with monitoring of product quality over time to assess product life, and testing to determine potential impacts of quality deterioration on end use.

Demonstration projects related to transportation applications included:

- private cars and/or fleet vehicles such as buses converted to operate on biofuels;
- larger marine vessel conversion to renewable diesel (e.g. State of County owned or operated)

<u>OUTCOME V – Promotion of Hawaii’s Renewable Biofuels Resources to Potential Partners and Investors for Development in Hawaii as Well as for Export Purposes</u>

Section 3.5 (Vol I), identified several activities that could promote Hawaii's renewable biofuels resources. These included legislative actions that reduce the regulatory burden and create financial incentives for project development, maintenance of the Hawaii Bioenergy Master Plan website, continued and active engagement by master plan participants in conferences and workshops that provide opportunities for establishing contacts, and keeping the State energy office staff engaged and informed about the bioenergy landscape.

The comprehensive approach required by Act 253, SLH 2007 has pointed to the requirement for a framework to enable government and stakeholders to work together to address the needs of the industry. During this effort, information gaps precluded project team recommendations on specific feedstocks, conversion technologies, or bioenergy products. For example, the economic impacts analysis was limited to data on sugar cane. Additional assessments are necessary to more fully address the adequacy of Hawaii’s water and land resources for bioenergy crops. Life cycle analyses of the various bioenergy value chains that can be considered for Hawaii -- including feedstock production options and impacts, energy requirements, emissions, land use changes, water use requirements, wastes, logistics, conversion technology alternatives, distribution, and end use – are not currently available.

This bioenergy master plan therefore points to a path for government and industry action needed to enable informed policy development, appropriate programmatic actions, response to stakeholder concerns, and decisions concerning feedstocks, conversion technologies, and products. It recognizes the need for government and stakeholders to continually monitor the industry and reset the priorities as technologies and opportunities evolve.

Reliable information will reduce the risk of unintended consequences for policy makers or business risk for investment partners. Information needs are represented in part by the following questions that have been raised during the course of this project:

- What feedstocks have the highest yields on non-prime agriculture land under various climatic conditions and management practices?
- Can energy crops be grown sustainably and economically?
- To what degree should agricultural land be dedicated to biofuel crops?
- What biofuel products make the most sense for Hawaii's future needs?
- Are the conversion technologies for these biofuels commercially available?
- How do we reduce the economic and technology risks inherent with new technologies?
- What will be the cost to modify Hawaii's distribution infrastructure to accommodate the various biofuel options?
- What are the appropriate incentives to encourage the production of energy feedstocks?

The development of a bioenergy industry as a component of a more secure and stable energy future for Hawaii will take the sustained support and commitment by industry, government, and the community. The industry is characterized by complexity and change. For Hawaii, there are additional challenges that relate to the need for low cost and reliable feedstock supplies. Hawaii is a unique place that may require unique solutions. With the wide range of issues, stakeholders, value chain components, changing market conditions, continuing technology innovations, and environmental incentives and disincentives, industry planning cannot and should not be a finite nor close-ended task.

Hawaii Bioenergy Master Plan

Volume I

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Part 1: Overview

"The department of business, economic development, and tourism shall develop and prepare a bioenergy master plan in consultation with representatives of the relevant stakeholders. The primary objective of the bioenergy master plan shall develop a Hawaii renewable biofuels program to manage the State's transition to energy self-sufficiency based in part on biofuels for power generation and transportation."

Act 253, SLH 2007

1.0 Introduction

This Bioenergy Master Plan report was developed in accordance with Act 253, Session Laws of Hawaii (SLH) 2007, which called for a bioenergy master plan to "set the course for the coordination and implementation of policies and procedures to develop a bioenergy industry in Hawaii." The State Department of Business, Economic Development and Tourism (DBEDT), tasked with preparation of the Plan, contracted with the University of Hawaii's Hawaii Natural Energy Institute (HNEI) in mid-2008 to achieve the specifications of the legislation.

Importantly, Act 253 Part III states: "**The primary objective of the bioenergy master plan shall [be to] develop a Hawaii renewable biofuels program to manage the State's transition to energy self-sufficiency based in part on biofuels for power generation and transportation**." Thus, the objectives of the legislation - bioenergy industry and bioenergy program development - were overarching considerations in the examination of the specified issues and outcomes. These issues and outcomes were therefore studied in the context of the primary value chain components necessary for a successful bioenergy industry – feedstock production and logistics, conversion, distribution, and end use.

Several stakeholder events were held and a website was established to disseminate information, and to receive input from stakeholders during the project. Input, especially from the breakout session discussions at the April 2009 stakeholder meeting, is incorporated in the Issue Reports (Vol II).

A Hawaii bioenergy industry is a necessary component of a more secure and stable energy future for Hawaii and its development will require the sustained coordination, support, and commitment of industry, government, and the community.

1.1 The Case for Hawaii Grown Biofuels

1.1.1 Hawaii's Energy Situation

Against the current backdrop of rising oil prices, a global recession, conflict in oil producing regions, and heightened anxiety over global warming, Hawaii's long standing goal of energy independence has become a rallying cry for change. The State's extreme over-reliance on imported petroleum as its primary energy source, increasingly from countries in politically unstable areas, is well known. Hawaii relies on imported oil to meet nearly 77% of its electricity needs, the highest percentage in the country. Without indigenous fossil fuels (petroleum, coal, and natural gas) and with isolated island-constrained utility grids, Hawaii imports nearly 50,000,000 barrels per year of crude and refined petroleum products to satisfy its need for electricity and transportation fuels. Hawaii's reliance on imported fuels, burned to power ships, planes, vehicles and power plants, results in billions of dollars drained annually from Hawaii's economy. Increasing global competition for diminishing petroleum reserves threatens the future stability of Hawaii's oil-dependent energy economy. The higher the cost per barrel, the higher will be the negative economic and societal impacts on Hawaii's businesses, environment, schools, and quality of life.

For decades, since the oil shortages of the 1970's, Hawaii's leadership has recognized Hawaii's energy vulnerability and has acted to codify State priorities and, especially in the 1970s and 1980s, to fund research, development, and demonstration projects to transition the state to increased use of its indigenous renewable energy resources. These efforts have provided the groundwork for current efforts to move the state toward greater use of its wind, solar, geothermal, ocean wave, ocean thermal, and biomass resources. While "cheap" oil derailed the focus on renewable energy resources in the mid-1980s, the price shocks of 2008 have prompted renewed urgency and resolve to meet the challenges of Hawaii's precarious energy situation.

This report has examined the wide range of components that must be in place for a bioenergy industry to succeed, many of which require a longer-term programmatic commitment to build. In order to reduce the state's extreme vulnerability to off shore oil markets and supplies, and to achieve a more secure energy future, Hawaii must commit to sustained support for industry development.

1.1.2 The Role of Bioenergy in Hawaii's Energy Mix

For generations, biomass-based energy, primarily waste from sugar cane production, bagasse, has been used in the state to produce electricity. In 1970, biomass energy provided nearly 12% of Hawaii's electricity. However, with the decline of Hawaii sugar operations and the increase in electricity consumption, biomass energy, other than from municipal solid waste, currently provides less than 1% of Hawaii's electrical energy supply.

Nevertheless, biomass for electricity generation or transportation fuels is viewed as an essential part of a more secure energy future because it can be locally sourced, is renewable, can help to mitigate green house gases, can support jobs diversification and economic development, and is a flexible and transportable fuel source. Biomass resources are generated by agricultural, forestry, and urban activities. Agricultural and forestry resources include residues from harvesting and processing operations, such as bagasse, saw mill slab wood, and crops and trees grown specifically for energy use. Urban biomass resources include the biogenic fraction of municipal solid waste, land fill gas, and biosolids and methane-rich gas generated from waste water treatment plant operations. Each of these resources can be converted into bioenergy products such as fuels, chemicals, heat, or electricity.

Regardless of the type of biofuel end product, however, biofuels are a form of energy that is transportable from source to the end-user, and from one island to another using conventional distribution systems. Unlike wind, solar, geothermal, or ocean energy, biofuels can be used in place of liquid fossil fuels like petroleum, solid fossil fuels like coal, or gaseous fuels, with relatively little technology modification by transportation and power generation end users. Especially for Hawaii's industrial ground and marine transport, biofuels present the only nearer term opportunity for fuel substitution.

Additionally, unlike the variable generation of wind and sun, the energy stored in biofuels is available on demand. When used in combination with renewable resources such as wind energy, the ability of biofuels to be available on demand can stabilize Hawaii's utility grids to enable greater use of these variable resources.

The increased use of the state's biomass resources for the production of fuels for transportation and electricity will diversify Hawaii's energy supplies and increase energy and economic security and sustainability. Thus, with a bioenergy industry based on locally sourced biomass of sufficient size to displace a significant amount of imported petroleum, Hawaii could enjoy greater economic stability and retention of dollars spent on imported fuels. The development of a sustainable bioenergy industry can yield long-term benefits for Hawaii's environment, while creating jobs and strengthening the state's energy security.

1.2 Toward Development of a Hawaii Bioenergy Industry

1.2.1 State Policy Support

For a number of compelling reasons, the use of biomass as a locally available source for renewable energy is attractive. Consequently, key landowners, business entrepreneurs, advocates for the environment, and state leadership have enthusiastically supported the idea that the establishment of the industry will be beneficial for the state.

In 2006 and 2007, several significant legislative measures were implemented as tangible evidence of a heightened interest in renewable energy and in bioenergy's integral role in the portfolio of potential renewable energy alternatives for Hawaii. Act 240 (SLH 2006) created an alternate fuel standard (AFS) for the State, with a goal to provide 10% of highway fuel demand from alternate fuels by 2010; 15% by 2015; and 20% by 2020. Act 159 (SLH 2007) established an energy feedstock program within the State Department of Agriculture. Act 162 (SLH 2006) strengthened and clarified Hawaii's Renewable Portfolio Standard (RPS), including biofuels as a renewable energy source. In April 2006, Hawaii's ten percent ethanol content requirement for gasoline established by Act 199 (SLH 1994) took effect.

The State also provides an investment tax credit for ethanol equal to 30% of nameplate capacity per year for the first 40 million gallons, a reduction in State and local fuel taxes, and a $0.05/gal State government procurement preference for biodiesel. These measures and incentives reflect a renewed interest in a targeted set of policies and initiatives toward bioenergy industry development that continues to the present.

However, despite substantial Federal, State and County incentives to support production and the use of biofuels, no ethanol plants have been constructed, and only two biodiesel plants are in operation, both for the conversion of waste cooking oil.

1.2.2 Bioenergy Activities and Act 253, SLH 2007

In recognition of the need for additional support for industry development, two statewide bioenergy events were convened in 2006, the Governor's Biofuels Summit and the Ag Bioenergy Workshop. The meetings were held in acknowledgment of the benefits, the complexity, and the challenges of Hawaii-based bioenergy industry development. Meeting participants represented all sectors of the bioenergy industry value chain – biomass production, conversion, distribution and storage, and end use – that are necessary elements of successful industry development. Participants in the 2006 meetings agreed that the development of a bioenergy industry in Hawaii poses significant challenges including limited land and water resources, adequacy of labor, lack of specialized production and distribution infrastructure, potential environmental impacts, and financial risk.

Separately, House Concurrent Resolution 195 (SLH 2006) required the Hawaii Energy Policy Forum (HEPF) to report to the 2007 State Legislature with recommendations "encouraging Hawaii's landowners, investors, county governments, and regulated electric utilities to pursue development and conversion of fuel crops for electricity generation." In its recommendations to the Legislature, HEPF called for the development of a Bioenergy Master Plan.

Consequently, HB 1003 HD3 SD2 CD1, Relating to Energy, was passed by the 2007 Legislature and signed into law as Act 253, SLH 2007 with Part III of the Act providing for the preparation of a bioenergy master plan by the State Department of Business, Economic Development and Tourism (DBEDT) to "set the course for the coordination and implementation of policies and procedures to develop a bioenergy industry in Hawaii." DBEDT subsequently contracted with the University of Hawaii's Hawaii Natural Energy Institute (HNEI) to prepare the master plan.

1.2.3 Hawaii Clean Energy Initiative

In January 2008, the U.S. Department of Energy and the State of Hawaii entered into a Memorandum of Understanding for the Hawaii Clean Energy Initiative (HCEI http://www.hawaiicleanenergyinitiative.org/). The goal of the initiative is to decrease energy demand and accelerate use of renewable, indigenous energy resources in Hawaii's residential, building, industrial, utility, and transportation end-use sectors so that efficiency and renewable energy resources will be sufficient to meet 70% of Hawaii's energy demand by 2030.

Related to HCEI, on October 20, 2008, the State of Hawaii and the Hawaiian Electric Companies signed an Energy Agreement (http://hawaii.gov/dcca/dca/HCEI/) that includes commitments to listed biomass projects.

1.3 Approach to the Hawaii Bioenergy Master Plan

1.3.1 Bioenergy Industry Value Chain

The bioenergy industry involves the production of biomass-based energy products, including solid, gaseous, or liquid biofuels, from raw materials for commercial sale. Products are passed through a series of essential business components, or chain of activities, on their way to the consumer. Planning for the development of a bioenergy industry requires an understanding of the chain of activities, often called the value chain.

A bioenergy value chain with five components is described in the National Biofuels Action Plan issued in October 2008 by the Biomass Research and Development Board. The Board, created by the Biomass Research and Development Act of 2000, comprises numerous Federal departments and agencies. The five value chain components are shown in the figure below.

http://www1/eere/energy.gov/biomass/pdfs/nbap.pdf

The components are:

1. Feedstock Production – Cultivation of biomass resources used as raw material inputs for biofuels production.
2. Feedstock Logistics – Harvesting or collecting of feedstock from the area of production, then storing and delivering it to conversion facilities.
3. Conversion – Transformation of the processed feedstock to gaseous, liquid or solid fuels.
4. Distribution – Transfer of the fuel from a conversion facility to the point of retail sale.
5. End Use – Purchase of biofuel by the consumer

Use of the value chain to frame the industry from feedstock production through end use forces examination of the interdependent components of the industry as they may apply to the many possible bioenergy production and use pathway alternatives. The concept can be flexibly applied to facilitate a deeper understanding of the synchronization involved in bioenergy industry development. For example, value chain conditions that must exist for the production of ethanol using sugarcane bagasse include certain bagasse supplies, economic delivery of bagasse to an ethanol facility, an operational ethanol facility, a distribution system, and a market. Similar conditions must exist to enable the use of forestry waste for utility power generation or the use of oil crops such as algae, jatropha, and oil palm for biodiesel for vehicles or power plants.

Planning from the value chain perspective identifies the components and linkages that need to be strengthened, and therefore points to measures, including partnerships, that can support continuity of industry processes from production to end use. Development of a bioenergy industry for Hawaii is thus both comprehensive and structured, with focus on understanding of component needs while at the same time maintaining a vision for the broader industry.

1.3.2 Industry Stakeholders

From feedstock production through end use, a bioenergy industry can have far reaching impacts on all members of Hawaii's community. The cultivation of biofuel crops will require the use of land and water resources, and agriculture labor will directly impact the economy of adjacent rural communities. Trucks to haul wood, bagasse, or other feedstocks to processing facilities may affect road and vehicle traffic. Barges to move biofuels or feedstocks between islands may require new harbors infrastructure. Biofuel mandates, such as the ethanol (E10) mandate that displaces fossil fuel use, will touch all users of the displaced fuel.

Besides these immediate impacts, the large scale production of biofuels has become a national conversation with the realization that biofuels choices have consequences that may impact the environment in ways that may be beneficial or harmful, depending on feedstock selection, production and conversion processes, and end products. The national and international experiences and Hawaii's unique environment and culture as well as land and water constraints demand an inclusive approach to industry planning. Thus, while Hawaii's needs for more dependable energy supplies are compelling, and bioenergy industry barriers are well documented as a result of the 2006 meetings, development of the industry must continue to consider a variety of viewpoints and needs.

Throughout the development of the bioenergy master plan, industry stakeholders were therefore provided with opportunities for input on the various issues. Recurring themes that were raised included the competition for agricultural water and land resources often expressed as "food vs. fuel" and the need for sustainable development.

1.3.3 Act 253, SLH 2007, Plan Requirements

Act 253 provides for development of a plan "that will set the course for the coordination and implementation of policies and procedures to develop a bioenergy industry in Hawaii." Specifically, the Act requires the Department of Business, Economic Development and Tourism (DBEDT) to prepare the plan "in consultation with representatives of the relevant stakeholders", and to provide an interim and a final report on the development of the plan.

The guidelines for the plan are provided in the Act as follows:

The "objective" establishes that the intent of the Act is for development of a plan that will address programmatic support for the state's transition to energy self-sufficiency as a longer-term goal.

> ***"The primary objective of the bioenergy master plan shall [be to] develop a Hawaii renewable biofuels program to manage the State's transition to energy self-sufficiency based in part on biofuels for power generation and transportation."***

The expectations for the plan are established in the outcomes.

"The bioenergy master plan shall address the following outcomes:

(1) Strategic partnerships for the research, development, testing, and deployment of renewable biofuels technologies and production of biomass crops;

(2) Evaluation of Hawaii's potential to rely on biofuels as a significant renewable energy resource;

(3) Biofuels demonstration projects, including infrastructure for production, storage, and transportation of biofuels;
(4) Promotion of Hawaii's renewable biofuels resources to potential partners and investors for development in Hawaii as well as for export purposes; and
(5) A plan or roadmap to implement commercially viable biofuels development."

These outcomes are reordered in this report to achieve a smoother progression of workflow resulting in the first two outcomes as follows:

- Outcome I - *Evaluation of Hawaii's potential to rely on biofuels as a significant renewable energy resource.* This outcome considered the following task areas -
  Water resources;
  Land resources;
  Distribution infrastructure for both marine and land;
  Labor resources and issues;
  Technology to develop bioenergy feedstock and biofuels;

- Outcome II - *A plan or roadmap to implement commercially viable biofuels development.* This Outcome considered the findings from Outcome I as well as the following additional task areas -
  Permitting;
  Financial incentives and barriers and other funding;
  Business partnering;
  Identification and analysis of the impacts of transitioning to a bioenergy economy while considering applicable environmental concerns

The specific issues, including pertinent policy requirements, were addressed by subject experts. The reports on these issues are in Vol II of this plan.

"The bioenergy master plan shall address the following issues:
(1) Specific objectives and timelines;
(2) Water resources;
(3) Land resources;
(4) Distribution infrastructure for both marine and land;
(5) Labor resources and issues;
(6) Technology to develop bioenergy feedstock and biofuels;
(7) Permitting;
(8) Financial incentives and barriers and other funding;
(9) Business partnering;
(10) Policy requirements necessary for implementation of the master plan; and
(11) Identification and analysis of the impacts of transitioning to a bioenergy economy while considering applicable environmental concerns."

Plan development activities included assembling a team of subject experts to study the various issue areas, stakeholder outreach and engagement activities, planning for and conducting tasks, integration of task findings and recommendations, and preparation of the draft and final Plan.

Work on the Plan was conducted from the value chain perspective to ensure appropriate attention to the industry components along the value chain. This framework also allowed for multiple inputs and outputs and consideration of the impacts of technology choices on the development of the industry.

While much of the analysis conducted during the project focused on liquid and solid biofuels, all bioenergy products, including biogases, are components of a bioenergy industry and should be considered in the implementation of incentives or other industry support recommendations.

The public stakeholder outreach and engagement activities were conducted as follows:

- *Kickoff Meeting* – May 21, 2008

An all-day kickoff meeting for the Bioenergy Master Plan was held to inform stakeholders of the project, initiate discussion of the issues involved in industry development, and survey their interests in the project.

- *A Conversation with Hawaii's Agriculture Sector* – September 5, 2008

A second stakeholder engagement event was held in conjunction with the biennial Hawaii Agriculture Conference at the Hawaii Convention Center.

- *Survey*

A survey was distributed to participants at a variety of events and made available on-line at http://hawaii.gov/dbedt/info/energy/renewable/bioenergy/index_html.

- *Stakeholder Meeting April 2, 2009*

A meeting was held to present progress reports on the development of the bioenergy master plan and to capture stakeholder input during issue breakout sessions. The meeting agenda, breakout session questions, and participant list are provided at http://www.hnei.hawaii.edu/bmpp/calendar.asp. Notes from the breakout sessions are included with the respective Issue Reports.

- *Continued Stakeholders Input*

Stakeholder review comment on the draft bioenergy master plan was requested and incorporated in plan revisions.

- *Hawaii Clean Energy Day, June 6, 2009*

HNEI staffed an exhibit booth for educational and outreach to stakeholders at the all day event featuring local and national speakers from government and the private sector.

- *Bioenergy Master Plan Website*

A website was developed for stakeholder education and outreach at http://www.hnei.hawaii.edu/bmpp/home.asp. An e-mail address was established for stakeholder communication.

Part 2: Perspectives on the Bioenergy Industry: Issue Reports

"There are lots of uncertainties and competition."

Stakeholder comment, April 2, 2009

2.0 Introduction

Part 2 provides the executive summaries and recommendations from nine separate reports on issues specified by Act 253. The cross-cutting issues - “specific objectives and timelines” and “policy requirements necessary for implementation of the master plan” - are addressed in Section 3.2.2. The complete issue reports are in the Volume II of this report.

2.1 Land and water resources
College of Tropical Agriculture and Human Resources (CTAHR), University of Hawaii

2.2 Distribution infrastructure
Marc M. Siah & Associates, Inc.

2.3 Labor resources
Department of Urban and Regional Planning/Political Science, University of Hawaii

2.4 Technology
Hawaii Natural Energy Institute and CTAHR, University of Hawaii

2.5 Permitting
Marc M. Siah & Associates, Inc.

2.6 Financial incentives
Hawaii Economic Research Organization, Energy and Greenhouse Gas Solutions, University of Hawaii

2.7 Business partnering
Agribusiness Incubator Program, CTAHR/University of Hawaii

2.8 Economic impacts
Department of Urban & Regional Planning, University of Hawaii

2.9 Environmental impacts.
Pacific Consulting Services, Inc.

2.10 State, County, and Federal plans, policies, statutes, and regulations
University of Hawaii

2.1 Water and Land Resources

EXECUTIVE SUMMARY

Project Background

Based on Act 253, SLH 2007, Part III, *"The primary objective of the bioenergy master plan shall be to develop a Hawaii renewable biofuels program to manage the State's transition to energy self-sufficiency based in part on biofuels for power generation and transportation."* The primary concern for consideration in the development of any bioenergy crops in Hawaii is the availability of the land and water necessary to produce such products. In addition to availability of large areas of land necessary for production, site suitability is also an important factor. Aspects related to this include bioenergy crop growing conditions, climatic factors, soils, geology and geography, land use patterns, surface and groundwater water resources, and infrastructure. In addition, potential agronomic productivity of the land must be evaluated. It is important to determine suitable locations in the Islands that can efficiently produce bioenergy crops while still being conveniently accessible to major consumers, including agricultural, industrial, and population centers, that will utilize the fuel once it is produced.

To evaluate Hawaii's water resources and their potential to support production of biofuels as a significant renewable energy resource, as well as to provide information, analysis, and recommendations, this study includes the following scope of work:

- Identify appropriate stakeholders, technical experts, and information sources throughout the state.
- Document the availability of existing water supplies for growing biofuels and biomass crops (indicate areas currently in production for food crops or diversified agriculture);
- Document the use, availability and allocation of water from streams, wells, and aquifers including environmental impacts and competing uses;
- Document the potential for additional sources of non-traditional water supplies – non-potable water, wastewater, stormwater, reclaimed water, desalinated water, and other;
- Document the potential for biomass production in conjunction with phytoremediation and bioremediation processes;
- Document methods to increase water use efficiency for bioenergy production including selection of biomass feedstocks, modeling of crop water use; technologies including irrigation techniques; and
- Estimate and document biofuel production potential based on water resources and available land assets.

To evaluate Hawaii's land resources and their potential to support production of biofuels as a significant renewable energy resource, as well as to provide information, analysis, and recommendations, this study also includes the following scope of work:

- Identify appropriate stakeholders, technical experts, and information sources throughout the state;

- Document the suitability (zoning, soil type, slope, temperature, etc.) of land resources for growing biofuels and biomass crops (indicate areas currently in production for food crops or diversified agriculture);
- Document the ownership, permissible use, location, availability, and allocation of appropriate land, and competing uses;
- Document methods to increase productivity of land use for bioenergy production including selection of biomass feedstocks, agricultural practices, and any other factors; and
- Estimate and document biofuel production potential based on water resources and available land assets.

This report presents results of a study conducted to explore and evaluate the land and water resources available for bioenergy crop production. The report presents data and information with GIS maps, graphs, tables, and appendices. In addition to the Executive Summary, this report consists of five major sections: i) Introduction, ii) Existing Water Supplies and Lands, iii) Existing Lands for Biofuels and Biomass Crops Production, iv) Agricultural Water Use for Potential Biofuels and Biomass Crops Production, and vi) Summary, Conclusions, and Recommendations.

Nature of Land and Water Resources Data

GIS maps of Agricultural Lands of Importance to the State of Hawaii (ALISH) date back to 1977 (Hawaii Statewide GIS Program, 2008) when most of the Hawaiian agricultural lands were under mono-cropping systems. The State Government made substantial changes in land leasing after the end of large-scale agricultural production. The historical land use changes have raised questions on the accuracy of the ALISH maps which need to be updated using remote sensing data validated through a ground-truthing process.

Sugarcane plantations used well engineered sophisticated irrigation systems. After four decades of neglect these systems need rehabilitation and maintenance. In addition to rehabilitation of existing irrigation systems, large-scale bioenergy crop production can make use of treated waste water resources. Any serious plan to use treated waste water will require building a system to deliver these water resources from their point of treatment to the agricultural lands. In places such as Kekaha in Kauai, even if the irrigation systems are still functional, the cost to rehabilitate them to deliver the amount of water needed for high water consumption crops could be prohibitive.

Input from Stakeholders

Participants in a stakeholders meeting held April 2, 2009, as well as other stakeholders, reviewed the first draft of this report. The emphasis was mainly on: i) critical information needed for decision making regarding bioenergy crop production, ii) current land and water resource availability and constraints, and iii) actions needed in the near-term that would address the priority constraints. Various sections of this report include and address the comments of various participants in the April meeting.

Existing Water Supplies for Biofuels and Biomass Crops Production

Efforts to utilize biofuels should include better characterizations of the “water budget” for various hydrological systems as it is an important factor in planning water use. The budget accounts for all of the inflows, outflows, and changes in storage within the system. Groundwater recharge is an important element of the water budget. Groundwater recharge is needed in managing groundwater resources including estimating aquifer sustainable yields. Utilization of groundwater resources for biofuel production will necessitate assessing its influence on aquifer recharge and on estimated aquifer sustainable yields. The entire water system is a complex network of inter-connected ditches, irrigation systems, diversions, flumes, and reservoirs.

The State of Hawaii owns and operates a number of water systems. Water from the State wells is mainly used for potable water supply, and irrigation. The water collected from existing State diversion is used primarily for agricultural operations. There are many systems that are privately owned and there is a lack of knowledge about the condition of these systems. Supplemental sources of water must be developed to meet the demands of an increasing population and sustainable water resource management, including the use of recycled water and rainwater catchment, to assure a continuous and reliable supply of water without concern about droughts or water restrictions. This option for developing a reusable water system provides additional advantage for utilizing the existing/dissolved nutrients in the wastewater thereby reducing the need for fertilization in most instances. Another advantage of establishing a recycled water system is that it is an environmentally friendly approach compared to the traditional disposal methods, i.e., through outfalls and injection wells. Although the applications of reusable water have historically increased in Hawaii, there are opportunities to continue expansion.

Continued development of bioenergy production systems requires accurate information on a reliable biomass feedstock supply, production and harvesting costs, and environmental impacts. Development of the bioenergy industry necessitates determining ways to lower biomass production costs including handling and transportation, reducing uncertainty of supply, and capturing the value of environmental benefits and transferring them to the producer.

Existing Lands and their Agricultural Water Use

Because of Hawaii’s geography and environmental conditions, each of its islands has unique soil types, climatic factors, land-use distribution (i.e., agricultural, conservation, rural and urban), and water resources. Acreages of different land uses in the State of Hawaii are shown in Fig. 1. ALISH (DOA, 1977) classes include “Prime Agricultural Lands”, “Unique Agricultural Lands”, “Other Agricultural Lands”, and “Unclassified Agricultural Lands” (Fig. 2). The following sections focus on lands designated for ‘Agricultural’ use by the State of Hawaii’s Land Use Commission. For bioenergy production, the most important factors include: i) mechanism and capability to harvest bioenergy crops, ii) transporting the harvested crops to processing facilities, and iii) delivering the final product to distribution points. In addition to the availability of land and water, community education is also a critical factor. Irrigation water needs and the high cost of agricultural lands may pose challenges for any large-scale operation to begin producing biofuel crops in sufficient quantity to meet the islands’ demand.

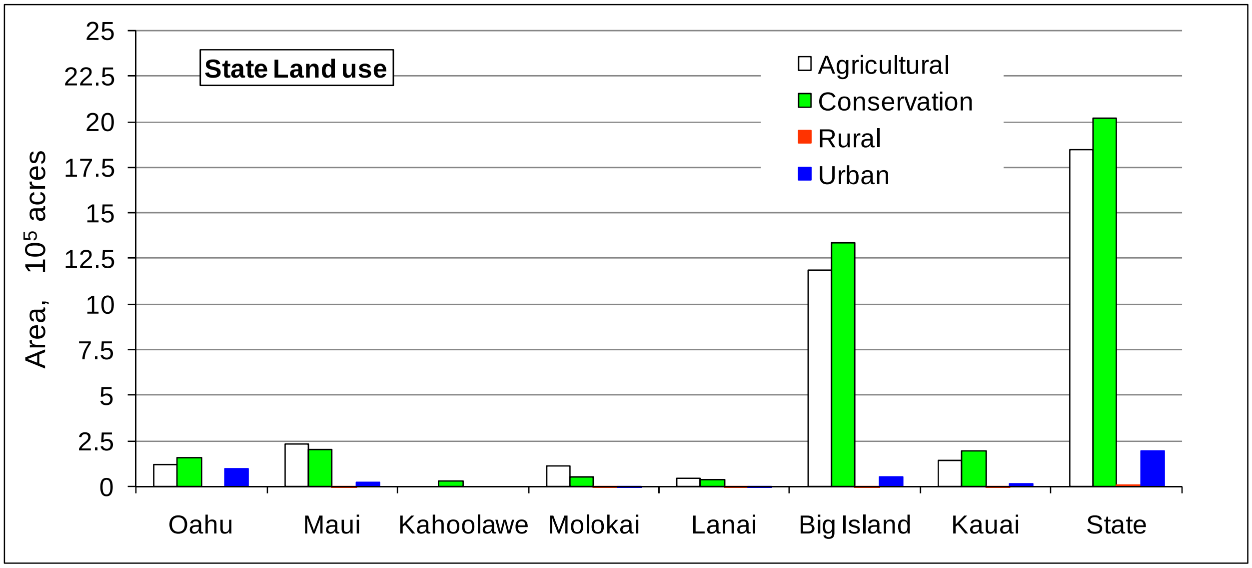

Fig. 1 Acreages of different land uses in the State of Hawaii.

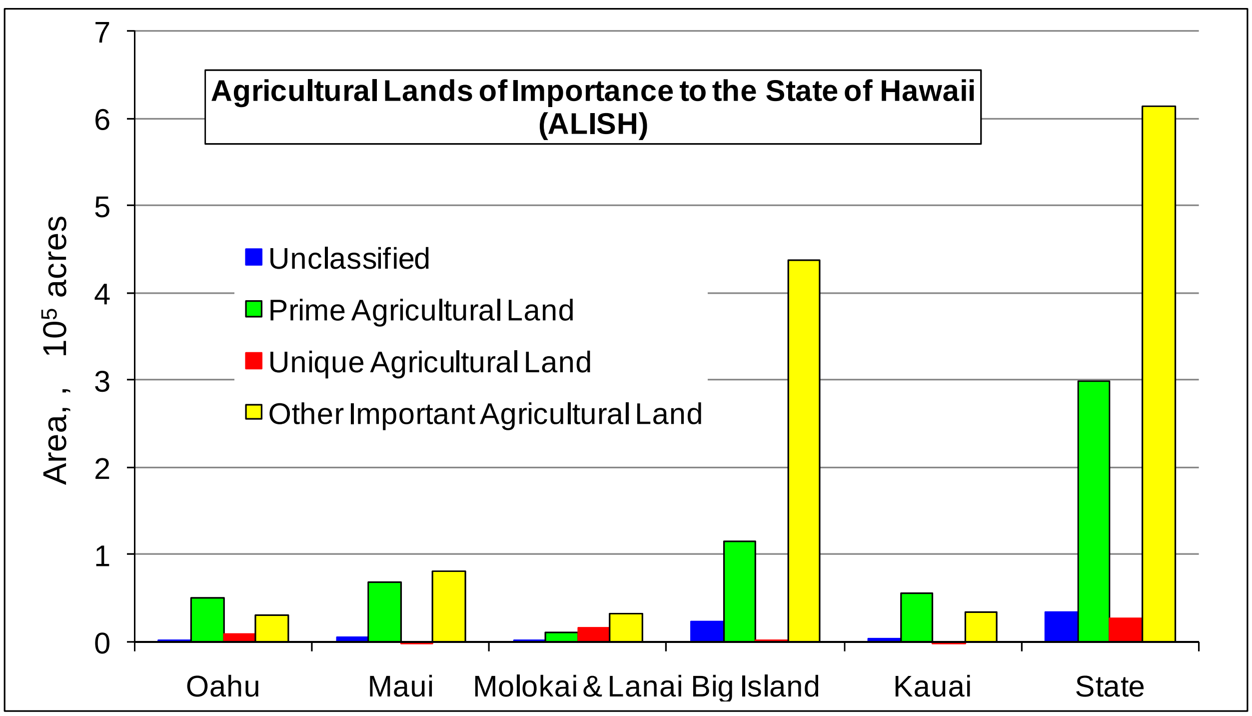

Fig. 2 Acreages of agricultural lands of importance to the State of Hawaii (ALISH).

Table 1 summarizes the existing agricultural lands and their irrigation water use in Hawaii. There is a total of 1.9 million acres of lands in the state Agricultural District of which 49% (942,000 acres) are classified by ALISH including prime, unique, or other important lands. In 2000, a total of 121,500 acres (which includes farmland plus non-agricultural uses like landscaping, golf courses and parks) were irrigated with an average 363.5 million gallons per day (MGD) of water (DBEDT, 2005).

Table 1. Agricultural lands and irrigation use for main Hawaiian islands and 10 studied irrigation systems (Source: DBEDT, 2005*)

	STATE RESOURCES			
Island	**Agr. District** 10,000 ac.	**ALISH** 10,000 ac.	**Irrigated Area** 1,000 ac.	**Irr. Water Use** MGD
Kauai	13.9	9.1	27.2	30.0
Oahu	12.9	8.8	31.1	39.2
Maui	24.5	14.9		
Molokai	11.2	3.9	Maui	County
Lanai	4.7	2.2	55.9	274.6
Big Island	121.4	55.3	14.5	19.7
State	**193.1**	**94.2**	**121.5**	**363.5**

*Sources: Hawaii DBEDT (2005) for state Agricultural District area and USGS (2000) for state Irrigated Area and Irrigation Water Use.

The Department of Natural Resources and Environmental Management (NREM) of the College of Tropical Agriculture and Human Resources (CTAHR) studied 10 irrigation systems across the Hawaiian Islands (Table 2) that account for < 5% of ALISH lands (NREM, 2008). The studied irrigation systems have design capacities to divert and utilize large quantities of water. Maximum capacities at the 10 larger systems total 387.4 MGD. Actual water use is typically much lower. Water measurement at the studied systems varies greatly in methods and accuracy. Ignoring these differences, recent NREM surveys found water diversions from the 10 systems total 190.5 MGD (NREM, 2008). This is about half the United States Geological Survey (USGS) irrigation water estimate, though the latter has likely increased since 2000. The studied systems account for over 90% (363.5 MGD) of 2000 irrigation water use (387.4 MGD capacity) on all islands except Maui and Lanai highlighting the importance of these systems in state water planning. The remaining, approximately 10% of the water, 23.9 MGD, may be used for growing bioenergy crops. Analyses were performed for the service and surrounding areas of the 10 irrigation systems studied and comprehensively documented in the NREM 2008 report to obtain baseline agricultural land maps and acreage estimates, which were: 1) ALISH, 2) soil types or land capability classes, 3) crop types (current land uses), and 4) potential wastewater sources for agricultural irrigation.

Table 2. Service area, ALISH, maximum capacity and average water use in the 10 studied irrigation systems (Source: NREM, 2008)

Island	STUDIED SYSTEMS				
	Irrigation Systems	Service Area acre	ALISH acre	Max. Capacity MGD	Avg. Water Use* MGD
Kauai	East Kauai (Kapaa-Kalepa)	5920	5510	100	5.5-8.0
	Kauai Coffee	4660	4370	33	27
	Kekaha	6570	6450	50	20
	total Kauai	17150	16330	*183*	*55*
Oahu	Waiahole Ditch	6270	5730	50	5-6
	Waimanalo	1580	1520	n/a	0.5-0.7
	total Oahu	7850	7250		*32.7*
Maui	Upcountry Maui (Olinda-Kula)	1720	1030	17.4	1
	West Maui (Wailuku)	6430	6300	120	55-66
	total Maui	8150	7330	*137.4*	*67*
Molokai Lanai	Molokai	9890	7780	n/a	3.4
Big Island	Lower Hamakua Ditch	4660	3950	17	12
	Waimea	1370	1240	n/a	4
	total Hawaii	6030	5190		*16*
State	Total	49070	43880	387.4	168.6

Sources: *Average diversions, except Waiahole Ditch includes water returned to streams under CWRM (Commission on Water Resource Management) order, Waimanalo is farm metered use, Molokai water measured at reservoir, and Waimea water entering reservoir. Where range given, island totals based on upper bound.

Land and Water Projections

The NREM report (NREM, 2008) projected agricultural acreages as an intermediate step to the year 2030 in 5-year increments, broken down by island, under different scenarios including *optimistic*, *pessimistic*, and *most likely*. Statewide for six crop groups (e.g., sugar, pineapple, seed crops, vegetable & melons, fruit & nut trees, and nursery & flowers) the report indicated an increase of 12,000-45,000 ac. under the three macroeconomic scenarios. Projections for the *most likely* scenario are shown in Table 3 where sugarcane accounted for the largest share in Kauai and Maui. Oahu, Molokai, and Big Island showed the least expected growth. In addition to the existing sugarcane acreage in Hawaii, GIS analysis of former plantation lands identified another 53,000 ac. that might be utilized for new bioenergy crops. Since large-scale bioenergy production in Hawaii is still speculative, this is an *optimistic* projection.

With the help of projected crop acreages presented in Table 3, future irrigation water demand for agriculture was estimated (Table 4). Equal water demands (approximately 15 MGD) for bioenergy crops are shown for Kauai and the Big Island followed by Oahu and Maui (< 10 MGD). In the *optimistic* scenario, state farm-level demand for water would grow to around 750 MGD in the year 2030 if all crops are fully irrigated, which is more than double the latest USGS estimate (Table 1) of irrigation water use for all purposes with an increase in demand by another 35 MGD of irrigation water for new bioenergy crops beyond current sugar operations (NREM, 2008). To meet these future needs, further study is needed regarding allocation and development of the state's water resources.

Table 3. Projected crop acreages for five islands under *most likely* scenario (Source: NREM, 2008).

Island/Year	**Big Island**		**Maui**		**Molokai**		**Oahu**		**Kauai**	
Crops	2030	2005	2030	2005	2030	2005	2030	2005	2030	2005
Sugar	496	39	37,239	34,993	419	33	457	36	9,345	8,291
Pineapple	0	0	5,118	5,394	0	0	7,334	7,497	0	10
Seed crops	423	11	1,011	513	1,933	1,243	1,304	867	2,006	1,309
Veg. & Melons	2,972	1,641	1,174	908	923	222	4,031	3,419	992	321
Fruit & nut trees	33,226	26,114	2,956	673	890	366	1,648	1,030	8,654	4,527
Nursery, flowers	3,139	2,441	841	549	74	32	894	665	594	247

Table 4. Projected irrigation water demand (MGD) for five islands under *most likely* scenario for different crops including potential bioenergy crop (Source: NREM, 2008).

	2030			2005
	Bioenergy	Pasture	Crops	Crops
Big Island	12	157	83	64
Maui	3	57	152	134
Molokai	0	25	13	5
Oahu	7	9	19	14
Kauai	13	35	45	30
Totals	35	283	312	247

This study is just one phase of an evaluation of resources for bioenergy crop production and the potential of this renewable energy resource. We hope that the issues raised in this report will be addressed in the future phases. As reflected from Table 3, the lands available from discontinued cultivation of sugarcane and pineapple provide a potential for renewable bioenergy crop production. Based on the analyses conducted during this study, the following points should be considered for further studies and future strategies to support development of Hawaii's bioenergy industry:

- Based on environmental conditions (windward vs. leeward) and seasonal variations (cold vs. warm), candidate species should be found that can adapt to site/region specific conditions.
- Soil management practices should be evaluated for 528,000 acres of unclassified lava lands. In addition, the current lands used for agriculture and forest plantings must be maintained despite reduction in sugarcane and pineapple production.
- This study does not address potential climate change impacts on Hawaii agriculture. A thorough study is needed to assess the impact of potential climate change on natural resources, especially water resources of Hawaii. Availability of irrigation water will be one of the key factors for bioenergy crop production.
- Conduct a study on ways to increase the supply of sustainable water for biomass crops.
- Long-term impact of planting bioenergy crops on land and other infrastructure need to be studied. For example, what happens when a certain crop is no longer in demand; can

the land be converted back for use with other crops? What would be the impact of discontinued production?

- Dual purpose use of resources such as biomass production from phytoremediation activities. As suggested by SunFuels Hawaii, creation of an ongoing fact-finding and policy discussion forum, an independent statewide panel with expertise in science, technology assessment and land use analysis.
- Remap ALISH to incorporate latest land use changes, availability of new lands (lava and non-ALISH lands), and proven potential of Hawaiian lands for diversified cropping.
- Detailed studies are needed with regards to: i) ground water resources, locations, and potential yields, ii) surface water sources, locations, and potential yields, iii) surface water diversions and locations, iv) modeling and economics of biofuel crop production, v) potential use of reclaimed water, and vi) implementation of important agricultural lands (IAL) classification.
- Further support of the objectives of water and land tasks and/or plan implementation pursuant to Act 253 regarding a Hawaii renewable biofuels program to manage the state's transition to energy self-sufficiency based in part on biofuels for power generation and transportation.

RECOMMENDATIONS (See Vol. II, Issue Report 2.1, Land and Water, Section 5.8)

Several limitations were observed during our analysis and are presented in this report. Among them are:

- Bioenergy crop performance is not known under all environmental conditions available in different Hawaii locations (temperature, moisture, soil depth) in the state. This information is needed to match bioenergy crops with their optimum production environmental conditions for optimum yield.
- The current bioenergy crop list is limited; there might be other species that could be better suited for certain Hawaii environments.
- There is a lack of on information on crop production for many of these new bioenergy crops. For instance, there is little experience with oil palm and Jatropha production in Hawaii. Mechanical harvesters for Jatropha are beginning to be available, but are not well tested.
- Crop varieties are constantly being improved. This may make this analysis obsolete in the near future.

The following recommendations are offered as a starting point for further work. These recommendations include suggestions from stakeholders.

- Find candidate species adapted to cool and cold regions for use at higher elevations. Most of the agriculturally zoned lands have cool and cold temperature regimes. Yet almost all the species evaluated seemed to perform better in the warm environment with the exception of *Eucalyptus*. There may be other species adapted to these temperature regimes that may equal or outperform *Eucalyptus*, which would give growers more options in deciding how to manage their lands. Find crop species adapted to dry environments. There are about 186,000 acres classified as dry throughout the state. Find crop species adapted to shallow soils.

- Develop a cropping system that could integrate bioenergy crops with regular crops for efficient utilization of resources such as land, water, time, and labor.
- An assessment is needed on the co-existence of bioenergy crops with other agricultural crops. A balance between food and fuel crops will ensure the equal and sustainable use of resources. Prioritize the use of resources for production of food and fuel crops.
- Develop a decision support system (DSS) that could match biological characteristics of crops to physical characteristics of soil and to environmental and ecological acceptance. Such a GIS-based DSS may help growers decide the best crop for their farms. Build a database for bioenergy crops detailing crop characteristics, potential yield, land and water requirements, and their suitability for integration with other crops and with environmental conditions in different regions in Hawaii.
- Help farmers conduct a cost-benefit analysis for a specific bioenergy crop.
- Climate change may pose a significant threat to bioenergy crop production. The present analysis is insufficient to forecast outcomes and is not able to deal with climate change scenarios. Better models will need to be developed to answer questions regarding the magnitude of the effects of climate change on crop production.
- Increase sustainable water supplies (traditional and non-traditional) for agriculture including bioenergy and biomass crops. Test water-harvesting technologies (e.g. stormwater harvest, reclamation and reuse) in Hawaii to minimize water runoff and maximize water storage. Other ways to increase and protect water resources in Hawaii may include watershed protection and improvement programs, reduce water conveyance losses and improve irrigation delivery efficiency, and others mentioned by Commission on Water Resource Management (CWRM) reports.
- Utilization of new groundwater resources for biofuel production will necessitate assessing its influence on aquifer recharge and on estimated aquifer sustainable yields.
- Study the potential effect of bioenergy crop production on drinking water resources. Assess the sustainable use of land and water resources. Any plan for developing biofuel crops should also include the potential effect on drinking water resources.
- Growing high water demanding bioenergy crops and biomass feedstocks in windward areas will use the available soil moisture and rainfall and require less supplemental irrigation.
- Growing less water demanding bioenergy crops and biomass feedstocks in leeward areas will suite environmental conditions and water availability in the area.
- Models that use daily water budget approach to calculate crop irrigation water requirements should be preferred in modeling crop water use.

- Drip irrigation system is considered a water saving system with high irrigation application efficiency. It can be preferred over micro-sprinkler irrigation system as its efficiency is not impacted by wind, and it can be used with recycled irrigation water.
- Develop or enhance water infrastructure sufficient to support biofuel use.
- Rehabilitate irrigation systems that are currently not in use where sugarcane growing has discontinued. In places such as Kekaha in Kauai, even if the irrigation systems are still functional, the cost to rehabilitate them to deliver the amount of water needed for high water consumption crops could be prohibitive.
- Since biofuel has commodity characteristics, bioenergy production may develop into a large industry. Therefore, a possible conflict and competition in the use of resources between bioenergy and food crops can exist. A study should be conducted to address this and related issues.
- Since the Department of Land and Natural Resources (DLNR) issues revocable permits to ranchers on state land that is zoned for agriculture, the impact of possible use of these lands for bioenergy crop production on the cattle industry needs to be assessed.
- Conduct a systematic study for costs/benefit analysis of potential reuse of treated water for bioenergy crops. Such analysis may include resources needed for expansion and upgrading of treatment facilities, construction of water delivery infrastructure to the agricultural lands, and scale of bionergy crop production.
- Long-term impacts of planting a certain crop on the land and other infrastructure need to be studied. For example, what happens when that crop is no longer in demand? Can the land be converted back for use with other crops? What would be the impact of discontinued production? This could be studied based on the experience gained from sugarcane and pineapple industry.
- Maintain land currently used for agriculture and forestry, and additionally, increase land available for bioenergy use sufficient to support biofuel use.
- Further understand Hawaii's water and land resources availability and constraints for bioenergy crops.
- Learn to manage lava lands. A significant portion of the 528,000 acres of unclassified land is lava. These lands are currently covered with volunteer trees that indicate it can support plant growth. Learning to cultivate these has the potential of opening large tracts of land for bioenergy crop production.
- Remap ALISH to incorporate latest land use changes, availability of new lands (lava and non-ALISH lands), and proven potential of Hawaiian lands for diversified cropping.
- Enact land policies necessary to keep agriculturally zoned lands in agriculture.
- Further support of the objectives of water and land tasks and/or plan implementation pursuant to Act 253 regarding Hawaii renewable biofuels program to manage the State's transition to energy self-sufficiency based in part on biofuels for power generation and transportation.

- Make sure that the changes in the State Administration do not affect implementation of this Master Plan. Educate the next generations as well as coming administrations for seamlessly carrying on of the work, and the wise use of land and water resources.
- As suggested by SunFuels Hawaii, creation of an ongoing fact-finding and policy discussion forum, an independent statewide panel steeped in science, technology assessment and land use analysis.
- A detailed study of projection and comparison of energy from biofuel crops with that from other technologies, e.g., solar- and wind-based energy. The study may focus on how will biofuel crops compete for the use of resources potentially set aside for wind and solar energy production.
- State residents are the most critical stakeholders, as they will benefit most from bioenergy production in Hawaii. Other stakeholders include scientists, researchers, students, policy makers, land owners, and growers/farmers.
- Technical experts for research and strategic planning on the State's future bioenergy plans include Principal Investigators of the current project, academia, and researchers and scientists working in local, state, and federal agencies.
- Encourage close collaborations among scientists, researchers, policy makers, extension agents, and farmers as a comprehensive link of information dissemination in order to provide the context for informed decision-making.
- Existing reports on the completed projects of Hawaii's water resource and planning studies (CWRM, 2003, 2005, 2007), DBEDT's reports, and agricultural land and water use plans (AWUDP, 2004, NREM, 2008), are sources of information.

NREM (2008) suggests further studies on various topics that closely relate to the current Bioenergy Master Plan. Descriptions of the suggested studies are summarized below.

- *Ground Water Resources, Locations, and Potential Yields*: Inventory of the records from different agencies i.e., DLNR. Groundtruthing and field determination of potential yield for the locations that have missing records. Estimating the costs of rehabilitation and upgrading of the existing infrastructure of the existing systems (if any).
- *Surface Water Sources, Locations, and Potential Yields*: Inventory of the records from different agencies i.e., DLNR. Groundtruthing and field determination of potential yield for the locations that have missing records. Estimating the costs of rehabilitation and upgrading of the existing infrastructure of the existing systems.
- *Surface Water Diversions and Locations*: Surveying the existing records to determine all diversion locations that are either active or were active in the past. Evaluating the status of the existing diversions. Assessing the needs to rehabilitate these diversions. Quantifying the potential delivery capacity of the existing systems.
- *In-Depth Study of Biofuels*: Simulating different crop energy sources based on their energy yield and their demand on natural resources, and economic analysis of the different potential scenarios.

- *Potential Use of Reclaimed Water*: Survey and analyses (engineering and statistical) of current reclamation schemes including physical facilities, water service, and costs. Identify barriers to expanding reclaimed water use, develop recommendations to overcome barriers.
- *Connection with Important Agricultural Lands (IAL) Classification*: Review of state and county policies for IAL designation and criteria related to water.

2.2 Distribution Infrastructure for Both Marine and Land

EXECUTIVE SUMMARY

This section of the Hawaii Bioenergy Master Plan describes distribution infrastructure issues for liquid and solid forms of bioenergy. Infrastructure components for liquid biofuels discussed hereafter are those that are situated downstream of the biomass conversion plant, i.e. finished biofuel products as they are transported from the biofuel refinery storage to the end user. Infrastructure components for solid biomass discussed are concerned with transporting biomass to thermal power plants. Gaseous biofuels are not addressed as biofuel candidates in regard to distribution system considerations. Gaseous biofuels, such as referred to as “biogas”, are typically produced close to the point of demand, which would typically be biogas powered electricity or steam plants. Biogas is an established and important renewable energy source in many countries of the world and biogas could provide important renewable energy supplies to Hawaii.

State and national energy goals support the increased supply of biomass-derived liquid, hereafter referred to as biofuels, to replace or augment petroleum products. The most common biofuels used today are ethanol, which can replace motor gasoline used in internal combustion engines, and biodiesel, which can replace petroleum diesel used in internal combustion diesel engines and in other prime movers for power generation. Straight vegetable oils, i.e. biofuels that are not refined further to obtain biodiesel, can be used in power plants. The straight vegetable oil would therefore replace heavier fractions of petroleum, such as residual oil.

The distribution modes for biofuel are basically the same as for petroleum products. The liquid products can be conveyed in pipelines, transported in rail tankers, tanker trucks or fuel tankers and stored in atmospheric storage tanks. The ideal scenario, the transformation of Hawaii’s fuel economy to one based on a significant portion of biofuels, would use the existing petroleum infrastructure, so that expensive new distribution infrastructure for biofuels could be avoided. The currently most common biofuels, ethanol, and biodiesel, however, have physical properties that cause a certain degree of incompatibility with existing petroleum systems.

Due to incompatibility issues, the transport of fuel grade ethanol and biodiesel requires either new dedicated distribution infrastructure or the modification of existing petroleum fuel systems. The incompatibility issues might require additional capital investment and operating costs for new dedicated distribution infrastructure or converted petroleum fuel systems. Replacing large amounts petroleum products with biofuels that have limited compatibility with existing fuel transport and storage systems would therefore require that biofuel compatible distribution systems be in place before an expanded biofuel supply is available to the end user.

Since the biofuel industry is a rapidly evolving energy field, new types of biofuels are developed that offer a higher degree of or even full compatibility with existing petroleum fuel distribution and engine systems. Examples of such new and promising fuels are bio-butanol and renewable diesel. Using such new biofuels would have the significant advantage that existing petroleum fuel systems could be used for the distribution of these biofuels with no or only slight modifications. These fuels would therefore allow a basically seamless transition of the fuel distribution from petroleum to renewable fuels and biofuels.

The issue of biofuel compatibility with existing petroleum distribution infrastructure has a significant impact on the required scope and capital investment of future biofuel use in Hawaii. The present market value of Hawaii's existing petroleum infrastructure is estimated at about $3.6 billion (excluding the value of the two local petroleum refineries) and thus represents a significant asset, which cannot be easily and expeditiously replaced. Furthermore, during the transition period from petroleum fuels to biofuels, both the petroleum and biofuel infrastructure would have to be maintained if there were to be incompatibility of biofuels with existing distribution infrastructure. Since possible production shortfalls or interruptions of a growing bioenergy industry might require, from time to time, supply substitution from out-of-state sources, import facilities for all the biofuels that will be used in Hawaii would serve as important infrastructure redundancies and would increase energy security.

It may be possible to convert components of the existing fuel infrastructure for distribution of ethanol and biodiesel if the material composition and other characteristics of the specific fuel containment components are exactly known. For large and interconnected fuel systems that combine many components, such as tanks, pipelines, and terminals, chances are that efforts to convert these complete existing petroleum fuel systems may present high investments or be practically impossible.

The distribution of solid bioenergy represents a technically and logistically smaller distribution challenge. In Hawaii, heavy truck operations are the mode of transporting solid biomass to bioenergy conversion plants. Heavy hauling trucks used for transport of biomass on public roads would be similar in size to trucks carrying 40-foot containers. The maximum weight of such trucks would be limited to 80,000 pounds. In most cases, the available cargo volume of trucks would be filled with lower bulk density solid biofuels before the maximum weight limit is reached. Therefore the transport of solid biofuel would typically be a "volume-limited" operation and measures to increase the bulk density of solid biofuel would decrease the amount of truckloads and hence impacts from solid fuel transport on public roads.

Trucking operations on private land could use larger and heavier trucks. The primary impact of solid biomass distribution would be from increased heavy truck traffic on public roads.

RECOMMENDATIONS (See Vol. II, Issue Report 2.2, Distribution Infrastructure, Section 11)

(Note: The underlined items are reflected in Table 4, Issue Report Recommendations.)

State policy supports the use of liquid and solid bioenergy products to help meet Hawaii's future demand for clean and renewable energy. Liquid bioenergy products can provide base load power supply, which is presently provided by petroleum and coal, as well as transportation fuel. Solid bioenergy products can provide base load power supply.

The following summarizes the major conclusions pertaining to liquid bioenergy (biofuel) distribution infrastructure:

1. As biofuel usage grows in Hawaii, it is imperative that a distribution infrastructure is developed to accommodate the increased volumes of biofuel flowing through the supply systems, so that the biofuel products can be supplied to the end user in a cost efficient and efficient way.

2. The existing fuel distribution infrastructure in Hawaii is built to supply large amounts of petroleum to power Hawaii's ground transportation, air transportation and electricity power generation. The existing petroleum distribution infrastructure in Hawaii is large and complex and uses storage tanks, terminals, pipelines, barges and tanker trucks to provide Hawaii with a secure and robust energy supply. The preferred future biofuel distribution system would utilize this petroleum fuel system and require no or minimum modifications of existing distribution assets.

3. The distribution of liquid biofuels utilizes infrastructure components that are similar to the existing petroleum fuel system. Conventional biofuel, such as ethanol and biodiesel are, however, not fully compatible with existing petroleum system, since they act as strong solvents and have strong affinity to water, which could result in water contamination of the fuel.

4. The most widely used biofuel in the US market today is ethanol followed by biodiesel. These biofuels represent "first generation" biofuels and they have a limited compatibility with existing petroleum distribution and end-uses. Newer types of biofuels that are under development or are in pre-commercial stages exhibit much better compatibility with existing petroleum equipment and distribution assets. Using types of biofuel that can be distributed in existing petroleum systems offer a considerable cost and operational advantage.

5. The selection of biofuel according to the compatibility with existing distribution infrastructure should be given high importance and weight. Certain properties of the conventional and established biofuels, ethanol and biodiesel, result in incompatibilities with most of the established petroleum distribution infrastructure and operation. Other evolving biofuels, such as bio-butanol and renewable diesel (i.e. diesel different from the ester type biodiesel and compliant to ASTM D975) should be compatible with existing petroleum distribution infrastructure components. From the viewpoint of facilitating the development of a biofuel distribution infrastructure that can support a rapidly expanding biofuel industry in Hawaii, such biofuel would be preferable to ethanol and biodiesel.

6. Whether existing petroleum storage tanks can be used or can be converted for use with biofuel has to be decided on a case-by-case basis. More recently built petroleum storage tanks might be more compatible with biofuels such as ethanol and biodiesel than older tanks. The use or conversion of existing petroleum storage for biofuels tanks would be less costly and would require less land than developing new biofuel storage

tank capacities. Considering the bioenergy use scenario of the Hawaii Bioenergy Master Plan, about 14% of the existing number of petroleum tanks would have to be built or converted, in order to create an appropriate stockpile of the envisioned volume of ethanol, biodiesel and renewable fuel oil.

7. Infrastructure developments require significant capital investment and time to implement. It is important that distribution infrastructure is flexible to changes in fuels. <u>Distribution systems that are built for specific biofuels, should be avoided since they become obsolete as the biofuel use may change resulting in large sunk costs that might not be recovered.</u>

8. Straight vegetable oil, e.g. biofuel that is not converted to higher quality products such as biodiesel, can be used for electricity generation. Straight vegetable oil could replace petroleum residual fuel, which is presently used in power plants in Hawaii. Straight vegetable oil seems to be fully compatible with the distribution system for residual fuel. Most likely straight vegetable oil would be conveyed through existing pipelines built to convey residual fuel. This assumed compatibility with existing petroleum fuel systems significantly facilitates the broad introduction of straight vegetable oil in Hawaii.

9. <u>The timeline for the introduction of new distribution infrastructure should be preferably 5 to10 years rather than a short 2 to 3 years</u>. With regard to distribution infrastructure, the transition from petroleum to biofuel requires specific operations know-how that can be more readily attained by a small number of larger consumers (i.e. conversion of power generation to biofuel) rather than building the distribution system for a large and dispersed group of small users (i.e. providing a large distribution network of transportation biofuel dispensing stations).

10. Pipeline operators typically are reluctant to make their existing petroleum transmission pipelines available for fuel grade ethanol or biodiesel. Therefore, it seems unlikely that long transmission pipelines, such as the pipelines on Oahu that connect the refineries with urban Honolulu, will be available to convey sizeable amounts of ethanol and biodiesel anytime soon. The new construction of dedicated biofuel pipelines over long distances in Oahu is equally unlikely in the near future. Therefore the transport of biofuel by means of tanker trucks may be the preferred transport mode for biofuels in the years to come. With the biofuel volume envisioned under the bioenergy use scenario of the Hawaii Bioenergy Master Plan, about 100 tanker truck operations per day would be required throughout the state to transport fuel grade ethanol and biodiesel. The transport of the biodiesel would be over public roads in the four counties.

11. The conversion of existing petroleum distribution infrastructure into dedicated biofuel systems might be a cost effective way to provide storage and transport capacities to the evolving biofuel industry in Hawaii. However, it is likely that Hawaii will still import sizeable amounts of petroleum products in the years to come, while petroleum is being replaced with cleaner and renewable fuel products. <u>Hawaii's petroleum infrastructure will therefore remain important and enough resources will have to be invested into the maintenance of the petroleum fuel system. Operating and maintaining two fuel systems</u>

in parallel, while the use of petroleum fuel decreases and that of biofuel increases, will require significant resources.

12. The preferred biofuel distribution infrastructure would allow petroleum and biofuels to be transported and stored side by side, without the need to segregate large parts of the fuel distribution system by either neat petroleum or neat biofuel needs. The type of biofuels used in Hawaii would preferably be blended upstream of the distribution value chain. Alternatively, biofuels and petroleum could be transported batch wise through the common distribution systems, similar to different petroleum products using distribution assets (e.g. batchwise conveyance through pipelines that serve compatible product groups).

13. While the large-scale introduction of biofuel in Hawaii could significantly affect the fuel distribution infrastructure in Hawaii, it is most likely that a large-scale use of biofuel in Hawaii would also affect the importation of petroleum to Hawaii. A decreased demand for certain petroleum fuel products due to displacement by biofuels could have impacts on the operations of the two local refineries. In order to respond to a reduced demand of certain petroleum products the refineries would have basically two options. Option One would be to lower the volume of imported and locally processed crude oil to adjust for the reduced demand of refined petroleum products. In this case imports of petroleum products might be required to make up for the production shortfall. Option Two would be to retain the present petroleum fuel production rate of the refineries and export the excess petroleum products. Both Option One and Two could affect the viability of the future operations of the two local refineries and therefore could significantly affect the energy and fuel supply to Hawaii. Stakeholders have pointed out that Option One, in which refinery throughputs are reduced as demand for conventional petroleum products declines, might be the most likely alternative. Stakeholders suggest that, since refinery yield flexibility is limited, reductions in throughput would likely result in an increased requirement for imports of selected refined petroleum products, which would no longer be supplied in the required volume from local fuel production. This would most likely require additional capital investments in new fuel facilities in Hawaii. Such investments for new petroleum infrastructure might take available capital investment away from a dedicated biofuel distribution infrastructure. If, however, the future biofuels used in Hawaii would have a high compatibility with the petroleum fuel products used in Hawaii, then much needed synergy in fuel distribution could be achieved.

The following summarizes the major conclusions pertaining to solid bioenergy (biofuel) distribution infrastructure:

14. The use of solid biomass provides opportunities to replace imported petroleum with locally grown fuel. Due to the lower heat content and density of solid biomass versus petroleum, the transport of solid biomass from the location of harvesting to conversion requires more volume and mass to be transported for the same amount of heat content.

Candidate solid biofuel feedstocks for presently proposed projects are various types of woods, forest residue and sugarcane.

15. The preferred mode of transport of the solid fuels to the conversion plants is by heavy trucks. Transport over private land is preferred over heavy trucks using public roads, where the dimensions and gross weight of the trucks is limited to 65 feet in length and 80,000 pounds. Typically transport with trucks is volume limited, which means that the trucks run out of available cargo volume before they reach the maximum allowable gross weight.

16. The frequency of truck operations to transport solid bioenergy to the power plants depends on the generation capacity and efficiency of the power plant, the heat value of the solid biofuel and the bulk density of the solid fuel. The types of wood fuel considered for the proposed solid bioenergy projects require less truck operations than less dense sugarcane bagasse.

17. The anticipated frequency of up to five truck operations per hour would cause some traffic impact on public roads. The level-of-service of these public roads might however not be significantly affected. It is more likely that more significant traffic impact would be more localized, such as close to the ingress and egress of biomass loading and power plant sites. It is anticipated that <u>appropriate traffic mitigation measures could be implemented to avoid significant impacts from solid bioenergy trucking operations</u>.

2.3 Labor Resources and Issues

EXECUTIVE SUMMARY

This section of the report focuses on the labor considerations associated with biofuels in Hawaii. In particular, it discusses how a potential biofuels industry might affect the labor market, as well as possible requirements for the industry. While the labor market generally responds to industrial dynamics, the following ideas and estimates should be accounted for when policy makers and leaders consider how best to support biofuels.

One major labor market question discussed here is whether the state's workforce could support a vibrant biofuels industry. Should Hawaii's bioenergy industry require the growing and harvesting of agricultural crops, particularly plantation grown crops, there may be a significant need for a lower-skilled labor force similar to that required for sugar cane production. For this type of labor, which is characterized by lower wages, there are two possible sources. First, labor might be imported from the U.S. mainland and/or internationally, as has been the case for earlier periods of agricultural growth in the state. Where such labor resources come from is largely a function of the types of work created (e.g. technical, manual, etc.). In addition to imported labor, the other major pool of currently available labor for a possible biofuels industry is the locally unemployed. Fortunately, higher unemployment rates on the Neighbor Islands may match biofuels production sites. Beyond these available sources, training and education might be a long term strategy for filling biofuel labor needs.

In terms of the scale of jobs created through biofuels, it is very difficult to base estimates on existing experience because there are many remaining technical questions on how the industry might evolve in Hawaii. Nevertheless, according to our rough preliminary estimates, it is possible that by 2030 that the industry might add 584 jobs in the processing side only, where the state is likely to have the greatest comparative advantage. Thus, if biofuels were the only alternative energy source substituting for current imported oil sources, by 2030 the industry would employ a small (excluding agriculture workers), but perhaps important part of the labor force.

It is not yet clear how a biofuels industry – and in particular which parts of the value chain are best located in Hawaii. In any case, it will be important for industry, government, labor and educational institutions to take initiative and develop programs to meet the full range of skills needed for "green" industries including bioenergy. Such a comprehensive approach towards supporting the biofuels labor market as part of a broader green energy agenda makes most sense from the view that investment in biofuels skills development will be at the leading edge of efforts to make the state an innovator in green industries.

One of the biggest challenges in Hawaii is the wages/cost-of-living ratio. Biofuels-related jobs in the state must provide "livable" wages that meet baseline needs of state residents as well as show potential for keeping up with steep rises in the consumer price index. In any case, the high and rising cost of living in Hawaii strongly suggests that the lower end of the biofuels jobs spectrum may not be attractive if other employment opportunities are available that pay above the minimum wage.

The growth of a biofuels industry in Hawaii is likely to require some significant investment from state resources. In particular, a state role in bridging the gap between existing training programs and industry needs can contribute to overall success and link the state to existing energy worker training programs. State legislation supporting these programs and promoting green jobs might help bolster industry success. The state can also explore opportunities to partner such job training programs with other public objectives in order to better integrate the workforce, including creating programs for low-income workers. For example, green-collar job training funds can be used to target low-income adults and youth in poverty.

This section of the report provides five recommendations and “thinking” points:

1. Given the likely small size of any biofuels workforce in Hawaii, other than agricultural workers, it is important for legislators to create synergies with other growing sectors of the economy. In particular, those fast-growing occupations related to the higher end of biofuels skills, such as industrial engineers, pharmacy technicians, and computer software engineers, who might share a workforce with biofuels professionals. On the lower-skilled end of occupations, manual laborers in the biofuels industry will likely share some concerns with other agricultural workers such as pay scales and working conditions.

2. The biofuels industry in Hawaii, as it evolves, will create some jobs for local residents as well as attract some new workers. To create a responsive and loyal employment base in the industry, legislators and business leaders might consider nurturing community—and regionally—specific worker bases to mobilize as much of the local unemployment base as possible. Such outreach is likely to create industry loyalty and identity since the size of the biofuels workforce is not likely to be large. This will increase labor channeling and networks that are easier to carve out as a stable employee base with less training.

3. Liveable wages are a problem for many workers in Hawaii. The report classifies those occupations in high- and low-wage categories, with the former likely to support a livable wage for Hawai`i, and the latter not likely to support a livable wage. Labor market subsidies to private sector firms, for example, might focus on those higher-end occupations and leave the lower-wage occupations to be performed by workers outside of the state of Hawaii, where they are likely to be more liveable wages. In this way, policy should focus on attracting those parts of the industry where wages are above manual labor level. There is some unemployment in Hawaii – especially on the neighbor islands – and efforts might be made to connect these jobless workers to any biofuels manual labor needs, however, and state investments to subsidize these production jobs, while good from a social service perspective, might not be the most effective way to build a sustainable biofuels industry in the state. State incentives should be focused on those investments that will enable the labor market to achieve a critical mass that becomes self-sustaining over time, rather than as a permanent subsidy.

4. A potential biofuels industry for Hawaii fits within a broader national and state effort to promote green technology and jobs. Thus, legislators should promote a model of workforce development in which biofuels training is connected to a broader effort to promote green technology jobs in the state.

2.4 Technology to Develop Bioenergy Feedstock and Biofuels

EXECUTIVE SUMMARY

A bioenergy technology assessment was conducted as part of the Hawaii Bioenergy Master Plan mandated by Act 253. This effort included the characterization of the status of crops and crop production technologies for bioenergy applications and of conversion technologies used to transform selected feedstocks into bioenergy products.

Crop characterizations included sugarcane (*Saccarum officinarum*), starch producers corn (*Zea mays)* and cassava (*Manihot esculenta*), fiber producers banagrass (*Pennisetum purpureum*), *Eucalyptus sp.*, and *Leucaena (Leucaena leucocephala*), and oil producers *Jatropha* (*Jatropha curcas*), oil palm (*Elaeis guineensis*), microalgae and biowastes. Of these, only sugarcane has an established history of commercial production in Hawaii. Although the state currently has several extensive *Eucalyptus* plantations, they have not been harvested to date. Harvesting was a common technology gap identified for terrestrial crops. Technology gaps associated with microalgae were found to be more extensive.

A summary of the assessment of conversion technologies is presented in Table E.1. The development status of each technology has been characterized as pilot, demonstration, or commercial facilities that might be constructed at scales on the order of <10, 100, and 1000 tons per day. All of the technologies identified in the table were deemed appropriate for Hawaii.

A number of recommendations have been developed based on stakeholder input and information collected in preparing this task and include:

1. The State should continue a bioenergy technology assessment activity that can provide updated information on the status of bioenergy conversion pathways and estimates of energy return on investment (EROI) for bioenergy value chain components.

2. Mechanized harvesting is a common theme across bioenergy crops. The State should fund a faculty position(s) in this area to work with the industry, conduct research as needed, and evaluate harvesting technologies for applications in Hawaii.

3. Support demonstration project development along the bioenergy value chain including energy crop production, transportation and logistics, and processing and conversion technologies. The State should develop funding mechanisms to leverage federal and private funds and support demonstration projects.

4. The State should provide support to the industry for preliminary feasibility studies of selected energy crop conversion alternatives to identify the most promising technology pathways and the resource requirements for those pathways.

5. The State should provide low-or-no cost land leases and expedited permitting to support pre-commercial bioenergy demonstration projects.

6. Hawaii should establish a bioenergy/biofuel development fund to support research, and technology development and demonstration where the University of Hawaii, other research organizations, and Hawaii-based industries should be encouraged to jointly participate.

7. Funds should be allocated to support training manpower in the field of bioenergy/biofuel technology.

Table E.1. Characterization of the development status of biomass conversion technologies

	Pilot	Demonstration	Commercial	Appropriate for HI?
Ethanol from Biochemical Route				
Sugar			X	Y
Starch			X	Y
Fiber[1]	X	X		Y
Gasification				
Heat			X	Y
Power	X	X		Y
Combined Cycle	X	X		Y
IC Engine	X	X		Y
Steam based			X	Y
Synfuels	X	X		Y
Pyrolysis[2]				
Bio-oil production			X	Y
Charcoal production		X	X	Y
Bio-oil production for fuels	X	X		Y
Combustion			X	Y
Renewable diesel via transesterification of vegetable oil			X	Y
Renewable diesel via hydrotreating of vegetable oil	X	X		Y
Anaerobic Digestion				
Heat			X	Y
Power			X	Y
Biogas production via cracking of fats, oil, and grease	X			

[1] Demonstration projects for cellulosic ethanol production currently underway
[2] Pyrolysis for bio-oil production as food ingredient is at commercial scale but use of bio-oil for energy other than combustion applications remains at pilot scale

2.5 Permitting

EXECUTIVE SUMMARY

Hawaii's bold and far reaching visions for a secure and sustainable energy future require an expeditious and broad implementation of clean and renewable energy applications including biofuels. Stakeholders in Hawaii's bioenergy industry, however, have identified Hawaii's permitting regime as a main obstacle to capital investment in the sector and successful implementation of promising bioenergy projects in the state. To meet its clean energy goals, Hawaii cannot afford the perception that investment and green energy initiatives are hindered by a lack of support from State and County permitting agencies.

To mitigate this problem, state leadership has called for swift improvements in permitting processes with passage of legislative measures affecting State and County permitting agencies. Several of these agencies have commenced implementation of process improvements, examples of which are provided in this report that show utilization of innovative online tools.

With the passage of HB 1464, HD 3, SD2, CD1, the 2009 State Legislature provided for expansion of the scope of the Renewable Energy Facility Siting Process, which regulates permitting of renewable energy facilities above certain thresholds for electricity generation and biofuel production capacities. The Renewable Energy Facility Siting Process prescribes process facilitation and establishes a maximum time period for government agencies to review a permit application. This should provide potential investors in renewable energy projects some assurance that their permit applications will be processed in a timely manner and with a maximum guaranteed time for processing the permit request.

While the changes in permitting of renewable energy facilities should provide significant improvements, the permitting regime could and probably must be further improved in the future to accommodate the large scope of renewable energy development required to move Hawaii closer to the Hawaii Clean Energy Initiative goal of 70 percent clean energy by 2030. The report suggests additional project management measures and the extensive use of online systems as means of further improvements.

RECOMMENDATIONS

(See Vol. II, Issue Report 2.5, Permitting, Section 4.)
(Note: The underlined items are reflected in Table 4, Issue Report Recommendations.)

While the efforts of streamlining permitting are applicable to a broad range of economic development projects, renewable energy development projects are generally receiving a prominent status. A web search conducted in April and May of 2009 has revealed the following elements of expedited and streamlined permitting, which could also be implemented in Hawaii:

- Expedited permitting is a major goal for many agencies but substantial time will be required by agencies to change their permitting processes towards a new permitting paradigm. Since pressing economic development and renewable energy implementation needs cannot wait until new permitting is universally accepted and implemented thoroughly by the organizations, <u>certain projects should qualify for preferential permitting treatment</u>. The decision whether a project qualifies for expedited permitting might be based on general procedural qualifiers or on case-by-case decisions.

- The permitting procedures should be defined as an efficient work process that encompasses work schemes of all participating agencies and stresses proactive cooperation between the agencies and the applicant. Where present permitting processes might already lead to efficient permitting within individual agencies, it is paramount to <u>facilitate the cooperation between agencies to remove redundancies in permits and information required for individual permits</u>.

- <u>The creation of a central contact point is seen as advantageous in order to efficiently communicate between applicants and permit awarding agencies. The central contact point would act as a facilitator who can help the applicant to reduce the burden of providing redundant information and keep the permitting project on a tight schedule</u>.

- <u>Each permit awarding agency should assign a point of contact that communicates between the central point of contact and the agencies that are part of the permitting process. The points of contacts within the agencies should also be responsible to establish and maintain efficient intra-agency communication for all permitting.</u>

- <u>There should be a pooled information repository where the applicant can deposit information that could then be used by different permits. This information repository would reduce the burden of the applicant to provide similar information to different agencies and for different permits</u>.

- <u>The permitting process should be accomplished within a certain time period. All agencies should endeavor to finish their permitting work within that time frame</u>. A range from 90 to 180 days has been identified by different state and county agencies for certain permit types. Certain unforeseen circumstances (i.e. non availability of information) might preclude the targeted permitting period but permitting should be completed as expeditiously as possible

- <u>The use of e-permitting is encouraged. The use of an online self-application for certain permits may be justified</u>.

- <u>Another venue for an expanded use of the Internet is an online permitting process with progress tracking and online exchange of information</u>. Such an e-permitting process would define permitting milestones and would process milestone tracking. <u>The applicant and all other process participants could get real time information about the status of the project and if the project permitting is on schedule</u>.

- <u>There should be a mechanism to inform applicants about what steps and in what order these steps need to be carried out in the permitting process</u>.

- Agencies should continuously train existing and new staff in the expedited permitting.

(See Vol. II, Issue Report 2.5, Permitting, Section 8)
The development and implementation of renewable energy projects, and specifically renewable biofuels, is of utmost importance to Hawaii. Presently Hawaii relies on petroleum for about 90% of its energy needs and has one of the highest per capita oil consumption rates in the world. The global oil market has been volatile for the past several years and sobering predictions by mainstream oil analysts warn of possible increasingly tight global oil supplies and high future oil prices starting as soon as in the next 2 to 5 years. Therefore time is of the essence to transform Hawaii's energy system towards more diversity of the state's energy supply.

Hawaii's leadership has developed bold visions of fundamentally transforming Hawaii's energy in the next two decades to provide up to 70 percent clean energy by 2030. Innovation at this staggering implementation scope and speed requires changes in the way governmental agencies work with developers of renewable energy facilities in the permitting of such projects.

The present permitting regime in Hawaii is seen by investors as the main hindrance to investment in Hawaii. Measures to streamline the permitting regime in Hawaii are therefore crucial to improve the attractiveness of Hawaii as a good place to invest in clean energy.

Improvements in Hawaii's permitting regime should involve new workflow processes within State and County permitting agencies as well as efficient interagency cooperation. While internal agency process improvements are ongoing and have resulted in numerous noticeable improvements, Hawaii's legislature has recently established the Renewable Energy Facility Siting Process that provides an overall permitting framework for renewable energy facilities above a certain capacity. Projects that qualify for the Renewable Energy Facility Siting Process will have a prescribed maximum time for permitting of 18 months, excluding the EIS process. An enforceable maximum time for permitting should provide investors some certainty that their permitting applications will be processed in a timely manner.

Innovative permitting approaches, such as the Renewable Energy Facility Siting Process, are laying important administrative foundations for expeditious development of a strong renewable energy industry in Hawaii.

While these new approaches to permitting of renewable energy facilities are timely and very important for Hawaii's secure and clean energy future, it is to be expected that Hawaii's permitting regime will require further changes in the years to come, in order to correct processes that lack efficiency improvements.

This report proposes possible further improvements to permitting for renewable energy facilities. The proposed further improvement of permitting processes would build on past accomplishments and recent legislative actions and would emphasize interagency cooperation in permitting project management and innovative online management tools.

It is felt that a structured and transparent interagency permitting framework working in concert with Hawaii's permitting agencies' own internal efficiency standards, is an appropriate administrative support to ensure the healthy growth of a strong renewable energy and bioenergy industry in Hawaii.

While progressive procedures and policies are the foundations to transform the permitting regime, human aspects in the organizations are the drivers that make re-engineering efforts successful and ensure that effective permitting strategies will become institutionalized.

2.6 Financial Incentives and Barriers and Other Funding

EXECUTIVE SUMMARY

The goal of this section of the Hawaii Bioenergy Master Plan (HBMP) is to identify and evaluate financial incentives and barriers at points along the bioenergy industry value chain (feedstock production, feedstock logistics, conversion, distribution, and end use) and their potential impact on the production of biofuels at levels sufficient to contribute a significant renewable energy resource to the State of Hawaii.

This section provides a comprehensive list of the financial barriers and incentives to entry and operation in the biofuel industry in the State of Hawaii. The scope covers both Federal and State financial instruments, including the American Recovery and Reinvestment Act of 2009. It includes discussion of innovative public and private financing vehicles for alternative energy and greenhouse gas (GHG) emissions reductions. The analysis was conducted through a legislative scan, stakeholder interviews, and surveys. Appendices summarize existing State and federal biofuel incentives, legislation proposed during the 2009 Hawaii legislative session, and policies for other Pacific region states and for selected countries.

A historic overview of biofuels legislation and industry activity provides a backdrop for the understanding of Hawaii’s present landscape. Hawaii biofuels initiatives date back to the mid-1970s, following a period of rapid fossil fuel price inflation. While biofuels have been used for electricity generation and transportation fuels, the development of a Hawaii industry has been slow. There does not currently exist local production or refining of Hawaii grown feedstock other than the long-established use of bagasse for electricity production.

This study analyzes the key threats to bioenergy across the value chain. Briefly, biofuels investors appear not to be confident in long-run profitability given challenges that they face in land acquisition, competition from energy substitutes (e.g. electric vehicles), highly concentrated purchasers, and fragmented State support.

The following recommendations are provided:

- Frame Hawaii’s bioenergy strategy around vital State interests. Energy security and greenhouse gas emissions reduction targets could provide justification for bioenergy support.
- Design a priori measurement and monitoring mechanisms to evaluate alternative individual projects based on State interests, particularly for the distribution of land leases.
- Act swiftly to capture funding made available through the American Recovery and Reinvestment Act of 2009, though recognize the funding would need to be balanced by sustained sources to carry the operation year after year.
- Consider House Concurrent Resolution 195 (HCR 195) and the subsequent recommendations of the Hawaii Energy Policy Forum (HEPF). Further study is

required to determine the most appropriate incentives at each part of the biofuels value chain. In particular, analysis is needed to determine: Locations for biomass project; Options for leasing State land for fuel crop development; Opportunities for state and county governments and private investors to secure federal grants to support the development of fuel crops and the conversion of fuel crops to generate electricity; and feasibility of setting up a revolving fund as a mechanism to provide incentives necessary to stimulate investment in fuel crops and the conversion of fuel crops to generate electricity.

- Establish a sub-committee of people with a mix of public and private experience raising capital for infrastructure and energy projects to put together the specific financial incentives to support HBMP. The sub-committee should, at a bare minimum, evaluate the incentive concepts proposed by HEPF in their response to HCR 195 (Appendix G).

- Create a dedicated office that will maintain an up-to-date list of State and Federal incentives, and provide guidance for prospective biofuel business owners on how to apply for incentives (grants, loans, tax credits, etc.). This office could also be the resource that guides business owners on the steps needed to valuate the environmental credits from the project. Perhaps this office could even provide business planning guidance. For example, a biomass power plant will likely be eligible for a waiver from the competitive bid process to provide HECO electricity. However, the waiver is for a period of four months. That is a prohibitively short period of time to get all the aspects of a plant’s operations lined up for negotiation of a power purchase agreement with the utility.

- Coordinate and make transparent the process for land acquisition for biofuel feedstock producers. Bioenergy and land use policy involves multiple State agencies (DLNR, DHHL, DOA, DBEDT). Biofuels may be perceived as competing with other land uses, such as food production and residential development. The State interest in bioenergy should be articulated relative to competing interests.

- Reconcile investor’s concern for exit strategies with biofuels incentives. “What are the business options if ethanol demand falls?” “What are my exit strategies?” “What other outlets exist for large ethanol stocks if transportation demand tanks?” Biofuels investors' decisions are typically based on 10-20 years for biofuel refinery plants.

- Align a flex fuel ethanol-based transportation strategy with the emergence of potential new transportation modes, including rail, and vehicle technologies, such as electric and hybrid vehicles. The State and counties are committed to alternative transportation strategies, and the role of biofuels should be assessed in that context.

- Synergize the biofuels master plan with the Hawaii Clean Energy Initiative goals. A higher profile for both will likely lead to more Federal dollars.

- Investigate Renewable Identification Number (RIN) market opportunities stemming from the Federal Renewable Fuel Standard (RFS). At present, Hawaii is opted-in to the Federal RFS. (Anon. 2008d) While further study is required, opportunities may exist to establish a complete, localized bioenergy value chain in Hawaii’s using the Federal

RFS. One resource we suggest to investigate is the RINMARK exchange (http://www.rinxchange.com/).

- Facilitate the measurement and monitoring of greenhouse gas emissions. An approach might include mandatory reporting through The Climate Registry (TCR). TCR sets consistent and transparent standards to calculate, verify and publicly report greenhouse gas emissions

- Coordinate biofuels policy with State goals to reduced GHG emissions. GHG emission reductions have actualized and perceived economic value in current and proposed initiatives to mitigate anthropogenic climate change. Provide research, education, and outreach on the role that biofuels might play relative to other strategies.

2.7 Business Partnering

EXECUTIVE SUMMARY

In order for Hawaii to have a productive bioenergy industry, successful partnering amongst industry "players" is essential. This section of the Hawaii Bioenergy Master Plan specifically evaluates facilitating the bioenergy industry through partnerships across and between sectors of the bioenergy value chain, and partnership with other organizations that control access to critical resources such as land and water.

Hawaii's bioenergy industry is in its infancy. Research found that a significant number of Partners demonstrate interest and intent—especially in the area of bioenergy conversion/processing— but most Partners have not yet reached the stage of commercial production. From a business partnership perspective, the following was noted:

- Partnering between various processes within the value chain is required for the vast majority of models identified.

  For the purposes of this report, a model is an example of the bioenergy production value chain that has differing partnership-handoff points/roles.

- More Partners are needed to fulfill identified functions. Many of the Partners are not necessarily associated with the bioenergy industry and thus the industry would benefit from a facilitator who can identify and match potential partners in the process chain.

- A greater number of Partners is needed in the Growing Processes area. Independent producers of bioenergy feedstock (biostock) are rare. Among the models with nearer term biostock production capability, a vertical integration was commonly found whereby the organization controls the processing and develops the biostock.

- Facilitative partnerships should be viewed on a per-island basis due to the economic obstacles of interisland shipping. One notable exception is in the transportation and distribution of liquid biofuels where there may be existing infrastructure.

- More information on production capacity (growing and processing) is needed and would greatly facilitate partnership identification and Partner planning.

The following represent key recommendations for advancing the bioenergy industry in Hawaii:

- **Provide "first-mover" incentives**
  In order to motivate the industry and build capacity in functions supporting the bioenergy industry, the State can provide incentives for early implementation of bioenergy production.

- **Develop and maintain a bioenergy Partner database**

A database of Partners, similar to the Bioenergy Partner Catalog in this report, would facilitate identification of partners for organizations without complete vertical integration, and assist with the identification of opportunities to fill the gaps in the bioenergy industry. This would benefit the State, in its industry facilitation efforts, as well as the private sector Partners.

- **Provide incentives to growers**
  Qualitative and quantitative information collected for this report indicates a need for greater capacity in bioenergy feedstock production. The objective of encouraging greater growing capacity can be approached from either end of the bioenergy value chain, but the authors believe that incentivizing growers directly is more effective for this objective.

- **Facilitate partnerships through a matchmaker**
  The State can significantly encourage necessary bioenergy partnerships through the creation of a position or program that facilitates such partnerships by identifying and encouraging needed Partners, introducing appropriate Partners, and acting as an industry advocate and government liaison.

2.8 Economic Impacts

EXECUTIVE SUMMARY

The objective of this study is to identify and evaluate potential economic impacts from the production of biofuels at points along the value chain. The "value chain" is here defined as: feedstock production, feedstock logistics, conversion, distribution, and end use. To accomplish this task, a macroeconomic model of Hawaii's economy, representing macro and sector-level inter-linkages, has been created. The model utilizes the 2005 State Input-Output Study for Hawaii, prepared by the Department of Business, Economic Development, and Tourism (DBEDT), as the primary data source. The 2005 Input-Output table is an excellent year in which to calibrate for this analysis because the recent price of world oil was similar: averaging $49/barrel.

Although there are several avenues by which a local bioenergy industry could develop, from biomass combustion for electricity to biomass for liquid fuel, this study focuses on sugarcane-to-ethanol. This scenario is chosen because 1) Hawaii has considerable experience with growing sugarcane as a feedstock and ethanol conversion is a currently commercially available technology, 2) a 10% ethanol-blending mandate for motor fuel was made effective and a 20% by 2020 Alternative Fuel Standard (AFS) was adopted in 2006, 3) ethanol blending facilities have been established within the state. Although the impetus of the 2006 mandate implementation, amongst other federal and state-level incentives, was to prompt a local bioenergy industry, the mandate has been met with imported ethanol sources.

To produce 93.7 million gallons of sugarcane derived ethanol in order to meet the AFS, 91,500 acres of irrigated agricultural land would need to be in sugarcane production. Assuming the industry is viable, it would be a $312 million sector and could produce ethanol at $3.33 per gallon – although costs may be brought down through the integration of byproducts with the electric sector. Roughly 1,200 jobs would be created with an average annual salary of $45,000. This results in an increase in gross state product of $272 million annually (+0.5%).

The creation of a local ethanol industry could serve to revitalize currently fallow agricultural lands as well as provide jobs in agriculturally oriented areas of Hawaii. On the other hand, it will take significant State support to make locally produced ethanol competitive with imported sources. The benefit stream must be assessed in relation to alternative agricultural activities, water consumption, community suitability and labor availability.

Ethanol is only one biofuel product that may be utilized within the state and findings about ethanol may not be applicable to other feedstock or conversion technologies. As bioenergy technologies become commercially available, both in Hawaii and elsewhere, there will be increasingly reliable information on their impacts and costs. Thus further study of biofuels for electricity generation and alternative liquid fuel products like biodiesel are needed to provide a more comprehensive view of the future of biofuels and their impacts to Hawaii's economy.

Information needs identified during this study:

Thus further study of biofuels for electricity generation and alternative liquid fuel products like biodiesel are needed to provide a more comprehensive view of the future of biofuels and their impacts to Hawaii's economy.

Biomass-to-electricity is another likely scenario for Hawaii's bioenergy future, given technological viability of current feedstock production. A comprehensive assessment of cost estimates, however, is outside the scope of this study and merits further analysis.

Although the energy-balance for ethanol from sugarcane is shown to be positive elsewhere, a Hawaii-specific analysis of total energy inputs versus energy output may be illustrative in order to better understand the full life-cycle costs of ethanol production in Hawaii.[1]

Community suitability and assessment studies will be needed in order to determine region-specific impacts, including impacts to food production (including crops and livestock).

The question of tradeoffs between labor and capital nonetheless is an important consideration in assessing the benefits of local biofuels, particularly for crops with longer periods between harvests.

The pressure on agricultural lands to be rezoned for urban use or made into "gentleman estates" is sizeable and merits further analysis.

In general, the impacts to the refineries of rising world oil prices and increasing local production of energy are not well understood and merit further analysis.

The costs of production for other feedstock for electricity are not addressed in this report. For tree crops, costs can vary widely depending on management practices such as coppicing versus replanting and is an area of future inquiry.

[1] The question of net energy balance is crucial to understanding whether policy outcomes are achieving their stated goals. For example, a 2002 USDA report on the energy balance for corn ethanol estimates that corn ethanol produces 34% more energy than it takes to produce it (USDA, 2002). Sugarcane is thought to be quite a bit more energy positive, estimated to increase energy output by nearly 80%.

2.9 Environmental Impacts

EXECUTIVE SUMMARY

An evaluation of the potential environmental impacts associated with bioenergy development in Hawaii was conducted as part of the Hawaii Bioenergy Master Plan mandated by Act 253 of the Hawaii State Legislature in 2007. This effort included the characterization of the general environmental impacts and issues associated with bioenergy development, the identification of potential environmental impacts in Hawaii for each portion of the biofuels value chain, and recommendations for State action.

Despite the obvious potential benefits of reduced greenhouse gas (GHG) emissions and energy self-sufficiency offered to Hawaii by bioenergy development, there are many potential environmental impacts that need to be considered when developing bioenergy policy and projects in Hawaii. The following is a summary list of the potential environmental impacts and issues associated with bioenergy development in Hawaii.

- Reduction in greenhouse gas emissions and use of fossil fuels
- Invasive species management
- Agricultural land use conflicts
- Water use and water rights
- Water pollution/quality
- Soil quality
- Air quality
- Residue management
- Socio-economic community impacts
- Cultural impacts
- Transnational environmental issues

The following list of recommendations has been developed based on stakeholder input and information collected in the preparation of this study.

1. Environmental Impact Assessment – As specific proposals are put forward for development of aspects of the bioenergy value chain, environmental assessments or environmental impact statements should be completed pursuant to the State of Hawaii environmental review law (Chapter 343, HRS) and the Department of Health Title 11-200 administrative rules governing the review process. It should be noted that not all bioenergy projects may trigger Chapter 343, HRS due to their proposed locations, land ownership, and/or funding.

   Environmental assessments and impact statements should include evaluations of the potential social, economic, and cultural impacts associated with the proposed projects, as required in the Title 11-200 administrative rules for the environmental review process. Assessments should strive to include analysis of how specific proposed projects for bioenergy development in Hawaii will effect and be affected by international market conditions. This analysis will give transparency to the potential indirect and direct environmental impacts of biofuels development in Hawaii.

2. Life-Cycle Analysis (LCA) – Life-Cycle Analysis (LCA) is the cradle to grave systems approach for examining technology and systems. LCA should be used to examine the specific technical aspects of any proposed biofuels value chain, the crops, energy requirements, emissions, land use changes, water use requirements, wastes, logistics, conversion technology, distribution, and end use to determine the net energy and greenhouse gas balances of the biofuel. This process is being used nationally and internationally to evaluate bioenergy development and could be employed for analysis of local conditions and permitting.

   The State should establish requirements for LCA based on Hawaii's specific environmental conditions, goals and needs. The State should establish guidelines for LCA, including certification of LCA methodologies, and the minimum attainment of positive net energy and greenhouse gas balances. LCA should be used as an integral component in a biofuels certification process.

3. Conservation Agriculture – Since most environmental impacts from bioenergy development are found in the feedstock production phase, the State should require appropriate conservation agriculture practices for biofuels feedstock production. This would help reduce water consumption, use of pesticides and fertilizers, and pollution.

4. Weed Risk Assessment (WRA) – Weed Risk Assessment (WRA) should be required for all candidate crops for biofuel production. Since Hawaii has sensitive natural resources that are susceptible to invasive species, the State should establish criteria for restricting certain candidate crops that may have the greatest potential for harm. It may also want to limit introduction of certain crops from areas near sensitive habitats depending on the individual characteristics of the candidate crop.

5. Examine the Issue of Agricultural Land Use and Biofuels – The State should commission a study to examine the potential issues related to agricultural land use and biofuels. The potential impacts to local agriculture from an introduction of large-scale biofuel development may be significant. Of particular importance is the potential loss of local food-crop production as prime agricultural lands are shifted to biofuels and non-agricultural uses.

   The study should examine how existing agricultural practices and uses of land, including small farming and ranching, may be impacted by the introduction of incentives and subsidies for biofuels. This should include an analysis of food security and fuel security issues in Hawaii. The study should also examine how the conversion of prime agricultural lands to non-agricultural uses may affect biofuels development and long-term viability.

6. Encourage Use of Existing Infrastructure – To minimize the potential environmental impacts from the development of new infrastructure needed to support bioenergy, the State should encourage the use of existing conversion facilities, pipelines, and other infrastructure where applicable.

7. Community-Based Bioenergy Working Group – Many stakeholders expressed concern about the lack of information regarding environmental issues and the State's plan for bioenergy development. Many requested a forum to exchange information. The State should establish a community-based working group with representatives from various stakeholders including, but not limited to, representatives from State of Hawaii Departments of Agriculture; Business, Economic Development and Tourism; Land and Natural Resources; Attorney General; bioenergy entrepreneurs; large landowners; small farmers; environmentalists; Native Hawaiian groups; the power industry; etc.

   This forum would be useful for creating community dialogue and understanding about bioenergy development and environmental issues in Hawaii. It could also be used as a tool for gathering information for social and cultural impact assessment.

8. Biofuel Certification Program – To safeguard Hawaii's unique native eco-systems and culture, and support sustainable biofuels development, the State should explore the possible development of a certification program for biofuels. Many countries are proposing that biofuels meet certain mandated targets or minimum goals to receive subsidies and government recognition. A certification program in Hawaii could include various sustainability requirements related to net energy and greenhouse gas balances, invasive species protection, water and land conservation, protection of local food supplies and farming, and other social and cultural issues.

   It should be noted that certification programs are difficult to employ and may, if too unwieldy or burdensome, constrain the development of the local biofuel industry in Hawaii. If employed, certification should be targeted at specific local problems and tailored to meet specific sustainability goals established by the Legislature.

   Due to the complexity of the issues, the State should commission a separate study to examine biofuels certification for Hawaii. The study should include analysis and recommendations for sustainability requirements, implementation and timing guidelines, and the specification of departmental permitting responsibilities. A central component of the study also should be the analysis of the various certifying methods including government run certification programs, preliminary certification for "First-Movers", voluntary certification, and third-party certification. Optimally, certification of any sort should not add to the duration of the overall permitting process. Efforts should be made to coordinate existing permitting and disclosure processes and reduce or eliminate redundancies.

   Optimally, a certification program should be established prior to the development of new subsidies for biofuels in Hawaii. However, due to the State's desire to encourage rapid development of bioenergy there may need to be some discussion about creating initial screening processes and preliminary certification to help first movers with "shovel-ready" projects or demonstration projects. If a "First-Movers Program" for preliminary certification was established, any participating programs should be required to complete a full and timely certification and LCA as part of their final permitting/compliance. Strict precautions would need to be taken in a preliminary certification process to safe-guard against invasive species and any other irreversible commitment of resources that may be proposed by a project under a “First-Movers Program”.

2.10 State, County, and Federal Plans, Policies, Statutes, and Regulations

This is a compilation of State, County, and Federal Plans, Policies, Statutes, and Regulations based on information available as of April 28, 2009. No Executive Summary is provided. The reader is referred directly to the report section in Vol. II.

Part 3: Potential and Actions

"A model that includes all pieces would allow decision analysis capabilities within the State to see how pieces fit together. Take system to community to increase understanding and get input, help them see where important connection points are, and how it can benefit or interfere. Allows for increased discussion."

Stakeholder comment, April 2, 2009

3.0 Introduction

This section addresses the five outcomes mandated in Act 253. Information needed to address each outcome was drawn from the issue reports in Section 2 and stakeholder input received during the preparation of this report. Section 3.1 answers the question, "Does Hawaii have the potential to rely on biofuels as a significant renewable energy resource?". Section 3.2 provides a bioenergy industry roadmap. Section 3.3 identifies strategic partnerships for research, development, testing, and deployment activities for renewable biofuels technologies and production of biomass crops. Section 3.4 addresses biofuel demonstration projects, including infrastructure for production, storage, and transportation of biofuels. Finally, Section 3.5 considers methods for promoting Hawaii's renewable biofuels resources to potential partners and investors for development in Hawaii as well as for export purposes.

3.1 Does Hawaii Have the Potential to Rely on Biofuels as a Significant Renewable Energy Resource? (Outcome 1)

Does Hawaii have the potential to rely on biofuels as a significant renewable energy resource? The adequacy of Hawaii's biomass resources to support bioenergy development is a central theme in the Act 253 enabling legislation and discussions on the topic have occurred at stakeholder and project-related meetings. Answering this question requires that a magnitude be associated with the word "significant." The scenario described below was developed to provide a reasoned estimate.

Three data sources were used to arrive at a "significant" bioenergy scenario for the purposes of the Hawaii Bioenergy Master Plan. These sources included the 2007 fuel consumption values for transportation and power generation, the Hawaii Clean Energy Initiative (HCEI) agreement signed between the State of Hawaii and Hawaiian Electric Industries utility companies, and the biomass power projects under consideration by the Kauai Island Utility Cooperative (KIUC). Table 1 summarizes the 2007 fuel consumption levels by county. Table 2 presents the Hawaii Bioenergy Master Plan bioenergy scenario based on 20% displacement of the 2007 fuel use from Table 1, the bioenergy components of the renewable energy commitments identified in the HCEI agreement, and the KIUC biomass projects. It is noted that this working scenario does not account for reductions in demand that are likely to occur due to increases in efficiency driven by higher energy prices or mandated by government policy.

Table 1. 2007 Fuel Consumption by County/Island in million gallons per year*

	Honolulu	Maui	Lanai	Molokai	Hawaii	Kauai	State
Transportation Fuel Use							
Gasoline	286.7	65.6			80.6	35.7	468.6
Diesel Oil (non-hwy)	186.2	11.7			14.8	22.3	235.0
Diesel Oil (hwy use)	25.4	9.2			13.2	4.8	52.7
Power Generation							
Fuel Oil	340.1	19.8			33.0		393.0
Diesel	4.1	57.2	2.4	2.8	11.8	34.6	112.9

* Data obtained from http://hawaii.gov/dbedt/info/economic/data_reports/energy-trends/

Table 2. Bioenergy use scenario by county/island to guide Hawaii bioenergy master plan activities(liquid fuels in 10^6 gal per yr, solid fuels in dry tons per yr).

	Honolulu	Maui	Lanai	Molokai	Hawaii	Kauai	State
Transportation Fuel Use							
Ethanol (20% of 2007 Gasoline Volume)	57.3	13.1	0.0	0.0	16.1	7.1	93.7
Renewable Diesel (non-hwy use) (20% of 2007 Non-Hwy Diesel Oil Volume)	37.2	2.3	0.0	0.0	3.0	4.5	47.0
Renewable Diesel (hwy use) (20% of 2007 Hwy Use Diesel Oil Volume)	5.1	1.8	0.0	0.0	2.6	1.0	10.5
Power Generation Use (20% of 2007 power generation use)							
Renewable Fuel Oil	68.0	4.0	0.0	0.0	6.6	0.0	78.6
Renewable Diesel	0.8	11.4	0.5	0.6	2.4	6.9	22.6
HECO/MECO/HELCO Power Generation Use Based on HCEI Agreement							
Simple cycle biofueled CT-1 (110 MW), CIP (under construction)	6						6.0
Distributed generation biofueled (8 MW) at HNL airport[1]	0.665						0.665
DG biofueled (30 MW) various substations[1]	2.5						2.5
Simple cycle biofueled CT-2 (110 MW), CIP	6						6.0
DG mixed renewables (100 MW) on military property[1]	8.5						8.5
Pulehu Energy (6 MW) on Maui operating on forest residues[2]		47,000					47,000
Hamakua Biomass (25 MW) or Hu Honua Biomass (22 MW), wood[2]					194,000		194,000
KIUC Power Generation							
Green Energy, 6 MW Biomass Power Project using Albizia						65,000	65,000
20 MW power plant using sugar cane bagasse						178,000	178,000
TOTALS							
Ethanol (million gal per year)	57.3	13.1	0.0	0.0	16.1	7.1	**93.7**
Renewable Diesel (million gal per year)	66.8	15.6	0.5	0.6	8.0	12.3	**103.7**
Renewable Fuel Oil (million gal per year)	68.0	4.0	0.0	0.0	6.6	0.0	**78.6**
Fiber (dry tons per year)		47,000			194,000	245,248	**486,000**

[1] Based on 1,000 hours of operation annually

[2] Based on 85% plant availability, 20% plant efficiency, wood higher heating value of 19 MJ/kg

Does Hawaii have the potential to rely on biofuels as a significant renewable energy resource? The working scenario used in this document to answer this question is based on requirements of 93.7 million gallons of ethanol, 103.7 million gallons of renewable diesel, 78.6 million gallons of renewable fuel oil, and 486,000 tons of dry fiber. Renewable diesel is an umbrella term that can include biodiesel derived from vegetable oil or synthetic diesel derived from gasification and liquid fuel synthesis technology. Renewable fuel oil would be a renewable replacement for residual fuel oil currently burned in steam based power generating units. In keeping with the value chain approach to analysis of bioenergy systems, the required adequacy of resources needed to address this question includes land, water, labor, infrastructure, and technology. Each is discussed below.

Land and Water

Based on the findings presented in the Land and Water issue report, it appears that there are sufficient ALISH lands to meet the targets for ethanol, renewable fuel oil, and fiber, individually. Analyses were conducted from different approaches to arrive at this conclusion.

One approach used GIS analysis to consider the potential of former sugar plantation lands. Plantation lands that closed prior to 1978, landholdings under 1,000 acres, or areas where sugarcane, seed crops, or coffee are currently being cultivated were excluded from the analysis. With the fact that not all of these lands are available for bioenergy crop production and by further eliminating former plantation areas where extremely large investments in infrastructure would be needed (e.g., Molokai), the optimistic projection is that roughly 53,000 acres might be utilized statewide. In this projection, the islands of Hawaii and Kauai have around 20,000 acres potentially available for bioenergy projects followed by Maui and Oahu with 3,000 and 10,000 acres, respectively. Due to lack of irrigation water, Molokai is projected to have no significant bioenergy production. Note that this assessment excludes lands currently planted to sugarcane and that removing this restriction could nearly double available land resources. By selecting former sugar lands, it can be assumed that adequate water would be available although investment in irrigation water delivery systems could be required. It is noted that agricultural land use patterns in the state can change based on time periods as short as crop production cycles. The recent announcement that the Gay and Robinson sugar plantation will cease sugar operations illustrates that changes can impact the near term availability of land in unpredictable ways.

A second approach to addressing land and water resources for bioenergy was conducted by modeling crop productivity to project potential yields. Sugar cane, oil palm, banagrass, *Leuceana*, *Eucalyptus*, and *Jatropha* were considered in the analysis. Based on crop yield data published for similar growing conditions, yields were projected by matching these bioenergy crops to agriculturally zoned lands with suitable land capability classes, climates, and soil depths. The ranges of ethanol production that could be produced from rainfed sugarcane, banagrass, *Eucalyptus*, and *Leucaena* are 71-110, 91-220, 230-350, and 93-370 million gallons of ethanol per year, respectively. The ranges of biodiesel produced from rainfed oil palm and *Jatropha*, respectively, are 22-50 and 8-78 million gallons per year. Ranges result from the use of several crop yield data sources rather than a single value. Note that these projections require soil depths of at least 36 inches and this necessarily restricts the available lands to those classified as ALISH. Land with shallower soil profiles and the requisite zoning and climate could be included in this analysis but crop yield data that would support these projections have not been published. Exploration of non-ALISH lands for bioenergy crop production merits additional research.

Estimated ranges of fiber production are shown in Table 3 by island and for the State as a whole. The data indicate that the State has the potential to easily meet the roughly 500,000 ton per year requirement identified in Table 2 using a combination of banagrass and trees.

Table 3. Estimates of fiber yields (dry ton per year) and potential renewable diesel production from three biomass feedstocks on agriculturally zoned lands with suitable land capability classes, climates, and soil depths based on crop and yield data published for similar growing conditions.

	-------------------million dry tons per year[1]-------------------					
	Banagrass		*Eucalyptus*		*Leuceana*	
	Low	High	Low	High	Low	High
Hawaii	0.90	1.83	1.25	1.68	0.49	1.34
Maui	0.42	1.74	0.46	0.72	0.35	1.15
Lanai	0.03	0.14	0.03	0.04	0.02	0.08
Molokai	0.12	0.52	0.12	0.19	0.10	0.35
Oahu	0.41	1.74	0.51	0.82	0.41	1.42
Kauai	0.56	1.90	0.46	0.70	0.33	0.95
State	2.44	7.87	2.84	4.16	1.69	5.29
	---million gal renewable diesel per year (high estimate)[2]--					
	Banagrass		*Eucalyptus*		*Leuceana*	
	Low	High	Low	High	Low	High
Hawaii	43.2	87.6	60.2	80.7	23.4	64.5
Maui	20.1	83.5	22.0	34.4	16.7	55.1
Lanai	1.5	6.5	1.3	2.1	1.0	3.7
Molokai	5.7	24.9	5.9	9.4	4.7	16.9
Oahu	19.6	83.5	24.7	39.2	19.5	67.9
Kauai	26.8	91.4	22.2	33.8	15.7	45.6
State	116.9	377.4	136.2	199.5	81.1	253.8
	---million gal renewable diesel per year (low estimate)[3]---					
	Banagrass		*Eucalyptus*		*Leuceana*	
	Low	High	Low	High	Low	High
Hawaii	16.2	32.8	22.6	30.3	8.8	24.2
Maui	7.5	31.3	8.2	12.9	6.3	20.7
Lanai	0.6	2.4	0.5	0.8	0.4	1.4
Molokai	2.1	9.3	2.2	3.5	1.8	6.3
Oahu	7.4	31.3	9.3	14.7	7.3	25.5
Kauai	10.0	34.3	8.3	12.7	5.9	17.1
State	43.8	141.5	51.1	74.8	30.4	95.2

[1] estimates are not mutually exclusive
[2] high estimate – 48 gal of renewable diesel per ton of dry biomass
[3] low estimate – 18 gal of renewable diesel per ton of dry biomass

Fiber can be used as a feedstock for synthesis gas production with subsequent conversion to a renewable diesel fuel via the Fischer-Tropsch process. Production of renewable diesel fuel using this method was estimated from the fiber production values in Table 2 for "high" and "low" diesel productivity values of 18 and 48 gallons per dry ton, respectively (Sims et al., 2008). Results are presented in the lower part of Table 3. The high renewable diesel yield based values in the middle part of the Table 3 indicate that the renewable diesel requirement identified in Table 2, 104 million gal per year, could be met in all but the low *Leuceana* yield case. The low renewable diesel yield values in the lower part of Table 3 are not as encouraging, meeting the 104 million gal per year target under only one scenario, that of high banagrass yield. As noted in the table, these scenarios are not necessarily mutually exclusive, but the differences in water requirements of the three crops provides some chance for combinations of crops to achieve the targets. It is also reasonable to assume that renewable diesel could be substituted for renewable fuel oil and thus this target could be met as well under some of the more productive scenarios, although renewable diesel would likely have a higher value as a transportation fuel rather than as a fuel for power generation.

From the two approaches outlined above for answering the question of whether Hawaii has the potential to rely on biofuels as a significant renewable energy resource, it would appear that sufficient land and water resources exist. Political and community acceptance of these activities remains unexplored and will be necessary to realize these levels of production.

There have been several assessments of current biomass resources in the state, the most recent mandated by Act 240, SLH 2006. Table 4 summarizes this most recent study (Easterly, 2008) is reproduced below. The results indicate that the many of the agricultural residues, such as bagasse, are currently utilized. Other opportunities for bioenergy production from underutilized components of these resources may be available for new bioenergy ventures. The reader is referred to the full report for complete details.

Table 4. Summary of biomass residues and biomass residue utilization in the State of Hawai'i broken down by County.

	tons/yr	Hawaii	Maui	Kauai	Honolulu
Solid Waste	as-received	300,000 (80,000)[a]	350,000 (80,000)[a]	120,000 (30,000)[a]	1,600,000 (500,000)[a]
Sewage Sludge	dry	200	3,400 (3,400)[a]	200	16,600 (900)[a]
Fat, Oil, Grease	dry	1,900	1,900 (1,900)[a]	1,000	10,000 (1,900)[a]
Bagasse Fiber	dry		220,000 (220,000)[a]	50,000 (50,000)[a]	
Cane Trash Dry			110,000	30,000	
Molasses	as-received		60,000	10,000	
Pineapple Processing Waste	dry		4,500 (4,500)[a]		
Macadamia Nut Shells	dry	17,000 (17,000)[a]			
Dairy Manure	dry	0			0
Poultry	dry				5,000
Swine Manure	dry	90	370	200	1,020
Forest Industry	dry	101,000		10,000	
Gross Total		420,190	750,170	221,400	1,632,620
Landfill Gas	ft^3/day	300,000		700,000	576,000

[a] Amount currently used.

Infrastructure

The determination of whether the existing fuel infrastructure could be used for future liquid biofuel applications would require case-by-case evaluation of compatibility between particular infrastructure components and biofuel products. In general, the current leading biofuels, ethanol and biodiesel from vegetable oil, are compatible with a limited number of infrastructure components.

Biofuel compatible infrastructure may require new installations of dedicated infrastructure or retrofitting of existing infrastructure that was previously used for petroleum products. Both would require investment and time to build. Given the probable ramp-up of production volume, trucking should be viable in the near term (at the cost of economic efficiency). Besides the financial expenditures for design and construction, building a new biofuel infrastructure would include land use issues including environmental impact assessment and permitting, very likely with involvement of the public.

Solid bioenergy distribution infrastructure will depend on commercial trucks on public roads for the transport of bioenergy feedstock (e.g. wood, forest residue, sugarcane). In general, capacities of roads to accommodate transport of bioenergy are quite elastic, since the planned transport quantity requirements with road-certified trucks do not seem excessive.

Infrastructure requirements for supporting biofuels as a significant renewable energy resource are not deemed to be major limitations.

Labor

The team conducting the labor task determined that it is possible that by 2030, the industry might add 584 jobs in the processing side only. Most agree that feedstock production and delivery will need much larger worker numbers than feedstock conversion so it is important that the field worker requirements be analyzed. The analysis of economic impacts found that the labor requirements for field activities would be roughly three times that required for feedstock conversion and the total workforce requirement, statewide, would exceed 1000. Based on the current labor force requirements for sugarcane production, it appears that this latter estimate is plausible. Given the ramp-up of labor demand and relatively high current unemployment it would appear that labor resources are present in the state to support the production of biofuels at levels that would constitute a significant renewable energy resource. Sugarcane industry workers are paid an average salary of $45,000 annually. To retain a workforce for bioenergy purposes, similar pay should be expected. Estimated costs of producing ethanol locally are $3.23 per gallon. This becomes competitive with comparable petroleum products when the world price of crude oil is above $60 per barrel. The price of imported ethanol, however, is likely to be substantially lower and thus imported sources are the largest economic barrier to local production.

Technology

Hawaii's potential to rely on biofuels as a significant renewable energy resource must be addressed at two major points in the value chain with regard to technology – harvesting technology for the biomass crop and technology to convert feedstock to useful bioenergy product, e.g. ethanol, renewable diesel, or electricity.

The crops considered in the report, sugarcane, *Jatropha*, oil palm, banagrass, *Eucalyptus*, and *Leucaena*, will require harvest technology adaptations and possibly improvements to realize full potential for Hawaii terrain and harvest conditions but this is not viewed as a major limitation. Equipment manufacturers exist for harvesting of sugarcane, forage grasses, and plantation forestry. Mechanized *Jatropha* harvesting equipment is currently under development by at least two equipment manufacturers (Oxbocorp and BEI) with prototypes under evaluation. The details can be found in *http://www.oxbocorp.com/jatropha.php* and *http://www.beiintl.com/Sway_Harvester.html*

The state of readiness for conversion technology is equally positive. Proven technologies to convert sugar and starch intermediate products to ethanol are available from multiple vendors. Similarly, combustion based steam generating units to produce firm power from biomass fuels are readily available; examples are currently in operation in Hawaii. Transesterification of vegetable oil is also mature technology and Hawaii currently has two commercial installations.

Cellulosic ethanol conversion technology through a biochemical route is currently in the early stages of development. Pretreatment and enzyme costs and fermentation of mixed sugars produced from fiber feedstock are issues that must be addressed before full-scale application. Technologies to produce ethanol, renewable diesel, and power from oil and fiber resources are the focus of significant development efforts and can be expected to provide new conversion opportunities by 2020.

Conclusion

Does Hawaii have the potential to rely on biofuels as a significant renewable energy resource? Assessment of the production factors of land, water, labor, infrastructure, and technology indicates that biofuels can provide a significant renewable energy resource for the state.

References

Sims, R., M. Taylor, J. Saddler, and W. Marbee. 2008. From 1st to 2nd Generation Biofuel Technology: An overview of current industry and RD&D activities. IEA Bioenergy, OECD/IEA. Paris, viewed 11/13/09 at
<http://www.iea.org/papers/2008/2nd_Biofuel_Gen_Exec_Sum.pdf>

3.2 Recommendations for a Hawaii Bioenergy Master Plan (Outcome II)

As prescribed by Act 253, this master plan addresses the wide range of issues that are involved in industry development. Recommendations from each of the Issue Reports have been presented in the reports in Volume II and are summarized in Part 2 (Vol I). The recommendations detail specific actions to support industry development and reflect stakeholder input obtained through a number of meetings held during the course of this project as well as direct contact with the project team.

To develop the Bioenergy Industry Roadmap, the Issue Report recommendations were evaluated, grouped and prioritized as shown in Table 4. Table 5 summarizes the programmatic actions recommended to be undertaken by a Renewable Biofuels Program. Finally, Roadmap action items are shown in Table 6.

An on-going challenge to the development of the Bioenergy Master Plan has been the wide-range of issues required to be addressed as a result of the inclusive approach of Act 253. Although the magnitude of this project required that the issues were studied by separate subject experts, there were concerns raised that deserve special consideration due to their cross-cutting impact on environment, community, or industry development.

As is evident from the April 2009 stakeholder meeting comments and the Issue Reports in Volume II, the preponderance of certain commonalities indicate four primary areas of concern that can underlie either the development of a vibrant bioenergy industry or the continuing challenges that have been Hawaii's experience. They are as follows:

1. Availability and use of resources

A central concern is the availability of resources – land and water – necessary for the production of agricultural feedstocks. Without locally available feedstocks in sufficient quantity, Hawaii cannot foster a bioenergy industry of the type envisioned by Act 253. Several of the April 2009 stakeholder group discussions focused on competition from alternative uses of these limited resources. The Business Partnering session, for example, found that, while there are many land opportunities, "the partnerships are hard to build and maintain because of competing uses for the land – solar, biomass, cattle". A solution was offered that "We need to work together to maximize use of resources."

The competition over land resources was exemplified in the recent controversy raised over the applications to the Board of Land and Natural Resources (BLNR) by Hamakua Biomass Holdings, LLC and Sunfuels Hawaii LLC for a direct lease of State lands for commercial forestry. The minutes of the November 14, 2008 BLNR meeting are instructive and can be viewed at http://hawaii.gov/dlnr/chair/meeting/minutes/2008/081114-minutes.pdf/view.

The continuing, and perhaps increasing, conflict over land and water resources in Hawaii is symptomatic of larger issues involving land use and agriculture. It would be beneficial for all sectors of the agriculture industry to coordinate in planning for appropriate use of agricultural lands. Planning for use of agricultural lands has been impeded by the lack of adequate resource information, a shortcoming that is highlighted in the Issue Report recommendations.

This area requires the development and implementation of strategies to minimize competition for the state's limited resources and ensure the availability of resources for bioenergy feedstock production.

2. Value chain interdependencies

The phrase "chicken and egg" appears in this report several times, in the context of value chain development and the development of necessary industry support including labor resources. As discussed in the Environmental Impacts report, "potential purchasers of biofuels, like electrical generating companies, may not invest in biofuel compatible generating plants unless there is a viable and economic supply of feedstock or finished biofuels." In the April 2009 Labor Session, a stakeholder commented that "It's a chicken and egg problem – we don't know the specifics. Each layer of biofuels needs different skills and expertise."

This area requires the development and implementation of a portfolio of strategies aimed toward ensuring the viability of each component of a bioenergy industry value chain. Strategies include financial incentives, community involvement, supportive and clear policies, identification of appropriate crops and technologies, and partnerships, among others.

3. Industry impacts

The bioenergy industry's value chain bridges nearly all aspects of our society and economy. By the nature of the industry's intent, i.e., displacement of imported fuels, and its value chain requirements, Hawaii's existing industries, most directly agriculture and the refineries, will be affected. For the benefit of the state, the industry, and its stakeholders, development should be undertaken with an understanding of these impacts. The industry should be compatible with other state goals including economic development, environmental protection, and food security.

This area requires assessments of environmental and economic impacts using life cycle and other analyses. The prevalence of issue recommendations related to assessments indicates an overwhelming need for new and updated analytical information.

4. Program level coordination

The cross-cutting concerns identified in this effort point to the need for a renewable biofuels program, as a priority, to work with stakeholders to establish clear bioenergy policy guidance and to coordinate the full range of actions necessary for bioenergy industry development.

3.2.1 Issue Report Recommendations

This roadmap is based on the evaluation and prioritization of the Issue Report recommendations from the perspective of the four concern areas. All of the recommendations made in the Issue Reports are presented in Table 4 below, categorized by four areas of concern. The relevant source Issue Report, type of recommended action, and implementation period are indicated. Priority recommendations are highlighted.

Table 5 : Issue Report Recommendations Grouped by Concern (Concern Numbering Code: 1 = Availability and use of Resources, 2 = Value Chain Interdependencies, 3 = Industry Impacts, and 4 = Program Level Coordination)

Concern	Issue Report	Recommendation	Type	1-3 yrs	> 3 yrs
1	Water/ Land	Remap ALISH to incorporate latest land use changes, availability of new lands (lava and non-ALISH lands), and proven potential of Hawaiian lands for diversified cropping.	Assessment - ALISH	X	
1	Water/ Land	Climate change may pose a significant threat to bioenergy crop production. The present analysis is insufficient to forecast outcomes and is not able to deal with climate change scenarios. Better models will need to be developed to answer questions regarding the magnitude of the effects of climate change on crop production.	Assessment – climate change	X	X
1	Water/ Land	Long-term impacts of planting a certain crop on the land and other infrastructure need to be studied. For example, what happens when that crop is no longer in demand? Can the land be converted back for use with other crops? What would be the impact of discontinued production? This could be studied based on the experience gained from sugarcane and pineapple industry.	Assessment - Impact	X	
1	Water/ Land	A detailed study of projection and comparison of energy from biofuel crops with that from other technologies, e.g., solar- and wind-based energy. The study may focus on how biofuel crops will compete for the use of resources potentially set aside for wind and solar energy production.	Assessment - Impact	X	
1	Water/ Land	A study should be conducted to address possible conflict and competition between bioenergy and food crops. Assess the impact of the possible use of ranch lands for bioenergy crop production.	Assessment - Impact	X	
1	Econ Impact	The pressure on agricultural lands to be rezoned for urban use or made into “gentleman estates” is sizeable and merits further analysis.	Assessment - land use	X	
1	Water/ Land	Further studies on various topics that closely relate to the current Bioenergy Master Plan. Description of the suggested studies is briefed below. *Ground Water Resources, Locations, and Potential Yields*: Inventory of the records from different agencies i.e., DLNR. Groundtruthing and field determination of potential yield for the locations that have missing records. Estimating the costs of rehabilitation and upgrading of the existing infrastructure systems (if any). *Surface Water Sources, Locations, and Potential Yields*: Inventory of the records from different agencies i.e., DLNR. Groundtruthing and field determination of potential yield for the locations that have missing records. Estimating the costs of rehabilitation and upgrading of the existing infrastructure of the existing systems. *Surface Water Diversions and Locations*: Surveying the existing records to determine all diversion locations that are either active or were active in the past. Evaluating the status of the existing diversions. Assessing the needs to rehabilitate these diversions. Quantifying the potential delivery capacity of the existing systems. *In-Depth Study of Biofuels*: Simulating different crop energy sources based on their energy yield and their demand on natural resources, and economic analysis of the different potential scenarios. *Potential Use of Reclaimed Water*: Survey and analyses (engineering and statistical) of current reclamation schemes including physical facilities, water service, and costs. Identify barriers to expanding reclaimed water use, develop recommendations to overcome barriers. *Connection with Important Agricultural Lands (IAL) Classification*: Review of state and county policies for IAL designation and criteria related to water.	Assessment – Resources	X	X
1	Water/ Land	Utilization of new groundwater resources for biofuel production will necessitate assessing its influence on aquifer recharge and on estimated aquifer sustainable yields. Models that use daily water budget approach to calculate crop irrigation water requirements should be preferred in modeling crop water use	Assessment - water	X	X

Concern	Issue Report	Recommendation	Type	1-3 yrs	> 3 yrs
1	Water/ Land	Conduct a systematic study for costs/benefit analysis of potential reuse of treated water for bioenergy crops. Such analysis may include resources needed for expansion and upgrading of treatment facilities, construction of water delivery infrastructure to the agricultural lands, and scale of bionergy crop production.	Assessment - Water	X	X
1	Water/ Land	Further understand Hawaii's water and land resources availability and constraints for bioenergy crops.	Assessment – water and land	X	
1	Water/ Land	Learn to manage lava lands. A significant portion of the 528,000 acres of unclassified land is lava. These lands are currently covered with volunteer trees that indicate it can support plant growth. Learning to cultivate these has the potential of opening large tracts of land for bioenergy crop production. Study the potential effect of bioenergy crop production on drinking water resources. Any plan for developing biofuel crops should also include the potential effect on drinking water resources. Growing high water demanding bioenergy crops and biomass feedstocks in windward areas will use the available soil moisture and rainfall and require less supplemental irrigation. Growing less water demanding bioenergy crops and biomass feedstocks in leeward areas will suite environmental conditions and water availability in the area. Increase sustainable water supplies (traditional and non-traditional) for agriculture including bioenergy and biomass crops. Develop or enhance water infrastructure sufficient to support biofuel use	Planning - resource	X	X
1	Env Impact	The State should require appropriate conservation agriculture practices for biofuels feedstock production. This would help reduce water consumption, use of pesticides and fertilizers, and pollution.	Policy - agriculture	X	X
1	Water/ Land	Drip irrigation system is considered a water saving system with high irrigation application efficiency. It can be preferred over micro-sprinkler irrigation system as its efficiency is not impacted by wind, and it can be used with recycled irrigation water.	Policy - agriculture	X	X
1	Water/ Land	Maintain land currently used for agriculture and forestry, and additionally, increase land available for bioenergy use sufficient to support biofuel use.	Policy – land use	X	X
1	Water/ Land	Enact land policies necessary to keep agriculturally zoned lands in agriculture.	Policy – Land use	X	X
1	Water/ Land	Rehabilitate irrigation systems that are currently not in use where sugarcane growing has discontinued. However, the cost to rehabilitate certain systems may be prohibitive.	Policy – Water	X	X
1	Finan Incent	Design *a priori* measurement and monitoring mechanisms to evaluate alternative individual projects based on State interests, particularly for the distribution of land leases.	Policy – projects	X	X

Concern	Issue Report	Recommendation	Type	1-3 yrs	> 3 yrs
1	Water/ Land	Find candidate species adapted to cool and cold regions for use at higher elevations. Most of the agriculturally zoned lands have cool and cold temperature regimes. Yet almost all the species evaluated seemed to perform better in the warm environment with the exception of *Eucalyptus*. There may be other species adapted to these temperature regimes that may equal or outperform *Eucalyptus*, which would give growers more options in deciding how to manage their lands. Find crop species adapted to dry environments. There are about 186,000 acres classified as dry throughout the state. Find crop species adapted to shallow soils. Develop a cropping system that could integrate bioenergy crops with regular crops for efficient utilization of resources such as land, water, time, and labor. An assessment is needed on the co-existence of bio-energy crops with other agricultural crops. A balance between food and fuel crops will ensure the equal and sustainable use of resources. Prioritize the use of resources for production of food and fuel crops. Develop a decision support system (DSS) that could match biological characteristics of crop to physical characteristics of soil and to environmental and ecological acceptance. Such a GIS-based DSS may help growers decide the best crop for their farms? Build a database for bioenergy crops detailing crop characteristics, potential yield, land and water requirements, and its suitability for integration with other crops and with environmental conditions in different regions in Hawaii.	Research - crops	X	X
1	Water /Land	Test water-harvesting technologies in Hawaii to minimize water runoff and maximize water storage.	Research - water	X	X
2	Technol.	The State should continue a bioenergy technology assessment activity that can provide updated information on the status of bioenergy conversion pathways and estimates of energy return on investment (EROI) for bioenergy value chain components. Mechanized harvesting is a common theme across bioenergy crops. The State should fund a faculty position (s) in this area to work with industry, conduct research as needed, and evaluate harvesting technologies for applications in Hawaii.	Assessment - technology	X	X
2	Technol.	The State should provide support to the industry for preliminary feasibility studies of selected energy crop conversion alternatives to identify the most promising technology pathways and the resource requirements for those pathways.	Assessment – technology	X	
2	Econ Impact	Assess biomass-to-electricity, another likely scenario for Hawaii's bioenergy future, given technological viability of current feedstock production.	Assessment – technology	X	
2	Water/ Land	Help farmers conduct a cost-benefit analysis for a specific bioenergy crop.	Coordination-facilitation	X	X
2	Technol.	Support demonstration project development along the bioenergy value chain including energy crop production, transportation and logistics, and processing and conversion technologies. The State should develop funding mechanisms to leverage federal and private funds and support demonstration projects. The State should provide low-or-no cost land leases and expedited permitting to support pre-commercial bioenergy demonstration projects. Hawaii should establish a bioenergy/biofuel development fund to support research, and technology development and demonstration where the University of Hawaii, other research organizations, and Hawaii-based industries should be encouraged to jointly participate.	Demonstration	X	X
2	Finan Incent	Reconcile investor's concern for exit strategies with biofuels incentives.	Incentives	X	

Concern	Issue Report	Recommendation	Type	1-3 yrs	> 3 yrs
2	Finan Incent	Consider House Concurrent Resolution 195 (HCR 195) and the subsequent recommendations of the Hawaii Energy Policy Forum (HEPF) Further study is needed to determine the most appropriate incentives at each part of the biofuels value chain.	Incentives	X	
2	Finan Incent	Establish a sub-committee of people with a mix of public and private experience raising capital for infrastructure and energy projects to put together the specific financial incentives to support HBMP.	Incentives	X	
2	Finan Incent	Investigate Renewable Identification Number (RIN) market opportunities stemming from the Federal Renewable Fuel Standard (RFS).	Incentives	X	
2	Partner	Provide "first-mover" incentives. In order to overcome the "chicken and egg" phenomenon and build capacity in functions supporting the bioenergy industry, the State can provide incentives for early implementation of bioenergy production. Include incentives that reduce the risk of being pioneers (financial risk, risk of legal/regulatory setbacks, etc.). Provide incentives to growers. The State could implement a purchase program (targeted at slightly below market rates to avoid competing with private industry) for surplus crops, with restrictions on annual volumes and the duration of the program.	Incentives	X	X
2	Technol.	Funds should be allocated to support training manpower in the field of bioenergy/biofuel technology.	Other action - Training	X	X
2	Infra-structure	The preferred future biofuel distribution system would utilize the existing petroleum fuel system and require no or minimum modifications of existing distribution assets. As biofuel usage grows in Hawaii, it is imperative that a distribution infrastructure be developed to accommodate the increased volumes of biofuel flowing through the supply systems. The timeline for the introduction of new distribution infrastructure should be preferably 5 to10 years rather than a short 2 to 3 years. The ideal biofuel distribution infrastructure would allow petroleum and biofuels to be transported and stored side by side, without the need to segregate large parts of the fuel distribution system by either neat petroleum or neat biofuel needs. Distribution systems that are built for specific biofuels should be avoided since they become obsolete as the biofuel use may change resulting in large sunk costs that might not be recovered.	Policy - infrastructure	X	X
2	Permit-ting	Certain projects should qualify for preferential permitting treatment based on general procedural qualifiers or on case-by-case decisions.	Policy - projects	X	X
2	Econ Impact	Incorporate accrued benefit stream in terms of improved outcomes for increased energy resiliency; reduced greenhouse gas emissions; and benefits to rural communities in Hawaii to determine if budgetary support measures are appropriate. Operating costs alone are not competitive with imported sources.	Policy – value benefits	X	X
2	Infra-structure	The selection of biofuel according to the compatibility to existing distribution infrastructure should be given high importance and weight.	Research-biofuels	X	X
2	Partner	Uncertainty surrounding crop selection can be reduced through State support of Hawaii-specific crop research and crop-specific incentives (e.g., market assurance). Research can be accelerated by greatly minimizing the number of crops receiving research funding, as determined by a science and industry panel.	Research - crops	X	X
3	Econ Impact	Assess potential benefits of biofuels in comparison to other renewable energy technologies. Assess benefits of local biofuels in relation to alternative agricultural activities, water consumption, community acceptance and labor availability.	Assessment - benefits	X	
3	Finan Incent	Facilitate the measurement and monitoring of greenhouse gas emissions, such as through mandatory reporting to The Climate Registry (TCR).	Assessment - GHG	X	X

Concern	Issue Report	Recommendation	Type	1-3 yrs	> 3 yrs
3	Econ Impact	Further study of biofuels for electricity generation and alternative liquid fuel products like biodiesel is needed to provide a more comprehensive view of the future of biofuels and their impacts to Hawaii's economy. Analyze Hawaii-specific total energy inputs versus energy output to better understand the full life-cycle costs of ethanol or other bioenergy production in Hawaii. Community suitability and assessment studies will be needed in order to determine region-specific impacts. Assess the tradeoffs between labor and capital, an important consideration, particularly for crops with longer periods between harvests. The costs of production for other feedstock for electricity are not addressed in this report. For tree crops, costs can vary widely depending on management practices such as coppicing versus replanting and is an area of future inquiry.	Assessment – impacts (costs)	X	
3	Env Impact	Environmental assessments or environmental impact statements should be completed pursuant to the State of Hawaii environmental review law (Chapter 343, HRS) and the Department of Health Title 11-200 administrative rules governing the review process. It should be noted that not all bioenergy projects may trigger Chapter 343, HRS due to their proposed locations, land ownership, and/or funding. Environmental assessments and impact statements should include evaluations of the potential social, economic, and cultural impacts associated with the proposed projects, as required in the Title 11-200 administrative rules for the environmental review process. Assessments should strive to include analysis of how specific proposed projects for bioenergy development in Hawaii will effect and be affected by international market conditions.	Assessment – impacts (env)	X	X
3	Econ Impact	Region-specific studies should be conducted to better understand the availability of labor.	Assessment - Labor	X	
3	Env Impact	Commission a study to examine the potential issues related to agricultural land use and biofuels including potential loss of local food-crop production as prime agricultural lands are shifted to biofuels and non-agricultural uses.	Assessment – land use impacts	X	
3	Econ Impact	In general, the impacts to the refineries of rising world oil prices and increasing local production of energy are not well understood and merit further analysis.	Assessment - refineries	X	X
3	Infra-structure	A decreased demand of certain petroleum fuel products due to displacement by biofuels could have impacts on the operations of the two local refineries.	Assessment - refineries	X	X
3	Env Impact	A Weed Risk Assessment (WRA) should be required for all candidate crops for biofuel production. The state should establish criteria for restricting certain candidate crops that may have the greatest potential for harm. It may also want to limit introduction of certain crops from areas near sensitive habitats depending on the individual characteristics of the candidate crop.	Assessment – weed risk	X	X
3	Env Impact	Life-Cycle Analysis (LCA) is the cradle to grave systems approach for examining technology and systems. LCA should be used to examine the specific technical aspects of any proposed biofuels value chain, their crops, energy requirements, emissions, land use changes, water use requirements, wastes, logistics, conversion technology, distribution, and end use to determine the net energy and greenhouse gas balances of the biofuel. This process is being used nationally and internationally to evaluate bioenergy development and could be employed for analysis of local conditions.	Assessment – Life Cycle Analysis	X	X
3	Env Impact	Explore the possible development of a certification program for biofuels to safeguard Hawaii's unique native eco-systems and culture. A certification program could include various sustainability requirements related to net energy and greenhouse gas balances, invasive species protection, water and land conservation, protection of local food supplies and farming, and other social and cultural issues. The State should commission a separate study to examine biofuels certification for Hawaii.	Policy - biofuels	X	

Concern	Issue Report	Recommendation	Type	1-3 yrs	> 3 yrs
3	Env Impact	Encourage use of existing infrastructure to minimize the potential environmental impacts from the development of new infrastructure.	Policy - Infrastructure	X	
4	Econ Impact	Involve specific communities through all steps of the process. The Hamakua community's outcry in November 2008 in response to the possibility of *Eucalyptus* plantation expansion without community input serves as testament to the importance of regional planning in the process of pursuing statewide energy goals.	Community involvement	X	X
4	Env Impact	The State should establish a community-based working group with representatives from various stakeholders including, but not limited to, representatives from State of Hawaii Departments of Agriculture; Business, Economic Development and Tourism; Land and Natural Resources; Attorney General; bioenergy entrepreneurs; large landowners; small farmers; environmentalists; Native Hawaiian groups; the power industry; etc.	Community Involvement	X	X
4	Water /Land	State residents are the most critical stakeholders, as they will most benefit from bioenergy production in Hawaii. Other stakeholders include scientists, researchers, students, policy makers, land owners, and growers/farmers.	Community involvement	X	X
4	Finan Incent	Create a dedicated office that will maintain an up-to-date list of State and Federal incentives, and provide guidance for prospective business owners in biofuel on how to apply for incentives (grants, loans, tax credits, etc.).	Coordination – industry facilitation	X	X
4	Water/ Land	Make sure that the changes in the State Administration do not affect implementation of this Master Plan. Educate the next generations as well as coming administrations for seamlessly carrying on of the work, and the wise use of land and water resources.	Coordination - policy	X	
4	Finan Incent	Synergize the biofuels master plan with the Hawai'i Clean Energy Initiative goals. Higher profile for both will likely lead to more Federal dollars.	Coordination - programs	X	
4	Water/ Land	Technical experts for research and strategic planning on State's future bioenergy plans include PIs of the current project, academia, and researchers and scientist working in local, state, and federal agencies. Encourage close collaborations among scientists, researchers, policy makers, extension agents, and farmers as a comprehensive link of information dissemination in order to provide the context for informed decision-making Existing reports on the completed projects of Hawaii's water resource and planning studies (CWRM, 2003, 2005, 2007), DBEDT's reports, and agricultural land and water use plans (AWUDP, 2004, HAWUDP, 2008), are sources of information.	Coordination - technical	X	X
4	Water/ Land	As suggested by SunFuels Hawaii, creation of an ongoing fact-finding and policy discussion forum, an independent statewide panel steeped in science, technology assessment and land use analysis.	Coordination - technical	X	X
4	Finan Incent	Provide research, education, and outreach on the role that biofuels might play relative to other strategies.	Education and outreach	X	
4	Finan Incent	Act swiftly to capture funding made available through the American Recovery and Reinvestment Act of 2009.	Investment	X	
4	Finan Incent	Coordinate and make transparent the process for land acquisition for biofuel feedstock producers.	Other action - Process	X	X

Concern	Issue Report	Recommendation	Type	1-3 yrs	> 3 yrs
4	Permit-ting	Improvements in Hawaii's permitting regime should involve new workflow processes within State and County permitting agencies as well as efficient interagency cooperation. Each permit awarding agency should assign a point of contact that communicates between the central point of contact and the agencies that are part of the permitting process. The points of contacts within the agencies should also be responsible to establish and maintain efficient intra-agency communication for all permitting. There should be a pooled information repository where the applicant can deposit information that could then be used by different permits. This information repository would reduce the burden of the applicant to provide similar information to different agencies and for different permits. The use of e-permitting is encouraged. The use of an online self-application for certain permits may be justified. There should be a mechanism to inform applicants about what steps and in what order these steps need to be carried out in the permitting process.	Other action - Process	X	X
4	Permit-ting	Another venue for an expanded use of the Internet is an online permitting process with progress tracking and online exchange of information. The applicant and all other process participants could get real time information about the status of the project and if the project permitting is on schedule. Facilitate cooperation between agencies to remove redundancies in permits and information required for individual permits. Creation of a central contact point in order to efficiently communicate between applicants and permit awarding agencies.	Other action - Process	X	X
4	Permit-ting	The permitting process should be accomplished within a certain time period. All agencies should endeavor to finish their permitting work within that time frame.	Other action - Process	X	X
4	Permit-ting	Agencies should continuously train existing and new staff in the expedited permitting.	Other action - Training	X	X
4	Labor	State and county governments should partner with federal agencies, private industry, and technical training schools to develop the labor requirements for industry growth. Legislators should work within these partnerships to create a range of certification and degree programs.	Partnerships	X	X
4	Partner	Develop and maintain a bioenergy Partner database. A database of Partners, similar to the Bioenergy Partner Catalog in this report, would facilitate identification of partners for organizations without complete vertical integration, and assist with the identification of opportunities to fill the gaps in the bioenergy industry. This would benefit the State, in its industry facilitation efforts, as well as the private sector Partners. Facilitate partnerships through a matchmaker. The State can significantly encourage necessary bioenergy partnerships through the creation of a position or program that facilitates such partnerships by identifying and encouraging needed Partners, introducing appropriate Partners to each other, and acting as an industry advocate and government liaison.	Partnerships	X	X
4	Finan Incent	Align a flex fuel ethanol-based transportation strategy with the emergence of potential new transportation modes, such as rail, and vehicle technologies, such as electric and hybrid vehicles.	Planning - transportation	X	X
4	Infra-structure	Appropriate traffic mitigation measures could be implemented to avoid significant impacts from solid biofuel feedstock trucking operations.	Planning - transportation	X	X

Concern	Issue Report	Recommendation	Type	1-3 yrs	> 3 yrs
4	Labor	To create a responsive and loyal employment base in the industry, legislators and business leaders might consider nurturing community—and regionally—specific worker bases to mobilize as much of the local unemployment base as possible. Promote a model of workforce development in which biofuels training is connected to a broader effort to promote green technology jobs in the state.	Planning - workforce	X	X
4	Finan Incent	Frame Hawaii's bioenergy strategy around vital State interests. Energy security and greenhouse gas emissions reduction targets could provide justification for bioenergy support.	Policy - GHG	X	
4	Finan Incent	Coordinate biofuels policy with State goals to reduced GHG emissions. GHG emission reductions have actualized and perceived economic value in current and proposed initiatives to mitigate anthropogenic climate change.	Policy – GHG	X	
4	Labor	Policy should only attempt to attract those parts of the industry where wages are above manual labor level.	Policy - labor	X	X

The types of recommended actions suggest significant industry and stakeholder needs and appropriate programmatic response as follows:

Table 6: Renewable Biofuels Program – General Programmatic Actions

Recommendation Type	Broad Industry and Stakeholder Need	General Programmatic Actions
Assessment	Better resource, land use, and impact information and analyses for decision making by policy makers and industry	Conduct resource and analytical assessments
Community involvement	Broad stakeholder engagement	Conduct community outreach activities
Coordination	Better coordination among key stakeholders	Facilitate stakeholder forums and other appropriate value chain support
Demonstration	Support for technology commercialization	Develop technology demonstration projects
Education and outreach	Informed public	Prepare and disseminate informational materials
Incentives	Reduced business risk	Conduct analysis of potential incentives
Investment	Project financial support	Provide information on financial support options
Partnerships	Multiple project participants	Facilitate research, demonstration and commercialization partnerships
Planning	Assistance with issue resolution	Develop programs to assist with resource and other planning
Policy	Clarification of state policies	Advocate for clear and supportive policies
Research	Appropriate crops, biofuels, and resource management	Facilitate and fund research opportunities
Other actions	Modifications to current processes, especially those related to permitting	Facilitate process improvements or other changes

3.2.2 Bioenergy Roadmap

Table 6 on the following pages lays out a bioenergy roadmap that includes the priority recommendations from Table 4 and programmatic actions from Table 5. Where appropriate, recommendations have been condensed into single action items.

These actions are recommended for implementation in the initial three years of the program. The majority of these near-term actions should be continued at least through the mid-term (4 – 9 years) to be responsive to advancements in crop and conversion technologies and changing market conditions. Longer-term (10 – 20 years) actions are those that should be continued as an on-going practice or capability.

Table 7. Summary of roadmap action items.

Roadmap Action Item	Near Term			Mid-Term			Long Term		
	2010	2011	2012	2013	2015	2018	2020	2025	2030
<u>Program Level Coordination</u>									
1. Establish a Renewable Biofuels Program: DBEDT shall establish a bioenergy program (Program) to manage the state's transition toward energy self sufficiency based in part on bioenergy for electricity and transportation. The bioenergy program shall receive $1.5 million dollars per year to establish three staff positions using up to $340,000 and the balance shall be used to fund assessments and co-fund demonstration projects as identified in the bioenergy master plan. Assessment and demonstration projects shall be prioritized by bioenergy technical advisory group and stakeholder input. Program personnel shall schedule regular outreach meetings to exchange information with communities on all islands where bioenergy development is proposed. In its first year, the Program shall develop an appropriate tax credit based on green house gas reductions resulting from the displacement of fossil fuels by bioenergy products that accrues to Hawaii bioenergy feedstock producers and bioenergy conversion facilities. Activities of the bioenergy program shall be reported to the legislature annually in December.									
2. Establish Bioenergy Technical Advisory Group that includes one representative each from DBEDT, the Department of Land and Natural Resources (DLNR), the Department of Agriculture (DOA), the Department of Hawaiian Home Lands (DHHL), the Department of Health (DOH), and 18 other members representing the bioenergy industry (3), refiners (2), agricultural producers (4), environmental concerns (3), utilities (3), the Office of Hawaiian Affairs (1), and bioenergy research (2). The advisory group will provide advisory support to the Renewable Biofuels Program.									
3. Involve specific communities through all steps of the process.									
4. Establish Community-Based Bioenergy Working Group.									
5. Maintain an up-to-date list of State and Federal incentives, and provide guidance to prospective bioenergy value-chain business owners on how to apply for incentives (grants, loans, tax credits, etc.).									
6. Synergize the bioenergy master plan with the Hawaii Clean Energy Initiative goals.									
7. Encourage close collaborations among scientists, researchers, policy makers, extension agents, and farmers as a comprehensive link of information dissemination in order to provide the context for informed decision-making.									
8. Establish an independent fact-finding and policy discussion forum, based in science, technology assessment and land use analysis to support programmatic and policy decisions.									

Roadmap Action Item	Near Term			Mid-Term			Long Term		
	2010	2011	2012	2013	2015	2018	2020	2025	2030
9. Provide research, education, and outreach on the role of biofuels.									
10. Act swiftly to capture funding made available through federal programs, especially related to economic stimulus.									
11. Work to promote new workflow processes within State and County permitting agencies as well as efficient interagency cooperation.									
12. Develop and maintain a bioenergy partner database similar to the Bioenergy Partner Catalog in this report.									
13. Facilitate partnerships through a matchmaker. The State can significantly encourage necessary bioenergy partnerships through the creation of a position or program that facilitates such partnerships…and acting as an industry advocate and government liaison.									
14. Position Hawaii's bioenergy strategy in the context of vital State interests such as energy security and greenhouse gas emissions reduction targets.									
15. Clarify whether the State should only attempt to attract those parts of the industry where wages are above manual labor level.									
<u>Availability and Use of Resources</u>									
1. Develop and prepare a single, clear, consistent policy on use and lease of State lands for agriculture, grazing, forestry, and bioenergy feedstock production, in consultation with relevant stakeholders and to promulgate policies of energy and food security. The plan shall include components describing favorable lease terms for bioenergy demonstration projects. Report of this policy shall be submitted to the Legislature by December 2011.									
2. Implement land policy developed in December 2011.									
3. Provide a tax credit of __% of investment to support the refurbishment and continued maintenance of irrigation systems supplying water to agricultural lands of importance to the State of Hawaii that are used for food or bioenergy feedstock production, employ appropriate conservation agriculture practices, and are committed to production agriculture or bioenergy feedstock production for 25 years.									
4. Study the potential effect of bioenergy crop production on drinking water resources. Assess influence of new groundwater resources for biofuel production on aquifer recharge and estimated aquifer sustainable yields.									
5. Conduct a systematic study for cost/benefit analyses of potential reuse of treated water for bioenergy crops.									
6. Increase sustainable water supplies (traditional and non-traditional) for agriculture including bioenergy and biomass crops.									

Roadmap Action Item	Near Term			Mid-Term			Long Term		
	2010	2011	2012	2013	2015	2018	2020	2025	2030
7. Assess the potential for sustainable use of resources for bioenergy crops and other agriculture including ranch lands. Prioritize the use of resources for production of food and fuel.									
8. Encourage appropriate conservation agriculture practices to help reduce water consumption, use of pesticides and fertilizers, and pollution.									
9. Maintain land currently used for agriculture and forestry, and additionally, increase land available for bioenergy use sufficient to support biofuel production.									
10. Conduct research on Hawaii-specific crops and Hawaii-specific crop incentives.									
11. Develop cropping systems that integrate bioenergy crops with current crops for efficient utilization of resources such as land, water, time, and labor.									
12. Develop a decision support system to match biological characteristics of crops to physical characteristics of soil and to environmental and ecological acceptance.									
13. Test water-harvesting technologies in Hawaii to minimize water runoff and maximize water storage.									
Value Chain Interdependencies									
1. Provide a __% tax credit for investments made to convert existing infrastructure to be compatible with bioenergy products or for construction of new infrastructure components for transporting and distributing bioenergy products derived from bioenergy feedstocks that are produced in Hawaii. The credit will be available in the first year that 50% of the total product volume of the infrastructure component is a bioenergy product.									
2. Provide funding for a full-time, tenure track, faculty position in the College of Tropical Agriculture and Human Resources (CTAHR) at the University of Hawaii at Manoa to conduct research and demonstration of appropriate bioenergy feedstock harvesting technologies suitable for Hawaii's conditions.									
3. Fund a continued bioenergy technology assessment activity that can provide updated information on the status of bioenergy conversion pathways and estimates of energy return on investment (EROI) for bioenergy value chain components.									
4. Provide support to industry for preliminary feasibility studies of selected energy crop conversion alternatives to identify the most promising technology pathways and the resource requirements for those pathways.									
5. Develop funding mechanisms to leverage federal and private funds and support demonstration projects.									

Roadmap Action Item	Near Term			Mid-Term			Long Term		
	2010	2011	2012	2013	2015	2018	2020	2025	2030
6. Establish a bioenergy/biofuel development fund to support research, and technology development and demonstration.									
7. Reconcile investors' concern for exit strategies with biofuels incentives.									
8. Provide incentives for early implementation of bioenergy production.									
9. Implement a purchase program, (targeted at slightly below market rates to avoid competing with private industry) for surplus crops, with restrictions on annual volumes and the duration of the program.									
10. Develop policy to provide benefit streams to bioenergy projects that result in increased State energy resiliency, reduced greenhouse gas emissions, and benefits to rural communities in Hawaii.									
11. Test biofuels under development or in a pre-commercial stage for compatibility with existing petroleum equipment and distribution assets.									
<u>Industry Impacts</u>									
1. Develop a methodology for evaluation of bioenergy projects based on the principles of life cycle assessment (including energy inputs vs. energy outputs and greenhouse gas balances) in consultation with relevant stakeholders.									
2. Establish policy and process whereby State agencies will require life cycle assessments for bioenergy development proposals that seek to use State lands or State funds.									
3. Develop a certification program for biofuels to safeguard Hawaii's unique native eco-systems and culture, and support sustainable biofuels development.									
4. Assess the impacts of rising world oil prices and increasing local production of bioenergy on the two refineries.									
5. Continue assessment of economic impacts of bioenergy production as industry develops and data become available.									
6. Encourage use of existing infrastructure to minimize potential environmental impacts from the development of new infrastructure.									

While all of the roadmap action items in the preceding table are necessary for the development of a Hawaii bioenergy industry, the following can be considered essential first steps and additional detail is provided below:

1. Establish a Bioenergy Program

To carry out the priority issue area recommendations, a Bioenergy Program must be adequately staffed and funded. The State Department of Business, Economic Development and Tourism (DBEDT) is the most likely location for the program, consistent with the statutory role of the State's Energy Resources Coordinator (ERC).

Program resources should include sufficient personnel and dedicated financial resources commensurate with this industry's vital importance to the economic and energy future of the state. Program staffing of three professionals with bioenergy technical and/or policy experience is recommended. The program term should be no less than 10 years to ensure continuity of industry development, with annual dedicated funding for personnel and program activities. Determination of additional resources to assure the viability of the industry value chain is subject to the assessments recommended as priority actions.

Program activities will include:

- Assessment, research and demonstration projects which will be prioritized by a bioenergy technical advisory group and stakeholder input.
- Community involvement and education and outreach, including conduct of regular outreach meetings to exchange information with communities on all islands where bioenergy development is proposed.
- Support of partnerships including maintenance of partner database.
- Policy and planning activities, in coordination with the bioenergy technical advisory group and stakeholders, including but not limited to the planning and policy requirement items listed in the priority issue area recommendations above.
- In its first year, development of an appropriate tax credit based on green house gas reduction resulting from the displacement of fossil fuels by bioenergy products that accrues to Hawaii bioenegy feedstock producers and bioenergy conversion facilities.
- Industry coordination activities including but not limited to such items listed in the priority issue area recommendations above.
- Annual reports to the legislature.

Responsible party: DBEDT
Implementation date: 2010 - 2020
Funding: $1.5 million annually including $340,000 for 3 full-time equivalent positions

2. **Establish a bioenergy technical advisory group**

A bioenergy technical advisory group should be established and facilitated by DBEDT. The advisory group should include one representative each from DBEDT, the Department of Land and Natural Resources (DLNR), the Department of Agriculture (DOA), the Department of Hawaiian Home Lands (DHHL), the Department of Health (DOH), and 18 other members representing the bioenergy industry (3), refiners (2), agricultural producers (4), environmental concerns (3), utilities (3), the Office of Hawaiian Affairs (1), and bioenergy research (2). The advisory group will provide advisory support to the Renewable Biofuels Program.

Responsible party: DBEDT
Implementation date: 2010 - 2020

3. Develop clear and consistent policy for use of State lands
A single, clear, consistent policy on use and lease of State lands for agriculture, grazing, forestry, and bioenergy feedstock production, in consultation with relevant stakeholders and to promulgate policies of energy and food security should be developed. The policy should include components describing favorable lease terms for bioenergy demonstration projects and lease application and process requirements.

Responsible parties: DBEDT, DLNR, DOA, DHHL
Report date: Due to the Legislature by December 2011.
Policy implementation: 2012

4. Develop methodology for evaluation of bioenergy projects
A methodology for evaluation of bioenergy projects based on the principles of life cycle assessment (including energy return on investment) should be developed in consultation with relevant stakeholders.

Responsible party: DBEDT
Report date: Due to the Legislature by December 2011.

5. Require Life Cycle Analysis for use of State lands or funding support
Establish policy and process whereby State agencies will require life cycle assessments for bioenergy development proposals that seek to use State lands or State funds.

Responsible party: DBEDT
Policy implementation: 2012

6. Provide a tax credit for irrigation systems
The State should provide a tax credit of **__**% of investment to support the refurbishment and continued maintenance of irrigation systems supplying water to agricultural lands of importance to the State of Hawaii that are used for food or bioenergy feedstock production, employ appropriate conservation agriculture practices, and are committed to production agriculture or bioenergy feedstock production for 25 years. The tax credit may be used over the 25 year period of performance.

Responsible party: Legislature/Administration
Tax credit implementation: 2012

7. Provide a tax credit for infrastructure systems

Provide a __% tax credit for investments made to convert existing infrastructure to be compatible with bioenergy products or for construction of new infrastructure components for transporting and distributing bioenergy products derived from bioenergy feedstocks that are produced in Hawaii. The credit will be available in the first year that 50% of the total product volume of the infrastructure component is a bioenergy product.

Responsible party: Legislature/Administration
Tax credit implementation: 2012

8. Appropriate funds for a research position

The State shall provide funding for a full-time, tenure track, faculty position inn the College of Tropical Agriculture and Human Resources (CTAHR) at the University of Hawaii at Manoa to conduct research and demonstration of appropriate bioenergy feedstock harvesting technologies suitable for Hawaii's conditions.

Responsible party: University of Hawaii - CTAHR
Faculty Hire: 2011

3.3 Strategic Partnerships for the Research, Development, Testing, and Deployment of Renewable Biofuel Technologies and Production of Biomass Crops (Outcome III)

The significance of partnerships to enable coordinated activities along the bioenergy industry value chain has been discussed in detail in the Business Partnering Issue Report (Vol II Section 2.7). The analysis of the participants in Hawaii industry activities found that business partners are needed to provide the feedstock production, conversion, distribution, and end use functions of the commercial industry. Additional supporting partners are also needed to provide the requirements (e.g. capital, labor, land, permitting) necessary to support the development of each of the components.

In addition to value chain business partnerships, Hawaii's nascent bioenergy industry requires support at the pre-commercial stage. Hawaii's attributes, including tropical climate, environmental fragility, geography, relatively high cost of living, and resource constraints, are among the factors that combined differentiate developmental needs for Hawaii's industry. Findings of this study support the perception that Hawaii is a unique place, and accordingly, the idea that solutions for Hawaii may be unique.

Throughout the Issue Reports (Vol II), a variety of information gaps were identified. Better information is needed to enable policy development, appropriate programmatic actions, response to stakeholder concerns, and technical information to assist commercial industry partners with feedstocks or conversion technology decisions. Reliable information will reduce the risk of unintended consequences for policy makers or business risk for investment partners.

Some of these information gaps may be attributable to the on-going technology innovation that characterizes the renewable energy industry. These information needs are represented in part by the following questions that have been raised in this report:

What feedstocks have the highest yields on non-prime agriculture land under various climatic conditions and management practices?
Can energy crops be grown sustainably and economically?
To what degree should agricultural land be dedicated to biofuel crops?
What biofuel products make the most sense for Hawaii's future needs?
Are the conversion technologies for these biofuels commercially available?
How do we reduce the economic and technology risks inherent with new technologies?
What will be the cost to modify Hawaii's distribution infrastructure to accommodate the various biofuel options?
What are the appropriate incentives to encourage the production of energy feedstocks?

Significant additional work will be necessary to answer these questions. The technology questions especially, those involving the production of feedstocks and conversion of feedstocks to biofuels, will require longer-term research and validation testing whether in field, laboratory, or demonstration projects. These types of projects typically require significant funding and partner commitment. For example, recent experience has shown that a field trial for one type of oil crop may require up to $500,000 over 3 – 7 years. With the urgent need to transition to an energy future less dependent on petroleum, Hawaii will need to nurture and expand research, development, demonstration, and deployment partnerships that can share expertise and funding resources to fill the information gaps. Depending on specific objectives, these partners may include, but not be limited to:

> Federal – U.S. Department of Energy, U.S. Department of Agriculture, U.S. Department of Defense, U.S. Environmental Protection Agency, U.S. Department of Energy National Laboratories
>
> State – Department of Agriculture, Department of Land and Natural Resources, DBEDT, Department of Health, University of Hawaii
>
> County –Planning and economic development agencies
>
> Private sector – Farmers and supporting agricultural businesses, biofuels converters, infrastructure companies including refineries and distributors, end use companies, landowners, investors, private research organizations.

Partnerships in Hawaii actively pursuing bioenergy development include member organizations from the public and private sectors and nonprofits. The listing below includes information on ongoing and planned partnerships that have formed to support bioenergy development goals of the member organizations. The partnerships appear in no particular order and the listing is necessarily incomplete, not by design, but by limitations imposed by the availability of information. Information has been provided by partnership participants identified in the bold subheadings. The readership is referred to the Business Partnering Issue Report included in Vol II of this document for additional information on commercial, value-chain focused partnership models.

Hawaii Clean Energy Initiative

Hawaii Clean Energy Initiative (HCEI) is a partnership between the state of Hawaii and the U.S. Department of Energy (DOE) launched in 2008. HCEI brings together business leaders, policy makers, and concerned citizens committed to leading Hawaii to energy independence. The goal of the Hawaii Clean Energy Initiative is to meet 70% of the State's energy needs by 2030 through energy efficiency and renewable energy. The lifeblood of the Hawaii Clean Energy Initiative consists of the more than 100 community members and national experts who have formed five working groups dedicated to helping Hawaiʻi harness its clean energy potential. The working groups were conceived as a means to integrate the technical and policy expertise of the U.S. Department of Energy (DOE) with Hawaii-based knowledge and project resources. Their role is to set out specific milestones to be achieved, create roadmaps for achieving those milestones, and clear the path to a clean energy future for Hawaii. The working groups are made up of local stakeholders, including people from the Hawaii State Energy Office, county economic development boards, and the Hawaiian Electric Company, as well as national energy experts from DOE and the National Renewable Energy Laboratory.

The five working groups are focused on end-use efficiency, electricity, fuels, transportation, and integration. Further details are available at http://www.hawaiicleanenergyinitiative.org/index.html.

University of Hawaii

A U.S. Department of Energy sponsored project, "*Development of High Yield, Tropical Feedstocks and Biomass Conversion Technology for Renewable Energy Production and Economic Development*," is a partnership between the University of Hawaii's College of Tropical Agriculture and Human Resources (CTAHR), the Hawaii Natural Energy Institute (HNEI), and industry partners.

A U.S. Department of Energy sponsored project, "*Hawaii Distributed Energy Resource Technologies for Energy Security***,**" includes tasks focused on analysis of bioenergy systems suitable for Hawaii and is managed by the Hawaii Natural Energy Institute.

The *National Science Foundation, Industry/University Cooperative Research Center Program, Center for Bioenergy Research & Development*, comprises a distributed center between the University of Hawaii, North Carolina State University, South Dakota School of Mines & Technology, Kansas State University, and the State University of New York at Stony Brook. The University of Hawaii site's current industrial members include Hawaii Bioenergy LLC, Office of Naval Research, and SunFuels Hawaii.

An Office of Naval Research sponsored project, "*Hawaii Energy and Environmental Technologies Initiative*" has devoted funds to biofuel research, development, and testing activities.

ClearFuels Technology

ClearFuels Technology's mission is to establish businesses that produce industry leading yields of clear clean renewable biofuels such as Fischer-Tropsch "FT" diesel and jet fuel, ethanol, hydrogen and electrical power from bagasse, wood waste, and other sustainable sources of cellulosic biomass using advanced thermochemical technologies. In the process of developing our business we have been fortunate to have had technical assistance from the Hawaii Natural Energy Institute (in evaluation of syngas and hydrogen production using reformer technology) the Hawaii Agriculture Research Center (in biomass crop evaluation), the Gay and Robinson sugar company (in planning for integration with sugar mills) , Pearson Technologies Inc.(in process technology), Hydro-Chem (in reformer design), Rentech (in Fischer-Tropsch technology applications) and others. Financial support from Hawaii and mainland sources has been essential to our progress to date.

Pacific Biodiesel

Big Island Biodiesel LLC **(BIB)** is a new entity created by Pacific Biodiesel Inc. (PBI) that will install a biodiesel plant with a multi-million gallon per year capacity that utilizes the latest technology in biodiesel processing. This state-of-the-art facility will be twice as efficient as Hawaii's existing biodiesel refineries, utilize zero-waste technology, create higher value by-products, include America's first commercial trap grease biodiesel processing, and be poised to commercially process the first home-grown crop oil available in Hawaii. Strategic partners include local Big Island farmers of biofuels crops as well as crop researchers at the Hawaii Island Economic Dev. Council.

Pathway To Hydrogen is a project on which Pacific Biodiesel is collaborating with HNEI to further its research on producing hydrogen from glycerin. In the past, this project has experimented with PBI's waste glycerin but found it to be too impure while market grade glycerin was too expensive. Now that BIB (see above) will be processing its waste glycerin into 85-90% purity, HNEI will be revisiting its hydrogen from glycerin research. Partners in the project are PBI, HNEI, the State of Hawaii (through the Hydrogen Fund grant, if awarded) and the hydrogen bus operation on the Big Island.

Mustards for Organic Pest Control and Biodiesel is a project which was just submitted as a grant application to Tri-Isle Resource Conservation & Development Council on Maui. PBI is partnering with agriculture researcher Wes Chun and a group of local farmers currently growing hybrid mustard plants developed by Jack Brown of University of Idaho. There are other products they seek to garner from these plants, but the relevant ones to renewable energy are bio-fumigants and biodiesel. Some objectives of the project are 1) test Wes' new growth enhancer, liquid compost factor, to see if it can stimulate higher oil yields, 2) gather info on the cost of growing mustard hybrids and their appropriateness for Maui, 3) estimate oil yield per acre, and 4) process oil into biodiesel and test fuel quality.

The Honolulu Clean Cities program recently completed its project focused on the potential for local crop species to produce biodiesel and funded by an *EPA West Coast Collaborative Diesel Emission Reduction* grant. This project involved crushing three different types of potential biodiesel crops which are currently growing in the islands (coconut, jatropha and kukui) using equipment purchased by grant funds (which will remain in the state), evaluating the oil, processing the biodiesel and testing it to U.S. biodiesel ASTM standards, and testing the emissions of the biodiesel. Partners included Honolulu Clean Cities, Pacific Biodiesel, Oceanic Institute, Grace Pacific and Hawaii Pacific University.

SunFuels Hawaii LLC

Hawaii Island Land and Biomass Analysis by Forest Solutions, Inc. In 2008, SunFuels Hawaii LLC retained Forest Solutions, Inc., a highly experienced commercial forestry firm, to perform a proprietary land analysis and biomass crop productivity assessment on the Big Island. The analysis focused on lands in (1) Kau extending from Kapapala Ranch to South Point and (2) east and north Hawaii extending from the Hamakua Coast to Waimea. Forest Solutions measured solar radiation, rainfall, temperature, elevation, soil depth and soil quality. They prepared climatological and edaphic characteristic maps supported by location-specific databases using advanced GIS technology. Hundreds of candidate tree species were evaluated. A combined site-species map was developed to analyze species growth data versus the suite of known site conditions. The map was further refined to include growth estimates for each species by location, such that parcel-by-parcel productivity was evaluated *vis a vis* the broad objective of feedstock supply. Thus, disparate land productivity characteristics were shown and a more accurate overall feedstock supply model was obtained. The analysis focused primarily on various Hamakua and North Hawaii lands with appropriate tree growth characteristics to supply wood chips for a biorefinery to produce clean, synthetic diesel fuel trademarked as SunDiesel™.

National Science Foundation Research Center SunFuels Hawaii LLC has provided funding support to the National Science Foundation's Industry/University Cooperative Research Center for a study undertaken by University of Hawaii researchers Scott Turn and John Yanagida titled "Life Cycle Analysis of Dedicated Biomass Production Systems." By examining methodologies suitable for life cycle analysis of dedicated biomass production systems, the study intends to determine net energy productivity, carbon balance, and system sustainability using plantation *Eucalyptus* as a model biomass crop for energy production.

Tree Trials on Parker Ranch Lands SunFuels Hawaii LLC is presently negotiating a right of entry agreement with Parker Ranch to conduct tree trials for potential commercial biomass on two plots of land in North Hawaii. SunFuels and Forest Solutions shall collaborate in the tree planting trials and maintenance and monitoring of the trial plots at Parker Ranch.

Kamehameha Schools Hamakua Ag Plan SunFuels Hawaii LLC has assisted New Energy Partners, a consulting firm under contract to Kamehameha Schools, to develop an agricultural plan, including commercial forestry, for Kamehameha Schools lands along the Hamakua Coast. Our information sharing and consultation focused on Choren gasification technology and production costs for biomass supply.

Hawaii Greenhouse Gas Emissions Profile, 1990-2005 Michael Saalfeld, founder of SunFuels Hawaii LLC, contributed funding support to the UHERO study by Denise Konan titled *Hawaii Greenhouse Gas Emissions Profile, 1990 and 2005*, one in a series of reports produced by the UHERO Energy and Greenhouse Gas Solutions (EGGS) initiative. The report found a dramatic increase in GHG emissions associated with Hawaii's transportation sector.

Hawaii Bioenergy LLC

Hawaii BioEnergy is involved in developing scalable processes for the cost-effective large-scale production of algae triglyceride oil and an algae-derived JP-8 jet fuel surrogate. Hawaii BioEnergy is participating on teams made up of university and industrial partners that will examine all aspects of the algae to fuel production process. Hawaii BioEnergy's participation on these teams is being done through two separate projects with research and testing facilities located on Oahu and Kauai. The goal is to reduce the cost of producing algae oil from microalgae with the intent of being able to develop a sustainable, reliable, long-term supply of biofuels. This will involve identifying key cost drivers and investigating multiple approaches to increasing productivity and reducing operating and/or capital costs. The program will address algae selection and growth; water, carbon dioxide and nutrient supply; algae harvesting; oil extraction; and conversion to JP-8, all in the context of an overall JP-8 life-cycle cost model.

Hawaii Bioenergy is also a partner of the University of Hawaii site of the National Science Foundation's Center for Bioenergy Research & Development. Hawaii Bioenergy's interests lie in net energy, green house gas, and life cycle analyses of bioenergy production systems for Hawaii.

Hawaii Agriculture Research Center
The Hawaii Agriculture Research Center's (HARC) *J. curcas* ('jatropha') research began in 2006 with funding from Hawaii Farm Bureau Federation, and has continued into 2009 with support from Hawaiian Electric Company (HECO) and the Hawaii Department of Agriculture (HDOA). Additional support has come from USDA- SBIR for co-product evaluation. The HDOA contract with the University of Hawaii which subcontracted with HARC has served as the primary support mechanism for the extended research program for jatropha (and other perennial oilcrops). The long-term backing of HDOA has provided support to multiple projects associated with the development of jatropha as a potential feedstock for biodiesel utilization.

There has been ~3 years of field trials, product development and initial selections work done on *Jatropha curcas* to assess long-term feasibility as a biodiesel/bio-oil feedstock crop for Hawaii. This work has consisted of agronomic determinations such as water use, tree structure, harvest concepts, and planting density. HARC is narrowing-in on precise water demands after 2 years of irrigation study. A new project is evaluating pruning effects on long-term fruit production. Early observations have been made as relates to carbon sequestration in young orchards. The HDOA funds have run out and limited funding from HECO is being used for continuing data collection from existing plantings.

Following up on a sweet sorghum program by USDA in the 1960s and 80s that HARC participated in and in which Hawaii had the highest yields, HARC has performed some small scale variety tests and seed increase operations with interested private partners.

Tesoro
Consistent with the company's goal of manufacturing low cost, clean fuels for our customers, Tesoro is actively working with other organizations in Hawaii to develop business opportunities which are also consistent with the goals of the Hawaii Clean Energy Initiative. These efforts allow Tesoro to contribute its expertise in fuel production and distribution to business ventures with other companies that have expertise in other parts of the renewable energy value chain. Many of these efforts are preliminary in nature and may fail to result in any viable business or opportunity. Among the development efforts that Tesoro is involved in are the following:

- Tesoro is currently participating with groups which are seeking ARRA funding for projects to build pilot scale algae production facilities. Tesoro will analyze the biomass produced from these projects to determine its suitability for processing into fuels.

- Tesoro is also in discussion with several of our customers to attempt to identify potential opportunities which would allow Tesoro to process renewable feedstocks and allow us to sell products to our customers which contain a renewable component. This could potentially result in joint investments to produce these renewable fuels.

- Tesoro is also considering projects to generate electricity from renewable sources including solar power and waste heat recovery. We and Axio Power are developing a 5 MW solar power project on land adjacent to the refinery. In addition, we are working with a geothermal development company to develop a project which could use their technology to generate electricity by recovering low-level energy from the refining process.

- Tesoro is working with Hawaii BioEnergy to evaluate a variety of opportunities to develop renewable fuels. The combination of HBE's land and expertise in growing and processing biomass, and Tesoro's abilities in the production and distribution of fuels are being leveraged.

- Tesoro is a foundational member of the National Advanced Biofuels Consortium (NABC). This Consortium has come together with the overall goals of 1) increasing the viability and deployment of renewable energy technologies and 2) spurring the formation of a domestic biofuels industry. The NABC represents a group of experienced and capable biofuels research, development, and deployment organizations including the National Renewable Energy Laboratory, the Pacific Northwest National Lab, UOP, Albemarle, Pall, Amyris, Weyerhaeuser and five other participants from the university and national lab sectors. The overall theme of the research being proposed by the Consortium is the manufacture of infrastructure-compatible high density transportation fuels by means of integration of biomass-derived materials into the existing conventional petroleum refinery infrastructure.

Hawaiian Electric Company

Hawaiian Electric Co. (HECO) has committed to the use of sustainable biofuels in its power plants, subject to acceptable biofuel pricing, availability, and technical feasibility. HECO has formed strategic partnerships in support of their efforts to secure renewable sources of electricity derived from biofuels as outlined in the HECO-NRDC Policy Implementation Report (see http://www.hawaiisenergyfuture.com/NRDC/HECO_NRDC_Policy_Implemen.html.) These include working with the Natural Resources Defense Council to publish the "Environmental Policy for the Hawaiian Electric Company's Procurement of Biodiesel from Palm Oil and Locally Grown Feedstocks." This policy requires that HECO's palm oil purchases satisfy principles and criteria identified by the Roundtable on Sustainable Palm Oil (RSPO). HECO is a member of the RSPO and participates in annual RSPO conferences.

HECO and the Electric Power Research Institute are co-funding work conducted by the Hawaii Agriculture Research Center, the University of Hawaii at Manoa's College of Tropical Agriculture and Human Resources, and the University of Hawaii at Hilo's College of Agriculture, Forestry, and Natural Resources Management to identify crops, production yields, infrastructure and other requirements for potential feedstocks that are adaptable to marginal use lands.

HECO has also entered into an agreement to work with HR BioPetroleum, Inc., and Alexander & Baldwin Co. to evaluate joint development of a commercial scale microalgae facility on Maui. The objective of this effort is to produce lipids from microalgae for the production of biodiesel and other co-products such as animal feeds. Biodiesel would be fired in Maui Electric's Maalaea power plant and carbon dioxide from the stack would be returned to enhance algae production.

HECO is a signatory to the October 2008 HCEI Agreement (see Section 1.2.3 of this document).

MECO has conducted preliminary testing with B99 biodiesel on various types of diesel generators in its fleet and a combustion turbine. MECO is planning a longer term test on selected generating technologies. HECO is planning to test crude palm oil blends with low sulfur fuel oil at its Kahe 3 steam boiler.

In addition, HECO, MECO and HELCO use B20 biodiesel on all its diesel fleet vehicles.

The Gas Company

The Gas Company LLC is working with California-based Primoris Renewables on an initiative to provide up to half of its utility gas from renewable sources within five years. A memorandum of understanding between the two firms announced on August 24, 2009, focuses on development of production facilities at The Gas Company's synthetic natural gas plant to process agricultural products and landfill gas into bio-methane, renewable diesel or similar products. It also addresses the improvement of energy and economic efficiency of operations at the plant. (Honolulu Advertiser, August 24, 2009)

Hawaii Renewable Energy Development Venture

Recognizing this vast untapped development potential and the creative potential of Hawaii clean energy enterprises, Senator Inouye and the US Congress, with the support of the Department of Energy, has funded the Hawaii Renewable Energy Development Venture (HREDV) through the Pacific International Center for High Technology Research (PICHTR). The principal mission of HREDV is to develop a larger and more robust clean energy industry sector in Hawaii to help achieve the state’s long-term energy independence objectives as articulated by policies enacted by Hawaii’s state government, and in partnership with the federal Department of Energy through the Hawaii Clean Energy Initiative. The Initiative envisions a wholesale transformation of Hawaii’s energy systems to 70 per cent clean energy by 2030.

Utilizing $1.2 million in funds appropriated in 2008, PICHTR collaborated with USDOE to initiate this program. The first phase, currently underway, will establish a firm foundation for the project by conducting a technology assessment to identify critical needs and identify emerging capabilities deserving of support, developing criteria and metrics for directed funding, providing education and outreach to interested energy stakeholders and energy consumers, and coordinating a variety of energy initiatives to enhance successful efforts at clean technology project development. A roadmap for the project will be prepared to document these strategies for USDOE’s approval.

To date HREDV has retained analytical expertise from the Hawaii Natural Energy Institute to prepare the assessments and project selection criteria and metrics, and is working with the county economic development boards to support outreach efforts to ensure that the needs and opportunities to be satisfied have the broadest reach and most significant effect.

HREDV has already been able to offer valuable services to the clean energy industry by serving as a credible, unbiased resource to advise prospective energy developers, and has facilitated strategic partnering with a number of renewable energy and energy efficiency entrepreneurs. With the current opportunities emerging from the American Recovery and Reinvestment Act, PICHTR is helping to facilitate the formation of competitive teams featuring Hawaii grown, or Hawaii-based clean energy companies for anticipated federal competitive solicitations. Through HREDV, Hawaii now is developing internal capacity to offer valued insight to private sector energy developers and entrepreneurs to get projects "in the ground," thereby stimulating private sector entrepreneurship and capital investment.

HREDV joined with HTDV to present Tech Enterprise 2009 in June to update the technology community of upcoming development opportunities, and to brief parties on progress made to date.

In phase two of this project, HREDV will solicit project specific proposals to co-fund worthy investments utilizing remaining funds from 2008 combined with additional funds ($3.8 million) obtained in 2009. With the addition of the 2009 funding HREDV will be able to offer much more substantive co-funding assistance with an anticipated support date in the latter half of 2009. Recognizing that good technology alone does not make for successful, sustainable clean tech enterprise, HREDV will also offer education and training to these clean tech entrepreneurs in business practices, government contracting, training to prepare competitive proposals, and mentoring and best practices.

While the sectors of interest for co-investments are still under development, HREDV intends to direct its efforts to complement the initiatives of the state and federal clean energy partnership, specifically as it relates to filling gaps to drive appropriate private sector technology and project development. These would include renewable energy, energy efficiency, clean energy-based transportation fuels and systems, integrating electricity and transportation systems to enhance development and utilization of clean energy resources unique to Hawaii, but with technology transfer capability to the mainland US and internationally.

Information gaps, including those requiring costly technology research and demonstration have been identified as a result of this planning initiative. Partnerships to conduct the pre-commercial research and demonstration to verify technologies and processes can help the industry succeed by providing appropriate information needed for technology-based decisions, thus reducing business risk. Especially for Hawaii, where unique solutions appear necessary for industry success, resources to support existing partnerships, attract new partners, and to create new partnerships are critical. These resources include science and technology experts, program funding, and project cost share. Additionally, continued planning and coordination to define and refine research needs should be available to help these partnerships target their efforts.

The partnerships/projects identified in the paragraphs above illustrate a wide range of partnering arrangements that have arisen from participants identifying a common goal or information gap. Future partnerships to enhance biofuels development can be expected to form from public-private-nonprofit organizations that leverage funds and or expertise from all parties. In keeping with the value chain approach, partnerships including land owners, biomass (agriculture or forestry) producers, technology providers, bioproduct distributors, and investors can be envisioned. Depending on the purpose, partnerships may form vertically across the value chain or horizontally to address needs identified in one industry segment. County, state, and federal entities can be envisioned as participants in the roles of land owners and as investors for the public good.

Several entities are already in place to help facilitate strategic partnering at points along the value chain. The Hawaii Clean Energy Initiative, the Hawaii Renewable Energy Development Venture, the Hawaii State Energy Office, University of Hawaii, Hawaii Agriculture Research Center, and other research institutions all can contribute to partnership building due to their involvement in activities related to bioenergy research, development, testing, and deployment. Coordination between these groups is important and should be fostered.

3.4 Biofuels Demonstration Projects (Outcome IV)

Key ideas for demonstrations garnered from the project team and interactions with stakeholders stressed the value chain theme and the use of life cycle analysis to evaluate system performance. Candidate projects largely fell in the categories of feedstock production, conversion technology verification, and transportation/end use demonstration. Life cycle analysis (LCA) addresses the environmental aspects and potential environmental impacts (e.g. use of resources and the environmental consequences) throughout a product's life cycle from raw material acquisition through production, use, end-of-life treatment, recycling and final disposal, i.e. from cradle to grave. Life cycle assessments conducted across a bioenergy production system value chain can assist in identifying opportunities to improve environmental performance, informing decision makers and stakeholders, and selecting relevant indicators of environmental performance.

Feedstock production has been identified as one of the key bottlenecks in the value chain. Projects designed to demonstrate crop performance included:

- field plantings of a variety of energy crop candidates in key climatic zones on different islands to determine plant response to varied environmental and management factors;
- farmer operated/managed feedstock demonstrations to provide realistic evaluation of production costs and resulting yields;
- feedstock production coupled with technology demonstration to include harvesting and supply logistics.

Demonstrations of specific technologies in new stand alone projects and those that are coupled to existing infrastructure were also suggested. Projects would focus on collecting data on individual component performance, operating costs, overall system performance and reliability, bioproduct yield, conversion efficiency, and maintenance requirements. Data would be used to improve systems' design and reduce risks associated with developing commercial units. Those identified include:

- oil crop production, harvesting, and oil extraction from the crop product with multiple uses for the oil such as biodiesel production via transesterification, hydrotreating for renewable diesel, and direct firing of the vegetable oil;
- pyrolysis of biomass to produce a bio-oil that can be transported and converted in one of the petroleum refineries for production of fuel substitutes or in direct fired power generation applications;
- gasification or reforming of biomass to produce a syngas for use in the production of renewable electricity or biofuels that may include renewable diesel or other synthesis products;
- controlled storage of biofuels with monitoring of product quality over time to assess product life and testing to determine potential impacts of quality deterioration on end use.

Demonstration projects related to transportation applications are also recommended. Projects should include monitoring and analysis of prime mover performance, changes in required maintenance, and acceptance and satisfaction by vehicle operators. Those identified include:

- private cars and/or fleet vehicles such as buses converted to operate on biofuels;
- larger marine vessel conversion to renewable diesel (e.g. State of County owned or operated)

Meeting current targets established by renewable portfolio standards for electricity and alternative transportation fuel standards provide incentives for broad value chain support for demonstration projects. The state can provide further incentives by providing low or no-cost lands leases for conducting demonstration projects, facilitating permitting, coordinating participation across the value chain, and sharing in project costs

3.5 Promotion of Hawaii's Renewable Biofuels Resources to Potential Partners and Investors for Development in Hawaii as Well as for Export Purposes (Outcome V)

Over many years, there have been a number of statewide initiatives to promote the development of renewable energy in Hawaii, largely conducted by the State through its energy office in cooperation with U.S. Department of Energy programs. Programmatic effort specifically for the promotion of Hawaii’s renewable energy resources to potential partners and investors, however, has been limited. An outward-looking, Asia-Pacific energy technology program was conducted several years ago to enhance business development opportunities for Hawaii’s energy and environmental companies.

The state’s geographic isolation, tropical climate, relatively stable political environment, commitment to the increased use of indigenous resources, research capability and mid-Pacific location combine to attract national and international interest in projects both for research and commercialization. The realization that Hawaii is a “living laboratory” for renewable energy innovation has helped to bring research projects to the state, and similarly can be an asset for the biofuels industry.

To foster promotion of Hawaii’s biofuels resources, a program should be developed to increase understanding of, and to capitalize on, the aspects of Hawaii’s industry that will appeal to research, business, and investment partners. At the same time, the program should be consistent with the goals, objectives, and findings of this master planning effort, i.e., partners should serve to strengthen the bioenergy industry value chain as discussed in Vol II Section 2.7, *Business Partnering*. Partners are also needed to contribute technical knowledge and funding to research, development and demonstration projects as discussed in Vol I Section 3.3, *Strategic Partnerships*.

A successful promotional program must incorporate an outcome-oriented approach to link bioenergy industry needs with the interests of appropriate partners. It should include the following general elements – clear objectives and goals, defined audience, action plan and timeline, and budget. With changing industry needs and participants, it will be important to maintain on-going coordination with Hawaii industry stakeholders in the planning and implementation process.

This master planning effort has provided the groundwork for such a program by assembling the range of bioenergy stakeholders that should be participants in industry promotion. Further, bioenergy information has been identified and assembled that can be used in a promotional campaign.

Development of the biofuel industry can also be promoted to value chain participants by legislative actions that reduce the regulatory burden and create financial incentives for project development. Broad discussion of these topics has been provided in the issue reports for permitting and financial incentives.

Hawaii's bioenergy resources can also be promoted through continued support of the bioenergy master plan website and active engagement by master plan participants in conferences and workshops that provide opportunities for establishing contacts. In the latter case, partial funding of travel or registration costs for Hawaii private sector bioenergy developers to attend conferences or workshops could be partially defrayed by State funding. The state could also consider holding a conference that would showcase Hawaii's bioenergy opportunities.

The DBEDT energy office is often a point of contact for investors seeking bioenergy opportunities in Hawaii and keeping energy office staff engaged and informed about the bioenergy landscape is an important promotional instrument.

Part 4: Conclusion

"Growing biofuel crops is a considerably long-term investment. We need to frame the food vs. fuel issue in tandem with the Bioenergy Master Plan so people are comfortable with large land commitments for biofuel. It is a multi-generational commitment to bioenergy."

Stakeholder comment, April 2, 2009

4.0 Conclusion

This Bioenergy Master Plan report was developed in accordance with Act 253, Session Laws of Hawaii (SLH) 2007, which called for a bioenergy master plan to "set the course for the coordination and implementation of policies and procedures to develop a bioenergy industry in Hawaii."

As required by the Act, it addresses the following issues -

"(1) Specific objectives and timelines;
(2) Water resources;
(3) Land resources;
(4) Distribution infrastructure for both marine and land;
(5) Labor resources and issues;
(6) Technology to develop bioenergy feedstock and biofuels;
(7) Permitting;
(8) Financial incentives and barriers and other funding;
(9) Business partnering;
(10) Policy requirements necessary for implementation of the master plan; and
(11) Identification and analysis of the impacts of transitioning to a bioenergy economy while considering applicable environmental concerns."

and the following outcomes -

"(1) Strategic partnerships for the research, development, testing, and deployment of renewable biofuels technologies and production of biomass crops;
(2) Evaluation of Hawaii's potential to rely on biofuels as a significant renewable energy resource;
(3) Biofuels demonstration projects, including infrastructure for production, storage, and transportation of biofuels;
(4) Promotion of Hawaii's renewable biofuels resources to potential partners and investors for development in Hawaii as well as for export purposes; and
(5) A plan or roadmap to implement commercially viable biofuels development."

During the course of the studies, a number of unique work products were prepared that will facilitate industry efforts. These resources may be found in the Issue Reports in Vol II as follows:

- Land and Water Resources (Section 2.1) – GIS map layers showing irrigation systems, soil, topography, climate, and potential selected irrigated and rainfed crop yields for Oahu, the Big Island, Maui county, and Kauai.
- Distribution Infrastructure (Section 2.2) – Diagrams and descriptions of statewide fueling infrastructure systems.
- Technology (Section 2.4) – Characterization of the status of crops and crop production technologies for bioenergy applications and of conversion technologies used to transform feedstocks into bioenergy products. Identification of technology gaps.
- Permitting (Section 2.5) – Process flow charts and comprehensive listing of permits.

- Financial Incentives (Section 2.6) – Comprehensive listings of current and proposed incentives.
- Business Partnering (Section 2.7) – Matrixes of partnership structures and components and a Bioenergy Partner Catalog.
- State, County, and Federal Plans, Policies, Statutes, and Regulations (Section 2.10)

Strategic partnerships identified in Section 3.3 (Vol I) were formed to address information gaps in the value chain and to leverage resources. Stakeholder input was instrumental in identifying biofuel demonstration projects as summarized in Section 3.4 (Vol I). Methods to promote Hawaii's renewable biofuels resources are contained in Section 3.5 (Vol I).

A bioenergy industry is a unique and inclusive industry, spanning nearly all of Hawaii's commercial and public sectors. To develop local biofuel production capacity sufficient to displace a significant amount of imported fuels, the industry must comprise all of the necessary components – locally available feedstocks including agricultural waste and/or crops, conversion of biomass to useable fuels, distribution infrastructure, and end user markets. Each component of this value chain must be economically and technically viable, requiring the support of investors, government regulators, policy makers, and researchers.

Its environmental and economic impacts affect a broad range of stakeholders including other industries and the community. Several stakeholder events were held and a website was established to disseminate information and to receive input from stakeholders during the project. Stakeholder input is incorporated in the Issue Reports (Vol II) and in the stakeholder review comments (Vol III).

Our analysis indicates that Hawaii does have the potential to meet the production scenario goals used in this report. However, the Issue Reports point to a number of industry challenges of which the most significant is the availability of reliable local supplies of economically feasible feedstocks to mitigate business risk and enhance the probability of value chain viability. Overcoming this challenge will require a Renewable Biofuels Program to serve as both an industry champion and an industry facilitator to carry out the recommendations in this report.

The industry roadmap recommends actions for a Renewable Biofuels Program to address the four primary areas of industry concern – availability and use of resources, value chain interdependencies, industry impacts, and program level coordination. These actions involve assessments, community involvement, partnerships, incentives, coordination, planning, education and outreach, demonstration projects, research, and policy requirements.

The Issue Reports underscore the need for more and better data and analytical tools, the lack of which will continue to challenge more precise industry planning. This bioenergy master plan therefore points to a path for government and industry action needed to enable informed policy development, appropriate programmatic actions, response to stakeholder concerns, and decisions concerning feedstock, conversion technology, and products. It recognizes the need for government and stakeholders to continually monitor the industry and reset the priorities as technologies and opportunities evolve.

The development of a bioenergy industry as a component of a more secure and stable energy future for Hawaii will take the sustained support and commitment by industry, government, and the community. With the wide range of issues, stakeholders, value chain components, changing market conditions, continuing technology innovations, and environmental incentives and disincentives, industry planning cannot and should not be a finite nor close-ended task.

It should be remembered that the renewable biofuels program will be responsible for the development of a new industry currently characterized by complexity and perceived competition for essential resources. If planned, coordinated, and implemented appropriately, this industry has the potential to benefit Hawaii's other industries, especially agriculture and the refineries, as well as to enhance the economic and energy security of the state.

Hawaii Bioenergy Master Plan

Volume II

Issue Reports

Prepared for

State of Hawaii
Department of Business, Economic Development and Tourism

By

University of Hawaii
Hawaii Natural Energy Institute
School of Ocean Earth Sciences and Technology

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Hawaii Bioenergy Master Plan

Land and Water Resources

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College of Tropical Agriculture and Human Resources
University of Hawaii at Manoa

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EXECUTIVE SUMMARY

Project Background

Based on Act 253, SLH 2007, Part III, *"The primary objective of the bioenergy master plan shall be to develop a Hawaii renewable biofuels program to manage the State's transition to energy self-sufficiency based in part on biofuels for power generation and transportation."* The primary concern for consideration in the development of any bioenergy crops in Hawaii is the availability of the land and water necessary to produce such products. In addition to availability of large areas of land necessary for production, site suitability is also an important factor. Aspects related to this include bioenergy crop growing conditions, climatic factors, soils, geology and geography, land use patterns, surface and groundwater water resources, and infrastructure. In addition, potential agronomic productivity of the land must be evaluated. It is important to determine suitable locations in the Islands that can efficiently produce bioenergy crops while still being conveniently accessible to major consumers, including agricultural, industrial, and population centers, that will utilize the fuel once it is produced.

To evaluate Hawaii's water resources and their potential to support production of biofuels as a significant renewable energy resource, as well as to provide information, analysis, and recommendations, this study includes the following scope of work:

- Identify appropriate stakeholders, technical experts, and information sources throughout the state.
- Document the availability of existing water supplies for growing biofuels and biomass crops (indicate areas currently in production for food crops or diversified agriculture);
- Document the use, availability and allocation of water from streams, wells, and aquifers including environmental impacts and competing uses;
- Document the potential for additional sources of non-traditional water supplies – non-potable water, wastewater, stormwater, reclaimed water, desalinated water, and other;
- Document the potential for biomass production in conjunction with phytoremediation and bioremediation processes;
- Document methods to increase water use efficiency for bioenergy production including selection of biomass feedstocks, modeling of crop water use; technologies including irrigation techniques; and
- Estimate and document biofuel production potential based on water resources and available land assets.

To evaluate Hawaii's land resources and their potential to support production of biofuels as a significant renewable energy resource, as well as to provide information, analysis, and recommendations, this study also includes the following scope of work:

- Identify appropriate stakeholders, technical experts, and information sources throughout the state;
- Document the suitability (zoning, soil type, slope, temperature, etc.) of land resources for growing biofuels and biomass crops (indicate areas currently in production for food crops or diversified agriculture);

- Document the ownership, permissible use, location, availability, and allocation of appropriate land, and competing uses;
- Document methods to increase productivity of land use for bioenergy production including selection of biomass feedstocks, agricultural practices, and any other factors; and
- Estimate and document biofuel production potential based on water resources and available land assets.

This report presents results of a study conducted to explore and evaluate the land and water resources available for bioenergy crop production. The report presents data and information with GIS maps, graphs, tables, and appendices. In addition to Executive Summary, this report consists of five major sections: i) Introduction, ii) Existing Water Supplies and Lands, iii) Existing Lands for Biofuels and Biomass Crops Production, iv) Agricultural Water Use for Potential Biofuel and Biomass Crop Production, and vi) Summary, Conclusions, and Recommendations.

Nature of Land and Water Resources Data

GIS maps of Agricultural Lands of Importance to the State of Hawaii (ALISH) date back to 1977 (Hawaii Statewide GIS Program, 2008) when most of the Hawaiian agricultural lands were under mono-cropping systems. The State Government made substantial changes in land leasing after the end of large-scale agricultural production. The historical land use changes have raised questions on the accuracy of the ALISH maps which need to be updated using remote sensing data validated through a ground-truthing process.

Sugarcane plantations used well engineered sophisticated irrigation systems. After four decades of neglect these systems need rehabilitation and maintenance. In addition to rehabilitation of existing irrigation systems, large-scale bioenergy crop production can make use of treated waste water resources. Any serious plan to use treated waste water will require building a system to deliver these water resources from their point of treatment to the agricultural lands. In places such as Kekaha in Kauai, even if the irrigation systems are still functional, the cost to rehabilitate them to deliver the amount of water needed for high water consumption crops could be prohibitive.

Input from Stakeholders

Participants in a stakeholders meeting held on April 2, 2009, as well as other stakeholders, reviewed the first draft of this report. The emphasis was mainly on: i) critical information needed for decision making regarding bioenergy crop production, ii) current land and water resource availability and constraints, and iii) actions needed in the near-term that would address the priority constraints. Various sections of this report include and address the comments of various participants in the April meeting.

Existing Water Supplies for Biofuels and Biomass Crops Production

Efforts to utilize biofuels should include better characterizations of the “water budget” for various hydrological systems as it is an important factor in planning water use. The budget accounts for all of the inflows, outflows, and changes in storage within the system. Groundwater recharge is an important element of the water budget. Groundwater recharge is needed in managing groundwater resources including estimating aquifer sustainable yields. Utilization of groundwater resources for biofuel production will necessitate assessing its influence on aquifer recharge and on estimated aquifer sustainable yields. The entire water system is a complex network of inter-connected ditches, irrigation systems, diversions, flumes, and reservoirs.

The State of Hawaii owns and operates a number of water systems. Water from the State wells is mainly used for potable water supply, and irrigation. The water collected from existing State diversion is used primarily for agricultural operations. There are many systems that are privately owned and there is a lack of knowledge about the condition of these systems.

Supplemental sources of water must be developed to meet the demands of an increasing population and sustainable water resource management, including the use of recycled water and rainwater catchment, to assure a continuous and reliable supply of water without concern about droughts or water restrictions. This option for developing a reusable water system provides additional advantage for utilizing the existing/dissolved nutrients in the wastewater thereby reducing the need for fertilization in most instances. Another advantage of establishing a recycled water system is that it is an environmentally friendly approach compared to the traditional disposal methods, i.e., through outfalls and injection wells. Although the applications of reusable water have historically increased in Hawaii, there are opportunities to continue expansion.

Continued development of bioenergy production systems requires accurate information on a reliable biomass feedstock supply, production and harvesting costs, and environmental impacts. Development of the bioenergy industry necessitates determining ways to lower biomass production costs including handling and transportation, reducing uncertainty of supply, and capturing the value of environmental benefits and transferring them to the producer.

Existing Lands and their Agricultural Water Use

Because of Hawaii's geography and environmental conditions, each of its islands has unique soil types, climatic factors, land-use distribution (i.e., agricultural, conservation, rural and urban), and water resources. Acreages of different land uses in the State of Hawaii are shown in Fig. 1. ALISH (DOA, 1977) classes include "Prime Agricultural Lands", "Unique Agricultural Lands", "Other Agricultural Lands", and "Unclassified Agricultural Lands" (Fig. 2). The following sections focus on lands designated for 'Agricultural' use by the State of Hawaii's Land Use Commission. For bioenergy production, the most important factors include: i) mechanism and capability to harvest bioenergy crops, ii) transporting the harvested crops to processing facilities, and iii) delivering the final product to distribution points. In addition to the availability of land and water, community education is also a critical factor. Irrigation water needs and the high cost of agricultural lands may pose challenges for any large-scale operation to begin producing biofuel crops in sufficient quantity to meet the islands' demand.

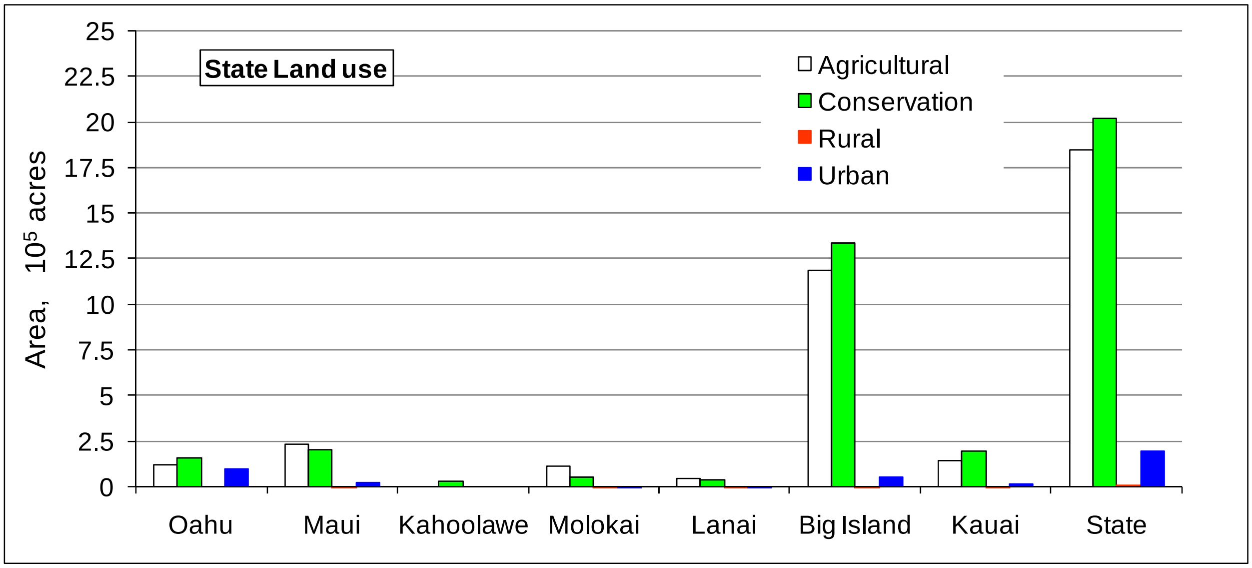

Fig. 1 Acreages of different land uses in the State of Hawaii.

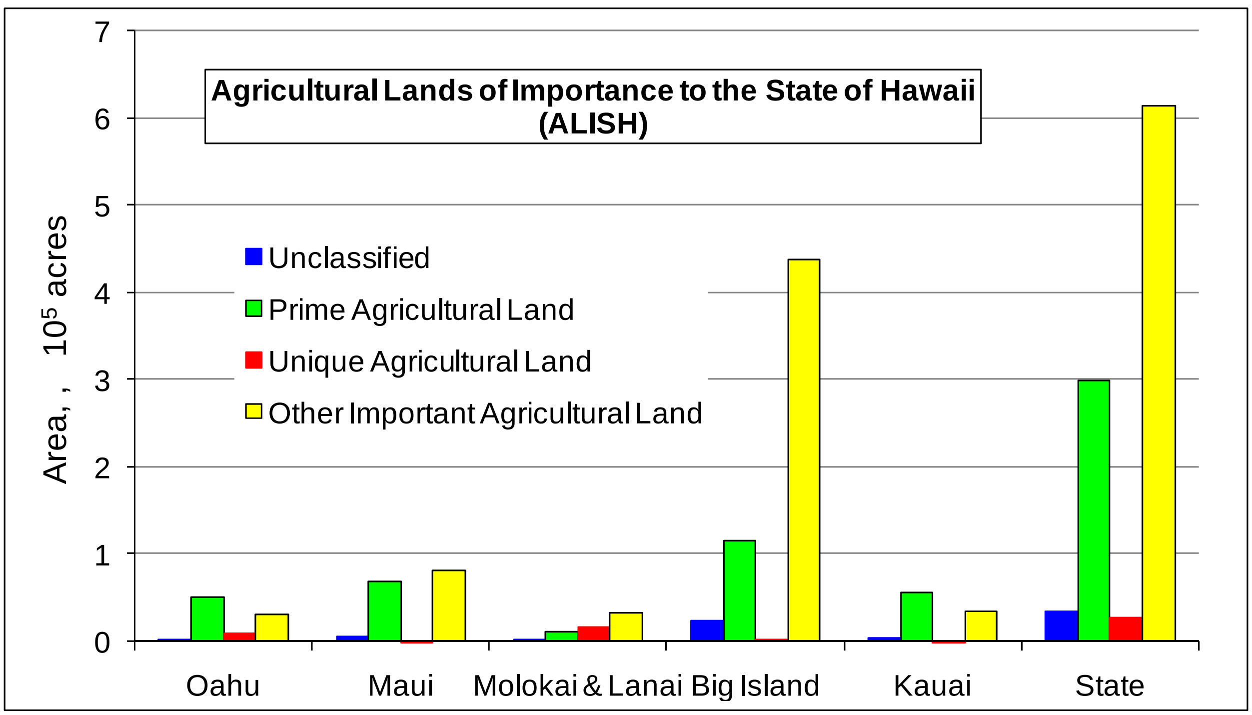

Fig. 2 Acreages of agricultural lands of importance to the State of Hawaii (ALISH).

Table 1 summarizes the existing agricultural lands and their irrigation water use in Hawaii. There is a total of 1.9 million acres of land in the state Agricultural District of which 49% (942,000 acres) are classified by ALISH including prime, unique, or other important lands. In 2000, a total of 121,500 acres (which includes farmland plus non-agricultural uses like landscaping, golf courses and parks) were irrigated with an average 363.5 million gallons per day (MGD) of water (DBEDT, 2005).

Table 1 Agricultural lands and irrigation use for main Hawaiian islands and 10 studied irrigation systems (Source: DBEDT, 2005*)

<table>
<tr><td></td><td colspan="4">STATE RESOURCES</td></tr>
<tr><td>Island</td><td>Agr. District
10,000 ac.</td><td>ALISH
10,000 ac.</td><td>Irrigated Area
1,000 ac.</td><td>Irr. Water Use
MGD</td></tr>
<tr><td>Kauai</td><td>13.9</td><td>9.1</td><td>27.2</td><td>30.0</td></tr>
<tr><td>Oahu</td><td>12.9</td><td>8.8</td><td>31.1</td><td>39.2</td></tr>
<tr><td>Maui</td><td>24.5</td><td>14.9</td><td rowspan="3">Maui
55.9</td><td rowspan="3">County
274.6</td></tr>
<tr><td>Molokai</td><td>11.2</td><td>3.9</td></tr>
<tr><td>Lanai</td><td>4.7</td><td>2.2</td></tr>
<tr><td>Big Island</td><td>121.4</td><td>55.3</td><td>14.5</td><td>19.7</td></tr>
<tr><td>State</td><td>193.1</td><td>94.2</td><td>121.5</td><td>363.5</td></tr>
</table>

*Sources: Hawaii DBEDT (2005) for state Agricultural District area and USGS (2000) for state Irrigated Area and Irrigation Water Use.

Department of Natural Resources and Environmental Management (NREM) of the College of Tropical Agriculture and Human Resources (CTAHR) studied 10 irrigation systems across the Hawaiian Islands (Table 2) that account for < 5% of ALISH lands (NREM, 2008). The studied irrigation systems have design capacities to divert and utilize large quantities of water. Maximum capacities at the ten larger systems total 387.4 MGD. Actual water use is typically much lower. Water measurement at the studied systems varies greatly in methods and accuracy. Ignoring these differences, recent NREM surveys found water diversions from the 10 systems total 190.5 MGD (NREM, 2008). This is about half the United States Geological Survey (USGS) irrigation water estimate, though the latter has likely increased since 2000. The studied systems account for over 90% (363.5 MGD) of 2000 irrigation water use (387.4 MGD capacity) on all islands except Maui and Lanai highlighting the importance of these systems in Hawaii water resources. The remaining, approximately 10% of the water, 23.9 MGD, may be used for growing bioenergy crops. Analyses were performed for the service and surrounding areas of the 10 irrigation systems studied and comprehensively documented in the NREM 2008 report to obtain baseline agricultural land maps and acreage estimates, which were: 1) ALISH, 2) soil types or land capability classes, 3) crop types (current land uses), and 4) potential wastewater sources for agricultural irrigation.

Table 2 Service area, ALISH, maximum capacity and average water use in the 10 studied irrigation systems (Source: NREM, 2008)

Island	STUDIED SYSTEMS				
	Irrigation Systems	Service Area acre	ALISH acre	Max. Capacity MGD	Avg. Water Use* MGD
Kauai	East Kauai (Kapaa-Kalepa)	5920	5510	100	5.5-8.0
	Kauai Coffee	4660	4370	33	27
	Kekaha	6570	6450	50	20
	total Kauai	17150	16330	*183*	*55*
Oahu	Waiahole Ditch	6270	5730	50	5-6
	Waimanalo	1580	1520	n/a	0.5-0.7
	total Oahu	7850	7250		*32.7*
Maui	Upcountry Maui (Olinda-Kula)	1720	1030	17.4	1
	West Maui (Wailuku)	6430	6300	120	55-66
	total Maui	8150	7330	*137.4*	*67*
Molokai Lanai	Molokai	9890	7780	n/a	3.4
Big Island	Lower Hamakua Ditch	4660	3950	17	12
	Waimea	1370	1240	n/a	4
	total Hawaii	6030	5190		*16*
State	Total	49070	43880	387.4	168.6

Sources: *Average diversions, except Waiahole Ditch includes water returned to streams under CWRM (Commission on Water Resource Management) order, Waimanalo is farm metered use, Molokai water measured at reservoir, and Waimea water entering reservoir. Where range given, island totals based on upper bound.

Land and Water Projections

The NREM report (NREM, 2008) projected agricultural acreages as an intermediate step to the year 2030 in 5-year increments, broken down by island, under different scenarios including *optimistic*, *pessimistic*, and *most likely*. Statewide for 6 crop groups (e.g., sugar, pineapple, seed crops, vegetable & melons, fruit & nut trees, and nursery & flowers) the report indicated an increase of 12,000-45,000 ac. under the three macroeconomic scenarios. Projections for the *most likely* scenario are shown in Table 3 where sugarcane accounted for the largest share in Kauai and Maui. Oahu, Molokai, and Big Island showed the least expected growth. In addition to the existing sugarcane acreage in Hawaii, GIS analysis of former plantation lands identified another 53,000 ac. that might be utilized for new bioenergy crops. Since large-scale bioenergy production in Hawaii is still speculative, this is an *optimistic* projection.

With the help of projected crop acreages presented in Table 3, future irrigation water demand for agriculture was estimated (Table 4). Equal water demands (approximately 15 MGD) for bioenergy crops are shown for Kauai and the Big Island followed by Oahu and Maui (< 10 MGD). In the *optimistic* scenario, state farm-level demand for water would grow to around 750 MGD in the year 2030, if all crops, pasture, and potential bioenergy crops are fully irrigated, which is more than double the latest USGS estimate (Table 1) of irrigation water use for all purposes with an increase in demand by another 35 MGD of irrigation water for new bioenergy crops beyond current sugar operations (NREM, 2008). To meet these future needs, further study is needed regarding allocation and development of the state's water resources.

Table 3. Projected crop acreages for five islands under *most likely* scenario (Source: NREM, 2008).

Island/Year	**Big Island**		**Maui**		**Molokai**		**Oahu**		**Kauai**	
Crops	2030	2005	2030	2005	2030	2005	2030	2005	2030	2005
Sugar	496	39	37,239	34,993	419	33	457	36	9,345	8,291
Pineapple	0	0	5,118	5,394	0	0	7,334	7,497	0	10
Seed crops	423	11	1,011	513	1,933	1,243	1,304	867	2,006	1,309
Veg. & Melons	2,972	1,641	1,174	908	923	222	4,031	3,419	992	321
Fruit & nut trees	33,226	26,114	2,956	673	890	366	1,648	1,030	8,654	4,527
Nursery, flowers	3,139	2,441	841	549	74	32	894	665	594	247

Table 4. Projected irrigation water demand (MGD) for five islands under *most likely* scenario for different crops including potential bioenergy crop (Source: NREM, 2008).

	2030			2005
	Bioenergy	Pasture	Crops	Crops
Big Island	12	157	83	64
Maui	3	57	152	134
Molokai	0	25	13	5
Oahu	7	9	19	14
Kauai	13	35	45	30
Totals	35	283	312	247

This study is just one phase of an evaluation of resources for bioenergy crop production and the potential of this renewable energy resource. We hope that the issues raised in this report will be addressed in the future phases. As reflected from Table 3, the lands available from discontinued cultivation of sugarcane and pineapple provide a potential for renewable bioenergy crop production. Based on the analyses conducted during this study, the following points should be considered for further studies and future strategies to support development of Hawaii's bioenergy industry:

- Based on environmental conditions (windward vs. leeward) and seasonal variations (cold vs. warm), candidate species should be found that can adapt to site/region specific conditions.
- Soil management practices should be evaluated for 528,000 acres of unclassified lava lands. In addition, the current lands used for agriculture and forest plantings must be maintained despite reduction in sugarcane and pineapple production.

- This study does not address potential climate change impacts on Hawaii agriculture. A thorough study is needed to assess the impact of potential climate change on natural resources, especially water resources of Hawaii. Availability of irrigation water will be one of the key factors for bioenergy crop production.
- Conduct a study on ways to increase the supply of sustainable water for biomass crops.
- Long-term impact of planting bioenergy crops on land and other infrastructure need to be studied. For example, what happens when a certain crop is no longer in demand; can the land be converted back for use with other crops? What would be the impact of discontinued production?
- Dual purpose use of resources such as biomass production from phytoremediation activities.As suggested by *SunFuels Hawaii*, creation of an ongoing fact-finding and policy discussion forum, an independent statewide panel with expertise in science, technology assessment and land use analysis.
- Remap ALISH to incorporate latest land use changes, availability of new lands (lava and non-ALISH lands), and proven potential of Hawaiian lands for diversified cropping.
- Detailed studies are needed with regards to: i) Ground Water Resources, Locations, and Potential Yields, ii) Surface Water Sources, Locations, and Potential Yields, iii) Surface Water Diversions and Locations, iv) Modeling and economics of biofuel crop production, v) Potential Use of Reclaimed Water, and vi) Implementation of Important Agricultural Lands (IAL) Classification.
- Further support of the objectives of water and land Tasks and/or Plan implementation pursuant to Act 253 regarding Hawaii renewable biofuels program to manage the State's transition to energy self-sufficiency based in part on biofuels for power generation and transportation.

TABLE OF CONTENTS

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1. INTRODUCTION

This document was prepared by the College of Tropical Agriculture and Human Resources under contract to the Hawaii Natural Energy Institute (School of Ocean and Earth Science and Technology), University of Hawaii at Manoa. The overall activities involved development of a bioenergy master plan that includes research, analysis, evaluation, and reporting on issue(s) pursuant to Act 253, SLH 2007, Part III Section 4(a), which states that the Department of Business, Economic Development, and Tourism shall develop and prepare a bioenergy master plan in consultation with representatives of the relevant stakeholders.

The scope of work defined for the evaluation of Hawaii's water and land resources and their potential to support production of biofuels as a significant renewable energy resource, as well as to provide information, analysis, and recommendations, is shown in Table 5 below.

This report consists six major sections; i) Introduction, ii) Existing Water Supplies and Lands, iii) Existing Lands for Biofuels and Biomass Crops Production, iv) Hawaii Agricultural Water Use Plan, and vi) Summary, Conclusions and Recommendations.

Section 1 introduces the scope of work and other sections. Section 2 outlines main components of existing water supplies and water resources for biofuels and biomass crops production at watershed or sub-watershed scales. Water uses including industrial, municipal, rural, agricultural, thermal power hydropower generation, fishing, boating, waste assimilation, and others are discussed. The section presents GIS maps for existing registered state owned wells, water systems, sustainable yield, water demand, and permitted water use by aquifer in all major island. Opportunities of water reuse for bioenergy crops, available and potential feedstocks, and potential for bioenergy production in conjunction with phytoremediation and bioremediation processes are discussed.

Section 3 details availability of existing lands for biofuels and biomass crops production through the use of GIS maps for ALISH classes, state land use, the Land Capability Classification (LCC) (irrigated and non-irrigated) and locations for all the major islands. The biophysical requirements for six crop species are used to estimate their yield. The section can be summarized as follows. Temperature and moisture are two major factors that determine the development and growth of plants. Temperature drives the development rate of a crop and impacts the yield per time unit. At lower temperatures, crops develop more slowly and biomass produced per unit time is reduced. Moisture is an absolute requirement for a crop. Without moisture, there is no growth.

Table 5 Bioenergy master plan "Task 1-Issue: Water Resources" and "Task 2-Issue: Land Resources" scope of work

Track 1 – Issue: Water Resources	**Track 2 – Issue: Land Resources**
• Identify appropriate stakeholders, technical experts, and information sources throughout the state.	• Identify appropriate stakeholders, technical experts, and information sources throughout the state;
• Document the availability of existing water supplies for growing biofuels and biomass crops (indicate areas currently in production for food crops or diversified agriculture);	Document the suitability (zoning, soil type, slope, temperature, etc.) of land resources for growing biofuels and biomass crops (indicate areas currently in production for food crops or diversified agriculture);
• Document the use, availability and allocation of water from streams, wells, and aquifers including environmental impacts and competing uses;	• Document the ownership, permissible use, location, availability, and allocation of appropriate land, and competing uses;
• Document the potential for additional sources of non-traditional water supplies – non-potable water, wastewater, stormwater, reclaimed water, desalinated water, and other;	• Document methods to increase productivity of land use for bioenergy production including selection of biomass feedstocks, agricultural practices, and any other factors; and
• Document the potential for biomass production in conjunction with phytoremediation and bioremediation processes;	• Estimate and document biofuel production potential based on water resources and available land assets.
• Document methods to increase of water use efficiency for bioenergy production including selection of biomass feedstocks, modeling of crop water use; technologies including irrigation techniques; and	
• Estimate and document biofuel production potential based on water resources and available land assets in cooperation.	

Section 4 discusses agricultural water use for potential biofuels and biomass crops production. The information presented in this section is based on 10 irrigation systems studied for NREM technical report (NREM, 2008). That report focused on transforming former plantation systems to diversified agriculture use, as well as maintaining systems already devoted to diversified agriculture use by (1) preparation of an inventory and plan for the rehabilitation of the irrigation systems, (2) identification of irrigable lands for diversified agriculture, and (3) forecasts of acreage and water needs for diversified agriculture for each irrigation system over a 20-year planning period. The purpose of this NREM study was to estimate current and future agricultural irrigation water demands for irrigation systems across the State of Hawaii. The study developed concepts, methodologies and procedures to produce 1) crop irrigation water duties at 10 irrigation systems, 2) state agricultural industry water projections under different scenarios, 3) water demand projections for 10 irrigation systems, 4) GIS maps and spatial analysis of the service and surrounding areas for 10 irrigation systems, 5) GIS maps for 11 previously unstudied irrigated areas identified in 2004 Agricultural Water Use Development Plan (AWUDP, 2004). Section 5 summarizes the report, presents major conclusions, and includes recommendations from current study and from stakeholders.

1.1 Land and Water Resources

GIS maps of ALISH provide basis for various agriculture studies. These maps date back to 1977 (Hawaii Statewide GIS Program, 2008) when most of the Hawaiian agricultural lands were under sugarcane and pineapple plantations. After the end of large-scale sugarcane plantation in 1978, the State Government made substantial changes in land leasing. Some of these lands became available for small farmers for use in diversified cropping systems. The decline of Hawaii plantation agriculture impacted Hawaii farming as most of their lands have been idled. Many of these agricultural lands are threatened by “gentlemen farmers,” who build houses on some of these lands but have no interest in commercial farming (NREM, 2008). Aforementioned land use changes have raised questions on the accuracy of the ALISH maps. There is a need for an updated information on land ownerships. Non-ALISH lands, i.e., shallow-soil and Lava lands have shown potential for some bioenergy crop production and need to be accurately and taken in consideration.

As discussed above, although ALISH maps are still used for estimation of current and future agricultural lands, projection of water demands for future agriculture, and other land use involving studies, information provided in these maps may be different from actual land use. Unfortunately, there are no data to document the extent of land use changes (NREM, 2008). Therefore, any accurate projection/estimation of bioenergy crop production requires an updated land use maps which can be achieved using remote sensing data validated through a groundtruthing process.

Surface and ground water are the major supplies of Hawaii irrigated agriculture. Sugarcane plantations were built around well engineered sophisticated irrigation systems (water pumping, storage, diversion ditches). Many of these systems could not all remain operational after four decades of neglect. Many of the systems need rehabilitation and maintenance. To meet the demands of Hawaii bioenergy crops, rehabilitation may need to go beyond reconstruction of the original infrastructure (NREM, 2008). Conventional irrigation management requires large labor costs for system operation and maintenance which can be optimized through the use of modern technologies.

In addition to rehabilitation of existing irrigation systems, large-scale of bioenergy crop production can make use of treated waste water resources. Any serious plan to use treated waste water will require building establishing a delivery system to deliver these water resources from their treatment facilities into the application lands. The major treatment plants, e.g., Sand Island Plant, are usually away from the nearest potential bioenergy production areas.

1.2 Stakeholders Input

During the April 2 2009 Hawaii Bioenergy Master Plan Meeting, stakeholders interested in Land and Water Resource discussed the following main points: i) What critical information would a producer or land owner need to have to make a decision on producing bioenergy crops? ii) What are current land and water resource availability constraints for biofuel production?, and iii) What actions can be taken in the next 2-3 years that would address the priority constraints? Inputs from the participants were summarized and grouped in major groups according to their commonalities (Appendices A and B). Then each participant voted to identify items that are critical for the success of any biofuel program in Hawaii. Contents of the first version of the report were also reviewed by various stakeholders. Stakeholders' feedback was included in various sections of this report and especially the recommendations section.

2. EXISTING WATER SUPPLIES AND DEMANDS

Table 6 outlines the main components of existing water supplies and water resources data, which are required for assessing water availability for biofuels and biomass crops production in a watershed or sub-watershed. Water utilization includes both withdrawal uses (e.g., industrial, municipal, rural, agricultural, thermal power and other sectors) and instream uses (e.g., hydropower generation, fishing, boating, waste assimilation, etc.). Detailed assessment of irrigation water is required due to the large spatial and temporal variability of irrigation-water demands for bioenergy crops and the need to consider physical, climatic, and operational factors.

An inventory of existing State owned and operated water systems was conducted by the State Water Projects Plan (SWPP) to assess the extent of the State's current water-related operations (CWRM, 2003). The inventory included information on existing water uses and sources registered by the State to provide a framework for planning and implementation of water development programs to meet projected demands for State projects. The inventories show that the State owns and/or operates 226 wells, 54 stream diversions and 36 water systems (11 public water systems, 7 agricultural irrigation systems and 18 smaller potable or non-potable water systems). The State Water Projects Plan data is used in Section 2.1 of this report as the basis for assessing water resource availability for biofuel production.

Table 6 Principal components of the water availability analyses

Component		Purpose/Description
WATER USE	Municipal	municipal water uses and water price as major variables can be disaggregated as residential, commercial, public, etc.
	Rural Domestic	household domestic water uses in rural areas
	Industrial	industrial water uses takes into account production level; water use practices; industry distribution and water prices; employs input-output techniques for growth and technological change analysis
	Thermal energy	monthly water use for each thermal power plant simulated
	Hydroelectric	hydroelectric energy generation from simulated flow at the plants
	Irrigation	irrigation water use by irrigation county/districts/watershed/sub-watershed; historical climatic data (precipitation and evapotranspiration); calculation of irrigation diversions and return flows; irrigation areas tied to water supply network based on their spatial distribution
	Livestock	livestock water use by animal type and county/watershed/sub-watershed
	Instream	flows required for instream water uses; calculates the frequency of violations of instream flow requirements and the severity of the problem
SUPPLY	Surface Water	natural streamflow
	Groundwater	water use data supplied from groundwater, sustainable yield and water demand ; does not account for interconnection between surface and groundwater sources
	Reservoir	reservoir levels and releases; evaporative loss based on surface area
OTHER	Off-Stream Storage	intake requirements due to off-stream storage
	Diversions	inter- or intra-basin water transfers

2.1. Availability and Allocation of Water from Streams, Wells, and Aquifers

A “water budget” for a hydrological unit or system is an important factor in planning water use. A hydrological system could be as small as a basin or as large as a whole island. The budget accounts for all of the inflows, outflows, and changes of storage within the system. Inflows and outflows may include water from tributaries, ditches, irrigation diversions, and other inputs. Water that may be flowing out of a source watershed into an entirely different basin also needs to be accounted for. Irrigation systems and groundwater withdrawals change natural flow patterns. In addition, water flows can directly or indirectly affect water quality by introducing pollutants or diluting chemical concentrations.

Groundwater recharge is an important element of the water budget. The rain that reaches the ground surface is divided into fractions that recharge the groundwater, transpire by plants or directly evaporate to the atmosphere, or flow overland and are captured by streams. Water from precipitation and irrigation percolates downward from the ground surface to recharge the aquifers. Stream base-flow (contribution to stream during dry season), well pumping, and discharge to the ocean withdraw water from the aquifers. Groundwater recharge is a critical factor in managing groundwater resources including estimating aquifer sustainable yields (see Section 2.1.2). The study by Whittier et al. (2004) complemented the estimates of aquifer recharge values provided by the USGS (2000). Fig. 3 shows estimates of recharge for various islands as provided by that study. Utilization of new groundwater resources for biofuel production will necessitate assessing its influence on aquifer recharge and on estimated aquifer sustainable yields. Irrigation water, from surface or subsurface sources, can affect water recharge to the aquifer, and ultimately influences the water budget.

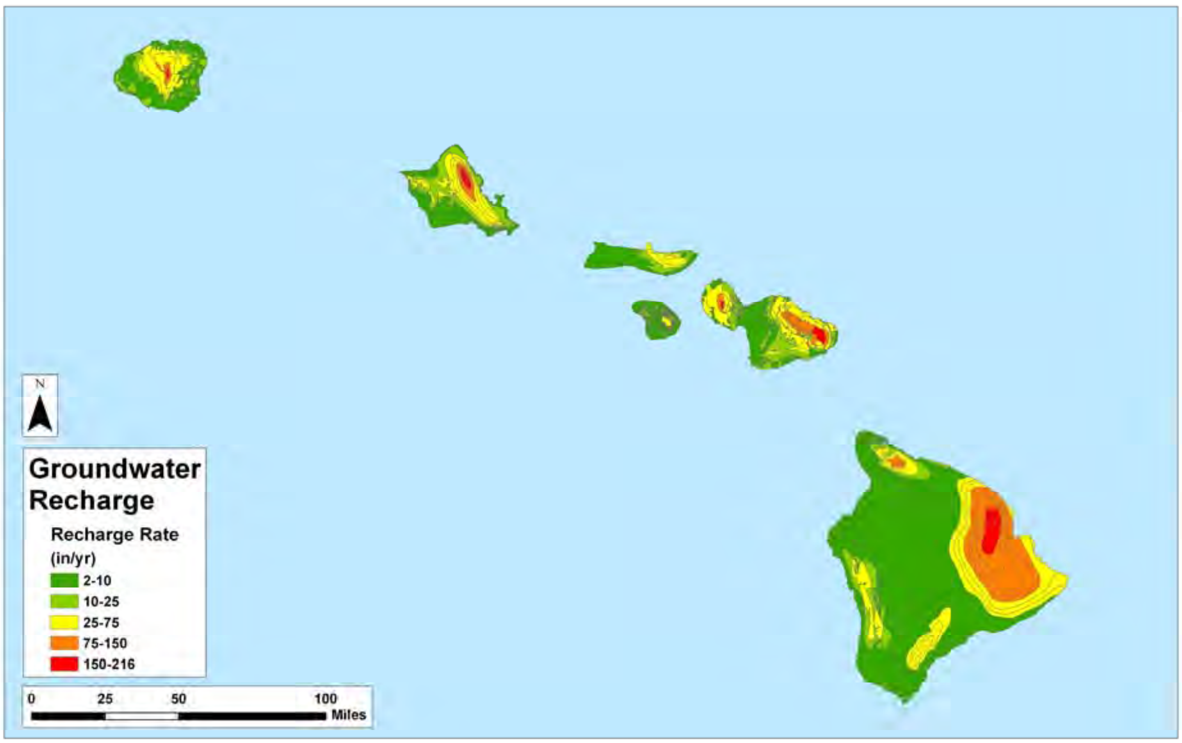

Fig. 3 Values of groundwater recharge for the Hawaiian islands (Whittier et al., 2004)

2.1.1 Wells and Stream Diversions

According to the SWPP (CWRM, 2003), a "well" is defined as any excavation or opening in the ground, or an artificial enlargement of a natural opening drilled, tunneled, dug, or otherwise constructed for the location, exploration, development, injection, or recharge of ground water and by which ground water is drawn or is capable of being withdrawn or made to flow. Water from the State wells is used for various applications with principal uses that include potable water supply and irrigation. Miscellaneous uses include cooling, landscaping, aquaculture, and wetland maintenance. Existing state wells include 79 on Oahu (Fig. 4), 23 on Maui (Fig. 5), 17 on Molokai (Fig. 6), 27 on Kauai (Fig. 7), and 49 on the island of Hawaii (hereafter referred to as the Big Island) (Fig. 8). No state wells exist on Lanai. [State well data and locations are based on the Commission on Water Resource Management (CWRM) report (CWRM, 2003)].

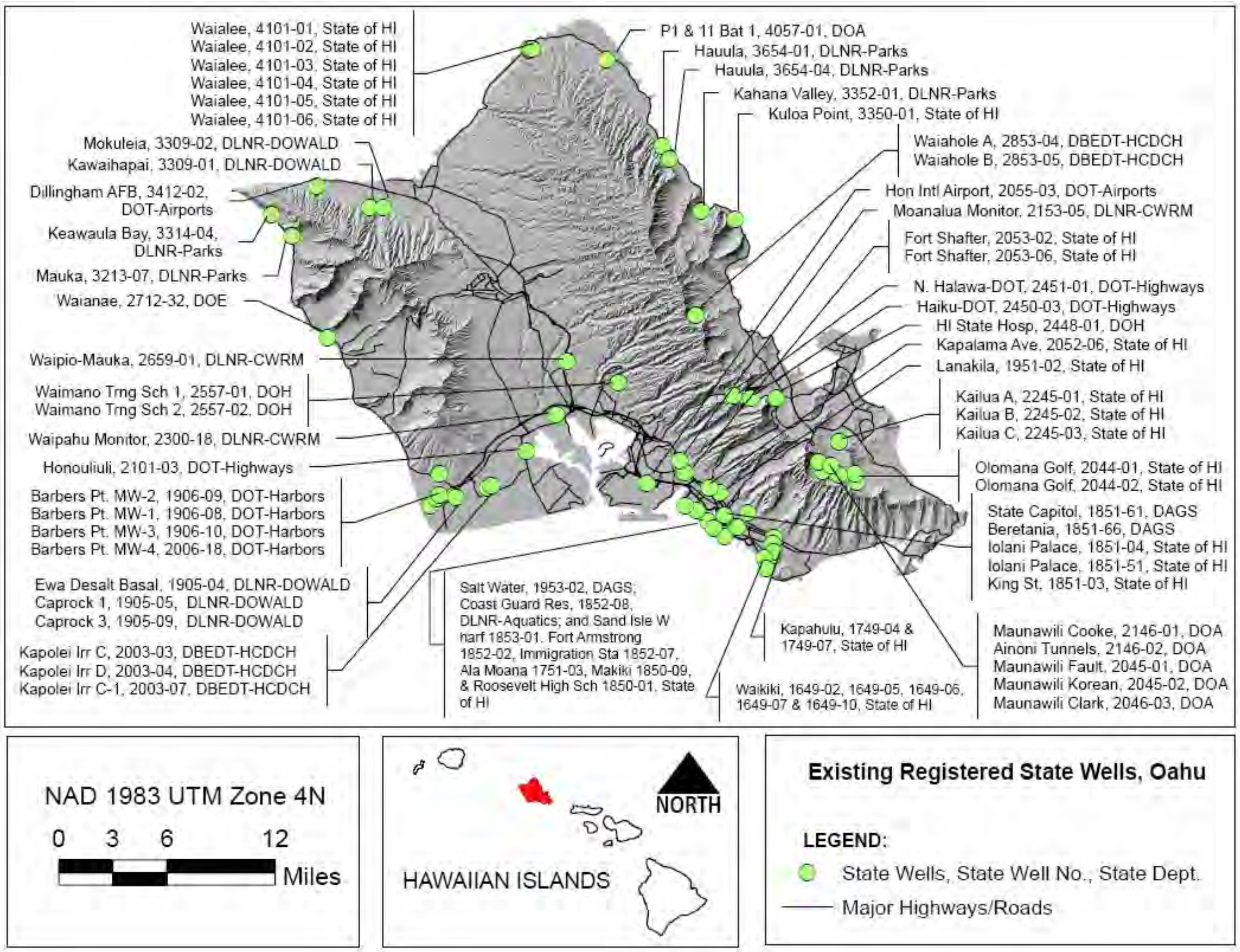

Fig. 4 Existing registered state wells, Oahu (Data Source: CWRM, 2003).

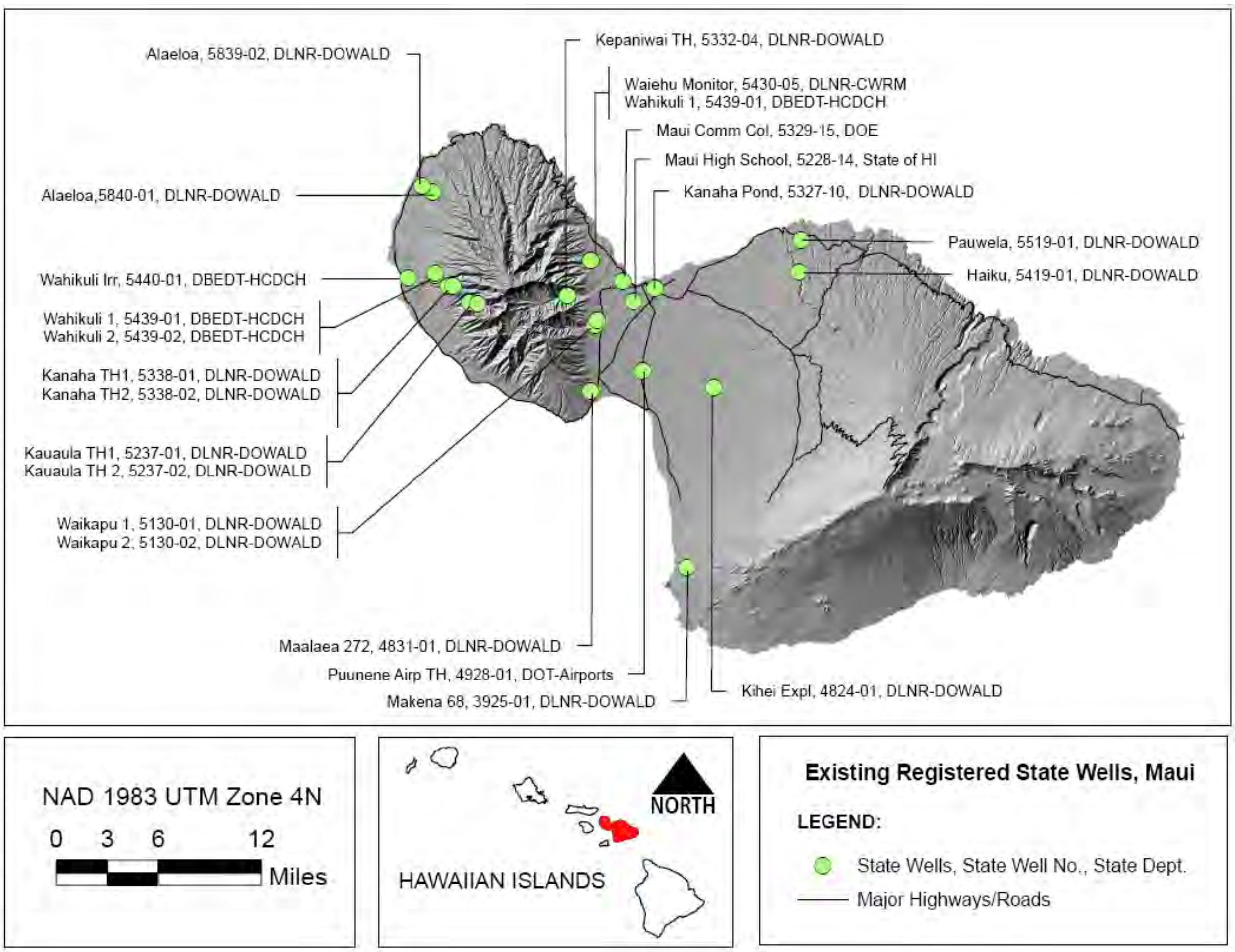

Fig. 5 Existing registered state wells, Maui (Data Source: CWRM, 2003).

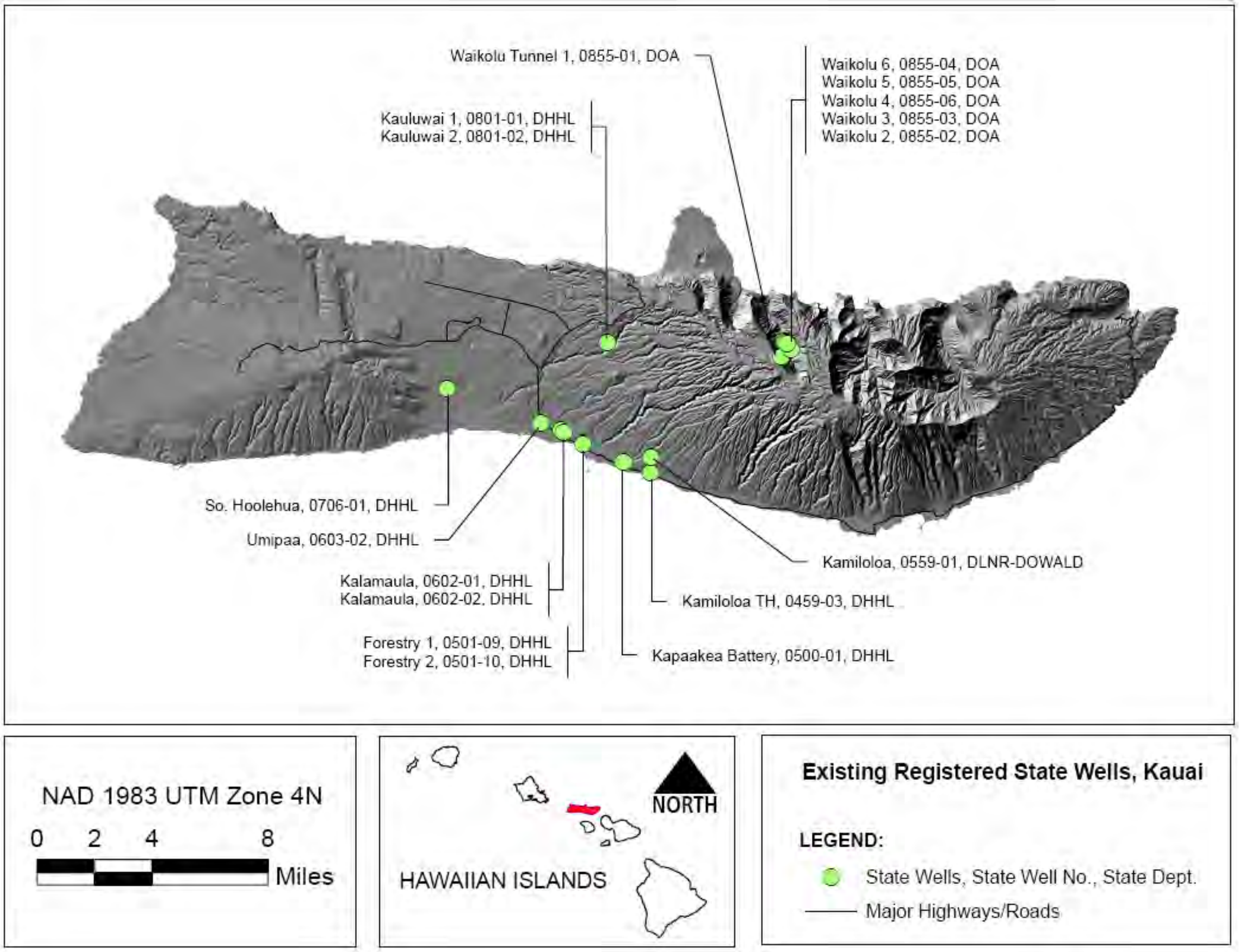

Fig. 6 Existing registered state wells, Molokai (Data Source: CWRM, 2003).

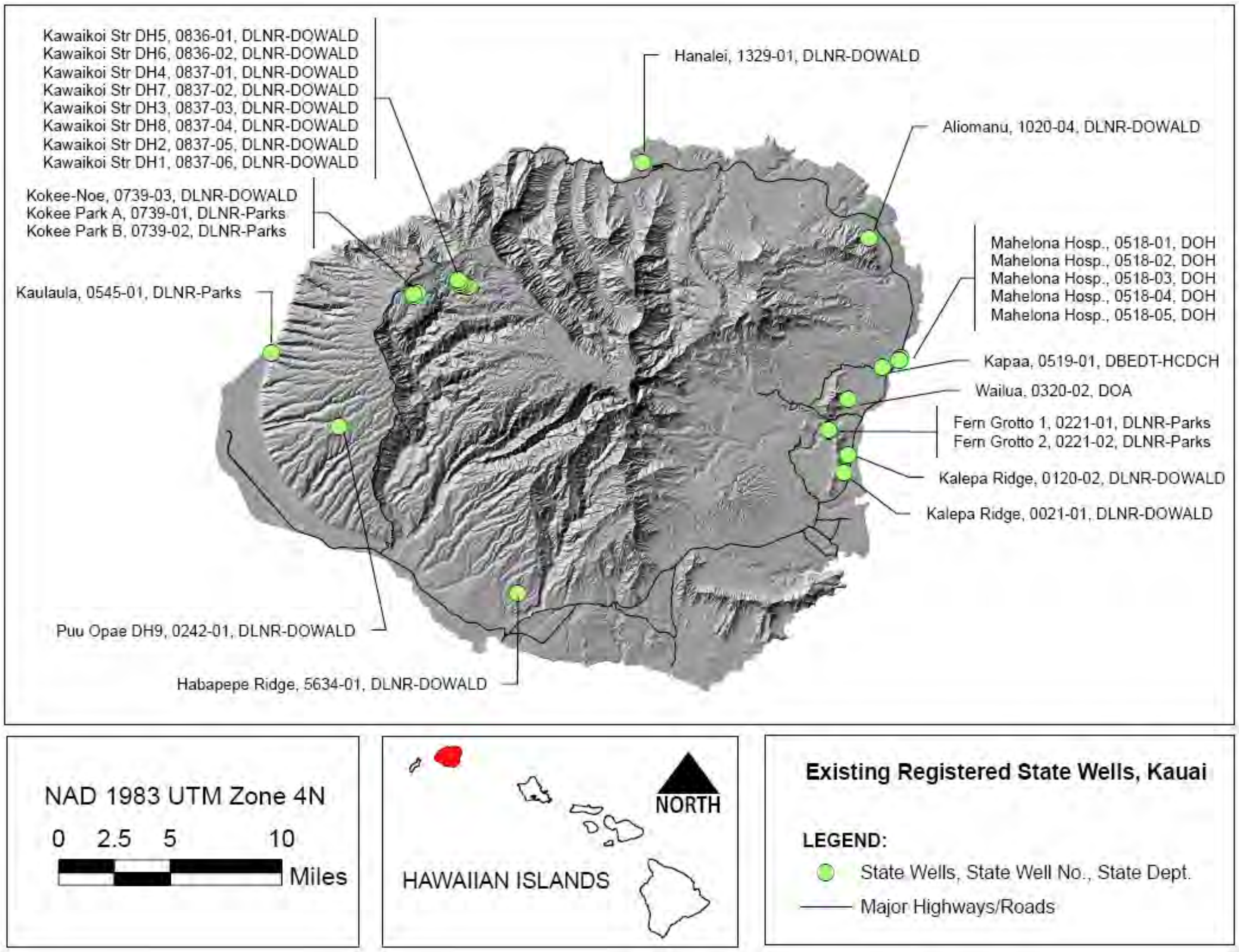

Fig. 7 Existing registered state wells, Kauai (Data Source: CWRM, 2003).

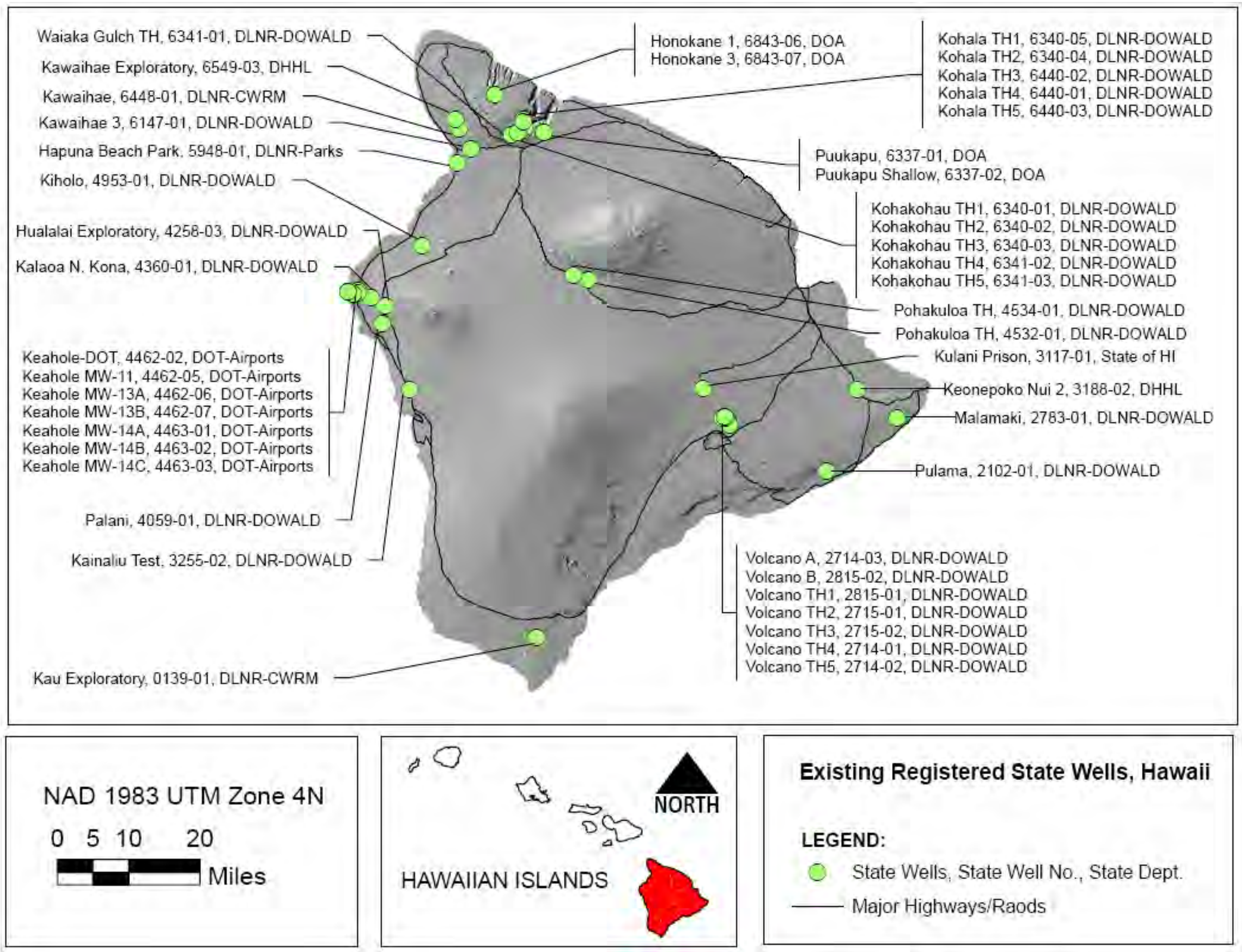

Fig. 8 Existing registered state wells, Big Island (Data Source: CWRM, 2003).

Any plan for developing biofuel crops should also include the potential effect on drinking water resources. The 1996 reauthorization of the Safe Drinking Water Act requires that each state in the U.S. addresses the protection of public surface and subsurface drinking water sources, including the development and implementation of a source water assessment program. Such a program includes delineating source-water assessment areas, inventorying potential contaminant sources within this area, and determining the water system's susceptibility to contamination. Contaminant sources included agriculture areas. The study by Whittier et al. (2004) covered the development of Hawaii’s source assessment program and provided an approach for implementation, which is consistent with the federal requirements. Both travel time and fixed distance approaches were used in the delineation process. The final product also includes numerical scores that quantify the relative source susceptibility to contamination. Example results are shown in Fig. 9 for the Island of Oahu that shows the delineated and susceptibility scores.

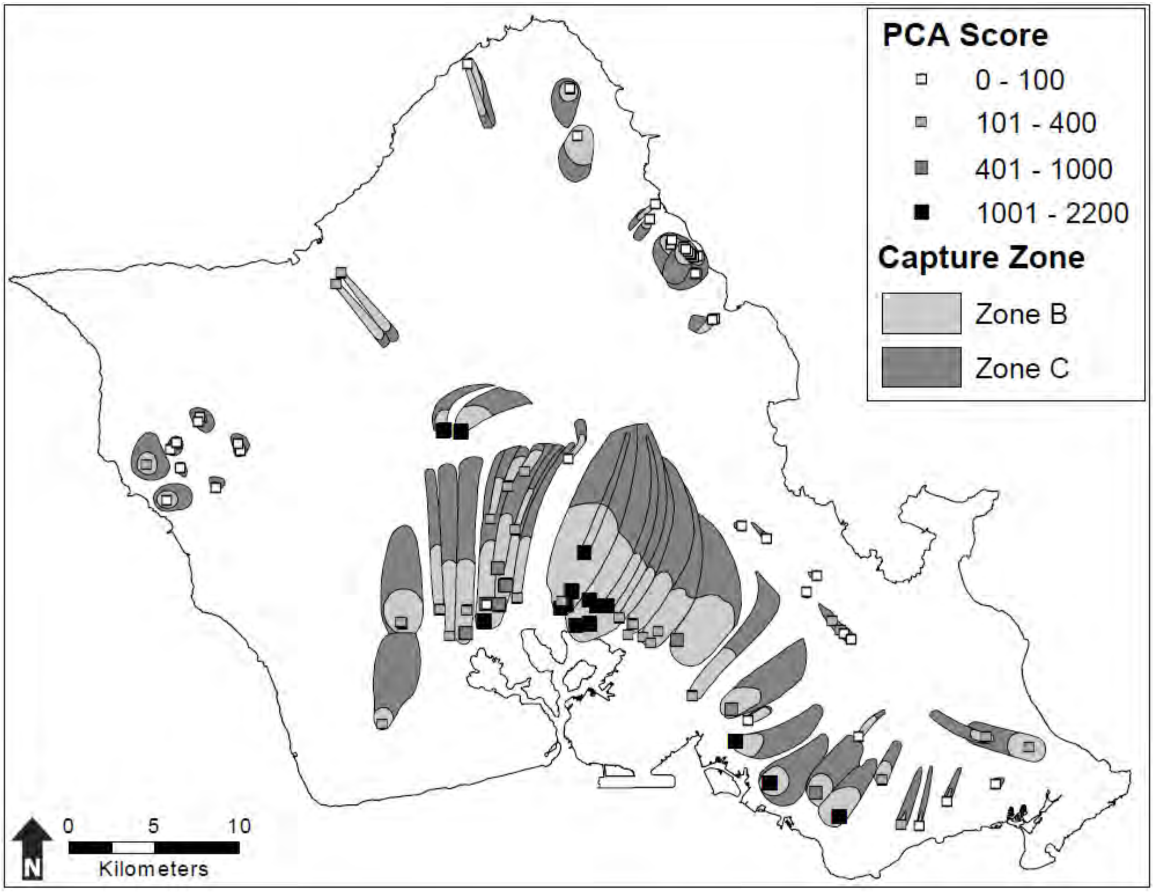

Fig. 9 Capture zones: Zone B for travel time of 2 years and Zone C for travel time of 10 years, and well susceptibility scores. The higher the score the higher susceptibility to contamination (Whittier et al., 2004). The acronym PCA refers to Potential Contamination Activity. The higher the PCA Score the higher well susceptibility to contamination.

The State Water Projects Plan (SWPP) (CWRM, 2003) defined a “stream diversion” as the act of diverting, pumping or otherwise removing water from a stream into a channel, ditch, pipeline, or other conduit. For example, on the Island of Kauai, when the sugar industry was emerging, and due to scarcity of water in some localities, complex networks of irrigation systems were built. The entire island’s water system has become a complex network of inter-connected ditches, irrigations systems, diversions, flumes, and reservoirs (El-Kadi et al., 2004). Although the sugarcane agriculture has drastically declined, water is still flowing through these systems.

The water collected from existing State diversion is used primarily for agricultural operations. Other uses include potable water supply, generally for remote areas, e.g., parks and recreation areas. Based on registered stream diversion records, the state of Hawaii currently owns and/or operates 54 stream diversions (Figs. 10 through 14 ; CWRM, 2003). Existing diversions are 10 on Oahu (Fig. 10), 4 on Maui (Fig. 11), and 9 on Molokai (Fig. 12), 9 on Kauai (Fig. 13), and 21 on the Big Island (Fig. 14). However, there are many other systems that are privately owned and there is a lack of assessable information about the condition of these systems, especially regarding operational status and the volumes of water diverted to other watersheds (El-Kadi et al, 2004).

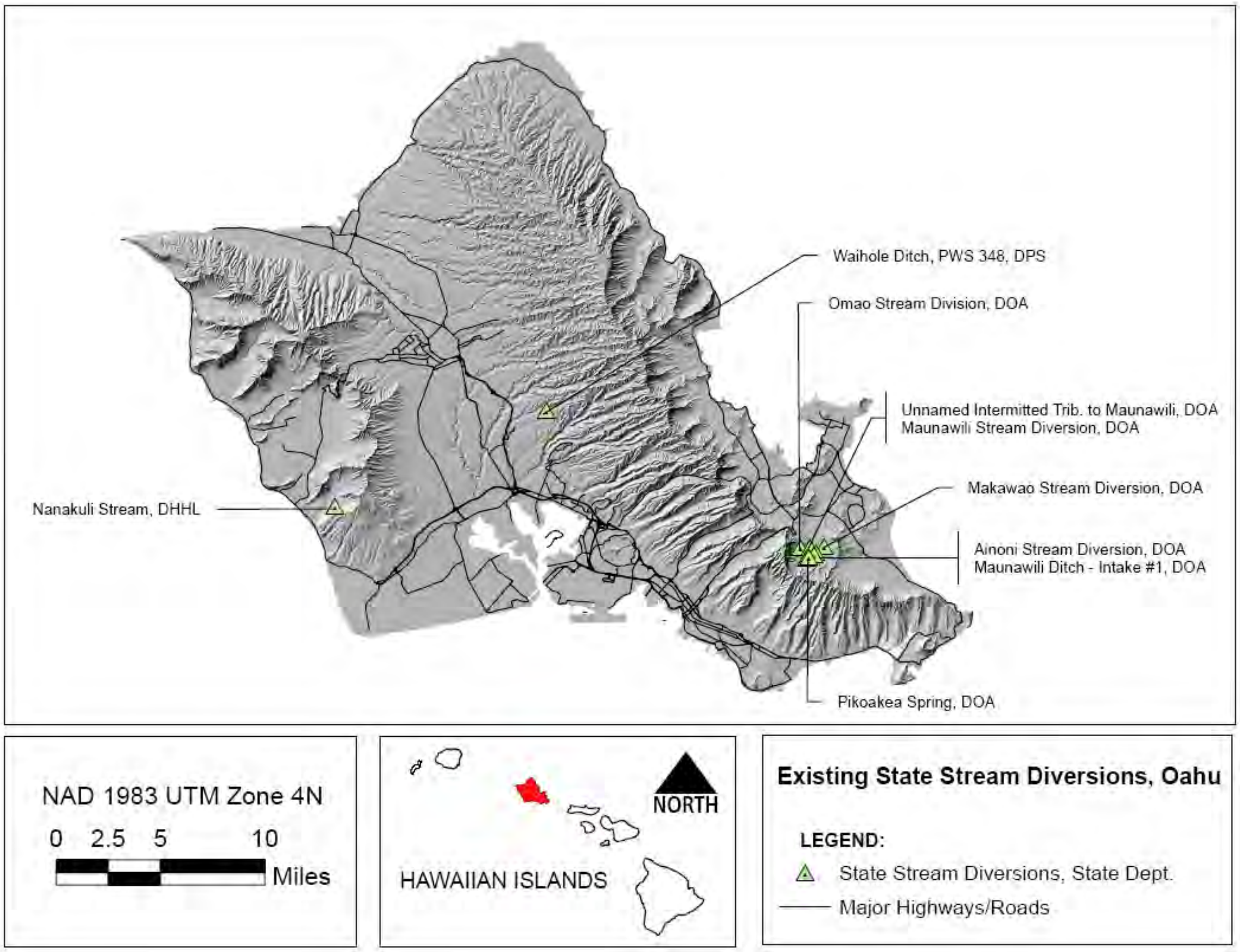

Fig. 10 Existing state steam diversions, Oahu (Data Source: CWRM, 2003).

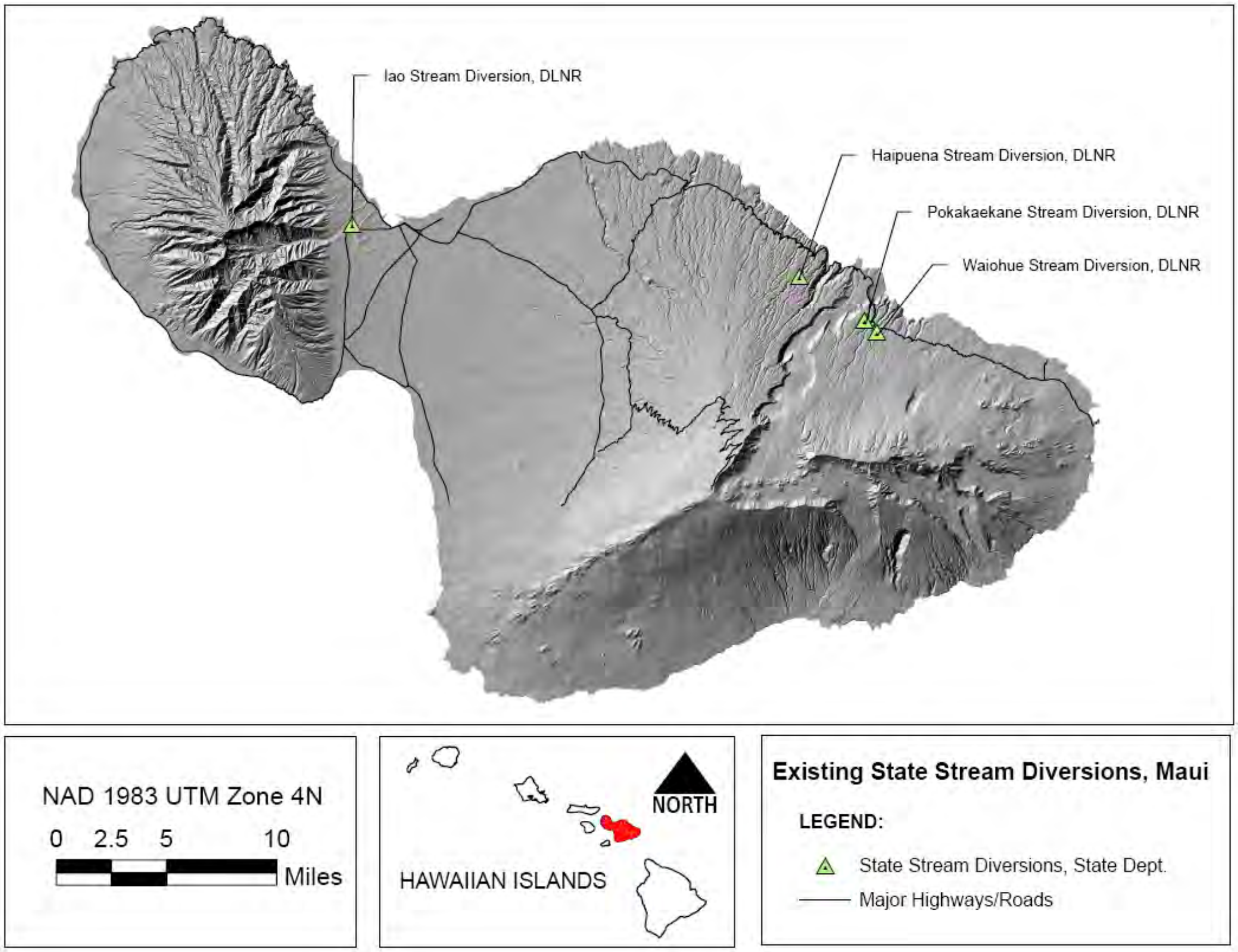

Fig. 11 Existing state steam diversions, Maui (Data Source: CWRM, 2003).

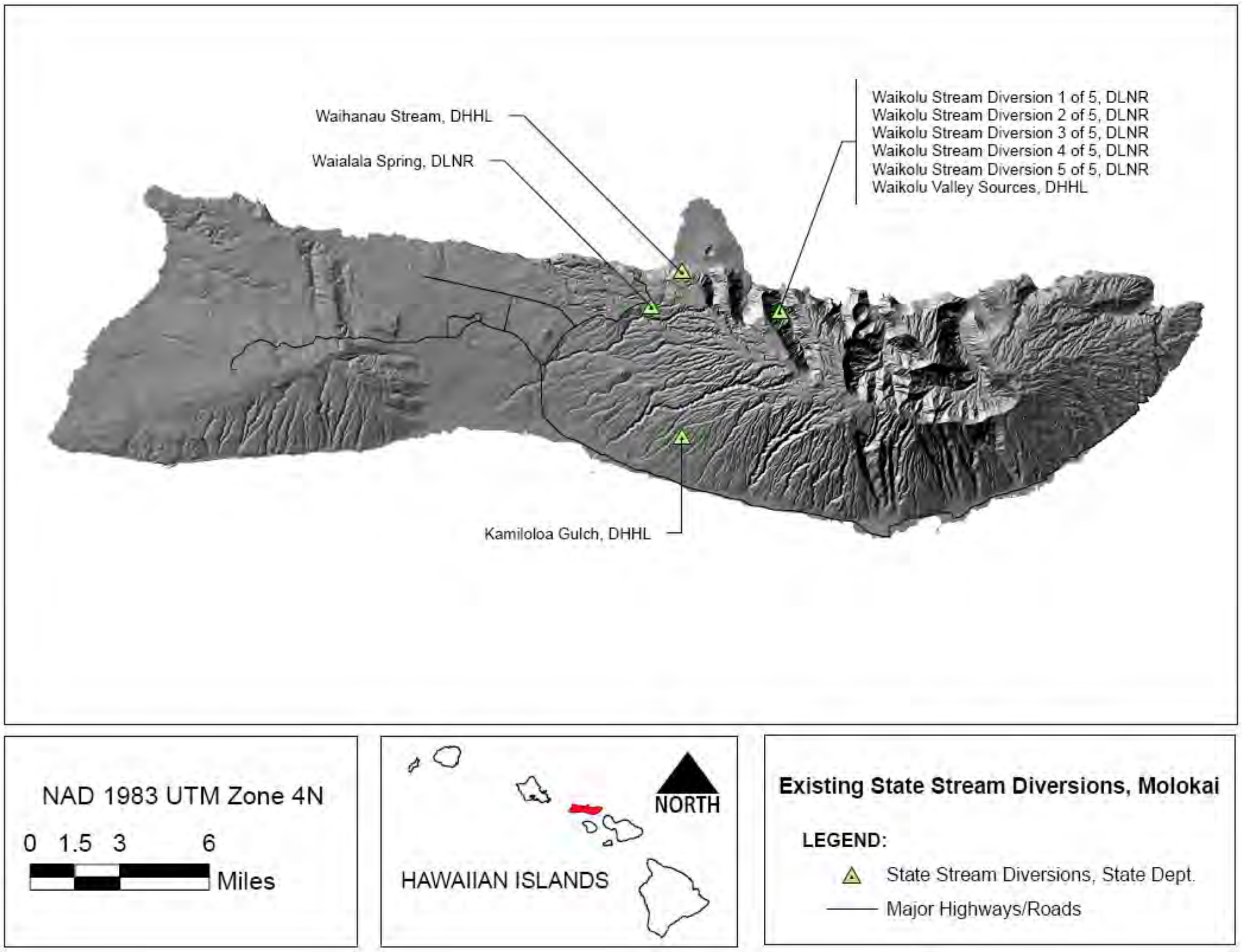

Fig. 12 Existing state steam diversions, Molokai (Data Source: CWRM, 2003).

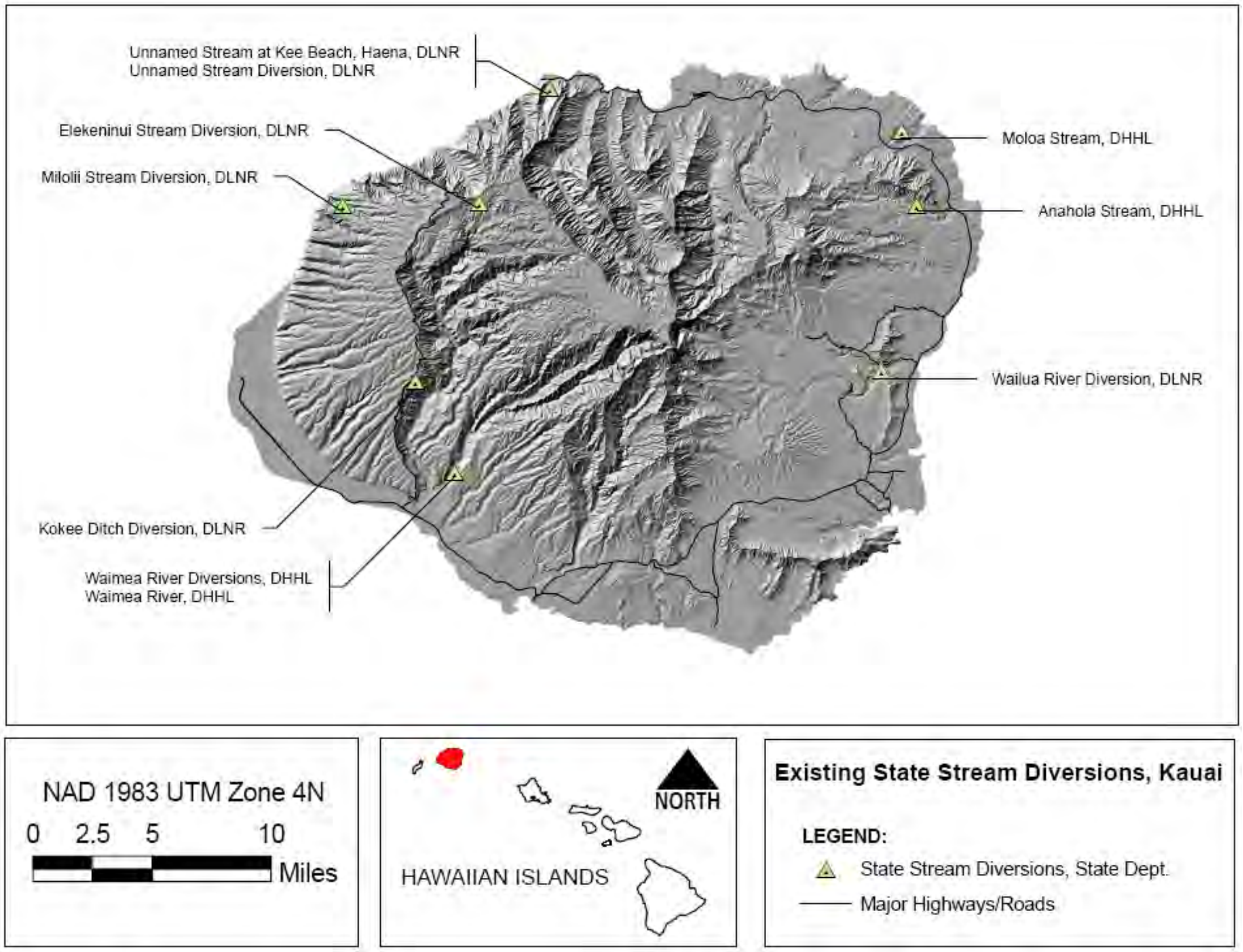

Fig. 13 Existing state steam diversions, Kauai (Data Source: CWRM, 2003).

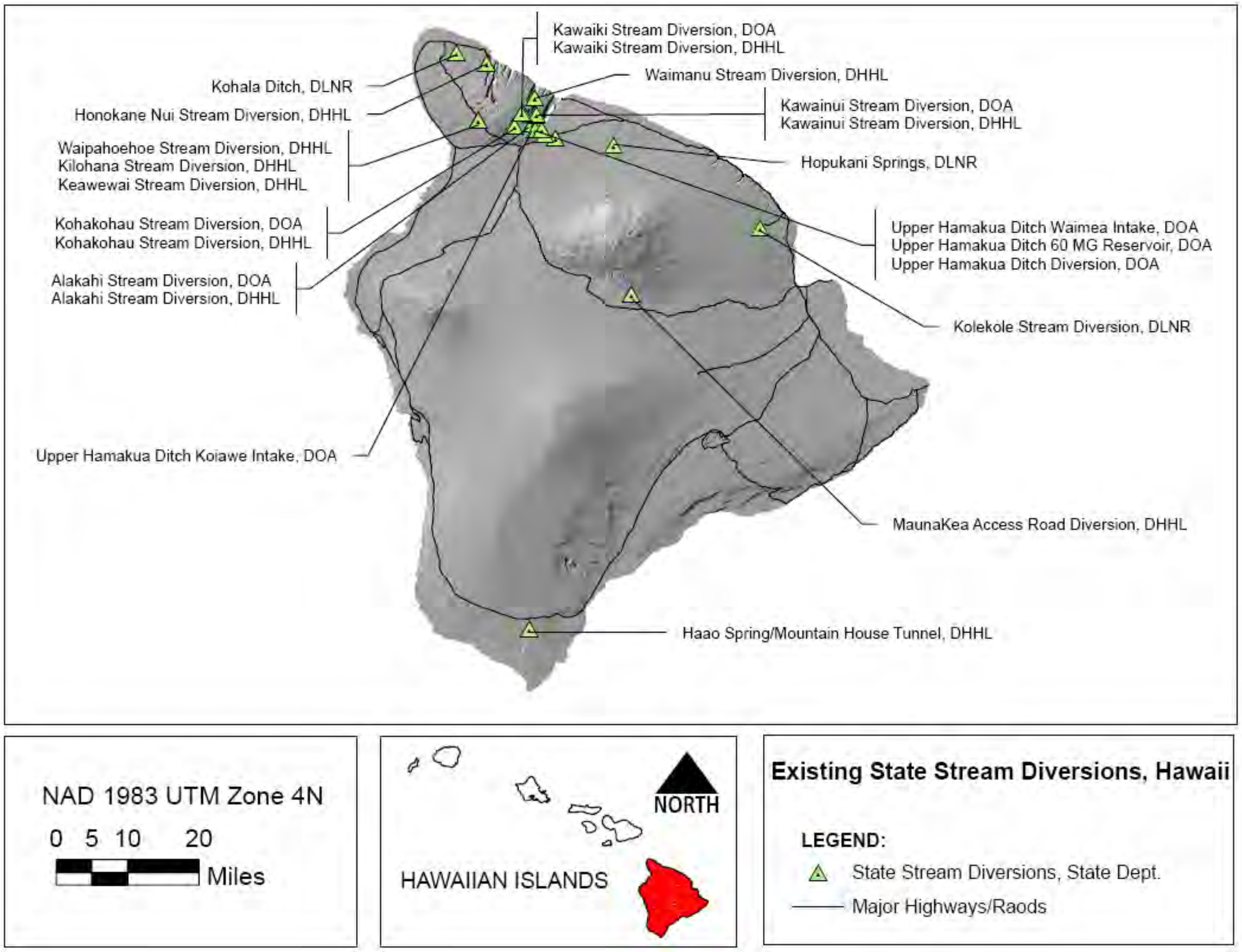

Fig. 14 Existing state steam diversions, Big Island (Data Source: CWRM, 2003).

2.1.1 State Owned and/or Operated Water Systems

According to the State Water Projects Plan, a state water system is a facility that is owned and/or operated by the State which provides water service to State projects or facilities; provides source water and treatment of source water; stores water in storage reservoirs; provides booster pump capacity; or conveys water through a distribution system and distributes water to service connections (CWRM, 2003). CWRM (2003) identified 36 State water systems, including 11 public water systems, 7 agricultural irrigation systems, and 18 smaller potable and non-potable water systems. As defined by the State Department of Health, a public water system is a potable water source, which has 15 or more service connections, or regularly serves an average of 25 or more people for at least 60 days each year. The State water systems are listed in Tables 7 through 10, while location maps of the systems on the islands of Oahu, Maui and Molokai, Kauai, and Big Island are shown in Figs. 15 through 19, respectively. The SWPP State water system inventory provides the following information: (1) a comprehensive list of State water systems; (2) a description of water system components and service areas including: source, storage, booster, pump, distribution, service connections, service area, primary water use, existing consumption and future water demand, a schematic diagram for each water system and GIS mapping; (3) identification of water systems that contain surplus source capacity (surplus source capacity is determined by comparing water source capacity (groundwater wells, catchment systems and/or stream diversions) against existing average daily and maximum daily consumption); and (4) an indication of whether water systems with surplus capacity could accommodate future State project water demands.

Table 7 Water systems owned or operated by the state, island of Oahu (Source: CWRM, 2003)

Water System Name	**State Agency**	**Island**	**Primary Use**	**State Owned**	**State Operated**
Kahuku Irrigation System	DOA	Oahu	Irrigation	Yes	Agribusiness Development Corporation (ADC)
Waiahole Ditch	Ag. Bus Dev Corp.	Oahu	Non-potable	Yes	Yes
Waimanalo Irrigation System	DOA	Oahu	Irrigation	Yes	Yes
Waiahole Water System	DBEDT	Oahu	Potable	Yes	Yes *
Hawaii State Hospital	DOH	Oahu	Potable	Yes, Source provided by BWS	Yes
Waimano Training School	DOH	Oahu	Potable	Yes	Yes
Hawaii Youth Correctional Facility	DHS	Oahu	Potable	Yes, Source provided by BWS	Yes
Kaena Point SP - Leeward	DLNR	Oahu	Non-potable	Yes	Yes
Kahana Valley SP	DLNR	Oahu	Potable	Yes	Yes
Keaiwa Heiau SRA	DLNR	Oahu	Potable	Yes	Yes
Makiki-Tantalus SP - Puu Ualakaa SW	DLNR	Oahu	Potable	Yes	Yes
Waahila Ridge SRA	DLNR	Oahu	Potable	Yes	Yes
Waiawa Correctional Facility	DPS	Oahu	Potable	Yes	Yes
Dillingham Airfield	DOT	Oahu	Potable	No, US Army	Yes *
Waialee Livestock Station	UH	Oahu	Irrigation	Yes	Yes

Note: * State water system operated by private contractor, managed by the State

Table 8 Water systems owned or operated by the state, islands of Maui and Molokai (Data Source: CWRM, 2003)

Water System Name	State Agency	Island	Primary Use	State Owned	State Operated
Molokai Irrigation System	DOA	Molokai	Irrigation	Yes	Yes
Hoolehua Water System	DHHL	Molokai	Potable	Yes	Yes
Kaumahina SW	DLNR	Maui	Non-potable	Yes	Yes
Polipoli Springs SRA	DLNR	Maui	Non-potable	Yes	Yes
Puaa Kaa SW	DLNR	Maui	Non-potable	Yes	Yes
Iao Valley SP	DLNR	Maui	Non-potable	Yes	Yes
Waialala SP	DLNR	Molokai	Potable	Yes	Yes

Note: * State water system operated by private contractor, managed by the State

Table 9 Water systems owned or operated by the state, island of Kauai (Data Source: CWRM, 2003)

Water System Name	State Agency	Island	Primary Use	State Owned	State Operated
Kekaha Irrigation System	DOA	Kauai	Irrigation	Yes	Agribusiness Development Corporation (ADC)
Anahola Water System	DHHL	Kauai	Potable	Yes	Yes
Haena SP	DLNR	Kauai	Non-potable	Yes	Yes
Kokee SP	DLNR	Kauai	Potable	Yes	Yes
Na Pali Coast SP	DLNR	Kauai	Non-potable	Yes	Yes
Polihale SP	DLNR	Kauai	Potable	Yes	Yes
Wailua River SP	DLNR	Kauai	Non-potable	Yes	Yes
Waimea Canyon SP	DLNR	Kauai	Non-potable	Yes	Yes

Note: * State water system operated by private contractor, managed by the State

Table 10 Water systems owned or operated by the state, Big Island (Source: CWRM, 2003)

Water System Name	**State Agency**	**Island**	**Primary Use**	**State Owned**	**State Operated**
Lower Hamakua Ditch	DOA	Big Island	Irrigation	Yes	Yes
Waimea Irrigation System	DOA	Big Island	Irrigation	Yes	Yes
NELHA	DBEDT	Big Island	Potable	Yes, Source provided by County, DWS	Yes
Hapuna SRA	DLNR	Big Island	Non-potable	Yes	Yes
Mauna Kea SP	DLNR	Big Island	Potable	Yes	Yes
Kulani Correctional Center	DPS	Big Island	Potable	Yes	Yes

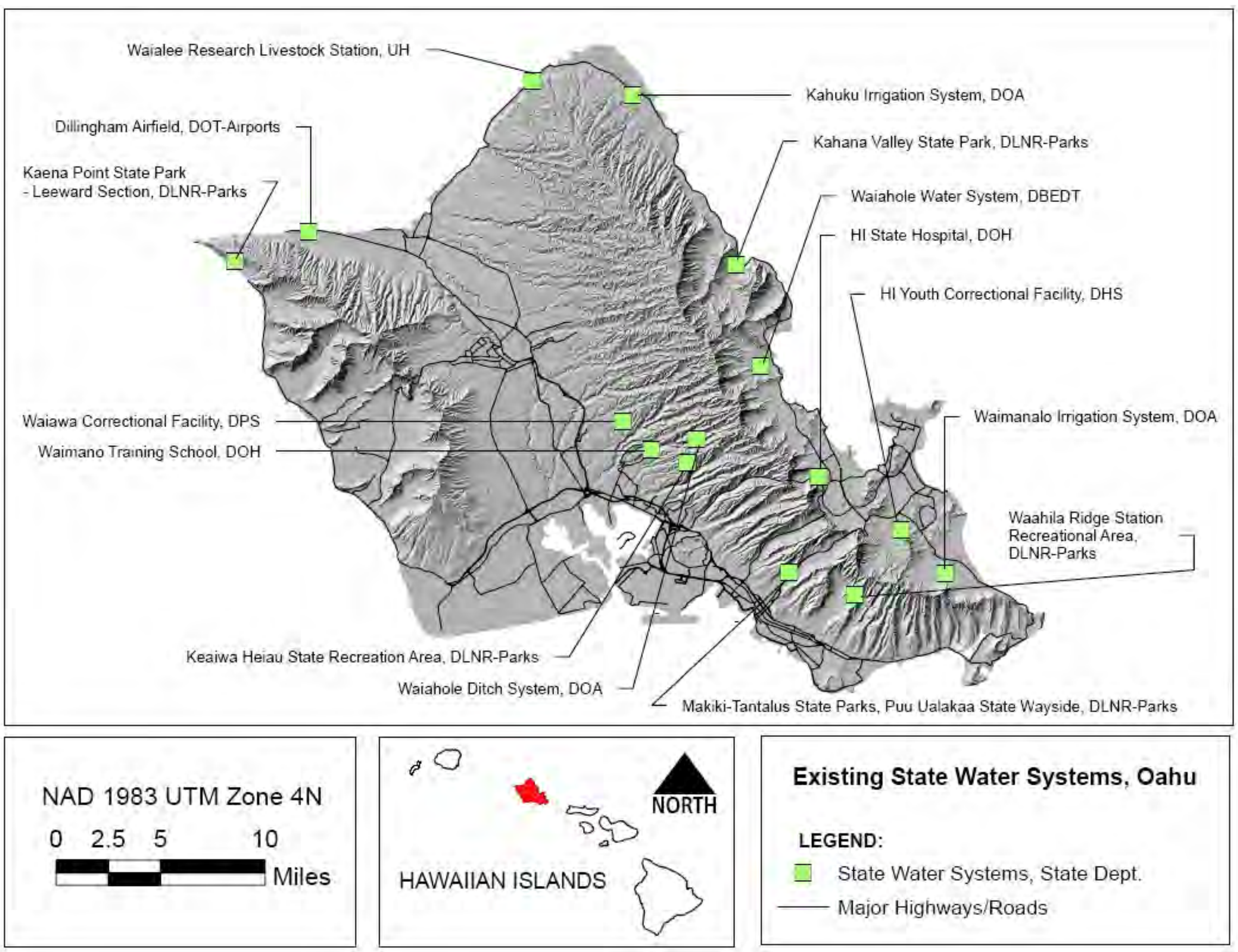

Fig. 15 Existing state water systems, Oahu (Data Source: CWRM, 2003).

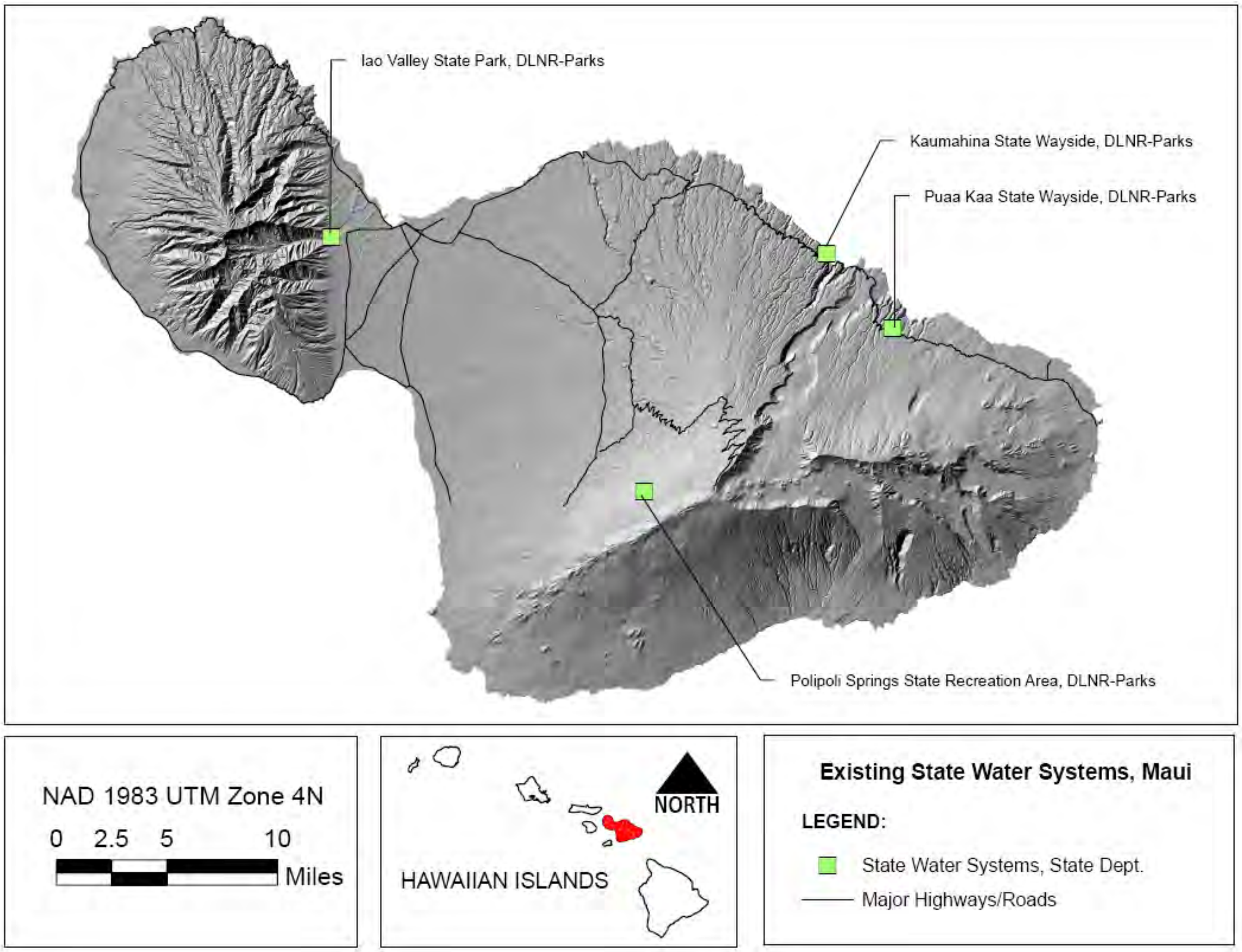

Fig. 16 Existing state water systems, Maui (Data Source: CWRM, 2003).

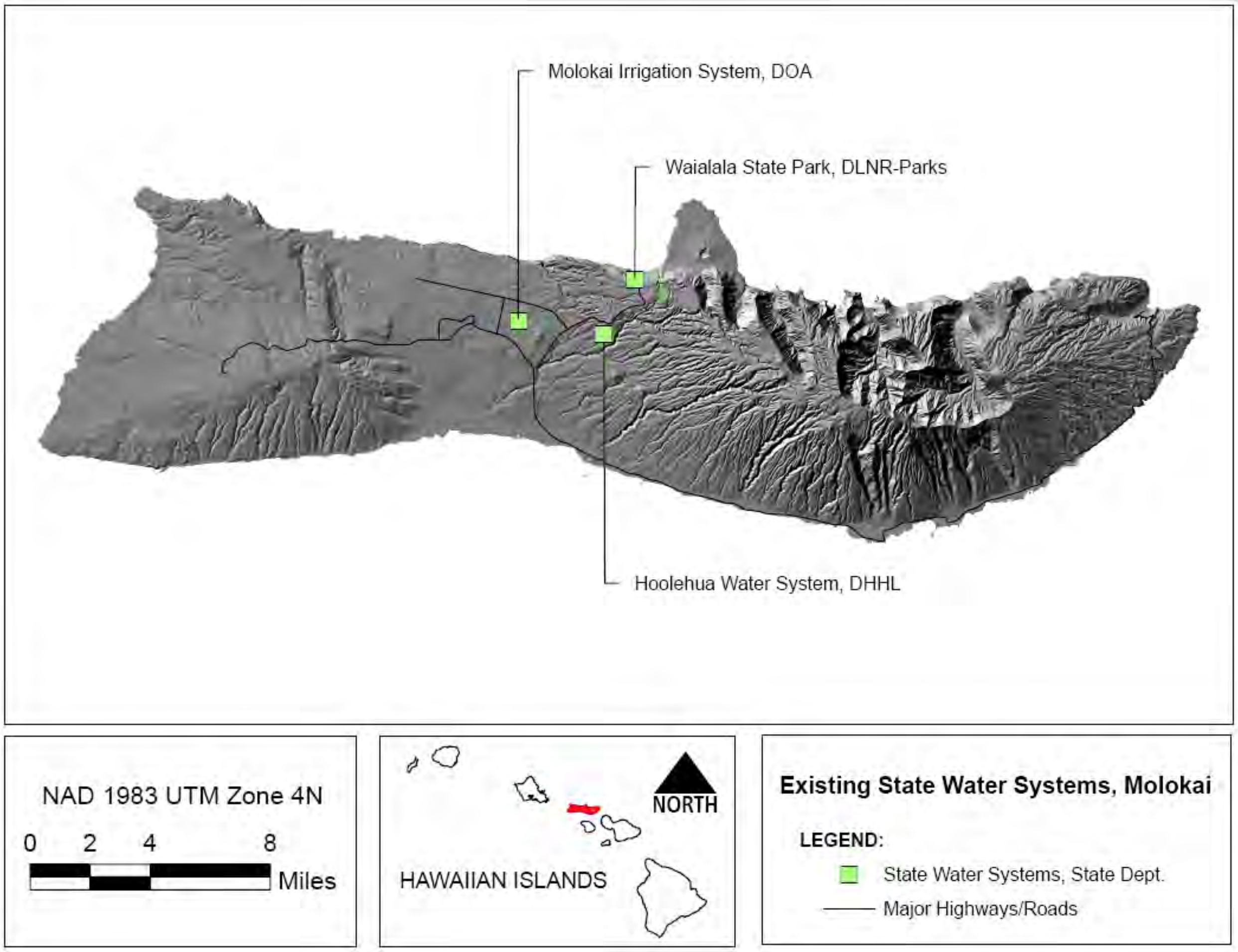

Fig. 17 Existing state water systems, Molokai (Data Source: CWRM, 2003).

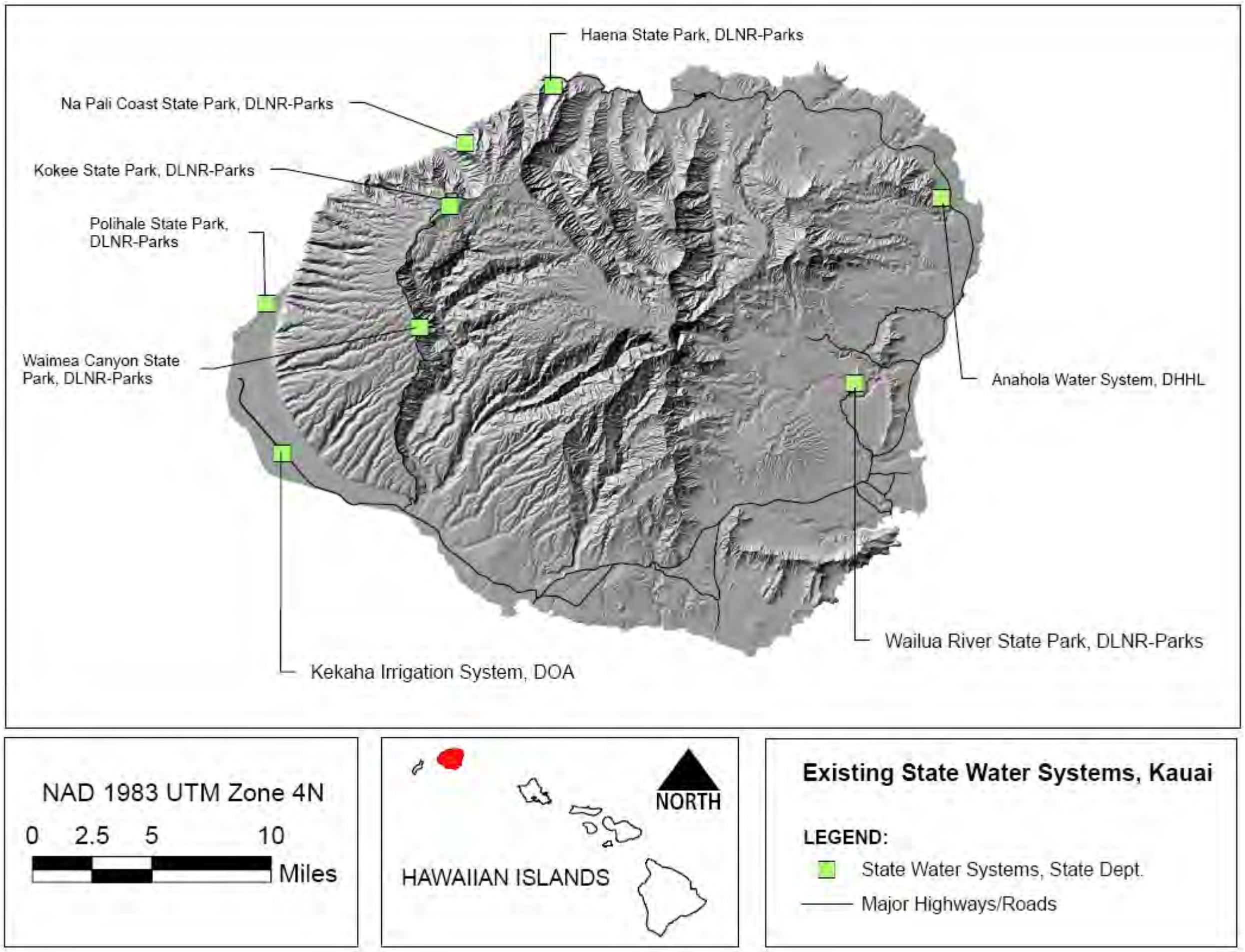

Fig. 18 Existing state water systems, Kauai (Data Source: CWRM, 2003).

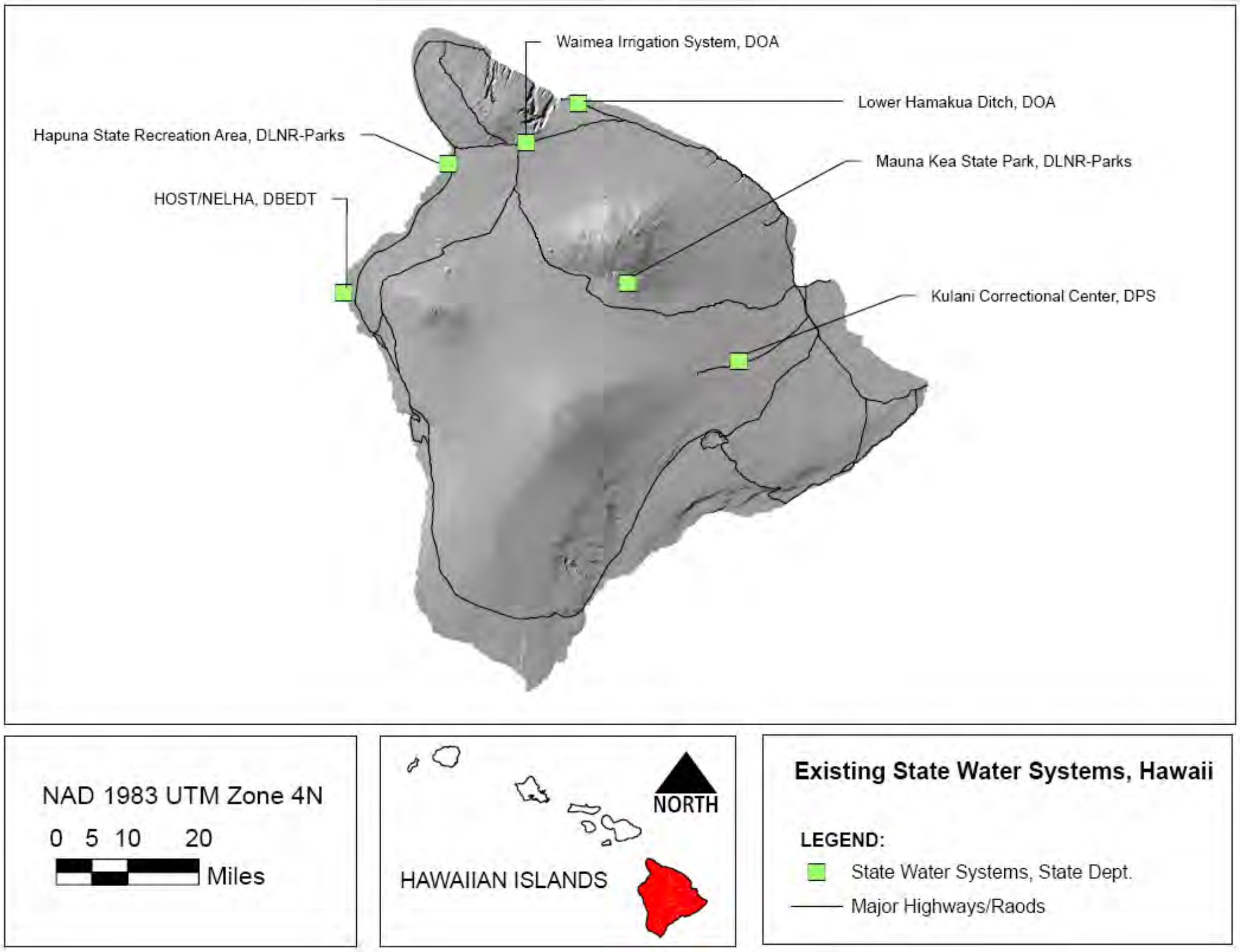

Fig. 19 Existing state water systems, Big Island (Data Source: CWRM, 2003).

As outlined in the State Water Code, the geographic boundaries for the development of regional plans coincide with the hydrological units established in the WRPP. The SWPP projected water demand, sustainable yield, and permitted water use by islands are shown in Fig. 20. The general boundaries of the various hydrological sectors and aquifer systems for each island are shown in Fig. 21 through Fig. 26. The hydrological maps identify the sustainable yields, permitted water use (where applicable), and the SWPP projected 2020 demands by hydrological sectors. CWRM maintains databases that include information about permitted water use allocations in water management areas, and reported ground and surface water uses throughout the State. Table A.1 (Appendix C) summarizes the sustainable yields, permitted water use and SWPP projected 2020 demands for each aquifer sector and system. The table provides an overview of future State water requirements in relation with current permitted water use and available sustainable yields. The additional water needed to support future State projects will affect available sustainable yields in several hydrological sectors, e.g., groundwater recharge. The sectors identified were: Honolulu, Pearl Harbor, Central (Oahu Sectors); and Central (Molokai Sector) (CWRM, 2003).

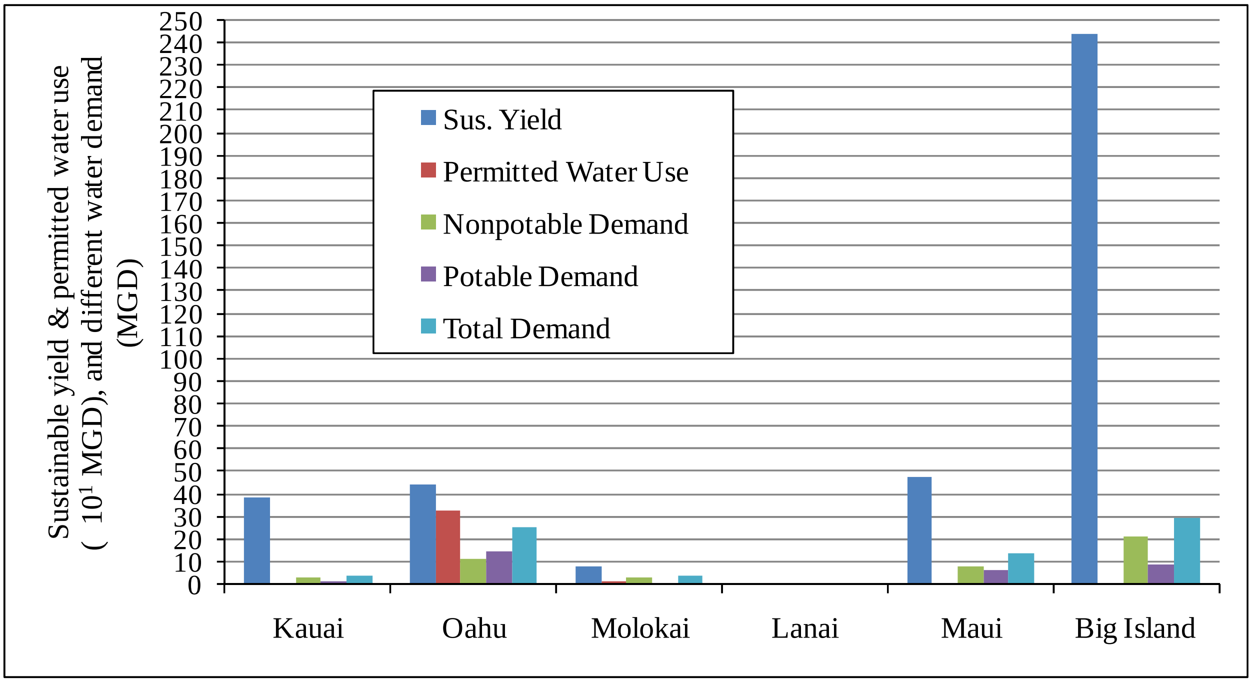

Fig. 20 SWPP Projected water demands, sustainable yield, and permitted water use by islands (Data Source: CWRM, 2003).

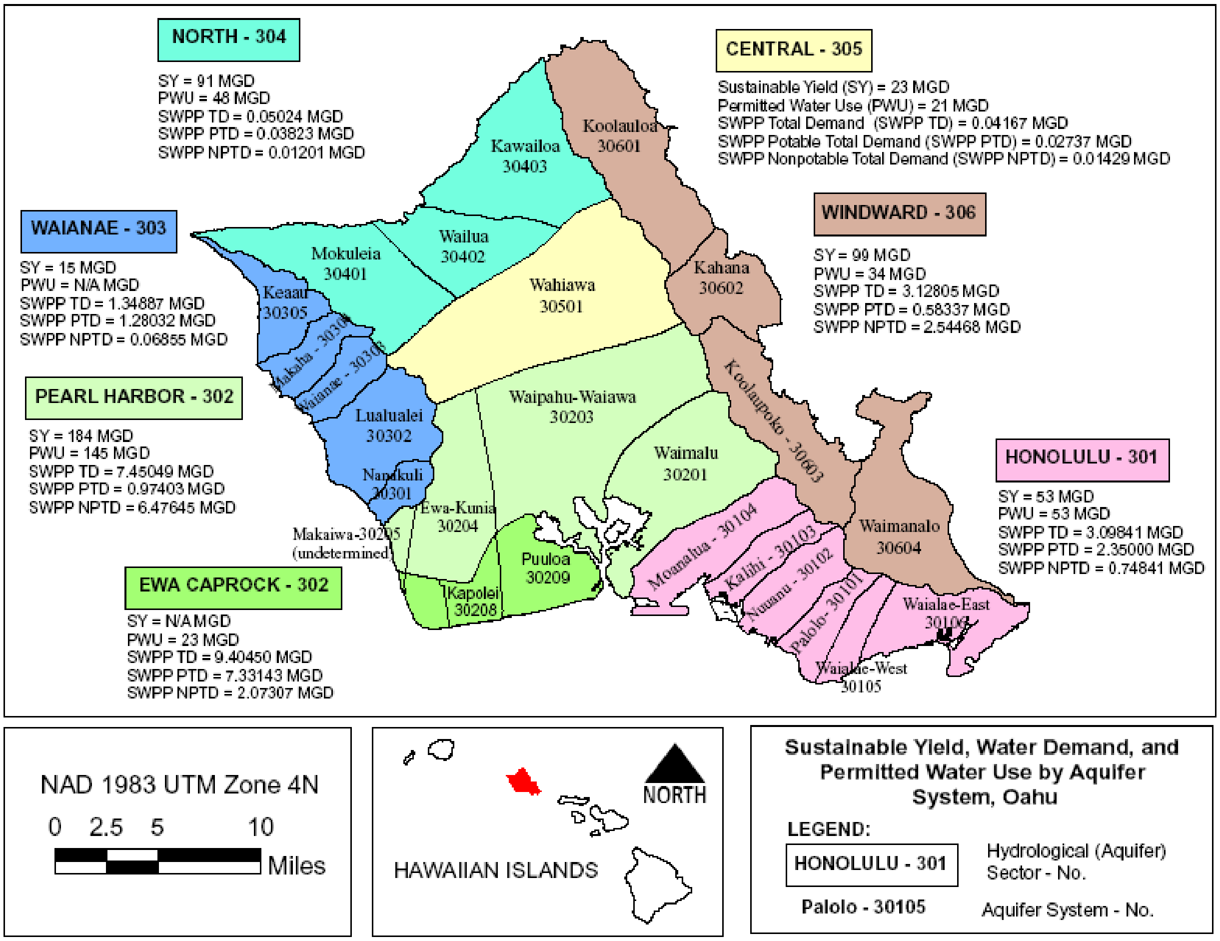

Fig. 21 Sustainable yield, water demand, and permitted water use by aquifer, Oahu (Data Source: CWRM, 2003).

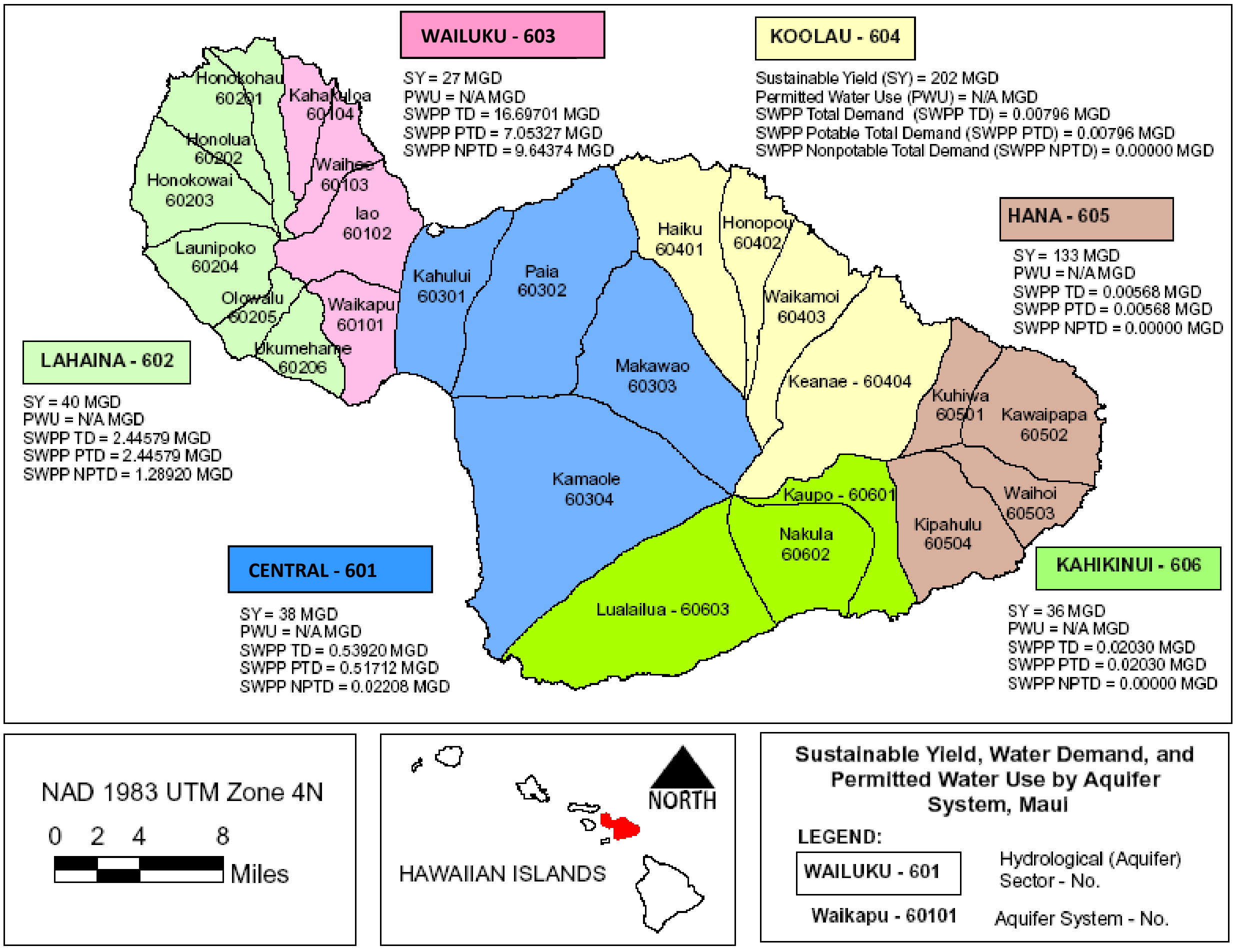

Fig. 22 Sustainable yield, water demand, and permitted water use by aquifer, Maui (Data Source: CWRM, 2003).

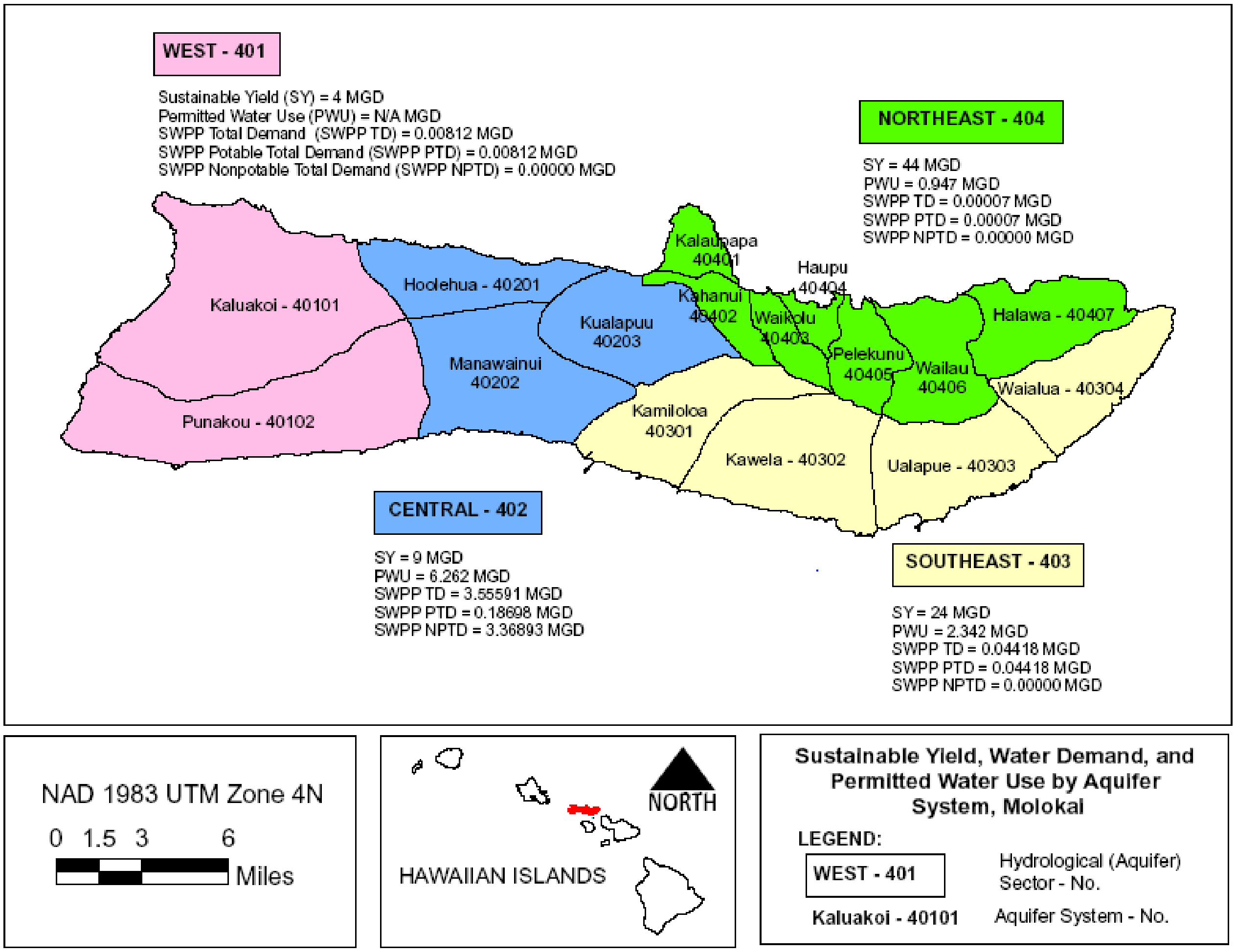

Fig. 23 Sustainable yield, water demand, and permitted water use by aquifer, Molokai (Data Source: CWRM, 2003).

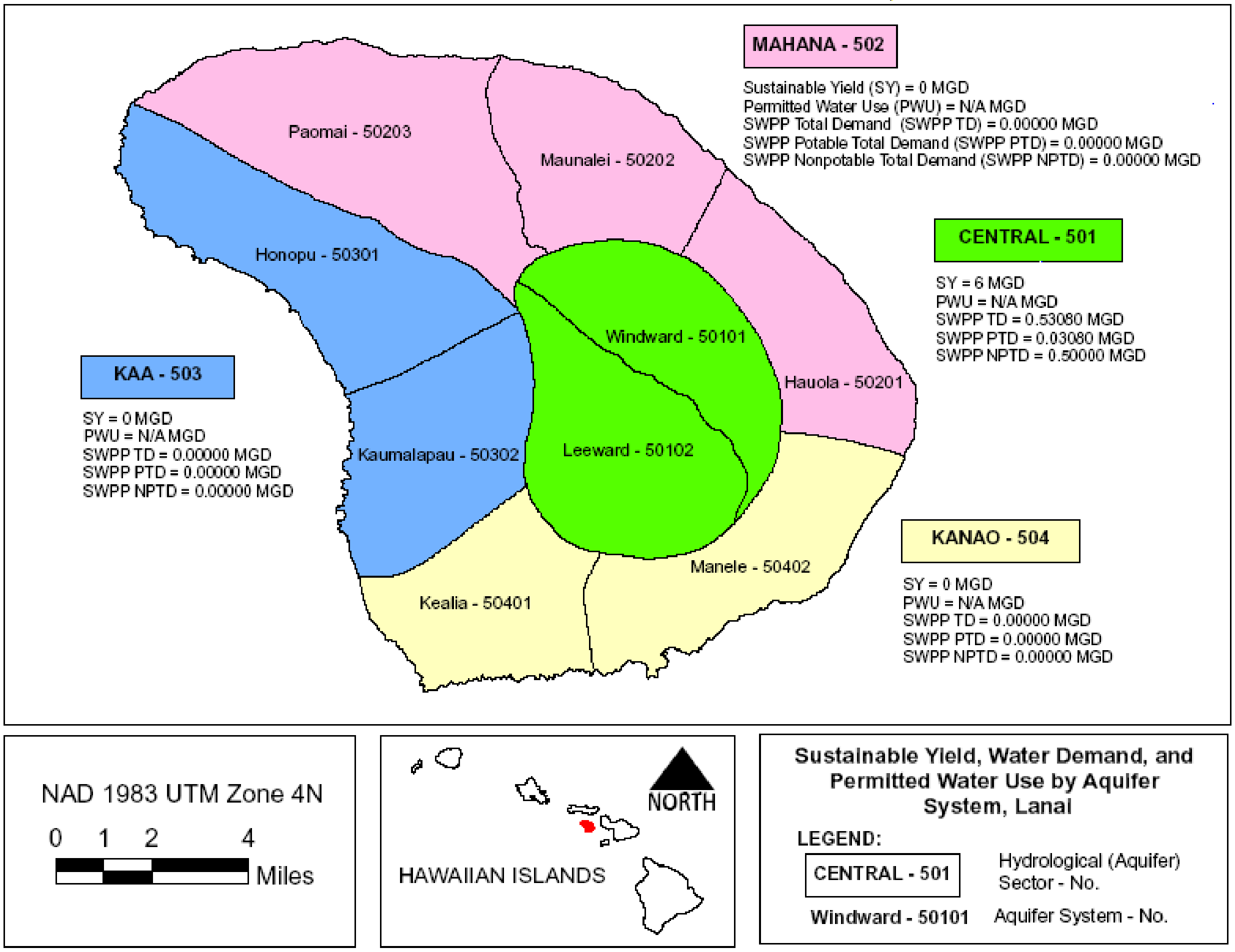

Fig. 24 Sustainable yield, water demand, and permitted water use by aquifer, Lanai (Data Source: CWRM, 2003).

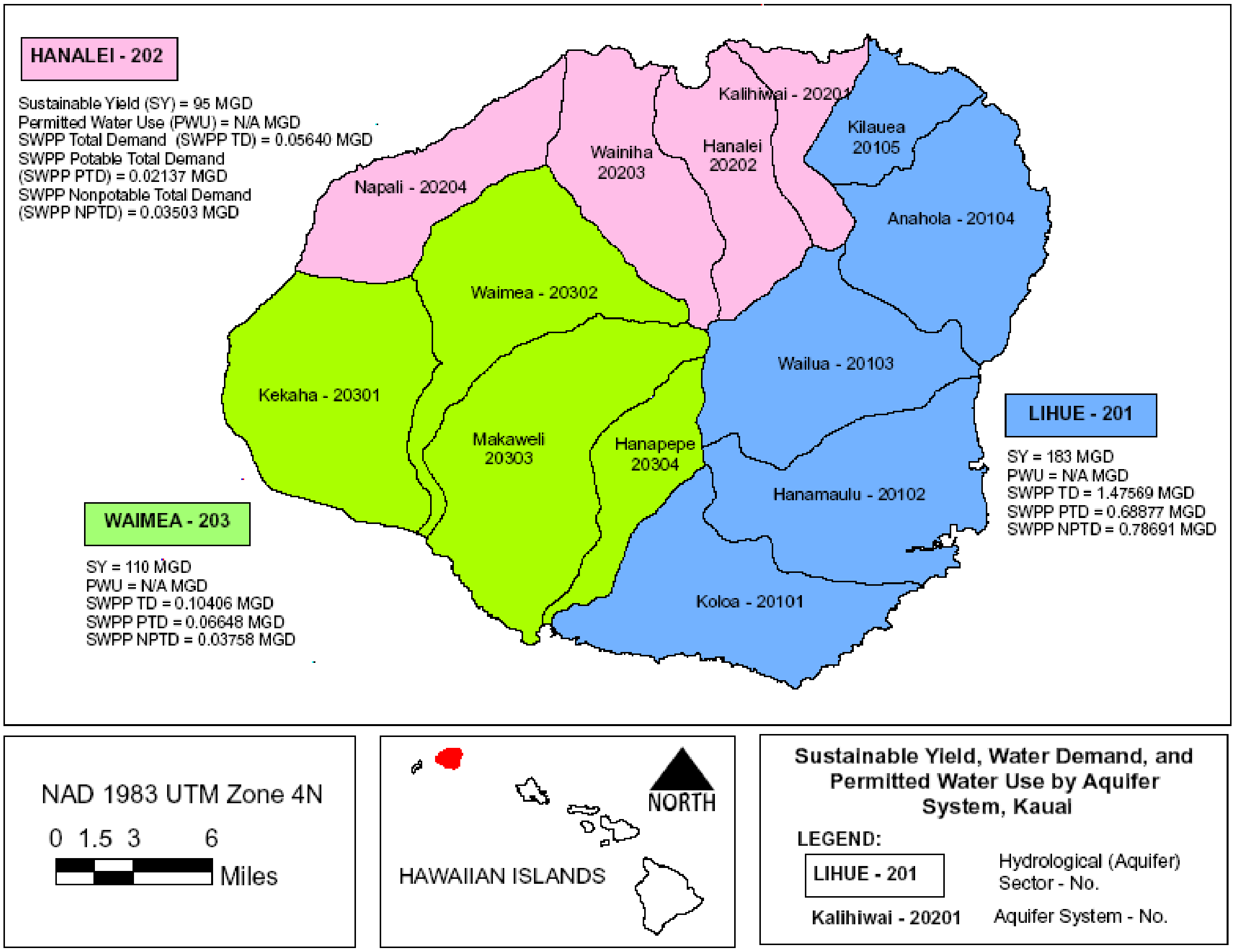

Fig. 25 Sustainable yield, water demand, and permitted water use by aquifer, Kauai (Data Source: CWRM, 2003).

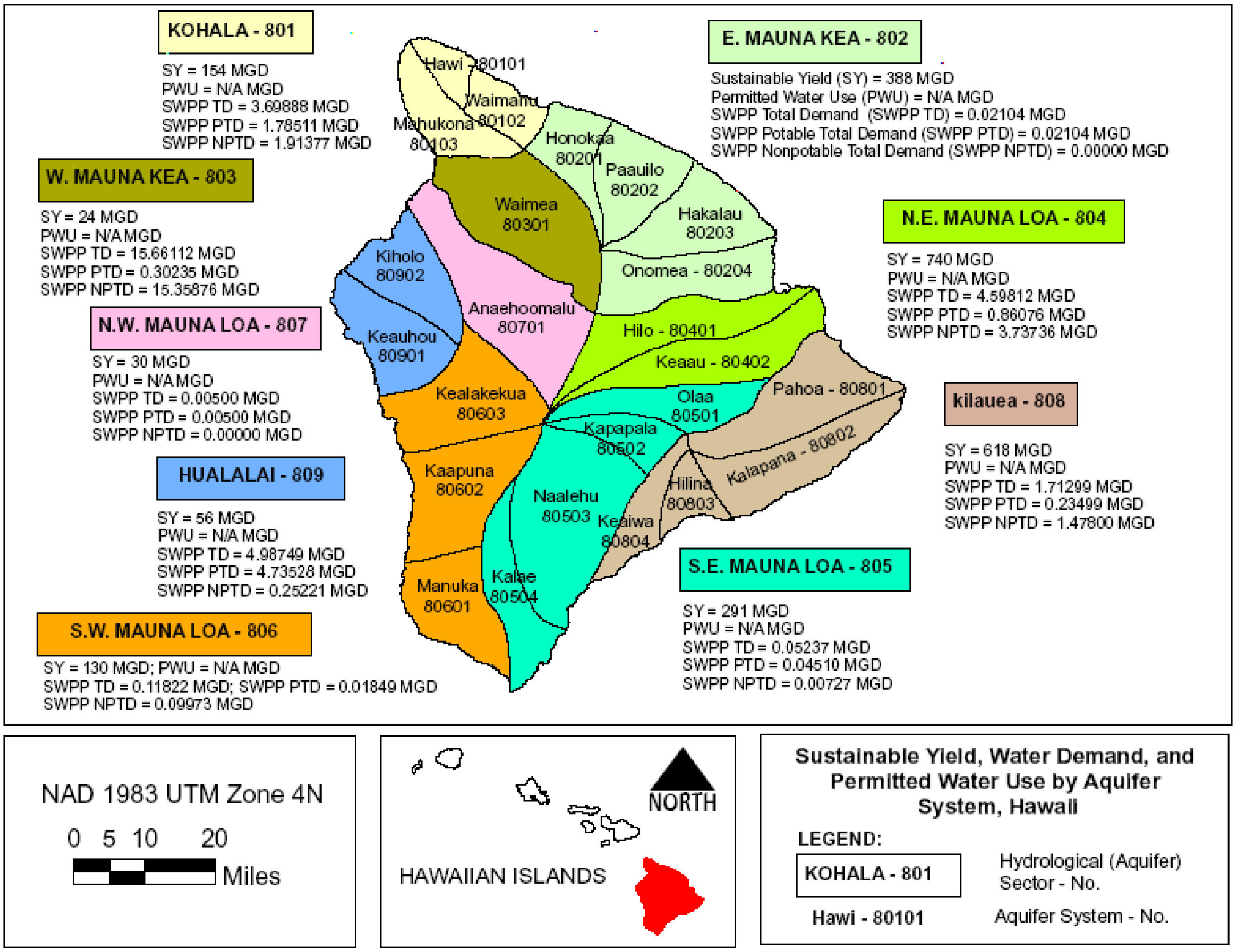

Fig. 26 Sustainable yield, water demand, and permitted water use by aquifer, Big Island (Data Source: CWRM, 2003).

A total of 575 future state projects were reported by the departments requiring water supply and/or service. For the designated 20-year planning horizon, agencies reported that an additional 81 million gallons per day (MGD) would be needed to supply such projects, which is beyond the current resource capability. Maximum capacity of the 10 studied systems (NREM, 2008) is 387.4 MGD out of which irrigation water use totals 363.5 MGD allowing approximately 74 MGD for new projects such as bioenergy crops (Table 2). Projected water demands as summarized by the SWPP have been categorized by department and island, as shown in Fig. 27 and 28, and presented in Tables 11 and 12. A SWPP Water Development Strategy was developed to identify and evaluate source development options.

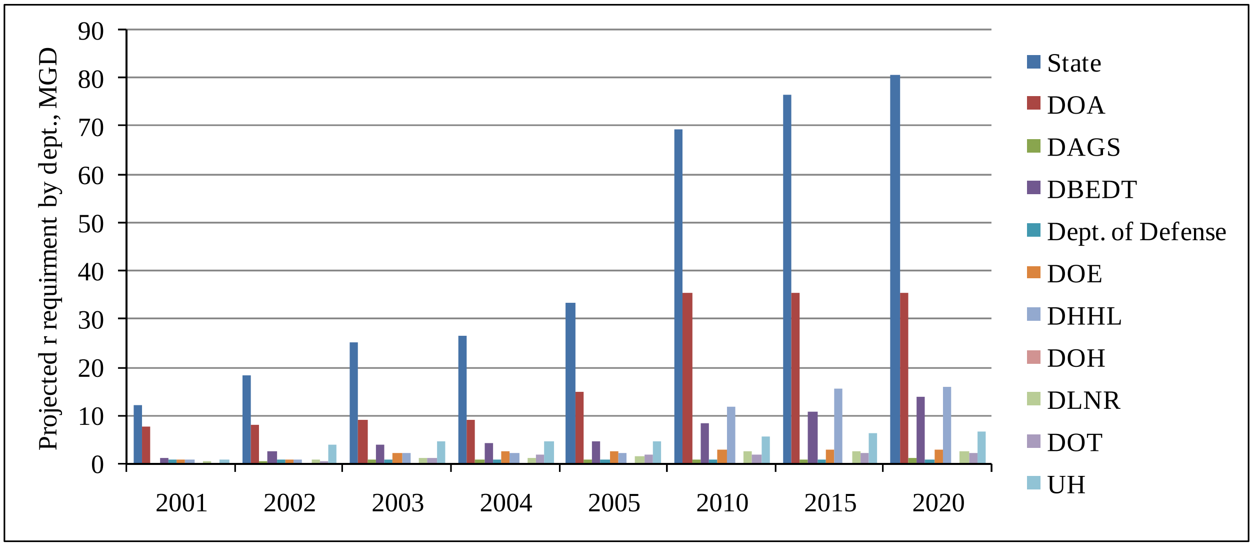

Fig. 27 Total projected demands by state department (Data Source: CWRM, 2003).

Table 11 Total projected demands by state department (Data Source: CWRM, 2003)

	Total Additional Yearly Projected Cumulative Average Day Demand (MGD)							
Department	**2001**	**2002**	**2003**	**2004**	**2005**	**2010**	**2015**	**2020**
DAGS	0.124	0.606	0.691	0.775	0.775	0.957	0.957	0.997
DOA	7.505	7.755	8.765	8.765	14.765	35.315	35.315	35.470
DBEDT	1.023	2.259	3.676	4.154	4.625	8.075	10.789	13.833
DOD	0.791	0.792	0.793	0.793	0.793	0.793	0.793	0.793
DOE	0.620	0.810	2.227	2.243	2.243	2.598	2.598	2.598
DHHL	0.648	0.660	2.025	2.025	2.025	11.659	15.390	15.815
DOH	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
DHS	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
Judiciary	0.000	0.000	0.008	0.008	0.008	0.008	0.008	0.008
DLNR	0.462	0.602	1.121	1.170	1.221	2.251	2.255	2.302
DPS	0.107	0.107	0.107	0.143	0.143	0.143	0.143	0.143
DOT	0.234	0.712	1.330	1.944	1.971	2.030	2.256	2.417
UH	0.669	3.789	4.466	4.554	4.623	5.579	6.038	6.486
State Totals	**12.194**	**18.089**	**25.221**	**26.586**	**33.204**	**69.421**	**76.554**	**80.874**

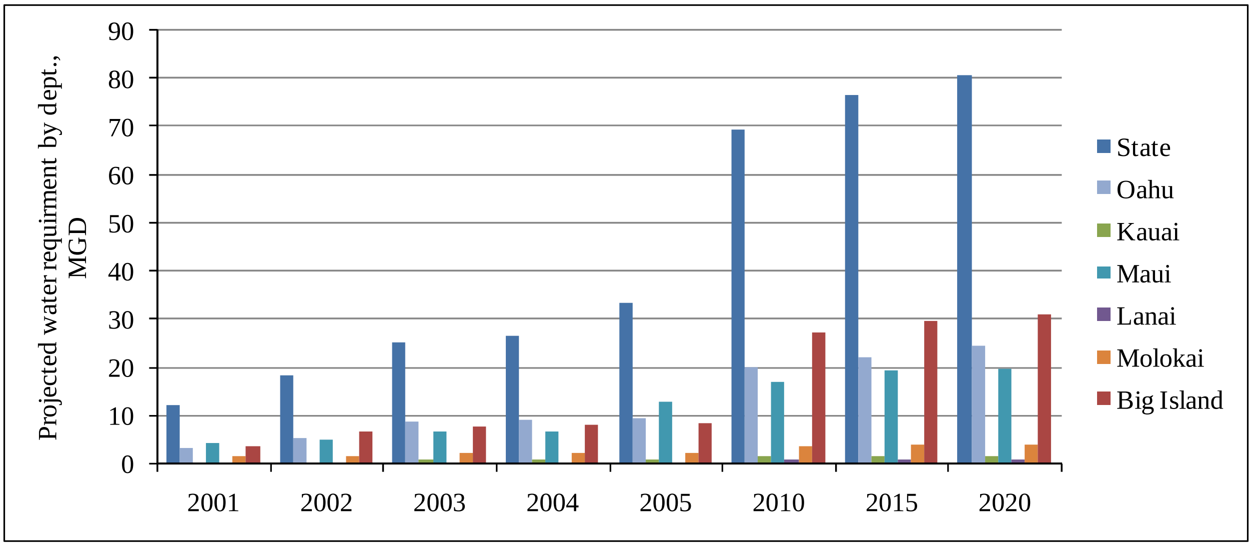

Fig. 28 Total projected demands by island (Data Source: CWRM, 2003).

Table 12 Total projected demands by island (Data Source: CWRM, 2003)

	Total Additional Yearly Projected Cumulative Average Day Demand (MGD)							
Island	**2001**	**2002**	**2003**	**2004**	**2005**	**2010**	**2015**	**2020**
Big Island	3.553	6.477	7.484	7.852	8.128	27.304	29.509	30.855
Kauai	0.261	0.325	0.838	0.937	0.905	1.524	1.584	1.636
Lanai	0.002	0.018	0.018	0.033	0.033	0.534	0.535	0.536
Maui	4.107	4.827	6.379	6.675	12.680	16.716	19.254	19.716
Molokai	1.336	1.336	2.064	2.064	2.064	3.570	3.607	3.608
Oahu	2.936	5.114	8.437	9.026	9.393	19.772	22.064	24.522
State Totals	**12.194**	**18.089**	**25.221**	**26.586**	**33.204**	**69.421**	**76.554**	**80.874**

The Water Development Strategy also identified Short-Term (2001-2010) and Long-Term (2011-2020) options to meet projected potable and non-potable water demands. The strategy's objective was to provide more effective planning, coordination, and development of water resources to meet projected state water demands. The strategy utilized several source development options including, but not limited to, existing and/or planned State water sources/systems, County/private water agreements, and existing master plans, all of which were prioritized and assigned to individual SWPP projects. In spite of some limitations, the strategy provided for the determination of "remaining" SWPP project water demands, which were not assigned to any specified source option. The Water Development Strategy proposed a formula for assessing the remaining balance of unmet SWPP project demand. The formula can be used with an iterative process to reduce SWPP project demands through assignment of available or planned source options (CWRM, 2003). The formula estimates the remaining SWPP Project

Demands (to be integrated within each County water use development project (WUDP) as equaling the total SWPP project water demand minus the sum of projects demands accounted for by various strategy options, that is:

Remaining Balance of Unmet SWPP Project Demands = X – (A+B+C+D+E+F+G)

In which

X = Total SWPP Project Water Demand (Potable and Non-potable)
A = Project demands accounted for by Existing State Water Systems
B = Project demands accounted for by Existing Master Plans
C = Project demands accounted for by Existing State or Private Sources
D = Project demands accounted for by County and Private Water Agreements
E = Project demands accounted for by New/Planned State Wells
F = Project demands accounted for by New State Water Systems
G = Project demands accounted for by Planned Private Sources

A summary of water development strategy results for the remaining balance of unmet SWPP project water requirements is given in Table 13. The Commission on Water Resource Management (CWRM) had suggested development of new State water sources and coordination with County water departments for integration and use of existing County supply/systems as options to meet remaining project demands (CWRM, 2003). The Commission had emphasized that additional planning and coordination between the County water departments and DLNR will be required.

As presented in Table 14, the SWPP project water demands were formulated into high, medium and low demand ranges (CWRM, 2003). The medium forecast was composed of SWPP project water demands as reported by various State departments. The low range forecast was developed by reducing the base or medium forecast demands by 20 percent. The reduction to the low demand forecast range accounts for demand side management measures, savings from water conservation, conservatism within the Water Standard System unit rates and uncertainties with project funding, construction of projects, and project delays. The high range forecast was determined by increasing the medium demand range by a 20 percent factor. The high-end forecast provides a contingency to the medium demand forecast to account for additional future State projects or modifications to SWPP projects.

Table 13 Summary of water development strategy results remaining balance of unmet SWPP project water requirements (Data Source: CWRM, 2003)

	Water Demands (MGD)							
State Water Demand Status	**2001**	**2002**	**2003**	**2004**	**2005**	**2010**	**2015**	**2020**
Total SWPP Project Demand Statewide	12.19	18.10	25.22	26.59	33.20	69.42	76.55	80.87
Demand Accounted for by Water Development Strategy	5.99	7.59	10.66	11.26	17.49	39.17	42.07	45.17
Remaining Balance of Unmet Demand								
Big Island	0.80	3.36	4.06	4.16	4.33	12.89	14.47	14.55
Island of Kauai	0.09	0.13	0.52	0.62	0.59	0.58	0.64	0.69
Island of Lanai	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Island of Maui	4.11	4.83	6.38	6.67	6.68	10.72	13.25	13.72
Island of Molokai	0.02	0.02	0.03	0.03	0.03	0.04	0.07	0.07
Island of Oahu	1.19	2.17	3.58	3.84	4.09	6.03	6.05	6.67
Statewide Remaining Balance Total	**6.20**	**10.51**	**14.56**	**15.33**	**15.72**	**30.25**	**34.48**	**35.71**

Table 14 Forecast ranges of unmet SWPP project water demand (Data Source: CWRM, 2003)

	Total Yearly Projected Cumulative Average Day Demand (MGD)							
Forecast Range	**2001**	**2002**	**2003**	**2004**	**2005**	**2010**	**2015**	**2020**
High Demand Range	7.44	12.61	17.47	18.39	18.86	36.30	41.38	42.85
Medium Demand Range	6.20	10.51	14.56	15.33	15.72	30.25	34.48	35.71
Low Demand Range	4.96	8.41	11.65	12.26	12.57	24.20	27.58	28.57

2.2 Opportunities of Water Reuse for Bioenergy Crops

Because of the projected demands on Hawaii's water resources, supplemental sources of water must be developed to meet the demands of increasing population and sustainable water resource management. This can include development of waste water treatment systems that are designed to include beneficial water reuse. Once a system is developed to recycle water, it assures continuous and reliable supply of water without worrying about droughts or water restrictions. A water reuse system provides additional advantage by utilizing the existing/dissolved nutrients in the wastewater thereby reducing the need for fertilization in most instances (CWRM, 2005). Another advantage of establishing a reusable water system is that it is an environmentally friendly approach compared to traditional disposal methods, i.e., through outfalls and injection wells. Although the applications of reusable water have been historically increased in Hawaii (Table D.1, Appendix D), there are still opportunities for expansion. The CWRM report summarizes the allowable uses, treatment, and quality requirements of all recycled water categories as: *R-1 Water is tertiary treated recycled water that has undergone a significant reduction in viral and bacterial pathogens. R-2 Water is disinfected secondary treated recycled water. R-3 Water is undisinfected secondary treated recycled water, and there are severe limitations on its use. Reverse osmosis (R-O) is wastewater that has undergone secondary treatment and then is purified via R-O. R-O is technically classified as R-3 water by the DOH, despite the fact that it is essentially pathogen free water.*

There are two existing R-1 recycled water distribution systems in the county of Maui. These distribution systems are potentially expandable. Of these two distribution facilities, the south Maui system is the most complete system and recycles water storage at the Kihei wastewater reclamation facility and offsite at an elevated covered storage tank. On the other hand, the west Maui system is limited in services. There are two water reclamation facilities at two of the eight wastewater treatment plants in the City and County of Honolulu. These facilities are at Honouliuli in the Ewa district and at Wahiawa in the central Oahu district. Both of these facilities are under consideration for expansion (CWRM, 2005). The Waianae wastewater treatment plant on the leeward coast of Oahu is under consideration for a future water reuse project. As reported by CWRM (2005), Kikiaola Land Company's development plans were delayed due to the lack of wastewater treatment capacity at the County of Kauai's Waimea wastewater treatment plants and the company has been planning for establishing its own R-1 wastewater treatment facility to utilize the recycled water to irrigate a new golf course and the common areas within a new residential subdivision within its proposed development. The County of Hawaii's Wastewater Division is planning to develop a recycled water distribution system to utilize recycled water from the Kealakehe wastewater treatment plants; the Division will continue attempting to secure federal funding to upgrade the Kealakehe wastewater reclamation facility to an R-1 quality system (CWRM, 2005).

On Maui, the Wailuku-Kahului wastewater reclamation facility is an R-2 facility that currently treats approximately 5.5 MGD and discharges most of this R-2 water to injection wells for disposal (CWRM, 2005). To irrigate bioenergy crops, this facility could be upgraded to R-1 category with a distribution system to deliver the treated water. On the Big Island, the Kealakehe wastewater reclamation facility, which is an R-2 facility, utilizes stabilization ponds. An upgrade to R-1 capability would be required in order to utilize the facility's recycled water for irrigation of bioenergy crops. Kikiaola Land Company's on the southwest Kauai currently leases its agricultural land to a seed corn company that uses diluted R-2 water from the County of Kauai's Waimea wastewater reclamation Facility for irrigation (CWRM, 2005).

The available wastewater resources include potential expansion of the wastewater systems in Maui's (South Maui system, West Maui system), Oahu (Honouliuli Waste Reclemation Facility, Wahiawa WWTP, Schofield Barracks WWTP), Kauai (Waimea WWRF), the Big Island (Kealakehe WWRF). No information is available to determine if all the currently recycled/reclaimed water is used. However, the current uses of the recycled water include constructed wetlands, groundwater recharge, in-stream flow restoration, recharge of natural wetlands, recreational uses, irrigation, construction uses, industrial uses, composting, and toilet and urinal flushing (CWRM, 2005). Appendix C of CWRM (2005) gives detail on the State of Hawaii Reuse Project Directory that includes project name, type, contact person, contact number, recycled water volume (MGD), recycled water price, recycled water quality, and the uses of the recycled water.

The NREM study (NREM, 2008) zoned up to 4 miles from water treatment facilities in Hawaii for potential reuse of the treated water. The 4-mile limit was based on current reuse areas and interviews with wastewater managers. It was shown that most agricultural lands on Oahu, Maui and Molokai are more than 2 miles from a wastewater recycling facility. Kauai may offer the best potential for wastewater reuse, where some system lands are within 2 miles of the Wailua and Waimea treatment plants. But almost all current capacity at these facilities is being utilized.

2.3 Efficient Use of Water Resources

Water use efficiency is defined as the ratio between the actual volume of water used for a specific purpose and the volume extracted or derived from a supply source for that same purpose. Crop water use efficiency (kg ha^{-1} mm^{-1}) is the ratio of economic yield (kg ha^{-1}) to the total water use (mm) (Zaffaroni and Schneiter, 1989; Copeland et al., 1993). Methods of improving water use efficiency for bioenergy crops will include selection of less water demanding bioenergy crops and biomass feedstocks. High water demanding crops may preferably be grown in windward areas for efficient use of the available soil moisture and rainfall and vice versa.

The model used in NREM (2008) estimates irrigation water requirements for 24 Hawaii crops (including bioenergy crops) at the 10 studied systems used a water budget approach. The model calculates crop irrigation requirements based on site-specific historical rainfall and evaporation data, soil physical properties, crop-specific growth parameters, and water-use coefficients. Irrigation requirements for annual crops were computed for the dry and wet seasons, while perennial crop IRR were for the whole year. The same crops were used for each system to allow consistent comparisons across systems. The model assumed different farm water use efficiency rates based on the type of irrigation application technology (e.g., drip, micro-sprinkler) used by a particular crop. Possible system water losses in delivering irrigation water to a farm were not considered due to a lack of data. The project produced detailed tables of water budget components including irrigation requirements for various irrigation systems, crops (including bioenergy crops), and growing seasons. Such approaches may be used in future in order to model crop water use for different bioenergy crops. Section 5.7.1 of this report provides detail on the use of daily water budget for irrigation water requirement estimation.

Surface flooding and pressurized irrigation are among the major irrigation techniques used for crop production. Topography of Hawaii does not permit the use of surface flooding. Pressurized irrigation techniques involve sprinkler and drip irritation systems. Sprinkler irrigation system includes overhead and micro-sprinkler systems where water is applied by spraying it through the air at high and low volumes, respectively. These systems are designed to apply water uniformly, as drops, over the application areas. The introduction of sprinkler irrigation systems allowed the use of non-uniform terrains for agriculture and saved substantial amounts of irrigation water as a result of their higher efficiency as compared to traditional irrigation practices (i.e., basin, furrow or flooding). However, their major disadvantages are: i) their low efficiency in windy conditions and during hot periods due to water loss by evaporation and by evaporation drift, ii) leaf damage of citrus crops as a result of irrigation water spraying, and iii) their high visible application rates that instigate public criticism of agricultural operations as a source of excess water use.

Drip irrigation is a low volume irrigation method that applies water through small emitter openings. A drip system can be laid at the soil surface, above it or buried at a given depth below it. This irrigation system aims at watering the crops frequently to meet consumptive use of the crops. Drip irrigation method is being adapted extensively as water resources are becoming scarce in many agricultural production regions around the world. If designed accurately and used properly, drip irrigation is one of the most efficient irrigation method that minimizes deep percolation, runoff and evaporation losses. Drip irrigation system is considered a water saving system with high irrigation application efficiency. In addition to the advantages of the micro-sprinkler irrigation system, drip irrigation has the following additional advantages: 1) its efficiency is not impacted by wind, and 2) it can be used with low quality irrigation water.

It is understood that among other factors, the water delivery efficiency rates of various systems vary with irrigation infrastructure and its condition, cropping patterns, and system management. It is not possible to develop even ballpark estimates of water delivery efficiency. If the average delivery rate is something like 50%, then actual increases in water demand could be double than that projected in a study.

3. EXISTING LANDS FOR BIOENERGY CROP PRODUCTION BY ISLAND

3.1 Existing Lands

Poteet (Poteet, 2006) conducted a thorough assessment of available lands in an earlier study of biodiesel production potential funded by the Hawaii Department of Agriculture. In this section, where appropriate the data have been updated, but assessment points that are deemed to have retained relevancy for the current work are closely summarized. The information has also been augmented with maps indicating ALISH classes and land capability classifications for irrigated and unirrigated lands on each island. This section details the availability of existing lands for biofuels and biomass crops production through the use of GIS maps for ALISH classes, state land use, the Land Capability Classification (LCC) (irrigated and non-irrigated) and locations for all the major islands.

3.1.1 Island of Oahu

Oahu has approximately 120,200 acres (48,643 hectares) of land classified as Agricultural (DBEDT, 2007). Areas of Oahu with State Land Use Districts and those classified as ALISH are presented in Figs. 29 and 30, respectively. Prime farmland is needed for row crop (e.g., seed corn) production. In Oahu, over 20,000 acres (8,100 hectares) of land are occupied by the pineapple industry, about half of which are harvested annually (DBEDT, 2007). Over 5,000 acres of land will be available for bioenergy crops production after Del Monte Fresh Produce's decision to halt pineapple production in Hawaii. These pineapple lands are located in the west of Mililani-Town and the former sugarcane lands on North Shore. The east of Waianae and Nanakuli on the Leeward Coast could be also utilized for bioenergy crops that would require very little moisture. Since these areas receive very low annual rainfall, lands of these areas may be used to grow the crops that require less irrigation water. Potential use of leeward lands (arid and/or semi-arid) for bioenergy production must consider a conversion facility with a sustainable, reliable feedstock, readily available water, and access to operational and distribution infrastructure.

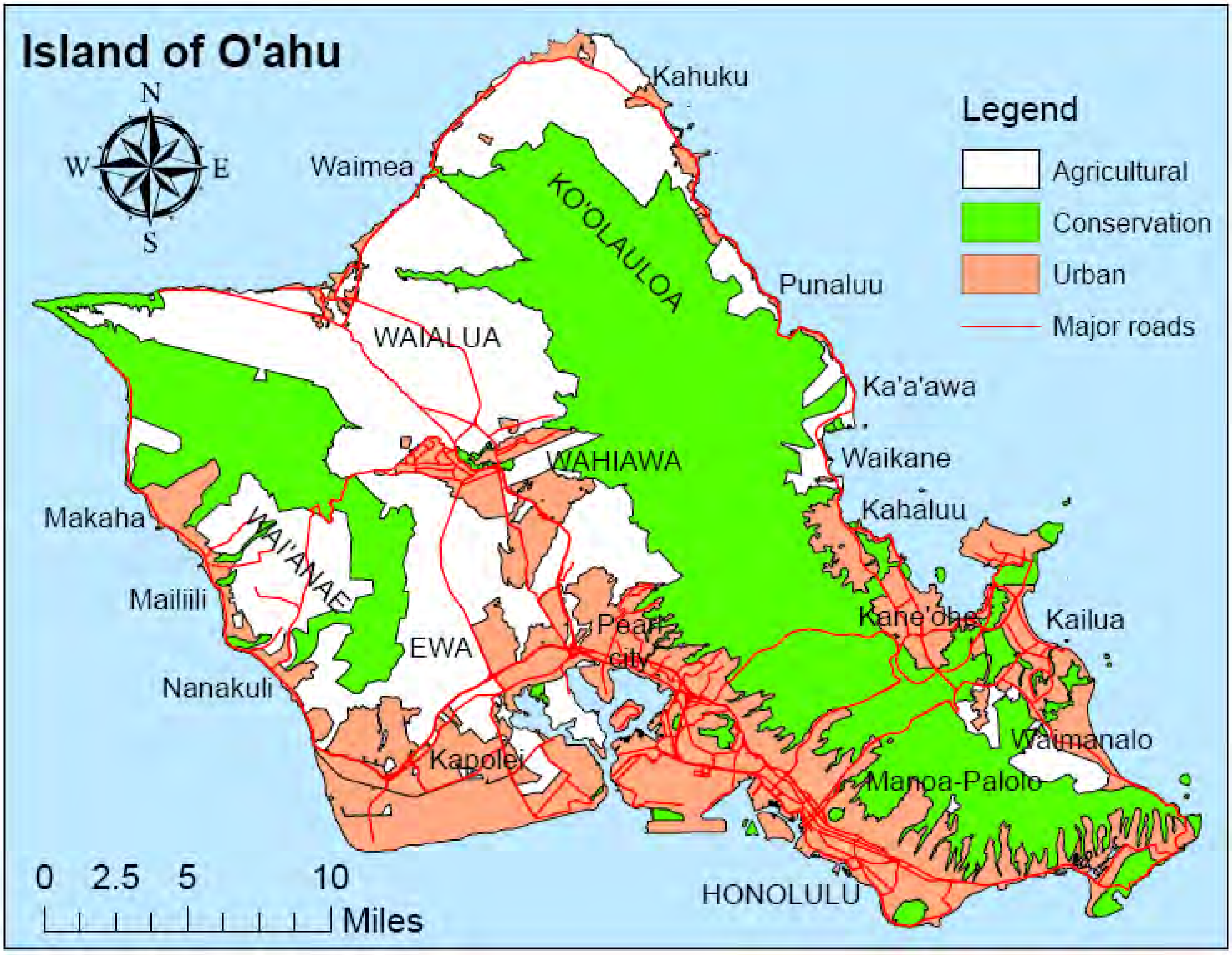

Fig. 29 Island of Oahu with state land use districts (Source: State Land Use Commission).

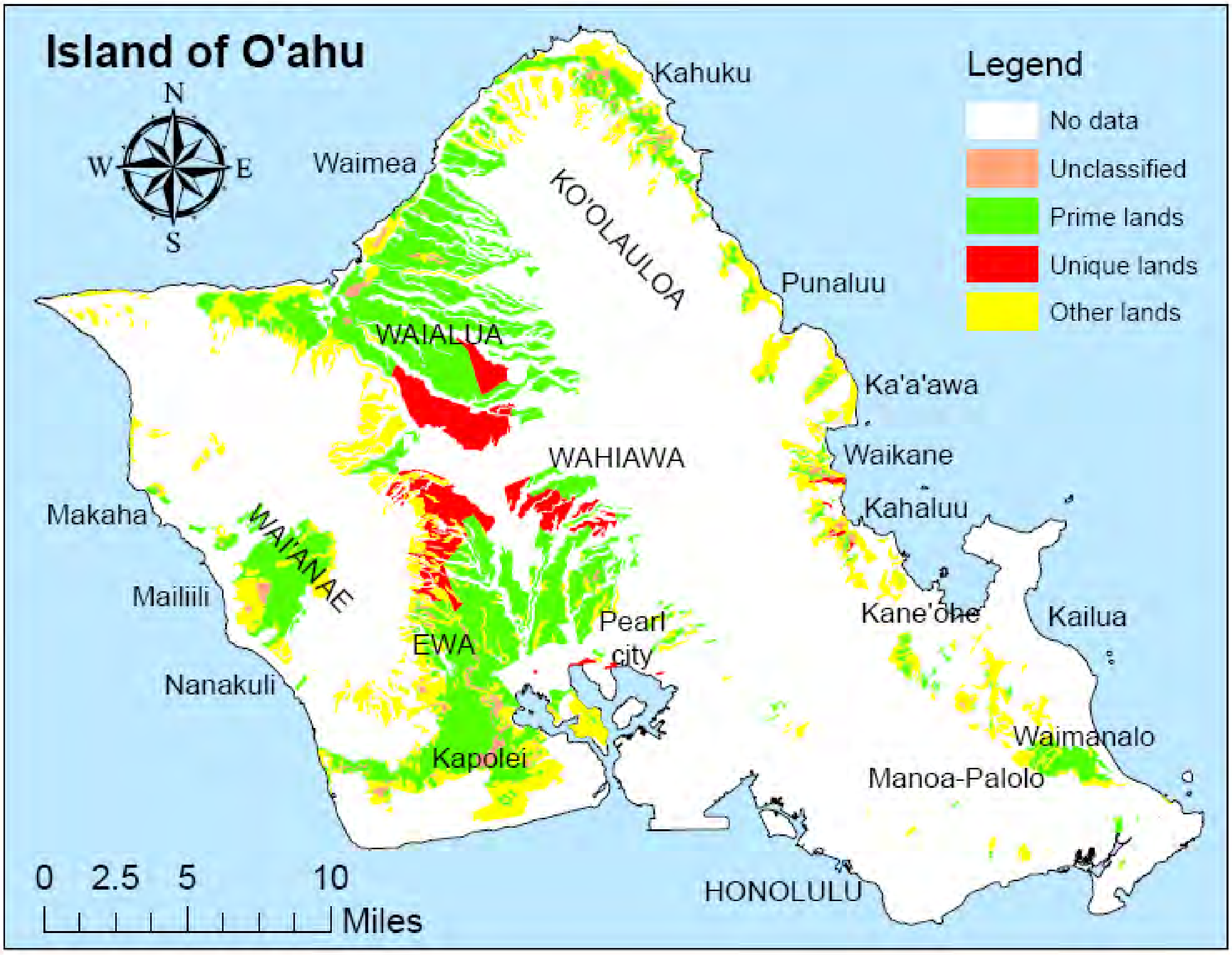

Fig. 30 Agricultural lands of importance to the state of Hawaii (ALISH) classes and locations for the island of Oahu (Source: Hawaii State Department of Agriculture, 1977).

The Land Capability Classification (LCC) characteristics (a rating system used by USDA-NRCS to determine potential productivity) are given in Table 15, where most of soil series have been assigned a LCC class for both irrigated (Fig. 31) and non-irrigated (Fig. 32) conditions. Total acreage of these five soil series on Oahu is approximately 35,600 acres, making up over 27% of Oahu's agricultural land use district (Foote et al., 1972). For these soils, the Land Capability Classes are Class I and IIe; where, 'e' represents erosion to be the limiting factor in quality production from irrigated lands. On the other hand, for non-irrigated sites, the classes range from Class IIe or IIc to Class IVc; where, 'c' represents climatic conditions to be the limiting factors, e.g., low annual rainfall.

Plans can also include land property of the Kamehameha Schools, i.e., approximately 6,500 acres stretching from Haleiwa northward to Waimea and inland to the Koolau Range with annual average rainfall ranging from 35 to 60 inches. Such areas would provide an excellent location for potential bioenergy crop production.

Table 15 Land capability classes (based on USDA, 1972)

Class*	Restrictions/Limitations**
I	No significant limitations restrict use.
II	Moderate limitations that may require conservation techniques be in place; slopes 0-8%, somewhat poorly drained, seasonal flooding, poor textural conditions, inadequate rainfall, shallowness.
III	Severe limitations that may reduce choice of plants and may require special conservation practices; potential for severe erosion, slopes up to 15%, excessive water, poorly drained, excessive stoniness, low water-holding capacity, limited rainfall, moderately low fertility.
IV	Very severe limitations affecting crop choice and requiring very careful management; slopes up to 25%, excessive drainage, potential for seasonal flooding, excessive stoniness, very droughty, low fertility.
V	Not likely to erode, but significant problems with fertility, stoniness, texture, tilth, wetness, droughtiness, or some other condition restricting crops. Can be used for woodland, wildlife, pasture or range.
VI	Generally unsuited for cultivation of row crops. Used for pasture, range, woodland and wildlife habitat; severe erosion potential, slopes up to 40%, extreme rockiness, limited rainfall.
VII	Unsuited for cultivation of row crops. Used for pasture, range, woodlands, or wildlife-may require conservation measures to remain sustainable; highly erosive, slopes up to 100%, excessive drainage, extremely low water-holding capacity, rock contents nearing 100%, crater areas with poor drainage.
VIII	Unusable for any commercial plant production. Used for wildlife, recreation, and esthetic beauty; prone to constant or unpredictable flooding, exposed stones cover greater than 80% of surface, marshes, steep mountainous slopes up to 100%, some coastal beaches.

*Soil classes are subdivided using letters: e (erosive), s (stoniness, shallowness, or sandiness), w (wetness) or c (climatic limitations). “I” has no subclasses, and “V” does not have subclass “e”.

**Specific limitations are detailed by subclass denotation (see above *). Any of the listed limitations are only examples. Specific limitations for any soil series should be referenced in the USDA-NRCS Soils Database online at www.soils.usda.gov/ or in a local Soil Survey. Guidelines detailed are for Hawaii soils.

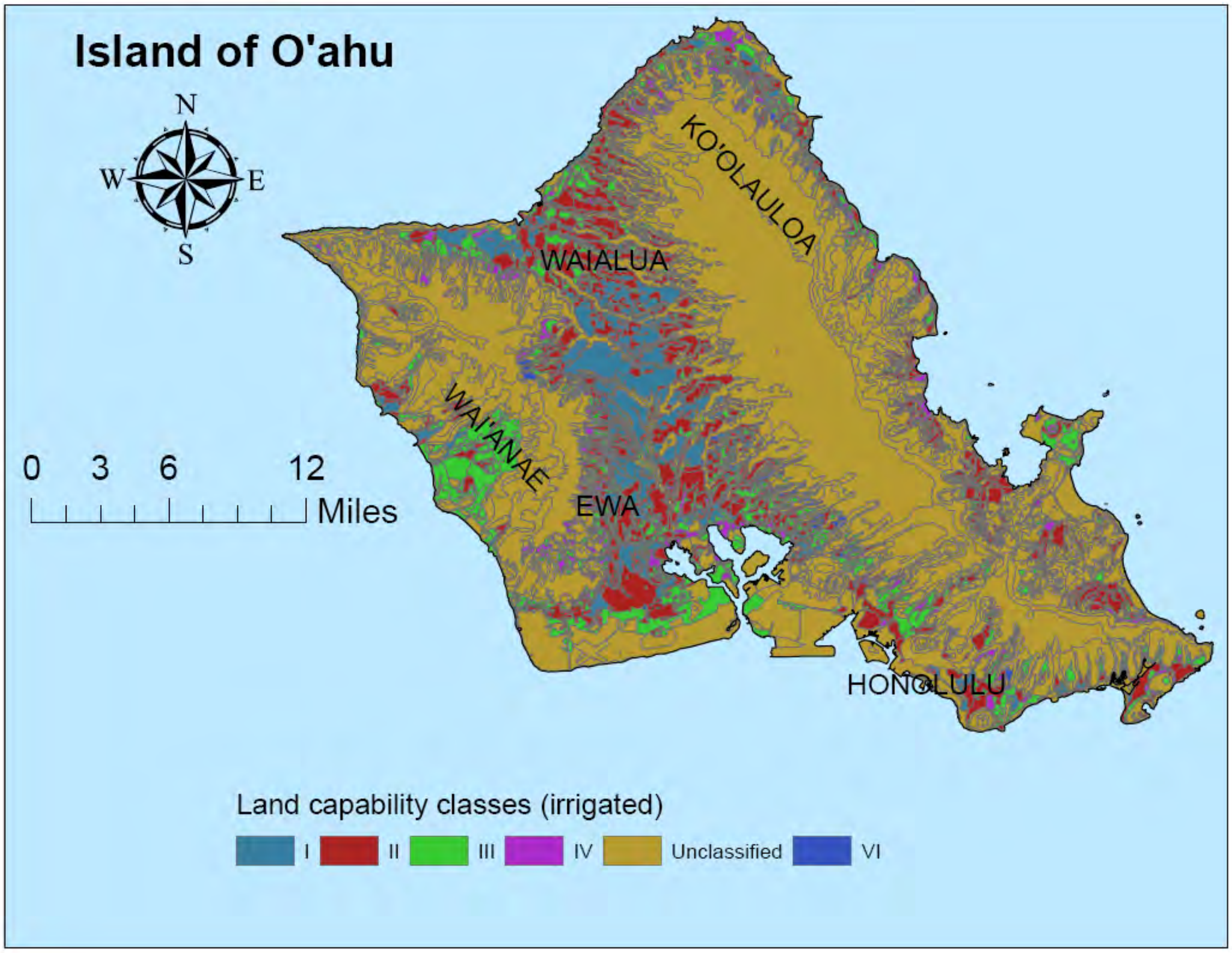

Fig. 31 The land capability classification (LCC) (Irrigated) for the island of Oahu (a rating system used by USDA-NRCS to determine potential productivity and LCC description in given in Table 15).

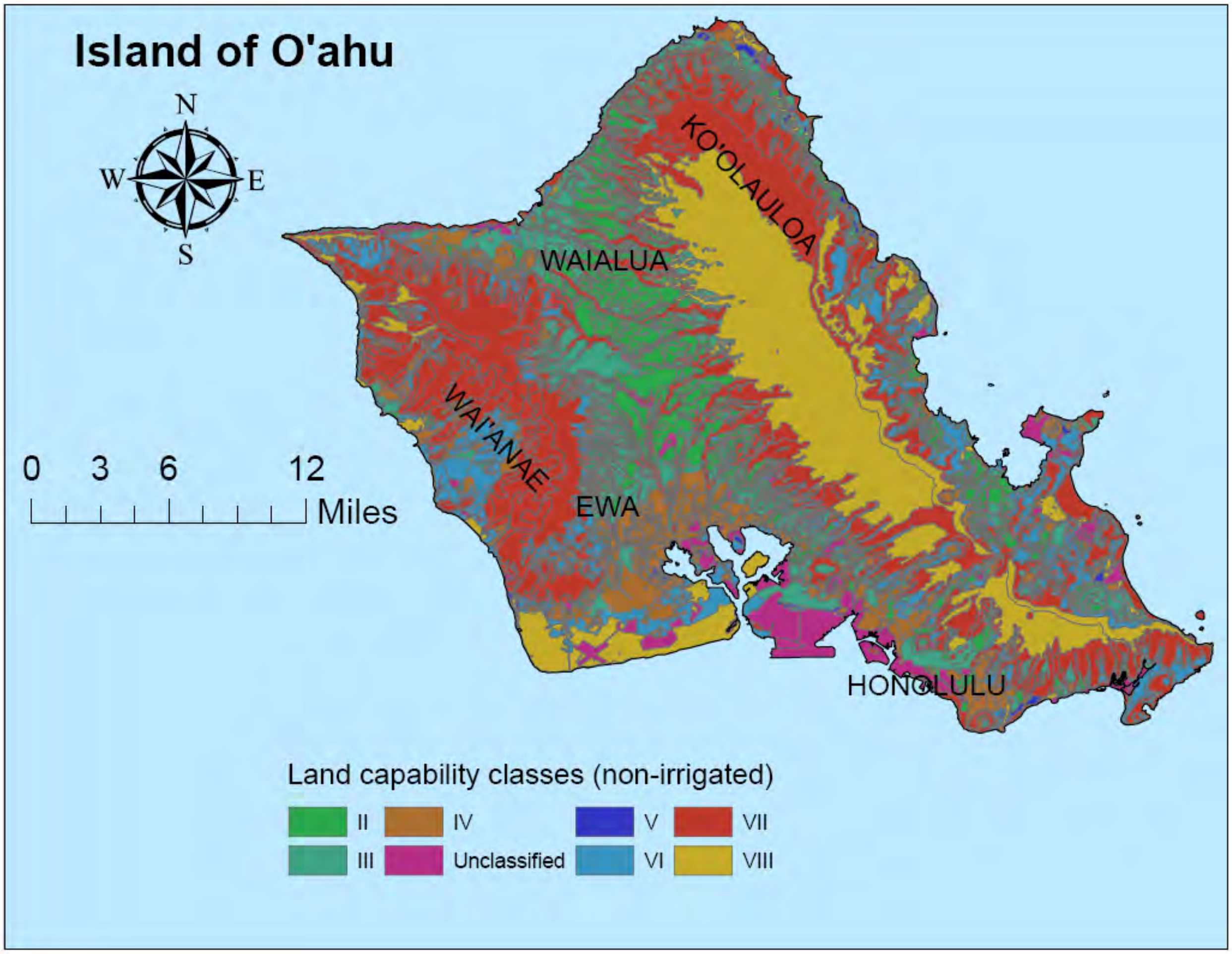

Fig. 32 The land capability classification (LCC) (Non-irrigated) for the island of Oahu (the LCC description in given in Table 15)

3.1.2 Island of Maui

Currently on Maui, Pacific Biodiesel produces approximately 300,000 gallons of biodiesel per year from waste vegetable oil. The company also produces about 700,000 gallons per year on Oahu. (King, 2006). Various land uses and ALISH classes in Maui are mapped in Figs. 33 and 34, respectively. Land classified as 'Agricultural' on Maui totaled almost 245,000 acres as of December 31, 2004 (DBEDT, 2007). Because of its small population and less urban expansion, Maui has widespread agricultural lands and thus offers more land for potential bioenergy crop production than Oahu. Areas that should focus on bioenergy crop production include West Maui, along the coastal areas just east and north of Lahaina towards Kahana and southward to Olowalu, and Central Maui, on the upper western slopes of Mt. Haleakala in the Kula region.

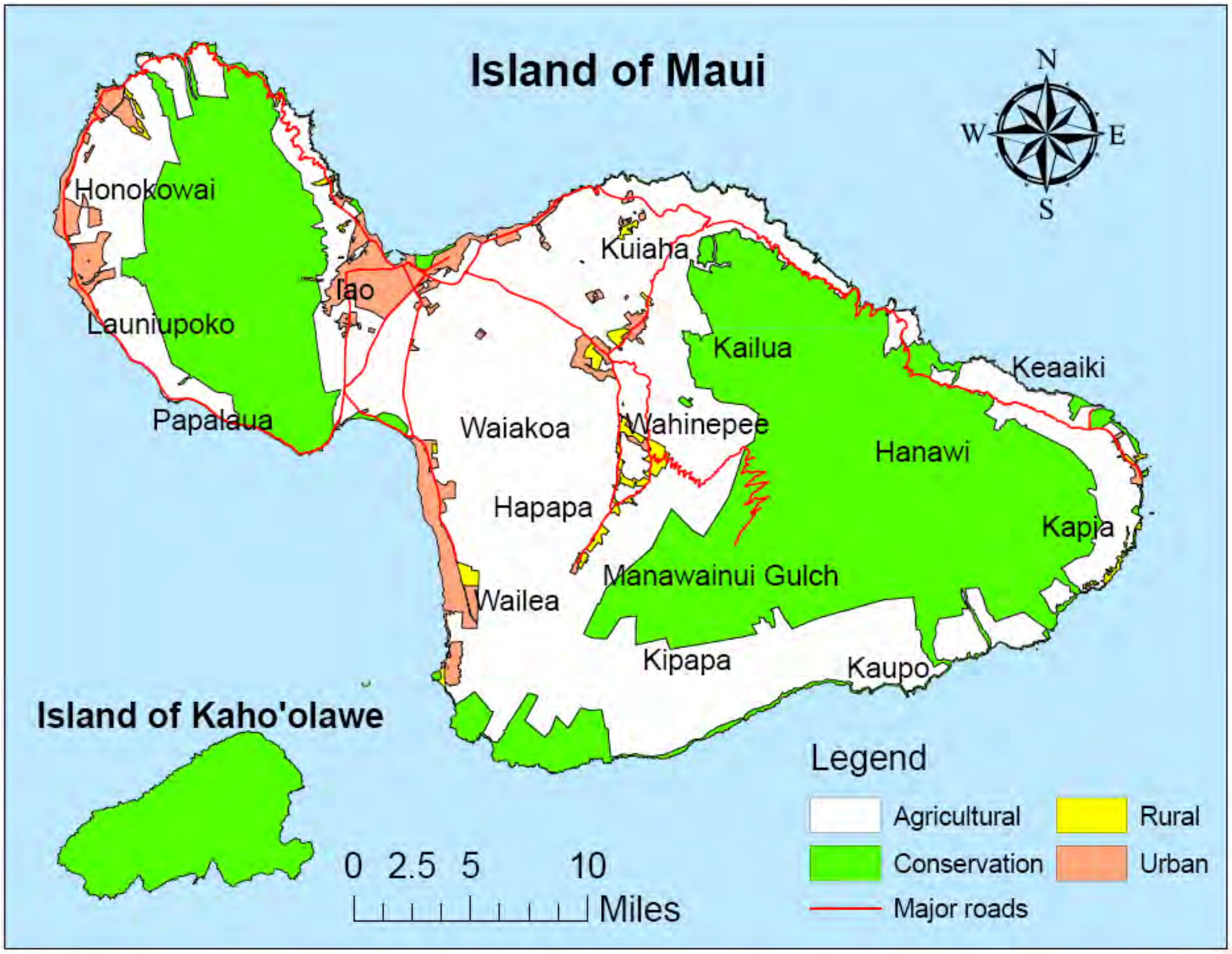

Fig. 33 Island of maui with state land use districts (Source: State Land Use Commission).

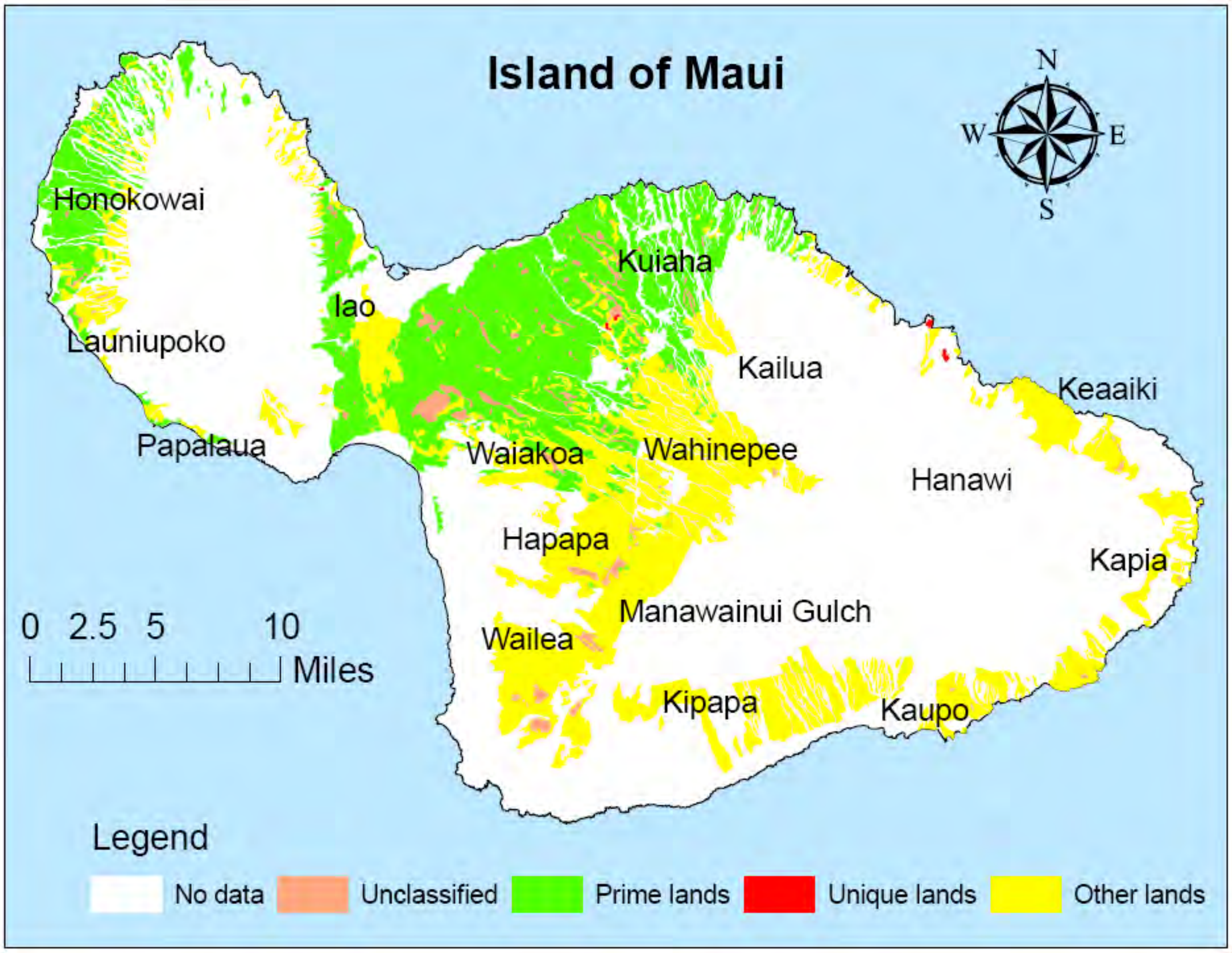

Fig. 34 Agricultural lands of importance to the state of Hawaii (ALISH) classes and locations for the island of Maui (Source: Hawaii State Department of Agriculture, 1977).

The LCC to determine potential productivity for the Island of Maui are shown in Fig. 35 (irrigated conditions) and Fig. 36 (non-irrigated conditions). Lands in the West Maui area belong to Maui Land and Pineapple, Inc., Kamehameha Schools, small landowners, and the State of Hawaii (Juvik and Juvik, 1998). Soils types for these lands are Kahana and Lahaina silty clay, Jaucas sandy and Ewa silty clay, and Alaeloa silty clay (SCS, 1972). Such areas are generally of high productivity. Slopes in these areas range from less than 3% in some coastal areas up to 25% in the uplands.

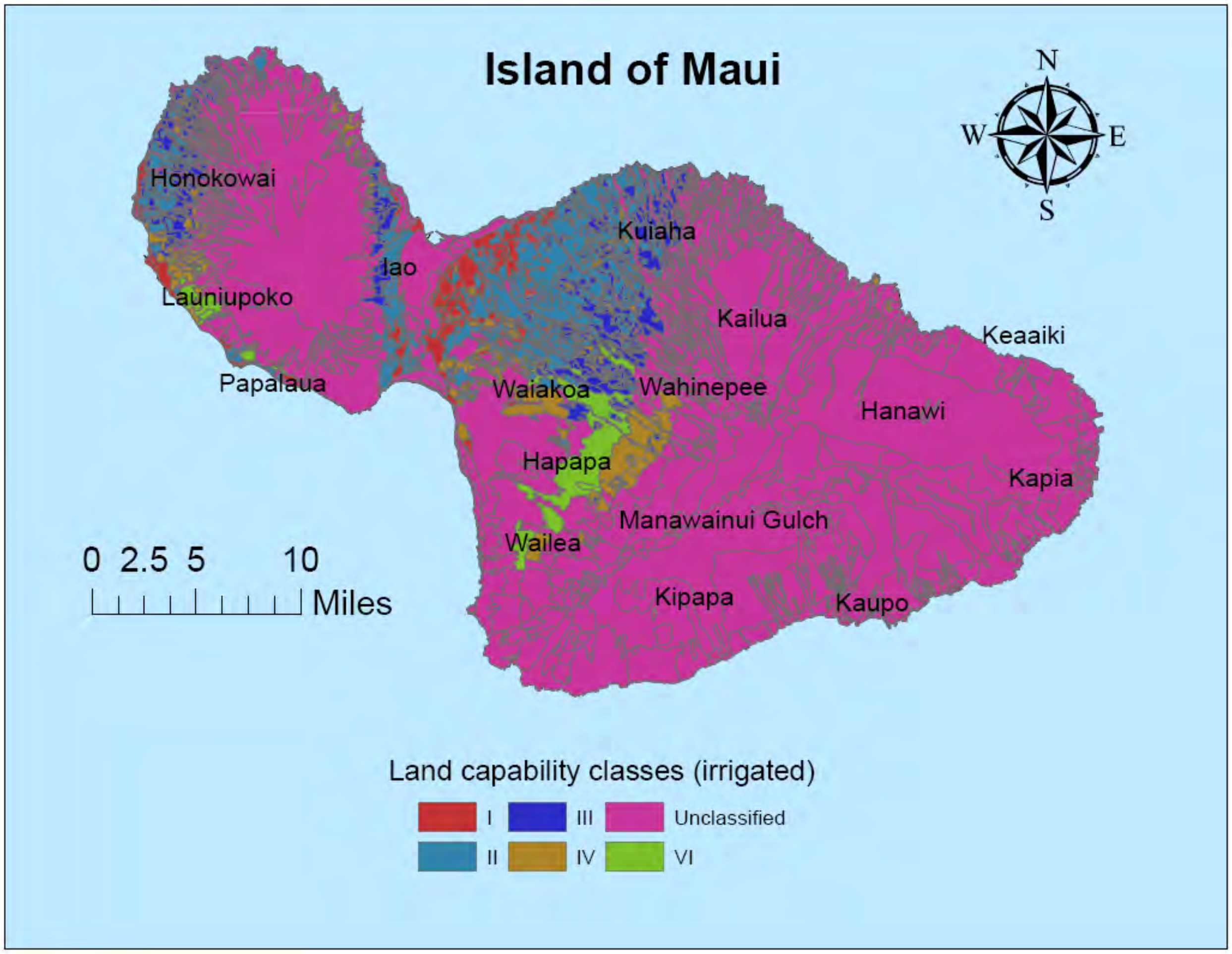

Fig. 35 The land capability classification (LCC) (Irrigated) for the island of Maui (the LCC description in given in Table 15).

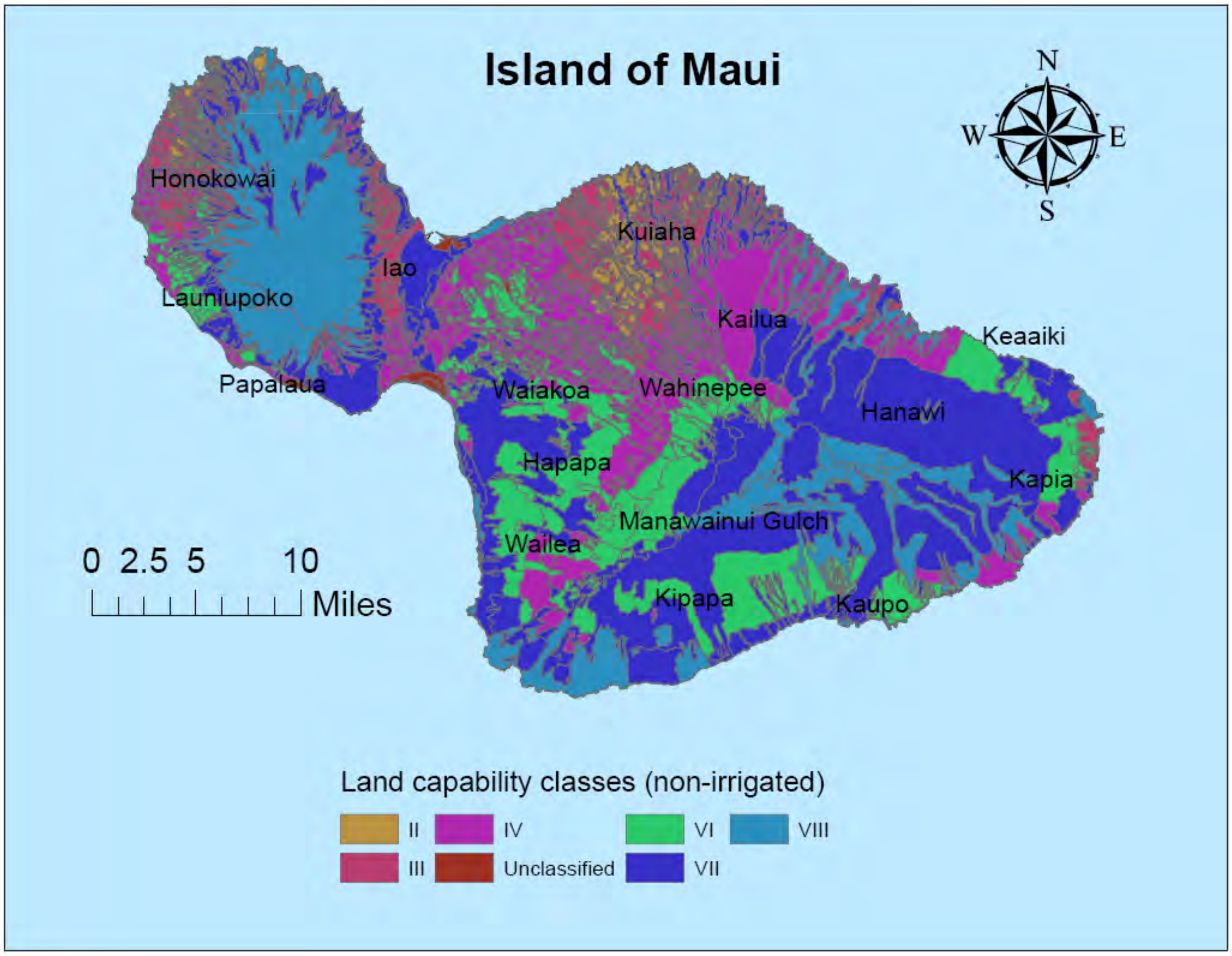

Fig. 36 The land capability classification (LCC) (Non-irrigated) for the island of Maui (the LCC description in given in Table 15).

3.1.3 Islands of Molokai and Lanai

Land uses and ALISH of the islands of Molokai and Lanai are shown in Figs. 37 and 38, respectively. Over 110,000 acres of the total (165,000) area of Molokai are classified as ‘Agricultural’ by the State Land Use Commission (DBEDT, 2007). Geographical and weather conditions make central and West Molokai the best region for bioenergy crop production at large scale. The Central Plateau of Lanai has the potential for growing bioenergy crops as the north side of Lanai has severely windblown soils, and the western and southern edges of the plateau below 1,200 feet of elevation have severely eroded and rocky soils. Since Lanai receives very little precipitation, irrigation and domestic water is taken from lava dikes found at high elevations which limits potential bioenergy crop production.

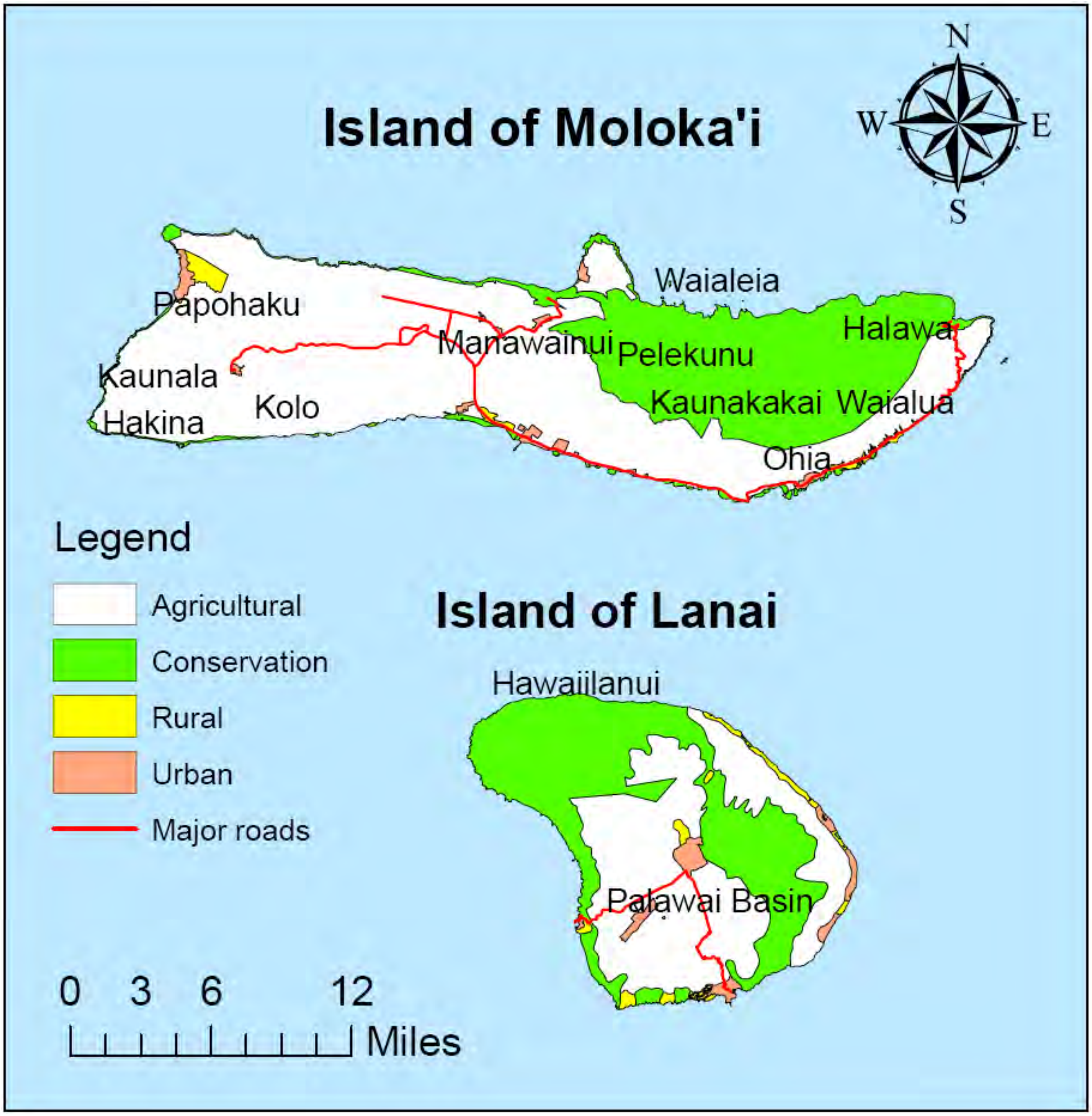

Fig. 37 Islands of Molokai and Lanai with state land use districts (Source: State Land Use Commission).

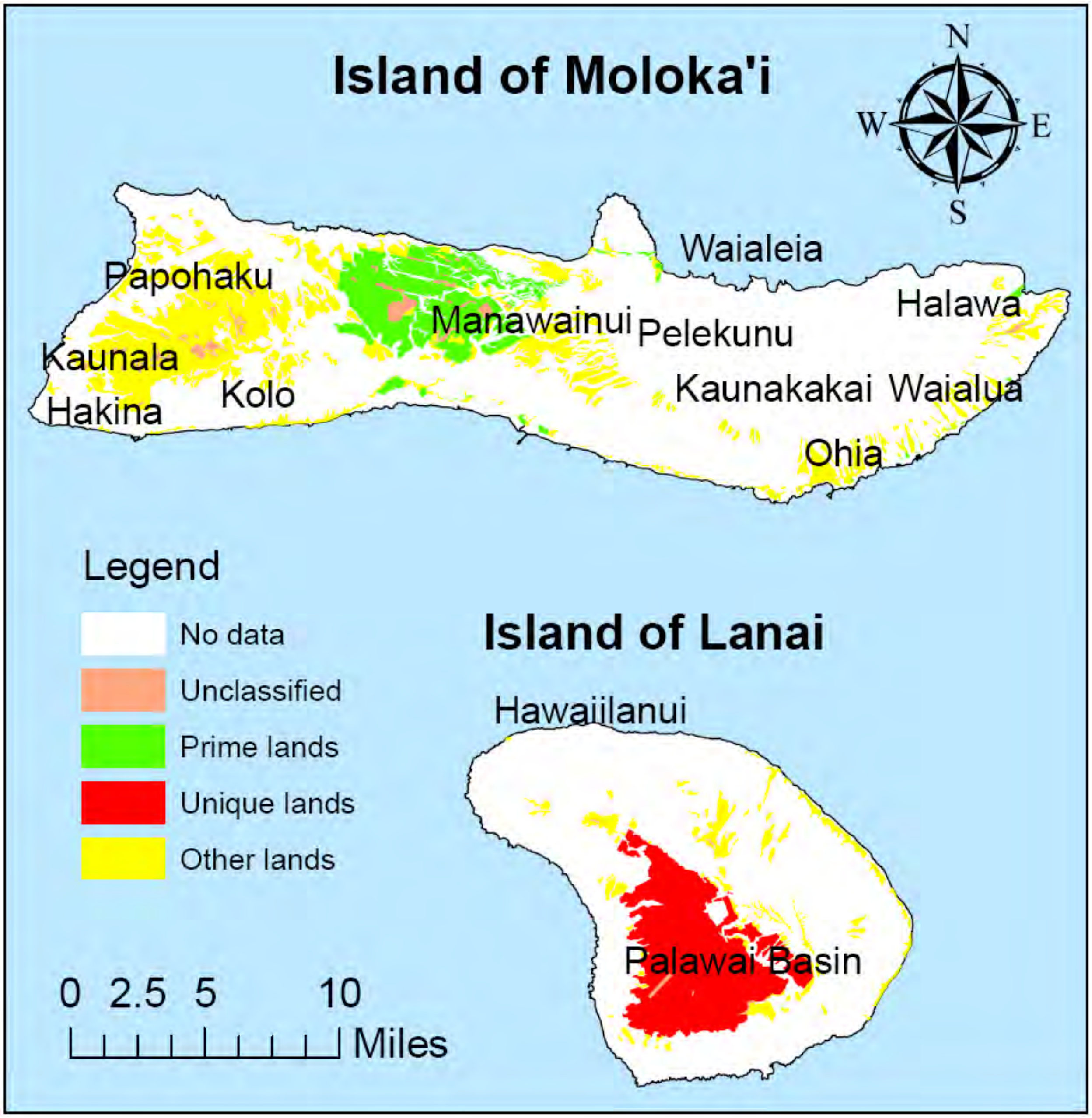

Fig. 38 Agricultural lands of importance to the state of Hawaii (ALISH) classes and locations for the islands of Molokai and Lanai (Source: Hawaii State Department of Agriculture, 1977).

Lanai, formed by a shield volcano, is over 3,400 feet above sea level on the eastern side of the island. To the southwest and west of this peak, the Central Plateau of Lanai was once the location of a 16,000 acre pineapple plantation (Armstrong, 1983). The Central Plateau has the potential for growing bioenergy crops as the north side of Lanai has severely windblown soils, and the western and southern edges of the plateau below 1,200 feet of elevation have severely eroded and rocky soils. Since Lanai receives very little precipitation, irrigation and domestic water is taken from lava dikes found at high elevations (Foote et al., 1972) which limits potential bioenergy crop production.

Molokai has about 23,000 acres of suitable land for pasture and cropland; the LCCs to determine potential productivity of the Island of Molokai are shown in Figs. 39 (irrigated conditions) and 40 (non-irrigated conditions). Most of this land is comprised of Lahaina silty clay, Hoolehua silty clay, Molokai silty clay, and Holomua silt loam soils, which are classified as IIe and IIIe with irrigation and IIIc and IVc without irrigation (SCS, 1972).

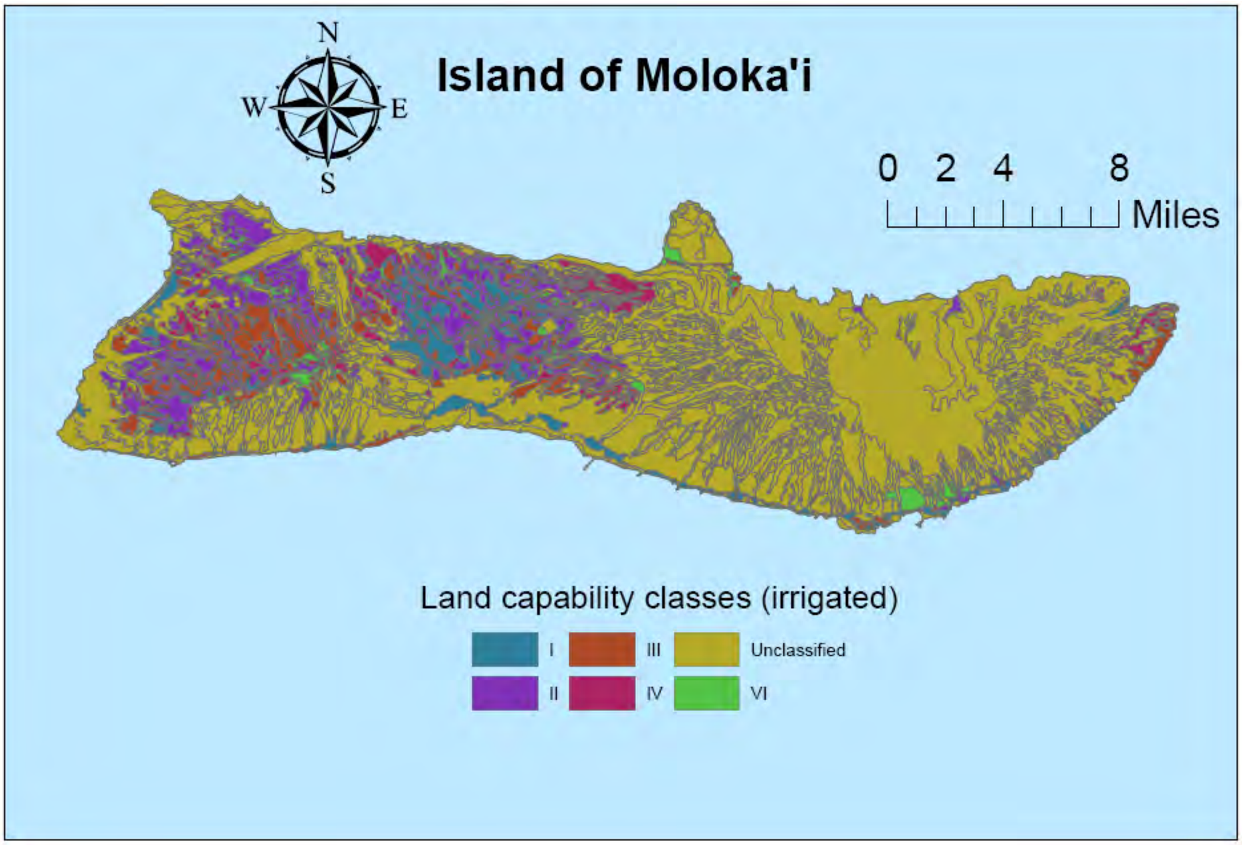

Fig. 39 The Land Capability Classification (LCC) (Irrigated) for the Island of Molokai (the LCC description in given in Table 15).

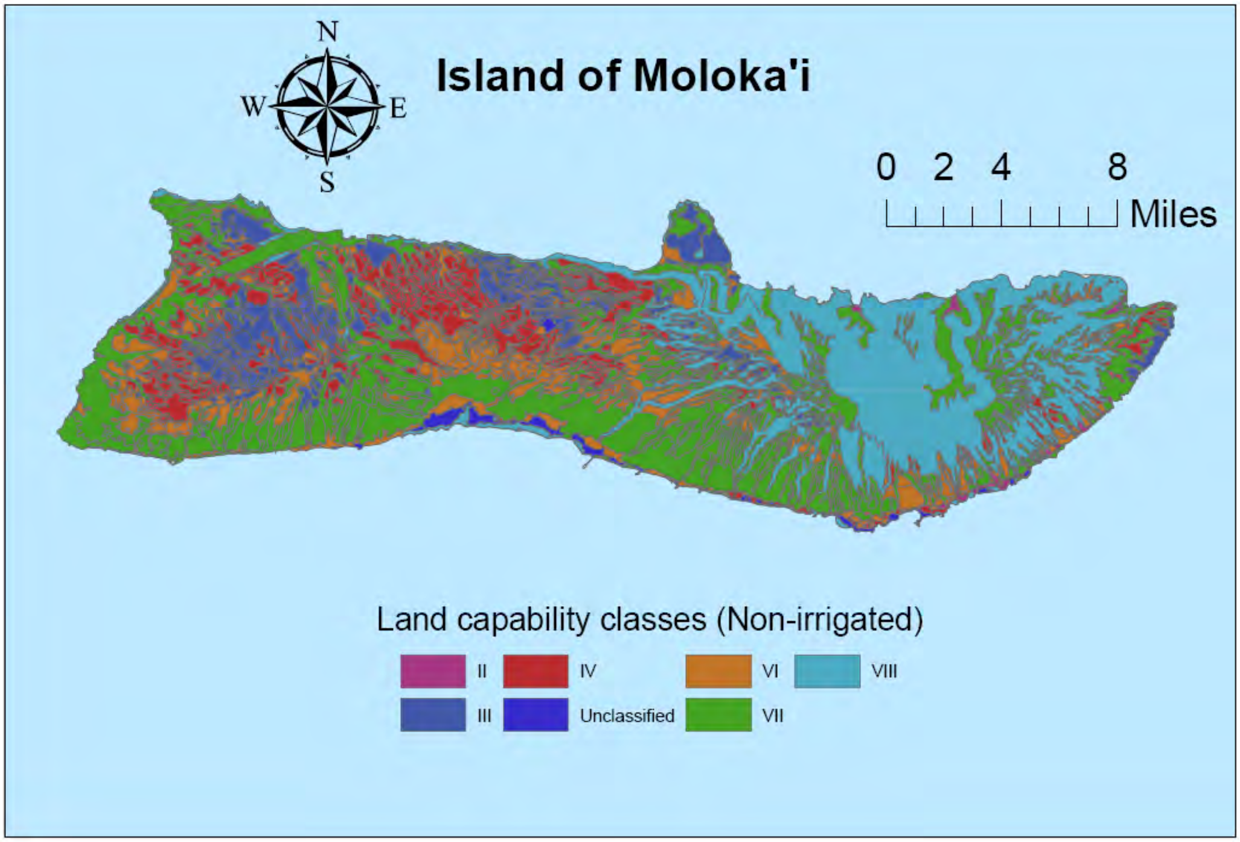

Fig. 40 The Land Capability Classification (LCC) (Non-irrigated) for the Island of Molokai (the LCC description in given in Table 15).

3.1.4 Islands of Kauai and Niihau

Kauai is a primarily rural and agricultural island with approximately 139,000 acres zoned agricultural as of 2004 (DBEDT, 2007). State lands (about 5000 acres) leased to various seed companies and aquaculture operations and private lands (about 3000 acres) may not be available for bioenergy crops. Land uses and ALISH of Kauai are presented in Figs. 41 and 42, respectively. Kauai has more land in farms (150,000 acres) than land actually designated as 'Agricultural' (139,000 acres) in 2002 (DBEDT, 2005). On Kauai, potential areas for bioenergy crop production may include the Mana Plain south of Koloa region and some areas of Lihue Basin. The region of south and east of Koloa, which stretches down to Poipu and Makahuena Point on the southern coast around to near Kamala Point is another possible bienergy crop production area. The area encompasses approximately 1,400 acres of land. Annual average rainfall ranges from 40 to 75 inches, which permits growing field crops with few irrigation requirements, in the areas without high rock content.

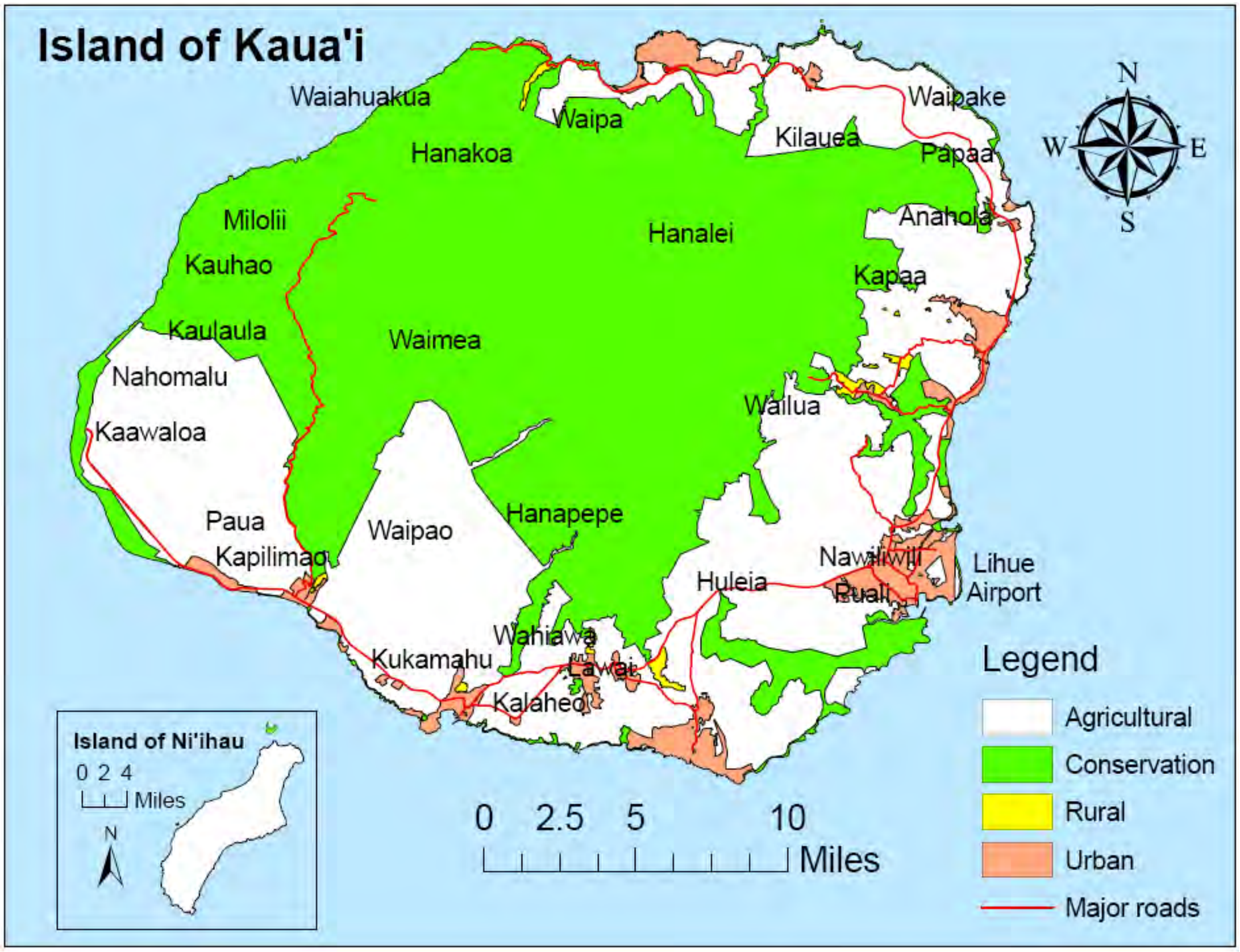

Fig. 41 Islands of Kauai with State Land Use Districts (Source: State Land Use Commission).

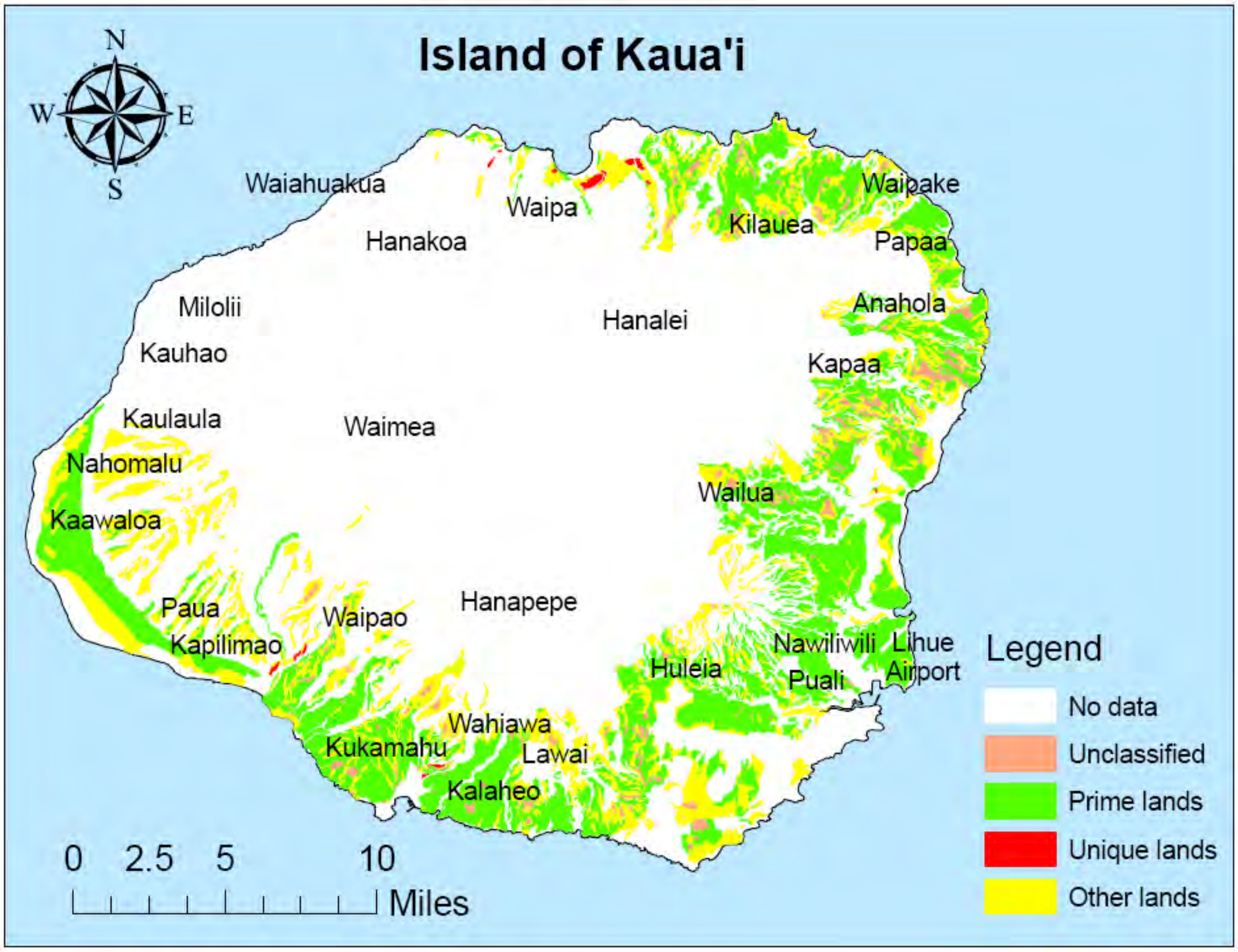

Fig. 42 Agricultural Lands of Importance to the State of Hawaii (ALISH) classes and locations for the Island of Kauai (Source: Hawaii State Department of Agriculture, 1977).

Kauai consists of many highly productive lands, which have been used for sugarcane production in the past with some of the highest sugarcane recorded yields in Hawaii (Keffer et al., 2006). The LCC classes to determine potential productivity for Kauai are shown in Figs. 43 (irrigated conditions) and 44 (non-irrigated conditions). Dominant soils in this area are Jaucas loamy fine sand, Kaloko, Lualualei, and Nohili clays, Kekaha clays and silty clays, and old Fill Land. Capability classes of these soils range from Class I to IIIw to IVs under irrigated conditions to Vw and VIs for un-irrigated areas with limiting factors in this area ranging from shallow water table, lack of rainfall, mild alkalinity, difficult workability, and poor drainage in some sites (Poteet, 2006). The region of south and east of Koloa encompasses approximately 1,400 acres of land owned mainly by small, private landowners, and Grove Farm and McBryde Sugar Co. Soils in this region are Kalihi and Keana clays (classified as IIIw), Koloa stony silty clay (class IIe, IVe when un-irrigated), and Waikomo stony silty clay and very rocky silty clay (classes IVs and VIs, respectively), and old Fill Land where cane mill slurry, dredged solids, and other wastes were concentrated (Foote et al., 1972).

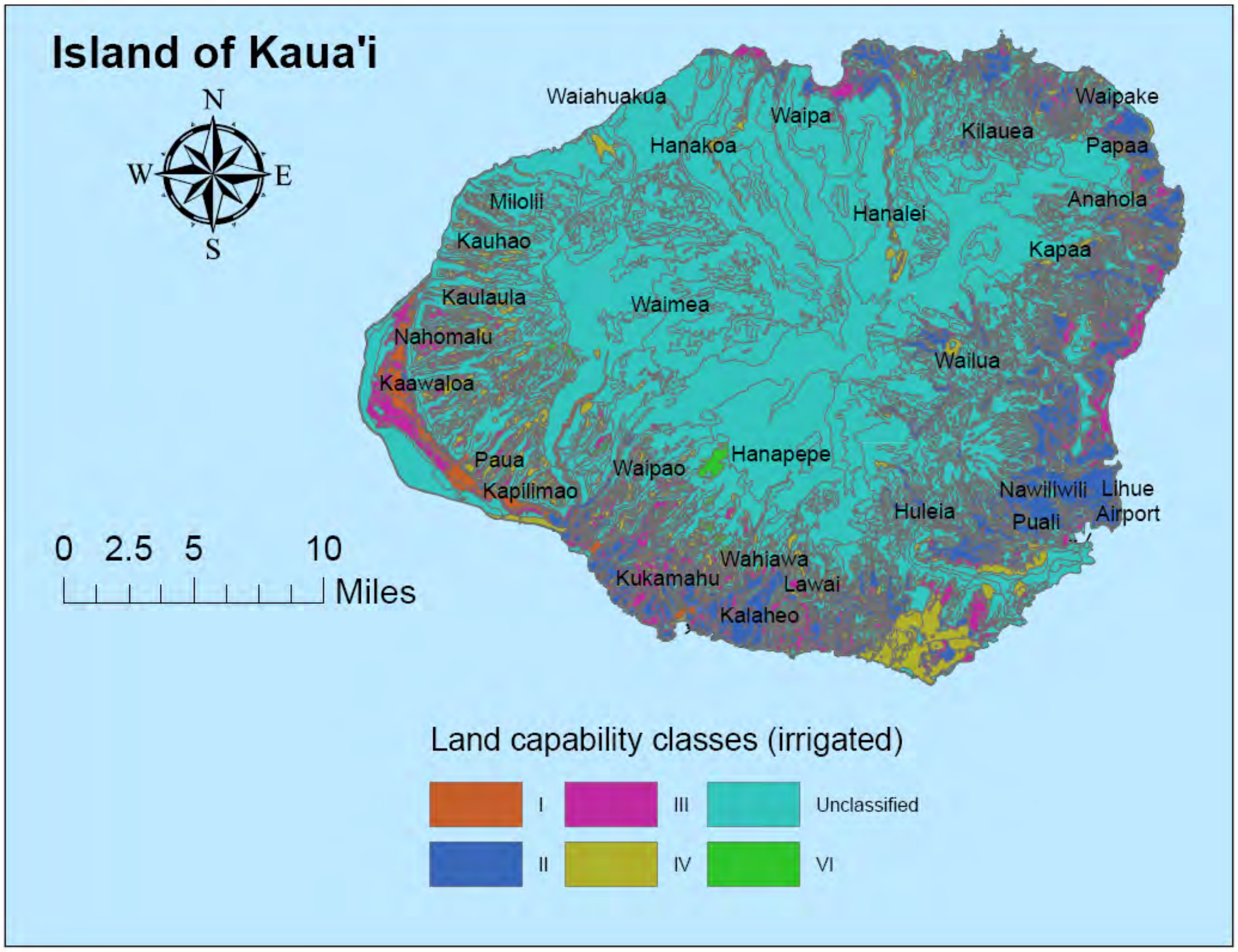

Fig. 43 The Land Capability Classification (LCC) (Irrigated) for the Island of Kauai (the LCC description in given in Table 15).

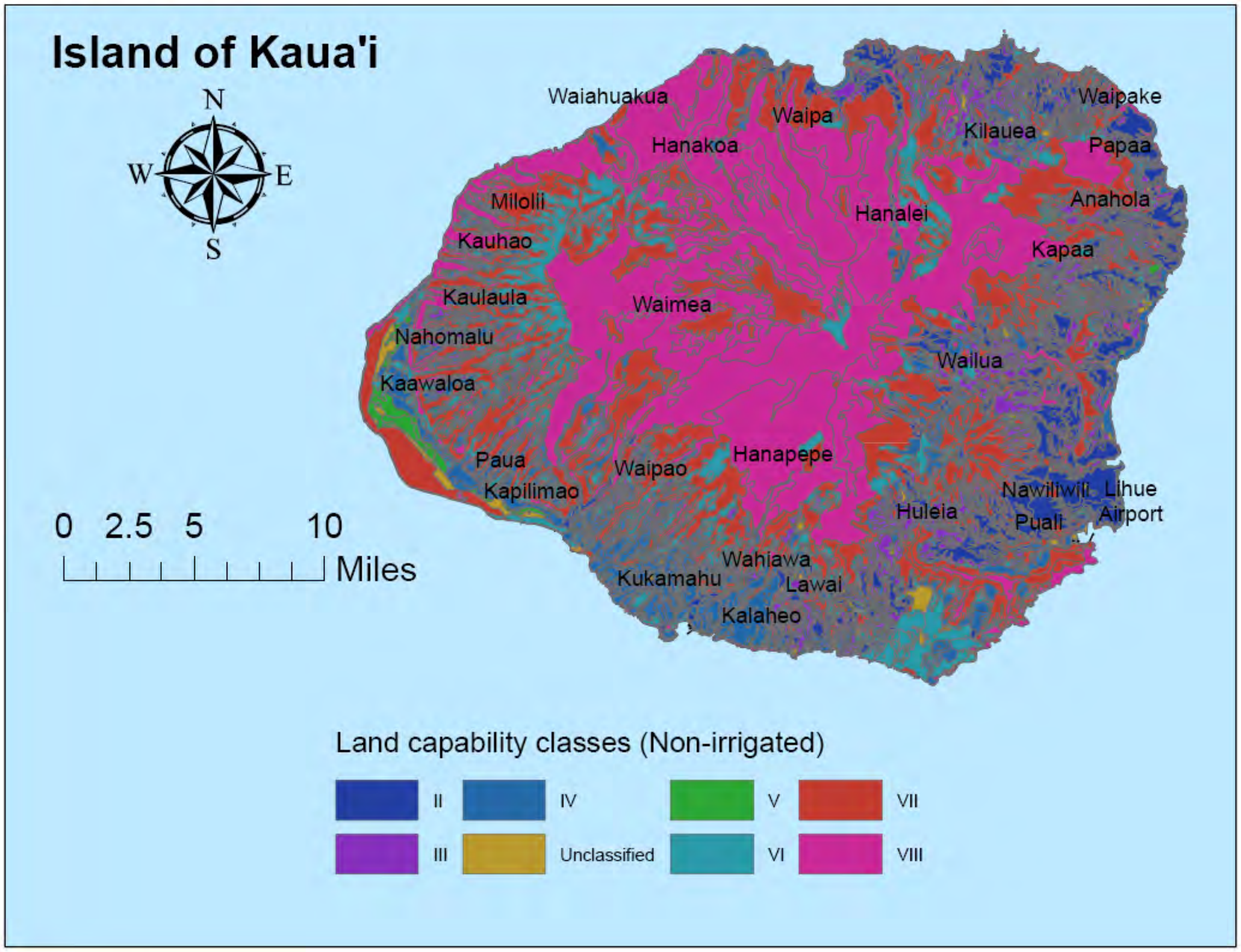

Fig. 44 The Land Capability Classification (LCC) (Non-irrigated) for the Island of Kauai (the LCC description in given in Table 15).

Soils of this region are i) dominated with clay content, ii) poorly drained, iii) very deep, and iv) support deep root plants. Soils with stone and rock contents are shallow (< 20 inches) to less deep (≤ 40 inches) with good available water holding capacity (SCS, 1972). Annual average rainfall on this part of the island ranges from 40 to 75 inches, which permits growing field crops with few irrigation requirements, in the areas without high rock content (Armstrong, 1983).

Lihue Basin comprising 1,600 to 2,000 acres that stretches directly north of Lihue to the South Fork of the Wailua River and west of Kalepa ridge, north of Hanamaulu, and from the South Fork Wailua River to the North Fork Wailua River is another potential area for bioenergy crop production. With average annual rain ranging from 60 up to 100 inches, the deep and acidic soils of this region allow deep rooting and support a wide variety of crops with enough moisture available to produce annual bioenergy crops. Soils of these upland areas are predominantly Kapaa and Lihue silty clays, Lihue gravelly silty clay, and Puhi clay loam. Land capability classes are IIe or IIIs for all soils under irrigation or not (Foote et al., 1972).

The entire island Niihau is zoned as Agricultural but no data is available for soils or land types on Niihau. Soils are believed to be shallow, rocky, relatively infertile, droughty, and have poor workability. Annual precipitation on Niihau ranges from only about 8-20 inches and freshwater is collected through dikes. Since no detailed soil and water resources information is available Gay & Robinson, Inc. will be the source of specific information.

3.1.5 The Big Island

The Big Island is geographically the largest among the seven islands. Over 60% of the lands of the Big Island are classified as 'Agricultural' with over 1.2 million acres (485,000 hectares) available for agricultural or bioenergy crop production endeavors (DBEDT, 2007). Land uses and ALISH of Big Island are shown in Figs. 45 and 46, respectively. The Big Island could possibly be tapped for production of bioenergy for export to other islands, if deemed economically feasible to ship out liquid fuels across the inter-island channels. Utilization of old croplands and marginal land is likely to be the initial component of the Big Island's bioenergy endeavors. A large number of existing ranches would benefit from the by-product associated with bioenergy crops. Average annual rainfall on the windward side of the island ranges from 100 to over 200 inches providing flexibility to grow bioenergy crops that require significant amounts of moisture.

The Big Island has unique climatic, soil, and topographic conditions. Utilization of old croplands and marginal land is likely to be the initial component of the Big Island's bioenergy endeavors. A large number of existing ranches on the Big Island would benefit from animal feed by-products associated with bioenergy crops. Agricultural lands are owned by the State of Hawaii, Kamehameha Schools, C. Brewer & Co., Hawaiian Home Lands, and other private landowners (Juvik & Juvik, 1998). Average annual rainfall on the windward side of the island ranges from 100 to over 200 inches providing flexibility to grow bioenergy crops that require significant amounts of moisture.

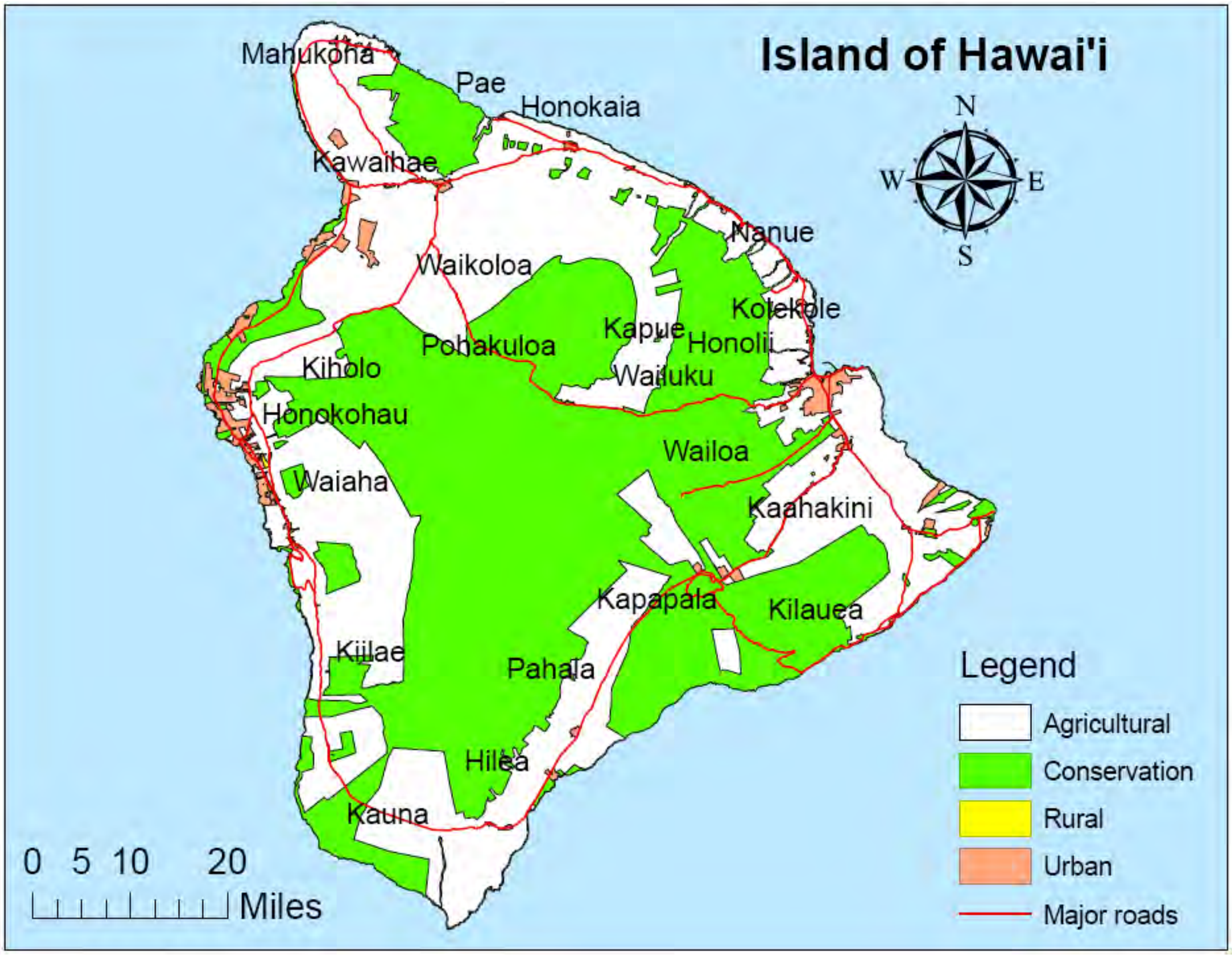

Fig. 45 Big Island with State Land Use Districts (Source: State Land Use Commission).

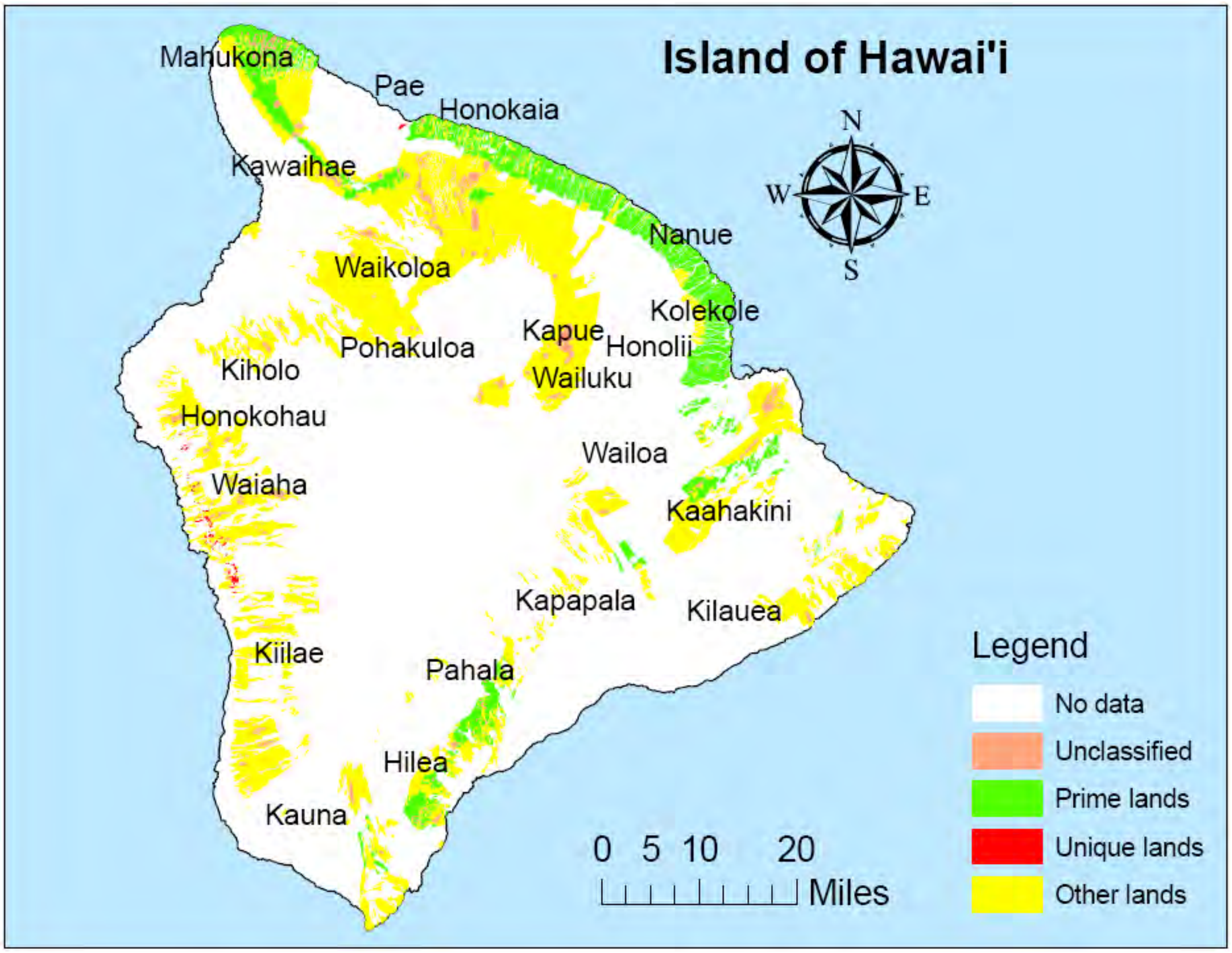

Fig. 46 Agricultural Lands of Importance to the State of Hawaii (ALISH) classes and locations for the Big Island (Source: Hawaii State Department of Agriculture, 1977).

The LCC classes to determine potential productivity for the Big Island are shown in Figs. 47 (irrigated conditions) and 48 (non-irrigated conditions). Akaka, Honokaa, Hilo, Kaiwiki, Kukaiau, Ookala, and Paauhau silty clay loams are the soils found from the inland, upland areas near Waimea to the coast, and down to Hilo (Sato et al., 1973). These soils, which are graded as IIIe or IVe, depending on their slope, are deep, well drained, acidic, and historically proven to be productive.

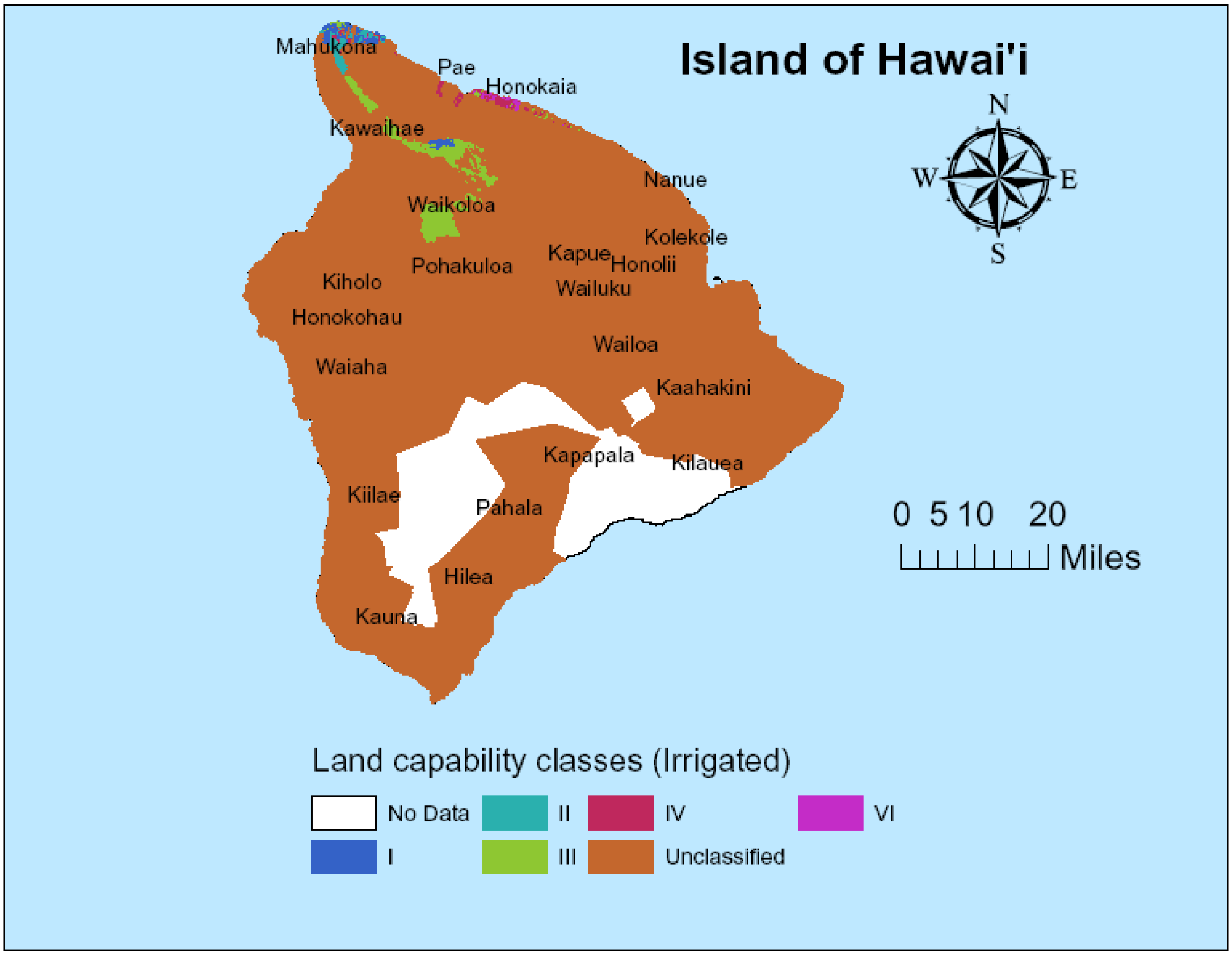

Fig. 47 The Land Capability Classification (LCC) (Irrigated) for the Big Island (the LCC description in given in Table 15).

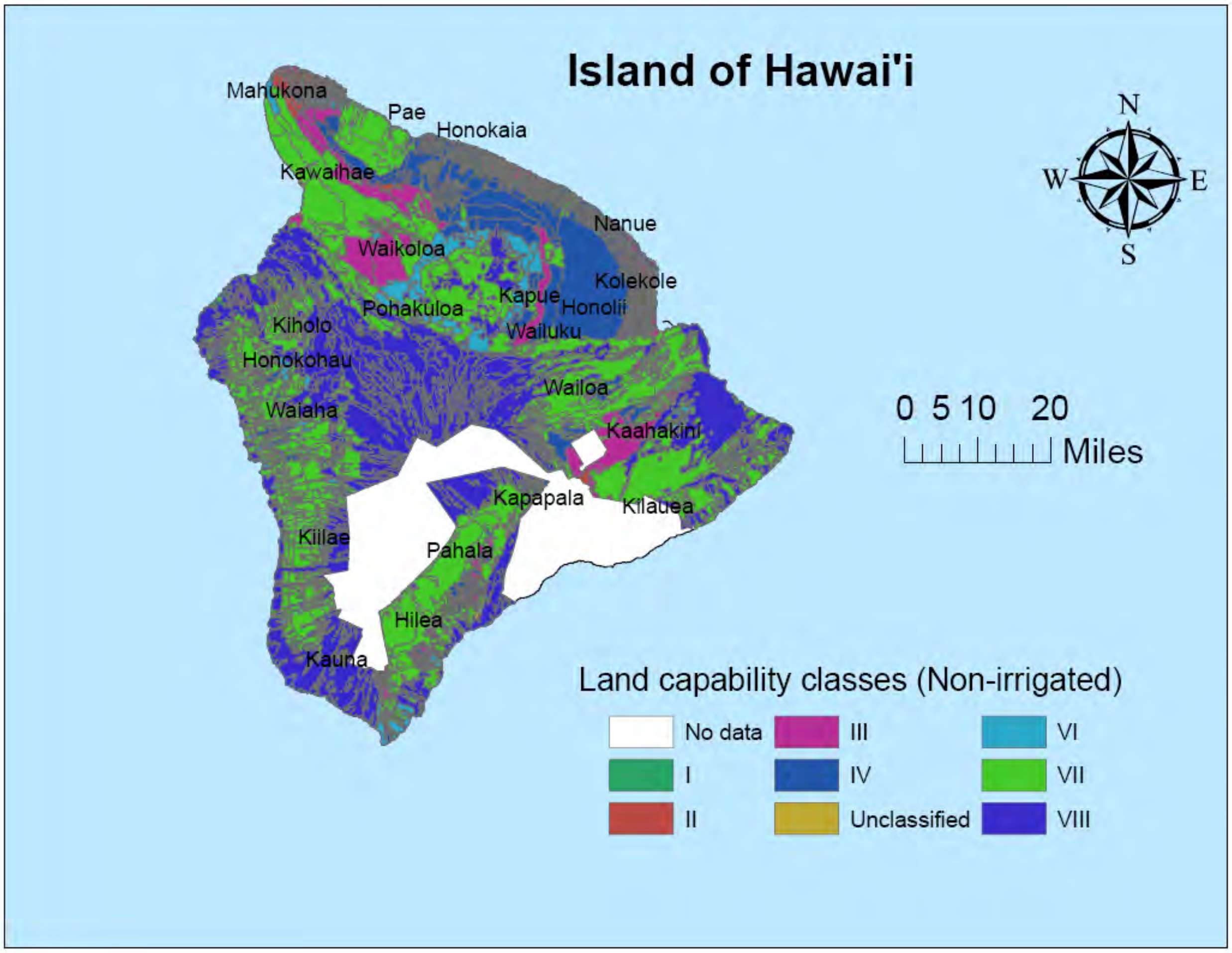

Fig. 48 The Land Capability Classification (LCC) (Non-irrigated) for the Big Island (the LCC description in given in Table 15).

Available lands include a region of approximately 100,000 acres comprised old sugarcane lands in the areas surrounding Glenwood to Kurtistown, and small areas of ranching, papaya, nursery crops, vegetables, and other miscellaneous crops. Potential lands also include areas positioned on the southern slopes of Mauna Loa on lands ranging from near sea level up to 7,000 feet above sea level where the average rainfall can be anywhere from 30 inches (leeward side) up to 80 inches (windward side). The soils are rocky which practically makes it impossible to work with, only tree bioenergy crops may be the possible option.

3.2. Biomass Production from Existing Lands of Hawaii

In this section, the biophysical requirements for six crop species are used to estimate their yield. Temperature and moisture are two major factors that determine the development and growth of plants. Temperature drives the development rate of a crop and affects the yield per time unit. At lower temperatures, crops develop more slowly and biomass produced per unit time is reduced. Moisture is an absolute requirement for a crop.

Input was solicited from stakeholders and compiled (Appendix A and B). Some of these inputs were addressed in the following analysis or in other sections. Other inputs were used as recommendations for future work. One important point as suggested at the stakeholder meeting was to estimate yields based on crop requirements and land characteristics. The use of the temperature, moisture, soil depth, and land capability class in this analysis corresponds to the stakeholder suggestion.

3.2.1 Available and Potential Feedstocks

Continued development of bioenergy production systems requires accurate information on a reliable biomass feedstock supply, production and harvesting costs, and environmental impacts. Understanding the cost and the quality of biomass production is critical for evaluating the competitiveness of biomass as feedstock. Development of a bioenergy industry necessitates determining ways to lower biomass production costs including handling and transportation, reducing uncertainty of supply, and capturing the value of environmental benefits and transferring them to the producer. Studies have characterized a number of existing municipal and agricultural waste streams that might be suitable for ethanol conversion (Shleser, 1994; Turn et al., 2002; Gieskes et al., 2003; BBI international, 2003; Surles et al., 2007). As reported by Surles et al. (2007), fiber-based (lignocellulosic) ethanol production involves large quantities of feedstock; data taken from the state biomass and bioenergy resource assessment are shown in Table 16.

Table 16 Summary of biomass resources and their degree of utilization (tones yr^{-1}) in the State of Hawaii by county in 2002 (Data Source: Turn et al., 2002; Surles et al., 2007)

	tons yr^{-1}	Big Island	Maui	Kauai
Swine Manure	Dry	410	540	180
Dairy Manure	Dry	-	-	
Poultry	Dry	1,520[1]	-	-
Bagasse Fiber	Dry	-	275,000 (275,000)[2]	74,000 (56,000)[2]
Cane Trash	Dry	-	137,000	37,000
Pineapple Processing Waste	Dry	-	7,500 (7500)[2]	-
Macadamia Nut Shells	Dry	19,000 (18,000)[2]	-	-
Municipal Solid Waste (MSW)	as-received	110,000	96,000	56,000
Food Waste[4,5]	as-received	24,000	15,000	5,800
Sewage Sludge[5]	Dry	183	3,352 (3,352)[2,3]	246
Fats/Oil/Grease	Dry	1,850	1,850	800

[1]combined poultry waste estimate for Big Island, Maui, and Kauai; [2]amount currently used; [3]tipping fee associated with utilization; [4]amount entering landfills; [5]included in municipal solid waste value.

According to Surles et al. (2007), bagasse, cane trash and municipal solid waste, and the largest waste streams are among the largest sources of biomass wastes. Municipal solid waste on Oahu and bagasse on Maui, are used for power production at the HPower waste-to-energy plant and the HC&S factory, respectively. Kauai's future supply of bagasse is uncertain following the 2008 announcement by Gay & Robinson of its plans to terminate its sugar operations.

The potential for specific locations for biomass energy crops has been reported in several studies (e.g., Yang et al., 1977; Brewbaker, 1980a, 1980b; Hubbard and Kinoshita, 1993; Anon, 1994; Phillips et al., 1993, 1995; Kinoshita and Zhou, 1999). As reported by Surles et al. (2007), among the most capable crops for fiber production are sugarcane (*Saccharum officinarum*) and banagrass (*Pennisetum purpureum*), and woody crops (*Eucalyptus grandis*, *Eucalyptus saligna*, and *Leucaena leucocephala*; giant *Leucaena* or haole koa). These crops are strong candidates as energy crops for sugar or fiber production. Currently, only sugarcane and *Eucalyptus* are being grown commercially. According to Surles et al. (2007), large acreages of *Eucalyptus* had been planted but none have been harvested to date; sweet sorghum, albizia, guineagrass have been proposed but large scale trials to evaluate their suitability as energy crops in Hawaii have not been carried out.

3.2.2 Crop production

Production of bioenergy crops relies on the environment. In the Hawaiian Islands, the environment has tremendous diversity. Of the 12 soil orders in the world according to the U.S. classification system, Hawaii has 10 of them (Deenik and McClellan, 2007). Across the islands, temperature ranges from warm, sun-drenched beaches to cold, snow-capped mountains. Combined with rainfall, conditions range from desert-like to rainforest. A variety of plants has adapted well to these environmental niches and performs. Within this diversity of environments and plants, bioenergy feedstock production is being considered.

Temperature and moisture will be the primary factors that determine both yield and where bioenergy crops may be grown in Hawaii. Other factors such as topography, soil depth, and soil strength will be considered to determine appropriate conditions for crop production.

Six crops were selected for evaluation as an initial step. The crops were selected as representative of the crop type (grass and trees) and feedstock type (sugar, fiber, and oil). The selected crops are sugarcane, banagrass, *Eucalyptus* (*Eucalyptus spp*.), *Leucaena* (*Leucaena leucocephala*), oil palm (*Elaeis guineensis*), and *Jatropha* (*Jatropha curcas*). In addition, the locations for algae production were considered.

Biomass production is usually considered as non-irrigated agriculture with soil temperature playing an important role in soil moisture dynamics and availability for consumptive use of crops, as well as crop development. Hawaii has approximately 1.85 million acres zoned for agriculture (Office of Planning, 2008). These lands are used for animal and crop production on six major islands as mentioned in the previous section. It is these lands that will be considered in the present analysis.

The intent of this analysis is to estimate biofuel yield based on land and water resource capabilities. This information may be used by decision-makers to consider or eliminate from consideration the production of biofuel crops on a particular section of land.

Input was solicited from stakeholders and compiled (Appendices A and B). Some of these inputs were addressed in the following analysis or in other sections. Other inputs were used as recommendations for future work. One important point as suggested at the stakeholder meeting was to estimate yields based on crop requirements and land characteristics. The use of the temperature, moisture, soil depth, and land capability class in this analysis corresponds to the stakeholder suggestion.

3.2.3 Soil Temperature

The Natural Resource Conservation Service (NRCS) of the U.S. Department of Agriculture has classified tropical soil in four categories. NRCS uses soil temperature, which is correlated well to air temperature, in part because soil temperature captures broad trends without the high variation that is associated with air temperature. Isofrigid is the term used to describe soil that has a mean annual temperature of less than 46 °F measured at 20 inch depth. Isomesic means soil has an average temperature between 46 and 59 °F. Isothermic refers to soil with an average temperature between 59 and 72 °F. Isohyperthermic describes soil that has an average temperature greater than 72 °F. In the agriculturally zoned lands of Hawaii, there are no soils with the isofrigid regime (Fig. 49). From this point forward, the terms isomesic, isothermic, and isohyperthermic will be replaced with the common terms cold, cool, and warm, respectively.

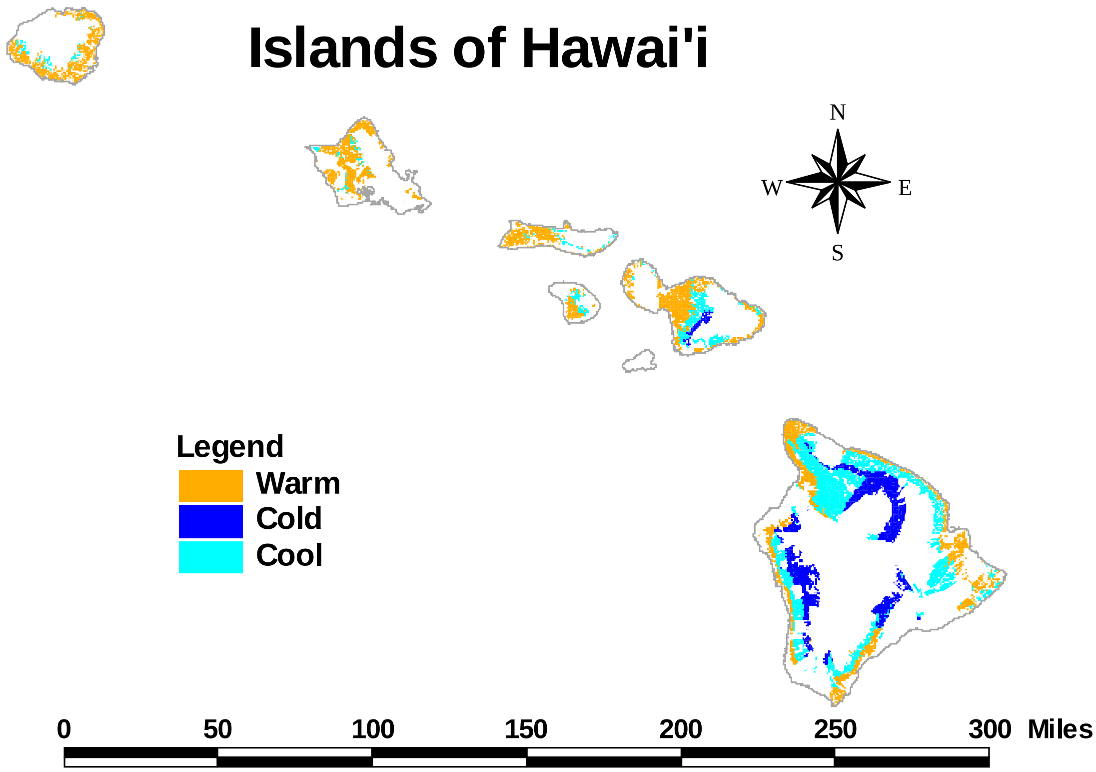

Fig. 49. Temperature regimes within agriculturally zoned land in Hawaii (Source: NRCS, USDA).

Most of the agriculturally zoned lands in Hawaii have a warm temperature regime, about 584,000 acres (Table 17). However, significant portions of land are classified as cool (482,000 acres) and cold (252,000 acres). About 528,000 acres of agriculturally zoned lands have not been classified with temperature or moisture regimes. These lands are mainly lava flows and may be productive. Some of these lava lands are being used to produce papaya. Much of these lava lands have trees growing on them. However, literature on the productivity of these lands does not exist yet.

Table 17. Acres of agriculturally zoned lands in Hawaii with specified temperature and moisture regimes (based on NRCS, USDA, 2006). About 528,000 acres of agriculturally zoned land is not classified with temperature or moisture regimes.

	Dry	Moist	Wet	Very wet	Saturated	Total
Warm	158,000	287,000	125,000	0	13,000	584,000
Cool	28,000	199,000	249,000	3,000	2,000	482,000
Cold	0	171,000	81,000	0	0	252,000
Total	187,000	657,000	456,000	3,000	15,000	1,320,000

3.2.4 Soil Moisture

Soil moisture descriptions are based on the number of months that the soil can supply water to plants. The supply of water is dependent on the amount of rain and the ability of the soil to store water. The term aridic is applied to soils that can supply plant water needs for less than half a year. Ustic describes soils that supply water to plants for less than 9 months of the year. Soils that supply water to plants for more than 9 months are called udic. When soils have more water than can be evaporated or are saturated they are called perudic and aquic, respectively. The terms aridic, ustic, udic, perudic, and aquic will be replaced with the common words dry, moist, wet, very wet, and saturated (Fig. 50). Moist (657,000 acres) and wet (456,000 acres) are the most common moisture regimes in the agriculturally zoned lands (Table 17).

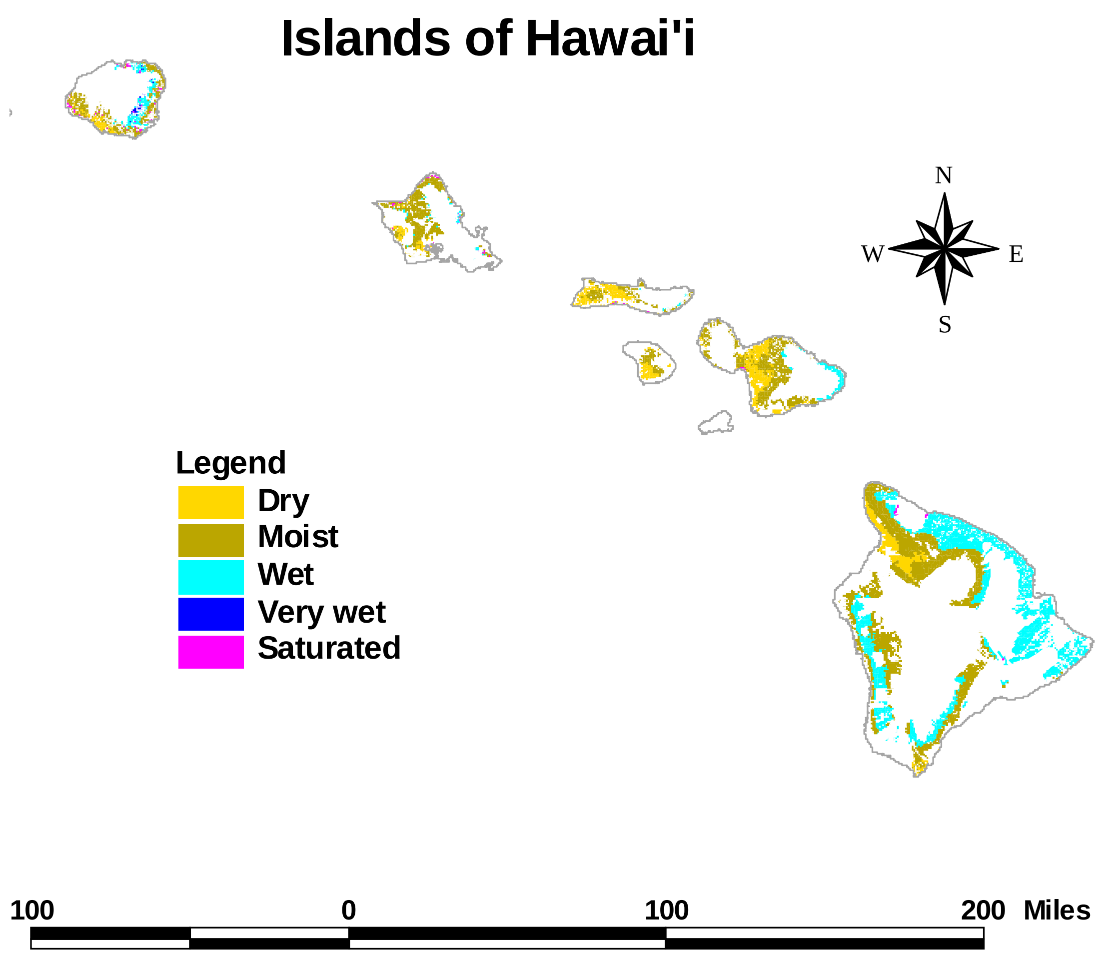

Fig. 50. Moisture regimes across the State of Hawaii (Source: NRCS, USDA).

3.2.5 Soil Depth
Soil depth is an important production factor especially in rain-fed systems. Depth is an indicator of soil moisture storage capacity. Where crops rely on rain, stored moisture is an essential source between rain events.

The NRCS (USDA, 2007) classifies soil depths in four categories. Class I is greater than 36 inches, deep. Classes II, III, and IV are 20-36, 10-20, and less than 10 inches (Fig. 51).

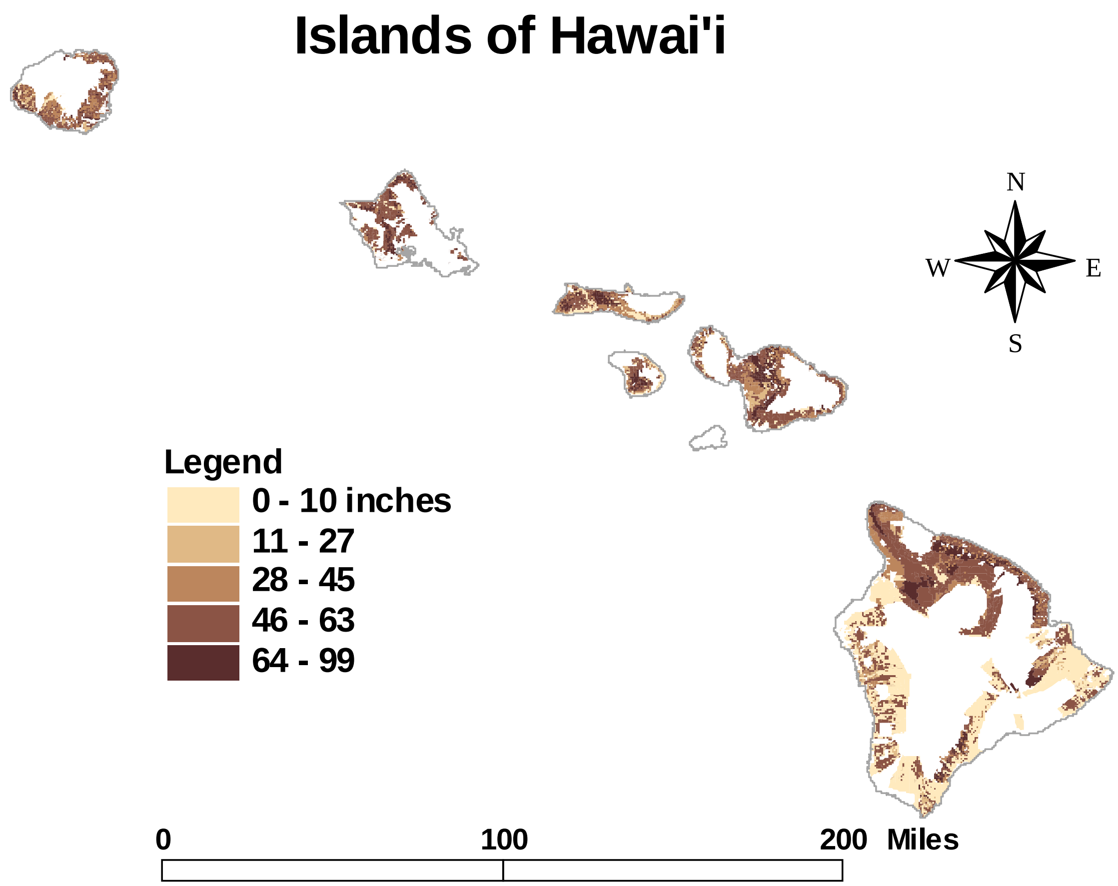

Fig. 51. Soil depth (inches) in agriculturally zoned lands in Hawaii (Source: NRCS, USDA).

3.2.6 Land Capability Classification
As mentioned in the previous section, the NRCS Land Capability Classification classifies soils with the objective of soil conservation. The land degradation potential increases with the increasing class number from I to VIII. As the potential degradation increases, certain limitations or practices are suggested for each class such as type of crop (row crop and forest) or erosion control practice as contour plowing. The Land Capability Classification will be used as a guide for estimating land areas for bioenergy crop production.

3.3 Estimating Bioenergy Yields

3.3.1 Crop Requirements

Temperature and moisture requirements for each of the six crops were derived from observed yield data and temperature/moisture regimes where the observations were made. Rain-fed crop data came from the following sources.

1. Sugarcane: Keffer et al., 2006; FAO, 2003; Government of Fiji and FAO, 1997
2. Banagrass: Vincente-Chandler et al., 1962; Vincente-Chandler et al., 1959 ; Watkins and Lewy-Van Severin, 1951; Paterson, 1935; Wilsie et al., 1940; Paterson, 1933.
3. *Eucalyptus* : Kinoshita and Zhou, 1999 ; Austin et al., 1997; Stape et al., 2004; Whitesell et al., 1992; DeBell et al., 1997; Skolmen, 1986; Binkley and Ryan, 1998.
4. *Leucaena*: Glover, 1988; Kinoshita and Zhou, 1999; Sun, 1996; Shi, 2003; Austin et al., 1997.
5. Oil palm: Papademetriou and Dent, 2001; Hai, 2000; Udom, 2002; Kallarackal et al., 2004; Oil World Annual 2004.
6. *Jatropha*: Heller, 1996; Foidl et al., 1996 ; Benge ; Ishii and Takeuchi, 1987 ; Wiesenhutter, 2003.

In a similar manner, irrigated yield data were collected for sugarcane and banagrass. Irrigated sugarcane yield on soils found throughout the state was estimated from the Soil Conservation Service (SCS, 1972; SCS, 1973). The sugar yield from the SCS compared well to the long-term yields from sugar companies in Hawaii. Raw sugar yield from seven plantations that had all its fields irrigated ranged from 6.0 to 7.1 tons/acre/year (Keffer et al., 2006) while the SCS estimate ranged from 6.0 to 7.5. Cane yield was estimated from sugar yield based on the assumption that sugar composed 13% of the cane (NASS, 2006). Irrigated banagrass yield was derived from Kinoshita and Zhou (1999) and Osgood et al. (1996). No irrigated yield data was found for *Eucalyptus*, *Leucaena*, oil palm, and *Jatropha*.

3.3.2 Conversion Factors for Feedstock to Biofuel

Conversion technologies are rapidly improving over time. As the conversion efficiency increases, the biofuel yield from a feedstock increases proportionally. Currently, there is a race between two conversion pathways, thermo-chemical and biochemical, that pushes the efficiencies higher. For this analysis, conversion factors were selected for each of the feedstocks - sugar, fiber from grass, and fiber from trees. These conversions are 141 gallons of ethanol per ton of sugar (Keffer et al., 2006), 67 gallons per ton of grass biomass (Gieskes and Hackett, 2003), and 65 gallons of ethanol per ton of tree biomass. Ethanol yield from sugarcane is the total derived from fermentable sugars and a fraction of the biomass residue converted to ethanol using the factor of 67 gallons per ton of biomass (Gieskes and Hackett, 2003). The biomass fraction converted to ethanol is the remaining biomass not used in power generation (Keffer et al., 2006), approximately 40% of the total. The conversion of vegetal oil to biodiesel was assumed to be 0.9 gallon of biodiesel per gallon of vegetal oil.

3.3.3 Matching Observed Yields to Land Characteristics

Ethanol and biodiesel yields were calculated from the feedstock yields and the conversion factors for each combination of temperature and moisture regimes where yield data existed under rain-fed (Table 18) and irrigated (Table 19) conditions. Sugarcane ethanol is derived from sugar (13% of cane-wet weight) and the cane residue.

Table 18. Ranges of ethanol and biodiesel yields (gallons per acre per year) from rain-fed crops grown in specified temperature and moisture regimes.

Temp	Moist	Sugarcane gal/ac/yr	Bana gal/ac/yr	*Eucalyptus* gal/ac/yr	*Leucaena* gal/ac/yr	Oil palm gal/ac/yr	*Jatropha* gal/ac/yr
Warm	Moist	400 - 590	580-2500	440-700	350-1300	110-270	26-340
	Wet	590 - 990	1000-2600	590-850	350-680	240-450	43-260
	Saturate	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Cool	Wet	n.d.	n.d.	490-780	n.d.	n.d.	n.d.
Cold	Wet	n.d.	550	590-660	0-430	n.d.	n.d.

n.d.: no data available.

Table 19. Ranges of ethanol yield (gallons per acre per year) from irrigated sugarcane and banagrass grown in specified temperature and moisture regimes

Temp	Moist	Sugarcane	Banagrass
Warm	Dry	1200 – 1500	1700 – 3200
	Moist	1200 – 1500	1000 – 2800
	Wet	790 – 990	n.d.
Cool	Dry	n.d.	n.d.
	Moist	590 – 890	670
	Wet	n.d.	n.d.
Cold	Moist	400 – 590	400 – 470
	Wet	n.d.	n.d.

n.d.: no data available

Under rain-fed conditions, biofuel yield generally increased as moisture increased within a temperature regime (Table 17). For these crops, moisture limited growth and the crop responded well to increased moisture. The exception was *Jatropha* which seemed to perform better under moist condition instead of wet.

The two tree species *Eucalyptus* and *Leucaena* responded differently to temperature. *Eucalyptus* performed well even as temperature decreased from warm to cold. However, *Leucaena* yield dropped dramatically across the same temperature regimes.

The responses to both moisture and temperature show that species have adapted differently to these two parameters. Knowing the range of adaptation for each species is an important piece of information when considering what crop would grow well in a specific area.

Maps of biofuel yield for each species were produced based on temperature/moisture regimes, Land Capability Classification (LCC), and soil depth. Observed feedstock yields were matched to the analogous temperature/moisture regimes across the state. For the crops that would be intensively cultivated (sugarcane, banagrass, oil palm), areas where LCC was IV or less were included. For the less intensively cultivated crops (*Eucalyptus*, *Leucaena*, and *Jatropha*), LCCs I to IV, VI, and VII were included. The lands where the LCC excluded production of a particular crop were classified as poor on the yield estimation maps.

Soil depth was included as a criterion to prevent the application of yield data to lands that were dissimilar to the land where the data was obtained. Where soil depth was greater than 36 inches, the yield estimates were applied. The exception to the soil depth criterion was to include Tropofolist for the tree crops (*Eucalyptus*, *Leucaena*, oil palm, and *Jatropha*). These are soils that have thin, organic layer overlying lava and are capable of supporting tree growth. Lands that had adequate temperature and moisture for a crop, but did not have the soil depth were classified as uncertain on the yield estimation maps. These lands would most likely support crop growth, but whether the yield data are applicable to that land is not known.

When the LCC and soil depth criteria were met, the yield data was applied to the temperature and moisture regimes for rain-fed sugarcane (Fig. 52), banagrass (Fig. 53), *Eucalyptus* (Fig. 54), *Leucaena* (Fig. 55), oil palm (Fig. 56), *Jatropha* (Fig. 57), and irrigated sugarcane (Fig. 58) and banagrass (Fig. 59).

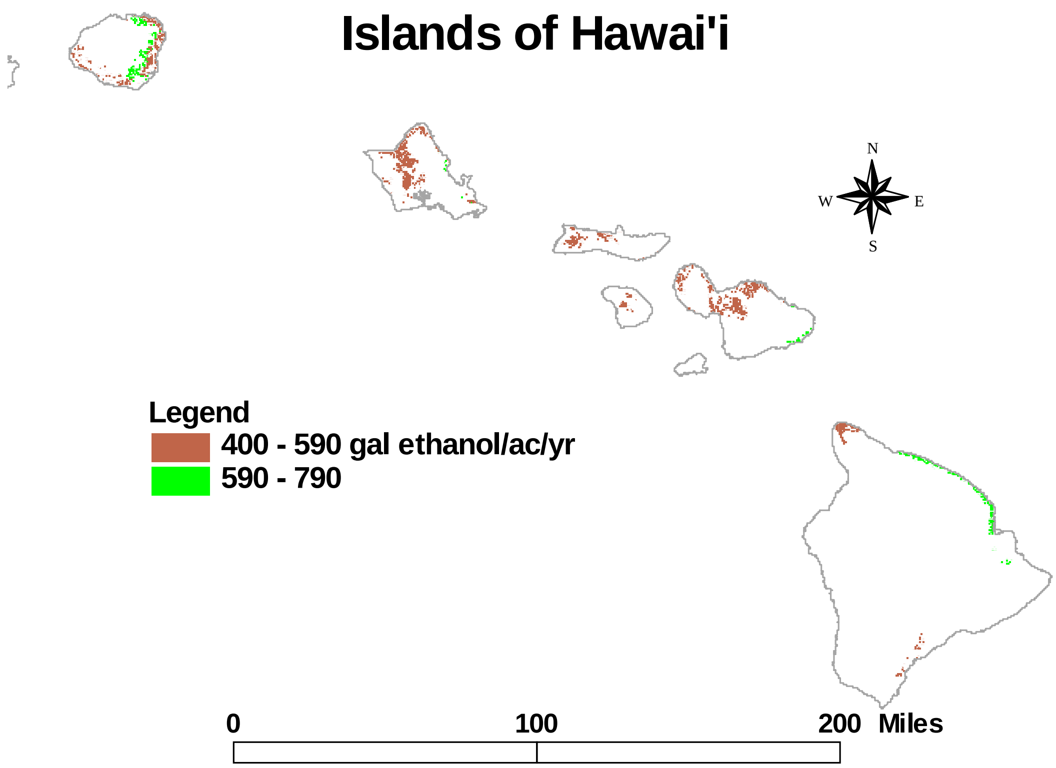

Fig. 52. Estimated ethanol yield from rain-fed sugarcane.

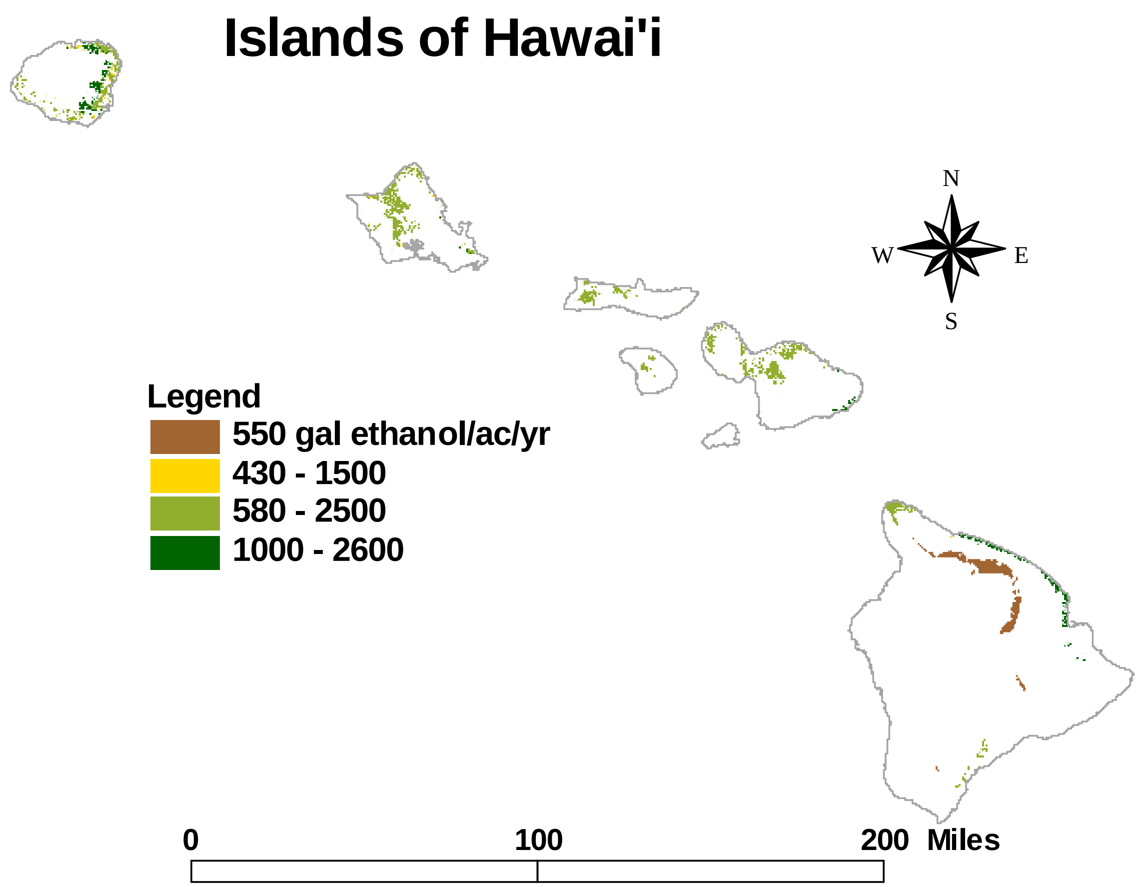

Fig. 53. Estimated ethanol yield from rain-fed banagrass.

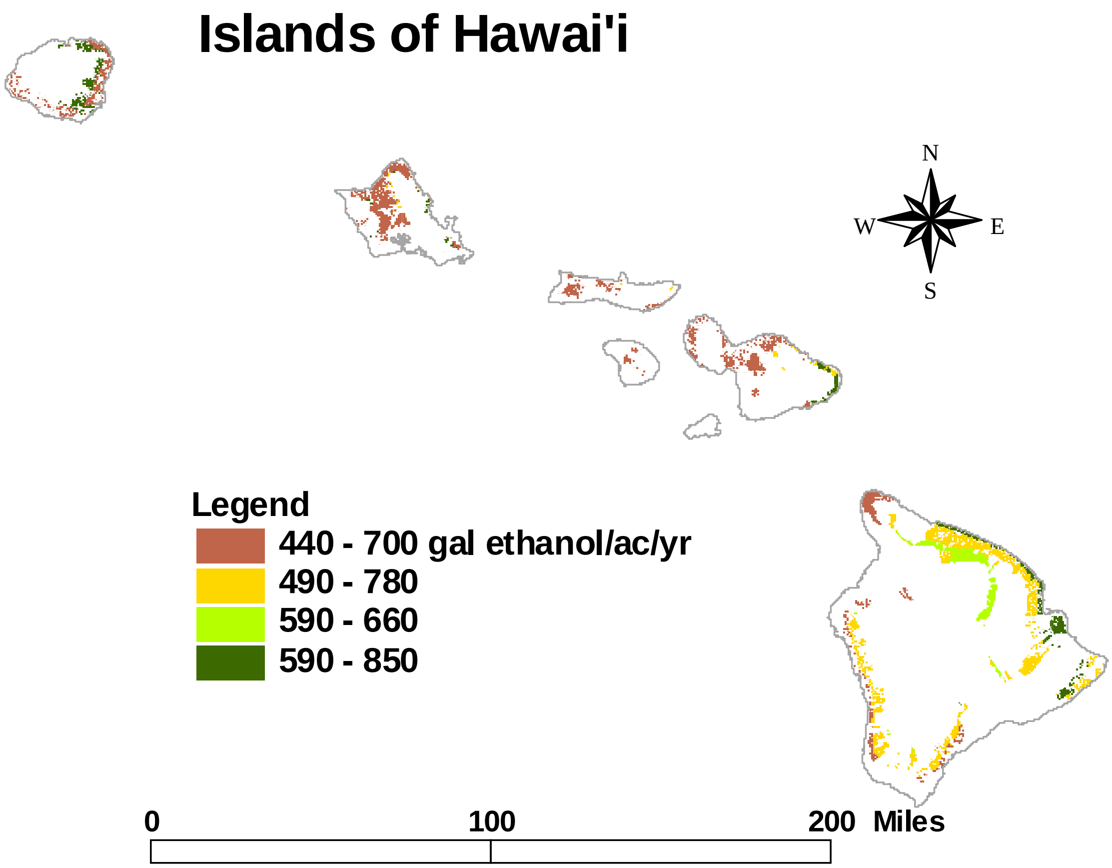

Fig. 54. Estimated ethanol yield from rain-fed *Eucalyptus*.

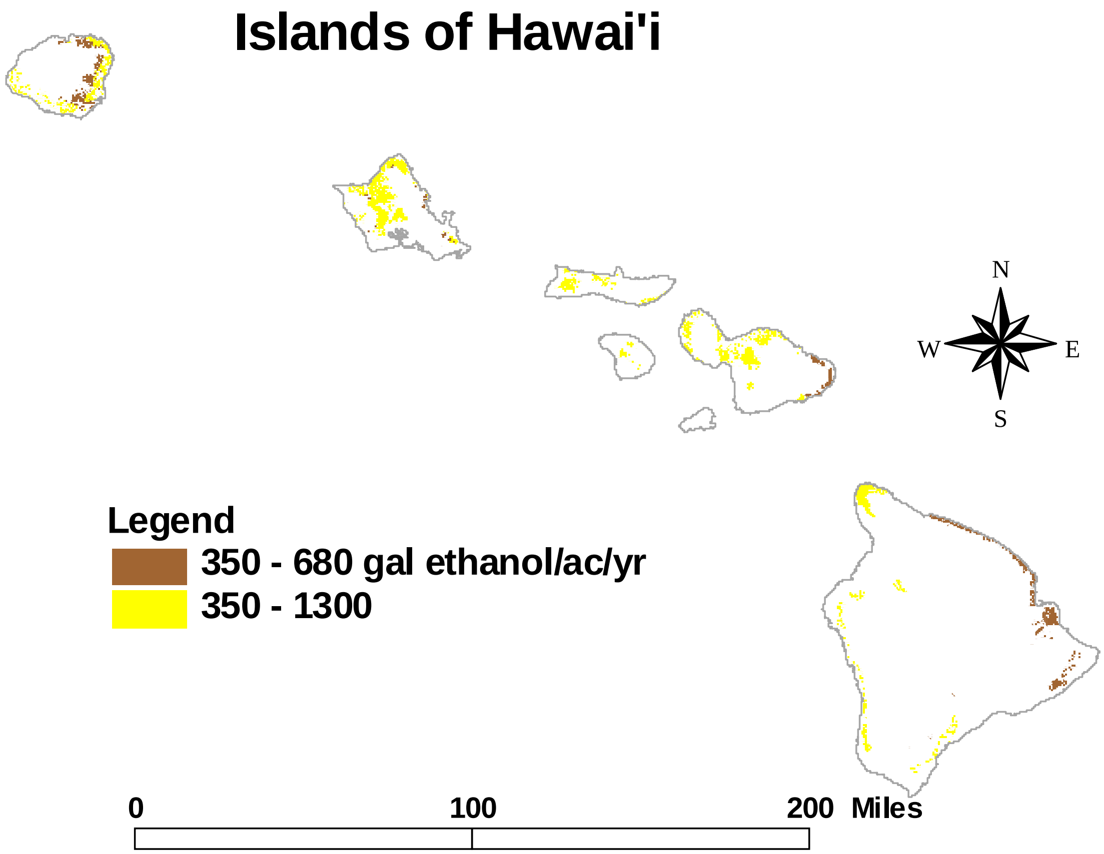

Fig. 55. Estimated ethanol yield from rain-fed *Leucaena*.

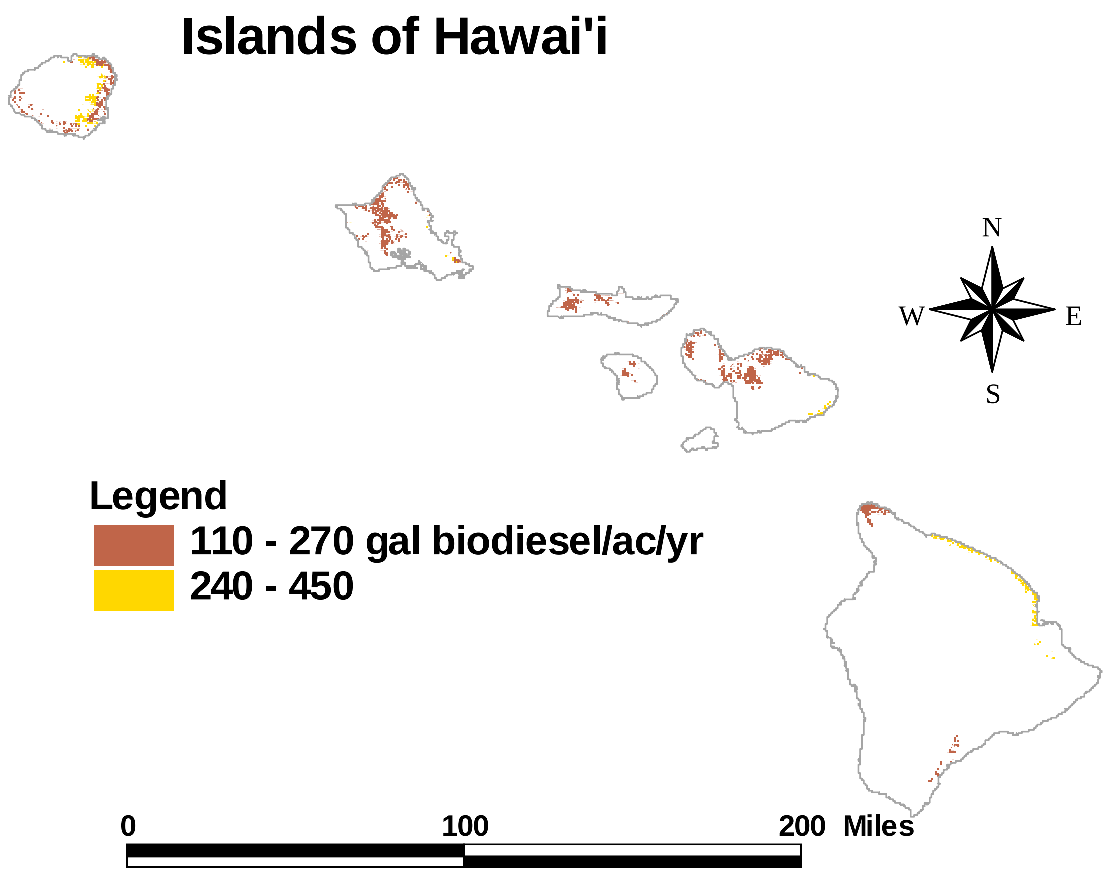

Fig. 56. Estimated biodiesel yield from rain-fed oil palm.

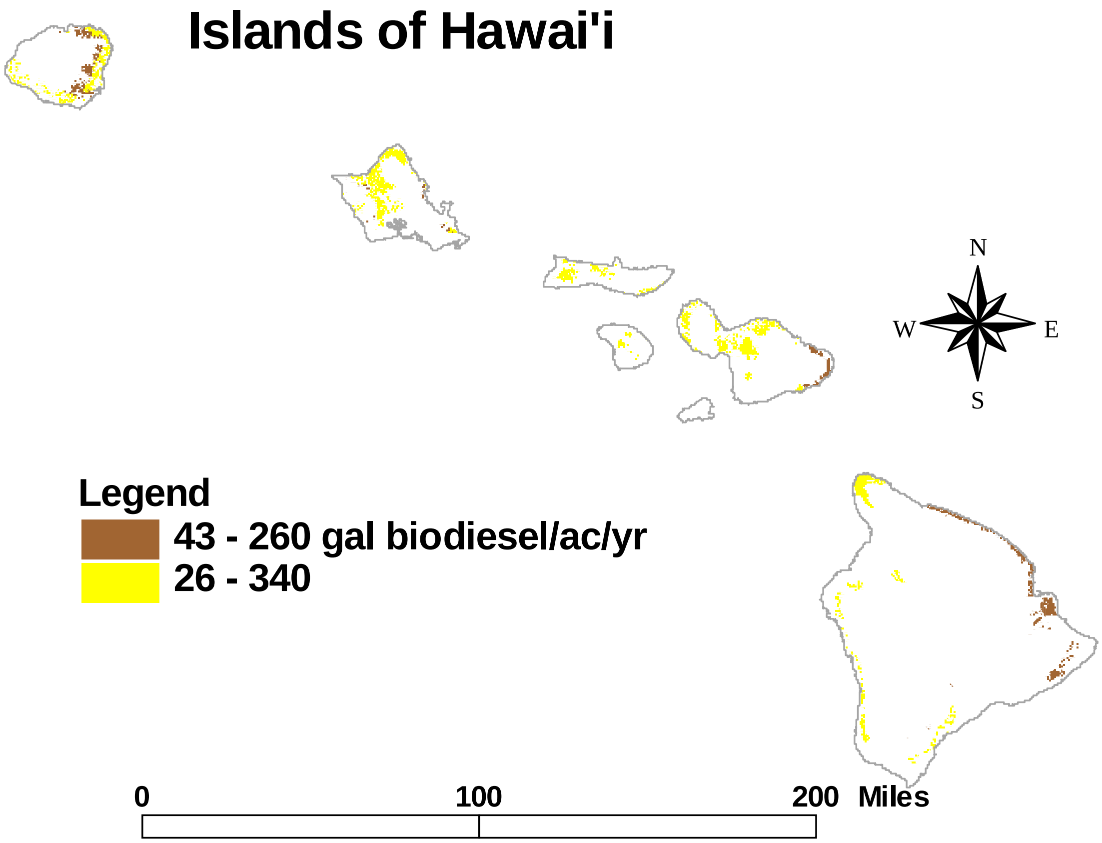

Fig. 57. Estimated biodiesel yield from rain-fed Jatropha.

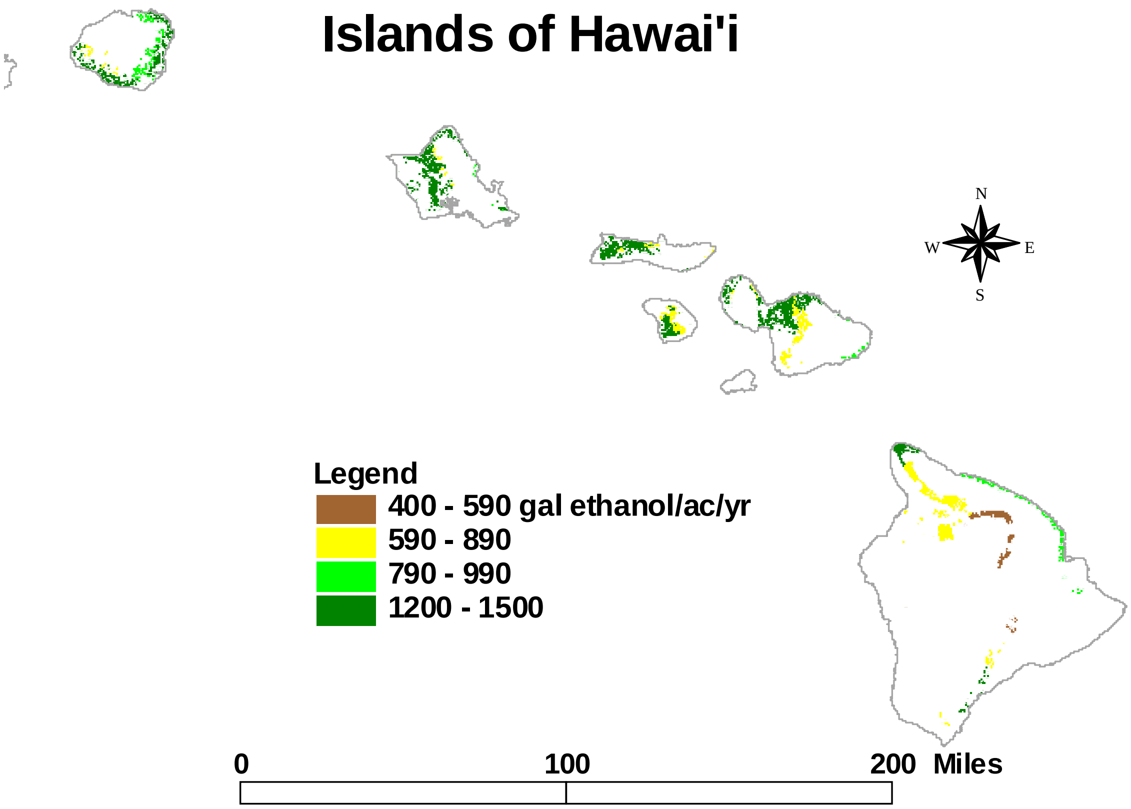

Fig. 58. Estimated ethanol yield from irrigated sugarcane.

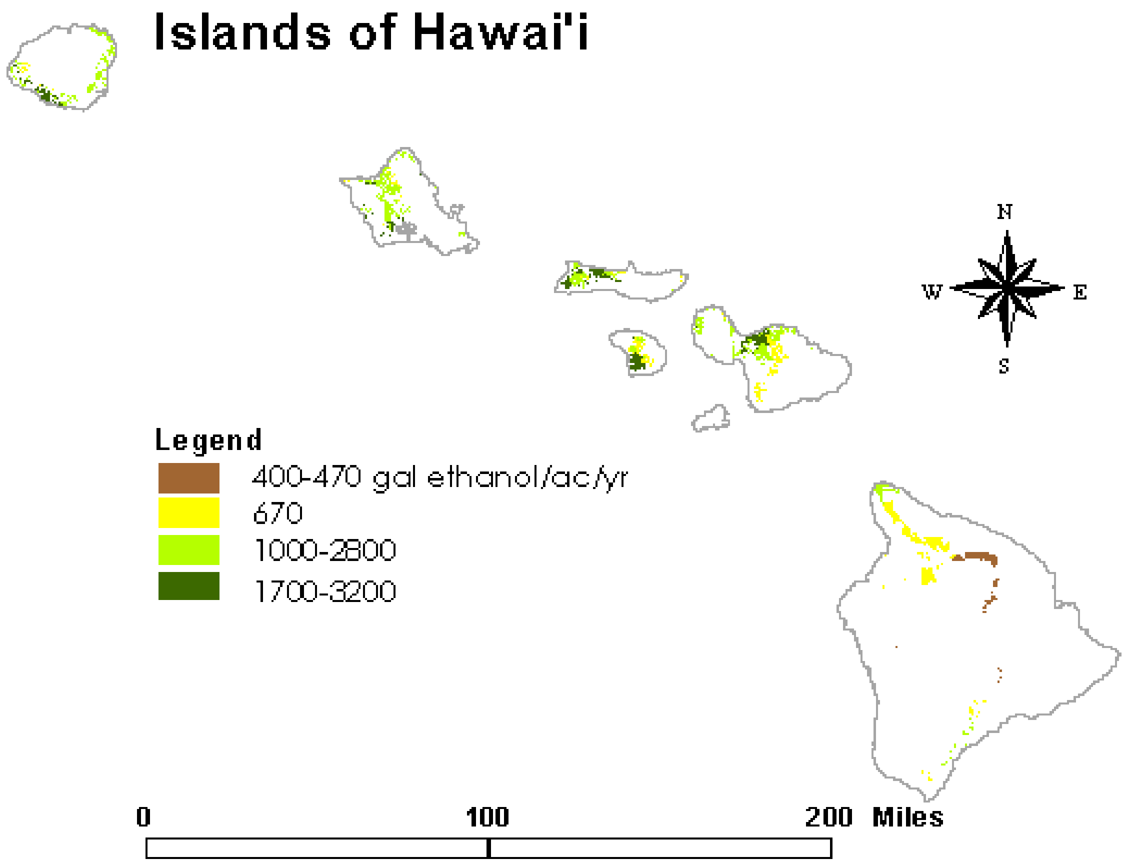

Fig. 59. Estimated ethanol yield from irrigated banagrass.

3.3.4 Biofuel Estimates from Feedstock Production

From the estimates of feedstock yield, biofuel production estimates can be made for the state. Major assumptions were made to perform this calculation and this is done only to determine whether there is a physical land constraint to reaching a fuel goal.

Biofuel production estimates were made for each crop under the assumption that all lands where yield estimates can be made are available and 15% of these lands are used for infrastructure such as roads and buildings. The state goal to replace 20% of liquid transportation fuel is 93.7 million gallons of ethanol or 103.7 million gallons of biodiesel per year.

The range of ethanol production that could be produced from rainfed sugarcane, banagrass, eucalyptus, and Leucaena are 71-110, 91-220, 230-350, and 93-370 million gallons ethanol per year, respectively. The range of biodiesel produced from rainfed oil palm and Jatropha are 22-50 and 8-78 million gallons per year.

3.3.5 Sites for Algae Production Based on Slope and Solar Radiation

Sites for possible algae production were selected based on solar radiation and slope of the land. The criteria include that the solar radiation should be greater than 4.65 kW hr/m^2/day or 400 cal/cm^2/day (Benemann et al., 1982) and slope should be no greater than 2% (Benemann et al., 1982; Lansford et al., 1990; Muhs, 2009). Lands that fit these two criteria were identified across the state (Fig. 60) with a total area of approximately 44,000 acres.

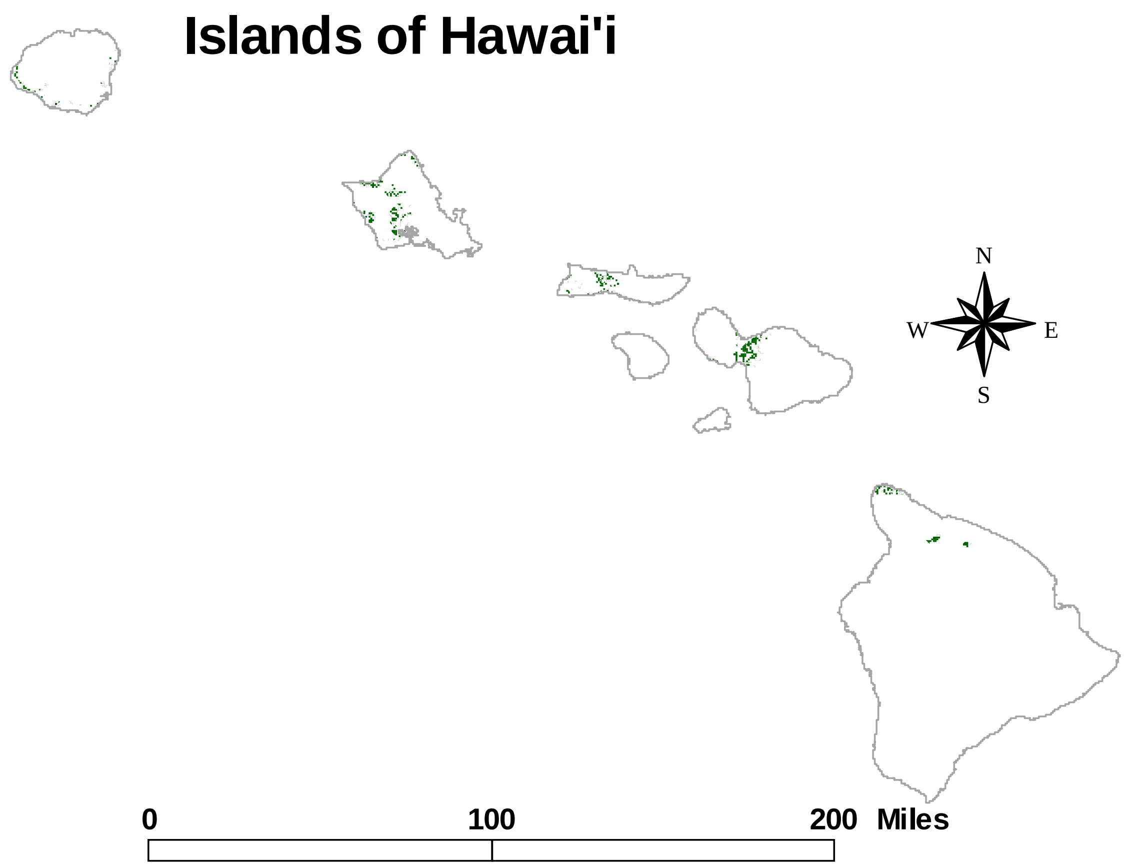

Fig. 60. Sites with adequate solar radiation and slope for algae production.

3.4 Potential for Bioenergy Production in Conjunction with Phytoremediation and Bioremediation Processes

The necessity to decontaminate polluted sites is recognized, because of the increasing importance placed on environmental protection and human health (DOH HEER, 2008). The need to develop effective and affordable methods for decontamination becomes more urgent as the number of sites and levels of contamination increases (Figs. E.1 through E.5 and Table E.1 of Appendix E). Phytoremediation describes the use of plants to mitigate the effects of contamination. There are four fundamental processes that make up phytoremediation: phytoimmobilization, phyto-stabilization, phyto-extraction and phyto-volatilization (Britt and Garstang, 2002). Phytoremediation is a low-cost option, particularly suited to large sites that have relatively low levels of contamination. Energy crops have the potential to utilize agricultural and municipal wastes, and to stabilize or clean up contaminated land. High yielding bioenergy crops offer good potential for the phytoremediation of sites contaminated with heavy metals (e.g., Britt and Garstang, 2002; Rockwood et al., 2006; Volk et al., 2006; Van Ginnenken et al., 2007). Different biomass crops, species and clones may show large differences in efficiency of heavy metal uptake. There can also be large differences in the concentration of metals in different plant parts.

A brief description of potential benefits and accompanying risks for bioenergy production in conjunction with phytoremediation and bioremediation processes is given by Britt and Garstang (2002). From the perspective of waste disposal/utilization, energy crops offer the following potential benefits:

- bioenergy crops are not going to enter the human food chain,
- bioenergy crops are mostly perennial crops, thus allowing long-term breakdown of organic matter in soils prior to converting to food cropping,
- bioenergy crops produce large quantities of biomass that, theoretically, require large quantities of nutrients, and thus are a waste nutrient sink.

From the perspective of bioremediation of contaminated sites, they offer the following potential solutions:

- bioenergy crops utilize land that would otherwise have no agricultural value,
- most bioenergy crops are non-food crops that will not enter the human food chain,
- bioenergy crops are perennial crops which may act as excluders of contaminants in the soil,
- alternatively, bioenergy crops may act as ‘tolerators’ of the contaminants, actively taking up the elements which, in some instances, can then be recovered during biomass combustion,
- bioenergy crops can also act as bioremediators of liquid leachates produced from rainfall onto landfill and other contaminated sites,
- in these situations, they may also act as recipients of agricultural and municipal wastes.

There are accompanying risks with the application of agricultural and municipal wastes and bioremediation. Possible risks include:

- risks of leaching nutrients applied in sludges into groundwater,
- risks of increased atmospheric emissions of greenhouse gases, associated with global warming,
- risks of contaminant accumulation in the production system, which are then emitted from power station stacks upon combustion of the biomass,
- negative impacts on the biodiversity associated with energy crops.

3.5 Resources and Constraints

The soils and climate in Hawaii are major resources for crop production. The soils of Hawaii are generally productive. The LCC identifies lands that are vulnerable to degradation, but these may be managed through appropriate crop selection and soil conserving practices. With careful consideration of these limitations, most lands can be productive. The climate in Hawaii is relatively mild and well suited for crop production. Temperature fluctuation over the course of a year usually does not vary more than 9 °F.

There are several limitations in this analysis:

- Crop performance of the six species is not known for all environments (temperature, moisture, soil depth) in the state. The yield for the dry/warm and cool, and moist/cool and cold environments are not known. These environments represent 574,000 acres.
- The crop list is limited. Other species that could be better suited to the environments may be missing.
- Yield data from crops such as Banagrass were derived from experimental plots which are usually higher than commercial production. Actual yield will vary from the reported values.
- Little is known about managing some of the crops. There is little experience with oil palm and Jatropha in Hawaii that could become problematic. For example, mechanical harvesters for Jatropha are being developed, but not well tested. Data for its efficiency and speed of harvesting is not well documented.
- ALISH lands were considered for feedstock production that becomes problematic in the food vs. fuel debate.
- Non-ALISH lands were not a major contributor to feedstock production because the majority of these lands have shallow soils that did not allow for yield estimation.
- Varieties are constantly being improved and yields will rise over time. This analysis will be obsolete in the near future.

4. AGRICULTURAL WATER USE FOR POTENTIAL BIOFUELS AND BIOMASS CROPS PRODUCTION

This section discusses agricultural water use for potential biofuels and biomass crops production. The information presented in this section is based on 10 irrigation systems studied for the 2008 NREM report (NREM, 2008).

4.1 Potential Irrigation Systems

The 2004 NREM report was developed to estimate current and future agricultural irrigation water demands for irrigation systems in the state of Hawaii. In this report, concepts, methodologies, and procedures were developed to produce 1) crop irrigation water duties at 10 irrigation systems, 2) state agricultural industry water projections under different scenarios, 3) water demand projections for 10 irrigation systems, 4) GIS maps and spatial analysis of the service and surrounding areas for 10 irrigation systems, 5) GIS maps for 11 previously unstudied irrigated areas identified in 2004 AWUDP report. The four main components of the 2008 NREM report were also used and documented in the analysis: 1) additional GIS analyses for 10 previously “studied” irrigation systems including potential for wastewater reuse; 2) a farm-level water use model and estimation of irrigation water requirements for selected crop categories at the 10 studied systems; 3) data collection and assessment of long-run agricultural potential at the 10 studied systems; and 4) projections of state agricultural irrigation water demand to the year 2030 by island and for the 10 studied systems, with assessment and preliminary projections for potential bioenergy crops.

GIS maps and acreage estimates of the 21 irrigation systems/areas are available in literature (AWUDP, 2004; NREM, 2008; Table 20). Fig. 61 shows the location of all systems covered in the 2004 and 2007 AWUDP studies and considered in this report.

Table 20 List of Irrigation Systems Covered in 2004 AWUDP and 2008 NREM Studies and Considered in the Present Analysis for Bioenergy Master Plan Water and Land Issues

No.	**Irrigation Systems/Areas (IS/IA)**	**AWUDP 2004***	**NREM 2008***	**Present Analysis**
1	Anahola Ditch IS	No	GIS	-
2	East Kauai IS (Kapaa-Kalepa)	Yes	Yes	Yes
3	East Maui IS	GIS	No	-
4	Kau Agribusiness IS	No	GIS	-
5	Kauai Coffee IS	GIS	Yes	Yes
6	Kawailoa IA	No	GIS	-
7	Kekaha IS	Yes	Yes	Yes
8	Kilauea IS	No	GIS	-
9	Kokee Ditch IS	Yes	No	-
10	Lihue-Koloa IA	No	GIS	-
11	Lower Hamakua Ditch IS	Yes	Yes	Yes
12	Maui Land & Pineapple/Pioneer Mill IS	Yes	No	-
13	Molokai IS	Yes	Yes	Yes
14	North Kohala IS	No	GIS	-
15	Olokele Ditch IS	No	GIS	-
16	Upcountry Maui IS (Olinda-Kula)	Yes	Yes	Yes
17	Waiahole Ditch IS	Yes	Yes	Yes
18	Waialua IA	No	GIS	-
19	Waimanalo IS	Yes	Yes	Yes
20	Waimea IS	Yes	Yes	Yes
21	West Maui IS (Wailuku)	GIS	Yes	Yes

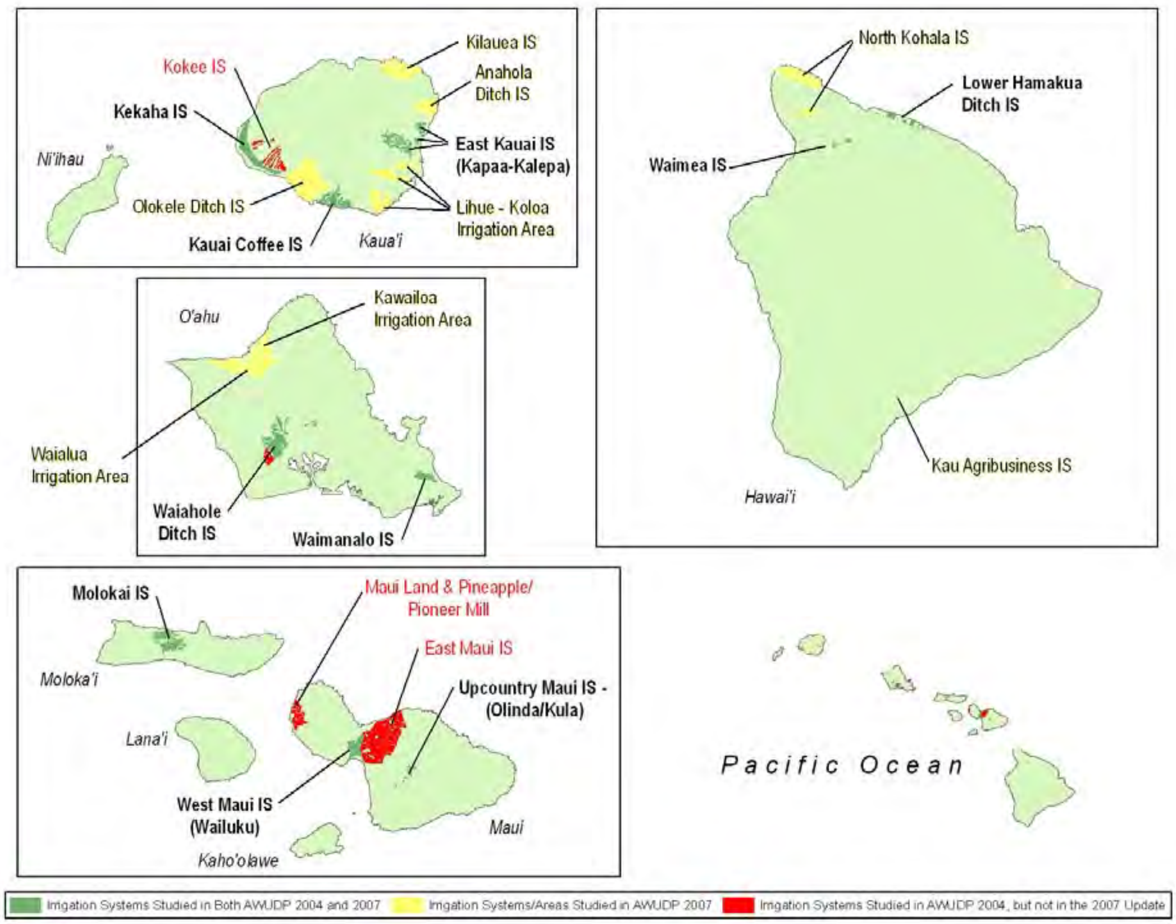

Fig. 61 Location of Irrigation Systems Covered by 2004 AWUDP and 2008 NREM Studies Studies and selected for Present Analysis for Bioenergy Master Plan Water and Land Issues (Source: NREM, 2008).

4.2 Agricultural Lands of Importance to the State of Hawaii (ALISH)

Three ALISH classes out of the four, “Prime Agricultural Lands,” “Unique Agricultural Lands,” and “Other Agricultural Lands,” were extracted from the ALISH GIS layer and were overlaid onto each of the 10 irrigation systems service areas in order to calculate the acreages for the 10 studied irrigation systems (Table 21).

Table 21 Estimated Acreage of ALISH Classes in the Studied Irrigation Systems (Units: 100 acres) (Source: NREM, 2008)

Irrigation System Name/ Service Area	Prime	Unique	Other	Total	In service area (%)
East Kauai (Kapaa-Kalepa)	50.1	–	5.0	55.1	93
Kauai Coffee	40.8	–	2.9	43.7	94
Kekaha	49.9	–	14.5	64.5	98
Waiahole Ditch	51.2	–	6.0	57.3	91
Waimanalo	11.6	–	3.6	15.2	96
Upcountry Maui (Olinda-Kula)	0.6	–	9.7	10.3	60
West Maui (Wailuku)	40.9	–	22.1	63.0	98
Molokai	74.1	–	3.6	77.8	79
Lower Hamakua Ditch	29.7	–	9.8	39.5	85
Waimea	10.3	–	2.1	12.4	91

4.3 Land Capability Classes (LCC)

The LCC system that groups soil series into 8 suitability classes provides an alternative assessment of land suitability for agriculture. Areas in the top two classes (I-II) do not have any serious conditions limiting agricultural use. Lands in the next two classes (III-IV) have one or more severe limitations but, with proper management practices, can still be utilized for some crops. Lower classes (V-VIII) are generally not suitable for growing crops but could be used for other purposes (e.g., grazing, woodland). Most soils are evaluated by LCC without and with irrigation. This provides one indicator of the importance of irrigation to an agricultural area. Most of soil series have been assigned a LCC class for both irrigated and non-irrigated conditions. Land Capability Class layers were added to the GIS database for the studied irrigation systems. LCC GIS layers were created for both irrigated and non-irrigated conditions in order to estimate, from overlay analyses, the acreages for non-irrigated and irrigated service areas (Tables 22 and 23).

Table 24 shows LCC classes suitable for crop cultivation in the system service areas. Four of the 10 systems (i.e., East Kauai, Waiahole, Waimanalo, Waimea) have significant acreage (>25%) in the top two classes for crop production without irrigation; however, a good majority of lands in all systems except Kekaha are in classes I-IV and suitable for agriculture. Irrigation water availability greatly increases top-rated lands for the systems on Kauai, Oahu, West Maui, and Molokai. A greater flexibility is thus available in selecting the type of bioenergy crops, while holding down the cost of inputs (irrigation water, conservation etc…). On the contrary, irrigation does not significantly improve cropland suitability at the two Big Island systems.

Table 22 Agricultural Land Suitability (LCC, Non-irrigated) Acreage Estimates for the 10 Studied Irrigation Systems (Units: 100 acres) (Source: NREM, 2008)

Irrigation System Name/ Service Area	East Kauai (Kapaa-Kalepa)	Kauai Coffee	Kekaha	Waiahole Ditch	Waimanalo	Upcountry Maui (Olinda-Kula)	West Maui (Wailuku)	Molokai	Lower Hamakua Ditch	Waimea
I	–	–	–	–	–	–	–	–	–	0.3
II	23.8	4.6	–	15.9	4.3	–	–	0.2	–	5.3
III	27.7	5.2	–	27.8	9.7	1	3.1	19.4	9.5	7.3
IV	4.1	33.7	26.3	16.2	0.4	12.4	37.9	45.2	19.7	–
V	0.1	–	18.1	–	–	–	–	–	–	–
VI	1	1.3	11.5	0.3	0.7	2.7	19.3	28.4	10.7	–
VII	2.1	1.1	–	2.3	0.5	1.1	4	4.3	6.4	0.5
VIII	0.4	0.6	0.4	0.1	<0.1	–	–	–	–	–
Un-classified	< 0.1	0.2	9.4	0.2	< 0.1	–	< 0.1	1.1	–	–

Table 23 Agricultural Land Suitability (LCC, Irrigated) Acreage Estimates for the 10 Studied Irrigation Systems (Units: 100 acres) (Source: NREM, 2008)

Irrigation System Name/ Service Area	East Kauai (Kappa-Kalepa)	Kauai Coffee	Kekaha	Waiahole Ditch	Waimanalo	Upcountry Maui (Olinda-Kula)	West Maui (Wailuku)	Molokai	Lower Hamakua Ditch	Waimea
I	–	< 0.1	24.4	23.1	0.1	–	21.2	23.2	–	5.3
II	23.9	28.1	2	27	10.6	–	19.9	44.1	–	–
III	8	12.8	25.7	6.3	0.2	1	–	15.5	7.6	7.3
IV	1.9	2.7	3.5	3.3	0.3	11.4	19.1	4.7	13.1	–
V	–	–	–	–	–	–	–	–	–	–
VI	0.2	0.7	–	0.1	–	–	–	3.8	7.6	–
VII	–	–	–	–	–	–	–	–	–	–
VIII	–	–	–	–	–	–	–	–	–	–
Un-classified	25.2	2.3	10.1	2.8	4.5	4.8	4	7.4	18	0.8

Table 24 Agricultural Land Suitability (LCC) for 10 Studied Irrigation Systems, without and with Irrigation (Source: NREM, 2008).

Irrigation System	Irrigation	Percent Area Classified LCC class I-II	LCC class III-IV
Waimea	with	40.8	56.7
	Without	40.6	53.4
L. Hamakua	with	0.0	72.2
	Without	0.0	62.6
Molokai	with	73.6	22.1
	Without	0.2	66.1
W. Maui	with	68.3	31.7
	Without	0.0	63.8
Upcnty Maui	with	0.0	100.0
	Without	0.0	77.9
Waimanalo	with	94.7	4.2
	Without	27.3	64.3
Waiahole	with	83.7	16.1
	Without	25.4	70.3
Kekaha	with	47.4	52.5
	Without	0.0	46.8
Kauai Coffee	with	63.5	35.0
	Without	9.8	83.9
East Kauai	with	70.3	29.2
	Without	40.2	53.8

For general crop type assessment, the NREM report provided an analysis of land cover/land use maps by classifying fine-resolution Emerge and/or IKONOS remotely-sensed images (NREM, 2008). The images were segmented and classified based on their colors and texture characteristics. Ground truthing was conducted to identify the land use types in the region. Table 25 summarizes acreage estimates of general land use types. Acreages for the five classes were calculated, including cultivated, grazing, cultivable, non-cultivable, and non-irrigable (areas that are unlikely to be used for any agricultural activities, e.g., cliffs, gullies, rock outcrops, residential areas, etc).

Table 25 Acreage Estimates of General Crop Types for the 10 Studied Irrigation Systems (Units: 100 acres) (Source: NREM, 2008)

Irrigation System Name/ Service Area	East Kauai (Kappa-Kalepa)	Kauai Coffee	Kekaha	Waiahole Ditch	Waimanalo	Upcountry Maui (Olinda-Kula)	West Maui (Wailuku)	Molokai	Lower Hamakua Ditch	Waimea
Cultivated	15.3	39	65.2	40	8.1	4	63.2	26.7	3.1	7.4
Grazing	43.8	4.9	–	–	1.1	2.5	–	6.8	36.7	5.7
Cultivable	–	–	–	18.8	5.2	8	0.1	57.9	2.4	< 0.1
Non-cultivable	–	–	–	0.5	0.2	0.2	< 0.1	5.8	–	–
Non-irrigable	0.2	2.8	0.5	3.4	1.2	2.5	0.9	1.6	4.5	0.5

"Cultivable" were areas that were not currently used for any agricultural activities, including forested areas, rangelands (shrublands), and abandoned areas. If an area (or a segment) was not identified either "cultivated", "grazing", or "cultivable", it was classified as "non-cultivable". "Non-irrigable" was defined as areas that are unlikely to be used for any agricultural activities, e.g., cliffs, gullies, rock outcrops, residential areas, etc.

4.4 Wastewater Reuse Potential for the 10 Irrigation Systems

The 2008 NREM report included assessment of potential wastewater reclamation and reuse sources for irrigation water for the service areas of the 10 studied systems (Table 26). Lists of the state-owned wastewater recycling facilities (WWRFs) and quality of their recycled water, their capacity, and their potential for agricultural irrigation were assessed by linear, horizontal distance divided into five classes, e.g., 0.25, 0.5, 1, 2, and 4 miles, and a series of buffer zones corresponding to these distances. Government-owned wastewater treatment plants (excluding Waianae) have a potential to supply approximately 47 MGD of the treated water, which is 25% of current water use (190.5 MGD in Table 2) at the 10 studied irrigation systems. Hawaii State Department of Health (Hawaii DOH, 2002) classifies recycled water based on the level of treatment: R-3, secondary treatment without disinfection; R-2, secondary treatment with disinfection; R-1, tertiary treatment; and RO, reverse osmosis treatment.

Table 26 State-owned Wastewater Recycling Facilities (WWRFs) and Their Potential for Agricultural Irrigation in the Service Areas (S.A.) of the 10 Studied Irrigation Systems (Sources: NREM, 2008)

Facility	**Quality**	**Capacity (MGD)**§	**Potential S.A.**
Lihu‘e WWRF (County of Kauai)	R-2	2.4 (2.4)	East Kauai IS (Kapaa-Kalepa)
Waimea WWRF (County of Kauai)	R-2	0.3 (0.3)	Kekaha iS
Wailua WWRF (Country of Kauai)	R-2	1.0-1.2 (1.5)	East Kauai IS (Kapaa-Kalepa)
Wahiawa WWRF (C & C Honolulu)	R-2 (R-1)*	2.0 (n/a)	Waiahole Ditch IS
Schofield Barracks WWRF, Army	R-1	1.6 (n/a)	Waiahole Ditch IS
Honouliuli WWRF (C & C Honolulu)	R-1/RO	12 / 2 (n/a)	Waiahole Ditch IS
Waianae WWRF (C & C Honolulu)	R-1 (planned)	(planned)	–
Kaunakakai WWRF (County of Maui)	R-2	0.008 (3)	Molokai IS
Kihei WWRF (County of Maui)	R-1	4.8† (8)	–
Lahaina WWRF (County of Maui)	R-1	4.9† (9)	–
Wailuku-Kahului WWRF (County of Maui)	R-2	5 (7.8)	West Maui IS (Wailuku)

§ The numbers in parentheses are the maximum dry weather capacity. * Wahiawa WWRF produces “R-1 like” R-2 reclaimed water; however, it does not qualify as an R-1 system (CWRM, 2005). The actual reuse amounts of reclaimed water are seasonally highly variable in these WWRFs.

4.5 Additional Irrigation Systems

NREM (2008) research team identified another 11 irrigated areas and added to the GIS database. Acreage estimates of the potential service areas of the 11 irrigation systems are presented in Table 27. In brief, these potential service areas were derived based on (1) land ownerships (current or inherited from former sugarcane companies), (2) elevation (since most of the irrigation systems are gravity-fed), (3) current land use, and (4) historical spatial extent and distribution of sugarcane fields. As shown in Table 23, a total of 69,700 acres of potential unstudied service areas was estimated, excluding the Kau system for which little information is available.

Table 27 Unstudied Irrigation Systems (Source: NREM, 2008)

System Name	**Former Plantation**	**Ditches**	**Potential Service Area,** 1,000 ac.
Kilauea IS	Kilauea Sugar	Kaloko & Puu Ka Ele	7.9
Anahola Ditch IS	Lihue Plantation	Anahola	4.3
Lihue-Koloa IA	Lihue Plantation Grove Farm Koloa Plantation	Upper & Lower Lihue Upper & Lower Haiku Waiahi-Kuia (Aqueduct) Koloa-Wilcox	10.9
Olokele Ditch IS	Olokele Sugar	Olokele-Koula	16.0
Waialua IA	Waialua Sugar	Wahiawa, Helemano, Tanada, & Ito	8.3
Kawailoa IA	Waialua Sugar	Opaeula & Kamananui	4.8
North Kohala IS	Kohala Sugar	Kohala & Kehena	17.5
Kau Agribusiness IS	Kau Sugar	n/a	n/a
		total	**69.7**

4.6 Crop Irrigation Water Duties

The (gross) irrigation water requirements (*IRR*) were determined for the highest value (including bioenergy) crops grown in Hawaii in the 10 selected irrigation systems located on major Islands of Hawaii using available historical climate data, soil physical properties, crop-specific water use coefficients, and average growing period of the crop (NREM, 2008). The *IRR* were calculated based on a daily water budget approach, which is formulated as water inputs (rainfall and irrigation) minus water outputs (runoff, crop evapotranspiration, and deep percolation or drainage) which equals change in the water storage in the root zone. Calculation for *IRR* in the NREM report included i) obtaining historical daily rainfall and reference crop evapotranspiration data for at least one location per system for each of the 10 systems, ii). potential evapotranspiration (ET_O) from daily pan evaporation measurements, iii) calculating reference crop (ET_C) by multiplying crop coefficient (K_C) with ET_O, iv) calculating surface runoff (Q_R) using the Soil Conservation Service (SCS) curve number method and daily rainfall data, and v) calculating drainage (Q_D) during daily water budget calculations as any amount of water exceeding field capacity after the soil water redistribution process ends. Subsequently *IRR*, the only unknown in the water budget approach, was calculated for each day of the historical climate data period. This followed performing a statistical analysis on the calculated long-term historical daily *IRR* data set to obtain seasonal or annual average, maximum, and minimum irrigation requirements.

4.6.1. Water Budget Approach

The daily water balance equation for the soil column (defined by the crop root zone expressed in terms of equivalent water depth per unit area) is:

$$\Delta S = P + G + IRR_{net} - (Q_D + Q_R + ET_c) \qquad (1)$$

where ΔS is the change in soil water storage expressed as equivalent water depth (inches), P is rainfall, G is groundwater contribution, and IRR_{net} is net irrigation requirements. The water storage capacity (S) is amount of water that is available for plant uptake and is calculated as the equivalent water between field capacity and permanent wilting point for a given soil multiplied by the depth of the root zone. Irrigations were assumed to start when the available water for plant uptake decreased to a predetermined minimum allowable level, which is termed as allowable soil water depletion (AWD) percentage. The AWD values were determined from the literature and are fractions of the available soil water storage capacity in the crop root zone which can be allowed to be depleted without significant reduction of crop yield. The AWD values for the annual crops used in this study are given in Table 28. An AWD value of 0.50 was used for all perennial crops. A value of 0.50 means that 50% of the available water in the irrigated crop root zone is allowed to be depleted between two consecutive irrigation events.

Irrigation is intended to replenish the water content in the root zone to reach field capacity (Fares, 2008). The gross irrigation requirement (*IRR*) was calculated for each crop using the following equation, which is derived from Equation 1:

$$IRR = \frac{\Delta S + ET_c - (P - Q_R - Q_D)}{f_i} \tag{2}$$

where f_i is the irrigation efficiency. The values of ET_C used in Equation 2 were calculated using long term historical daily ET_O values, which were calculated using historical pan evaporation data or 1985 Hargreaves equation (Hargreaves and Samani, 1985). The Hargreaves equation uses historical daily maximum and minimum temperatures.

The values of K_C used for annual and perennial bioenergy crops are listed in Tables 28 and 29, respectively. Perennial crops differ from annuals in that K_C values are primarily determined by annual reproductive cycles and are calculated monthly. Table 28 also lists a range of initial to final root depths of the selected crops.

Table 28 Effective root depth, Kc values, irrigation type, and efficiency of irrigation systems for annual bioenergy crop (Source: NREM, 2008)

Crop	Root depth (in)	$Kc_{initial}$	Kc_{mid}	Kc_{late}	Irrigation type	Irrigation efficiency (%)
Banagrass (Sudan), 1st cut	18-36	0.5	0.9	0.85	Drip	85
Banagrass (Sudan), 2nd cut	36	0.5	1.15	1.1	Drip	85
Seed Corn	12-18	0.4	1.2	0.5	Drip	85
Sugarcane, New- year 1	18-36	0.4	1.25	1.25	Drip	85
Sugarcane, New- year 2	36	1.25	1.25	0.75	Drip	85
Sugarcane, ratoon	36	0.4	1.25	0.75	Drip	85
Sweet potato	8-12	0.5	1.15	0.65	Drip	85

Table 29 Effective root depth, monthly Kc values, irrigation type, and efficiency of irrigation systems for perennial bioenergy crops (Source: NREM, 2008)

Crop	Root depth (in)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Irrigation type	Irrigation efficiency (%)
Eucalyptus closed canopy	72	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	Micro spray	80
Eucalyptus young	48-72	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	Micro spray	80
Leuceana (Old)	72	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	Micro spray	80
Leuceana (Young)	48-72	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	Micro spray	80

4.6.2. Historical Climate Data for Irrigation Requirement Calculations

Long-term daily rainfall data were obtained for stations within each system from the National Climate Data Center (NCDC), except Kunia substation rainfall data (Waiahole system) that was obtained from the Hawaii Agriculture Research Center (NREM, 2008). The data set of the Hawaii Agriculture Research Center or of Ekhern and Chang (1985) were used in preference to the online database because it was accompanied with simultaneous measurements of daily pan-evaporation (*PE*), which was used to determine ET_O using the formula $ET_O = PE \times K_P$, where K_P is a pan coefficient. Actual value of K_P for tropical areas ranges between 0.60 and 1.1 depending on season and location, with a mean value close to 0.80 across these variables (Harmsen et al., 2003; Pereira et al, 1995; Sumner and Jacobs, 2005). Because extensive climate data was not available to adjust K_P to site specific conditions, a K_P value of 0.8 was used across systems. Reliable pan evaporation data was unavailable for the Waimanalo and Upcountry systems. Therefore, the 1985 Hargreaves equation and long term historical daily temperature data for these systems were used for ET_O calculations (Appendix F).

Climatic information for the stations within each system (Appendix F; Figures F.1 through F.4) is given in Table 30. Waimea, Waiahole, Upcountry and Kekaha systems receive the lowest annual rainfall per annum (i.e., 17, 21, 24, and 25 inches, respectively); whereas the Lower Hamakua and East Kauai systems receive the highest rainfall (i.e., 95 and 74 inches, respectively). Values of ET_O range from 47 to 94 inches and are less variable compared with variations rainfall data that range from 17 to 94 inches per annum. Because of greater annual rainfall than water losses through ET_O, the Lower Hamakua and East Kauai systems have clear water excess as they receive an excess of 31 and 18 inches of rainfall, respectively.

Table 30 Climate stations and characteristics of the 10 studied irrigation systems (Source: NREM, 2008)

				------------------Rain-----------------			--------------------ET------------------		
System	**Station**	**Map ID (Appendix F)**	**State Key Number**	**Years of record**	**Period**	**Annual mean, (in)**	**Years of record**	**Period**	**Annual mean, (in)**
Kekaha	Mana	1	1026.0	45	1950-1995	28.4	4	1962-83	60.3
Kekaha	Kekaha	2	944.0	48	1950-1999	21.3	9	1960-83	58.9
Kauai Coffee	Wahiawa	3	930.0	54	1950-2004	35.3	15	1960-83	67.2
Kauai Coffee	McBryde Station (ET)	4	986.1	0	--	--	16	1960-83	62.5
Kauai Coffee	Bydswood Station (rain)	5	985	50	1952-2004	59.2	0	--	--
East Kauai	Lihue Variety Station	6	1062.1	36	1964-1999	73.5	11	1965-83	54.8
Waiahole	Kunia Substation	7	740.5	10	1994-2005	20.8	9	1994-2005	57
Waimanalo	Waimanalo Experiment Station	8	795.1	29	1970-2000	42.5	31	1970-2000	47.5
Molokai	Kualapuu Res. (ET)	9	531.1	0	--	--	11	1970-1984	94.2
Molokai	Kualapuu (rain)	10	534.0	26	1950-1977	33.8	0	--	--
West Maui	Pohakea Bridge (Rain)	11	307.2	40	1950-2004	19.4	0	--	--
West Maui	Field 906 (ET)	12	310.1	0	--	--	19	1962-83	77.7
Upcountry	Kula Branch	13	324.5	24	1979-2005	23.8	23	1979-2005	49.5
Waimea	Lalaumilo Field Office	14	191.1	23	1981-2004	16.9	4	1976-84	51.4
Lower Hamakua	Hamakua Makai	15	221.3	0	--	--	15	1964-1982	63.7
Lower Hamakua	Paauilo	16	221.0	55	1950-2005	94.9	0	--	--

4.6.3. Soil

Representative soil series, textures, and water-holding capacities, soil thicknesses, and water table depths for each system are given in Table 31, as identified from the USDA Soil Survey of the State of Hawaii and supporting documents (USDA, 1972; USDA, 1979). The water storage capacity within in the crop root zone was defined as the product of the soil water-holding capacity of the soil and the depth of the effective root zone for annual (Table 28) and perennial (Table 29) crops. Field capacity (FC) is defined as the volumetric water content retained in the soil at a soil water potential of -10 centibars (cb). Permanent wilting point (PWP) is the soil water potential beyond which a crop cannot extract water and dies, and is defined as the volumetric water content retained in the soil at a water potential of -15 bars (Smajstrla, 1990). Available soil water capacity is defined as the difference between FC and PWP.

Table 31 Representative soils for each of the 10 irrigation systems (Source: NREM, 2008)

Station	Irrigation Systems	Soil series	Soil Water holding capacity (in/in)	Soil Texture
Lihue Variety	East Kauai	Kapaa	0.14	Silty clay
Wahiawa	Kauai Coffee	Makaweli	0.15	Stony silty clay loam
Brydswood	Kauai Coffee	Koloa	0.11	Stony silty clay
Kekaha	Kekaha	Kekaha	0.105	Silty clay
Mana	Kekaha	Lualualei	0.115	Clay
Kunia.Sub	Waiahole	Kunia	0.13	Silty clay
Wai.Exp.Sta	Waimanalo	Waialua	0.14	Silty clay
Kaunakakai	Molokai	Molokai	0.12	Silty clay loam
Pohakea	West Maui	Pelehu/Jaucas	0.13 / 0.04-0.05	Clay loam / Sand
Kula	Upcountry	Kula	0.14	Loam
Lalaumilo	Waimea	Waimea	0.14 at 0-50 in 0.02 at 50-90in	Very fine sandy loam
Paauilo	Lower Hamakua	Paauhau	0.14 at 0-50 in 0.06 at 50-90 in	Silty clay loam

0-50 or 50-90 in are the soil depths.

4.6.4. Surface Runoff

Value of Q_R used in Equation 2 was calculated using SCS curve number method which uses P and S values as:

$$Q_R = \frac{(P - 0.2S)^2}{P + 0.8S} \tag{3}$$

Potential maximum water retention (S) is related to curve number (CN), which is a measure of the imperviousness of a surface, and is calculated as:

$$S = \frac{1000}{CN} - 10 \tag{6}$$

Hydrologic soil groups and land use type are used to determine CN. The value of CN for impervious and water surfaces is 100 and for natural surfaces is always less than 100. For the systems considered in this report, the hydrological soil groups are in group C., A *CN* value of 78 was chosen for the *IRR* calculations based on cultivated land and a group C hydrologic soil.

4.6.5. Irrigation System Types

Irrigation systems, such as drip and micro-sprinkler were considered for calculating irrigation requirements for most crops. For drip, micro-sprinkler irrigation systems, the system efficiency (f_i) was assumed to be 85 and 80%, respectively (Tables 28 and 29).

4.6.6. Irrigation Losses

The calculated values of *IRR* were divided by f_i in order to add irrigation losses to irrigation requirements; however, water losses due to conveyance losses were not included in the calculations. In US, the conveyance losses vary from 30% to 50% with the average of 41% (Bos and Nugteren, 1990). Therefore, losses depend on the type and quality of conveyance properties of on farm site specific irrigation systems, a conveyance efficiency factor can be considered to incorporate conveyance losses. Conveyance efficiency in pressurized closed conduits may be nearly 100% but it may be quite low in open surface irrigation channels and ditches.

4.6.7. Irrigation Requirement Calculation Procedure

Based on the procedures reported in NREM (2008), the following steps were followed to calculate *IRR* and other water budget components for each bioenergy crop type for each irrigation system:

1. Long term historical daily rainfall and ET_O values were obtained for each station. ET_O was estimated from pan evaporation records or the 1985 Hargreaves equation using daily maximum and minimum temperature records.
2. Daily surface runoff was calculated by SCS curve number method with historical daily rainfall data
3. Net rainfall (P_{net}) was calculated by subtracting runoff from measured rainfall. P_{net} is the portion of rainfall infiltrates to ground surface for crop use.
4. ET_C was calculated by multiplying K_C with ET_O. The value of K_C changes with growing stage of crop.
5. Historical daily *IRR* were calculated using water budget approach.
6. Statistical analysis was performed on the calculated *IRR* data set. Mean, maximum and minimum values, median, and coefficient of variation of the *IRR* were calculated. Finally these daily values were summed along the growth season of each crop to obtain weekly, monthly, seasonal, or annual *IRR* values.
7. Along the *IRR* values and its statistics for each crop, other water budget components (i.e., net rainfall, runoff, drainage, and crop *ET*) are also calculated for each crop in each system.
8. The calculated *IRR* data set was fitted to Type I Extreme Value Distribution for positive non-zero irrigation values using the least square curve fitting method to determine the *IRR* values having non-exceedance probabilities of 50%, 80%, and 90%, which correspond to the average climate year, 1 in 5, and 1 in 10 year drought conditions, respectively. These probabilities of occurrences of *IRR* are not presented in this report whereas only the mean, maximum and minimum *IRR* values are presented.

4.7 Bioenergy Crop Irrigation Requirement

The *IRR* values for each bioenergy crop type in each irrigation system are shown in Figs. 62 through 85. Predicted hydrologic components of seasonal water requirements for bioenergy crops for each irrigation systems are also tabulated in Appendix G (Tables G.1 through G.12). The hydrological components include minimum, maximum, and average IRR values for each bioenergy crop together with net rainfall, runoff, drainage, and crop ET. Bioenergy crops include corn, sugarcane, banagrass, and *Leucaena*. Sudan grass and *Eucalyptus* were used to calculate *IRR* requirements for banagrass and *Leucaena*, respectively.

Basic components that affect irrigation requirements of a crop include temporal and spatial variability in rainfall and the planting periods for the crops. Because of the variable rainfall (both temporal and spatial) across the Hawaiian Islands, the calculated *IRR* demands vary for the irrigation systems even within the same island. Areas in the Hawaiian Islands are hydrologically characterized as windward and leeward with the windward receiving significantly more rainfall. As a result, windward areas need less *IRR*. Windward areas such as Waimanalo, East Kauai, and Lower Hamakua, require less irrigation for their crops, due to their higher rainfall, compared to leeward areas such as Molokai, West Maui and Waiahole.

Crop growing seasons also affect *IRR* values; such that crops grown during October through February require less water as this period falls under wet season. Crop grown during dry season (April to August) require more *IRR* because of more crop consumptive use (evapotranspiration). For Waimea, Waiahole, Upcountry and Kekaha systems where average annual rainfall values are less (i.e., 17, 21, 24, and 25 inches, respectively), the *IRR* values are generally the highest for all crops. Similarly, for East Kauai and Lower Hamakua systems where average annual rainfall values are high (i.e., 95 and 74 inches, respectively), the *IRR* values are the lowest for all crops. The Lower Hamakua and East Kauai systems have clear water excess as they receive more annual rainfall than water losses through *ET* (31 and 15 inches more, respectively). Multiple annual crops can be grown within a span of one year in the same location by determining which of the crop needs less water and which needs more. The crop requiring more water can be grown during the wet season to reduce the amount of water usage while the crop with lesser *IRR* can be grown during the dry season.

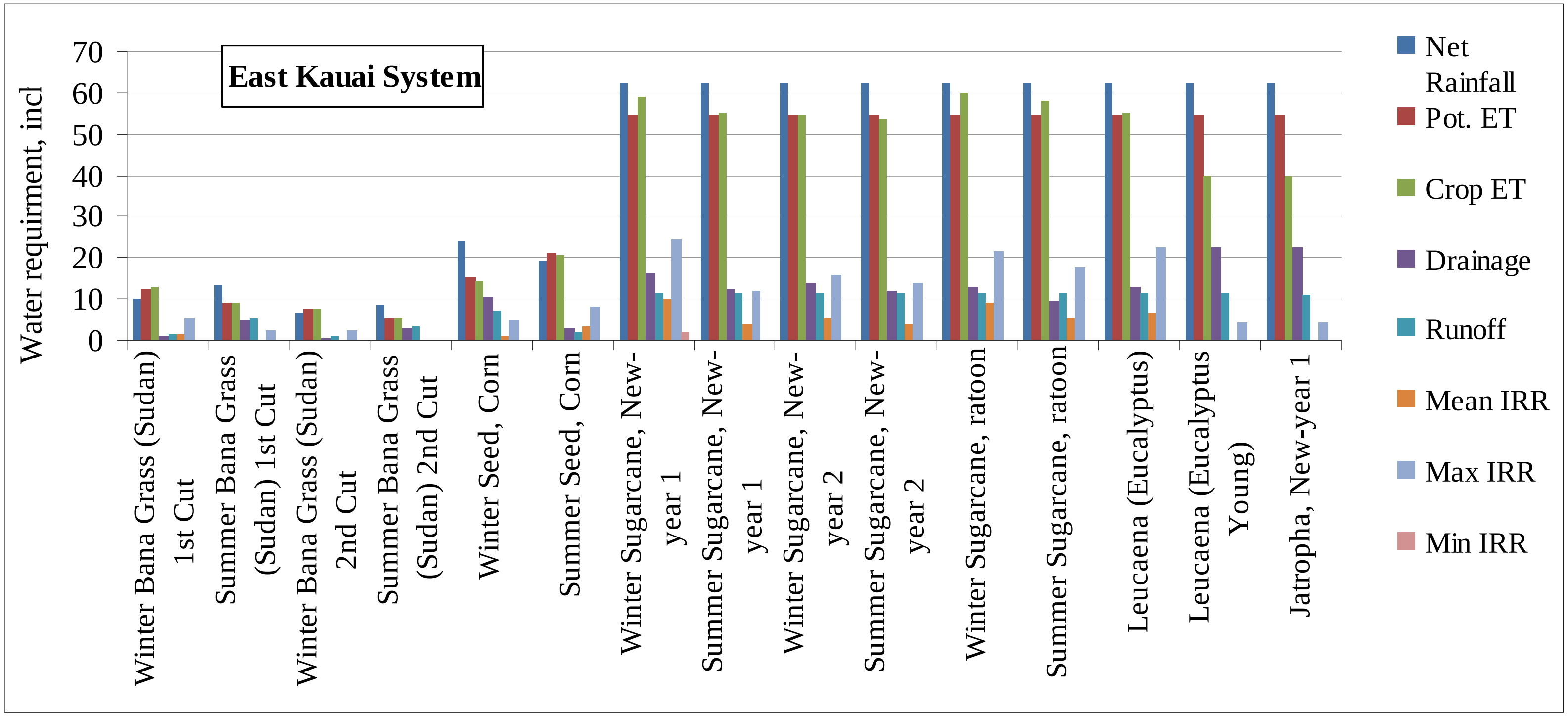

Fig. 62 Predicted hydrologic components of seasonal water requirements for bioenergy crops in East Kauai irrigation system (Data source: NREM, 2008).

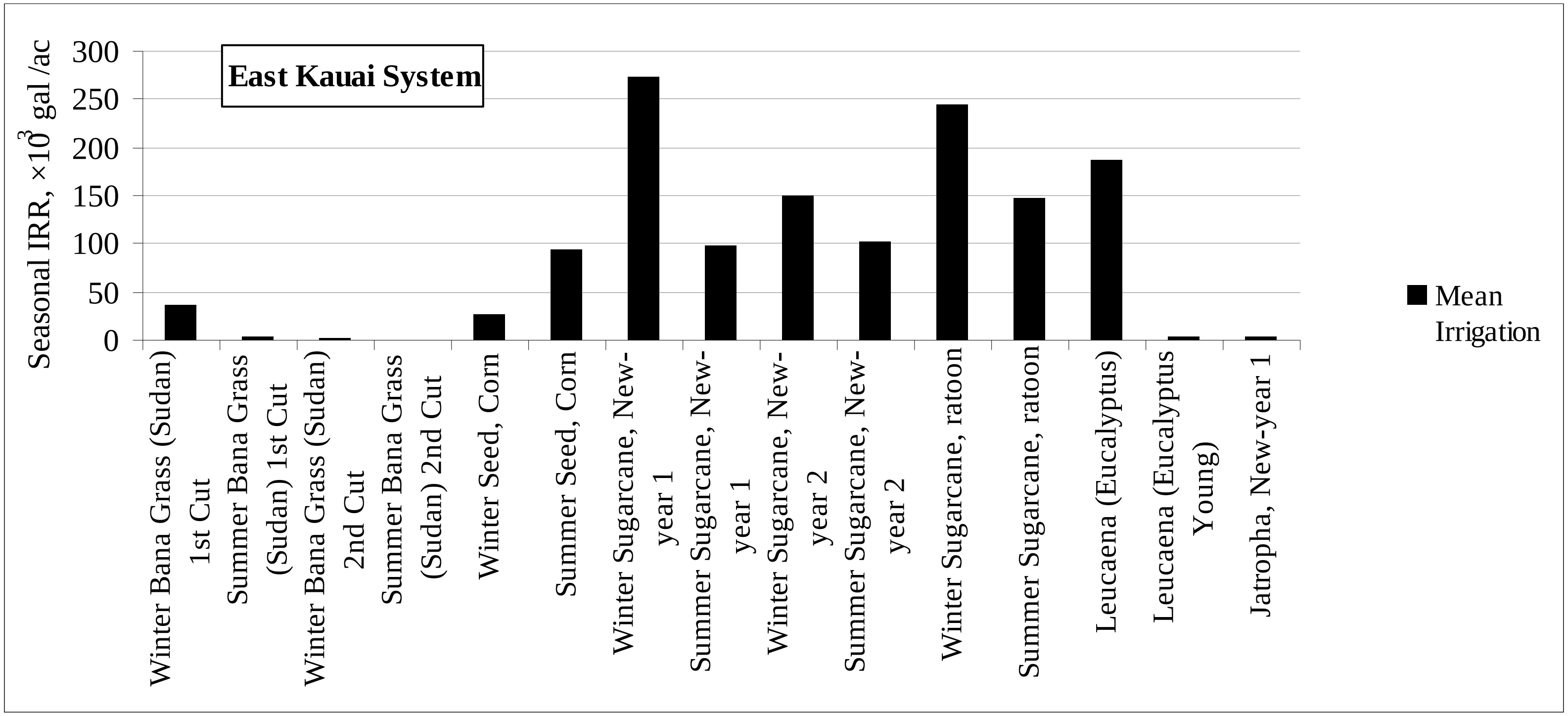

Fig. 63 Predicted seasonal irrigation water requirements for bioenergy crops in East Kauai irrigation system (Data source: NREM, 2008).

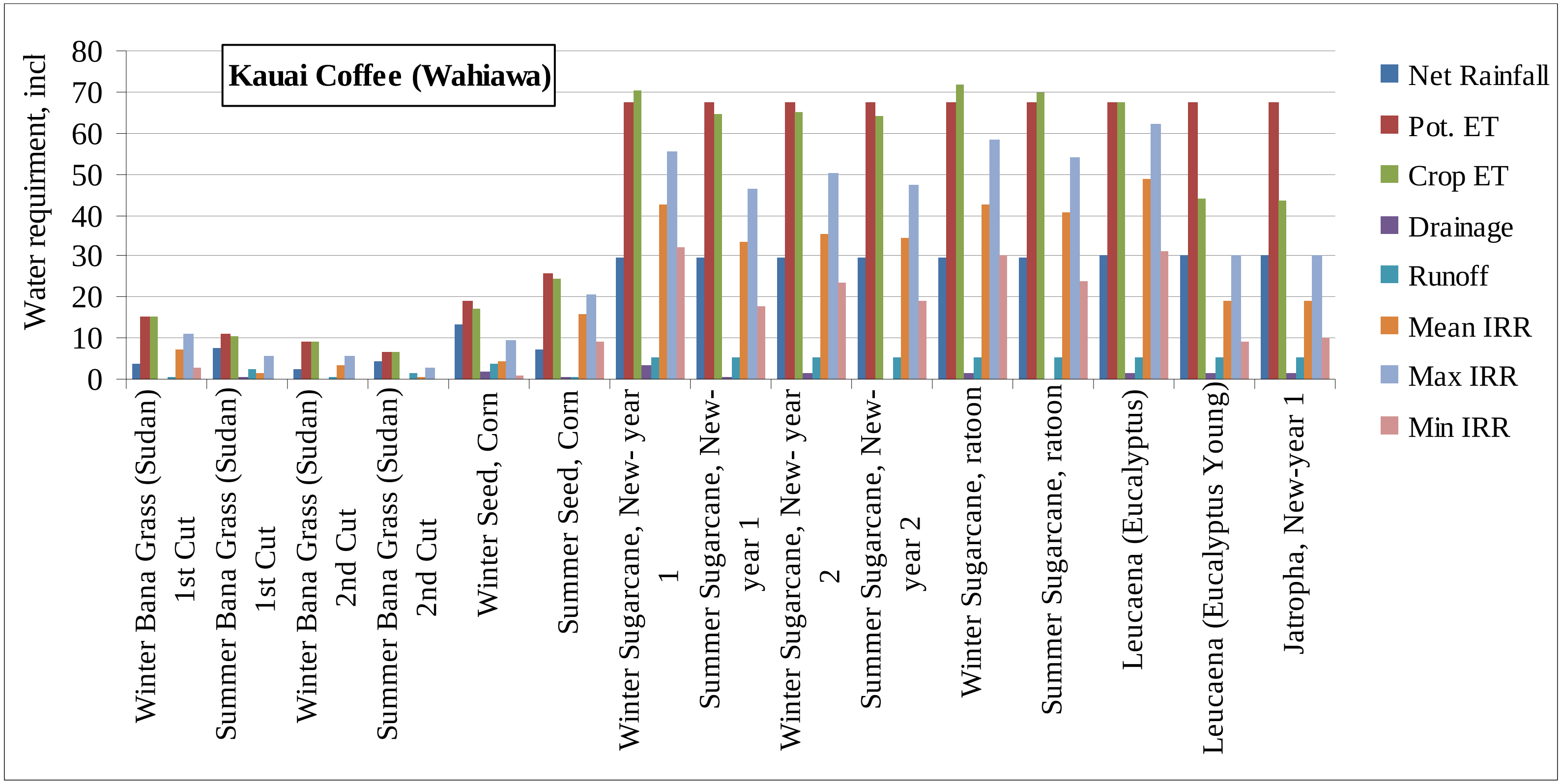

Fig. 64 Predicted hydrologic components of seasonal water requirements irrigation water requirements for bioenergy crops in Kauai Coffee (Wahiawa) irrigation system (Data source: NREM, 2008)

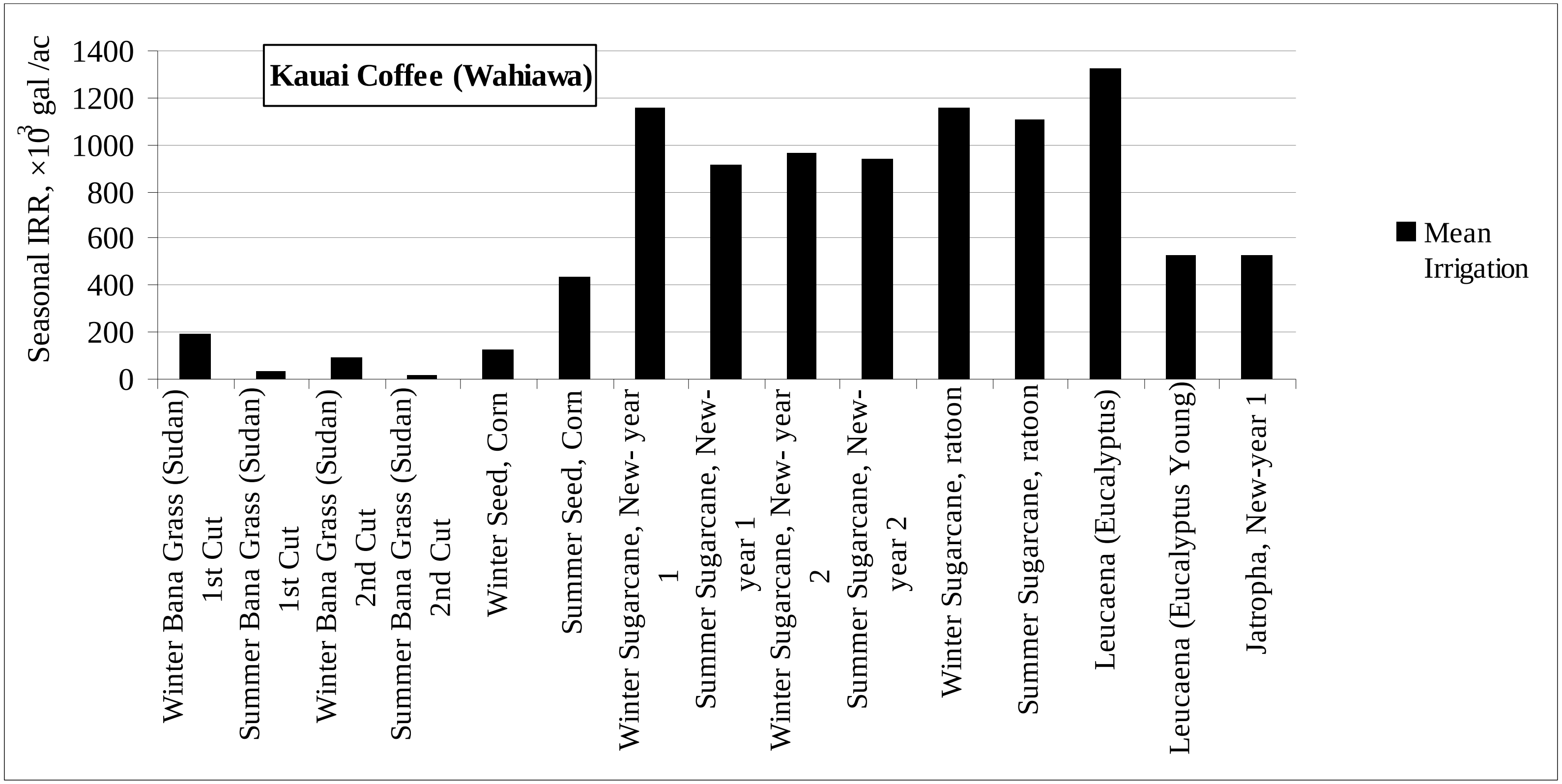

Fig. 65 Predicted seasonal irrigation water requirements for bioenergy crops in Kauai Coffee (Wahiawa) irrigation system (Data source: NREM, 2008).

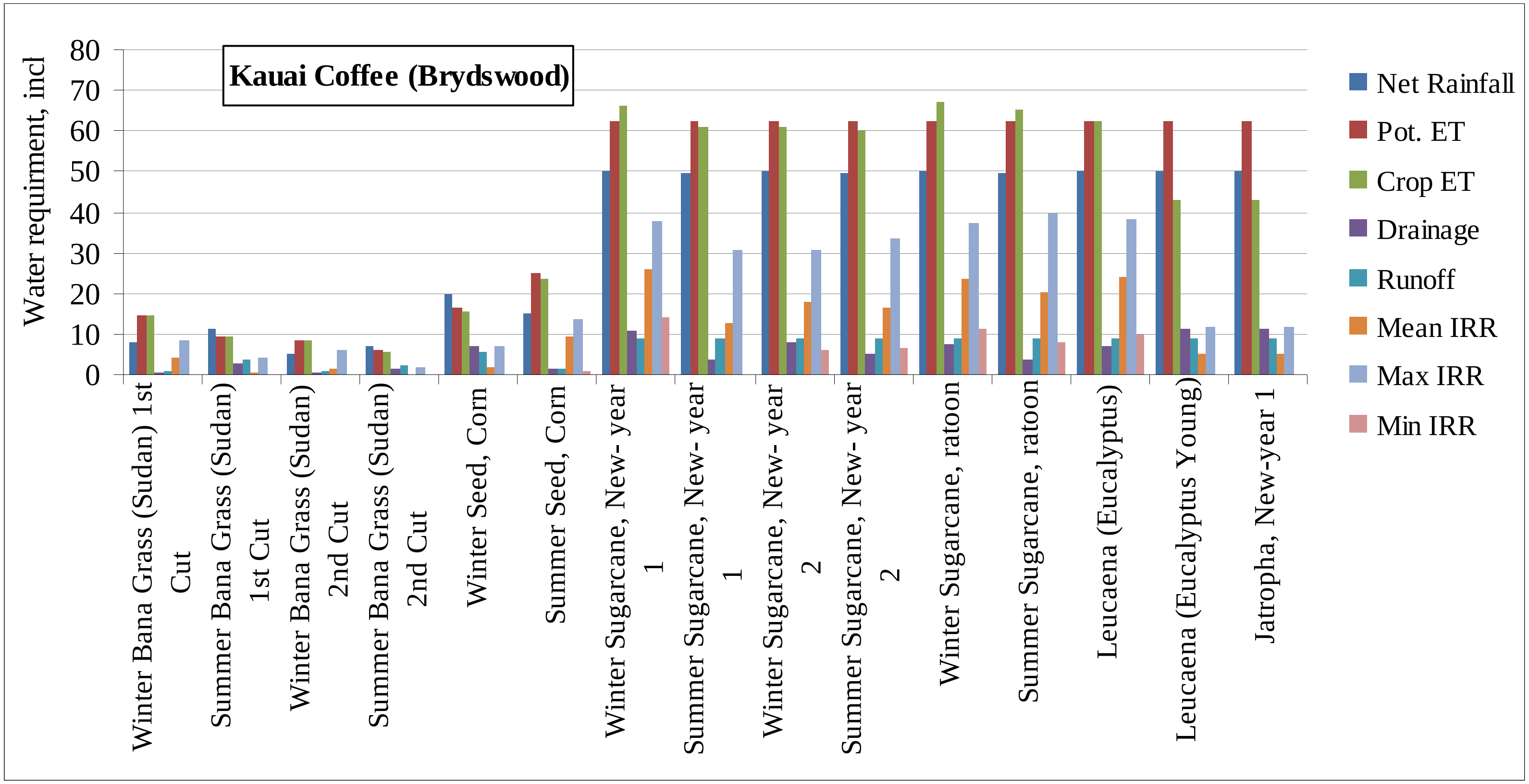

Fig. 66 Predicted hydrologic components of seasonal water requirements for bioenergy crops in Kauai Coffee (Brydswood) (Data source: NREM, 2008).

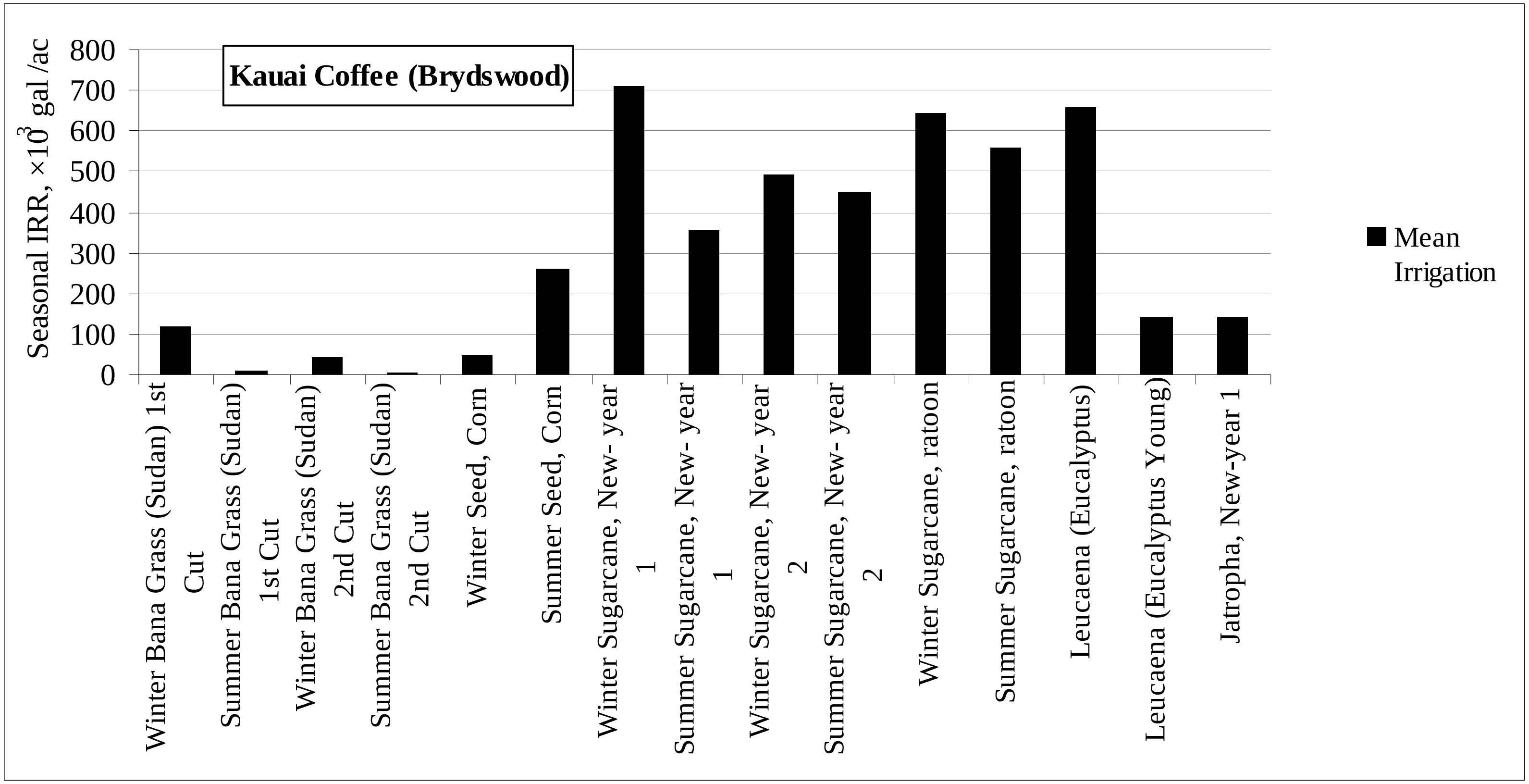

Fig. 67 Predicted seasonal irrigation water requirements for bioenergy crops in Kauai Coffee (Brydswood) (Data source: NREM, 2008).

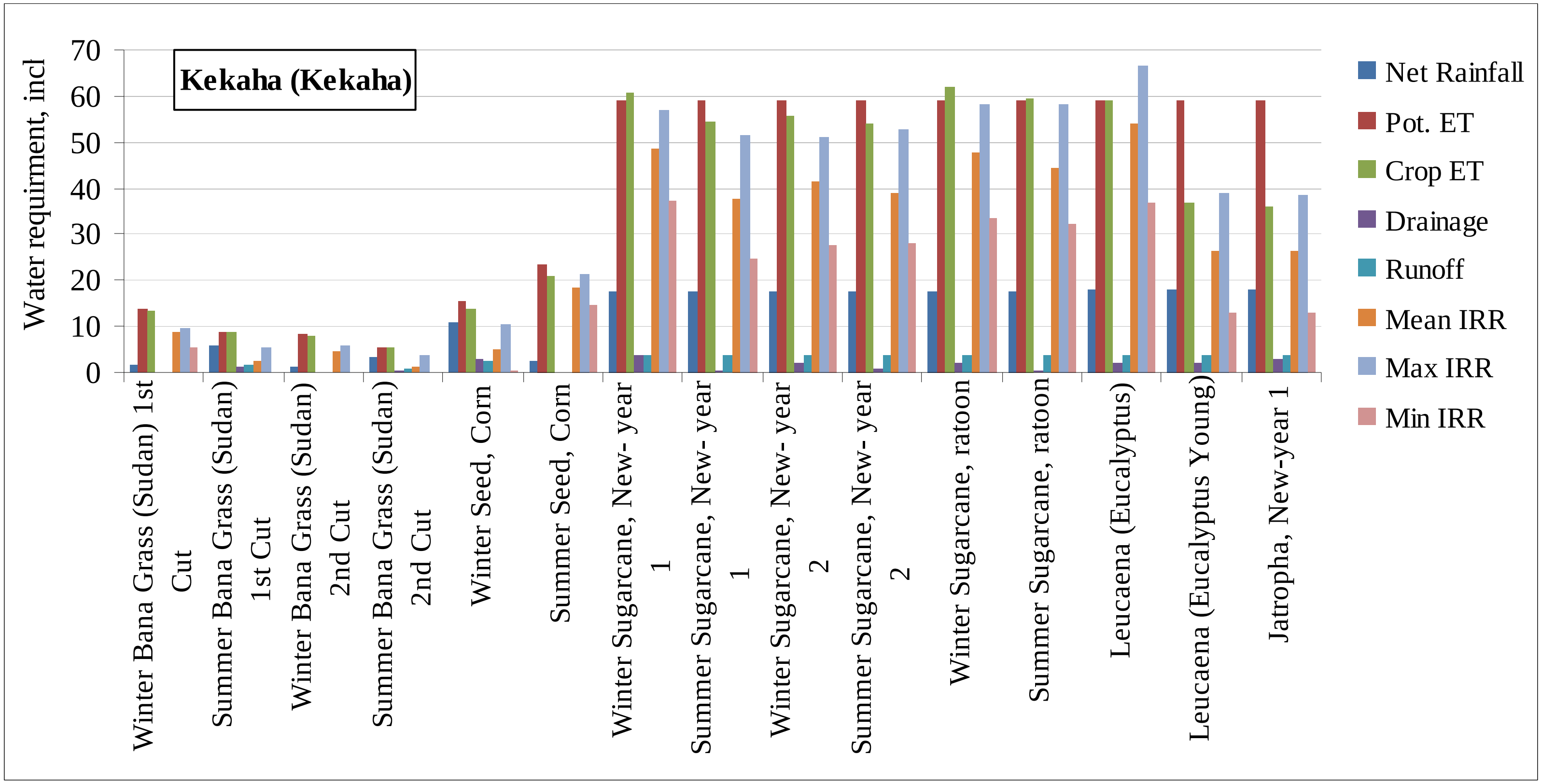

Fig. 68 Predicted hydrologic components of seasonal water requirements for bioenergy crops in Kekaha (Kekaha) irrigation system (Data source: NREM, 2008).

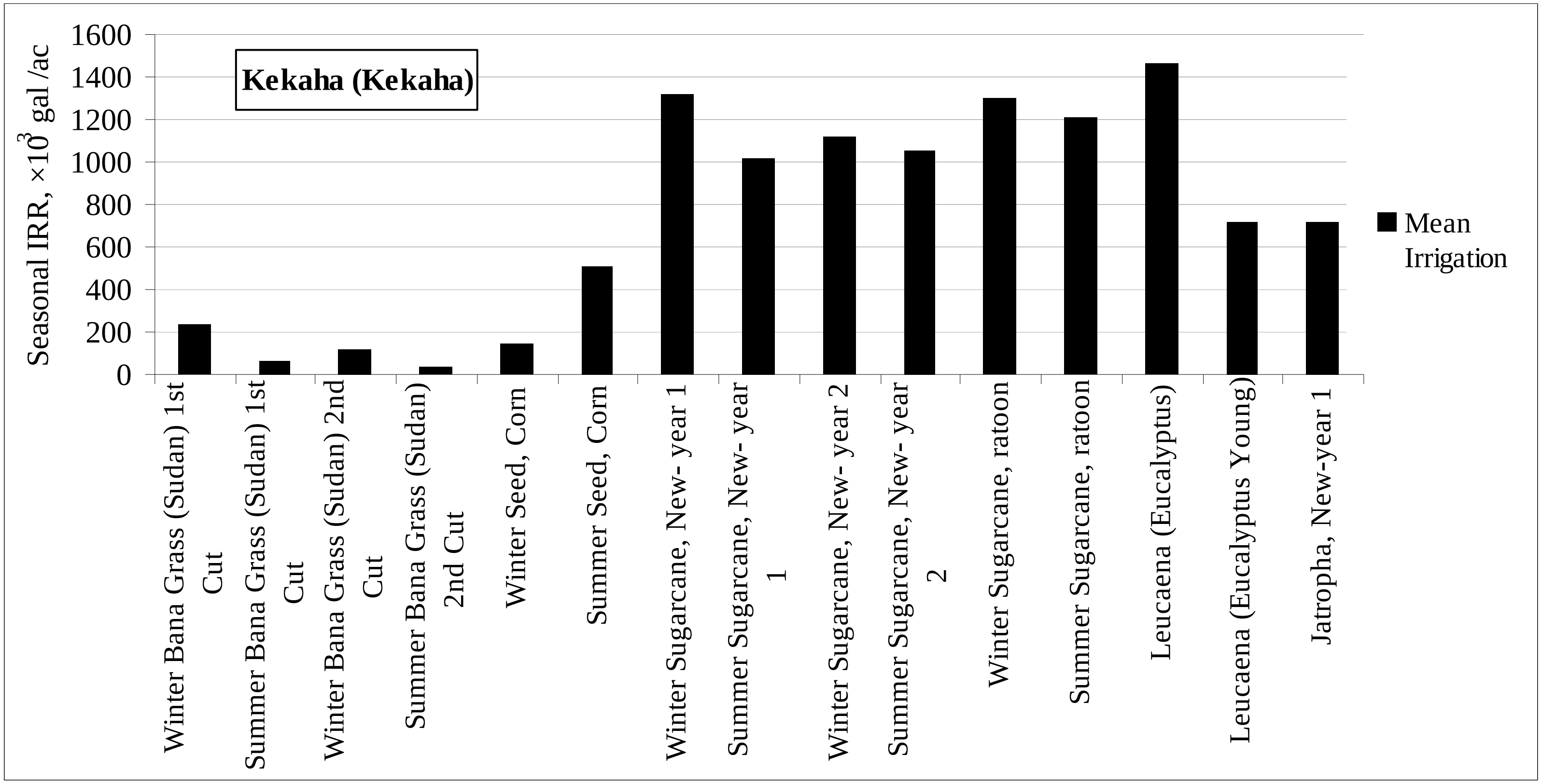

Fig. 69 Predicted seasonal irrigation water requirements for bioenergy crops in Kekaha (Kekaha) irrigation system (Data source: NREM, 2008)

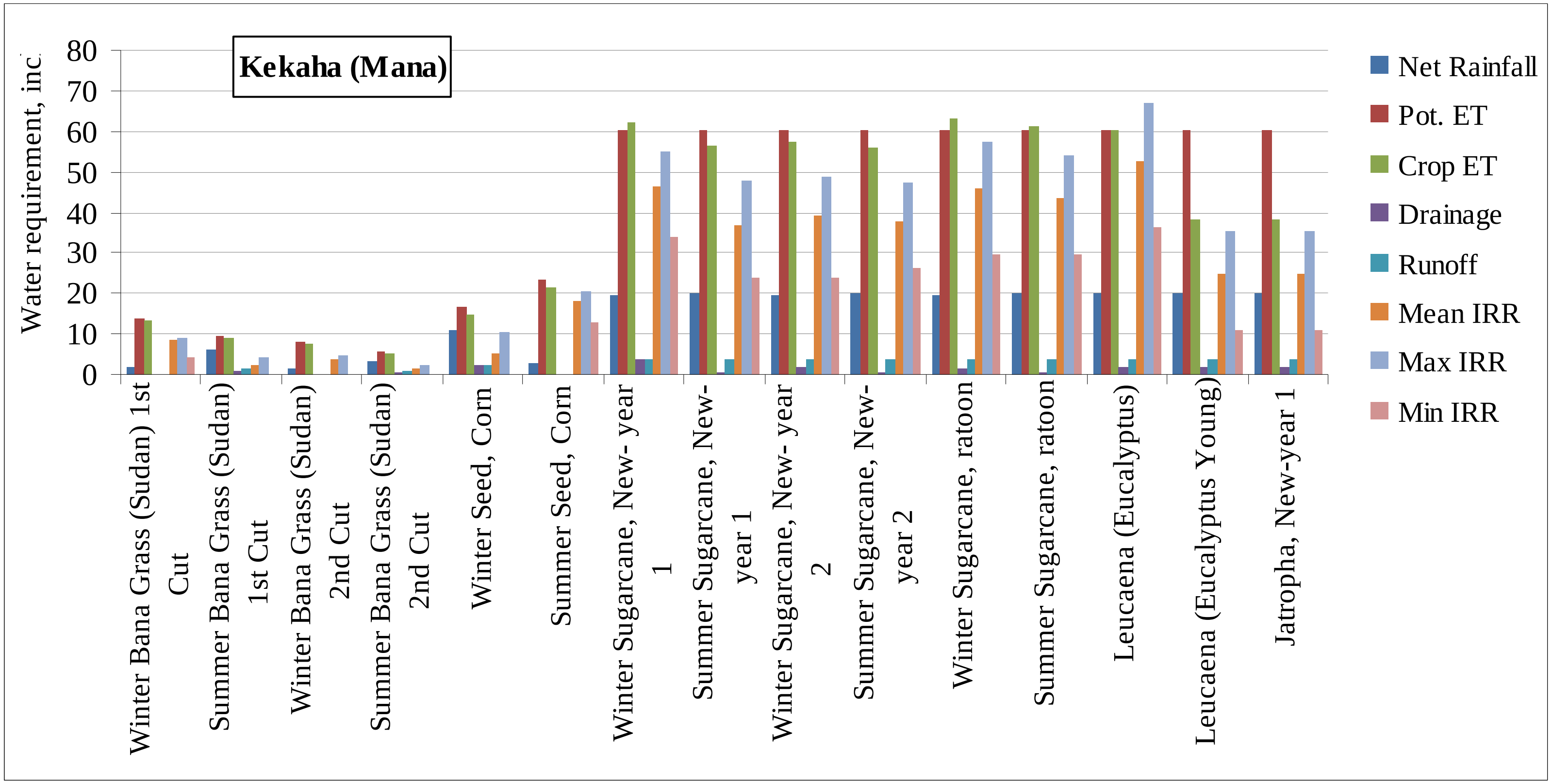

Fig. 70 Predicted hydrologic components of seasonal water requirements for bioenergy crops in Kekaha (Mana) (Data source: NREM, 2008)

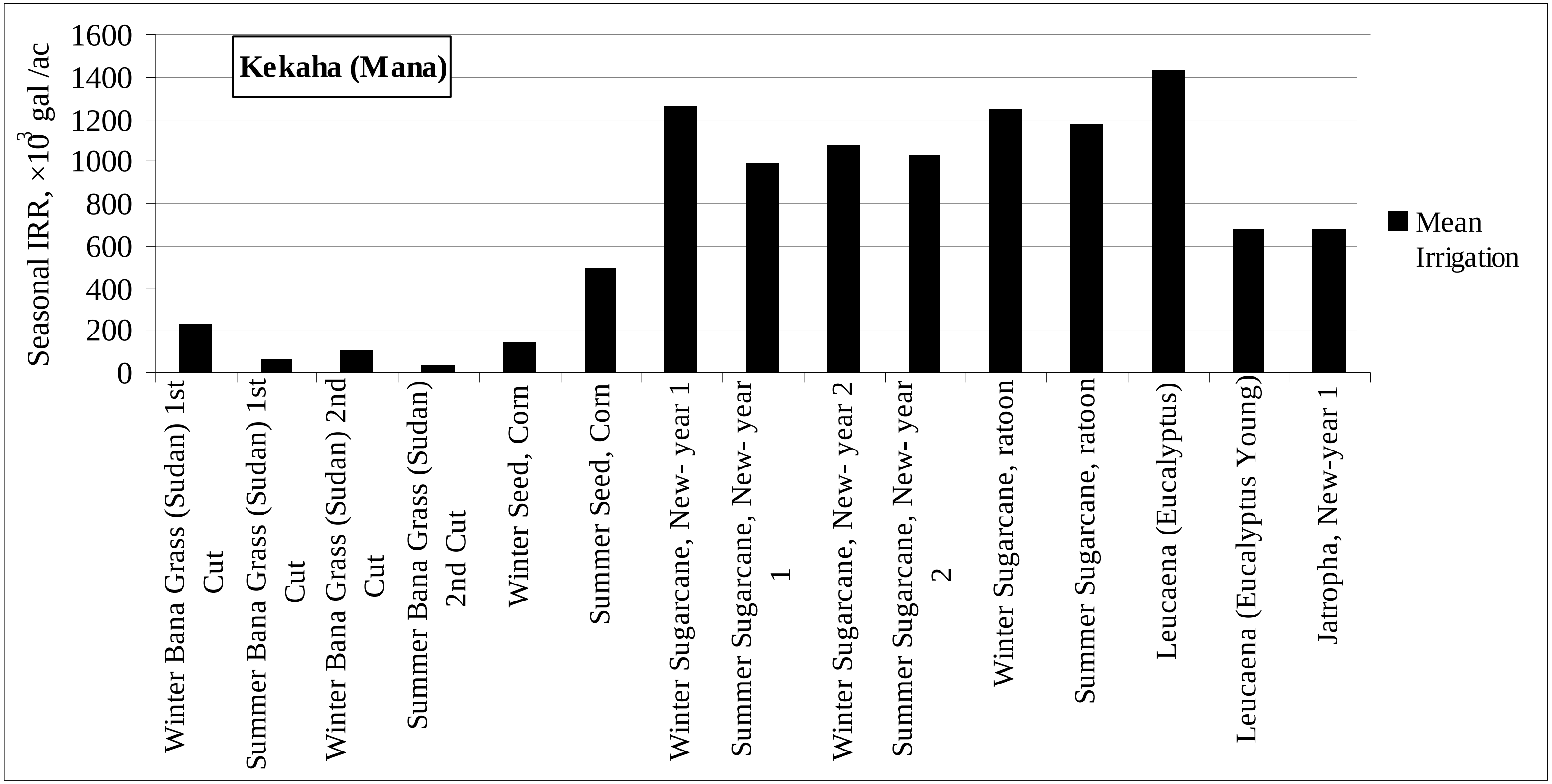

Fig. 71 Predicted seasonal irrigation water requirements for bioenergy crops Kekaha (Mana) (Data source: NREM, 2008)

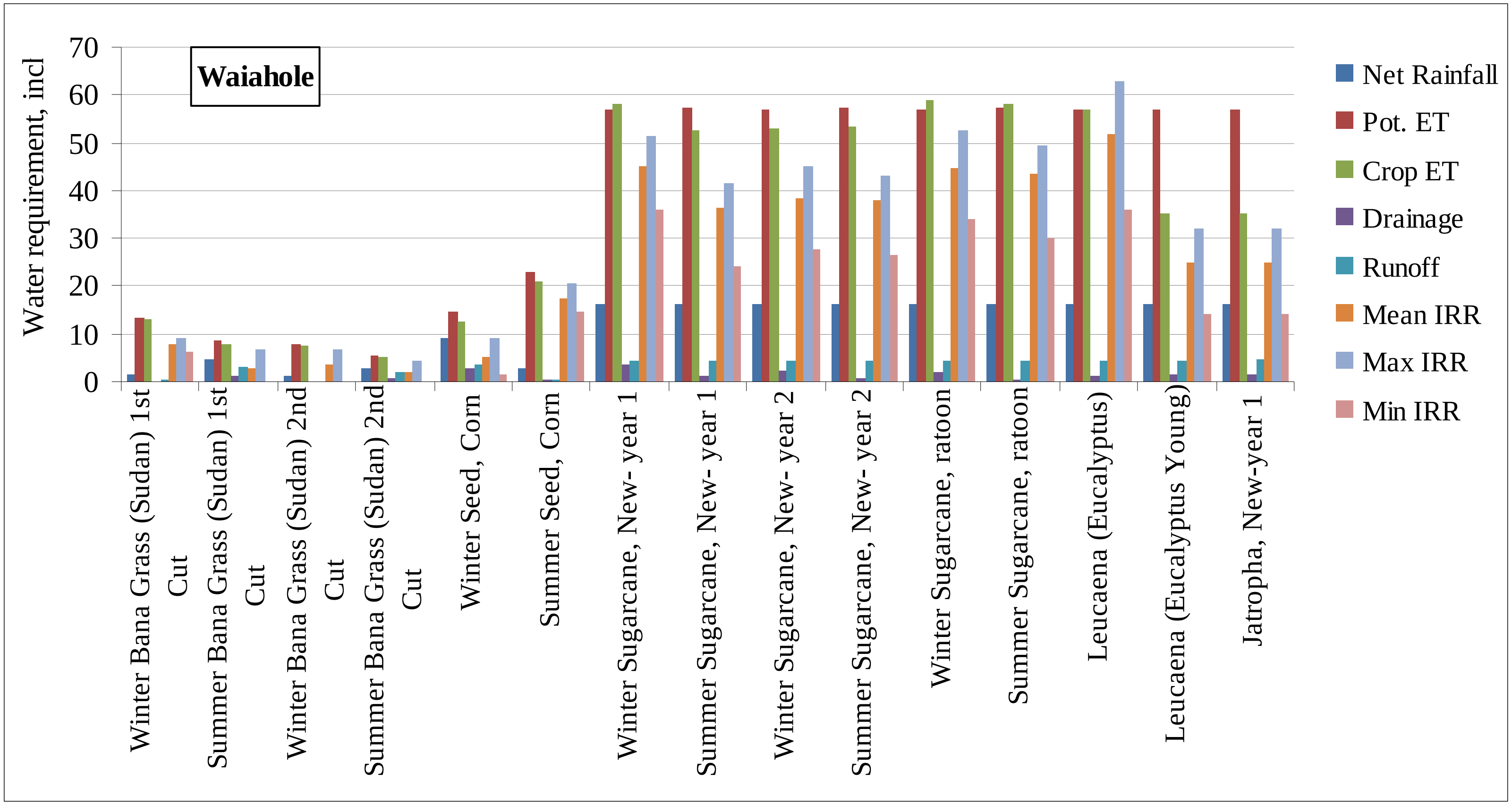

Fig. 72 Predicted hydrologic components of seasonal water requirements for bioenergy crops in Waiahole Ditch irrigation system (Data source: NREM, 2008)

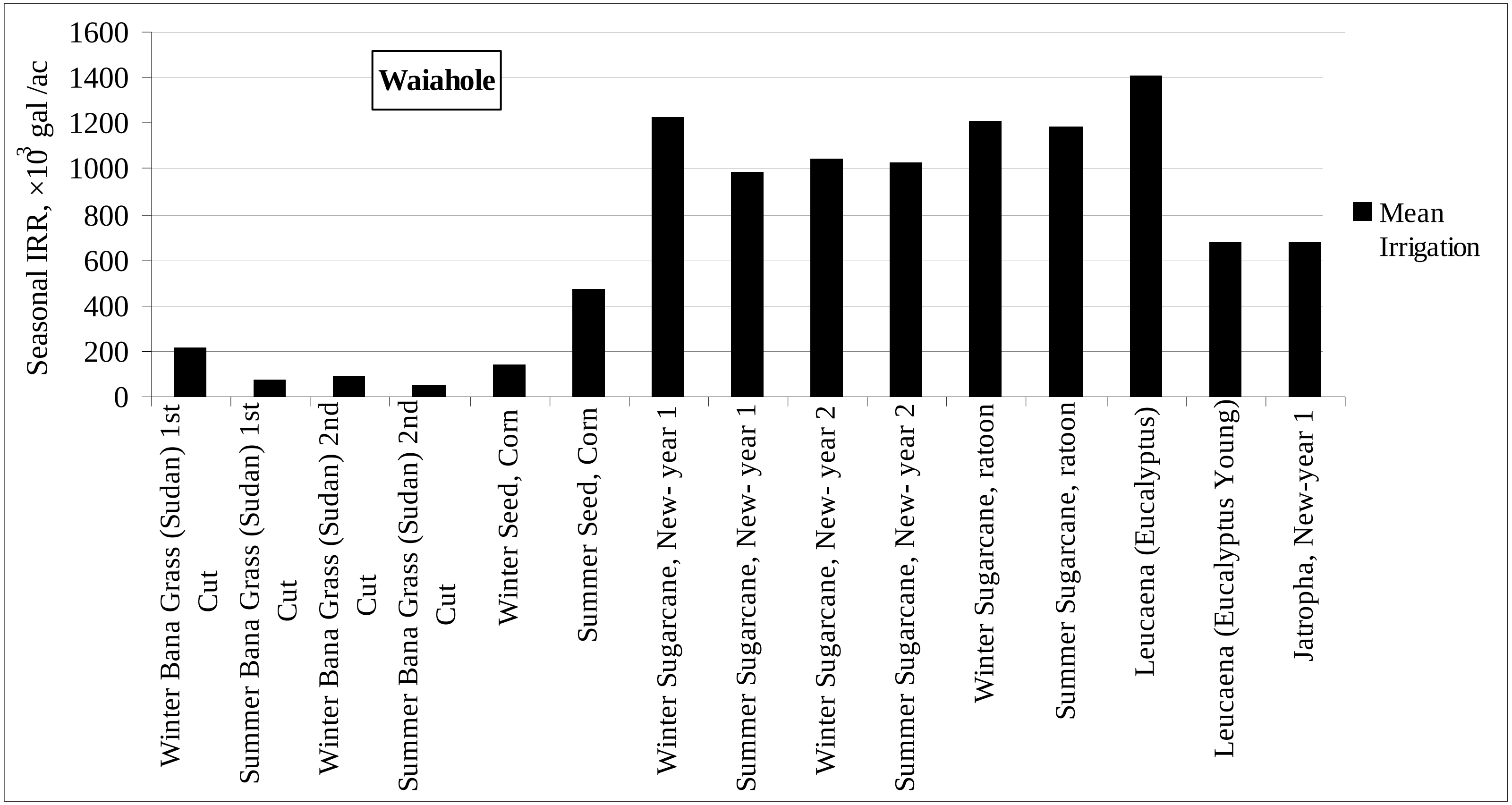

Fig. 73 Predicted Seasonal irrigation water requirements for bioenergy crops in Waiahole Ditch irrigation system (Data source: NREM, 2008)

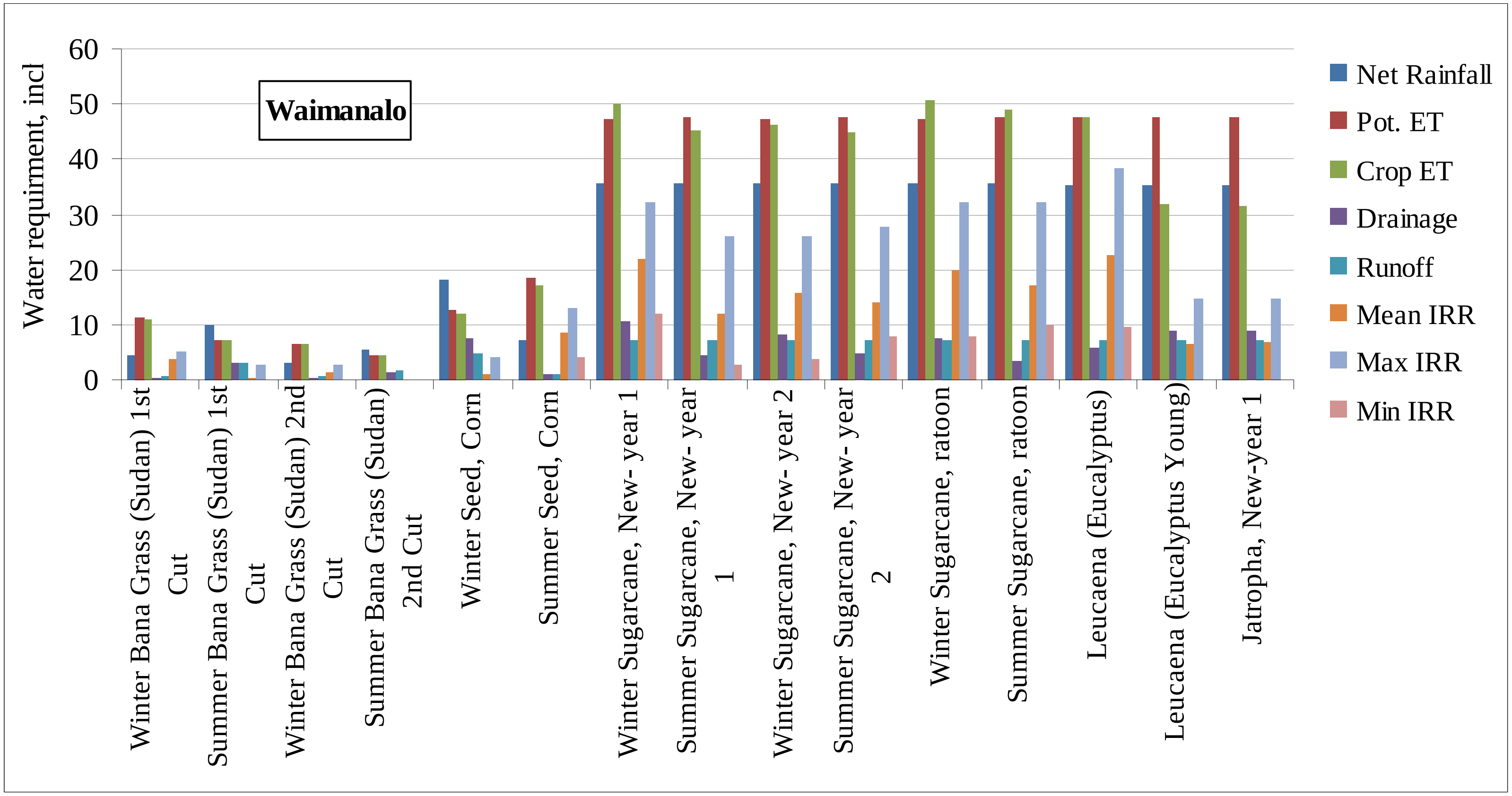

Fig. 74 Predicted hydrologic components of seasonal water requirements for bioenergy crops in Waimanalo irrigation system (Data source: NREM, 2008)

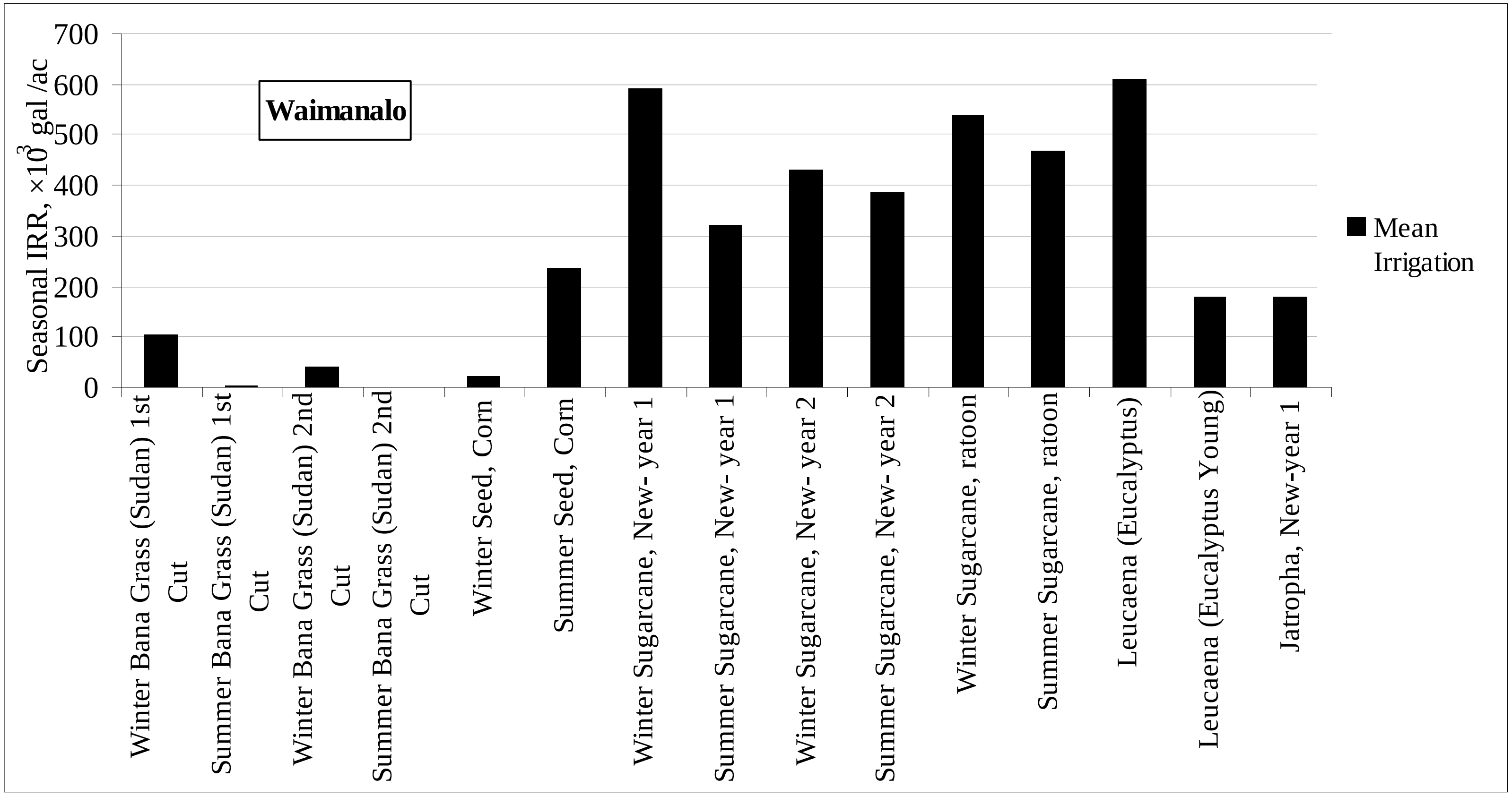

Fig. 75 Predicted seasonal irrigation water requirements for bioenergy crops in Waimanalo irrigation system (Data source: NREM, 2008)

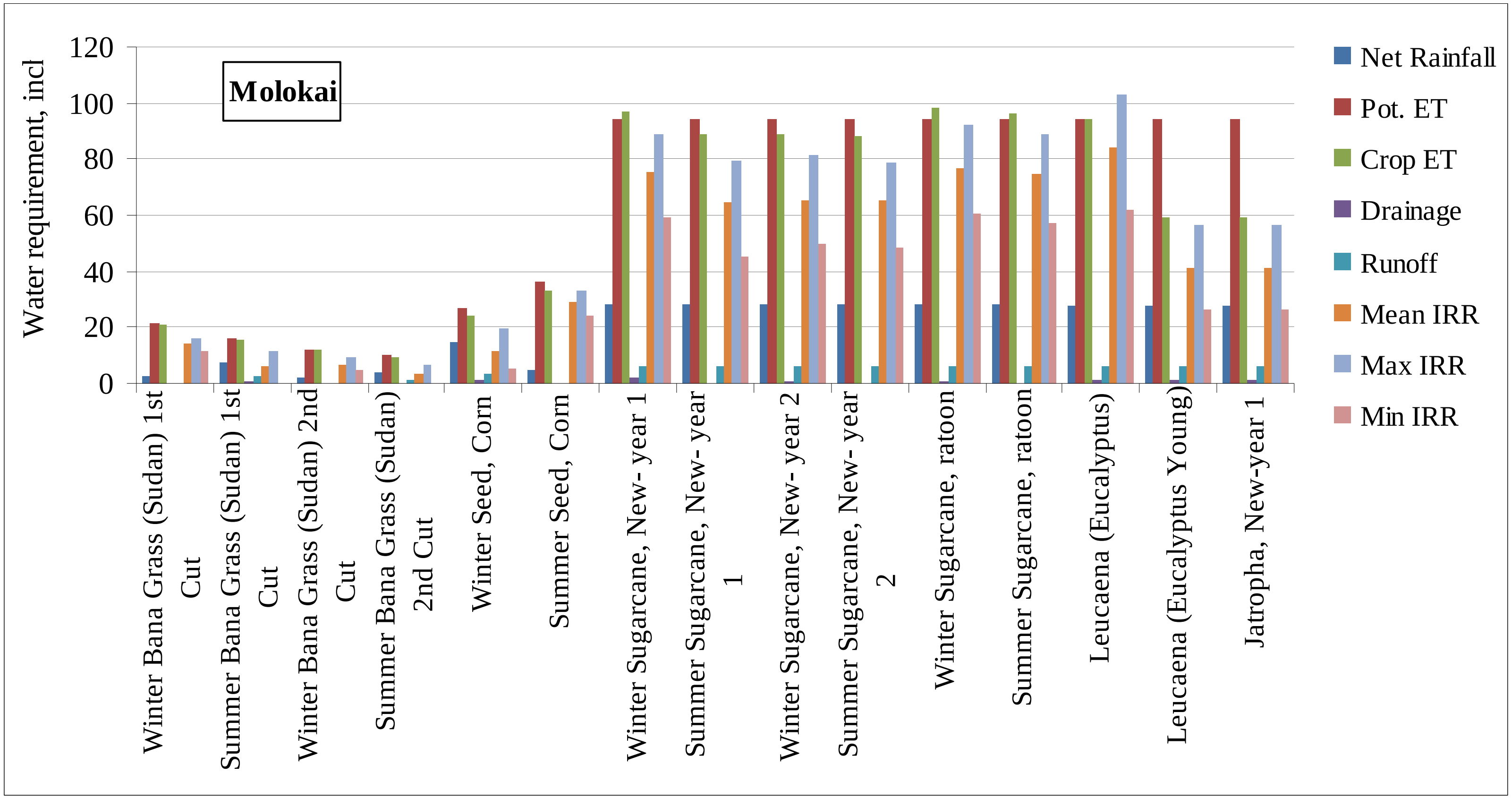

Fig. 76 Predicted hydrologic components of seasonal water requirements for bioenergy crops in Molokai irrigation system (Data source: NREM, 2008).

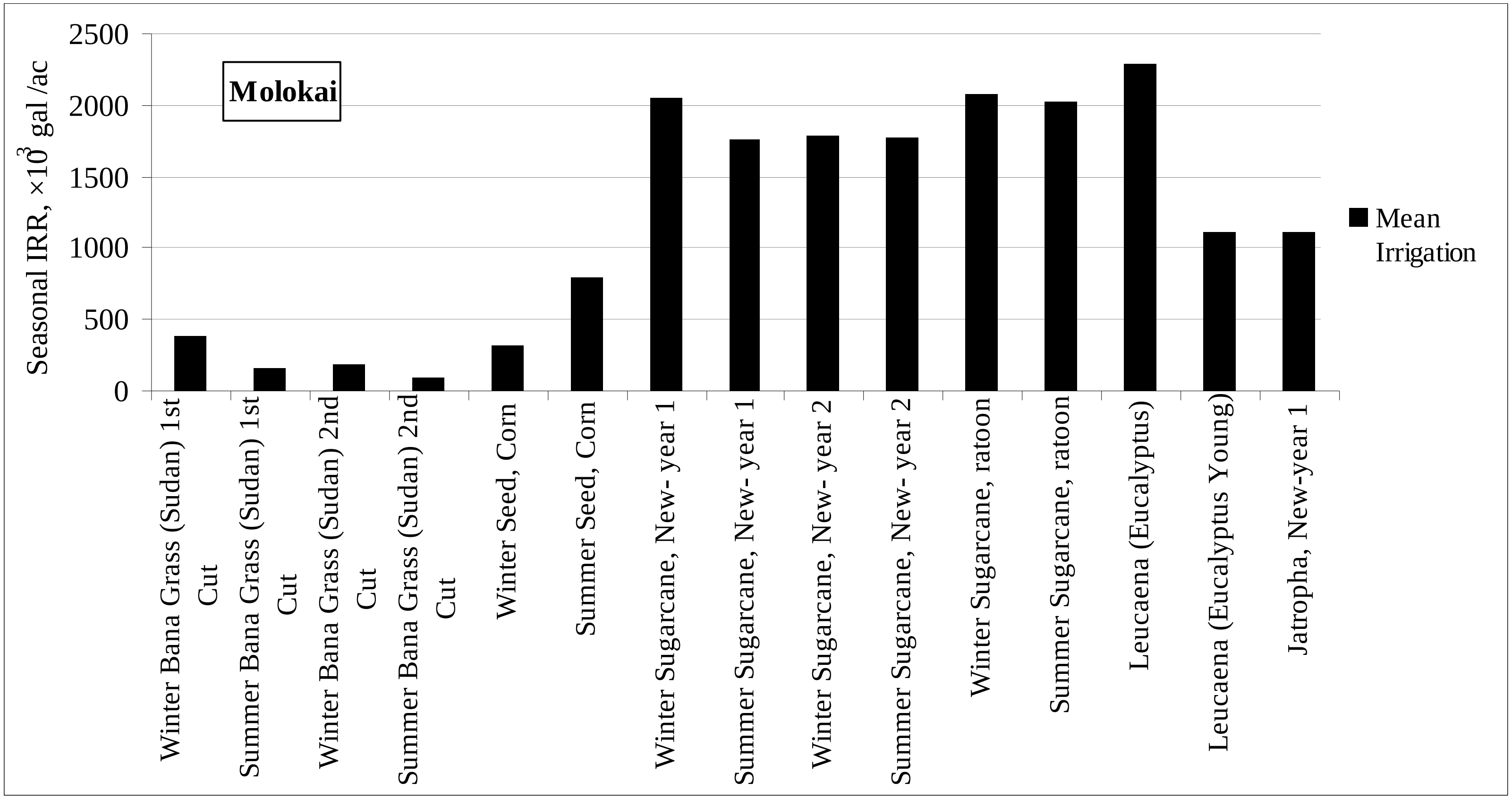

Fig. 77 Predicted seasonal irrigation water requirements for bioenergy crops in Molokai irrigation system (Data source: NREM, 2008).

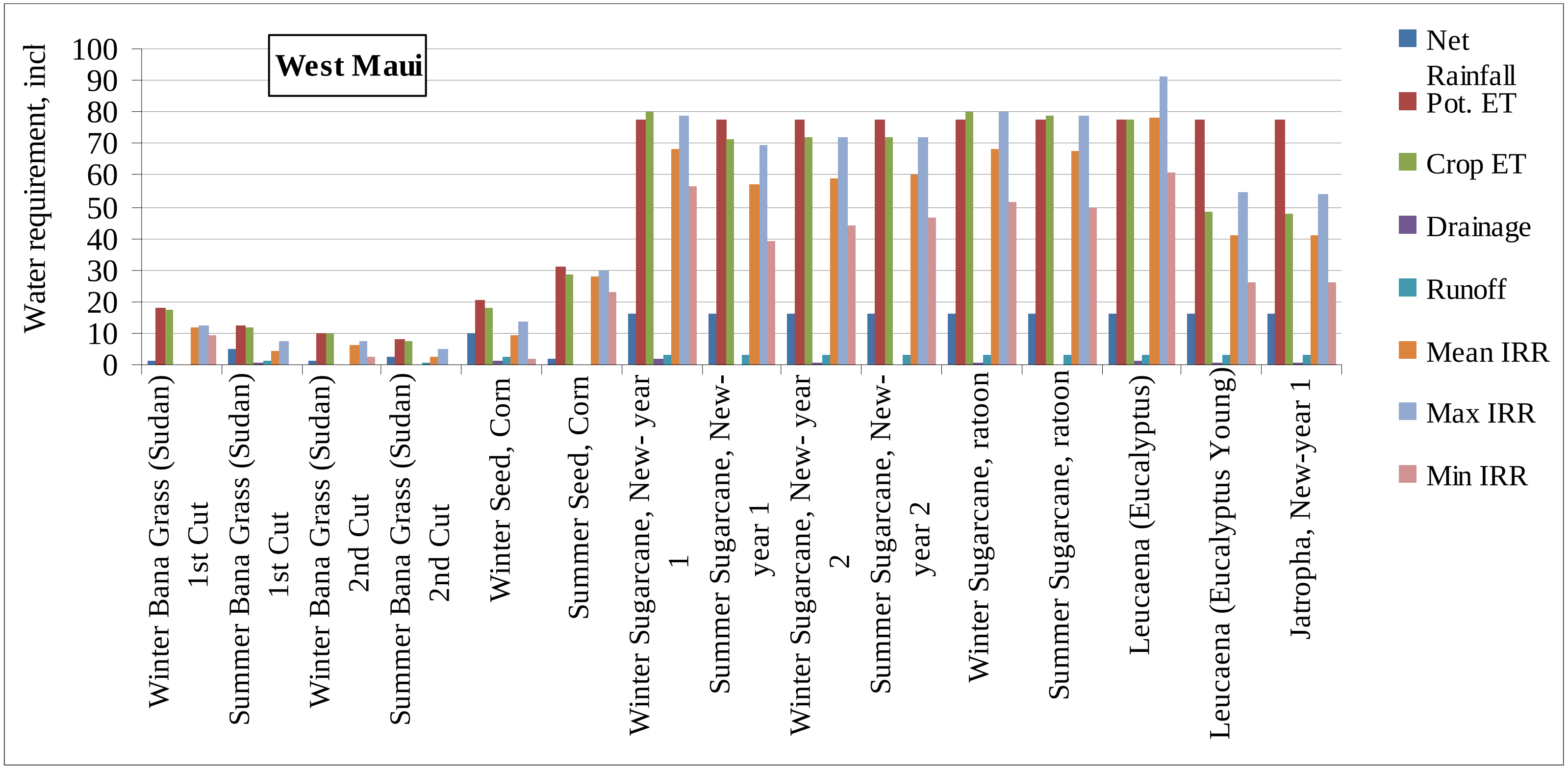

Fig. 78 Predicted hydrologic components of seasonal water requirements for bioenergy crops in West Maui irrigation system (Data source: NREM, 2008).

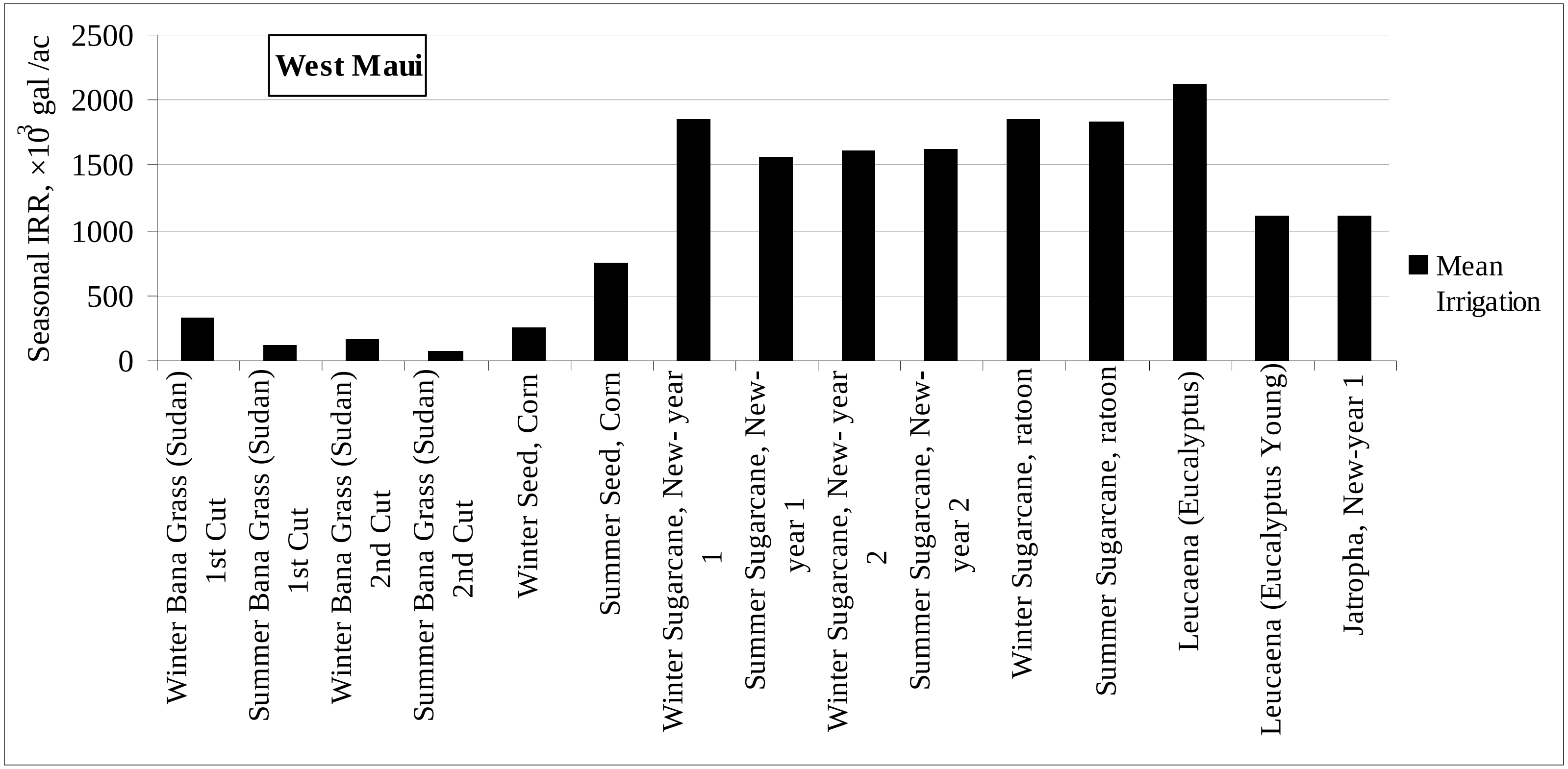

Fig. 79 Predicted seasonal irrigation water requirements for bioenergy crops in West Maui irrigation system (Data source: NREM, 2008).

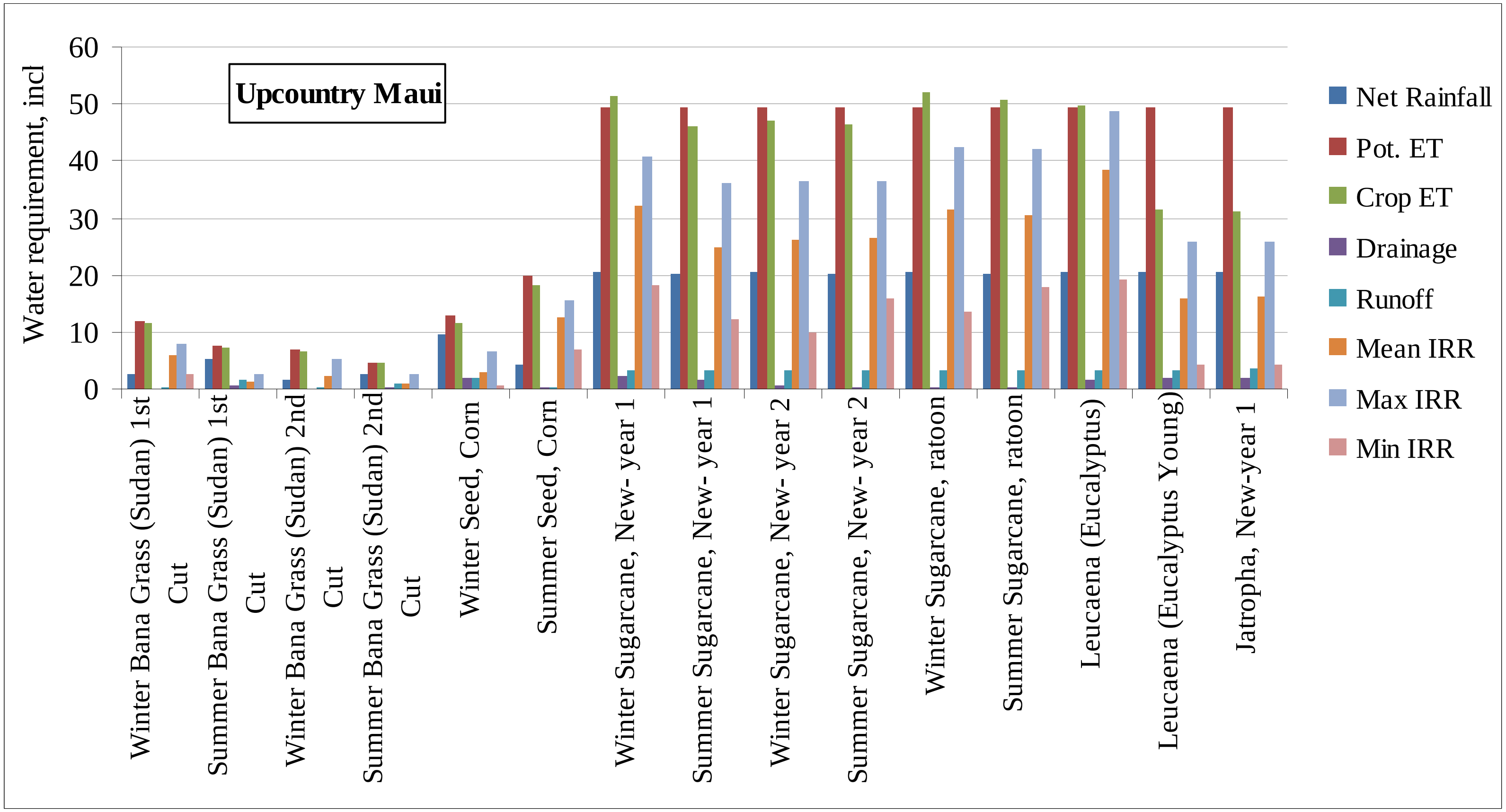

Fig. 80 Predicted hydrologic components of seasonal water requirements for bioenergy crops in Upcountry Maui irrigation system (Data source: NREM, 2008)

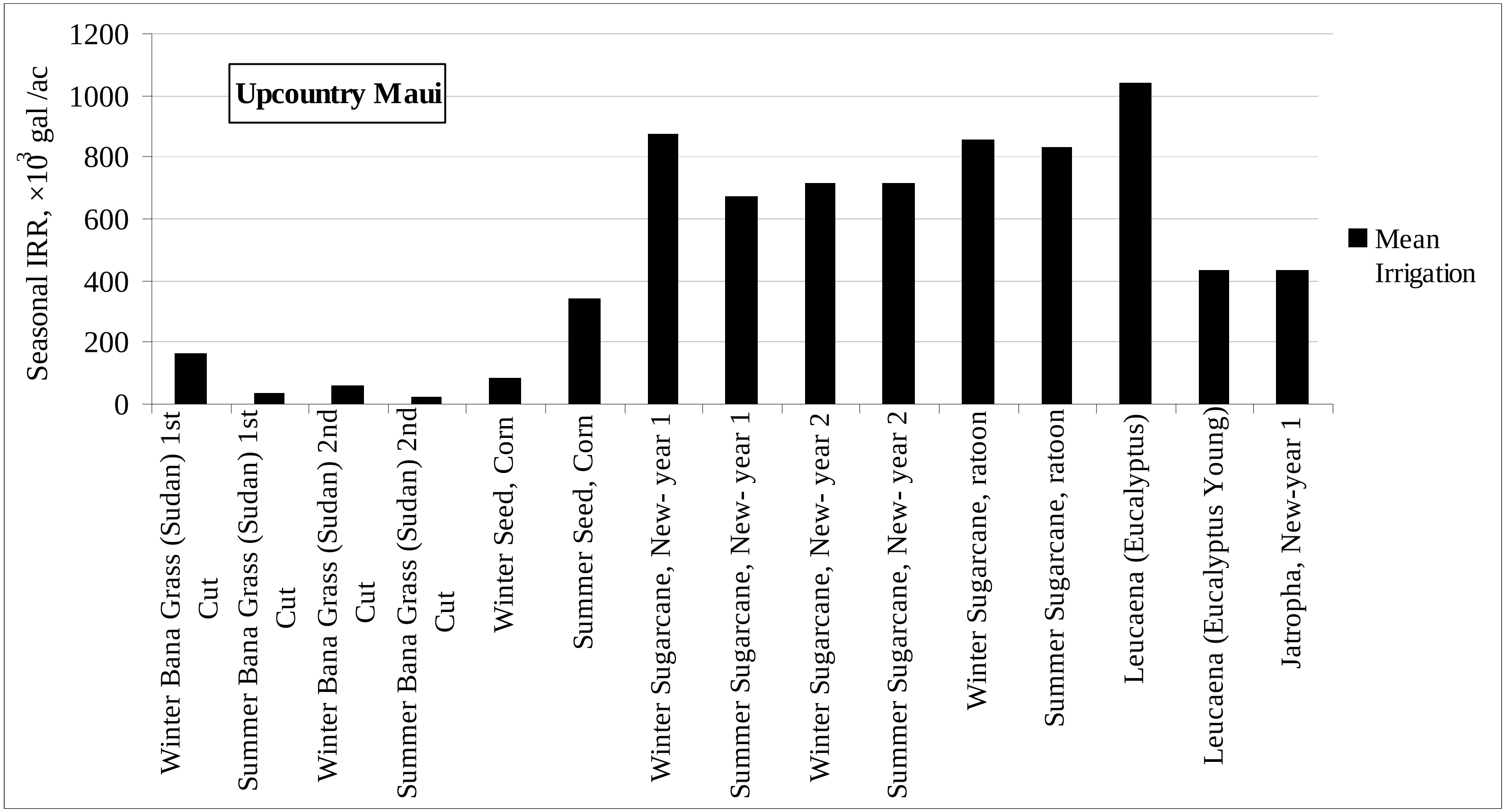

Fig. 81 Predicted seasonal irrigation water requirements for bioenergy crops in Upcountry Maui irrigation system (Data source: NREM, 2008).

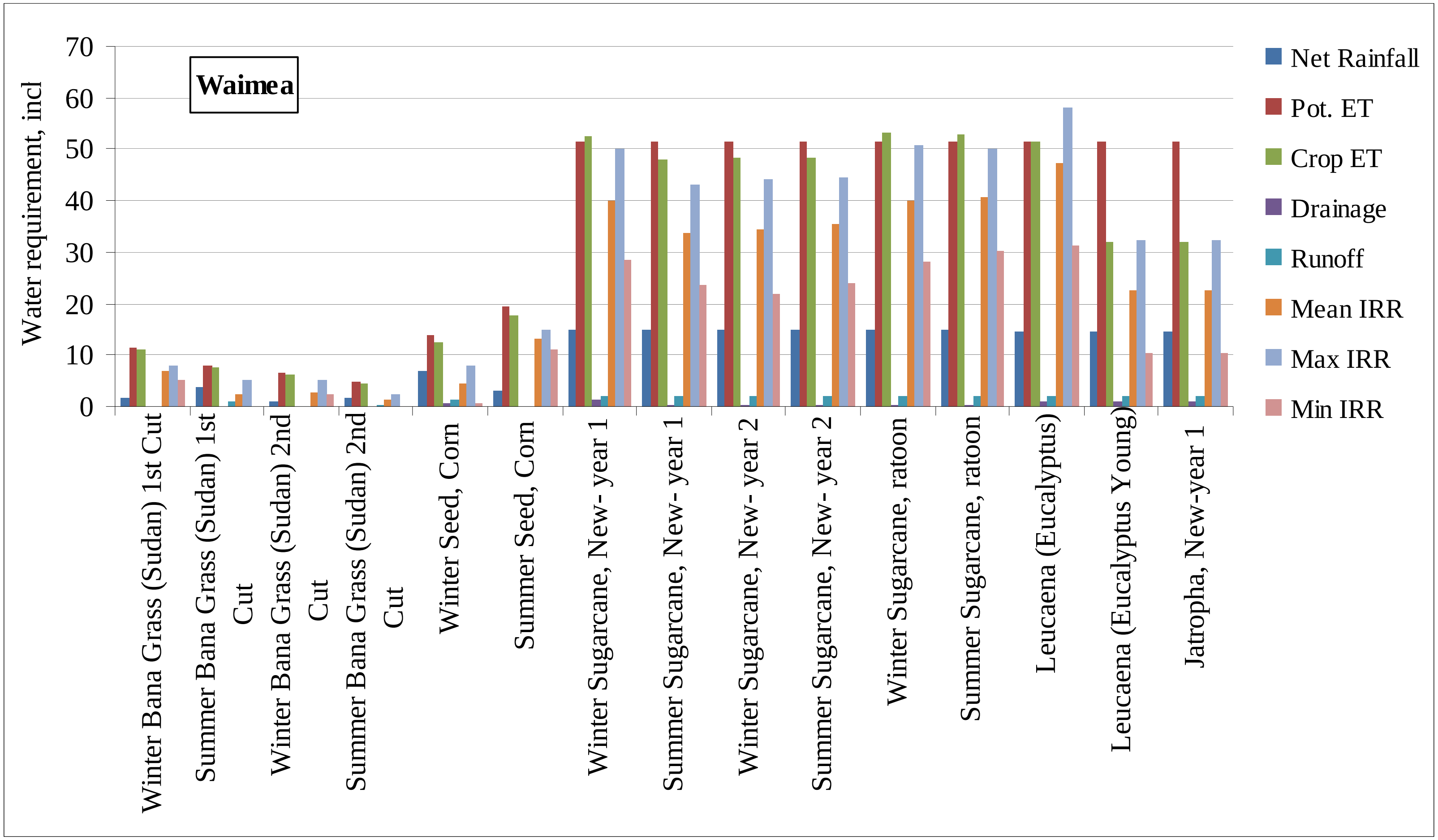

Fig. 82 Predicted hydrologic components of seasonal water requirements for bioenergy crops in Waimea irrigation system (Data source: NREM, 2008).

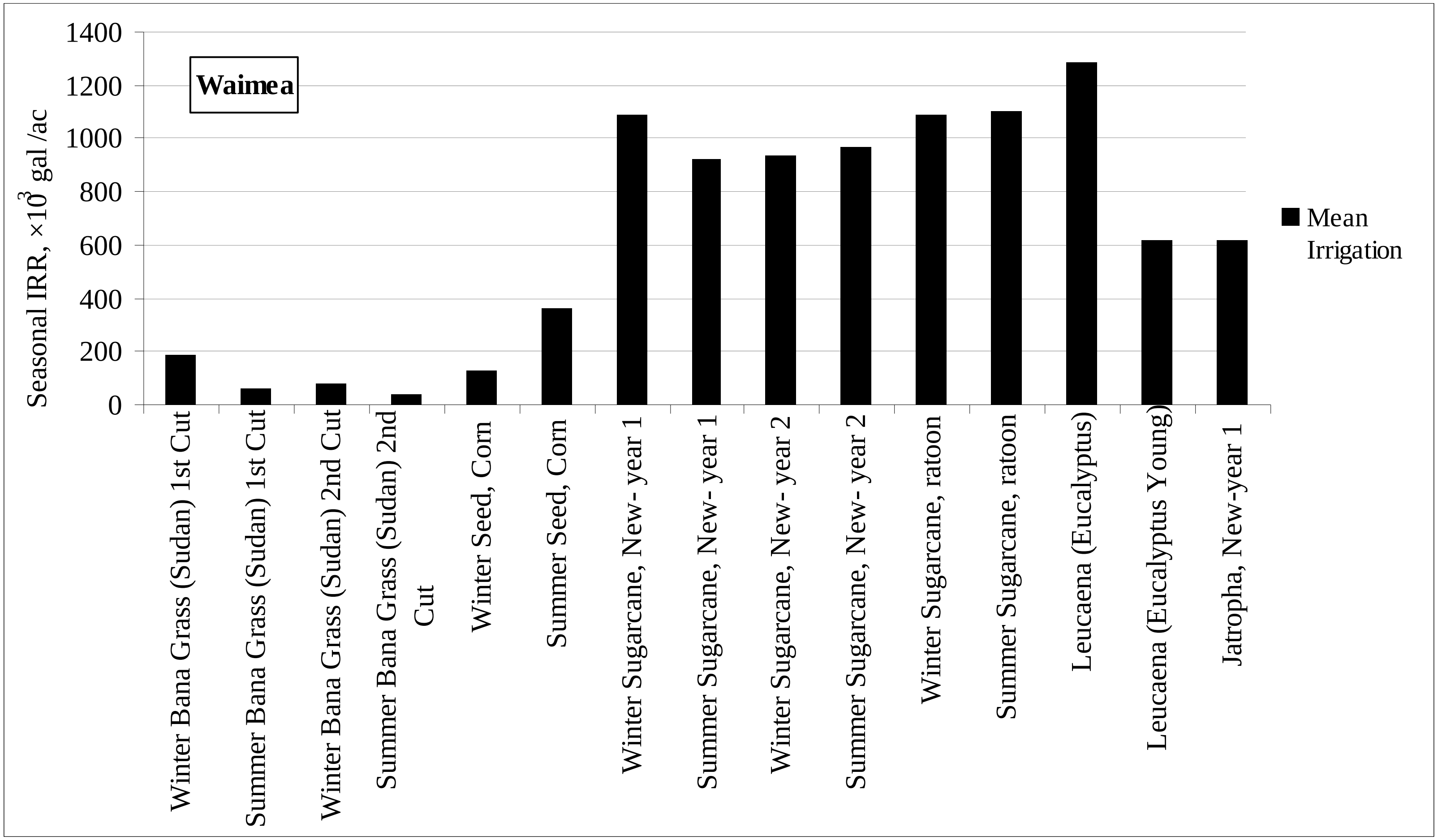

Fig. 83 Predicted seasonal irrigation water requirements for bioenergy crops in Waimea irrigation system (Data source: NREM, 2008).

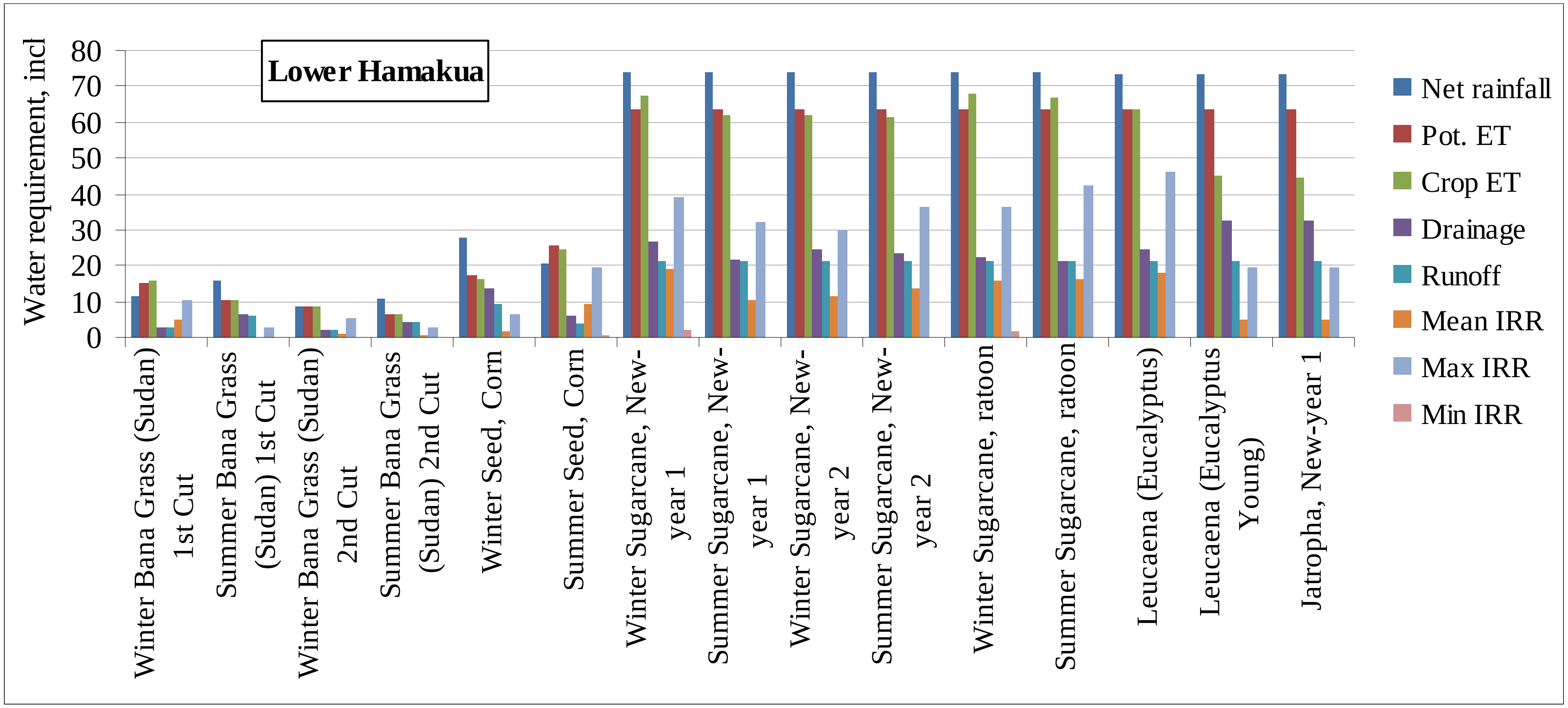

Fig. 84 Predicted hydrologic components of seasonal water requirements for bioenergy crops in Lower Hamakua Ditch irrigation system (Data source: NREM, 2008).

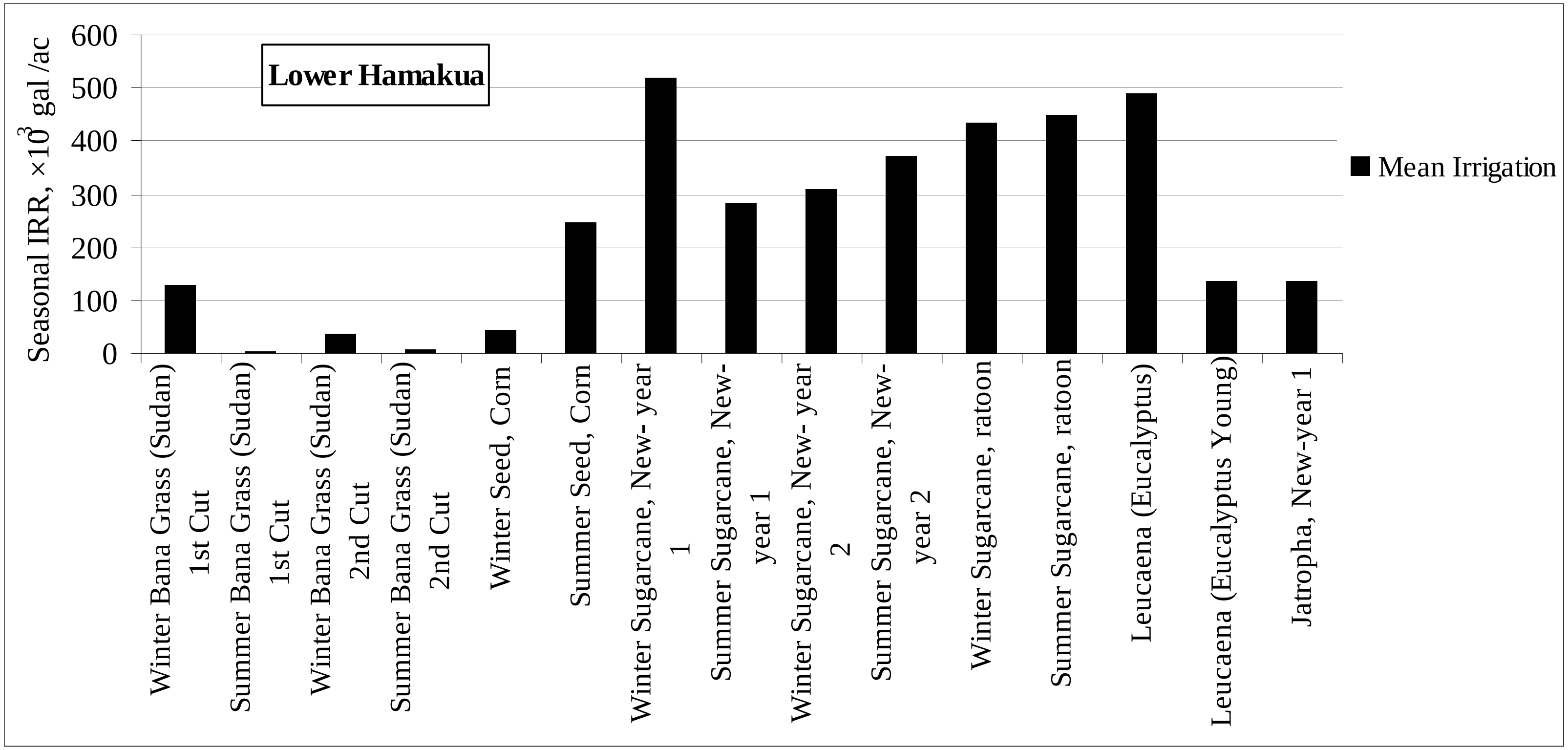

Fig. 85 Predicted irrigation water requirements for bioenergy crops in Lower Hamakua Ditch irrigation system (Data source: NREM, 2008).

4.8 Agricultural Potential of Irrigation Systems

The 2008 NREM report developed an empirical conceptual model in order to assess the long-run agricultural potential of an irrigation system (Fig. 86).

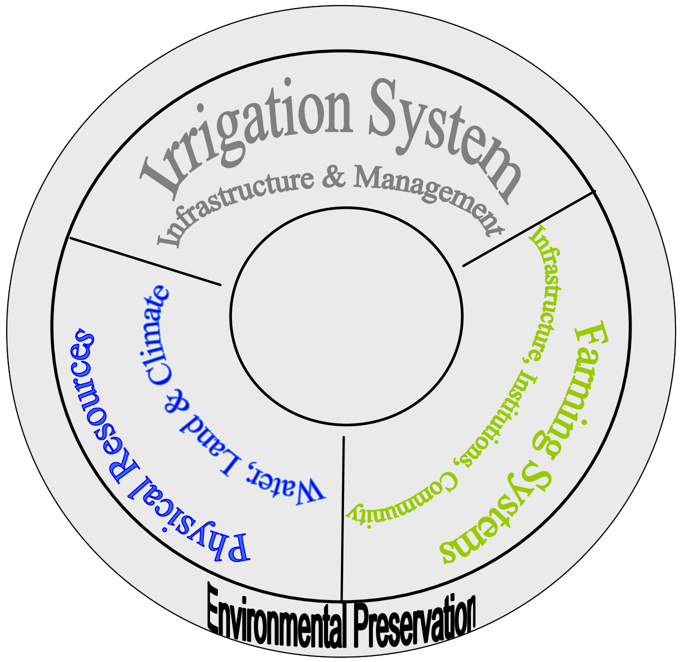

Fig. 86 Conceptual model for assessing long-run agricultural potential of an irrigation system (Source: NREM, 2008)

Seven major components with relative importance given in parentheses that constitute this model are:

1) Irrigation water supply (31%)
2) Irrigation infrastructure and water delivery (19%)
3) Irrigation system management (9%)
4) Land resources (21%)
5) Farm infrastructure and institutions (7%)
6) Relations with non-agricultural community (7%)
7) Environmental preservation (6%).

An expert panel estimated the relative importance of different factors, and validated the model for two hypothetical systems. The model was operationalized by 82 indicators developed and tested at the 10 studied irrigation systems. Most of the data used to quantify indicator ratings came from visits to the irrigation systems conducted during the first half of 2006 and were supplemented by information in the 2004 AWUDP report (NREM, 2008).

Ninety-six percent of studied system service area is irrigable (Table 32). Cultivated use is variable. The right hand side of Table 32 presents the results from the model of long-run agricultural potential. Actual system scores fall within a narrow range compared to those from the model validation exercise (hypothetical “good” 89-91 points, “bad” 34-44 points). The Waimea IS received high ratings for most model components and had the top score, without and with rehabilitation (NREM, 2008). The next tier of systems–Waiahole, Kauai Coffee, Kekaha, West Maui–have large diversion capacities and are located in leeward areas, where the demand for irrigation water is high. Systems in the bottom tier (<65 points without rehabilitation) all experience serious problem(s) with water supply, which the expert panel judged the single most important determinant of long-run agricultural potential (NREM, 2008).

Table 32 Long-run agricultural potential of 10 studied irrigation systems, without and with rehabilitation (NREM, 2008)

Irrigation System	**LAND AREAS**			**AGR. POTENTIAL***			
	Service	**Irrigable**	**Cultivated**	**w/o rehab**		**with rehab**	
	acre	acre	% irrigable	score	rank	score	*rank*
East Kauai (Kapaa-Kalepa)	5920	4000	26	63	8.5	72	5
Kauai Coffee	4660	4380	89	69	3	69	7
Kekaha	6570	6520	100	69	3.5	76	2.5
Waiahole Ditch	6270	5930	68	71	2	71	6
Waimanalo	1580	1460	56	56	10	68	8.5
Upcountry Maui (Olinda-Kula)	1720	1470	27	63	8.5	74	4
West Maui (Wailuku)	6430	6340	99	68	5	68	8.5
Molokai	9890	9730	27	64	6.5	76	2.5
Lower Hamakua Ditch	4660	4210	7	64	6.5	66	10
Waimea	1370	1320	56	77	1	82	1
Total/Average	49070	45360	**56**	**66**		**72**	

*Model scores (0-100 scale); ranks based on scores where midpoint value given for ties. No rehabilitation proposal by AWUDP 2004 for Kauai Coffee and West Maui systems (NREM, 2008)

Suggested plans to rehabilitate infrastructure at 8 of the 10 studied systems (AWUDP, 2004) would raise agricultural potential scores by an average 10% at these systems. However, the individual improvements of the Waiahole Ditch and Lower Hamakua systems, which underwent thorough rehabilitation within the past 10 years did not significantly increase their scores. The Upcountry Maui, Molokai, and Waimanalo systems expect the largest overall gains from rehabilitation. The potential benefits from irrigation system rehabilitation will have to be weighed against the respective costs which are given in Table 33 (AWUDP, 2004; NREM, 2008) compared to the respective increase in model scores. The Kekaha, Molokai, and East Kauai systems show the highest potential returns from the increase in long-run agricultural potential. Rehabilitation would cost about $4,300 per acre on average, a relatively modest expenditure given the cost of agricultural land and farm operations in Hawaii.

Table 33 Estimated rehabilitation costs and potential impacts at 8 studied irrigation systems (AWUDP, 2004; NREM, 2008)

Irrigation System	**Rehabilitation Costs**		**Increase in Agr. Potential**	
	Irrigable Area × E+03$/ac.	**Total** × E+06$	**Model Score**	**Impact:Cost** × E+03$/ac.*
East Kauai (Kapaa-Kalepa)	1.8	10.5	9	5.1
Kekaha	1.1	7.3	7	6.3
Waiahole Ditch	1.8	11.3	0	0.0
Waimanalo	4.3	6.8	12	2.8
Upcountry Maui (Olinda-Kula)	5.4	9.3	11	2.0
Molokai	2.0	19.8	12	6.0
Lower Hamakua Ditch	2.1	9.6	2	1.0
Waimea	15.6	21.3	5	0.3
Average	**4.3**	**12.0**	**7.3**	**1.7**

*Increase in model score points (0-100 scale) divided by rehabilitation costs ($1,000/irrigable acre).

4.9 Projecting Bioenergy Crop Acreages

4.9.1 Macroeconomic Scenarios and Drivers of Agricultural Growth

Development of Hawaii agriculture and the demand for irrigation water through the year 2030 depends on macroeconomic conditions including the following ten factors, which are characterized as either trend (t) or uncertainty (u) (NREM, 2008). An expert panel developed a qualitative model explaining the linkages between these factors and the supply and demand for Hawaii agricultural products (Figs. 87 and 88).

1) Capital investment flows into Hawaii (t)
2) Cost of living and housing in Hawaii (t)
3) Growth in U.S. gross domestic product (t)
4) Hawaii population growth (t)
5) Investment in Hawaii transportation infrastructure (t)
6) Number of visitors to Hawaii (t)
7) Price of oil (t/u)
8) Terrorist attack in Hawaii (u)
9) U.S. per capita incomes (t)
10) Value of the U.S. dollar (u)

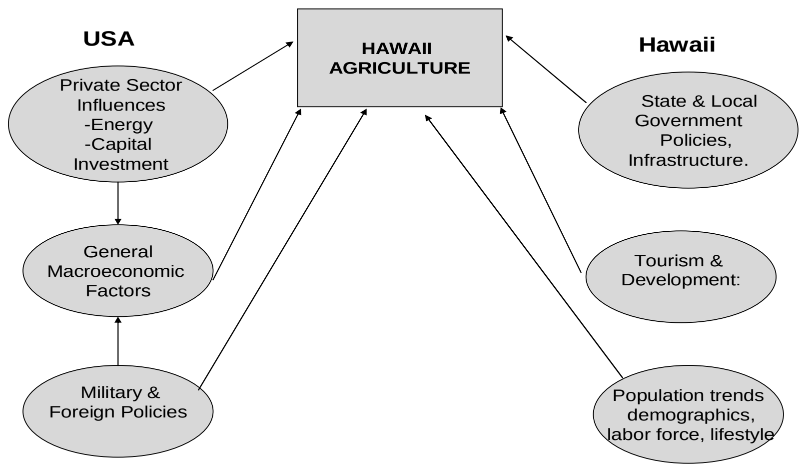

Fig. 87 Relationship between important macroeconomic factors that affect the future supply and demand of Hawaii agricultural products (NREM, 2008).

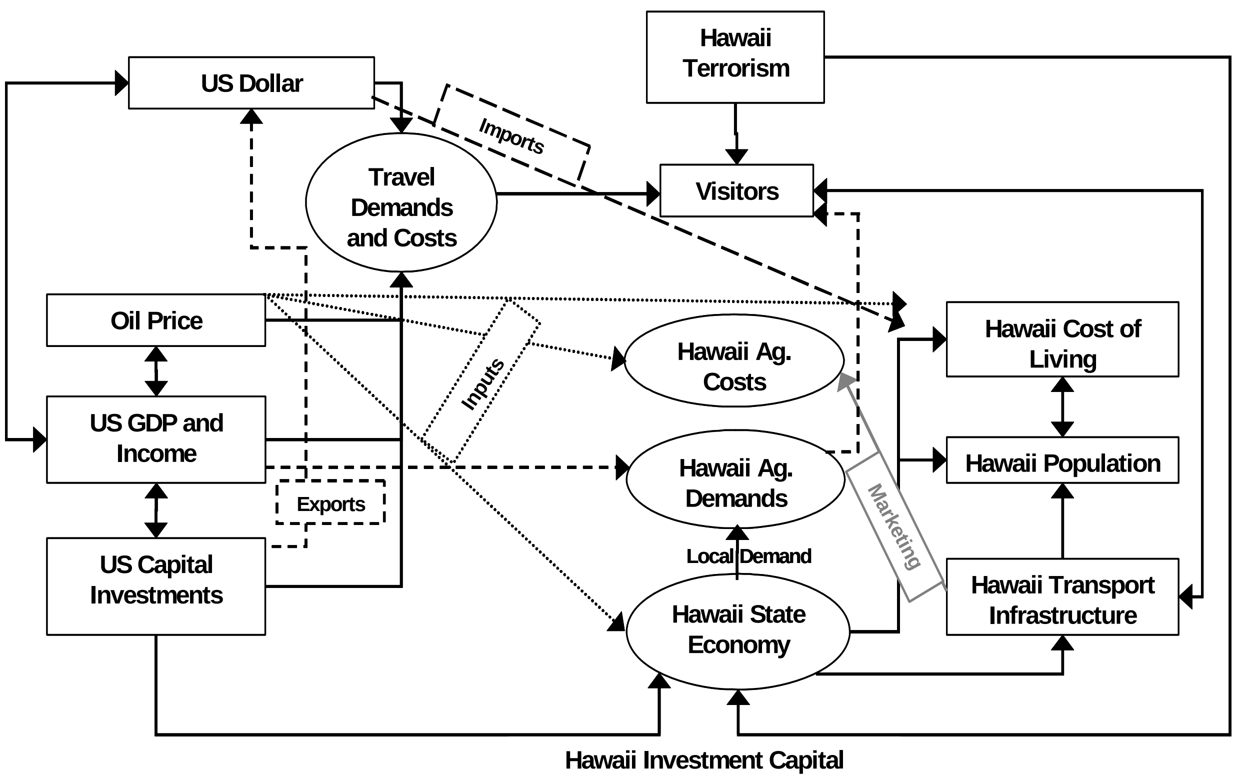

Fig. 88 Hawaii macroeconomic-agriculture linkages (NREM, 2008).

Planning scenarios (Table 34) were developed from this model and panel descriptors for a plausible range of conditions, which were considered in developing projections of land use acreage for bioenergy production (NREM, 2008).

Table 34 Macroeconomic scenarios' key features (NREM, 2008)

Scenario	**Hawaii Agriculture**	**General Economy**
Optimistic	growth exceeds other sectors new specialty crops & bioenergy industry increased marketing efficiency	strong growth stabilized oil prices, depreciating dollar higher local incomes
Pessimistic	gradual decline rising costs, low-cost competitors slow export growth	stagnation with sharp downturns volatile dollar, increasing oil prices falling local incomes credible terrorist threat
Most Likely	modest growth higher costs, shipping congestion increased exports	moderate growth higher oil prices, fluctuating dollar increasing local cost of living

Attributes for the scenarios presented in Table 34 were as follows (NREM, 2008). In the *optimistic scenario* i) Hawaii agriculture will flourish with the establishment of a bioenergy industry, ii) Local infrastructure will improve bioenergy transport systems, iii) The price of oil will level off, but bioenergy demand will remain strong at the same time, iv) Moderate prices for energy restrain agricultural production costs, increasing profits. In the *pessimistic scenario* i) The price of oil will continue to rise, with occasional spikes above $100 per barrel due to unpredictable supply and high costs of alternative energy sources, ii) There will be inadequate public investment to address transportation problems, iii) Inadequate labor and water make bioenergy crops impossible to cultivate. In the *most likely scenario* i) Visitors and resident population will increase domestic demand for agriculturally-based products, providing a steep opportunity cost for converting those products to bioenergy crops, ii) Higher oil prices, however, will raise local farm production and agricultural marketing costs, iii) The high oil prices coupled with a maturing public conscience will make bioenergy crops an appealing option. The macroeconomic panel's analysis found that Hawaii agricultural development is closely related with the general economic conditions and the *most likely scenario* mirrors economic projections in 2004 (DBEDT, 2004), where agricultural output is expected to grow 1.5-1.7% per year through 2030 (NREM, 2008).

4.9.2 Survey Report on the Likelihood of Bioenergy Cultivation

The 2006 Hawaii Agriculture Conference was held from October 26-27. The conference hosted a bioenergy workshop on October 27 and attracted experts and parties interested in bioenergy development in Hawaii. About 60 % of the 150 attendees filled out the survey. The detailed survey results are given in NREM (2008). In brief, the survey results were weighted based on respondent's self-assessment on their knowledge of agriculture and bioenergy. The question asked during the survey was the likelihood that bioenergy crops (sugar, starch, fiber or oil based crops) would be cultivated in Hawaii by the year 2030. Sixty-eight percent of the survey respondents believed that significant bioenergy crop cultivation is highly likely, two percent believed that it is not likely, and the remaining had checked the option for somewhat likely (Fig. 89). The survey questions also included the opinion of the participants regarding the most likely start date and the time period for bioenergy crop cultivation to reach its maximum potential.

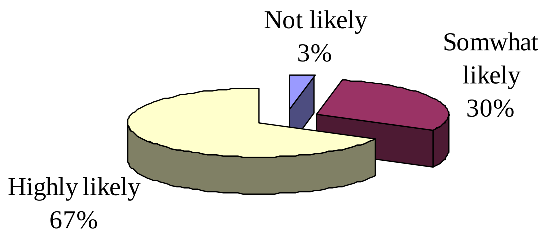

Fig. 89 Likelihood of bioenergy crop cultivation in Hawaii in the year 2030 (Reproduced from: NREM, 2008)

The participants were also asked about the likelihood of bioenergy crops in five production areas of Kauai, Oahu, Maui, and Big Island. None of the five production areas was chosen as a top location for irrigated bioenergy production (Table 35), and some of the participants suggested including Molokai and Lanai as other potential areas for irrigated bioenergy production.

Table 35 Likelihood of irrigation systems for bioenergy crop production (Source: NREM, 2008).

Production Areas	Likelihood, %	
West Maui: Pioneer, ML&P	1.84	Not likely
Oahu: North Shore (Waialua Sugar)	1.98	
Big Island: Hilo to Waipio Valley	2.40	
Central Maui: Wailuku, HC&S	2.82	
Kauai: Kekaha, East Kauai	2.89	Highly likely

In this survey, the participants were also asked to suggest potential irrigated crops or the likelihood of Hawaii farmers cultivating particular crops. Sugarcane was judged the most likely crop for bioenergy, followed by banagrass and *Leucaena* (Table 36). The survey narrowed down possible bioenergy crops to sugarcane (for ethanol production), corn starch (for ethanol production), and banagrass or *Leucaena* (as fiber for biomass energy production) based on the study conducted by Kinoshita and Zhou (1999). Although oilseed bearing crops and trees for the production of biodiesel have been identified by many scientists and experts, the economic viability of these crops was considered less certain in this analysis (NREM, 2008). Since *Eucalyptus* is not likely to be irrigated, it was excluded from the survey as the study focused on agricultural water demands (i.e., irrigated crops only); however, *Leucaena* and banagrass are considered as irrigated crops as they require irrigation for optimal growth (Kinoshita and Zhou, 1999).

Table 36 Likelihood for Hawaii production of specific bioenergy crops (NREM, 2008).

Crop	Likelihood, %	
Corn	11.7	Not likely
Leucaena	28.2	↑
Banagrass	36.8	↓
Sugarcane	61.8	Highly likely

4.9.3 Potential Bioenergy Production Lands

The 2008 NREM study developed maps for potential bioenergy crop lands by overlaying GIS data on the former plantation lands, irrigation systems, and large landholdings (Hawaii Office of Planning, 2006) (Figs. 90 through 96).

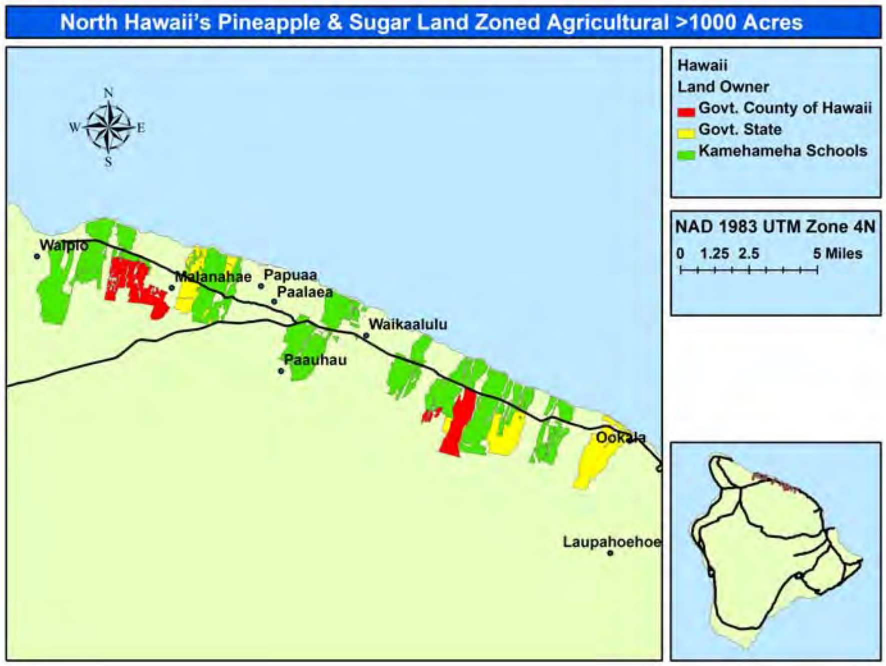

Fig. 90 Potential bioenergy crop land on the Big Island (North) (Source: NREM, 2008).

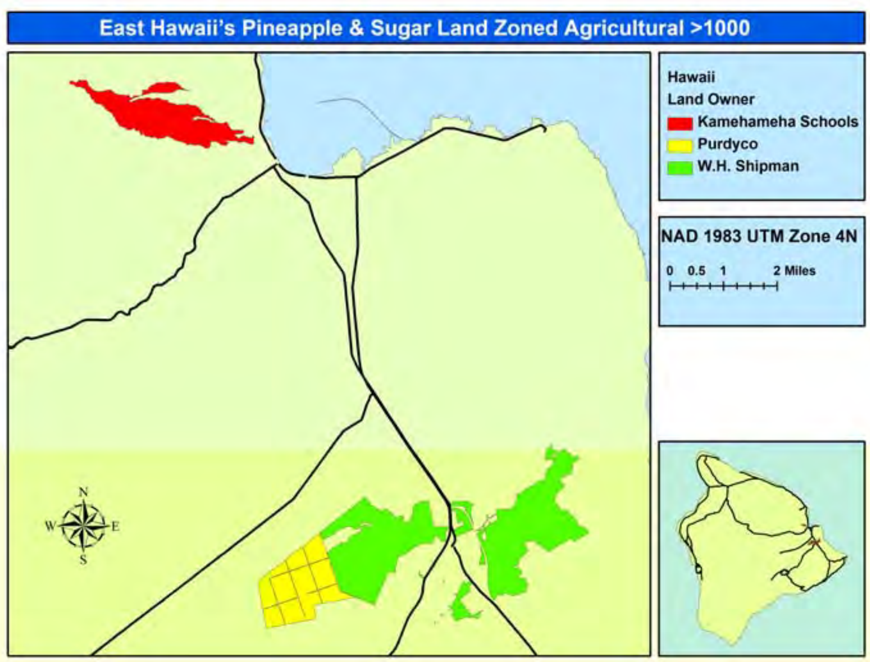

Fig. 91 Potential bioenergy crop land on the Big Island (East) (Source: NREM, 2008).

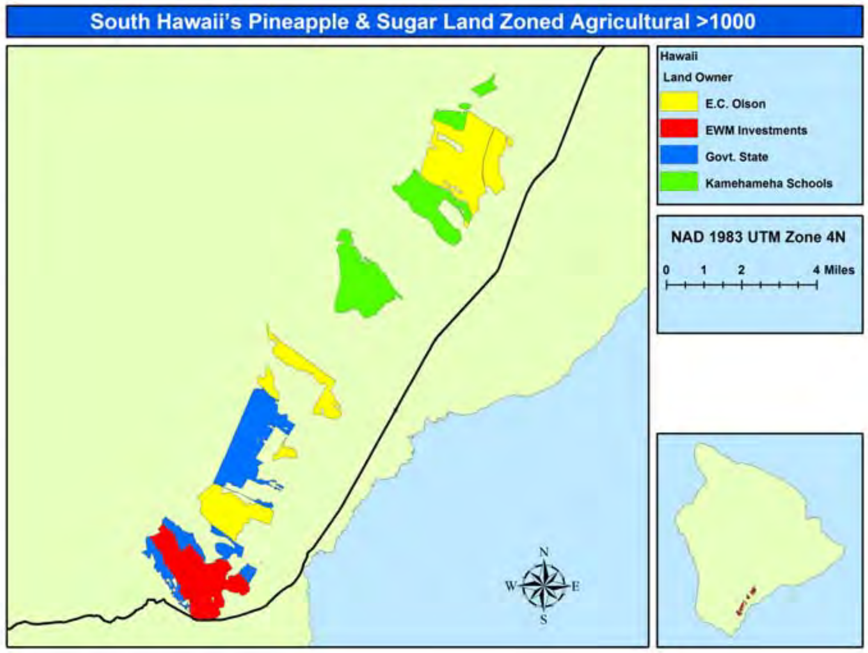

Fig. 92 Potential bioenergy crop land on the Big Island (South) (Source: NREM, 2008).

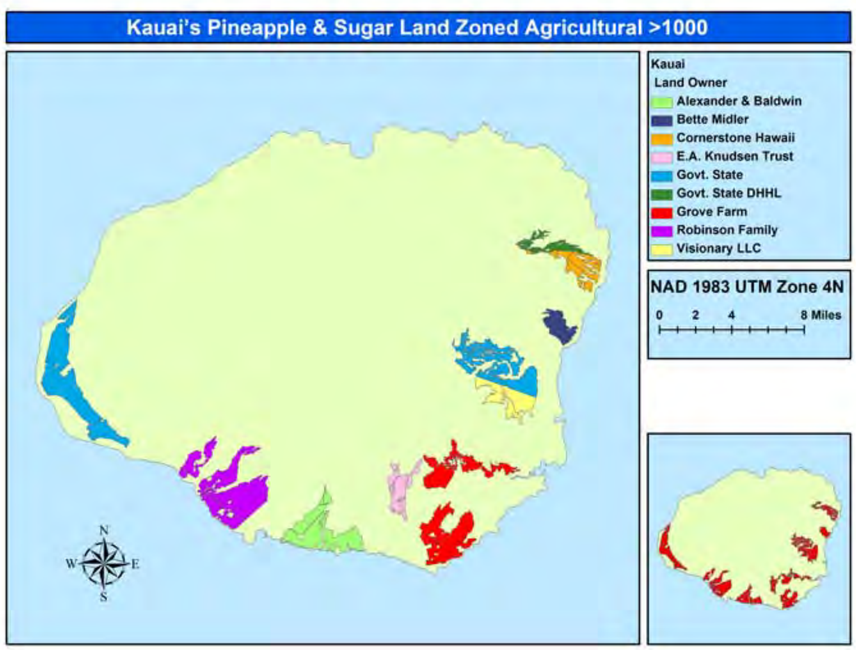

Fig. 93 Potential bioenergy crop land on Kauai (Source: NREM, 2008).

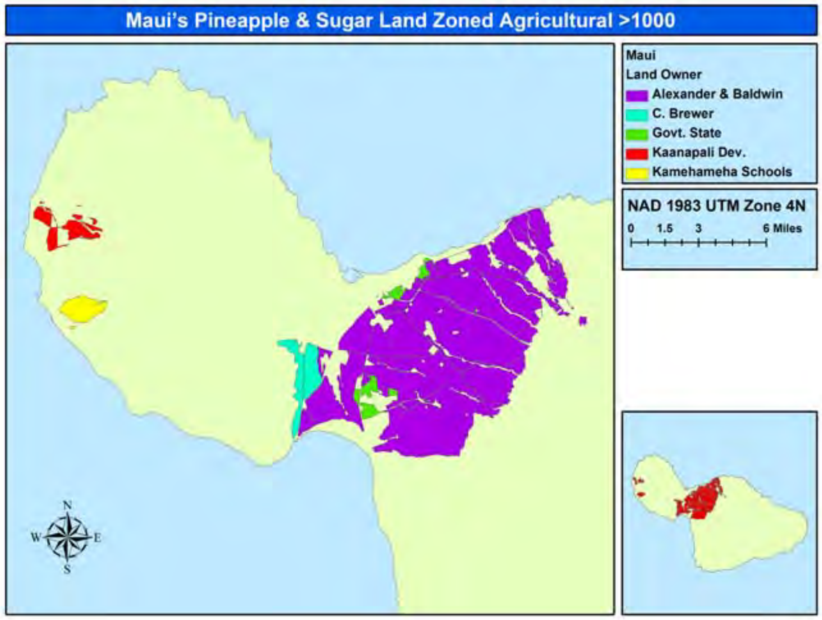

Fig. 94 Potential bioenergy crop land on Maui (Source: NREM, 2008).

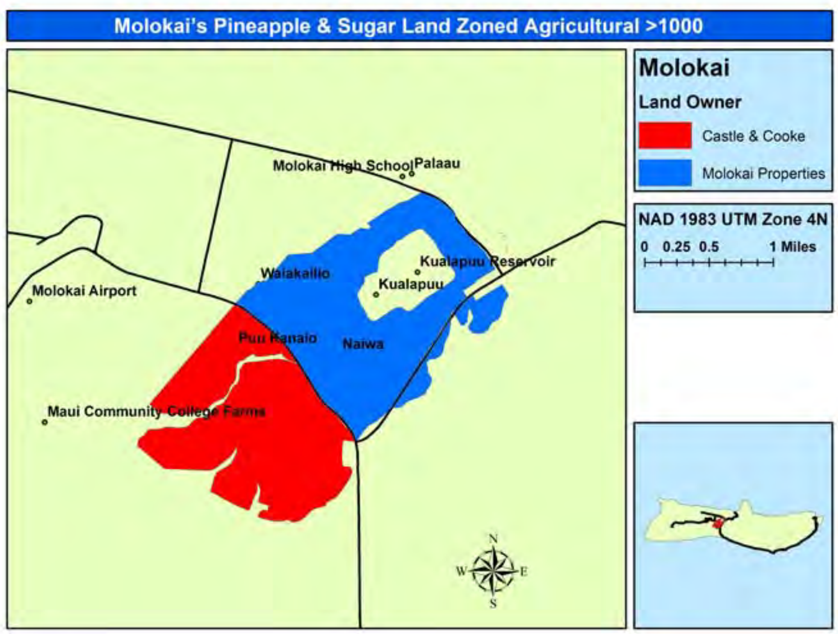

Fig. 95 Potential bioenergy crop land on Molokai (Source: NREM, 2008).

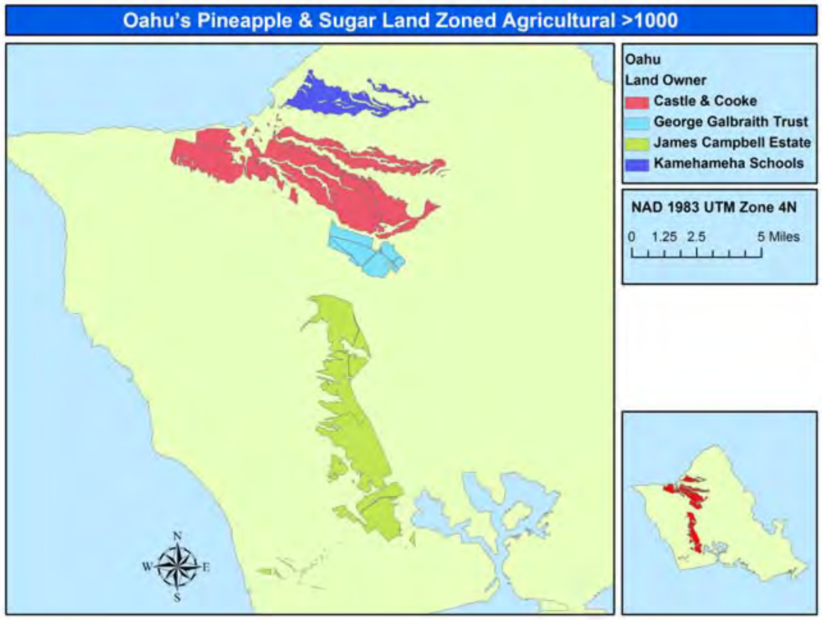

Fig. 96 Potential bioenergy crop land on Oahu (Source: NREM, 2008).

4.9.4 Scenarios of Bioenergy Acreage Projections

It was computed from these maps (Figs. 90 through 96) that approximately 137,000 acres of former plantation lands could be used for bioenergy crop production (Table 37). These lands do not include plantation lands that closed prior to 1978, or landholdings under 1,000 acres where sugarcane, seed crops, or coffee are currently being cultivated. With the fact that not all of these lands can be used for bioenergy crop production and by further eliminating the former plantation areas where extremely large investments in infrastructure would be needed (e.g., Molokai), the optimistic projection is for 53,000 acres statewide that might be utilized (Table 38). In this projection, Big Island and Kauai have around 20,000 acres available on these islands for bioenergy projects followed by Maui and Oahu with 3,000 and 10,000 acres, respectively. Due to lack of irrigation water, Molokai is projected to have no significant bioenergy production. Bioenergy acreage (Table 38) that lies within the 10 studied irrigation systems (Table 39) reflect that substantial bioenergy production is not projected to occur in 6 of the 10 studied systems. The highest projection is for East Kauai followed by Lower Hamakua, Waiahole, and Kekaha irrigation systems.

Table 37 Availability of former plantation irrigated lands for bioenergy, by island (NREM, 2008)

Island	Public	Private	Total
	------------------------------acre----------------------------		
Big Island	8,618	27,299	35,917
Kauai	10,766	22,149	32,915
Maui	1,109	42,371	43,480
Molokai	0	2,102	2,102
Oahu	0	22,259	22,259
Statewide	20,493	116,180	136,673

Table 38 Projected irrigated acreage under bioenergy crops in year 2030, by island (NREM, 2008)

Island	Optimistic	Mid-Point	Pessimistic
	------------------------------acre------------------------------------		
Big Island	20,771	10,386	0
Kauai	19,377	9,689	
Maui	2,951	1,476	
Molokai	0	0	
Oahu	10,147	5,074	
Statewide	53,246	26,623	

Table 39 Projected irrigated acreage under bioenergy crops in year 2030 for 10 studied irrigation systems (NREM, 2008)

Irrigation System	Optimistic	Mid-Point	Pessimistic
	------------------------------acre------------------------------------		
East Kauai	2,200	1,100	0
Kauai Coffee	0	0	0
Kekaha	5,621	2,811	0
Lower Hamakua	16,997	8,499	0
Molokai	0	0	0
Upcountry Maui	0	0	0
Waiahole	1,600	800	0
Waimanalo	0	0	0
Waimea	0	0	0
West Maui	0	0	0

4.9.5 Water Requirements for Bioenergy Crops

Coefficients of irrigation water requirements for the energy crops (i.e., banagrass, seed corn, sugar cane, and Leucaena) were estimated for each studied irrigation system (NREM, 2008). Because of physiological similarity, sudangrass and *Eucalyptus* were used to estimate coefficients for banagrass and *Leucaena*, respectively. Drip irrigation was assumed for sugarcane, leucaena, and for banagrass with 85% system irrigation efficiency for the two systems, respectively. Following the analysis conducted by NREM (2008) projecting crop demand for irrigation water over the next 25 years combines estimates of irrigation water requirements with the projections of acreages for general crop groups. Projections are by island and for the 10 studied irrigation systems under three macroeconomic scenarios: Most Likely, Optimistic, and Pessimistic. NREM (2008) presents estimates of farm-level irrigation water requirements for a number of crops and varied practices. Simple average IRR for the studied systems of a particular island was used for projections by island. Table 40 summarizes the assumptions to aggregate (simple average) coefficients used in projecting total irrigation water demands.

Table 40 Assumptions for developing crop group water requirement coefficients for studied irrigation systems (NREM, 2008)

General Crop Group	Water Coefficients	Number of Coefficients Averaged
Sugar	Year 1&2 by Spring and Fall plantings	4
Vegetables Crops	Spring and Fall plantings	24
Seed Crops	Spring and Fall plantings	2
Fruit & Nut trees	initial and ratoon crops, bananas only	8
Pasture		1
Bioenergy	see above crops	6

Estimates of seasonal irrigation water requirements are given by irrigation system in Figs. 97 and 98 by island. Projected bioenergy crop acreages are multiplied by irrigation water requirements to project irrigation water needed. Final projections of agricultural irrigation water demand for the 10 studied irrigation systems are given in Table 41. In the Optimistic scenario, growth in water demands is about double the Most Likely case, which shows the largest growth in demand, increasing an average 0.77 MGD per year by the year 2030 for Kekaha irrigation system. In the Optimistic scenario, the least growth is expected at the Waimanalo and East Kauai systems. The Pessimistic scenario projects no growth in irrigation demands at all systems. NREM (2008) proposed rehabilitation projects for 8 of the 10 studied irrigation systems with expectations to increase a system's long-run potential. Table 41 shows the estimated increase in 2030 demands from system rehabilitation. NREM (2008) also used the Hawaii Crop Improvement Association's estimate of growth in seed corn acreage at 8 studied irrigation systems (excluding Waimea and Lower Hamakua), plus other irrigated area(s) on the North Shore of Oahu (Table 42).

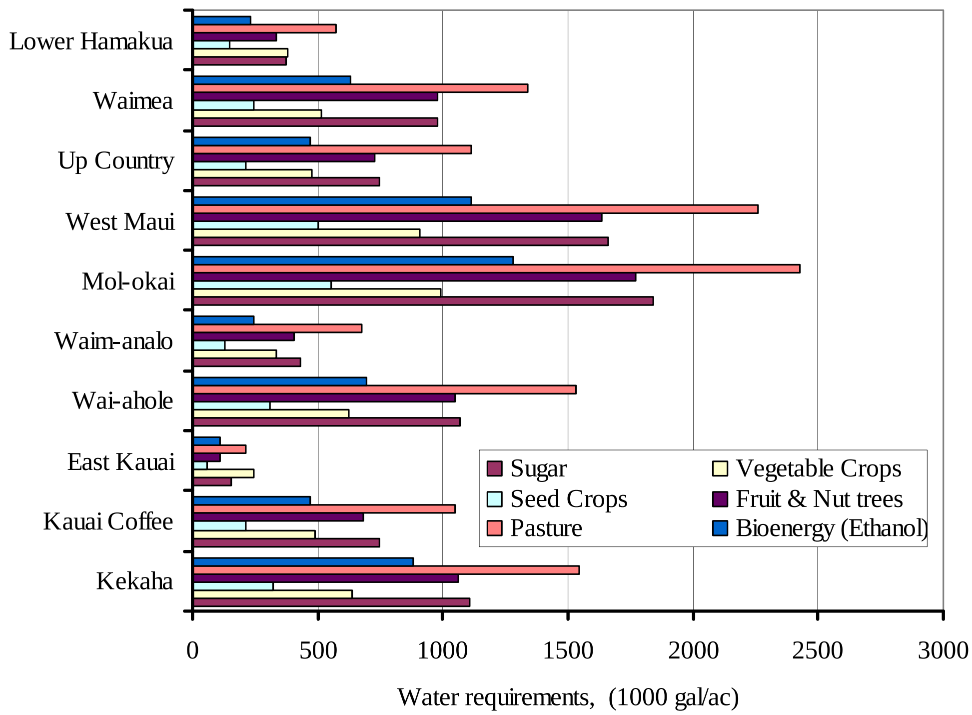

Fig. 97 Estimated seasonal irrigation water requirements, by irrigation system (1000 gal/ac) (Data extracted from NREM, 2008)

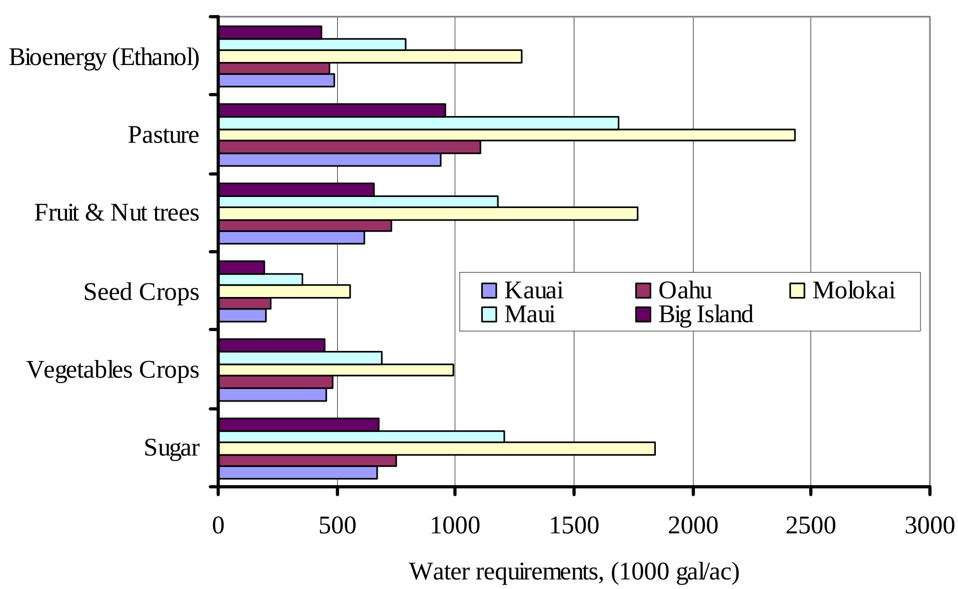

Fig. 98 Estimated seasonal irrigation water requirements, by island (1000 gal/ac) (Data extracted from NREM, 2008)

Table 41 Projected change in irrigation water demand for 10 studied irrigation systems, without and with system rehabilitation (million gallons per day) (NREM, 2008)

Scenario system	**WITHOUT REHAB**			**WITH REHAB**
	Avg. Annual 2005-2030	**Total 2005-2015**	**Total 2016-2030**	**Additional 2030 Demand**
Optimistic Scenario				
Kekaha	1.73	16.09	27.25	
Kauai Coffee	0.40	3.83	6.05	
East Kauai	0.09	0.90	1.44	
Waiahole	0.40	3.68	6.34	
Waimanalo	0.13	1.25	2.11	
Molokai	0.93	8.70	14.66	
West Maui	0.52	5.06	7.90	
Upcountry Maui	0.39	3.68	6.18	
Waimea	1.09	10.19	17.14	
Lower Hamakua	0.77	7.15	12.03	
Pessimistic Scenario				
Kekaha	-0.11	-1.54	-1.25	
Kauai Coffee	0.00	-0.04	-0.05	
East Kauai	0.01	0.10	0.16	
Waiahole	-0.02	-0.27	-0.25	
Waimanalo	0.00	0.00	0.04	
Molokai	-0.07	-0.78	-1.04	
West Maui	0.00	-0.06	-0.03	
Upcountry Maui	-0.01	-0.18	-0.07	
Waimea	0.05	-0.33	0.85	
Lower Hamakua	-0.02	-0.33	-0.19	
Most Likely Scenario				
Kekaha	0.77	7.81	11.53	8.05
Kauai Coffee	0.19	2.09	2.71	n/a
East Kauai	0.05	0.51	0.69	2.07
Waiahole	0.18	1.76	2.69	0.00
Waimanalo	0.04	0.40	0.58	1.96
Molokai	0.40	4.09	5.97	27.01
West Maui	0.25	2.76	3.48	n/a
Upcountry Maui	0.18	1.84	2.69	2.59
Waimea	0.54	5.51	8.07	1.25
Lower Hamakua	0.69	7.02	10.22	0.79

Table 42 Seed corn industry acreage estimates and impact on projected irrigation water demands, selected areas (Source: NREM, 2008)

Location	Industry Estimated Area (ac.)		Projected Water Demand (MGD)*	
	2005-2015 Growth	2016-2030 Growth	2005-2015 Increase	2016-2030 Increase
Studied System				
Kekaha	575	243	0.45	0.08
Kauai Coffee	150	200	0.07	0.08
East Kauai	475	455	0.08	0.07
Waiahole	1,685	475	1.40	0.33
Waimanalo	0	0	0.00	0.00
Molokai	100	100	0.14	0.12
West Maui	100	100	0.10	0.05
Upcountry Maui	250	250	0.14	0.14
N. Shore Oahu	200	250	0.17	0.21

4.9.6 Crop Irrigation Water Demands – by Island

Water demand is defined to be the irrigation water requirement to achieve full (non-deficit) production, regardless of whether any irrigation system is currently available. Based on the 2008 NREM report, estimated growth in acreage for different crop groups were used to allocate different islands based on proportions estimated in a Delphi survey (NREM, 2008). These rates were applied to 2005 crop acreages to project cultivated area to 2030. Projected acreages were multiplied by the respective coefficients to estimate island irrigation water demand through to 2030.

Fig. 99 presents the projected water demands for all crops under the three scenarios and shows that Oahu and Molokai are the islands with the smallest irrigation water demand, while the Big Island and Maui have the largest. Since growth in water demand depends on the scenario considered, in the Most Likely scenario, demand increases by about 50% for Kauai, Oahu and Molokai by 2030. Due to much larger base demands, the relative growth is 15-20% lower for Maui and the Big Island. Water demand roughly doubles for Kauai, Oahu and Molokai, with 30-40% growth on Maui and the Big Island in the Optimistic scenario. Whereas, in the Pessimistic scenario, demand is relatively flat, with growth less than 10% over 25 years.

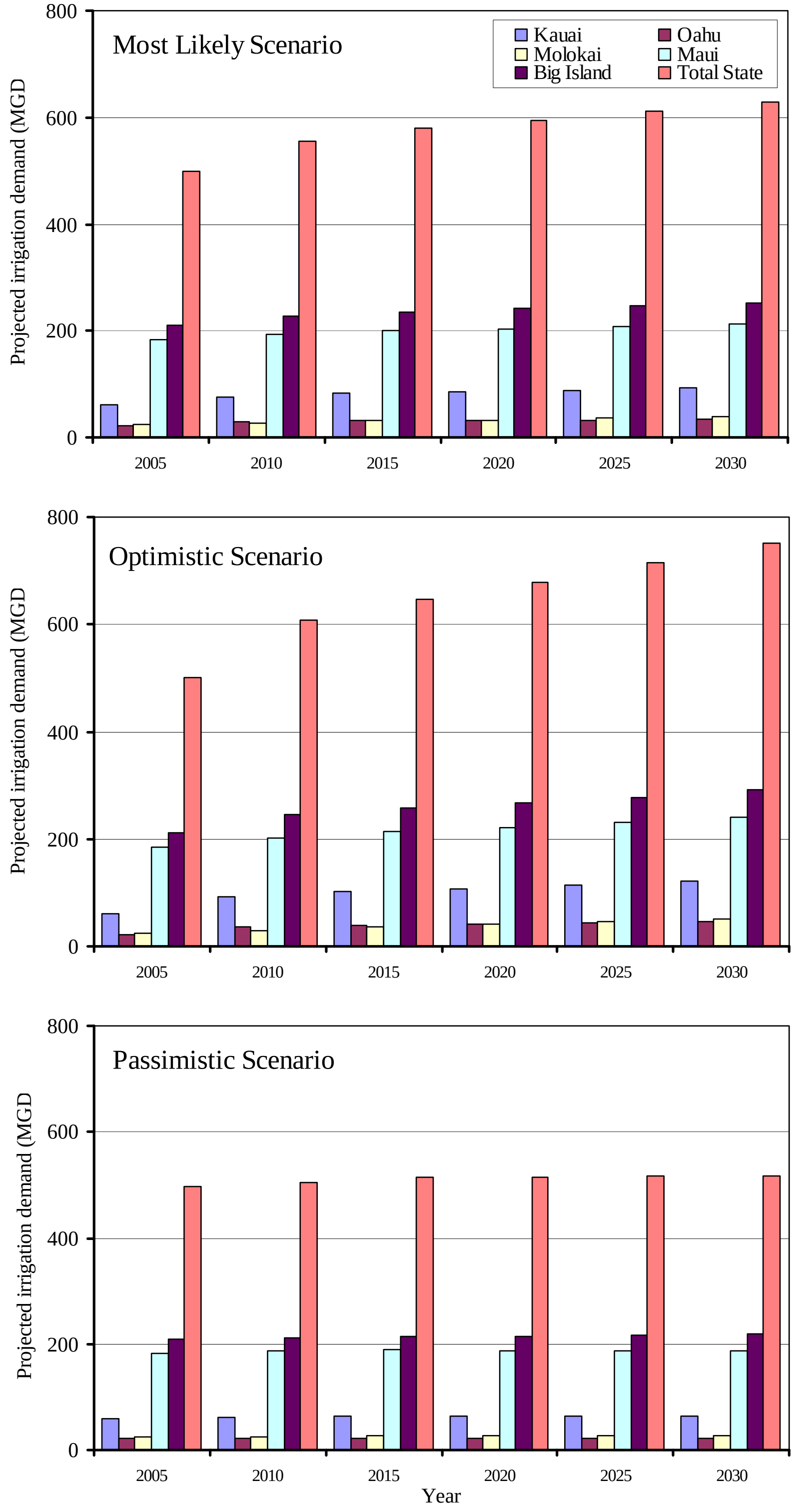

Fig. 99 Projected 2005-2030 irrigation water demands (MGD) by island under three macroeconomic scenarios (NREM, 2008)

5. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

This report explores and evaluates land and water resources available for bioenergy crop production. The report presents data and information with GIS maps, graphs, and tables that are used to assess adequacy of these valuable resources for bioenergy production. Recommendations are also provided including describing areas of research needed to complement available information. A complete assessment is hindered by the lack of information in some aspects, especially related to water resources.

5.1 Available Water Resources

Key issues in water resources include assessing water resources of the Hawaiian Islands, evaluating current uses, and discussing plans for future uses, including bioenergy demands. Also of paramount importance are issues related to efficient water uses and the development of alternate water resources. Conclusions from the analysis are presented below.

Efforts to utilize biofuels should include better characterizations of the “water budget” for various hydrological systems as it is an important factor in planning water use. The budget accounts for all of the inflows, outflows, and changes in storage within the system. Groundwater recharge is an important element of the water budget. Groundwater recharge is needed in managing groundwater resources including estimating aquifer sustainable yields. Utilization of groundwater resources for biofuel production will necessitate assessing its influence on aquifer recharge and on estimated aquifer sustainable yields. The entire water system in key islands is a complex network of inter-connected ditches, irrigations systems, diversions, flumes, and reservoirs. Information about private diversions is lacking.

The 2008 Natural Resource and Environmental Management report projected agricultural acreages as an intermediate step to the year 2030 in 5-year increments, broken down by island, under different scenarios including *optimistic*, *pessimistic*, and *most likely*. In the *optimistic* scenario, state farm-level demand for water would grow to around 750 MGD in the year 2030 if all crops are fully irrigated, which is more than double the latest USGS estimate of irrigation water use for all purposes with an increase demand by another 35 MGD of irrigation water for new bioenergy crops beyond current sugar operations (NREM, 2008). To meet these future needs, further study is needed regarding allocation and development of the state’s water resources.

A total of 575 future state projects were reported by various departments requiring water supply and/or service. For the designated 20-year planning horizon, agencies reported that an additional 81 million gallons per day (MGD) would be needed to supply such projects, which is beyond the current resource capability. Maximum capacity of the 10 studied systems (NREM, 2008) is 387.4 MGD out of which irrigation water use totals 363.5 MGD allowing approximately 24 MGD for new projects such as bioenergy crops.

The forecast of the State Water Projects Plan (SWPP) water demands were formulated into high, medium and low demand ranges (Fig. 100). The medium forecast was composed of

SWPP project water demands as reported by various State departments. The low range was developed by reducing the base or medium forecast demands by 20 percent. Such a reduction accounts for demand side management measures, savings from water conservation, conservatism within the Water Standard System unit rates and uncertainties with project funding, construction of projects, and project delays. The high range forecast was determined by increasing the medium demand range by a 20 percent factor. The high-end forecast provides a contingency to the medium demand forecast to account for additional future State projects or modifications to SWPP projects. Demands for bioenergy should also adopt a structure that is consistent with these ranges. Adopting savings and other measures consistent with the low demand range is highly recommended which can translate to enhanced availability of water for bioenergy.

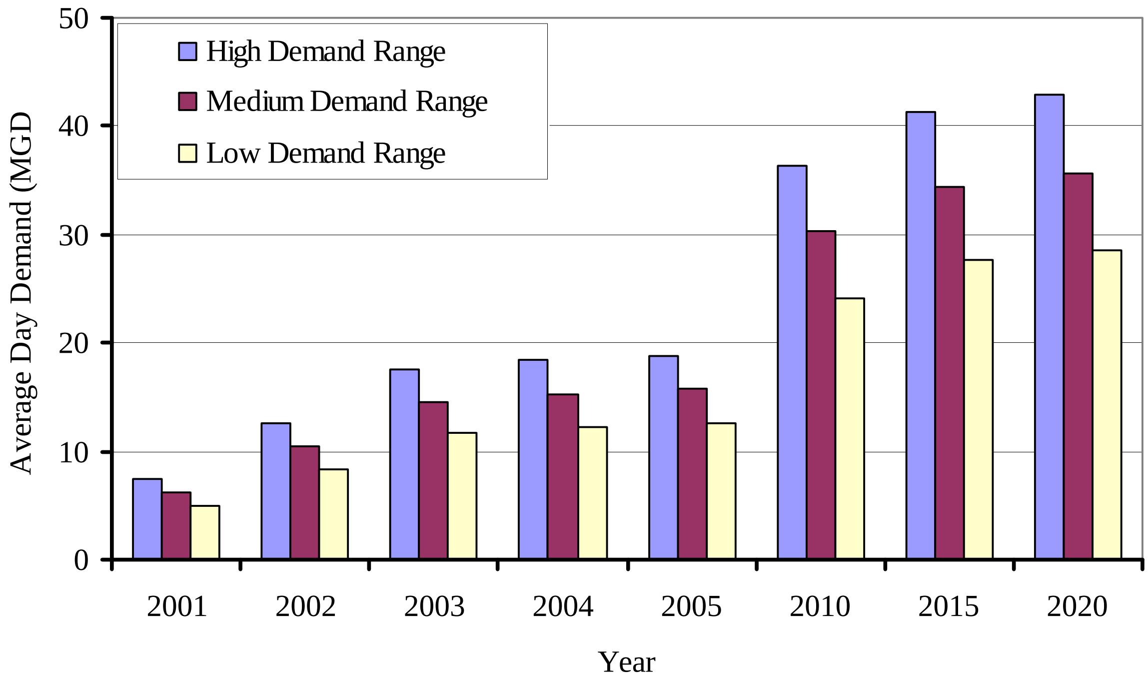

Fig. 100 Forecast Ranges of Unmet SWPP Project Water Demand (Data Source: CWRM, 2003)

5.2 State Owned and/or Operated Water Systems

The State of Hawaii owns and operates water systems including wells, stream diversions, and water systems that include public water and agricultural irrigation systems. Water from the State wells is used for various applications with principal uses that include potable water supply and irrigation. Miscellaneous uses include cooling, landscaping, aquaculture, and wetland maintenance. Any plan for developing biofuel should also include the potential effect on drinking water resources. The 1996 reauthorization of the Safe Drinking Water Act required that each State in the U.S. addresses the protection of public drinking surface and subsurface water sources, including the development and implementation of a source water assessment program.

The water collected from existing State diversion works is used primarily for agricultural operations. Other uses include potable water supply, generally for remote areas, e.g., parks and recreation areas. However, there are many systems are privately owned and there is a lack of knowledge about the condition of these systems, especially regarding whether they are operational or not, and regarding the volumes of water diverted to other watersheds. Obviously future plans for biofuel necessitate accurate accounting of water budgets including diversions.

Agricultural practices for Bioenergy developments should conform to the State Water Code. In addition, relevant water use would be consistent with and with projected water demand. Relevant issue in the State Water Code is the fact that geographical boundaries for the development of regional plans, including bioenergy, coincide with the hydrological units established in the Water Resources Protection Plan. As such, water resource protection and environmental quality should be subject to limitation of the State Water Code. Bioenergy water demand should be contingent on projected water demand, sustainable yield, and permitted water use by islands, as documented by SWPP. The additional water needed to support future State projects, including bioenergy, will affect available sustainable yields in several hydrological sectors. The water development strategy also identified Short-Term (2001-2010) and Long-Term (2011-2020) options to meet projected potable and non-potable water demands. Estimating available water for bioenergy should follow the strategy of SWPP the objective of which was to provide more effective planning, coordination, and development of water resources to meet projected State water demands. The strategy provides the basis for determining the “remaining” SWPP project water demands, which were not assigned to any specified source option. The Water Development Strategy proposed a formula for assessing the remaining balance of unmet SWPP project demand. The formula can be used with an iterative process to reduce SWPP project demands, including bioenergy, through assignment of available or planned source options.

5.3 Opportunities of Water Reuse for Bioenergy Crops

Reuse of the treated wastewater offers opportunities to stretch natural supplies of water for bioenergy crops. Cost of new infrastructure and operational expenses (e.g., energy for pumping) to deliver reclaimed water to irrigable areas needs calculations/estimations. We believe that besides water availability, feasibility of reuse irrigation for bioenergy crops will depend on the cost of constructing new pipelines and delivering water to irrigated areas. To our knowledge, no systematic study of such costs/benefit analysis has been conducted in Hawaii. Without more information on the cost of recycled water capacity and distribution, potential for increasing reuse of treated irrigation water cannot be assessed.

Development of supplemental sources of water is needed in order to meet the demands of increasing population and sustainable water resource management. A well developed system to recycle water, assures continuous and reliable supply of water without worrying about droughts or water restrictions. Option for developing a reusable water system provides additional advantage for utilizing the existing/dissolved nutrients in the wastewater thereby reducing the need for fertilization in most instances. Another advantage of establishing a reusable water system is that it is environmentally friendly approach compared to the traditional disposal methods through outfalls and injection wells. Although the applications of reusable water have been historically increased in Hawaii, there are still chances of expanding this opportunity.

There are two existing R-1 recycled water distribution systems in the county of Maui. These redistribution systems are potentially expandable. There are two water reclamation facilities at two of the eight wastewater treatment plants in the City and County of Honolulu. These facilities are at Honouliuli in the Ewa district and at Wahiawa in the central Oahu district. Both of these facilities are under consideration for expansion. The Waianae wastewater treatment plant on the leeward coast of Oahu is under consideration for a future water reuse project.

5.4 Available and Potential Feedstocks

Accurate information on a reliable biomass feedstock supply, production and harvesting costs, and environmental impacts are among key factors for continued development of bioenergy production systems requires. Understanding the cost and the quality of biomass production is critical for evaluating the competitiveness of biomass as feedstock. Development of the bioenergy industry necessitates determining ways to lower biomass production costs including handling and transportation, reducing uncertainty of supply, and capturing the value of environmental benefits and transferring them to the producer. Studies have characterized a number of existing municipal and agricultural waste streams that might be suitable for ethanol conversion. Fiber-based (lignocellulosic) ethanol production involves large quantities of feedstock.

According to Surles et al. (2007), bagasse, cane trash and municipal solid waste, and the largest waste streams are among the largest sources of biomass wastes. Municipal solid waste on Oahu and bagasse on Maui, are used for power production at the HPower waste-to-energy plant and the HC&S factory, respectively. Surles et al. (2007) reported that the Gay & Robinson (G&R) sugar factory on Kauai used to produce excess bagasse; the facility was recently sold to a third party for power generation.

Among the most capable crops for fiber production are sugarcane and banagrass, and woody crops (*Eucalyptus grandis, Eucalyptus saligna,* and *Leucaena leucocephala*; giant *Leucaena* or haole koa). These crops are strong candidates as energy crops for sugar or fiber production. Currently, only sugarcane and *Eucalyptus* are being grown commercially. Large acreages of *Eucalyptus* had been planted but none have been harvested to date. Additionally, sweet sorghum, albizia, and guineagrass have been proposed but large scale trials to evaluate their suitability as energy crops in Hawaii have not been carried out.

5.5 Potential for Bioenergy production in conjunction with phytoremediation and bioremediation processes

The need to develop effective and affordable methods for decontamination becomes more critical urgent as the number of sites and levels of contamination increases. Phytoremediation is a low-cost option, particularly suited to large sites that have relatively low levels of contamination. Energy crops have the potential to utilize agricultural and municipal wastes, and to stabilize or clean up contaminated land. High yielding bioenergy crops offer good potential for the phytoremediation of sites contaminated with heavy metals.

Potential benefits a in conjunction with phytoremediation include the fact that bioenergy crops are not going to enter the human food chain, bioenergy crops are mostly perennial crops, thus allowing long-term breakdown of organic matter in soils prior to converting to food cropping, bioenergy crops produce large quantities of biomass that, theoretically, requires large quantities of nutrients, and thus are a sink for the nutrients in waste.

There are accompanying risks with the application of agricultural and municipal wastes and bioremediation. Possible risks include: risks of leaching nutrients applied in sludges into groundwater, risks of increased atmospheric emissions of greenhouse gases, associated with global warming, risks of contaminant accumulation in the production system, which are then emitted from power station stacks upon combustion of the biomass, negative impacts on the biodiversity associated with energy crops.

5.6 Availability of Existing Lands for Biofuels and Biomass Crops Production

Studies indicated that approximately 137,000 acres of former plantation lands could be used for bioenergy crop production. Considering various limitation, such as the need for extensive infrastructure, the optimistic projection is that only 53,000 acres statewide can be utilized for bioenergy crop production. The estimated acreage for the Big Island, Kauai, Maui, and Oahu are, 21,000, 19,000, 3,000, and 10,000 acres, respectively. The following sections discuss specific land availability on various islands for bioenergy development.

5.7 Stakeholders Input

Stakeholders with interest in Land and Water Resource for the Hawaii Bioenergy Master Plan met on April 02, 2009. Participants were asked to brainstorm their ideas regarding: i) critical information required by producers or land owners to make a decision for bioenergy crop production, ii) availability constraints for current land and water resources for biofuel production, and iii) actions required in next 2-3 years to address the priority constraints. Similar ideas from the participants were grouped and labeled (Appendices A and B). The participants then voted to identify the group’s most critical information needs. Ideas from the participants and from the stakeholders who reviewed first version of the report have been included in the recommendation sections of this report.

5.8 Recommendations

Several limitations were observed during our analysis and are presented in this report. Among them are:

- Bioenergy crops performance is not known under all environmental conditions available in different Hawaii locations (temperature, moisture, soil depth) in the state. This information is needed to mach bioenergy crops with their optimum production environmental conditions for optimum yield and production.
- The current bioenergy crop list is limited; there might be other species that could be better suited for certain Hawaii environments.
- There is a lack of on information on crop production for many of these new bioenergy crops. For instance, there is little experience with oil palm and *Jatropha* production in Hawaii. Mechanical harvesters for *Jatropha* are beginning to be available, but not well tested.

- Crop varieties are constantly being improved. This may make this analysis obsolete in the near future.

The following recommendations are offered as a starting point for further work. These recommendations include suggestions from stakeholders.

- Find candidate species adapted to cool and cold regions for use at higher elevations. Most of the agriculturally zoned lands have cool and cold temperature regimes. Yet almost all the species evaluated seemed to perform better in the warm environment with the exception of *Eucalyptus*. There may be other species adapted to these temperature regimes that may equal or outperform *Eucalyptus*, which would give growers more options in deciding how to manage their lands. Find crop species adapted to dry environments. There are about 186,000 acres classified as dry throughout the state. Find crop species adapted to shallow soils.

- Develop a cropping system that could integrate bioenergy crops with regular crops for efficient utilization of resources such as land, water, time, and labor.
- An assessment is needed on the co-existence of bio-energy crops with other agricultural crops. A balance between food and fuel crops will ensure the equal and sustainable use of resources. Prioritize the use of resources for production of food and fuel crops.
- Develop a decision support system (DSS) that could match biological characteristics of crops to physical characteristics of soil and to environmental and ecological acceptance. Such a GIS-based DSS may help growers decide the best crop for their farms. Build a database for bioenergy crops detailing crop characteristics, potential yield, land and water requirements, and their suitability for integration with other crops and with environmental conditions in different regions in Hawaii.
- Help farmers conduct a cost-benefit analysis for a specific bioenergy crop.
- Climate change may pose a significant threat to bioenergy crop production. The present analysis is insufficient to forecast outcomes and is not able to deal with climate change scenarios. Better models will need to be developed to answer questions regarding the magnitude of the effects of climate change on crop production.
- Increase sustainable water supplies (traditional and non-traditional) for agriculture including bioenergy and biomass crops. Test water-harvesting technologies (e.g. stormwater harvest, reclamation and reuse) in Hawaii to minimize water runoff and maximize water storage. Other ways to increase and protect water resources in Hawaii may include watershed protection and improvement programs, reduce water conveyance losses and improve irrigation delivery efficiency, and others mentioned by CWRM reports.

- Utilization of new groundwater resources for biofuel production will necessitate assessing its influence on aquifer recharge and on estimated aquifer sustainable yields.
- Study the potential effect of bioenergy crop production on drinking water resources. Assess the sustainable use of land and water resources. Any plan for developing biofuel crops should also include the potential effect on drinking water resources.
- Further understand Hawaii's water and land resources availability and constraints for bioenergy crops.
- Growing high water demanding bioenergy crops and biomass feedstocks in windward areas will use the available soil moisture and rainfall and require less supplemental irrigation.
- Growing less water demanding bioenergy crops and biomass feedstocks in leeward areas will suite environmental conditions and water availability in the area.
- Models that use daily water budget approach to calculate crop irrigation water requirements should be preferred in modeling crop water use.
- Drip irrigation system is considered a water saving system with high irrigation application efficiency. It can be preferred over micro-sprinkler irrigation system as its efficiency is not impacted by wind, and it can be used with recycled irrigation water.
- Develop or enhance water infrastructure sufficient to support biofuel use.
- Rehabilitate irrigation systems that are currently not in use where sugarcane growing has discontinued. In places such as Kekaha in Kauai, even if the irrigation systems are still functional, the cost to rehabilitate them to deliver the amount of water needed for high water consumption crops could be prohibitive.
- Since biofuel has commodity characteristics, bioenergy production may develop into a large industry. Therefore, a possible conflict and competition in the use of resources between bioenergy and food crops can exist. A study should be conducted to address this and related issues.
- Since the Department of Land and Natural Resources (DLNR) issues revocable permits to ranchers on state land that is zoned for agriculture, the impact of possible use of these lands for bioenergy crop production on the cattle industry needs to be assessed.
- Conduct a systematic study for costs/benefit analysis of potential reuse of treated water for bioenergy crops. Such analysis may include resources needed for expansion and upgrading of treatment facilities, construction of water delivery infrastructure to the agricultural lands, and scale of bioenergy crop production.
- Long-term impacts of planting a certain crop on the land and other infrastructure need to be studied. For example, what happens when that crop is no longer in demand? Can the land be converted back for use with other crops? What would be

the impact of discontinued production? This could be studied based on the experience gained from sugarcane and pineapple industry.

- Maintain land currently used for agriculture and forestry, and additionally, increase land available for bioenergy use sufficient to support biofuel use.
- Further understand Hawaii's water and land resources availability and constraints for bioenergy crops.
- Learn to manage lava lands. A significant portion of the 528,000 acres of unclassified land is lava. These lands are currently covered with volunteer trees that indicate it can support plant growth. Learning to cultivate these has the potential of opening large tracts of land for bioenergy crop production.
- Remap ALISH to incorporate latest land use changes, availability of new lands (lava and non-ALISH lands), and proven potential of Hawaiian lands for diversified cropping.
- Enact land policies necessary to keep agriculturally zoned lands in agriculture.
- Further support of the objectives of water and land Tasks and/or Plan implementation pursuant to Act 253 regarding Hawaii renewable biofuels program to manage the State's transition to energy self-sufficiency based in part on biofuels for power generation and transportation.
- Make sure that the changes in the State Administration do not affect implementation of this Master Plan. Educate the next generations as well as coming administrations for seamlessly carrying on of the work, and the wise use of land and water resources.
- As suggested by SunFuels Hawaii, creation of an ongoing fact-finding and policy discussion forum, an independent statewide panel steeped in science, technology assessment and land use analysis.
- A detailed study of projection and comparison of energy from biofuel crops with that from other technologies, e.g., solar- and wind-based energy. The study may focus on how will biofuel crops compete for the use of resources potentially set aside for wind and solar energy production.
- State residents are the most critical stakeholders, as they will most benefit from bioenergy production in Hawaii. Other stakeholders include scientists, researchers, students, policy makers, land owners, and growers/farmers.
- Technical experts for research and strategic planning on State's future bioenergy plans include principal investigators of the current project, academia, and researchers and scientists working in local, state, and federal agencies.
- Encourage close collaborations among scientists, researchers, policy makers, extension agents, and farmers as a comprehensive link of information dissemination in order to provide the context for informed decision-making

- Existing reports on the completed projects of Hawaii's water resource and planning studies (CWRM, 2003, 2005, 2007), DBEDT's reports, and agricultural land and water use plans (AWUDP, 2004, NREM, 2008), are sources of information.

NREM (2008) suggests further studies on various topics that closely relate to the current Bioenergy Master Plan. Description of the suggested studies is briefed below.

- *Ground Water Resources, Locations, and Potential Yields*: Inventory of the records from different agencies i.e., DLNR. Groundtruthing and field determination of potential yield for the locations that have missing records. Estimating the costs of rehabilitation and upgrading of the existing infrastructure of the existing systems (if any).

- *Surface Water Sources, Locations, and Potential Yields*: Inventory of the records from different agencies i.e., DLNR. Groundtruthing and field determination of potential yield for the locations that have missing records. Estimating the costs of rehabilitation and upgrading of the existing infrastructure of the existing systems.

- *Surface Water Diversions and Locations*: Surveying the existing records to determine all diversion locations that are either active or were active in the past. Evaluating the status of the existing diversions. Assessing the needs to rehabilitate these diversions. Quantifying the potential delivery capacity of the existing systems.

- *In-Depth Study of Biofuels*: Simulating different crop energy sources based on their energy yield and their demand on natural resources, and Economic analysis of the different potential scenarios.

- *Potential Use of Reclaimed Water*: Survey and analyses (engineering and statistical) of current reclamation schemes including physical facilities, water service, and costs. Identify barriers to expanding reclaimed water use, develop recommendations to overcome barriers.

- *Connection with Important Agricultural Lands (IAL) Classification* : Review of state and county policies for IAL designation and criteria related to water.

6. REFERENCES

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Hawaii Bioenergy Master Plan

Distribution Infrastructure
for Both Marine and Land

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Executive Summary

This section of the Hawaii Bioenergy Master Plan describes distribution infrastructure issues for liquid and solid forms of bioenergy. Infrastructure components for liquid biofuels discussed hereafter are those that are situated downstream of the biomass conversion plant, i.e. finished biofuel products as they are transported from the biofuel refinery storage to the end user. Infrastructure components for solid biomass discussed are concerned with transporting biomass to thermal power plants. Gaseous biofuels are not addressed as biofuel candidates in regard to distribution system considerations. Gaseous biofuels, referred to as “biogas”, are typically produced close to the point of demand, which would typically be biogas powered electricity or steam plants. Biogas is an established and important renewable energy source in many countries and biogas could provide important renewable energy supplies to Hawaii.

State and national energy goals support the increased supply of biomass-derived liquid, hereafter referred to as biofuels, to replace or augment petroleum products. The most common biofuels used today are ethanol, which can replace motor gasoline used in internal combustion engines, and biodiesel, which can replace petroleum diesel used in internal combustion diesel engines and in other prime movers for power generation. Straight vegetable oils, i.e. biofuels that are not refined further to obtain biodiesel, can be used in power plants. The straight vegetable oil would therefore replace heavier fractions of petroleum, such as residual oil.

The distribution modes for biofuel are basically the same as for petroleum products. The liquid products can be conveyed in pipelines, transported in rail tankers, tanker trucks or fuel tankers and stored in atmospheric storage tanks. The ideal scenario, the transformation of Hawaii’s fuel economy to one based on a significant portion of biofuels, would use the existing petroleum infrastructure, so that expensive new distribution infrastructure for biofuels could be avoided. The currently most common biofuels, ethanol, and biodiesel, however, have physical properties that cause a certain degree of incompatibility with existing petroleum systems.

Due to incompatibility issues, the transport of fuel grade ethanol and biodiesel requires either new dedicated distribution infrastructure or the modification of existing petroleum fuel systems. The incompatibility issues might require additional capital investment and operating costs for new dedicated distribution infrastructure or converted petroleum fuel systems. Replacing large amounts of petroleum products with biofuels that have limited compatibility with existing fuel transport and storage systems would therefore require that biofuel compatible distribution systems be in place before an expanded biofuel supply is available to the end user.

Since the biofuel industry is a rapidly evolving energy field, new types of biofuels are being developed that offer a higher degree of or even full compatibility with existing petroleum fuel distribution and engine systems. Examples of such new and promising fuels are bio-butanol and renewable diesel. Using such new biofuels would have the significant advantage that existing petroleum fuel systems could be used for the distribution of these biofuels with no or only slight modifications. These fuels would therefore allow a basically seamless transition of fuel distribution from petroleum to renewable fuels and biofuels.

The issue of biofuel compatibility with existing petroleum distribution infrastructure has a significant impact on the required scope and capital investment for future biofuel use in Hawaii. The present market value of Hawaii's existing petroleum infrastructure is estimated at about $3.6 billion (excluding the value of the two local petroleum refineries) and thus represents a significant asset, which cannot be easily and expeditiously replaced. Furthermore, during the transition period from petroleum fuels to biofuels, both the petroleum and biofuel infrastructure would have to be maintained if there were to be incompatibility of biofuels with existing distribution infrastructure. Since possible production shortfalls or interruptions of a growing bioenergy industry might require, from time to time, supply substitution from out-of-state sources, import facilities for all the biofuels that will be used in Hawaii would serve as important infrastructure redundancies and would increase energy security.

It may be possible to convert components of the existing fuel infrastructure for distribution of ethanol and biodiesel if the material composition and other characteristics of the specific fuel containment components are exactly known. For large and interconnected fuel systems that combine many components, such as tanks, pipelines, and terminals, chances are that efforts to convert these complete existing petroleum fuel systems may present high investments or be practically impossible.

The distribution of solid bioenergy represents a technically and logistically smaller distribution challenge. In Hawaii, heavy truck operations are the mode of transporting solid biomass to bioenergy conversion plants. Heavy hauling trucks used for transport of biomass on public roads would be similar in size to trucks carrying 40-foot containers. The maximum weight of such trucks would be limited to 80,000 pounds. In most cases, the available cargo volume of trucks would be filled with lower bulk density solid biofuels before the maximum weight limit is reached. Therefore the transport of solid biofuel would typically be a "volume-limited" operation. Measures to increase the bulk density of solid biofuel would decrease the number of truckloads and impacts from solid fuel transport on public roads.

Trucking operations on private land could use larger and heavier trucks. The primary impact of solid biomass distribution would be from increased heavy truck traffic on public roads.

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1. Hawaii Fuel Infrastructure Challenge

The Hawaiian Islands are geographically isolated from the continental United States and are not connected to the nation's electric grid or to the petroleum or gas pipeline systems. Given this unique energy situation, Hawaii has to import all conventional energy resources by ship, where petroleum is the leading energy carrier.

Hawaii gets about 90% of all its energy from imported oil and petroleum products. The state is very heavily dependent on petroleum for virtually all its transportation and much of its electricity needs. While Hawaii's economy is not necessarily energy intensive, its average per capita oil consumption is over 40 barrels per year compared to 24 for the U.S. mainland. The per capita comparison between Hawaii and major growing world economies of China and India shows an even bigger discrepancy, since China's per capita oil consumption is about 2.2 and India's is close to 1.0.

The main contributors to Hawaii's high dependency on oil stem from high levels of aviation fuel consumption and the fact that about 80% of total electricity produced in the islands is petroleum based. On the U.S. Mainland, the portion of electricity that is produced from petroleum is between 1% and 1.5%. Historically, oil contributed much more to the generation of electricity, but since the late 1970s, after the two oil shocks in the 1980s, petroleum was generally replaced in the U.S. by natural gas and coal as preferred fuels for electricity production. Hawaii's energy infrastructure was built around cheap and easily transported petroleum, and alternatives, such as coal for power generation, were historically not given much consideration as major energy contributors before the 1980s. Starting some 20 years ago, however, larger quantities of coal for power generation were used, diversifying Hawaii's energy supply away from petroleum fuel. Today Hawaii uses coal, geothermal and other indigenous sources for power generation. The role of petroleum as the primary supplier of Hawaii's energy needs is, however, still unchallenged and petroleum will still play an important part in Hawaii's energy supply for many years to come.

The high reliance of all sectors of Hawaii's economy on petroleum requires a robust petroleum infrastructure, which includes marine and land fuel terminals, petroleum refinery process facilities, storage for crude oil and refined petroleum products, and marine and land fuel transportation and distribution systems to serve the end-user. The existing petroleum infrastructure has expanded over many decades to its present extent and represents a very large capital investment. During a transition period, should biofuel use in Hawaii grow and finally dominate the fuel supply, capital investment will be required for maintenance and replacement of petroleum distribution infrastructure, while at the same time significant investments will be required to build a modern biofuel distribution infrastructure in Hawaii.

While many petroleum infrastructure components were built decades ago when the consumption rates were lower than Hawaii's current needs, the existing petroleum fuel system has to cope with unabated demand and aging components. Since a serious initiative to introduce biofuels as alternatives to petroleum fuel in Hawaii has started only relatively recently, it might take years or decades to replace significant volumes of petroleum with biofuels in the islands. During the time of transition towards higher biofuel consumption, the petroleum infrastructure system has to be maintained at a safe operational level and new capital investments will be necessary to replace system parts that are beyond their useful service life and to sustain operations within a sound environmental and post 9/11-security envelope.

As parts of Hawaii's fuel supply system are changed in accordance with the increased development of biofuels and the increased use of other renewable energy sources, a hitherto balanced fuel market in Hawaii, supplied by local refineries that produce petroleum products from imported crude oil, may need readjustments. In the process, segments of the fuel system may lose their economic advantage. New and substantial infrastructure investments may be required to keep the overall fuel system operational, during the transition towards a higher reliance on biofuels and renewable energy supplies.

As an example, described in subsequent sections in more detail, Hawaii's energy and fuel supply is developed around the two existing petroleum refineries on Oahu. Most (around 90%) of the petroleum fuel needs of Hawaii are met by importing crude oil and processing it locally to a Hawaii specific output slate (e.g. proportional composition of refined petroleum products such as gasoline, diesel, jet fuel, residual fuels, etc.). The output slate is generated to meet Hawaii's unique energy needs and reflects the processing capabilities of the two local refineries, configured to cater to Hawaii's fuel needs. If future fuel consumption would deviate significantly from the existing output slate, for example due to a large scale fuel replacement of residual fuel by biofuels for Hawaii's power plants, significant changes in the fuel infrastructure and energy system might be necessary. Therefore the transition towards biofuels, and to a certain extent also towards renewable fuels, might bring about investment needs for both petroleum and biofuels. In order to keep the required new investment in Hawaii's future fuel infrastructure within manageable proportions, care must be taken to make the inevitable introduction of biofuels both cost effective and non-disruptive to the existing petroleum fuel infrastructure.

2. General Approach of Adding Biofuels to Fuel Distribution System

The discussion of biofuel distribution does include liquid and solid biofuels. Since liquid fuels are by far the most important sources of energy for Hawaii, and thus represent the biggest potential of replacing petroleum products by biofuel, the discussion in the following chapters mainly considers liquid biofuels. Solid biofuels are primarily important as point sources for power and steam plants and the discussion of distribution considers the hauling of solid biofuels, e.g wood or sugarcane. Gaseous biofuels, "biogas", is typically consumed close to the point of production. Power and steam plants that use biogas would preferably be located close to the gasification plant. Biogas distribution though pipelines or through compressed gas transport vessels are emerging technologies, which are not considered viable energy distribution options within the timeframe of the bioenergy master plan. As point source of bioenergy, biogas might become an important element of the future Hawaii bioenergy system.

There are two basic approaches of incorporating liquid biofuel into the fuel distribution system of Hawaii -- establishing dedicated biofuel fuel systems and sharing legacy system assets between petroleum and biofuels.

2.1 Dedicated Biofuels Systems

Dedicated fuel systems are used when fuel end-uses require neat biofuels (e.g. pure biofuel or a blend with a small percentage of petroleum fuel) or if the blending ratio of biofuels and petroleum fuels is higher than allowable in legacy systems. In the case of E85 (85% ethanol fuel blended with 15% petroleum fuel) the material and operational requirements of E85 fuel are significantly different from conventional petroleum fuel systems to such an extent that either new or modified (where possible) infrastructure components are needed.

Dedicated biofuel systems must be specifically configured to meet the material and operational needs of the biofuels. Standards for the design, construction and operation of dedicated biofuel systems are currently developed, but their wide acceptance in the fuel industry might be years away, since long-term experiences with evolving biofuels are still somewhat limited. In comparison, after many decades of successfully using petroleum in many aspects of our society, virtually all construction and operational aspects of petroleum fuel systems are well known and reliable standards regulate all aspects of petroleum distribution.

If dedicated biofuel systems are required, the fuel infrastructure should be designed and built in such a way to ensure compatibility with a widest range of biofuels possible. At present fuel-grade E85 and B100 batches are typically transported separately in order to avoid impacts to the transport assets (e.g. pipelines) and deterioration of the biofuel – petroleum fuel blend during transport (e.g. avoiding water contamination).

2.2 Shared Petroleum and Biofuel Infrastructure

In shared fuel systems both biofuels and petroleum fuels can be handled, transported and stored, using the same distribution infrastructure components. In shared systems neat biofuel batches could use pipeline systems in sequence with petroleum products, much in the same way as current batch pipeline transport of different petroleum products, without dangers of fuel cross-contamination and system deterioration. Likewise, in shared fuel systems, blends of biofuels and petroleum can be transported without endangering the infrastructure and the fuel itself.

At present, pipeline operators are generally reluctant to allow use of their assets for either neat biofuels or higher blend ratios. There have been some reports of pilot projects where biofuel and petroleum blends with low blend ratios were successfully transported in existing pipelines (e.g. B5). But existing petroleum pipelines are typically not used for neat biofuels or higher blend ratios of petroleum and biofuel mixtures due to possible corrosion and water problems.

As can be seen later in this report, certain newer biofuels have promising product properties that are similar to conventional petroleum fuel products. If newer biofuels could fit seamlessly into existing fuel distribution infrastructure or at least with less material and operational impacts than ethanol and biodiesel, then significant infrastructure expenditures could be saved and the introduction of biofuels into Hawaii's energy system could be greatly facilitated.

3. Existing Fuel System in Hawaii

With a developed Hawaii bioenergy industry, biofuels will complement conventional petroleum fuel supplies. In order to make the future biofuel supply infrastructure as cost-effective as possible, biofuel should use the legacy fuel system, built for the petroleum industry, to the largest extent possible. It is therefore important to consider the existing petroleum fuel supply system of Hawaii in order to identify opportunities for future integration of biofuels.

3.1 Hawaii's Existing Fuel System

The historic development trend for petroleum consumption in the state's total energy supply over the past decades is depicted in Figure 1. Although the contribution of petroleum, measured as percentage of total energy supply, has been reduced over the past three decades through increased diversity of energy supplies, the dependence on petroleum still remains high for Hawaii's energy needs. The petroleum centered energy system of Hawaii has been a logical response to the unique energy demands in the state; it is a result of a long history of technical and economic development of the islands, which have energy demands that are similar to the US mainland, yet are not connected to the nation's electric grid and oil and gas pipeline systems.

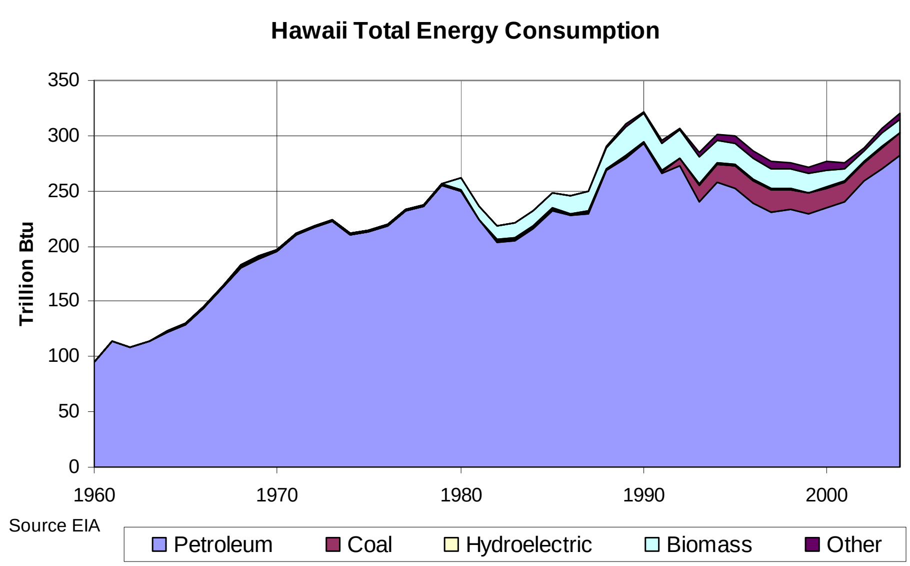


Figure 1 Total energy consumption in Hawaii by source [EIA, 2008,C]

Petroleum fuel is mostly imported in the form of crude oil, which is then refined locally into a slate of petroleum products. More specifically, approximately 90 percent of liquid-bulk cargo imports into the state are crude oil and only 10 percent are refined products. Thus, the largest portion of the current fuel supply to Hawaii passes through the two petroleum refineries on Oahu, which makes the refineries crucially important links in Hawaii's fuel supply system. The crude oil is converted into a specific output slate of petroleum products in the two island refineries. The output slate of petroleum products are balanced and optimized based on the demands of energy sectors in Hawaii, such as electricity generation, ground transport and air transport. The unloading of crude oil from the large tankers is by means of two offshore mooring systems (one single-point mooring and the other multi-point mooring) owned by the two local refineries. The crude oil is pumped from the tankers to receiving tank farms, which can hold several weeks of reserves.

The refined products are stored in large holding tank farms before they are distributed on Oahu or transported to the neighboring islands. The transport to the neighboring islands is by fuel barges. Both Kalaeloa Barbers Point Harbor and Honolulu Harbor have fuel transfer facilities to load fuel barges for transport and distribution to the neighboring islands.

The sources of the crude oil imported to and processed in Hawaii have radically changed over the past 15 years. Figure 2 shows that in 1994 about 90 percent of crude oil imports were from three producing regions, Alaska, Indonesia and Australia. While the overall import level has remained relatively constant (the production capacities of the two refineries on Oahu have not changed in this time), the level of import from these countries has fallen to 30%, of the total crude import in recent years. This is partially due to the fact that crude oil production in these countries has entered a terminal decline phase. The reduced import volumes from the three main suppliers have been made up with imports from a number of other countries as shown in Figure 2.

The imported crude oil is processed by the two refineries on Oahu into an output slate, a proportional composition of refined products produced from the crude oil stock, that is specific to the fuel needs of Hawaii. Figures 3 and 4 show a comparison of fuel consumption in Hawaii and the US mainland by product and sector, respectively. Figure 3 compares the use of five main petroleum products in Hawaii and the US mainland. In Figure 3 "Distillate" represents heavier petroleum fractions such as "road" diesel and heavier fuel oil. "MoGas" refers to motor gasoline, a light petroleum fraction used in automobiles and lighter trucks. "Residual" refers to residual oil, which is the heaviest fraction of fuel oil. Residual oil, and derivatives thereof, is used in power plants and very large prime movers, such as ships. "LPG" refers to liquefied petroleum gas, such as propane and butane and mixtures thereof. Figure 3 shows consumption data for these five products as percentages of their total for Hawaii and for the US (data shown depicts consumption data for 2005).

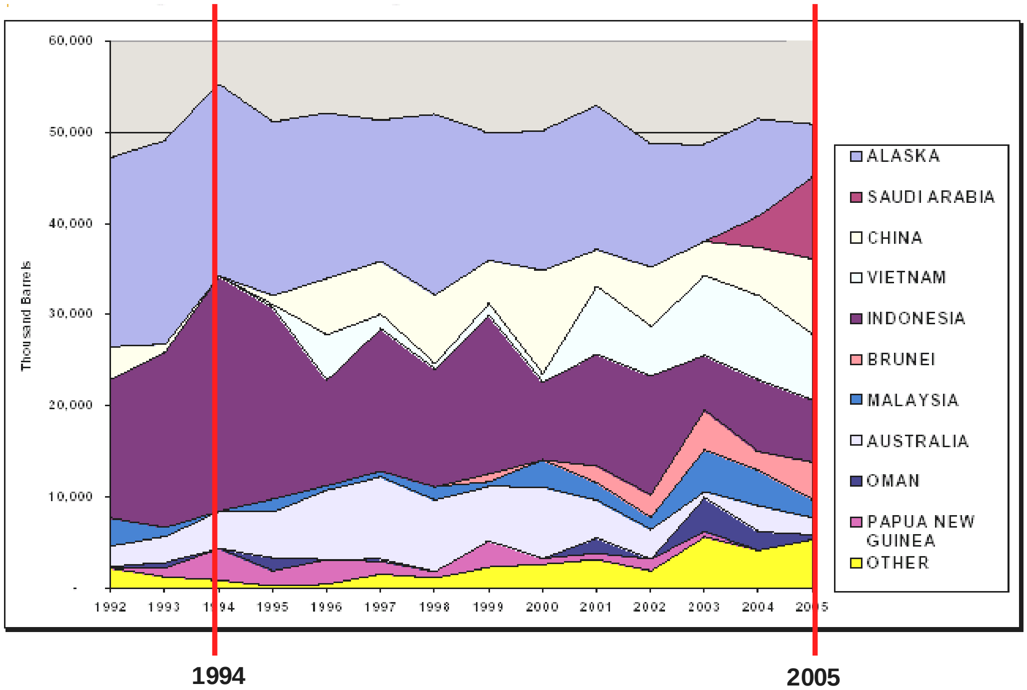


Figure 2 Changes in origins of Hawaii's crude oil [DBEDT, 2008]

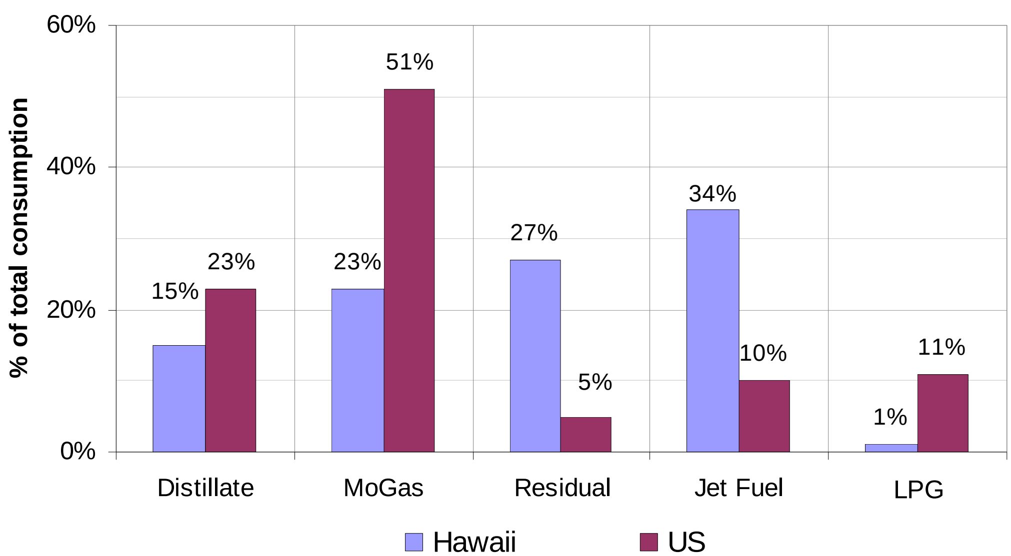


Figure 3 Fuel consumption by product for the Hawaii and entire U.S. [EIA, 2008A and 2008B]

Figure 4 compares the use of petroleum products by four sectors, namely ground transport, air transport, power generation and "others". The information presented in Figures 3 and 4 suggests a striking difference between the use of petroleum products in Hawaii and the US mainland. The percentage of motor gasoline used on the US mainland is almost twice as high, which is a result of less driving and shorter trip lengths in Hawaii. Percentage of residual oil use in Hawaii is five times larger than on the US mainland. This is due to the fact that approximately 80% of Hawaii's electric power is from oil, while only about 1.5% of electricity on the mainland is produced by oil. The percentage use of jet fuel in Hawaii is almost four times as high as in the US mainland, due to the fact that Hawaii's economy has developed to include the high use of airplanes to transport people and goods to and from the islands.

Owing to the different petroleum consumption patterns in Hawaii and the US mainland, the two refineries in Hawaii have different petroleum product output patterns than refineries on the mainland. Figure 5 compares the average refinery yields in Hawaii and the mainland. The biggest differences between refineries in Hawaii and the mainland are the fractions of motor gasoline and residual fuel oil. In order to satisfy needs in Hawaii, the local refineries are producing significantly more of the heavier petroleum fractions (e.g residual fuel, distillates and jet-fuel) and much less lighter motor gasoline than the average mainland refineries.

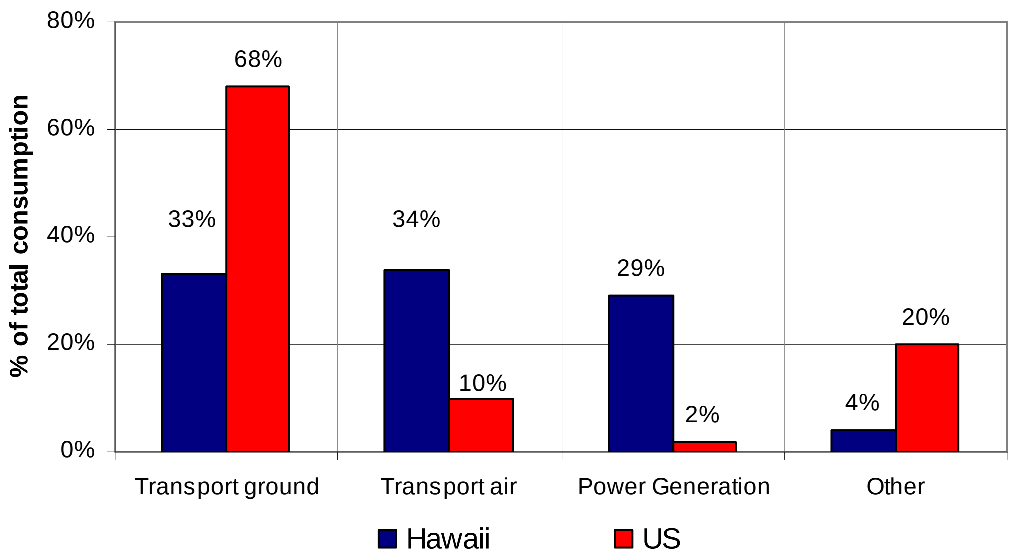


Figure 4 Fuel consumption by sector for the Hawaii and entire U.S. [EIA, 2008A and 2008B]

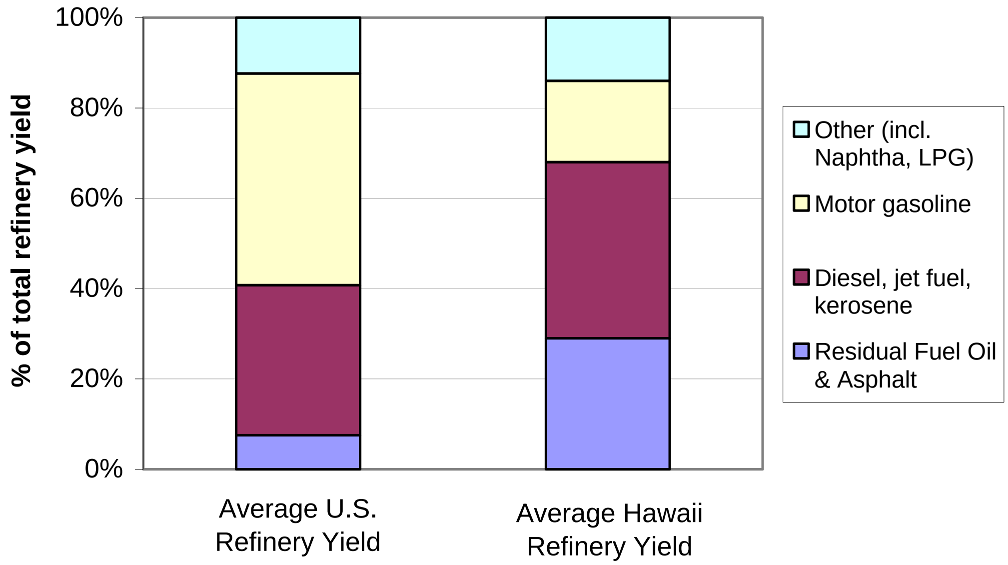


Figure 5 Fuel consumption by sector for the Hawaii and entire U.S. [EIA, 2008A and 2008B]

It is important to keep in mind that the state's output slate represents both the specific demand pattern of Hawaii (which has evolved over a long period of time and reflects the existing energy conversion infrastructure) as well as the process capabilities of the refineries. The process equipment in refineries represents a large investment and cannot easily be revamped if demand patterns of consumers and utilities in Hawaii change.

For example, if a significant supply of biofuels replaces some portions of the petroleum output at the local refineries, the displaced products might not find a market in Hawaii and would have to be exported. This would increase the costs of the local fuel industry. The introduction of biofuels would therefore immediately and significantly change the energy equation for the existing petroleum industry and might trigger investment needs for new petroleum fuel infrastructure, such as fuel terminals in the State harbors, storage tanks, and the like.

In addition to refined petroleum fuels, such as the main products motor-gasoline, diesel, jet fuel and heavier fuel fractions, the gas supply of Hawaii would be affected by changes in the operation of the refineries. Changes in the supply of petroleum fractions to the local gas production facilities, such as decreasing supply of locally produced petroleum products, might require import facilities for LPG and chemical feedstock from out-of-state sources to safeguard the production of synthetic natural gas on Oahu and the supply of LPG.

3.2 Existing Fuel Supply System of Hawaii

Figure 6 shows the existing fuel supply and distribution systems in Hawaii. (Coal, an important solid fuel for power generation on Oahu, is not depicted in the graphics). The fuel product flow is referred to with numeric designator (1 through 6) and the basic infrastructure components groups with alphabetic designators (A through G).

Most (about 90%) of the fuel supply for Hawaii is unloaded as crude oil (1) at two offshore terminals along Oahu's southern coast. The two refineries (A) process the crude into the ranges and quantities of petroleum products that are used in the state. Petroleum products that are for consumption on Oahu are held in centralized storage

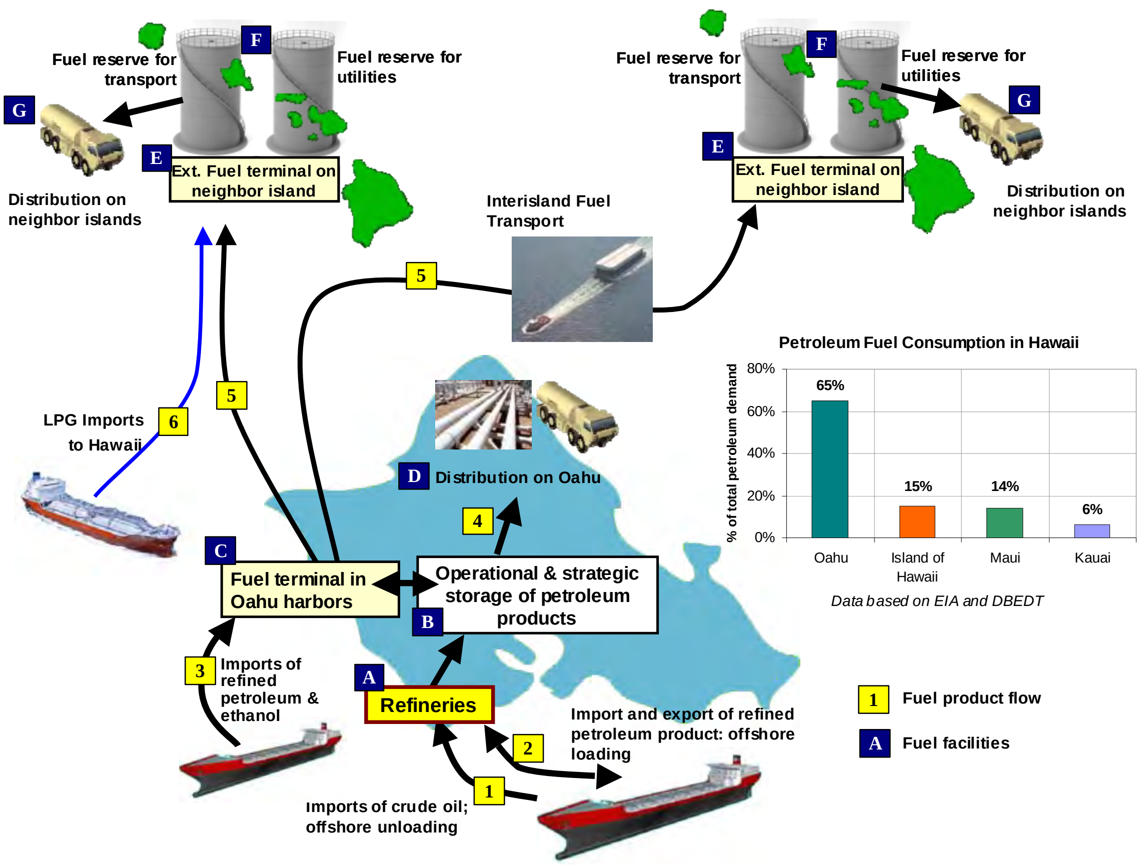


Figure 6 Existing fuel supply system of Hawaii

tanks (B), owned and operated by various fuel companies, for subsequent distribution. There is a mandated strategic reserve capacity of about 30 days for utilities. Excess refined petroleum products (2), e.g. the volume of refined petroleum which is not consumed in Hawaii, are exported via an offshore terminal. Selected liquid fuel product shipments (3), such as motor gasoline, jet fuel and ethanol, are received through fuel facilities in Honolulu and Kalaeloa Barbers' Point harbors.

Figure 6 indicates that about 65% of the total fuel consumption in Hawaii occurs on Oahu (4). The three other counties, Hawaii, Maui and Kauai consume 15%, 14% and 6%, respectively. These numbers represent an average of published consumption data. [Stillwater, 2003 and FACT, 2003].

The fuel distribution system on Oahu (D) comprises a pipeline system (e.g. “the energy corridor” linking Campbell Industrial Park to downtown Honolulu and includes several liquid fuel pipelines and a gas pipeline system), tanker trucks, and numerous end-user storage tanks. The fuel supply on Oahu includes a heavy petroleum fraction for power generation and bunker fuel, medium and light transportation fuel, ethanol as a mandated blending agent for gasoline, SNG (synthetic natural gas) that is produced from petroleum feedstock, and LPG for various end-user applications. The fuel supply for the neighboring islands (5) is withdrawn from the centralized storage (B).

The fuel supply for the neighbor islands (5) is loaded on barges using facilities in Honolulu Harbor and Kalaeloa Barbers Point Harbor [C]. The fuel supply to the neighbor islands comprises all major petroleum fractions including LPG, but excludes the heaviest fractions, e.g. residual oil, which is only consumed on Oahu. There are instances when LPG supply from the local refineries, has to be augmented by direct imports from offshore. These imports are received at selected harbors on the neighbor islands (6).

The fuel received on the neighbor islands is unloaded at fuel facilities in the commercial harbors (E) and are then conveyed to operational and strategic storage tanks (F) for final distribution (G) via tanker trucks. With the exception of short pipelines connecting fuel transfer facilities in the harbors and between tank farms, there are no pipeline systems on the neighbor islands for liquid fuel distribution.

3.3 Major Fuels Use in Hawaii at Present

Table 1 lists the major petroleum and other liquid fuel products that are presently used in Hawaii.

Table 1 Major petroleum and other liquid fuel products that are presently used in Hawaii

Fuel type	Description
Aviation gasoline	Aviation Gasoline is a high-octane fuel for piston-engine powered aircraft (usually a gasoline known as Avgas).
Jet fuel	Jet fuel has different quality designations, depending on commercial or military applications. Jet fuel has similar fuel characteristics to diesel fuel. New aircraft fuel developments include jet fuel for aviation piston engines and investigation of the use of jet fuel blends containing a substantial percentage of biofuels.
Motor gasoline	Motor gasoline (also known as MoGas) is a light hydrocarbon fuel for use in internal combustion engines, excluding those in aircraft. Oxygenates, such as ethanol, are blending components, to improve engine emissions.
Diesel fuel (or distillate)	Diesel fuel is a blend of petroleum products that is used in diesel engines. Diesel is typically designated as fuel oil No. 1 through No. 4. Diesel fuel oil No. 2 is the most widely used diesel fuel and is used for on-highway diesel engines, such as those in trucks and automobiles, as well as off-highway engines. Fuel oil No. 4 is typically used for electricity generation or as a bunker fuel. New emissions standards in the U.S. have introduced ultra-low sulfur diesel (ULSD) in order to curb emissions from diesel engines.
Fuel oil	Fuel oil is classified into six classes, according to its application and chemical properties, such as boiling temperature and composition. Fuel oil No.1, No.2 and No 3 (rarely used) are referred to as “distillate” or “diesel fuel oil.” No. 5 and No. 6 are referred to as residual fuel oils (RFO) or heavy fuel oils.
Residual fuel oil	Residual fuel oil is typically referred to as Fuel oil No. 6, since far more fuel oil No. 6 is produced than No. 5. Residual fuel oil is typically used in power plants and large ships. Residual fuel oil is so viscous that it has to be heated with a special heating system before use and it contains relatively high amounts of pollutants.
Bunker fuel	Bunker fuel designates the use of fuel oil on ships. There is a range of bunker fuels, ranging from “light” to “heavy”.
Naphtha	Naphtha is a generic term applied to a petroleum fraction which is used primarily as feedstock in the chemical and petrochemical industry In Hawaii, naphtha is also used in power generation.
Liquefied petroleum gas	LPG is a mixture of hydrocarbon gases used as a fuel in heating appliances and vehicles. LPG is a product of crude oil refining or is extracted from a natural gas stream as it emerges from the ground. LPG includes gas mixes that are primarily propane and butane. LPG is a vapor at ambient temperature and pressure, but condenses to a liquid at pressures of ~125 psi or at reduced temperature.

3.4 Hawaii Petroleum Distribution Infrastructure

The existing petroleum infrastructure serves 90% of all the energy needs in Hawaii. Petroleum products supply the energy for most ground transport, all of air transport and about 80% of power generation.

Oahu, the center of fuel supply and the island with about two thirds of the total state fuel demand, has a highly developed and complex petroleum distribution infrastructure. Figure 7 shows a schematic view of Oahu's existing petroleum distribution infrastructure.

The so-called "Energy Corridor" contains several pipelines, in two pipeline systems owned by two refinery operators (Chevron and Tesoro), which connect the two refineries at Barbers Point to the urban area of Honolulu, the Honolulu International Airport and several electric power plants:

- Several large electric power plants are served by an 8-inch "black" oil pipeline that conveys heavy fuel oil fractions, e.g. residual oil, for firing of the steam plants. Residual oil requires an elevated temperature to flow through the pipelines and therefore the fuel is heated before being pumped through the pipeline.
- Two "clean" oil product pipelines, one 8-inch and one 10-inch pipeline, convey lighter fractions in product batches, such as motor gasoline, diesel and jet fuel.
- One 16-inch gas pipeline conveys synthetic natural gas (SNG). The gas is produced from petroleum feedstock and is used on Oahu by commercial and residential customers.

The pipelines terminate in the central part of Honolulu. Clean products are pumped to bulk storage facilities (about 1,300,000 barrels of total storage capacity) in urban Honolulu, which are owned by various fuel companies, before they are trucked to the end-user, for example, the gas stations. The SNG is delivered to all subscribed customers using the pipeline system of The Gas Co. The black product pipeline terminates at a power plant in the heart of Honolulu.

Jet fuel has a special importance and is stored in two tank farms in the vicinity of Honolulu International Airport. The larger tank storage is located close to Honolulu Harbor (about 1,050,000 barrels of storage capacity) and the smaller (about 180,000 barrels) is located adjacent to the airport. Both tank farms are operated by Honolulu Fueling Facilities Corporation (HFFC), which supplies the airlines operating from Honolulu International Airport. Jet fuel is delivered to the two jet fuel tank farms through one clean-product pipeline from Barber's Point. A significant part of the jet fuel supply comes from direct import of refined jet fuel. Tankers bringing the jet fuel to Honolulu unload at Pier 51 in Honolulu Harbor from where the jet fuel is delivered to the Sand Island jet fuel terminal.

Aloha Petroleum, Ltd., a privately held oil marketer, has a fuel storage terminal in Campbell Industrial Park on Oahu. There are transmission pipelines connecting this fuel terminal facility and the fuel dock in Kalaeloa Barbers Point Harbor. This fuel marketer either buys the fuel products from the local refineries or directly imports them from out-of-state fuel suppliers.

As noted, Oahu is the hub of the fuel distribution system of Hawaii. Refined petroleum products are shipped from Oahu to the neighboring islands by means of fuel barges. The fuel barges are loaded in Honolulu Harbor (Pier 30) and in Kalaeloa Barbers Point Harbor (KBPH) at Piers 1, 5, and 6.

The existing petroleum infrastructure on the neighboring islands mostly comprise fuel facilities in the harbors that receive the petroleum products and convey the products through interconnecting pipelines to tank farms that are typically located outside, yet close to the harbors. Form the receiving tank farms on the neighboring islands, the petroleum products are then distributed by tanker trucks.

Figure 8 illustrates the “hub-and spoke” fuel infrastructure for the main islands of Hawaii. The most important features of the statewide fuel infrastructure, outside the complex fuel infrastructure of Oahu, are the fuel facilities in the main commercial harbors and the different downstream fuel distribution facilities and terminals operated by fuel companies on the neighboring islands.

<u>Kauai County:</u> Kauai County has two commercial harbors with fuel docks. Nawiliwili receives most of the transportation fuel for Kauai at Pier 2; while Pier 3 receives liquid petroleum gas (LPG). There are two fuel tank farms adjacent to the harbor with a total storage capacity of 60,000 barrels. Besides transportation fuel needs, the Port Allen harbor serves the main electric power plant on Kauai. The total storage capacity at Port Allen is 130,000 barrels, which safeguards the mandated reserve capacities for the utilities.

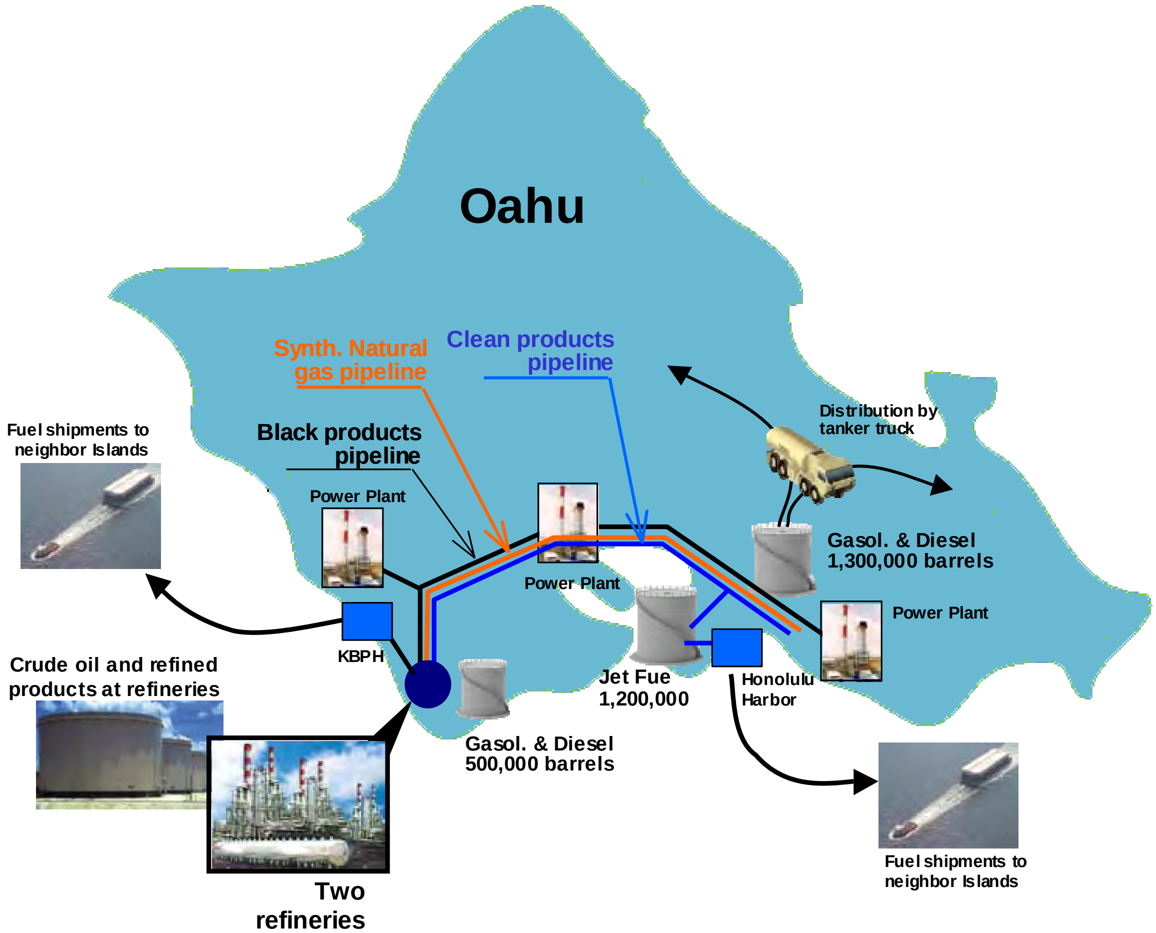


Figure 7 Oahu petroleum distribution infrastructure

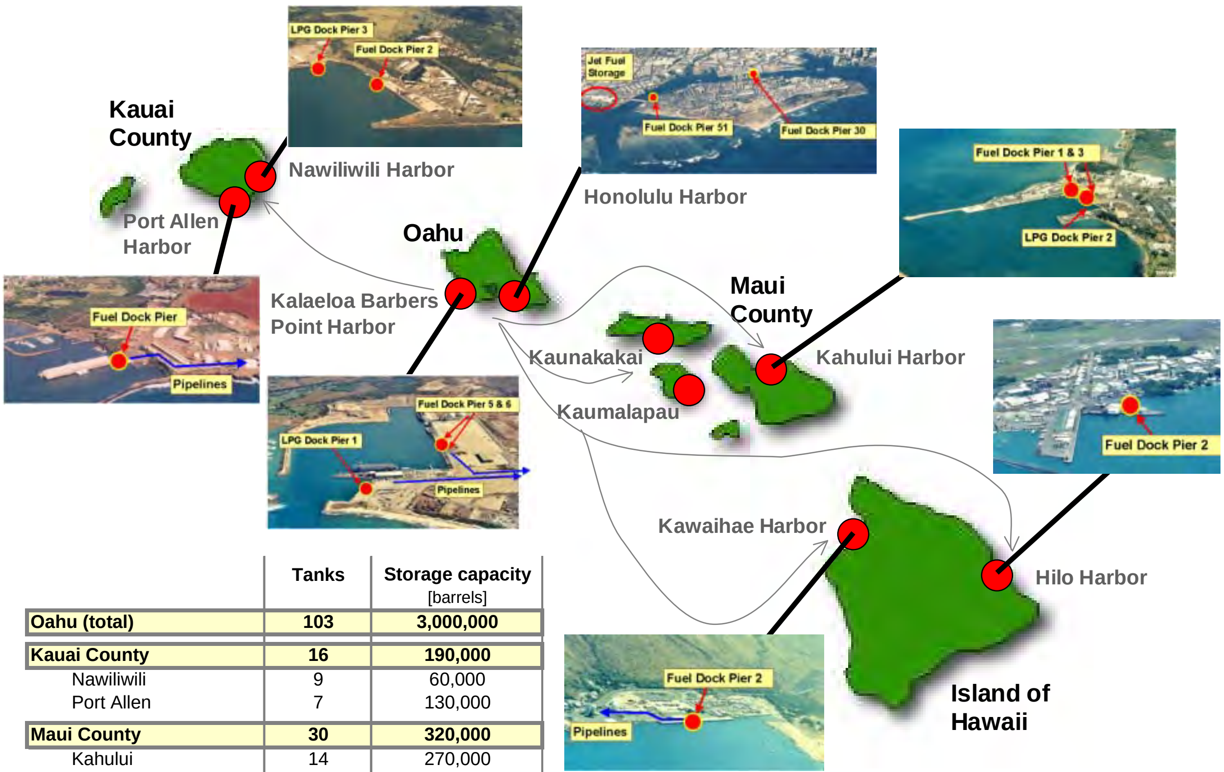
Maui County: The main fuel facilities of Maui County are on Maui, at and in the vicinity of Kahului Harbor. Most of the transportation fuels and heavier fuel fractions (for power generation) are received at Piers 1 and 3. LPG is received at Pier 2. The fuel products are transported with pipelines to the tank farms owned by different fuel companies and located close to the harbor. The fuel facilities at Kahului Harbor are the only fuel installations that can accommodate unloading of fuel barges on the island of Maui. The island of Maui has therefore no fuel transfer redundancy in the form of a second harbor or dedicated pier capable of significant fuel transfer. In comparison, the islands of Oahu, Kauai and Hawaii, all have two harbors with fuel transfer capacities. This fact increases challenges for introducing new fuels or higher fuel capacity on Maui.

The islands of Molokai and Lanai have fuel facilities at Kaunakakai and Kaumalapau harbors, with storage capacities of 30,000 and 20,000 barrels, respectively.

Hawaii County: The Island of Hawaii has fuel terminals in Hilo and in Kawaihae. Historically, Hilo Harbor has been the center of the fuel infrastructure for Hawaii. Most of the fuel companies have their tank and distribution facilities close to Hilo

Harbor. Most of the electric power plants on the Island of Hawaii are in the Hilo region and receive their fuel through Hilo harbor. Fuel is unloaded at Pier 3 where a short pipeline conveys it to receiving tank facilities in the vicinity. Kawaihae Harbor, which serves the western end of the Island of Hawaii, has only limited capacities to receive and store fuel. Therefore a large portion of the fuel that is consumed in West Hawaii, e.g. the Kona Coast, is trucked from Hilo. Kawaihae harbor receives fuel barges at Pier 2. There are two tank farms in or close to the harbor with a total storage capacity of about 60,000 barrels. Only one tank farm is connected by pipeline to the fuel pier in the harbor. The other tank farm serves as storage capacity for distribution.

With the historic growth of Hawaii's economy and population, the situation in Hawaii's commercial harbors is characterized by increasing cargo shipments and competing demands for passenger operations, causing congestion in the harbors. Since fuel shipments can only be unloaded at fixed locations where there are appropriate receiving fuel hatches at the docks, fuel shipments are increasingly plagued by scheduling conflicts. It is therefore necessary to improve the conditions for fuel shipments in all state commercial harbors, especially in light of the planned expansion of biofuels. Plans for expanded fuel facilities in the commercial harbors include construction of new fuel docks for petroleum and biofuel shipments, upgrading of existing fuel docks and provision of additional fuel storage capacities in or close to the state harbors.



	Tanks	Storage capacity [barrels]
Oahu (total)	**103**	**3,000,000**
Kauai County	**16**	**190,000**
Nawiliwili	9	60,000
Port Allen	7	130,000
Maui County	**30**	**320,000**
Kahului	14	270,000
Kaunakakai	12	30,000
Kaumalapau	4	20,000
Hawaii County	**36**	**330,000**
Hilo	26	270,000
Kawaiahe	10	60,000

Figure 8 Existing fuel distribution to the neighboring islands

4. Biofuel Candidates

Biofuels are intended to replace a significant volume of petroleum fuels in Hawaii's future energy system. Liquid fuels are essential to Hawaii since they are the drivers of ground and air transportation and supply crucial base load electric power, whereas most renewable energy sources supply intermittent power.

The different biofuels referred to in this chapter are produced by different processes and have merits in terms of physical properties (such as net energy and impacts on the environment) or economic and feedstock considerations. This chapter discusses the different biofuel candidates only in respect to requirements and challenges they pose for the distribution systems of such biofuels.

4.1 Exclusion of Distributed Gaseous Biofuels

The biofuel candidates that are discussed in this section represent only liquid biofuels, which will be distributed in Hawaii. Gaseous biofuels, "biogas", derived from organic material through different gasification processes, are not considered in this discussion.

Non-inclusion of biogas in the discussion of candidate biofuels does not signify that biogas is not considered a viable and potentially important future renewable fuel for Hawaii, in the contrary. At present, biogas is an important and established source of renewable energy in many parts of the world and the potential for biogas might be considerable for Hawaii. Typically biogas is consumed in steam or power conversion applications where the conversion plants are close to the biogas production facility. Biogas is, at the present time, not distributed.

Biogas could be distributed through pipelines in the same fashion as natural gas, but the technology to convey biogas in pipelines, either in dedicated pipelines or in some form of mixed or batched fashion with natural gas, is an evolving technology. Initial applications on a commercial scale might commence only after a pilot installation has proven successful and sufficient operational experience has been collected.

Distributing biogas to end users through existing or new infrastructure could be a promising energy solution for places like Hawaii. Unlike the mainland, where gas supplies are basically available exclusively from natural gas, the existing gas supply in Hawaii is inherently connected to oil supplies. Synthetic natural gas is produced from products derived from crude oil refining on Oahu. If significant changes in Hawaii's petroleum supply occur in the near future as discussed elsewhere in this report, distributed biogas might be a promising and commercially viable substitute for portions of the present synthetic natural gas supply in Hawaii.

Neighboring islands are presently supplied with liquefied petroleum gas (LPG). The transport modes for biogas and LPG are fundamentally different. LPG can be transported in liquefied form in moderately pressurized transport vessels at ambient temperature. Biogas can only be transported economically in gaseous form and in highly pressurized transport vessels. Such vessels, including compressed gas barges and ships, are being developed for transporting natural gas from stranded gas fields to centers of consumption. This technology might be also available for interisland biogas transport in Hawaii in the longer term. At present and in the foreseeable future, however, it would be more feasible for biogas production facilities to be built close to the locations of gas consumption and avoid distribution other than through pipelines.

Considering the limited, albeit promising, technical and commercial application potential for distributed biogas in Hawaii, gaseous fuel derived from organic matter is being considered in this study only in conjunction with power plants using solid biofuel. In these facilities the organic matter is gasified and directly supplied to the power plants as gaseous fuel. The gasification and power plant facilities are close together thus distribution systems are not required.

4.2 Review of Candidate Liquid Biofuels

Beside the currently most widely used biofuel products, i.e. ethanol and biodiesel, there are other renewable fuels, such as bio-butanol and renewable diesel, which offer advantages in terms of fuel production processes as well as compatibility with existing distribution infrastructure and end-user applications. The following listed biofuels do not represent all potentially qualifying renewable fuels, since the “advanced” biofuel market (2^{nd} and 3^{rd} generation biofuels) is a rapidly evolving field. Instead, two “evolving” biofuels, bio-butanol and renewable diesel are mentioned, since they potentially offer distinct advantages in regard to a future fuel distribution system on Hawaii.

Ethanol (an established biofuel):

Presently, ethanol is the most widely used biofuel in the US. Ethanol is an alcohol fuel that is produced by fermentation of biomass. After production and prior to transporting and further use, ethanol must be denatured, typically by blending in 5% gasoline to ensure fuel ethanol is not consumed by humans. Denatured ethanol is distributed in the same manner as gasoline or diesel, e.g. stored in atmospheric fuel tanks and tanker trucks. Ethanol is a versatile solvent, miscible in water and many organic solvents.

Ethanol’s strong miscibility in water gives rise to operational challenges in handling neat ethanol and ethanol and gasoline mixtures. Water introduced into fuel systems containing ethanol can render the ethanol fuel or ethanol gasoline mix out of specification. In regular petroleum fuel systems, water separates from the fuel and can be readily drained at low points from the fuel system. With ethanol–gasoline fuel blends, water content over a certain threshold causes phase separation. Neat ethanol or E85 blends also have specific material specifications for storage, transportation containments, and pipelines systems that are different from typical petroleum fuel systems.

Due to these fuel properties, conveyance of neat ethanol or blends of ethanol in pipelines over long distances is not yet a routine operation. Lower ethanol blends, such as E10, are currently mixed with gasoline and transported, stored, and dispensed in existing infrastructure. Higher ethanol blends, such as E85, however, require separate infrastructure because E85 cannot be used in all vehicles, and can corrode some materials. Denatured ethanol has about 70% of the energy density by volume of neat gasoline, therefore about 40% more volume has to be stored and transported to supply the same amount of energy content of motor gasoline [BP, 2009].

The fundamental challenges for an expanded future ethanol distribution system are ethanol’s strong miscibility in water, strong solvent characteristics and stress corrosion in storage and transport containments. These fuel properties require special materials for tanks, pipelines and transport containments, sealants, pipe fittings and fuel transfer equipment and appurtenances. The handling of ethanol is an established operation in the chemical and petrochemical industry. The handling of large volumes of fuel grade ethanol, however, could present operational challenges, such as the potential for large ethanol fires and large ethanol spills.

Biodiesel (an established biofuel):

After ethanol, biodiesel is the second most widely used biofuel in the US, which use has been steadily increasing.

Biodiesel (B100) is defined as a fuel comprising "monoalkyl esters of long-chain fatty acids derived from vegetable oils or animal fats." Biodiesel is typically produced by the reaction of a vegetable oil or animal fat with an alcohol (e.g methanol or ethanol) in the presence of a catalyst to yield monoalkyl esters (biodiesel) and glycerin; a process referred to as transesterification. Biodiesel is defined in the ASTM specification D6751 "Standard Specification for Biodiesel Fuel Blend Stock (B100) for Middle Distillate Fuels." Biodiesel is distinct from "renewable diesel ", which can meet all of the requirements of ASTM D975, Standard Specification for Diesel Fuel Oils. Biodiesel fuel is a blendstock for use in blending with petroleum diesel fuel and is intended for use in diesel engines, such as trucks, buses, diesel cars but also generator sets.

Typically a blend of 5% biodiesel in petroleum diesel that is in compliance with ASTM D975 causes no deterioration of equipment that is designed for ASTM D975 diesel. The use of higher blends, up to B20, is sometimes deemed by certain original equipment manufacturers (OEM) to cause no detriment to existing infrastructure and equipment performance. The use of blends higher than B20 is discouraged by OEMs due to the lack of experience with such blends in existing distribution infrastructure and equipment.

Biodiesel has a higher flashpoint than petroleum diesel, which makes it safer to handle. Biodiesel is a stronger solvent than petroleum diesel, which results in biodiesel's tendency to dissolve the accumulated particulates and sediments found in diesel storage and engine fuel systems. Such dissolved impurities can cause problems in distribution and equipment infrastructure. Biodiesel, being a methyl ester, may also degrade and break down certain elastomers with prolonged exposure. Certain gaskets, hoses, seals and o-rings found in older fuel systems may experience leaks or seepage problems.

Biodiesel has a greater affinity for water than petroleum diesel, which can result in operational problems if water contaminates the fuel, such as corrosion and filter plugging in existing fuel systems. Storage tanks, transport containers and pipelines that contain certain compounds, such as soft metals (brass, bronze, copper, lead, tin or zinc) can be subject to operational problems due to corrosion and creation of sediments. Unfortunately, such compounds are found in many fuel systems, causing material incompatibility problems with existing distribution infrastructure.

Due to incompatibility problems, neat biodiesel should be transported and stored only in fuel systems that are tested to be compatible or new dedicated biodiesel infrastructure must be designed to handle fatty acid methyl ester (FAME) diesel.

In regard to handling large amounts of biodiesel, the fuel might have some flow and mixing problems at lower temperatures, which would not be a typical operational concern in the warm climate of Hawaii. Biodiesel, however, is susceptible to product contamination from both flammable products and water sources. Storage and transport vessels must therefore be thoroughly cleaned and dried before being used for biodiesel. A dedicated distribution infrastructure would be preferable to avoid material incompatibility, cross contamination and operational complications.

Biodiesel contains no hazardous materials and is considered safe to use. Typically methyl esters biodegrade much more rapidly than conventional fuel, which mitigates fuel spills and increases environmental friendliness of the fuel.

Bio-butanol (an evolving biofuel):

Butanol is a four-carbon alcohol in widespread use as an industrial solvent in the US market. Butanol can be produced from petroleum or from biomass; the latter is referred to as bio-butanol.

Bio-butanol is produced by fermentation of the type of feedstock that is also used for ethanol production. The volumetric yield of butanol produced from corn is equivalent to corn ethanol's fermentative yield. The energy content of bio-butanol is about 26% higher than ethanol by volume. Hydrogen is generated as a co-product in the production process of bio-butanol and can be converted to produce energy. Therefore accounting for the energy gained from hydrogen during the butanol production process would increase the total energy value of butanol and its co-products.

With older standard butanol production processes (e.g. "ABE Process" for acetone butanol and ethanol fermentation), operational difficulties arose that made production of butanol more complicated than ethanol. Recent improvements in production of bio-butanol have, however, improved the effectiveness of the production process and could eventually make bio-butanol in some ways superior to ethanol as a replacement for petroleum gasoline. According to the literature, ethanol production plants can be reconfigured to produce bio-butanol without extensive revamping of process equipment [BP, 2009].

Butanol's energy content is 85% of gasoline while ethanol's energy content is only 68%; therefore butanol has 25% greater energy content than ethanol. The higher energy density results in less fuel volume required to deliver the same energy as compared to ethanol fuel. Butanol's vapor pressure is lower than both gasoline and ethanol, which improves engine performances and allows safer handling. This decrease in vapor pressure results in fewer problems with evaporation of butanol, which renders it safer and environmentally friendlier than other fuels [BP, 2007].

Butanol can be blended with gasoline for use in conventional gasoline engines at much higher proportions than ethanol without compromising engine performance or volatile organic pollution standards or requiring fuel system modifications. Butanol is non-corrosive, can be distributed through existing pipelines, and can be—but does not have to be—blended with fossil fuels. Butanol, like gasoline, is immiscible in water, and less corrosive than ethanol, allowing the fuel to be stored and transported with the existing gasoline infrastructure without requiring modifications in storage and transport vessels, blending facilities or retail pump stations. Unlike existing biofuels, it is expected (but has to be verified in large scale testing) that butanol is suitable for transport in pipelines. As a result, bio-butanol could be introduced into existing fuel distribution systems more readily and eliminate the need for additional large-scale supply infrastructure.

Renewable Diesel (an evolving renewable fuel):

Renewable diesel is an emerging renewable fuel with a significant potential of creating a renewable substitute for petroleum diesel. While some production processes of renewable diesel are in commercial use, other processes are still in the R&D stages. Since renewable diesel fits more or less seamlessly into existing process and distribution systems, there is a major initiative underway by traditional oil companies to add renewable diesel to their fuel portfolio.

Biodiesel is chemically distinct from petroleum diesel and both have different fuel ASTM specifications; biodiesel follows the ASTM fuel standard D6751 while renewable diesel has the same ASTM standard as petroleum diesel, D975. Both biodiesel and renewable diesel are produced from renewable feedstock, but the latter is an ester and chemically distinct from biodiesel.

There are several processes that can produce renewable diesel. The commercially available processes produce renewable diesel through hydrotreating, which is a process traditionally used by petroleum refineries to remove sulfur impurities from diesel fuel. Renewable diesel produced using this process can either be produced in a “bio-only” unit that uses only vegetable oils or animal fats as feedstock or in a co-process with petroleum where oils or fats are processed in the presence of distillate fractions derived from petroleum. Other production technologies for renewable diesel are presently in the development stages, such as converting biomass (predominantly cellulosic material) through high-temperature gasification into synthetic gas or “syngas” and then using a Fischer-Tropsch process to catalytically convert the syngas to liquid fuel. Yet another evolving process for producing renewable diesel would use pyrolysis or other thermal conversion process (TCP) to convert biomass material to an “alternative-oil” or "bio-oil" that is then refined into diesel-like fuel.

All of these processes produce a mixture of hydrocarbons, which has been reported to meet the ASTM standard for petroleum diesel (D975). The renewable diesel fuel produced through these processes, consequently, could utilize the existing infrastructure currently used for blending and transporting petroleum fuels. Consequently, renewable diesel could be blended at any blending ratio with petroleum diesel, and still use the same distribution infrastructure as conventional petroleum diesel. As a significant advantage, renewable diesel can be blended with petroleum diesel at the refinery and transported in existing pipelines and transport containers and stored in existing tanks.

4.3 Interfuel Replacement Options

The different biofuel candidates can replace corresponding petroleum fuel products for different applications provided that engines are compatible with the replacement biofuel and the fuels adhere to EPA fuel standards. Table 2 indicates the interfuel replacements, i.e. fuel substitution, by application sector:

It should be noted that the discussion of interfuel replacement options, which means the potential of replacing petroleum fuels with certain biofuels for different applications, does not include all promising types of liquid biofuels. The discussion only includes biofuels that have been mentioned before, such as ethanol, bio-butanol, biodiesel and renewable diesel, because of their different compatibility characteristics in regard to existing petroleum fuel systems. In addition, the discussion includes straight vegetable oil (SVO) which represents an unrefined biofuel and which could be used in certain thermal applications to replace residual oil or other heavier petroleum fractions. The field of biofuel is a rapidly developing field where other biofuels evolve, which might become important biofuel candidates in the years to come. From the standpoint of fuel distribution systems such new fuel types would likely not create additional distribution challenges than those discussed for the before mentioned biofuels.

Table 2 Interfuel replacements, i.e. fuel substitution, by application sector

Table 2 Interfuel replacements, i.e. fuel substitution, by application sector	
Ground transport : Fuels for gasoline engines	
Conventional fuels:	Petroleum gasoline, different grades according to the octane rating; E10 blend is mandated in Hawaii
Replacement renewable fuels:	Ethanol, Butanol (other biofuels also possible)
Blending ratios and issues to be considered:	o Ethanol blending can be done up to E10 (e.g. 90% gasoline and 10% ethanol) without requiring engine modifications; higher blending ratios require special engines types, maximum blending ratio is E85. o Butanol can be blended up to BU16 (e.g. 84% gasoline and 16% butanol) without requiring engine modifications; higher blending ratios require special engines types, maximum blending ratio is BU100.
Ground transport : Fuels for diesel engines (only on-road vehicles considered)	
Conventional fuels:	Petroleum diesel, typically diesel #2 grade; effective 2006 ultra-low sulfur diesel (ULSD) is required for all on-road diesel uses (some exceptions apply)
Replacement renewable fuels:	Biodiesel, renewable diesel, SVO (straight vegetable oil)
Blending ratios and issues to be considered:	o Biodiesel can be use in virtually all diesel vehicles up to a B5 blending ratio (5% biodiesel, 95% petroleum diesel); blending ratios up to B20 are considered by many equipment manufacturers; higher blending ratios (up to B100) require adjustments of the engine and/or fuel systems o Renewable Diesel can be blended in all blending ratios up to RD100. o SVO can be used in selected diesel engines
Marine Transport: Marine gasoline engines (for marine spark-ignition engines)	
Conventional fuels:	Gasoline in various grades, E10 blends are presently used but also neat gasoline is permissible for marine engine use
Replacement renewable fuels:	Ethanol (in weak blends), Butanol

Table 2 Interfuel replacements, i.e. fuel substitution, by application sector	
Blending ratios and issues to be considered:	o E10 blends are already used, since this blend ratio requires no engine modifications; higher blends are questionable due to potential water contamination o Butanol blends of up to BU16 can be used, since this blend ratio requires no engine modifications; higher blends are possible (providing appropriate marine engines are available) since butanol does not have problems with water contamination as with ethanol
Marine Transport: Marine diesel engines (for boats and ships using internal combustion diesel engines)	
Conventional fuels:	Petroleum diesel
Replacement renewable fuels:	Biodiesel, renewable diesel
Blending ratios and issues to be considered:	o Biodiesel can be used in virtually all diesel vehicles up to a B5 blending ratio (5% biodiesel, 95% petroleum diesel); blending ratios up to B20 are considered by many equipment manufacturers; higher blending ratios (up to B100) require adjustments of the engine and/or fuel systems o Renewable Diesel can be blended in all bending ratios up to RD100.
Air Transport: Fuels for aviation	
Conventional fuels:	Jet fuel, Aviation gasoline
Replacement renewable fuels:	No replacement fuels in commercial use; R&D efforts continue; some renewable fuels have shown potential to replace kerosene based aviation fuels.
Power Generation: Fuel and steam turbines for large central power generation	
Conventional fuels:	Residual fuel (lighter fuel oil fractions are not considered here)
Replacement renewable fuels:	SVO (Straight Vegetable Oil)
Blending ratios and issues to be considered:	SVO has been considered as a fuel replacement in conventional power plants. The SVO would most likely be used as a neat fuel, or with certain additives.

Table 2 Interfuel replacements, i.e. fuel substitution, by application sector	
Power Generation: Smaller power generation plant with diesel generator sets	
Conventional fuels:	Lighter or heavier fractions of fuel oil and diesel
Replacement renewable fuels:	Biodiesel, renewable diesel
Blending ratios and issues to be considered:	The use of biodiesel might necessitate modifications of the prime mover units and fuel delivery systems Renewable diesel could be used without any modification to the prime mover units and fuel delivery systems

5. Fuel Distribution Infrastructure Options

This section discusses various options for a future fuel distributions infrastructure that can accommodate petroleum and renewable fuels, either as dedicated systems or as combined fuel systems.

5.1 Basic Liquid Fuel Infrastructure Options

Downstream of the fuel production in the refinery, the fuel enters the distribution chain, where it is either stored in tanks, contained in transport vessels, or is in transition between storage or transport modes.

The fuel distribution infrastructure comprises the following main components:

<u>Storage tanks:</u> Storage tanks are physical fuel containments, made either of metal or durable plastic material. Sometimes tanks are also made of concrete. The tanks are either above or below ground. The below ground configuration has to have a safeguard against leakage, such as a double containment. The above ground configuration needs a containment that can capture the fuel in case of leakage and spillage. For large fuel tank farms a containment wall surrounds the tanks built on impermeable surfaces. Since fuels generally can cause dangerous fires, suitable fire fighting equipment has to be available to provide the foam and water for cooling and fire fighting. The tanks have to be compatible with the fuel properties. Some fuels, such as ethanol are strong solvents that are not necessarily compatible with existing tank materials.

The tanks considered for the future fuel distribution infrastructure hold liquid fuel at atmospheric pressure. When the tanks are filled, the displaced gas is normally vented to the atmosphere, if the environmental impact is not deemed significant. If the displaced gaseous phase contains flammable or explosion prone fumes or hazardous agents (e.g. from lighter petroleum fractions or light alcohols) the vapor has to be collected and disposed of in a controlled manner (e.g. a vapor control system). Advanced fuel tank designs have a "floating roof" that minimizes the vapor phases and mitigates related adverse effects. Such floating roofs are, however, prone to water intrusions, which can cause significant problems with certain renewable fuels (e.g. ethanol).

Pipelines: The transport of fuel through pipelines is the most cost effective and safest way to move fuel. As described earlier, there are several fuel pipelines systems on Oahu, which link fuel supply and consumption over significant distances. Other pipelines connect storage tanks to each other or to the loading terminals. The fuel transport through pipelines avoids batch transport modes with tanker-trucks. While the transport of petroleum products through pipelines is common practice, the transport of biofuels through pipeline represents a largely untested operational mode. Transporting biofuels through pipeline systems that were built to convey petroleum products can cause significant operational problems due to material incompatibilities, water problems and fuel cross-contamination. Dedicated biofuel pipelines would be the logical answer to avoid operational problems, but the costs of pipelines are significant and require sufficient transport volumes in order to achieve economy of scale.

Marine transport: Surrounded by water Hawaii has to receive all its fuel by ship and has to use marine transportation to distribute fuel from Oahu to the neighboring islands. Hawaii imports and exports significant volumes of crude oil and refined petroleum products through offshore mooring on Oahu's southern coast. Selected fuels are imported by smaller tankers to commercial harbors on Oahu. The fuel facilities in the commercial harbors serve the interisland shipments of fuel. Fuel barges are loaded on Oahu and unloaded in the commercial harbors on the neighboring islands.

There are two main shipping companies, which operate fuel barge services. The fuel barges differ in capacity between 4,000 and 70,000 barrels, depending on their route. The barges are towed by tugs and have their own pumping capacity for fuel unloading. The barges typically carry multiple fuel products contained in several cargo compartments.

The fuel installations in the harbors (e.g. fuel "hatches" on docks, interconnecting pipelines, storage tanks, terminals) are owned by fuel companies and not the State. The State owns and manages the cargo docks and other harbor installations. Much of the fuel equipment is old and might require replacement in order to accommodate future fuel operations, especially those involving new fuels to be introduced in Hawaii, and to adhere to stricter safety and environmental standards.

Tanker Trucks: The delivery of fuel to the end user is accomplished by tanker trucks. Large trucks typically have capacities ranging from 5,500 gallons to 9,000 gallons. In order to be able to carry biofuels, tanker trucks must be fitted with appropriate materials for hull, seals and appurtenances to ensure compatibility.

Blending facilities: Most of the biofuel is presently used in blends with petroleum products rather than as neat biofuel. With the conventional first generation biofuels ethanol and biodiesel, it is presently common operational practice to transport the biofuel separately from petroleum products. The blending of biofuel and petroleum occurs as close to the end-user as possible in order to avoid fuel related operational problems. Typically, blending occurs when a tanker truck is loaded. It is important that the process of blending ensures a good mixture of the different fuels and avoids phase separation or stratification.

5.2 Requirements of a Future Biofuel Supply System for Hawaii

The present biofuel supply for Hawaii is composed of imports of ethanol for blending with motor gasoline and some volume of biodiesel, which is produced by a Hawaii biofuel company. In addition to local production of biofuels, the future biofuel supply for Hawaii will most likely require imports of refined biofuel and feedstock and the distribution of various types of biofuels. This will require a future distribution system similar to that illustrated in Figure 9.

While the goals of the long-term biofuel supply for Hawaii are to satisfy the fuel demand through biofuel produced in Hawaii, in the short-term, and during a transition phase, refined biofuel products and/or biofuel feedstock will be imported from out-of-state. Biofuel products movements 1 and 2, in Figure 9, show that imported biofuel and feedstock would most likely come through Oahu, while direct imports of biofuel products and/or feedstock to the neighboring islands are also envisioned.

Biofuel produced from feedstock on Oahu would be converted into refined biofuels products and distributed on Oahu. Excess biofuel would be transported to the neighboring islands (3) using marine fuel transport modes through existing or future fuel facilities in the harbors [A]. Neighboring islands with feedstock production and biofuel conversion plants [B] could satisfy local demand and export volumes of refined biofuels to Oahu or other neighboring islands (4). Neighboring islands without biofuel conversion plants [C] would have facilities to unload fuel transported from fuel production inside the state and from direct biofuel imports to Hawaii.

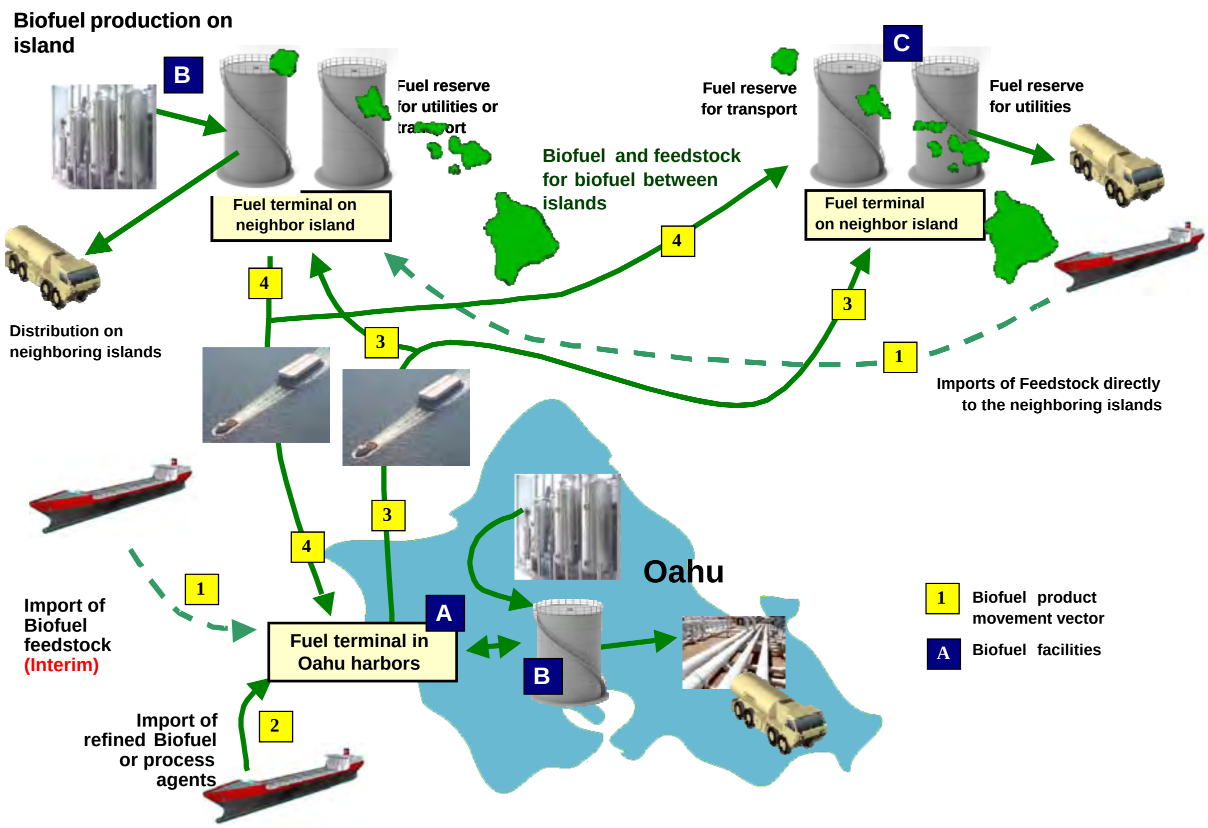


Figure 9 Biofuel supply system for Hawaii

5.3 Fuel Distribution Infrastructure Options

The governing design consideration for the future fuel distribution infrastructure in Hawaii may be the extent to which the legacy fuel infrastructure can be used. As noted before, the fuel infrastructure system of Hawaii, especially on Oahu, is sophisticated and complex. The existing fuel infrastructure is the result of many decades of construction and fine-tuning the different infrastructure components into a "well oiled" fuel distribution system that has been reliably serving Hawaii for many years. The existing fuel distribution infrastructure furthermore represents an extraordinarily high capital investment, which is estimated in the order of \$3.6 billion. This investment does not include the two local refineries, whose combined total market values should be around \$1.3 billion to \$1.5 billion.

At present, ethanol is used as a fuel additive in a State mandated volume fraction of 10%. Storage, transport and blending of petroleum and ethanol fuels has been handled successfully by the local fuel industry, using elements of the existing infrastructure. Future increases in the volume and range of renewable fuels are likely to cause additional scaling challenges for Hawaii's fuel industry. As the volume of biofuels increases and replaces petroleum products, the distribution infrastructure will have to be modified to meet new demand. New infrastructure might have to be added in order to allow expansion of Hawaii’s biofuel industry.

While the transition away from petroleum fuel towards renewable fuels is a State policy goal, the transition period will be challenging. While petroleum fuel is being phased out or at least its use decreased significantly, the petroleum infrastructure will still need scheduled replacement and maintenance in order to maintain the system in proper and safe working conditions. At the same time new infrastructure might be required to serve the increasing volumes of different biofuels. This transition time with parallel operations of large scale petroleum and biofuel fuel systems will require significant capital investment, a well trained workforce and flexibility in technical and operational terms.

The “age of biofuel” has just begun, and the success of biofuels in our society will largely depend on the cost-effectiveness, safety, and environmentally friendly handling of large-scale distribution and end-use applications.

The following paragraphs present three basic operational process diagrams of an integrated petroleum and biofuel distribution infrastructure for Hawaii.

Option 1 – Biofuel Augmentation (Existing Fuel Distribution in Hawaii)

Figure 10 shows the existing fuel distribution infrastructure in Hawaii, which combines fuel supply for petroleum and biofuels. In Figure 10, the petroleum distribution system comprises tanks and fuel transport assets downstream of the two refineries. The two refineries have storage capacities to allow for operational flexibility and redundancies. Downstream of the two Oahu refineries, the petroleum fuel products are distributed in a well developed system of storage tanks, pipelines and transport means.

At present, biofuel products are distributed in a dedicated fuel infrastructure that consists of storage tanks that are either converted petroleum tanks or have been built specifically for the biofuel products. With the infrastructure Option 1, the transportation of biofuel is done exclusively with tanker trucks.

Most of the currently used volumes of biofuel products are mixed with petroleum to create blended fuels. At the present time, the blended fuel of motor gasoline with ethanol represents the most widely used form of biofuel in Hawaii.

Besides the use of blended biofuel, most of the petroleum fuel is used as neat petroleum fuel energy applications of ground, marine and air transportation and in power generation. The use of neat biofuel is presently done on a relatively small scale.

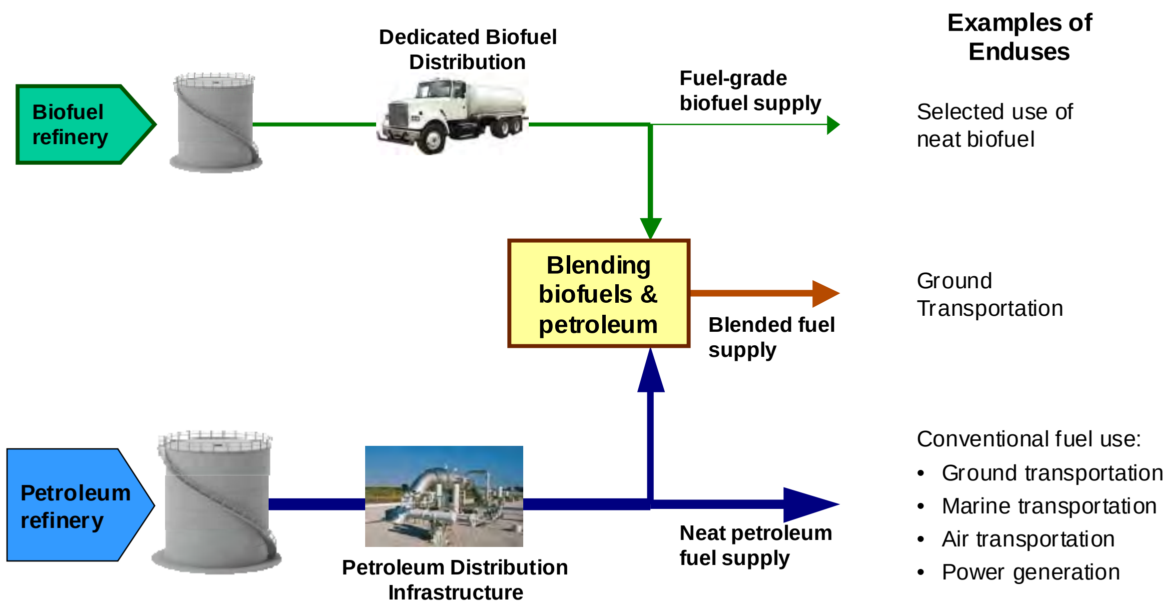


Figure 10 Option 1 – Biofuel augmentation (existing fuel distribution in Hawaii)

Option 2 – Parallel Distribution of Petroleum and Biofuels

As the volume of biofuel in the energy system of Hawaii increases, the demand on complexity and scope of the biofuel infrastructure will also grow. At the same time the volume of petroleum in the energy system would decrease. As the volume and range of biofuel to be distributed increases above a certain rate it will be more cost and energy effective to move biofuels through transportation assets that resemble the present petroleum infrastructure, such as pipelines rather than with tanker trucks. Figure 11 shows the Option 2 scheme, which is similar to Option 1, where biofuels and petroleum are transported and distributed separately from petroleum fuel to be blended close to the end user, but at a more expanded scope than Option 1. The expanded biofuel distribution infrastructure would comprise converted components of the petroleum infrastructure and the newly built biofuel infrastructure, designed to be compatible with a wide range of new fuel products.

The expanded use of biofuel would be due to new end-use applications. Although much of the fuel used in Hawaii would be blends of petroleum and biofuel, both biofuel and petroleum would still be used as neat fuels, e.g. unblended fuel.

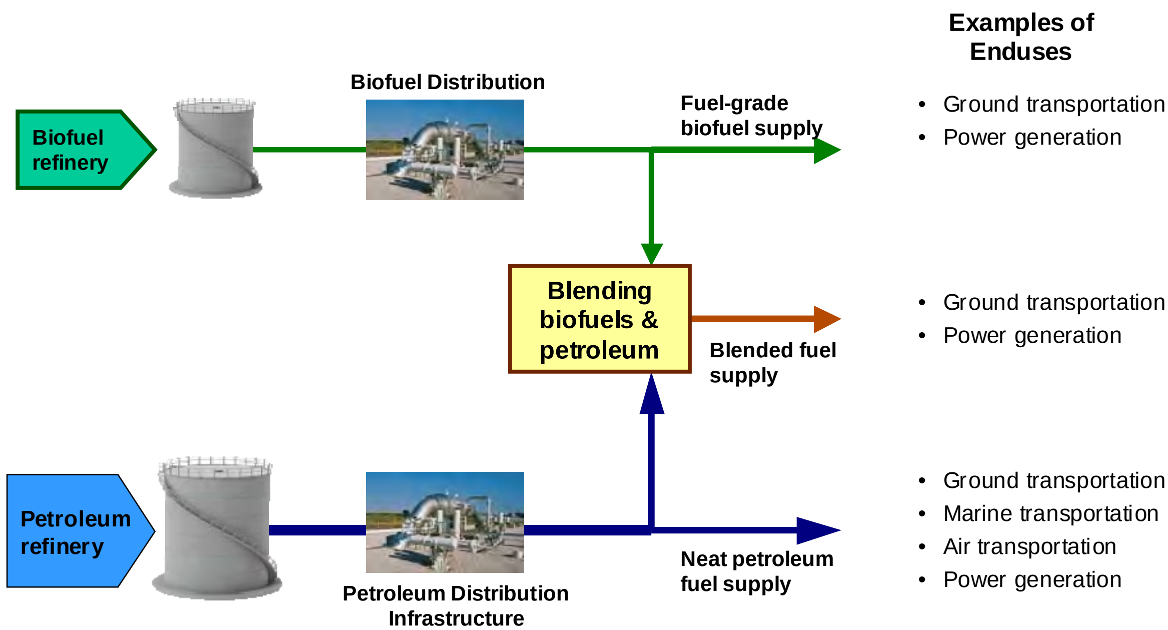


Figure 11 Option 2 – Parallel distribution of petroleum and biofuels

Option 3 – Mixed Petroleum and Biofuel

The distribution infrastructure concepts in Options 1 and 2 are based on the need for distribution of biofuels by means of dedicated distribution infrastructure components, e.g. neat biofuels and petroleum fuels cannot be conveyed in the same distribution components, and blending of biofuel and petroleum should occur close to the point of end-use. Option 3, on the other hand, considers the use of biofuels, which are compatible with petroleum fuel and can thus be transported and stored in existing distribution infrastructure, without the need for significant revamping and modifications of fuel infrastructure.

While currently used biofuels such as ethanol and biodiesel cannot be considered for the distribution infrastructure concept of Option 3, other biofuels can. Promising candidate biofuels with entire or increased compatibility with petroleum fuel are bio-butanol (transportation fuel that would replace or be blended with motor gasoline) and renewable diesel (fuel that could replace or be blended with petroleum diesel).

Figure 12 illustrates Option 3 of a future distribution infrastructure for Hawaii. Biofuel could be either blended with petroleum fuel and transported in the existing petroleum infrastructure or it could be transported batchwise in the existing petroleum distribution system. Batchwise transport of biofuel in petroleum fuel systems would be essentially the same operation as the present transport of different, yet compatible petroleum products in a pipeline or tanker. For example, different “clean” petroleum products, such as motor gasoline of different grades, diesel and jet fuels, can be transported in a common pipeline, where the fuel batches are sequentially conveyed through the pipeline. The mixed volumes between sequential fuel products typically require special treatment or can be used in a fuel application that requires less product quality than the original un-mixed fuel products.

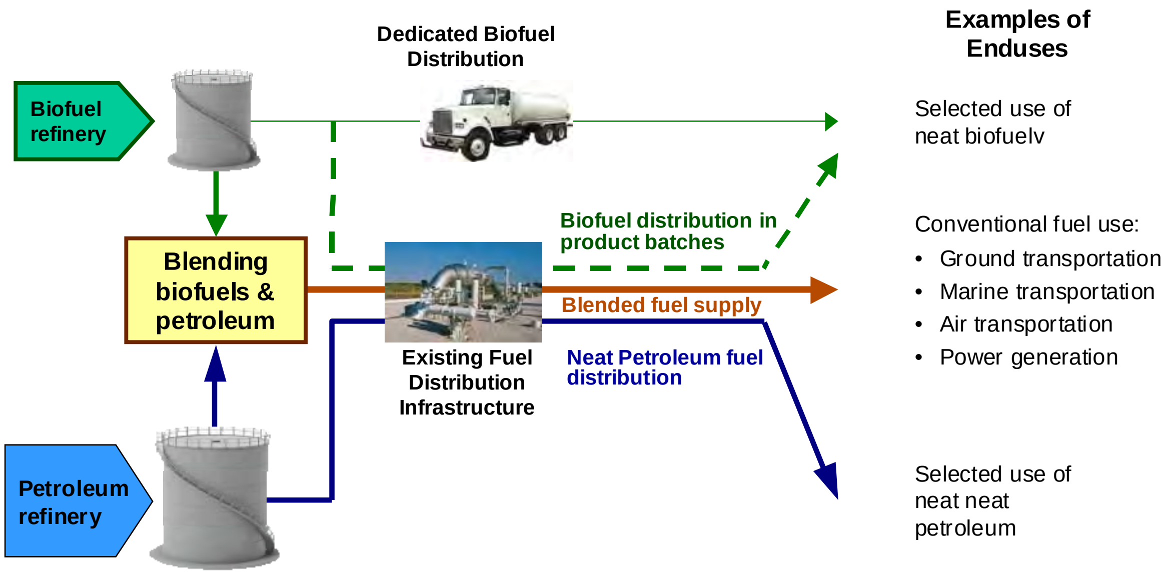


Figure 12 Option 3 - Mixed petroleum and biofuel distribution system

A possible fuel production scenario that could be the basis for Option 3 would be the production of renewable diesel in the process equipment of Oahu's refineries or newly built process plants. Since the renewable diesel would be compatible with ASTM D975 petroleum diesel, the renewable diesel could be mixed with petroleum diesel at the refinery and at any blending ratio. All downstream fuel applications would be possible using the blended petroleum and renewable diesel blend. Such an operational mode would be very cost-effective and would significantly facilitate the introduction of diesel from renewable sources.

Likewise, bio-butanol, preferably derived from cellulosic biomass feedstock, could be produced in process plants and then introduced into the existing petroleum distribution infrastructure.

Besides blended fuel products, there would still be a demand for neat fuel products. The neat petroleum and neat biofuel products could be transported batchwise using the existing petroleum infrastructure or transported in dedicated distribution systems if logistically superior and more cost-effective.

5.4 Aspects to Consider for Future Fuel Distribution System for Hawaii

The choice of a preferred future fuel distribution system for Hawaii will be affected by several conditions:

- The type of biofuels to be used by Hawaii's fuel industry. Biofuels from different feedstock exhibit different properties in regard to the handling in distribution systems. In order to arrive at the least costly distribution infrastructure system such biofuels should have the highest compatibility with the existing fuel infrastructure. The benefits of compatibility with existing fuel infrastructure cannot be over emphasized. Fuel compatibility means that biofuels can be expeditiously introduced and all existing fuel distribution assets can be utilized with no modifications. This would include such aspects as retaining pipeline delivery for virtually all fuels on Oahu, retaining economic benefits for the refineries, retaining a much needed level of redundancies in the fuel system, maintaining a well trained and experienced work force to handle all types of fuel, either biofuels or petroleum fuels.

- The breadth of biofuel usage in Hawaii: Will the bulk of the biofuel energy conversion applications be point-locations, such as converting power stations to run on biofuels, or will biofuel be used in many different end-use applications? The point-locations of biofuel use might be served with relatively minor infrastructure modifications since the power plant fuel system would be designed for specific fuel applications. On the other hand, if a wide range of end-users would use biofuels for their energy needs, the resulting infrastructure needs would be much more complex and costly.

- The origin of biofuel and biofuel feedstock: It is conceivable that refined biofuel or biofuel feedstock would be imported for at least several years during a transition period, rather than produced in Hawaii. Since shortfalls or interruptions of local biofuel production have to be considered as possibilities, biofuel import facilities should be provided and properly maintained as indispensable fuel infrastructure facilities which increase energy and fuel supply security for the state. For biofuel imports, an appropriate biofuel infrastructure has to be installed in the commercial harbors in order to allow for unloading and storage capacities.

- The cost of infrastructure upgrading: The costs of revamping the existing or of building new distribution infrastructure depend on the degree of compatibility of the biofuels with the existing fuel infrastructure of Hawaii.

- The time frame of transition to biofuel: With a longer timeframe, fuel distribution infrastructure assets could be converted successively, partly with ongoing maintenance or scheduled replacement of components of the existing petroleum fuel distribution systems. A longer time frame for the introduction of biofuels in Hawaii could eliminate the need to build new fuel distribution assets if the biofuel is not compatible with the existing fuel infrastructure. A longer time frame for the introduction of biofuel would also give more time to train a workforce, learn from lessons gathered, and develop standards that are based on experience in commercial fuel operations.

- Level of system redundancies: The existing fuel infrastructure has a high level of redundancies to compensate for failures of components of the existing petroleum fuel system. In a transition period both the existing petroleum infrastructure and the newly developed biofuel distribution infrastructure would have to maintain certain redundancies. Hawaii has been dependent on petroleum for many years and there are limits to which the existing infrastructure can be converted to accommodate the use of more biofuels. Redundancies also require continuous investment into replacement of infrastructure components, at their limits of operational life. Therefore, even as a new biofuel infrastructure is being developed, the existing petroleum infrastructure will need significant investment in order to safeguard a reliable petroleum fuel supply.

5.5 Preferred Scheme of Biofuel Distribution System for Hawaii

Figure 13 shows a preferred scheme for a future fuel distribution system in Hawaii.

The major portion of the biofuel supply in Hawaii would be composed of biofuels that are compatible with the existing petroleum distribution infrastructure. The preferred blending approach would be at a point upstream of the main distribution assets, such as pipelines, major storage facilities, marine transport routes, etc. If neat biofuel and renewable fuels would be desired, such fuels could be distributed batchwise, using the existing petroleum distribution system.

A smaller portion of the entire biofuel supply for Hawaii might come from decentralized biofuel conversion plants. Such plants would produce types of biofuels that are more or less compatible with the existing petroleum distribution system. In these cases the distribution could be accomplished using selected and dedicated fuel systems, built to the specific needs of the biofuels to be handled.

The advantages of such a system would be that most of the existing petroleum distribution systems could be retained and expensive conversions and large scale infrastructure projects could be avoided. The transition to a biofuel centered liquid fuel supply for Hawaii could progress at the speed of increased availability of biofuel and renewable fuel supply, thus it would be an upstream controlled fuel system expansion.

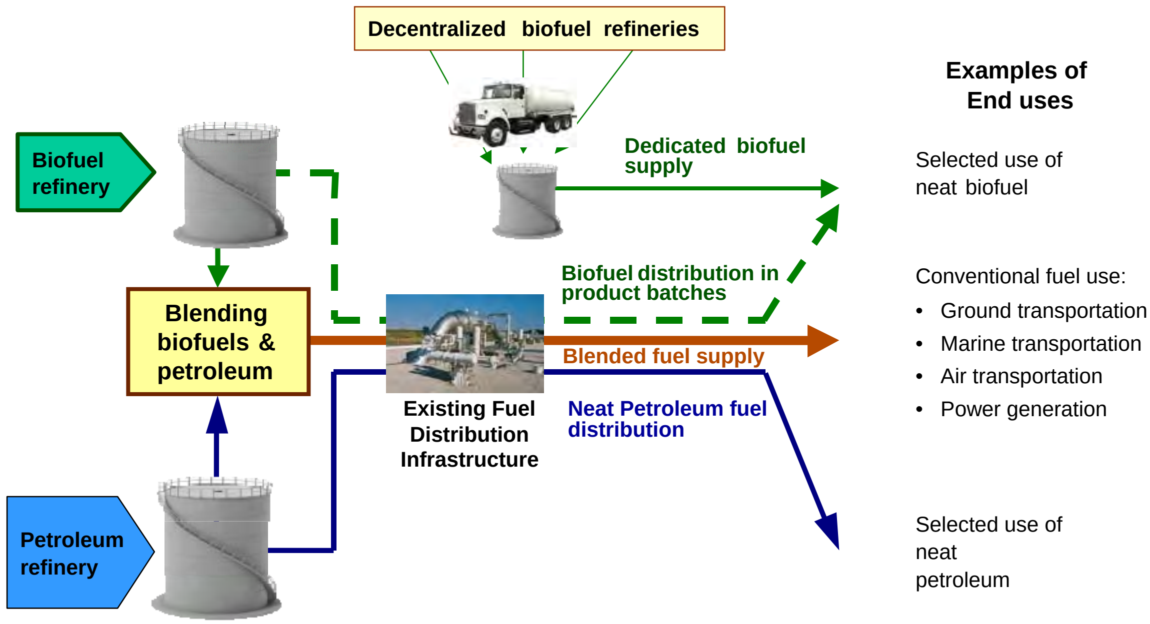


Figure 13 Preferred scheme of biofuel distribution system for Hawaii

6. Distribution Infrastructure Development Needs

Development needs for the distribution infrastructure for biofuel entail short-term and longer-term actions:

Short-term development needs would include biofuel distribution infrastructure projects that would serve preferably point-location end-uses, such as the planned use of biodiesel in electric power plants. These short-term biofuel supply projects would most likely require the importation of refined biofuels rather than the short-term establishing of biofuel conversion plants in Hawaii. The infrastructure for such dedicated biofuel projects would entail a limited, though not insignificant commitment of capital investment. The benefits of such biofuel end-use projects would be gaining operational experience in handling large volumes of biofuels over a longer period. Such operational experiences would be valuable for the future expansion of biofuel use in Hawaii and the phasing out or phasing down of petroleum distribution in Hawaii.

Longer-term development needs would be a plan to maximize the use of the existing petroleum distribution infrastructure for future use by biofuels. For the selection of what biofuel to use in Hawaii in the future, the degree of compatibility with existing petroleum distribution infrastructure ought to be a key decision criterion. Presently, the biofuels in most widespread usage are ethanol and biodiesel. Both of these established biofuels have fuel properties that either excludes, or at least complicates their handling in existing distribution systems. New biofuels, such as bio-butanol and renewable diesel, show very promising properties of high compatibility with the existing petroleum distribution. A longer–term development need would be to investigate, under operational conditions, if newly introduced biofuels, such as renewable diesel and bio-butanol, could indeed be handled in existing petroleum distribution systems.

7. Feedback from Hawaii's Bioenergy Stakeholders

The following paragraphs present comments received from stakeholders. The comments are summarized in categorized groups:

More infrastructure is need to handle an increased biofuel market:

"To meet the 25% biofuel goal, we need significantly more infrastructure than is currently available", "Tankage is needed, especially neighbor islands; barge capacity and service; pipelines, tanker trucks", We are deficient in the ship to refinery leg. We need more longshore and transport capacity. Additional facilities are needed to accommodate biofuels"

The comments suggest the need to increase the scope and complexity of new distribution infrastructure to meet the planned expansion. The statement also suggests that the envisioned volume of biofuel cannot be transported with the biofuel distribution systems that are in place.

Petroleum infrastructure is still needed:

"To handle biofuels, we cannot discard equipment for petroleum fuels since we are still going to need that",

The comments suggest that even when the use of biofuel increases, the existing petroleum infrastructure still has to be maintained at a safe and reliable level. Taking infrastructure assets away from the petroleum fuel system and converting them to use for biofuel would reduce the redundancies in the petroleum system and might negatively affect the operational readiness of the petroleum system to serve the islands.

Long-term time frame needed for introduction of biofuel:

"Long term biofuel needs have to be planned carefully so infrastructure does not become obsolete in 10 years after having invested much of the resources in the infrastructure", "we need a 10 year plan and not a 3 year plan", "The plan has to be more in the 5-10 years range rather than 2-3 years. We need to consider impacts of the other alternative energy sources on biofuel demand, i.e. more wind and solar alternative energy, less demand for biofuel", "huge issues ahead for conversion to alternative energy";

The comments suggest that the transition to biofuel must be carefully planned and cannot be accomplished in a short term. A short term (e.g. 2-3 year) plan for introduction of biofuels to Hawaii should be rethought in favor of a longer-term plan, so that decisions made for the distribution of biofuels will not result in systems that become obsolete in a matter of “10 years”.

Select “Right” biofuel that can use existing infrastructure:

“decide which biofuels we’re going to develop, then develop the infrastructure to support it”, “infrastructure costs to convert from petro to biofuels could be minimized if we select the right biofuel, that is, one that is compatible with the existing fuels and that can be transported with the existing distribution modes (barge, truck, pipeline)”, “the biofuel selected for the development will have significant impact on the level (amount and complexity) of biofuel infrastructure needed..”, “the current biodiesel accommodations having some difficulties. Equipment conversion from petroleum to biodiesel is problematic”

The comments suggest that the selection of biofuel types for Hawaii needs to take into account compatibility with the existing petroleum infrastructure. Significant capital and operational costs could be avoided if only those biofuels, that are compatible with the existing petroleum infrastructure are used.

8. Possible Expansions Required for Liquid Biofuel Distribution Infrastructure

The extent of the required expansion of the liquid fuel distribution infrastructure in Hawaii due to increased biofuels use will depend on the degree of compatibility of the biofuels and the existing petroleum distribution infrastructure.

As pointed out earlier in the report, if mainly biofuels and renewable fuels are used which are compatible with the existing petroleum infrastructure, such as butanol, renewable diesel (e.g. fuel compliant with ASTM 975) or straight vegetable oil (SVO), there would be virtually no need for new and expanded liquid fuel distribution infrastructure components. These so-called second generation biofuels and renewable fuels would merely be replacing volumes of petroleum products and could be distributed within the existing petroleum distribution infrastructure, which comprises of pipelines, storage tanks, fuel tankers and barges and tanker trucks.

The Bioenergy Use Scenario of the Hawaii Bioenergy Master Plan suggests, however, a biofuel use scenario where the conventional biofuels ethanol, biodiesel and Renewable Fuel Oil (identical to straight vegetable oil) need to be distributed. This scenario would require the following distribution infrastructure scheme:

- For the expanded fuel distribution, additional volume for ethanol and biodiesel would have to be furnished within bulk terminal storage facilities. It would have to be assessed on a case-by-case basis if an existing petroleum storage tank is compatible with the storage of denatured ethanol or neat biodiesel. If the storage tank could not be converted, because of material issues or geometry, new storage tank capacities would have to be furnished. Certain volume allowances for back-up or redundancies might have to be considered for the new storage capacities.

- Renewable fuel oil (identical to straight vegetable oil) should be compatible with most petroleum fuel systems. For example, renewable fuel oil is likely suitable for conveyance through existing pipelines that are presently used for the conveyance of residual fuel to power plants on Oahu.

- The current transport mode of denatured ethanol and neat biodiesel is limited to rail tankers and tanker trucks since the conveyance of these biofuels through pipelines is currently not common in fuel operations. Furthermore, though the proposed use scenario of ethanol and biodiesel represents a significant expansion of biofuel use in Hawaii, their volume would probably not justify the construction of new, biofuel compatible long pipelines, such as the existing petroleum pipelines on Oahu, which connect the two refineries at Barbers Point with the Honolulu area, the Honolulu Harbor and the Honolulu International Airport. Consequently, with the absence of commercial railways in Hawaii to transport cargo, the additional volumes of ethanol and biodiesel would have to be transported on roads with tanker trucks.

- Table 3 suggests the extent of additional storage tanks and truck operations to handle the proposed volumes of ethanol and biodiesel. Table 3 assumes that storage capacity for ethanol, biodiesel and straight vegetable oil would have to be furnished that amounts to a 30 day stockpile. The average tank volume of the required additional tanks is assumed to be different in the four counties to allow for more operational flexibility on Maui, Kauai and island of Hawaii. The required number of additional tanks would include a backup or redundancy allowance, which would increase the required number of tanks by 35%. The data in Table 3 suggests that the number of required new tanks (including existing tanks that could be converted) would be approximately 14% of the number of existing petroleum product bulk storage tanks in the State of Hawaii. The existing petroleum bulk storage tanks include tanks for jet fuel. Jet fuel, however, cannot be replaced with conventional biofuels at this time.

- Table 3 indicates the assumed capacities of tanker trucks to transport the additional biofuel volumes, which is different for the four counties. Typical capacities of tanker trucks are between 5,500 and 9,000 gallons. Often tanker trucks have several compartments, enabling them to transport different fuel products. For the estimates on additional tanker truck operations it is assumed that the total volume of the tanker trucks would be used for the specific biofuel. Table 3 suggests that the likely additional daily tanker truck operations in the State would be about 94.

Table 3 Anticipated increased demands for biofuel bulk storage volume and transport operation

Description	units	Counties: Honolulu	Maui	Hawaii	Kauai	State
Ethanol	gallons	57,300,000	13,100,000	6,100,000	7,100,000	83,600,000
Renewable diesel	gallons	66,800,000	16,700,000	8,000,000	12,300,000	103,800,000
Renewable Fuel Oil	gallons	68,000,000	4,000,000	6,600,000	0	78,600,000
Required storage						
days of consumption for strategic reserves	days	30	30	30	30	
volume stored (**)						
Ethanol	barrels	112,000	26,000	12,000	14,000	164,000
Renewable diesel	barrels	131,000	33,000	16,000	24,000	204,000
Renewable Fuel Oil	barrels	133,000	8,000	13,000	0	154,000
aveage storage tank volume at bulk terminal storage (**)	barrels	11,000	8,000	8,000	8,000	
number of additional tanks at bulk terminal storage (***)		**15**	**5**	**3**	**3**	**26**
number of petroleum tank existing		103	30	36	16	**185**
Fuel transport by tanker truck						
days of fuel truck operations	days	310	310	310	310	
hours of truck operation	hours/d	8	8	8	8	
average capacity of tanker truck (****)	gallons	7,500	5,500	5,500	5,500	
volume to be transported by tanker trucks (****)						
Ethanol	gal/d	185,000	42,000	20,000	23,000	270,000
Renewable diesel	gal/d	215,000	54,000	26,000	40,000	335,000
Renewable Fuel Oil	gal/d	fuel transport through pipeline				
Number of additional tanker trucks						
Ethanol	truck/d	25	8	4	5	**42**
Renewable diesel	truck/d	29	10	5	8	**52**
Total number of additional trucks	truck/d	**54**	**18**	**9**	**13**	**94**
	truck/h	**7**	**3**	**2**	**2**	

** numbers rounded to next 10,000 gallons
*** Including allowance for backup tanks
*** numbers rounded to next 1,000 gallons

9. Impacts of Solid Bioenergy Distribution

The Bioenergy Use Scenario of the Hawaii Bioenergy Masterplan lists four proposed bioenergy projects that use solid biomass for electricity generation. These four projects might be realized within the next three to five years and serve as an illustration of future distribution infrastructure needs and impacts of expanded use of solid bioenergy fuels in Hawaii.

Descriptions of the projects are as follows:

<u>County of Hawaii, Hu Honua Biomass 22 MW Project:</u>

Information on the project was furnished by the management of Hu Honua Bioenergy, LLC. [Hu Honua, 2009]. The planned facility has a 21.5 MW rated capacity. The plant will use an existing steam boiler and wood for feedstock. During off-peak hours, e.g. at night, output will be scaled back to about 10 MW. Biomass feedstock transported to the plant will be about 50% wood chips and 50% logs. Logs are preferred since they have a higher bulk density. There is a wood storage area on the site of the plant that has a capacity of about 5-7 days of wood chips and 25 days of logs. The wood will be transported to the plant by tractor-trailers which will use public roads. Typical truck operations include about 25 to 30 truckloads per day. Traffic impacts are anticipated only in the vicinity of the plant. The developer will mitigate adverse traffic impacts through local street improvements such as a separate left turn lane or separate deceleration lane.

<u>County of Maui, Pulehu Energy, 6 MW Project:</u>

Information about the project was furnished by Maui Electric Company, Ltd [MECO, 2009] and the website of the developer [Bioenergy, 2009]. The project is in the initial development phases. The site of the proposed plant has not been finalized. The plant would have a rated capacity 6 MW using forest residues for fuel. The plant would be operated intermittently. The plant would be a new power pant using thermal gasification to covert the biomass for subsequent power generation. The wood fuel would be brought to the plant by truck over public roads.

<u>County of Kauai, Green Energy, 6 MW Project:</u>

Information about the project was furnished by Kauai Island Utility Cooperative (KIUC) [KIUC, 2009]. The project is in the initial development phases. The site of the proposed facility has not been finalized. The plant would have a rated capacity 6.7 MW using albizia trees as its primary fuel source. The fuel would be transported on private land; therefore there would be no or very minimal traffic impact on public roadways.

<u>County of Kauai, Sugar cane bagasse, 20 MW Project:</u>

Information about the project was furnished by Kauai Island Utility Cooperative (KIUC) [KIUC, 2009]. The project is in the initial development phases. The site of the proposed plant has not been finalized. The plant would have a rated capacity 20

MW using sugar cane bagasse as its fuel source. The fuel would be mainly transported on public roads.

The fuel transportation mode for all four solid bioenergy projects would be similar. The wood feedstock would be transported either as wood chips or as logs to the power plant. The sugarcane feedstock would be mechanically harvested and chopped before transportation. At all power plants there would be storage capacities for several days of plant operation in order to avoid disruptions of power generation if there were interruptions of solid fuel supply.

The biomass would be transported with heavy trucks, whose overall maximum length and gross weight would be limited to 65 feet for truck-tractors and semi-trailers and 80,000 pounds for any vehicle that operates or moves on any public road, street, or highway, other than interstate highways and certain qualifying federal aid highways as designated by the director of transportation. [Section 291-34 and 291-35, HRS].

The bulk density of the solid biomass determines if transport by truck is weight or volume limited. Assuming that the typical usable cargo volume of a semi-trailer is 3,400 cubic feet and the assumed payload is 30 tons, or 60,000 pounds, the limiting bulk density would be about 17.7 pounds per cubic feet. Therefore if the bulk density is smaller than 17.7, the truck would transport less gross weight than weight limits would allow; i.e. the transport would be volume limited. If the bulk density of the solid biomass were greater than 17.7, then the truck payload capacity would be weight limited; i.e. the truck could not fill its entire usable cargo volume to transport the biomass.

The bulk density of wood and wood chips varies considerably as a function of water content and dimension of the logs, chips or residue. For this assessment of distribution infrastructure impacts, the assumed bulk densities for the wood fuel feedstock is 16 pounds per cubic feet (260 kg/cbm) [EVA, 2006].

The bulk density of sugarcane differs considerably depending on the state of sugarcane products. Billeted cane, where the sugarcane is chopped at harvest into approximately 12-inch sticks, has the highest bulk density with 22 pounds per cubic foot. Bagasse exiting the final mill process has the lowest bulk density with 7.5 pounds per cubic foot. [SEL,2009]. For this assessment of distribution infrastructure impacts, the assumed bulk density for the bagasse feedstock is 11 pounds per cubic feet (175 kg/cbm), which represents somewhat compacted sugarcane bagasse.

The resulting payloads of the trucks transporting wood or sugarcane bagasse to the thermal power plants would be 27 tons or 17 tons, respectively. Both the wood and sugarcane hauling trucks would therefore be volume limited and would be less then the maximum allowable gross weight of 80,000 pounds.

Table 4 shows a summary of the characteristics of the four example projects.

Table 4 Summary of four example projects that convert solid biomass

Referenced bioenergy project on island		Big Island	Maui	Kauai	Kauai
Bioenergy plant characteristics; project characterics are still subject to change	units	Thermal conversion of wood chips to generate electricity (22MW)	Using forest residue to generate electricity (6MW)	Thermal conversion of wood chips to generate electricity (6.7MW)	Thermal conversion of sugarcane bagasse to generate electricity (20)MW)
Required biomass	tons/year	194,000	47,000	65,000	178,000
Anticipated plant operation	days/year	310	310	310	310
	tons/day	630	150	210	570
Tuck payload capacity	tons	27	27	27	17
Operating hours	h/day	8	8	8	8
Required number of truck operations (**)	trucks/day	**24**	**6**	**8**	**34**
	trucks/h	**3**	**1**	**1**	**5**

(**) The 6.7 MW proposed plant on Kauai would move the wood feedstock on private land and not public roads

Table 4 suggests that the maximum number of truck operations per day differs between 24 and 34, for wood and sugarcane feedstock.

The impact on traffic cannot be assessed without specifics of the routes and the existing level-of-service on the affected public roads. A maximum frequency of five trucks passing on a road per hour might not significantly decrease the level-of-service of county highways, but could cause traffic impact on smaller feeder roads and ingress and egress to harvesting areas or sites of the conversion plants. Typically, the plant operator would implement measures to mitigate traffic impacts. Such measures could comprise dedicated left-turn lanes, deceleration lanes or special accommodations for bike and pedestrian traffic.

10. Other Impacts of Bioenergy on Hawaii's Future Energy Supply

This chapter presents two impacts that are indirectly related to the configuration of the future biofuel distribution infrastructure:

10.1 Impact of Increased Bioenergy Use on the Petroleum Supply of Hawaii

Increased bioenergy consumption in Hawaii will reduce the amount of petroleum products consumed in Hawaii assuming aggregate energy demand remains constant. This reduction of petroleum use in Hawaii may have negative economic and operational effects on the local refineries and the petroleum supply system in Hawaii

The petroleum supply system in Hawaii is the backbone of Hawaii's existing energy system. The existing fuel supply system is a product of decades of reliable service to Hawaii and represents a complex and expansive system of marine terminals, refinery facilities, distribution of refined petroleum products through pipelines and with barges and tanker trucks.

The two refineries on Oahu receive crude oil at two offshore terminals. The crude oil comes from an increasing and varying group of supplier countries and regions while the suppliers that represented up to 80% of Hawaii's crude oil in the past, Alaska and Indonesia, are in production decline. The refineries in Hawaii have somewhat different process capacities than typical refineries on the US mainland. Hawaii's refineries are equipped to supply Hawaii with a output slate and output volume of petroleum products which is specific to Hawaii. The refineries utilize the price advantage of transporting crude oil in lieu of finished petroleum products to create market advantage.

Should refineries retain the present production level despite a decreasing market for petroleum products in Hawaii, they might have to export selected petroleum products that are replaced by biofuels and that cannot be sold in Hawaii. The increased export of selected types and volumes of petroleum fuel will likely add to the operational costs of the refineries and result in an increase in fuel prices in Hawaii. Another possible response to a decreased demand for selected petroleum products, which offer the highest margins for the refineries, might be reduction in production volume to match the change in demand pattern. Since this could result in an undersupply of selected petroleum products from the local refinery operations, such a response would require increased imports of refined petroleum products, which would most likely also increase costs for fuel in Hawaii.

The above possible responses by the local refineries to a reduced petroleum demand due to interfuel replacement by biofuel would most likely change the demand on transport modes that supply the State of Hawaii with petroleum from offshore. New or modified fuel infrastructure assets and related investment needs would most likely be required. For example, the need to supply Hawaii with refined petroleum fuel could result in a demand for expanded fuel facilities in the commercial harbors on Oahu to handle more imports.

In another possible scenario one or both local refineries could find it hard to compete in a future fuel market where a significant portion of the refineries' local demand for product is displaced by renewable energy sources. It is conceivable and even likely that, as a minimum one, and possibly both, of the local refineries would be uneconomical to operate and could shut down. Considering shutdown of all or a significant part of the local refinery petroleum operations and considering the type of biofuels which could use certain process facilities of the refineries (e.g. renewable diesel could be good fuel candidate) it might be possible that certain local refinery operations could be converted to produce selected biofuels. This would be an advantageous situation since part of the refinery operations could stay in Hawaii and at least part of a highly trained workforce could be retained for future biofuel process operations. Another benefit of a fuel scheme where biofuels that are compatible with legacy fuel systems are produced at the existing refineries is the possibility that existing fuel distribution systems on Oahu could be used as they are, or with only minor adjustments. Furthermore, without current refinery capacity, significant public expenditure might be required to align the fuel supply of Hawaii to increased imports of refined petroleum products or imported biofuels if locally produced biofuels are not available.

The existing fuel import and distribution infrastructure would most likely require some form of fuel facility upgrades as a result of increased consumption of biofuels.

10.2 Impact of Byproducts from Biofuel Production

A significant volume of byproducts might be generated in the production process of biofuels. These byproducts have to be transported to the points of end use, conversion or disposal. These needs may require significant transportation system infrastructure, depending on the scope of biofuel production and the quantity of process byproducts.

An example of such byproducts handling is glycerin, which is removed from vegetable oil in the production of conventional biodiesel. The glycerin could be a feedstock for more energy conversion (e.g. it can be converted to heat and therefore electricity) or it could be a feedstock for other industrial products, such as soap production and the cosmetic industry. The possible economic and social benefits of byproducts of biofuel productions should be included in the analysis of the impacts of the future biofuel supply system in Hawaii.

11. Conclusions and Recommendations

State policy supports the use of liquid and solid bioenergy products to help meet Hawaii's future demand for clean and renewable energy. Liquid bioenergy products can provide base load power supply, which is presently provided by petroleum and coal, as well as transportation fuel. Solid bioenergy products can provide base load power supply.

The following summarizes the major conclusions pertaining to liquid bioenergy (biofuel) distribution infrastructure:

1. As biofuel usage grows in Hawaii, it is imperative that a distribution infrastructure is developed to accommodate the increased volumes of biofuel flowing through the supply systems, so that the biofuel products can be supplied to the end user in a cost efficient and efficient way.

2. The existing fuel distribution infrastructure in Hawaii is built to supply large amounts of petroleum to power Hawaii's ground transportation, air transportation and electricity power generation. The existing petroleum distribution infrastructure in Hawaii is large and complex and uses storage tanks, terminals, pipelines, barges and tanker trucks to provide Hawaii with a secure and robust energy supply. The preferred future biofuel distribution system would utilize this petroleum fuel system and require no or minimum modifications of existing distribution assets.

3. The distribution of liquid biofuels utilizes infrastructure components that are similar to the existing petroleum fuel system. Conventional biofuel, such as ethanol and biodiesel are, however, not fully compatible with existing petroleum system, since they act as strong solvents and have strong affinity to water, which could result in water contamination of the fuel.

4. The most widely used biofuel in the US market today is ethanol followed by biodiesel. These biofuels represent "first generation" biofuels and they have a limited compatibility with existing petroleum distribution and end-uses. Newer types of biofuels that are under development or are in pre-commercial stages exhibit much better compatibility with existing petroleum equipment and distribution assets. Using types of biofuel that can be distributed in existing petroleum systems offer a considerable cost and operational advantage.

5. The selection of biofuel according to the compatibility to existing distribution infrastructure should be given high importance and weight. Certain properties of the conventional and established biofuels, ethanol and biodiesel, result in incompatibilities with most of the established petroleum distribution infrastructure and operation. Other evolving biofuels, such as bio-butanol and renewable diesel (i.e. diesel different from the ester type biodiesel and compliant to ASTM D975) should be compatible with existing petroleum distribution infrastructure components. From the viewpoint of facilitating the development of a biofuel distribution infrastructure that can support a rapidly expanding biofuel industry in Hawaii, such biofuel would be preferable to ethanol and biodiesel.

6. Whether existing petroleum storage tanks can be used or can be converted for use with biofuel has to be decided on a case-by-case basis. More recently built petroleum storage tanks might be more compatible with biofuels such as ethanol and biodiesel than older tanks. The use or conversion of existing petroleum storage for biofuels tanks would be less costly and would require less land than developing new biofuel storage tank capacities. Considering the bioenergy use

scenario of the Hawaii Bioenergy Master Plan, about 14% of the existing number of petroleum tanks would have to be built or converted, in order to create an appropriate stockpile of the envisioned volume of ethanol, biodiesel and renewable fuel oil.

7. Infrastructure developments require significant capital investment and time to implement. It is important that distribution infrastructure is flexible to changes in fuels. Distribution systems that are built for specific biofuels, should be avoided since they become obsolete as the biofuel use may change resulting in large sunk costs that might not be recovered.

8. Straight vegetable oil, e.g. biofuel that is not converted to higher quality products such as biodiesel, can be used for electricity generation. Straight vegetable oil could replace petroleum residual fuel, which is presently used in power plants in Hawaii. Straight vegetable oil seems to be fully compatible with the distribution system for residual fuel. Most likely straight vegetable oil would be conveyed through existing pipelines built to convey residual fuel. This assumed compatibility with existing petroleum fuel systems significantly facilitates the broad introduction of straight vegetable oil in Hawaii.

9. The timeline for the introduction of new distribution infrastructure should be preferably 5 to10 years rather than a short 2 to 3 years. With regard to distribution infrastructure, the transition from petroleum to biofuel requires specific operations know-how that can be more readily attained by a small number of larger consumers (i.e. conversion of power generation to biofuel) rather than building the distribution system for a large and dispersed group of small users (i.e. providing a large distribution network of transportation biofuel dispensing stations).

10. Pipeline operators typically are reluctant to make their existing petroleum transmission pipelines available for fuel grade ethanol or biodiesel. Therefore, it seems unlikely that long transmission pipelines, such as the pipelines on Oahu that connect the refineries with urban Honolulu, will be available to convey sizeable amounts of ethanol and biodiesel anytime soon. The new construction of dedicated biofuel pipelines over long distances in Oahu is equally unlikely in the near future. Therefore the transport of biofuel by means of tanker trucks may be the preferred transport mode for biofuels in the years to come. With the biofuel volume envisioned under the bioenergy use scenario of the Hawaii Bioenergy Master Plan, about 100 tanker truck operations per day would be required throughout the state to transport fuel grade ethanol and biodiesel. The transport of the biodiesel would be over public roads in the four counties.

11. The conversion of existing petroleum distribution infrastructure into dedicated biofuel systems might be a cost effective way to provide storage and transport capacities to the evolving biofuel industry in Hawaii. However, it is likely that Hawaii will still import sizeable amounts of petroleum products in the years to

come, while petroleum is being replaced with cleaner and renewable fuel products. Hawaii's petroleum infrastructure will therefore remain important and enough resources will have to be invested into the maintenance of the petroleum fuel system. Operating and maintaining two fuel systems in parallel, while the use of petroleum fuel decreases and that of biofuel increases, will require significant resources

12. The preferred biofuel distribution infrastructure would allow petroleum and biofuels to be transported and stored side by side, without the need to segregate large parts of the fuel distribution system by either neat petroleum or neat biofuel needs. The type of biofuels used in Hawaii would preferably be blended upstream of the distribution value chain. Alternatively, biofuels and petroleum could be transported batch wise through the common distribution systems, similar to different petroleum products using distribution assets (e.g. batchwise conveyance through pipelines that serve compatible product groups).

13. While the large-scale introduction of biofuel in Hawaii could significantly affect the fuel distribution infrastructure in Hawaii, it is most likely that large-scale use of biofuel in Hawaii would also affect the importation of petroleum to Hawaii. A decreased demand for certain petroleum fuel products due to displacement by biofuels could have impacts on the operations of the two local refineries. In order to respond to a reduced demand for certain petroleum products the refineries would have basically two options. Option One would be to lower the volume of imported and locally processed crude oil to adjust for the reduced demand for refined petroleum products. In this case imports of petroleum products might be required to make up for the production shortfall. Option Two would be to retain the present petroleum fuel production rate of the refineries and export the excess petroleum products. Both Option One and Two could affect the viability of the future operations of the two local refineries and therefore could significantly affect the energy and fuel supply to Hawaii. Stakeholders have pointed out that Option One, in which refinery throughputs are reduced as demand for conventional petroleum products declines, might be the most likely alternative. Stakeholders suggest that, since refinery yield flexibility is limited, reductions in throughput would likely result in an increased requirement for imports of selected refined petroleum products, which would no longer be supplied in the required volume from local fuel production. This would most likely require additional capital investments in new fuel facilities in Hawaii. Such investments for new petroleum infrastructure might take available capital investment away from a dedicated biofuel distribution infrastructure. If, however, the future biofuels used in Hawaii would have a high compatibility with the petroleum fuel products used in Hawaii, then much needed synergy in fuel distribution could be achieved.

The following summarizes the major conclusions pertaining to solid bioenergy (biofuel) distribution infrastructure:

14. The use of solid biomass provides opportunities to replace imported petroleum with locally grown fuel. Due to the lower heat content and density of solid biomass versus petroleum, the transport of solid biomass from the location of harvesting to conversion requires more volume and mass to be transported for the same amount of heat content. Candidate solid biofuel feedstocks for presently proposed projects are various types of woods, forest residue and sugarcane.

15. The preferred mode of transport of the solid fuels to the conversion plants is by heavy trucks. Transport over private land is preferred over heavy trucks using public roads, where the dimensions and gross weight of the trucks is limited to 65 feet in length and 80,000 pounds. Typically transport with trucks is volume limited, which means that the trucks run out of available cargo volume before they reach the maximum allowable gross weight.

16. The frequency of truck operations to transport solid bioenergy to the power plants depends on the generation capacity and efficiency of the power plant, the heat value of the solid biofuel and the bulk density of the solid fuel. The types of wood fuel considered for the proposed solid bioenergy projects require less truck operations than less dense sugarcane bagasse.

17. The anticipated frequency of up to five truck operations per hour would cause some traffic impact on public roads. The level-of-service of these public roads might however not be significantly affected. It is more likely that more significant traffic impact would be more localized, such as close to the ingress and egress of biomass loading and power plant sites. It is anticipated that appropriate traffic mitigation measures could be implemented to avoid significant impacts from solid bioenergy trucking operations.

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Abbreviation and Acronyms

ABE	Acetone, butanol and ethanol fermentation process
ASTM	ASTM International (ASTM), originally known as the American Society for Testing and Materials
B100	Fuel grade biodiesel
B5	Fuel blend 5% biodiesel fuel blended with petroleum diesel fuel
BU16	Fuel blend of 16% butanol fuel and 84% gasoline fuel
DBEDT	Hawaii State Department of Business, Economic Development & Tourism
E85	Fuel blend 85% ethanol fuel blended with 15% petroleum gasoline
EIA	Energy Information Agency
EVA	Energieverwertungsagentur, the Austrian Energy Agency
FAME	Fatty acid methyl esters
HECO	Hawaiian Electric Company
HFFC	Honolulu Fueling Facilities Corporation
HRS	Hawaii Revised Statutes.
KBPH	Kalaeloa Barbers Point Harbor
KIUC	Kauai Island Utility Cooperative
LPG	Liquefied petroleum gas
MECO	Maui Electric Company, Ltd
MoGas	Motor gasoline
RD100	Neat renewable diesel
SEL	The Sugar Engineers' Library
SNG	Synthetic natural gas)
SVO	Straight vegetable oil)
ULSD	Ultra-low sulfur diesel

Hawai'i Bioenergy Master Plan

Green Jobs, Biofuels Development, and Hawaii's Labor Market

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EXECUTIVE SUMMARY

This section of the report focuses on the labor considerations associated with biofuels in Hawai'i. In particular, it discusses how a potential biofuels industry might affect the labor market, as well as possible requirements for the industry. While the labor market generally responds to industrial dynamics, the following ideas and estimates should be accounted for when policy makers and leaders consider how best to support biofuels.

One major labor market question discussed here is whether the state's workforce could support a vibrant biofuels industry. Should Hawai`i's bioenergy industry require the growing and harvesting of agricultural crops, particularly plantation grown crops, there may be a significant need for a lower-skilled labor force similar to that required for sugar cane production. For this type of labor, which is characterized by lower wages, there are two possible sources. First, labor might be imported from the U.S. mainland and/or internationally, as has been the case for earlier periods of agricultural growth in the state. Where such labor resources come from is largely a function of the types of work created (e.g. technical, manual, etc.). In addition to imported labor, the other major pool of currently available labor for a possible biofuels industry is the locally unemployed. Fortunately, higher unemployment rates on the Neighbor Islands may match biofuels production sites. Beyond these available sources, training and education might be a long term strategy for filling biofuel labor needs.

In terms of the scale of jobs created through biofuels, it is very difficult to base estimates on existing experience because there are many remaining technical questions on how the industry might evolve in Hawai'i. Nevertheless, according to our rough preliminary estimates, it is possible that by 2030 that the industry might add 584 jobs in the processing side only, where the state is likely to have the greatest comparative advantage. Thus, if biofuels were the only alternative energy source substituting for current imported oil sources, by 2030 the industry would employ a small (excluding agriculture field labor), but perhaps important part of the labor force.

It is not yet clear how a biofuels industry – and in particular which parts of the value chain are best located in Hawai'i. In any case, it will be important for industry, government, labor and educational institutions to take initiative and develop programs to meet the full range of skills needed for "green" industries including bioenergy. Such a comprehensive approach towards supporting the biofuels labor market as part of a broader green energy agenda makes most sense from the view that investment in biofuels skills development will be at the leading edge of efforts to make the state an innovator in green industries.

One of the biggest challenges in Hawai'i is the wages/cost-of-living ratio. Biofuels-related jobs in the state must provide "livable" wages that meet baseline needs of state residents as well as show potential for keeping up with steep rises in the consumer price index.
In any case, the high and rising cost of living in Hawai`i strongly suggests that the lower end of the biofuels jobs spectrum may not be attractive if other employment opportunities are available that pay above the minimum wage.

The growth of a biofuels industry in Hawai'i is likely to require some significant investment from state resources. In particular, a state role in bridging the gap between existing training programs and industry needs can contribute to overall success and link the state to existing energy worker training programs. State legislation supporting these programs and promoting green jobs might help bolster industry success. The state can also explore opportunities to partner such job training programs with other public objectives in order to better integrate the workforce, including creating programs for low-income workers. For example, green-collar job training funds can be used to target low-income adults and youth in poverty.

This section of the report provides five recommendations and "thinking" points:

1. Given the likely small size of any biofuels workforce in Hawai`i, other than agricultural workers, it is important for legislators to create synergies with other growing sectors of the economy. In particular, those fast-growing occupations related to the higher end of biofuels skills, such as industrial engineers, pharmacy technicians, and computer software engineers, who might share a workforce with biofuels professionals. On the lower-skilled end of occupations, manual laborers in the biofuels industry will likely share some concerns with other agricultural workers such as pay scales and working conditions;

2. The biofuels industry in Hawai`i, as it evolves, will create some jobs for local residents as well as attract some new workers. To create a responsive and loyal employment base in the industry, legislators and business leaders might consider nurturing community—and regionally—specific worker bases to mobilize as much of the local unemployment base as possible. Such outreach is likely to create industry loyalty and identity since the size of the biofuels workforce is not likely to be large. This will increase labor channelling and networks that are easier to carve out as a stable employee base with less training;

3. Liveable wages are a problem for many workers in Hawai`i. The report classifies those occupations in high- and low-wage categories, with the former likely to support a livable wage for Hawai`i, and the latter not likely to support a livable wage. Labor market subsidies to private sector firms, for example, might focus on those higher-end occupations and leave the lower-wage occupations to be performed by workers outside of the state of Hawai`i, where they are likely to be more liveable wages. In this way, policy should focus on attracting those parts of the industry where wages are above manual labor level. There is some unemployment in Hawai'i – especially on the neighbor islands – and efforts might be made to connect these jobless workers to any biofuels manual labor needs, however, and state investments to subsidize these production jobs, while good from a social service perspective, might not be the most effective way to build a sustainable biofuels industry in the state. State incentives should be focused on those investments that will enable the labor market to achieve a critical mass that becomes self-sustaining over time, rather than as a permanent subsidy.

4. A potential biofuels industry for Hawai`i fits within a broader national and state effort to promote green technology and jobs. Thus, legislators should promote a model of workforce development in which biofuels training is connected to a broader effort to promote green technology jobs in the state;

5. Industrial development depends on the availability of a good and reliable workforce. State and county governments should partner with federal agencies, private industry, and technical training schools to develop the labor requirements for industry growth. Legislators should work within these partnerships to create a range of certification and degree programs that identify the skills necessary for biofuels-related work as part of a larger workforce upgrading effort that includes green-technology skills, as well as support for the other growing occupations in the economy.

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1. INTRODUCTION

Many in Hawai`i have recognized that the state has the potential to utilize its natural resources to produce sustainable energy. Uniquely located and highly dependent on both importing food and energy, Hawai`i faces mounting concerns regarding sustainable forms of energy. Fortunately Hawai`i is arguably the state with the best potential for a range of alternative energy solutions. Renewable energy technologies are in many cases entirely ready, and in some cases nearly ready, to answer the environmental, political and economic needs to move away from oil. However, there is still no clear image of the future, and many questions remain.

As an example, The Blue Planet Foundation in 2008 convened a three-day Global Energy Summit in which dozens of industry experts met to advance ways for Hawai`i to achieve its sustainable energy goals. Recent bills passed in Hawai`i during the Twenty-Fifth Legislature, 2009, promoting related initiatives include, HB 1271 under "food and energy security" and HB 1464 under "renewable energy; energy efficiency." As noted in HB 1271: "It has been estimated that Hawaii exported $8,600,000,000 for food and oil in 2008, and every dollar exported is a lost opportunity to support and invest in local business. Our dependence on imports also exposes residents and businesses to volatile food and energy costs as oil prices fluctuate" (2). The opportunities to create a more food and fuel independent state are immense.

In December 2005, the Hawai`i State Legislature appointed a Task Force to oversee the creation of a Sustainability Plan addressing both challenges and opportunities related to sustainability issues. Based on the Office of Sustainability at the University of Hawai`i, the report's working definition of sustainability" is "living in ways that meet our present needs without limiting the potential of future generations to meet their needs" (10). The report identifies challenges such as, "the steady deterioration of public infrastructure, lack of affordable housing, groundwater supplies reaching dangerously low or unsustainable levels, continued reliance on low wage tourism jobs, the vulnerability of Hawai`i in a volatile global energy market, possible interruptions in travel and needed food supplies, threats to our fragile island ecosystems, [and] population growth, particularly on the neighboring islands, increasing at a rapid rate," that must be addressed in order to help secure the healthy future development of the state (Sustainability Task Force 2005). The challenges and opportunities Hawai`i faces in promoting greater clean energy initiatives are immense. Hawaii's heavy reliance on imported energy has steadily increased in recent years. For example, from 2006 to 2007, primary energy consumption was up 2.3%, petroleum use was up 2.9%, and coal consumption was up 4.6%. Additionally, the 48.7 million barrels of oil Hawai`i imported in 2007, costing around $3.6 billion, constituted almost 93% of the State's energy consumption (DBEDT Energy Resources Coordinator's 2008 Annual Report). Statewide incorporation of renewable energy sources should be utilized to help Hawai`i develop ways to feasibly displace 20% of its fuel use by 2020, as noted in the Hawaii Bioenergy Master Plan, thus reducing the State's heavy reliance on imported oil. As noted in HB 1464: "To enable energy efficiency and renewable energy resources to meet forty per cent of Hawaii's energy demand by 2030, the Hawaii clean energy initiative set goals for energy efficiency, renewable and indigenous electricity production, energy delivery and improvements to the electrical grid, and diversification of energy sources for transportation." Hawai`i has various alternative energy options to examine in pursuing its energy independence and reducing the amount of oil imported including biofuels, wind, solar, geothermal, hydroelectric, and ocean including wave-energy and ocean thermal energy conversion (OTEC). In fact, Hawai`i has a range of alternatives that might contribute towards meeting the legislation's targets.

Overall, the State is looking to move away from a dependence on 'low wage tourism jobs' and anticipating that "green jobs" created by a renewable energy industry might provide higher skilled job opportunities along with higher wages. Policy makers and planners considering biofuel alternatives should keep several labor issues in mind. First, the issue of food self-sufficiency may be a competing state concern. There is an inherent tradeoff between biofuels and food self-sufficiency not only on land use, but in the labor market as well. Second, it is difficult to estimate the number of jobs created through bioenergy development, and the possibility of imported labor arises if the jobs are mainly low wage and unskilled. Finally, the state's plantation economy history may be an asset in workforce development for biofuels, but in a broader economic view, cheap labor and surplus of land, areas in which Hawai`i is relatively weak, have historically created advantage in global and national markets.

2. HAWAII'S BIOFUELS POTENTIAL

2.1. BACKGROUND

2.1.1. LABOR MARKET STRUCTURE IN HAWAI`I

Biomass for the production of renewable energy could have an important role in Hawai`i due to the state's rich agricultural history. Although in this sense similar to other states where local economies are or were highly reliant on an agricultural industry, the availability of land, water and labor may contrast starkly between Hawai`i and mainland states. In particular, the structural shift from an agricultural to a service–based economy has transformed labor supply and demand in the state over the past few decades. Initially, as the sugar industry experienced a great deal of growth over the past century, labor shortages became apparent, prompting sugar planters and the Hawai`i government to recruit workers from Japan, Korea, the Philippines, Spain, Portugal, Puerto Rico, England, Germany, and Russia in the period after annexation. These efforts increased the population from 109,020 in 1896 to 232,856 in 1915. Since the 1970s the defense and agriculture sectors have slowed in growth, and the most recent growth in the workforce has been generated by the tourism industry (La Croix 2001).

In recent years, the labor market in Hawai`i has centered on industries related to tourism. Statehood in 1959 brought about the first jet service to Hawai`i and government funded initiatives increased including advertising of Hawai`i as a vacation destination. While the industry grew dramatically from the 1960s through the 1980s, tourism slowed from 1991 to 1994 as higher fuel prices associated with the Gulf War combined with economic downturns in the U.S. and Japan. Nonetheless, tourism has remained the state's dominant industry.

Although the government, along with private industry, supported and encouraged the tourism sector, initially there was not a sufficient workforce. Even today there are labor shortages; the Hawai`i Tourism Authority (HTA) formed a partnership with the University of Hawaii at Manoa to meet visitor industry workforce needs by developing a "Tourism Workforce Development Strategic Plan: 2007-2015" to assist in the needed development and coordination of employment, training and human resources services (HTA Website).

Although workforce development in this industry may not have grown alongside actual industry growth, the need for a skilled workforce became readily apparent as the industry developed. A labor market and related policies in bioenergy-related industries is likely to evolve in a similar way through several incremental stages as the industry grows.

The scale of this shift from agricultural to service industries should not be underestimated. Table 1 provides some insight into the degree to which the Hawai`i labor market has structurally shifted over the past several decades to one in which agriculture currently plays a relatively small role. Throughout the 1990s and up until 2008, dominant nongovernment industries in Hawai`i have been in the “Trade, Transportation and Utilities,” “Leisure and Hospitality,” and “Education and Health Services” categories with the first two categories employing the most people overall, and the last experiencing the most growth. These industries are listed in the table below. Comparatively, the Agriculture Industry experienced a decline in job count with the average job count decreasing from 8,210 in the 1990s to 6,340 during the current decade. However, the average agriculture annual wage in 2007, at $29,567, was comparable to that of the Retail Trade, and Accomodation & Food Services categories.

Table 1: Non-Government Industries Employing the Highest Job Count (1990-2008)*

INDUSTRY	**Average Job Count (1990 – 1999)**	**Average Job Count (2000 – 2008)**	**Growth**	**Average Annual Wage (2007)**
Total Nonagricultural Wage & Salary Jobs	534,670	586,322	9.7%	
Trade, Transportation & Utilities	111,960	114,167	2.0%	
Retail Trade	66,970	67,483	0.8%	$26,779
Leisure & Hospitality	95,890	103,472	8.0%	
Accommodation & Food Services	85,720	92,133	7.5%	$25,693
Education & Health Services	52,860	67,339	27.4%	
Health Care & Social Services	42,970	54,306	26.4%	$41,703
Agriculture	8,210	7,044	-14.2%	$29,567

* Non-government industries listed in this table may not be mutually exclusive as they reflect those areas with the highest job count.

Source: Adapted from State of Hawai’i Employment and Wages of Workers Covered by Hawai’i Employment Security Law for Calender Year 2007 and Hawai’i Workforce Informer http://www.hiwi.org/article.asp?ARTICLEID=515&PAGEID=94&SUBID.

In general, labor market synergy across industries has been shown to create sustainable economic development forces that attract both workers and businesses in related industries. Thus, it is important to consider the kind of labor market synergies that might exist for a nascent biofuels industry in Hawai`I, particularly for the higher-skilled end of the labor market. Currently, the projected fastest growing occupations—defined as having a growth rate of 2.7% or higher—in Hawai`i do not include renewable energy (RE) or energy efficiency (EE) jobs as noted in Table 2 below. Which of these fast-growing occupations, if any, create synergy with a potential bioenergy industry? Based on this list, pharmacy technicians and industrial engineers may have some synergy with higher-skill occupations created by a bioenergy industry. On the other hand, it is unlikely that any of the growth industries will be competing with a biofuels industry for other, lower-skilled workers.

Table 2: Top 10 Fastest-Growing Occupations, State of Hawai`i, 2006-2016

Occupation	Employment 2006	Employment 2016	Average Annual Growth
Personal and home care aides	3,720	5,260	4.2%
Network systems and data communications analysts	1,130	1,600	4.1%
Computer software engineers, applications	570	800	4.0%
Home health aides	1,640	2,250	3.7%
Pharmacy technicians	1,080	1,400	3.0%
Interpreters and translators	190	250	2.8%
Forensic science technicians	70	80	2.8%
Industrial engineers	80	110	2.7%
Computer software engineers, systems software	380	480	2.7%
Skin care specialists	520	660	2.7%

Source: Hawai'i Workforce Informer
www.hiwi.org/admin/uploadedPublications/1876_state-LTOP2006-16-fastgrowing.pdf

Should Hawai`i's bioenergy industry require the growing and harvesting of agricultural crops, particularly plantation grown crops, there may be a significant need for a lower-skilled labor force similar to that required for sugar cane production. For this type of labor, which is characterized by lower wages, there are two possible sources. First, labor might be imported from the U.S. mainland and/or internationally, as has been the case for earlier periods of agricultural growth in the state. Where such labor resources come from is largely a function of the types of work created (e.g. technical, manual, etc.). In addition to imported labor, the other major pool of currently available labor for a possible biofuels industry is the locally unemployed. Beyong these available sources, training and education might be a long term strategy for filling biofuel labor needs.

2.1.2. A LOCAL BIOFUEL INDUSTRY AND JOB CREATION

Much of the debate around labor resources for a bioenergy industry in Hawai`i will center on the industry's ability to generate new jobs as alternatives to the state's dominant service sector jobs, and its ability to alleviate unemployment, especially amongst those groups in which it is most prevalent. The primary question, therefore, is how many jobs the nascent industry is likely to create, for example, from feedstock production to research and development. Based on the biofuel value chain there is potential for job creation in all three skill tiers: low, mid and high. This report discusses the issues associated with the range of skill-levels in the industry, and makes some preliminary estimates on the higher category occupations.

Efforts to develop a biofuels industry should continue to consider community sentiment, and leaders should continue to consider some of the broad alternative scenarios within which the discussion on labor issues must take place. In general, a positive scenario for Hawaii would entail a win-win regarding public cost, lowered waste disposal, prosperity for businesses and farmers, reduced pollution, and sustainability; an alternative scenario might result in forest destruction, net increase in CO2, increased utility costs, overuse of water, strain on landfill, and food shortages. How the bioenergy industry develops, including possible importation vs. local production of feedstock, will impact labor needs. These general concerns must be considered when assessing labor demand, supply and impacts on employment. Additionally, planning for labor resources for the industry must consider that wages should be responsive to near and long-term cycles of inflation and economic expansion.

While there is much discussion on the potential of biofuels for Hawai'i, there is naturally little historical evidence of its impact, to date. However, several bioenergy projects have been announced on the Big Island, Maui and O'ahu, that allow for some analysis based on business projections. Royal Dutch Shell has partnered with HR BioPetroleum to explore biofuel production using algae. Imperium Renewables had proposed to provide biodiesel to Hawaiian Electric's generating plant at Campbell Industrial Park on O'ahu, near Kalaeola Barber's Point Harbor. According to a recent magazine article, "BlueEarth Biofuels, in cooperation with Hawaiian Electric, plans a factory on Maui to convert imported oil crops into biodiesel, and is working with local officials and researchers on developing local oil crops—such as jatropha, a tree that has seeds that can be crushed to make an oil—for biodiesel" (Honolulu Magazine 2008).

Whether or not the plans these facilities are realized, they indicate the importation of feedstock until local production is sufficient to meet production needs**.** If these scenarios are realized, the importation of feedstock will impact an assessment of job growth and labor needs. BlueEarth estimated that 50 jobs would be created during the first phase of operations. Imperium determined that it would create around 50-60 jobs. Together, the two plans would create approximately 100 jobs based on importation of feedstock.

These estimates are helpful in getting a general picture of job market potential. More importantly, the estimates provided by the firms allow us to estimate the job generation potential of biofuels given specified reduction rates in existing imported oil energy sources. While our estimates are very rudimentary, they can provide policy makers with some scale of labor market impact given the existing state policy environment.

Table 3 shows several scenarios associated with the current biofuels and alternative energy legislation using a basic method for estimating job creation (see Appendix A). These estimates include only jobs created through conversion of biofuels and cannot address other parts of the value chain. Other sections in this report suggest some of the parameters for growing feedstock in hawaii, but as of yet there are no estimates on jobs created associated with the range of alternatives currently available, given available land, water, and other inputs. In a business environment in which private sector processors are free to purchase imported or locally-grown feedstock, the production of biofuels may include the production of raw materials as well as processing, or only one of the two. These job estimates inlcude only potential jobs associated with processing because the labor market needs are less variable and more predictable than those associated with growing. The section of this report focused on economic impacts estimates roughly 1,200 jobs associated with biofuels throughout the value chain, which is consistent with our estimates of up to half of this number being provided within the processing stages.

It should also be noted that one of the major projected employers in biofuels processing used to make these estimates recently failed to negotiate an agreement in Hawai'i due to the possibility of it raising electricity rates for customers. This experience indicates the difficulty of making reliable labor market estimates in a sector such as biofuels, where there is little historical evidence in general, and none for the Hawai'i labor market. The following estimates should be seen as best-case scenarios for biofuels processing in Hawai'i, especially given this lack of reliable historical experience.

Table 3: Possible Biofuels Jobs Created

Year	Imported Oil (in barrels)	Oil Reduction (in barrels)	Biofuel Production Increase	Possible Biofuels Jobs Created
2007	48,700,000			
2010	43,830,000	4,870,000	204,540,000	146.1
2015	41,395,000	7,305,000	306,810,000	219.15
2020	36,525,000	12,175,000	511,350,000	365.25
2030	29,220,000	19,480,000	818,160,000	584.4

According to these estimates, reducing imported oil by 10% (or 4.87 million barrels) by 2010 would add roughly 146 additional jobs to the state economy. Reducing oil by 15% (or 7.31 million barrels) by 2015 would add 219 jobs, by 25% (or 12.175 million barrels) by 2020 would add 365 jobs, and by 40% (or 19.48 million barrels) by 2030 would add about 584 jobs. Thus, if biofuels were the only alternative energy source substituting for current imported oil sources, by 2030 the industry would employ approximately the same workforce as the skin care industry (660 workers in 2016) or the computer software systems engineers/system software (480 workers in 2016). Alternatively, if the biofuels industry substitutes only 10% of imported oil, the size of the workforce would only be slightly larger than the number of industrial engineers (110 workers in 2016).

As importantly, the sustainability of these jobs created through biofuels development depends on their ability to provide realistic livelihoods in the state of Hawai`i.

2.2. GREEN INDUSTRY FORMATION

This report provides an overview of the labor market and job growth implications of a potential bioenergy industry in Hawai`i. Regardless of outcomes, it is evident that many stakeholders will be affected and should be involved in the various processes surrounding bioenergy industry formation. As plans proceed to implement various measures and facilities supporting a bioenergy industry—from policies to business incentives—the need for a comprehensive and strategic outlook on how these factors contribute to labor and population issues is vital, especially with respect to cost-of-living issues for workers and other residents of the state.

To date, some national partnerships and statewide initiatives have already begun. Hawai`i and the U.S. Department of Energy (DOE) have partnered to establish the Hawaii-DOE Clean Energy Initiative, with a Memorandum of Understanding signed by Governor Lingle in

January 2008 specifying six major initiatives. Workforce development is not only specifically identified but is also supported by the other foundational initiatives having to do with Hawai`i as a clean energy-based economic model for the world. The initiatives are as follows:

1. Achieve a 60-70% or greater clean energy basis for Hawaii within a generation;
2. Serve as an "open source" learning opportunity: make Hawaii a replicable model for achievement of a clean energy-based economy of the world
3. Increase the energy security of Hawaii;
4. Create economic opportunity at all levels of society: develop and diversify Hawaii's economy through innovative, market-based mechanisms that allow every sector to benefit from the transition to clean energy;
5. Foster and demonstrate innovation: in the technology, financial and organizational and policy models used to achieve a clean energy future;
6. Build the workforce of the future: help Hawaii build educational and employment opportunities necessary to sustain a clean energy economy.[1]

A burgeoning renewable energy industry can expand the job base while simultaneously contributing to greater energy independence and environmental quality. With a multifaceted industry such as a biofuels industry, it is important to consider the differing aspects of related labor resources and development. For example, the government and public are generally concerned with employment and a living wage, tax base contributions, and environmental issues. The private sector is concerned with labor skills and availability, as are training institutions such as universities. Finally, labor unions are primarily concerned with how jobs in a nascent biofuels industry affect union membership regarding wages and benefits.

As concerns over the mounting economic recession in the U.S. and abroad proliferate, potential employment opportunities in industries that are beneficial to the nation's long-term sustainability goals have been positioned as a top priority on the policy agenda. As a result, federal and state governments are establishing "green" initiatives to boost the economy while creating greater energy independence and reducing greenhouse gas emissions (GHG). On Earth Day 2009, President Obama's administration once again touted "green jobs" as part of a plan to resuscitate the economy with supporting legislative measures aimed at creating jobs in energy and the environment, stimulating labor demand in a wide range of skill categories. (Workforce Management 2009).

A leading industry publication recently stated that "manufacturers should align their business strategies with state/federal investments, and train workers in the latest energy skills… The law will boost energy cost savings and long term job growth through significant spending on energy efficiency (EE) and renewable energy (RE) development. Key appropriations include $5 billion for weatherization projects, $4 billion to retrofit public housing, $2.5 billion for energy efficiency research and $500 million for green job training. In the short run—the next five years or so—the greatest job growth will be in jobs which contribute to reducing energy consumption" (Industry Week 2009). The Obama administration has mentioned that the stimulus package could "create or save 3.5 million jobs over the next two years, and a sizable

[1] Presentation on the Hawaii-DOE Clean Energy Initiative: Strategic Vision and Implementation, March, 2008. Last accessed at <http://hawaii.gov/dbedt/info/energy/hcei/> on August 19, 2009.

chunk of these jobs are now expected to be so-called “green-collar jobs” (Business Green 2009

National labor trends, data and related issues can help shed light on how the “green job” market is unfolding, allowing for a better assessment of what types of skills and job opportunities may be needed. It should be noted that existing skills may transfer over to “green jobs” yet there is still a need for specialization and expertise. Secondly, the industry provides an opportunity to fill a national shortage of jobs with opportunities in a wide range of skill sets. If there is a demand, workforce development done the right way can provide a supply of well-trained individuals for these jobs. Finally, the renewable energy industry may provide workers with greater job security since these jobs could be difficult to outsource. The bottom line is that it will be important for industry, government, labor and educational institutions to take initiative and develop programs to meet the full range of skills needed for “green” industries including bioenergy. Skills training for “green jobs” should not hinder immediate job growth if many different jobs can also capitalize on existing skill sets (Los Angeles Times 2008).

These general principles of how a set of “green” jobs are likely to evolve in the U.S. are important considerations in analyzing the potential for biofuels to maximize any comparative advantages inherent to Hawai`i, and contribute significantly to the state’s labor market.

3. LABOR AND BIOFUELS DEVELOPMENT IN HAWAI’I

3.1 UNEMPLOYMENT AND THE DISTRIBUTION OF WORK IN HAWAI`I

One of the central areas of labor concern is the degree to which a biofuels industry is able to address unemployment issues in the state, a key concern of state lawmakers. Hawai`i has a diverse population, and ethnic niches have, like elsewhere, tended to develop around certain occupations. Studies of low-wage labor markets often suggest that employment niches grow particularly when there are social components of the workforce that share information, skills, and interests. Thus, gender, race/ethnicity, and age have historically been components of labor market analyses and this assessment of unemployment serves simultaneously as an overview of the distribution of the labor market and as an indicator of likely employees to fill lower wage jobs. As seen in Table 4 below, the 2007 unemployment rate is highest among American Indians and Alaska Native Persons, Native Hawaiians and Other Pacific Islanders, and Persons of Hispanic or Latino Origin, comprising a total of 17.6% of the general population. However, from a raw number count, Asians and Whites are disproportionally higher in population and have a higher total number of unemployed.

As a further consideration, if 48.4% of the civilian labor force was female in 2007 and only 16.1% of ‘laborers and helpers’ were female, agricultural farming jobs may be deficient in alleviating unemployment for the female segment of the workforce. It will be important to draw further distinctions among population segments, including gender, especially if a good portion of the agricultural and manufacturing aspects of bioenergy-related jobs will employ mainly males.

Table 4: 2007 Population Estimates and Unemployment for the State of Hawai'i by Race Based on Total Population Estimate of 1,283,388.

	Percent of Total Population	Number of Unemployed	Unemployment Rate
Persons under 18 years old	22.3%		
Persons 65 years old and over	14.3%		
Female persons	49.7%	7,450	2.4%
White persons	29.1%	4,100	2.4%
Black persons	2.9%	300	4%
American Indian and Alaska Native persons	0.5%	100	6.2%
Asian persons	39.9%	5,100	1.8%
Native Hawaiian and Other Pacific Islander	8.9%	2,800	5.2%
Persons reporting two or more races	18.6%	4,500	3.7%
Persons of Hispanic or Latino origin	8.2%	1,750	4.5%
White persons not Hispanic	24.7%		

Source: U.S. Census Bureau. http://quickfacts.census.gov/qfd/states/15000.html. Unemployment breakdown by race from Labor Force Estimates from 2007 Annual Local Area Unemployment Statistics (LAUS), based on 2000 Census.

A further breakdown of race and sex taken from the 2000 Census Bureau for the State of Hawai`i is included below in Table 5. Whites and Asians dominate all job categories as percent most employed (and unemployed). While this is partly understandable due to sheer population size since Asians and then Whites consist of the poplulation majority, Table 5 also implies that Native Hawaiian and Pacific Islanders may be disproportionately represented in lower-skilled jobs. This group makes up a significantly smaller proportion of the labor force in professional occupation (6.2% compared to 10.5% of the total workforce), managment and officials (7.8% compared to 10.5%), and technicians (7.7% compared to 10.5%). These lower figures for Native Hawaiians and other Pacific Islanders are mirrored in disproportionate White and Asian figures, which show slightly elevated percentages that represent relatively large numbers of workers.

Table 5: Percent Distribution of the Civilian Labor Force by EEO-1Job Categories, Sex and Race

State of Hawai`i, 2000 (Horizontal Percent Distribution)

JOB CATEGORIES	TOTAL	White	Black	AIAN	Asian	NHOPI	Balance 2+ Races	Hispanic	Total Minority (All Non-White)	Total Females
Total Civilian Labor Force	573,754	24.2%	1.2%	0.7%	46.9%	10.5%	10.3%	6.1%	75.8%	48.3%
Officials and Managers	61,694	34.2%	1.2%	0.8%	44.3%	7.8%	7.8%	4.0%	65.8%	40.8%
Professionals	101,350	36.2%	1.5%	0.9%	45.1%	6.2%	6.4%	3.8%	63.8%	54.9%
Technicians	11,493	24.5%	1.4%	0.7%	51.8%	7.7%	8.0%	5.9%	75.5%	47.8%
Sales Workers	70,025	23.7%	0.9%	0.6%	49.8%	8.9%	10.0%	6.2%	76.3%	59.8%
Administrative Support Workers	95,800	18.5%	1.4%	0.7%	50.1%	11.1%	12.0%	6.3%	81.5%	75.2%
Craft Workers	50,171	23.2%	0.9%	0.8%	43.7%	12.0%	13.1%	6.3%	76.8%	5.5%
Operatives	35,279	15.4%	1.4%	0.5%	46.4%	15.8%	13.4%	7.1%	84.6%	24.6%
Laborers and Helpers	29,837	17.9%	1.2%	0.5%	41.7%	16.8%	13.7%	8.2%	82.1%	16.1%
Service Workers	111,069	18.5%	1.2%	0.7%	48.8%	12.0%	11.0%	7.7%	81.5%	51.2%
Unemployed, No Civilian Work Experience	7,036	15.8%	1.6%	0.4%	33.7%	22.1%	15.3%	11.2%	84.2%	51.4%

Source: U.S. Bureau of the Census, 2000 Special EEO Tabulation, Data as of 4/28/04
http://www.census.gov/eeo2000/index.html
Note: Totals may not add due to rounding
NHOPI: Native Hawaiian or Other Pacific Islander
AIAN: American Indian or Alaska Native

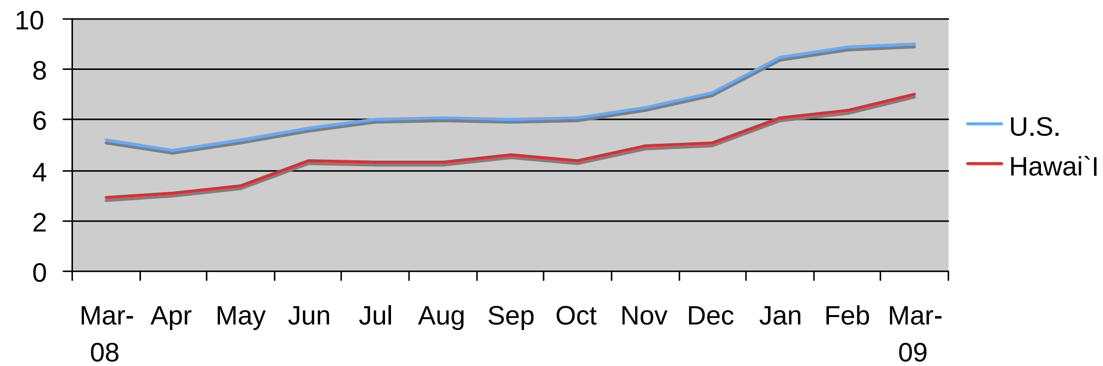
Table 6 displays state unemployment trends from October 2008 to March 2009 and the accompanying graph shows state unemployment from March 2008 to March 2009 in comparison to the national average. As unemployment rates rise, it can be assumed that there is a more available labor force however depending on the nature of the work and the qualifications of the workforce, it cannot be easily assumed that one job opening is equal to one job filled by an unemployed individual. Rather, skills must be ”matched” to job openings, and further examination of the skills and experience of Hawai`i's unemployed (as well as jobless that would be looking for work in a biofuels industry) is an important future informational need. A further breakdown of the demographics of unemployment trends by industry will be important to examine in order to better understand the current and future available labor force. Additionally, it will be valuable to explore who is employed (e.g., by race, age, gender, and skill set) by which industries.

Table 6: **Unemployment in the State of Hawai`i**

Labor Force Data	October 2008	November 2008	December 2008	January 2009	February 2009	March 2009
Unemployment (000s, seasonally adjusted)	29.9	31.9	33.4	39.8	42.4	45.5
Unemployment Rate (%; seasonally adjusted)	4.6	4.9	5.1	6.1	6.5	7.1

Source: U.S. Bureau of Labor Statistics, April 19, 2009. Available at: http://www.bls.gov/eag/eag.hi.htm#eag_hi.f.2

Figure 1: Percentage of Unemployment in the State of Hawai`i as Compared to the National Average (March 2008-March 2009)



Source: Adapted from the U.S. Bureau of Labor Statistics, April 19, 2009. Available at: http://www.bls.gov/eag/eag.hi.htm#eag_hi.f.2

One of the unique characteristics of the state of Hawai`i is its geography whereby the ocean separates the islands. These ocean barriers mean that the state is actually several local labor markets that interact with each other based on the costs of transportation between islands rather than one single local market. Thus Table 7 lists recent unemployment figures by island. In general, Oahu has relatively low unemployment, whereas the neighbor islands have rates between 50 and 100% higher than Oahu. This pattern is evident during growth and decline periods. If biofuel production will utilize land to a greater extent on neighboring islands and since unemployment is higher in Hawai`i County and Maui County, there may be increased opportunity for an available, underutilized labor force in the bioenergy production value chain. As noted in Table 6, in March 2009, the unemployment rate in Hawai`i hit 7.1 percent due to the continued economic recession and subsequent effects on the tourism industry, although the rate was under the national unemployment rate of 8.5%. Neighbor island unemployment rates were significantly higher, especially on Kaua'i, Hawai`i, and Moloka'i. These differences suggest that the labor force for a biofuels industry, especially for crop production, is likely to be more easily filled through local labor on these islands in comparison with O'ahu.

Table 7: Unemployment Rate (%) by Island (Not Seasonally Adjusted)

	March 2009	February 2009	March 2008
State	7	6.4	2.9
O'ahu	5.8	5.4	2.6
Hawai`i County	10.1	9.1	4
Kaua'i	10.3	9.2	3.1
Maui County	9.0	7.9	3.3
Maui Island	8.9	7.7	3.2
Moloka'i	12.4	13	5.4
Lanai	8.7	7.7	4.7
U.S.	9	8.9	5.2

Sources: U.S. Bureau of Labor Statistics, April 19, 2007. Available at:
http://www.bls.gov/eag/eag.hi.htm#eag_hi.f.2
Hawaii Department of Labor and Industrial Relations, Hawaii Workforce Informer. Available at: www.hiwi.org

3.2 WAGES AND THE CONSUMER PRICE INDEX

Table 8 examines possible categories of jobs, mainly tied to agriculture, most relevant to the biofuels industry. Jobs listed are estimates for 2017 and are for the City and County of Honolulu. The table also notes wage information to better determine which jobs will be higher or lower wage and skill level. Dollar amounts listed range from around $9 to $35. Thus, the range of occupations likely to be associated with biofuels ranges in payscale from roughly $31,200 to $72,800 depending on occupational qualifications.

Table 8: Possible Categories of Agricultural Jobs Related to Bioenergy

(Job count and median Earnings Per Worker EPW for the City and County of Honolulu)

Potential Biofuels-Related Jobs: Agricultural	**Estimated Jobs by 2017**	**Training Required**	**Median EPW**
Agricultural Equipment Operators	63	Moderate-term on-the-job training	$8.91
Agricultural Graders and Sorters	191	Work experience in a related field	$9.31
Agricultural Inspectors	75	Work experience in a related field	$21.48
Agricultural Workers (all others	26	Short-term on-the-job training	$8.91
Construction Laborers	3,031	Moderate-term on-the-job training	$21.03
ENGINEERS			
Agricultural	53	Bachelor's degree	$24.93
Chemical	81	Bachelor's degree	$36.80
Environmental	311	Bachelor's degree	$33.30
Mechanical	410	Bachelor's degree	$34.89
Farm Product Purchasers	1,247	Work experience in a related field	$24.43
Farm, Ranch and Other Agricultural Managers	164	Degree plus work experience	$18.63
Farmers and Ranchers	367	Long-term on-the-job training	$12.70
Industrial Truck & Traffic Operators	1,292	Short-term on-the-job training	$13.90
SCIENTISTS			
Chemists	159	Bachelor's degree	$23.15
Environmental	555	Master's degree	$24.68
TECHNICIANS			
Agricultural & Food Science	133	Associate's Degree	$15.47
Environmental Engineering	65	Associate's Degree	$18.77
Environmental Science & Protection	140	Associate's Degree	$16.93
Industrial Engineering	206	Associate's Degree	$33.10

*Source: Adapted from PERI & CAP (Greener Pathways, EPA's Clean Energy Environment Tech Forum, 2/24/09), the EPA report and Occupation Data by SOC Level 5 for Honolulu by Economic Modeling Specialists, Inc. – 5/07.

Wages ranging between these two figures in Hawai`i have historically had to support families and individuals living in one of the highest-cost regions of the U.S. Thus, whether biofuels jobs are competitive depends on how wages associated with these jobs compares to the trends in the consumer price index, the conventional estimate of the cost-of-living.

In general, in 2008 prices were up 4.8% in the state of Hawai'i—the second highest in the nation—due to inflation as compared to 2.8% nationally. In particular, housing and grocery cost increases drove the high rate of inflation in Honolulu (Honolulu Advertiser 2008). Increased fuel costs due to food production and transportation were likely linked to the increase in food prices. In any case, the high and rising cost of living in Hawai`i strongly suggests that the lower end of the biofuels jobs spectrum may not be attractive if other employment opportunities are available that pay above the minimum wage.

3.3 BIOENERGY INDUSTRY WORKFORCE CONSIDERATIONS

The workforce for a biofuels industry is not likely to depend on a unique skill set applicable only to the production of bioenergy. Even under the more optimistic assumptions of job creation described above, the number of workers in the industry will be relatively small. Thus, any investments in training and education must be part of a larger workforce development effort partnering several industries—including biofuels—with state and local governments to support the growth of new jobs. In addition to agriculture, the most likely set of related industries for the biofuels workforce programs is predominantly in the renewable energy (RE) industry, although skill sets may transfer and overlap between already existing industries.

The basic challenge is to integrate green jobs initiatives—including biofuels work—into existing workforce systems. Many believe that workforce development initiatives will be ineffective unless participants see opportunity in the addition of "green" skills to existing occupations (Dressler 2009). For biofuels, then, the challenge is in adding a new set of skills to the middle-level workforce in energy production rather than agricultural work which will likely remain dependent on the same skill set as has historically been the case.

Targeting this part of the biofuels workforce makes additional sense because it would be focused on college-educated professional workers with advanced degrees and skilled technical workers (EPA 2009). Because of the limited number of jobs in the biofuels industry for Hawai`i – estimated at roughly 500 processing jobs in this chapter and 1,200 jobs throughout the value chain in the economic impact chapter, other related jobs that could be included in a broader workforce development initiative might include buying and selling energy of related products, building energy assessment, EE building construction, building operations and maintenance, project engineering and implementation, energy transmission and distribution, and/or transportation systems and services.

The logical partners in developing the "green" skills in existing workforces are community colleges, vocational/technical high schools, community-based organizations, labor unions, trade associations, and four-year colleges and universities (EPA 2009). Training and education would include institutions in areas such as research (degree programs at universities in business, engineering, sciences, etc.), business applications and public policy, community colleges (2 year business and technical degree programs), trade schools that offer certificates and government agencies (DOL).

A state role in bridging the gap between training programs and industry needs can contribute to overall success and pinpoint different funding sources that specifically finance sustainable energy worker training programs. Legislation promoting green jobs can help bolster industry success. The state can also explore opportunities to partner with established training facilities in order to better integrate the workforce, including creating programs for low-income workers. For example, green-collar job training funds can be used to target low-income adults and youth in poverty (EPA 2009).

3.4 POLICY CONSIDERATIONS

Effective policies will be important in supporting a comprehensive sustainable energy framework with input from all stakeholders, including labor as a key aspect. For example, "The Green Jobs Act of 2007 would authorize as much as $125 million a year for national and state programs to train workers in areas such as biofuel development, energy efficient buildings, renewable power, solar panel installation and energy efficient cars" (GreenBiz 2007). As a workforce develops, long-term investment should be a major consideration so policies can encourage industry growth and thus support a skilled workforce. Additionally, the EPA report laid out that to develop an effective clean energy workforce, clean energy policies need to support a market for businesses and therefore jobs, "current and future projections of business and labor market status in the target market(s) are needed to identify gaps and partnerships across workforce development entities are critical to the development of successful and sustainable tactics and approaches for closing gaps."

It is essential for RE and EE policies to support industry growth and subsequent job opportunities if the industry is to succeed as a whole. "The challenge for U.S. policy makers is to sort through all the confusion about 'green jobs' and make investments that really pay off for the economy… One thing is clear: the vast majority of green jobs will not require completely new skills. Rather, million of workers in manufacturing, construction, and facilities management will need to add a layer of 'green' skills requirements to their traditional education and training. Green job skills will cut across many industry sectors, and affect workers at all levels – from clerks and truck drivers to engineers and scientists" (Industry Week 2009). "Current and future projections of business and labor market status in target markets are needed to identify gaps. Partnerships across workforce development entities are critical to the development of successful and sustainable tactics and approaches for closing the gaps" (EPA 2009). Additional support could come from state-level regulations such as tax incentives that encourage a green workforce. Utilizing and maximizing existing state resources may be more efficacious in workforce and industry creation. Finally, a chief concern will be how to better measure and track wage and labor count based on agreed upon definitions and standardized metrics, in relation to a growing sustainable energy industry so success or failure in certain areas can be better assessed and analyzed.

3.5 UNRESOLVED QUESTIONS

The creation of a biofuels industry in Hawaii presents an interesting possibility to match some of the natural resource assets in the state with the increasing demand for greater energy independence as a geographically isolated island society. Before such an industry can move forward, legislators and others must engage with several important, yet unresolved questions about the labor market and biofuels. These unresolved questions address issues that fall outside the scope of an analysis of the labor market issues associated with developing a biofuels industry, but importantly affect how one should interpret the analysis and recommendations associated with labor in biofuels development in Hawaii.

Potentially competing state agendas:

Part of the state's interest in a biofuels industry is in its potential for reducing reliance on "imported" oil from outside the islands. While growing energy in the Hawaiian islands may replace some of the energy currently refined from oil, the strategy depends on a set of resources that are currently important for a related state objective on reducing "imported" food from outside the islands. The biofuels strategy depends on precisely the same key resources upon which any plan to reduce food imports depend: land, labor, and water. At first glance, every acre used for biofuels is an acre not used for food production, unless some kind of shared use of land can grow both fuel for energy and food for consumption. The same issue arises with labor resources and water resources, the other two major inputs into agriculture. In part the balance of each of these resources directed to either objective depends on whether reducing energy dependence or reducing food dependence is more important. In part, it depends on which process is more effective at reducing the risk of physical isolation in comparison to non-local and local alternatives for reducing imports (e.g. solar, wind, wave, etc for energy; hydroponics and others for food).

Liveable wages or social support?

Any agriculture labor market in Hawaii is a segmented one, with a clear low-skilled one, and a higher-tech one. The attractiveness of biofuels development for Hawaii is that it presents the possibility of creating affordable, locally-grown energy while at the same time providing additional jobs to local workers. These two aspects of a biofuels industry may not necessarily complement one another: a sustainable biofuels energy alternative may not create jobs, and if it does create jobs, then the energy itself may be relatively expensive to consumers. This balance ultimately is a question of benefits to consumers and benefits to producers. Energy costs, like most production, are based on comparative advantage of inputs, and Hawaii does not have a global or national relative advantage in the costs of labor. Thus, if a biofuels industry develops with a large share of lower-skilled jobs, it will either have to keep manual labor wages high, and then push the costs of production on to the consumer, or it will have to find cheaper labor to fill the manual parts of the production process. Keeping manual labor high and increasing the cost of energy effectively turns the job creation aspects of the biofuels industry into a wage subsidy to low-skilled workers, or a social support program. This strategy may be an important aspect of developing the industry, but it would need to make clear to the consumer the importance of using higher-pay manual labor locally to produce energy. The alternative would be to either outsource the growing and harvesting processes to lower-cost production sites where labor and land are cheaper than the cost of transportation of raw materials (crops) to Hawaii, or to import low-skilled manual labor, which is an unlikely alternative. This tradeoff between consumer affordability and local manual labor job creation has the policy implication that support for the higher-end skills able to provide comparatively good and liveable wages should be prioritized.

4. STRATEGIC PARTNERS

Leveraging intra- and inter-industry partnerships will be important in developing a clean energy workforce. Identifying and addressing stakeholders and their needs are vital to successful industry formation. Major stakeholders include government, the public, private industry, educational institutions, and environmental groups. In developing a clean energy economy, coalitions must be built across different sectors and agencies. "Clean energy workforce development requires partnerships between policymakers, business, and labor—but also across state and local agencies and departments, along with educators" (EPA 2009). Partners may include the "Department of Labor, workforce investment boards, industry associations, chambers of commerce, local unions, green jobs-related NGOs (Green for All, Apollo Alliance), public housing authorities, prison systems, community-based organizations…local workforce investment boards, and local one-stop career centers where numerous programs may already be in place that could incorporate a "green jobs" component or approach" (EPA 2009).

On a national scale, Hawai`i and the United States Department of Energy have formed a long-term partnership in order to promote "the use and development of energy efficiency and renewable energy technologies; allowing Hawai`i to serve as a model and demonstration for the United States and other island communities." This "system transformation" may lead to higher wages and skilled jobs through R&D opportunities. a larger tax base, economic development, and workforce development. Universities and other relevant educational institutions should be able to capitalize on "green" career development.

Various inter-industry partnerships will have to form in order to support a growing infrastructure surrounding clean energy initiatives and the subsequent labor needed. HB 1464, passed during the 2009 Legislative Session, seeks to align the state's energy policy laws with the state's energy goals, which may provide many partnership opportunities between the government (e.g., policy makers and institutional planners concerned with infrastructure and capital investment), industry, and education (e.g., need for technological development and implementation). As an example of the variety of stakeholders involved, the Hawaii – DOE Energy Initiative identified the following "anticipated partners and participants":

Table 9: Anticipated Partners and Participants

Public Sector Representatives	Industry, NGO, and Other Representatives
1. Governor Lingle	1. Hawaiian Electric Industries, HECO, MECO, HELCO
2. Partial US Congressional Delegation and staff	2. Kauai Island Utility Cooperative
3. Partial Hawaii Legislature and staff	3. Hawaii Energy Policy Forum representatives
4. County Mayors	4. County Economic Development Boards
5. Selected County Council members	5. Environmental organizations
6. Department of Business, Economic Development and Tourism and Hawaii energy leadership	6. Native Hawaiian community members
7. DOE EERE and OE representatives	7. Kohala Center
8. Hawaii DOD Commanders	8. Hawaii Natural Energy Institute Representatives
9. USDA Hawaii State Director	9. University and community college representatives
10. Public Utilities Commission representatives	10. Private industry, e.g. General Electric, UPC Wind, Castle and Cook, Hawaiian Commercial & Sugar, Gay & Robinson, Pacific Biodiesel
11. Consumer Advocate	11. Others

5. CONCLUSIONS AND RECOMMENDATIONS

A review of labor and job creation issues associated with any potential biofuels industry in Hawai`i suggests that policy makers and others should take a nuanced approach towards supporting a biofuels industry. Hawai`i is not likely to become a global producer of biofuel energy, given the small landmass and generally high costs of production, nor is biofuels likely to develop a labor market similar to the tourism industry. Nevertheless, the development of a biofuels industry might contribute towards a broader Research and Development job creation agenda, as well as a small number of manual jobs in some aspects of facility operations. With production of local agricultural feedstocks, however, the number of jobs created may be significant. These benefits must be balanced by biofuel production impacts on the consumer price index through potential increases in food prices. This report suggests five areas in which legislators and other public decision makers might consider approaches to support the industry's development:

1. Given the likely small size of any biofuels workforce in Hawai`i, other than agricultural workers, it is important for legislators to create synergies with other growing sectors of the economy. In particular, those fast-growing occupations listed in Table 2 related to the higher end of biofuels skills, such as industrial engineers, pharmacy technicians, and computer software engineers, might share a workforce with biofuels professionals. On the lower-skilled end of occupations, manual laborers in the biofuels industry will likely share some concerns with other agricultural workers such as pay scales and working conditions;

2. The biofuels industry in Hawai`i, as it evolves, will create some jobs for local residents as well as attract some new workers. To create a responsive and loyal employment base in the industry, legislators and business leaders might consider nurturing community—and regionally—specific worker bases to mobilize as much of the local unemployment base as possible. Table 7 showed that the pool of potential workers is likely to be particularly high on the neighbour islands, and Table 4 displayed that unemployment by ethnic groups. Creating institutions to educate about the potential benefits of work within the biofuels industry might best target potential workers. Such outreach is likely to create industry loyalty and identity since the size of the biofuels workforce is not likely to be large. This will increase labor channelling and networks that are easier to carve out as a stable employee base with less training;

3. Liveable wages are a problem for many workers in Hawai`i. Table 8 lists a range of occupations related to the skills necessary for a biofuels industry. It classifies those occupations in high- and low-wage categories, with the former likely to support a liveable wage for Hawai`i, and the latter not likely to support a liveable wage. Labor market subsidies to private sector firms, for example, might focus on those higher-end occupations and leave the lower-wage occupations to be performed by workers outside of the state of Hawai`i, where they are likely to be more liveable wages. In this way, policy should focus on attracting those parts of the industry where wages are above manual labor level. There is some unemployment in Hawai'i – especially on the neighbor islands – and efforts might be made to connect these jobless workers to any biofuels manual labor needs, however, and state investments to subsidize these production jobs, while good from a social service perspective, might not be the most effective way to build a sustainable biofuels industry in the state. State incentives should be focused on those investments that will enable the labor market to achieve a critical mass that becomes self-sustaining over time, rather than as a permanent subsidy.

4. A potential biofuels industry for Hawai`i fits within a broader national and state effort to promote green technology and jobs. Thus, legislators should promote a model of workforce development in which biofuels training is connected to a broader effort to promote green technology jobs in the state;

5. Industrial development depends on the availability of a good and reliable workforce. State and county governments should partner with federal agencies, private industry, and technical training schools to develop the labor requirements for industry growth. Legislators should work within these partnerships to create a range of certification and degree programs that identify the skills necessary for biofuels-related work as part of a larger workforce upgrading effort that includes green-technology skills, as well as support for the other growing occupations in the economy.

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Hawaii Bioenergy Master Plan

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Executive Summary

A bioenergy technology assessment was conducted as part of the Hawaii Bioenergy Master Plan mandated by Act 253. This effort included the characterization of the status of crops and crop production technologies for bioenergy applications and of conversion technologies used to transform selected feedstocks into bioenergy products.

Crop characterizations included sugarcane (*Saccarum officinarum*), starch producers corn (*Zea mays)* and cassava (*Manihot esculenta*), fiber producers banagrass (*Pennisetum purpureum*), *Eucalyptus sp.*, and *Leucaena (Leucaena leucocephala*), and oil producers *Jatropha* (*Jatropha curcas*), oil palm (*Elaeis guineensis*), microalgae and biowastes. Of these, only sugarcane has an established history of commercial production in Hawaii. Although the state currently has several extensive *Eucalyptus* plantations, they have not been harvested to date. Harvesting was a common technology gap identified for terrestrial crops. Technology gaps associated with microalgae were found to be more extensive.

A summary of the assessment of conversion technologies is presented in Table E.1. The development status of each technology has been characterized as pilot, demonstration, or commercial facilities that might be constructed at scales on the order of <10, 100, and 1000 tons per day. All of the technologies identified in the table were deemed appropriate for Hawaii.

A number of recommendations have been developed based on stakeholder input and information collected in preparing this task and include:

1. The State should continue a bioenergy technology assessment activity that can provide updated information on the status of bioenergy conversion pathways and estimates of energy return on investment (EROI) for bioenergy value chain components.

2. Mechanized harvesting is a common theme across bioenergy crops. The State should fund a faculty position(s) in this area to work with the industry, conduct research as needed, and evaluate harvesting technologies for applications in Hawaii.

3. Support demonstration project development along the bioenergy value chain including energy crop production, transportation and logistics, and processing and conversion technologies. The State should develop funding mechanisms to leverage federal and private funds and support demonstration projects.

4. The State should provide support to the industry for preliminary feasibility studies of selected energy crop conversion alternatives to identify the most promising technology pathways and the resource requirements for those pathways.

5. The State should provide low-or-no cost land leases and expedited permitting to support pre-commercial bioenergy demonstration projects.

6. Hawaii should establish a bioenergy/biofuel development fund to support research, and technology development and demonstration where the University of Hawaii, other

research organizations, and Hawaii-based industries should be encouraged to jointly participate.

7. Funds should be allocated to support training manpower in the field of bioenergy/biofuel technology.

Table E.1. Characterization of the development status of biomass conversion technologies

	Pilot	Demonstration	Commercial	Appropriate for HI?
Ethanol from Biochemical Route				
Sugar			X	Y
Starch			X	Y
Fiber[1]	X	X		Y
Gasification				
Heat			X	Y
Power	X	X		Y
Combined Cycle	X	X		Y
IC Engine	X	X		Y
Steam based			X	Y
Synfuels	X	X		Y
Pyrolysis[2]				
Bio-oil production			X	Y
Charcoal production		X	X	Y
Bio-oil production for fuels	X	X		Y
Combustion			X	Y
Renewable diesel via transesterification of vegetable oil			X	Y
Renewable diesel via hydrotreating of vegetable oil	X	X		Y
Anaerobic Digestion				
Heat			X	Y
Power			X	Y
Biogas production via cracking of fats, oil, and grease	X			

[1] Demonstration projects for cellulosic ethanol production currently underway
[2] Pyrolysis for bio-oil production as food ingredient is at commercial scale but use of bio-oil for energy other than combustion applications remains at pilot scale

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1. Introduction

This section addresses technology issues related to bioenergy development in Hawaii in the framework of crops and conversion technologies presented in Figure 1. The bioenergy potential of urban residue streams (municipal solid waste, municipal waste water, solid waste in place in land fills) and residues from current agricultural activities is available from past analysis (Turn, et al., 2002) and from other projects currently funded by the Department of Business, Economic Development & Tourism. This technology section treats the lesser explored bioenergy production systems presented in Figure 1.

The plants listed on the left hand side of the figure are not all inclusive but represent a selection of the broad spectrum that are being considered as potential bioenergy species. These plants were selected based on their capacity to generate the intermediate products depicted in the figure; sugar, starch, fiber, and oil. Sugarcane (*Saccarum officinarum*) and sweet sorghum (*Sorghum vulgare*) can produce both sugar and fiber. Corn (*Zea mays)* and cassava (*Manihot esculenta*) are starch and fiber producers. Both grass and tree species are considered for their fiber production; guinea grass (*Panicum maximum*), banagrass (*Pennisetum purpureum*), *Eucalyptus sp.*, and *Leucaena (Leucaena leucocephala*). Oil bearing species include the widest variety, including *Jatropha* (*Jatropha curcas*), kukui (*Aleurites moluccana*), microalgae (eg. *Chlorella sp.*) and diatoms, soybean (*Glycine max*), peanut (*Arachis hypogaea*), sunflower (*Helianthus annuus*), and oil palm (*Elaeis guineensis*). Discussion on anaerobic digestion of biowastes for methane gas production is also included in this report.

As shown in Figure 1, the intermediate products are transformed into bioenergy products using conversion technologies. Starch is hydrolyzed into sugars which can then be fermented to produce ethanol or butanol. The hydrolysis step is not required for sugar bearing crops. Fiber can also be used to produce ethanol or butanol by hydrolyzing its cellulose and hemicellulose portions to simple sugars that can be fermented. Fiber can also be converted into a number of bioenergy products including electricity, heat, synthetic diesel, charcoal, etc. The primary conversion technologies required to realize these transformations include gasification, pyrolysis, and combustion. Finally oils from oil seed, tree nuts, or algae can be directly combusted to produce heat and power or converted to biodiesel for use as a transportation fuel or in stationary power applications.

Figure 1 illustrates that multiple pathways exist between plant/crop options on the left of the diagram and bioenergy products on the right. A number of technology components may be required for any given pathway. Agricultural producers in Hawaii have grown a variety of crops and the basic cultural practices of land preparation, seed production, planting, fertilization, and weed control are well understood and are not viewed as primary technology challenges. Crop harvesting and the transportation of the material from field to conversion facility are two remaining unit operations. Many of the crops proposed for bioenergy development have not previously been grown commercially in the State and cost effective harvesting techniques will be important. For sugarcane, harvesting accounts for ~30% of total production costs, thus harvesting costs play a large role in determining economic viability. Due to Hawaii’s higher agricultural worker wage rate (>$10 per hour) and anticipated prices for bioenergy products, hand harvesting techniques are not considered to be viable and mechanized harvesting techniques will be required.

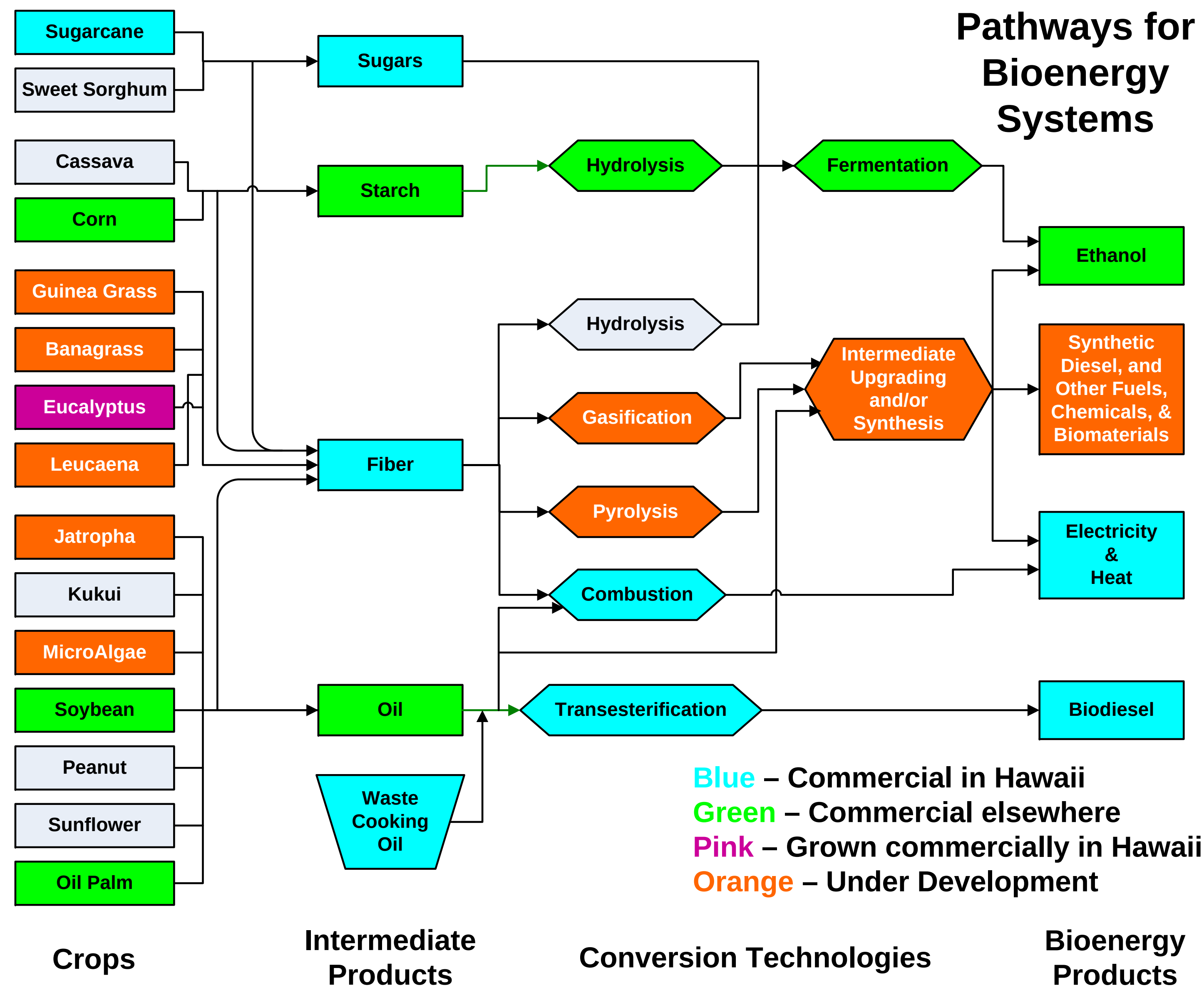

Figure 1. Pathways for bioenergy production systems.

2. Objectives

This chapter is organized in four sections. The first section discusses stakeholders' input received during the preparation of this document. The second section describes crop production technologies for several of the species identified in Figure 1 and identifies technology gaps where appropriate. While not all inclusive, the crops are representative of groups under consideration. The third section provides descriptions of bioenergy conversion technologies and characterizes their development status into three main categories of laboratory- , demonstration-, or commercial-scale. The fourth section summarizes recommendations identified during the course of preparation of this document.

3. Stakeholders' Input

A stakeholder meeting for the master plan was held on April 2, 2009, and included a facilitated discussion on conversion technology. Participants were asked to respond to four questions shown below. The technology breakout session notes are included in Appendix 1 of the section. Highlights of the responses to the questions are provided below.

<u>Question 1.</u> Where do you see the greatest technology gaps in the production of biomass feedstocks?

Responses to Question 1 included (1) harvesting of new bioenergy crops, (2) extraction or separation of the targeted intermediate product from the harvested material, (3) selection and development of bioenergy feedstocks, (4) methods for algae production, and (5) development of co-products from new feedstocks, (6) lack of sustainable production methods.

<u>Question 2.</u> What are the greatest areas of risk or uncertainty regarding bioenergy technologies?

Responses to Question 2 included (1) inability to realize economies of scale, (2) costs of technology development and the availability of research and development funding, (3) the use of biofuels in existing fossil-based combustion facilities, (4) unknown commercial yield of bioenergy crops, (5) compatibility with legacy of infrastructure systems.

<u>Question 3.</u> What types of bioenergy demonstration projects would be most useful to reduce risks?

Responses to Question 3 included (1) crop/feedstock production trials, (2) harvesting technologies, (3) oil crop extraction technology, (4) gasification plant (5) projects that interface bioenergy products with existing infrastructure, (6) projects that demonstrate value-added byproducts in addition to the energy component, (7) projects that demonstrate storage, transport, and blending of bioenergy products, (8) bio-oil production/pyrolysis plant, and (9) projects that demonstrate changes in bioenergy product quality as a function of storage conditions and duration.

<u>Question 4.</u> In the next two to three years, what policy changes would address the gaps and reduce the risks for bioenergy technologies?

Responses to Question 4 included (1) provide incentives for bioenergy (2) temporary land use changes and fast-tracked permitting to allow demonstration projects, (3) change land and water use policies to address competition for resources, allocation priorities, and highest use, (4) place heavy tax on imported oil, (5) Public Utilities Commission handling of renewable energy.

4. Crop Production Technology

Candidates for biomass feedstock production include a wide variety of crops that produce starch, sugar, fiber, or oil. The reduced list of crops described below includes sugarcane, banagrass, *Eucalyptus*, *Leuceana*, oil palm, *Jatropha*, and microalgae. While not exhaustive, this selection represents larger classes of crops that may be suitable for Hawaii and their associated technology challenges. Down selection was done based on one of the following criteria: (a) citation in the scientific literature, (b) grown in Hawaii, (c) tropical crop suitable for Hawaii's environment, (d) limited risk of invasiveness.

4.1 Sugarcane

Sugarcane (*Saccharum officinarum*) originated in the southern Pacific region, most likely New Guinea. It grows well in the tropics where temperatures are warm, with moderately high rainfall, and heavy soils. Sugarcane has been grown commercially in Hawaii for more than 170 years and the technology for producing and processing sugarcane is well established in the state.

Soil preparation for sugarcane in Hawaii typically consists of leveling, as necessary; cross-ripping and dragging; multiple passes with large disc harrows; followed by rip-dragging the entire field. Sugarcane seed pieces, vegetative cuttings of young sugarcane stalks, are planted in furrows at a density of roughly 7 tonnes per hectare (3 tons per acre), using mechanical planters. Fertilizer (N, P, and K) could be applied at the time of planting or shortly thereafter.

Fertilizer requirements for sugarcane are high, ~200 kg per hectare (~200 lb per acre) of N, ~200 kg per hectare (~200 lb per acre) of K, and significant levels (~50-300 kg per hectare [~50-250 lb per acre]) of P probably would be needed annually. These can be applied initially with the planter as solid fertilizers or soon after planting via the irrigation tubing. Thereafter, soluble formulations containing N and K would be applied monthly through the drip irrigation tubing.

Weeds usually can be kept under control with an effective weed control program. Weed control measures for the plant crop might include a preemergence herbicide, interrow herbicide applications at approximately one month, and then spot applications, as needed. Canopy closure should occur within eight weeks of planting (slightly longer during the winter), after which in-field weed control would not be needed. Considerably less weed control would be required for ratoon (unseeded regrowth following harvesting) crops owing to heavy ground cover from harvesting operations and rapid canopy closure following harvesting.

For optimal growth, sugarcane needs ~180 cm (70 inches) of irrigation (via rainfall or applied mechanically) per year. If rainfall amounts are not adequate, it is assumed that sugarcane would be irrigated, using drip irrigation.

Sugarcane grown commercially in Hawaii normally is ripened (through a combination of water withdrawal and the application of a chemical ripener) toward the end of its growth cycle, to maximize sucrose content. The field normally is burned immediately before harvesting to reduce the amount of extraneous fibrous material (called “sugarcane trash”) that needs to be handled in the processing facility (the sugar mill).

Throughout most of the cane-growing world, the plant crop (i.e., the seeded crop) for sugarcane is harvested at 14 to 18 months of age, then, annually, in ratoon crops. By contrast, sugarcane grown commercially in Hawaii is harvested, nominally, at 24 months intervals. Though Australian-style billet harvesters have been used commercially in this state (mostly for cutting seed cane), in Hawaii, sugarcane typically is harvested using push rakes (V-cutters and other mechanical harvesters also have been used in the past). The reaped cane is consolidated into large windrows in the field, and loaded into truck-trailers using hydraulic cranes. The sugarcanes truck-trailers typically carry loads of 20-50 tonnes (20-50 tons) of cane to the sugar mill. There has been considerable debate over whether sugarcane grown for energy (ethanol or other biofuels) purposes might better be harvested on a one-year rotation, unburned, using billet harvesters. Their use in Hawaii probably would require the selection of new sugar cane varieties that are better suited to the shorter rotation. Energy cane, i.e., sugarcane varieties that have been selected for fiber rather than sugar production, is also a bioenergy crop option.

Most sugarcane producers have owned and maintained large networks of private agricultural roads including a broad, paved, cane-haul system that interconnect all fields with the sugar mill. This road network provides adequate infrastructure to transport harvested sugarcane from the field to any processing facility.

Technology Gaps

Because sugarcane has been produce commercially in Hawaii for nearly two centuries, there are no major technology gaps in the production, harvesting, and delivery of sugarcane, though refinements potentially could increase yields and reduce costs incrementally. Whether sugarcane produced in Hawaii should be grown under a one- or two-year cycle and whether sugarcane grown for energy purposes should or should not be burned prior to harvesting, continue to be debated. Decisions on such questions would impact agronomic, harvesting and transporting practices as well as the breeding and selection of commercial sugarcane varieties.

4.2 Banagrass

Bana or Elephant grass (*Pennisetum purpureum* Schumach) is of tropical African origin but has been introduced to all tropical areas of the world and has become naturalized throughout Southeast Asia. It typically grows as a perennial in tropical areas of South America and Asia. Banagrass is not being produced commercially in Hawaii at this time, though cultivars of banagrass have been grown in the islands for use as windbreak and on trial bases as energy and forage crops. Banagrass grows on a wide range of soil types, best in deep, well-drained friable loams with a pH of 4.5-8.2. Banagrass grows best in temperatures between 25 and 40°C (75 and 100°F), and little growth below about 15°C (60°F), and in elevations ranging from sea level to 2000 meters (6500 feet) (Cook *et al*., 2005).

Though not fully optimized for commercial production, cultivation and harvesting strategies have been developed for banagrass grown as an energy crop and ongoing research is being conducted on this species at the University of Hawaii at Manoa. Owing to similarities between banagrass and sugarcane, production strategies often mimic those for sugarcane, with a few exceptions, as noted below.

Soil preparation would be very similar to that used in sugarcane. The planting density of banagrass seed would be considerably lower than for sugarcane, around 2 to 3 tonnes per hectare (1 to 1.5 tons per acre). Fertilizer application would be comparable to sugarcane both in rate (kg of N, P, and K applied per hectare-year) and method of application. The method and rate of application of irrigation water also would be similar to sugarcane. Banagrass is listed as an invasive species in the Pacific Islands and in Florida; though it can be controlled by regular cutting or by applying herbicide.

It is anticipated that banagrass would be harvested, nominally, at eight months of age, though trials being performed by the University of Hawaii at Manoa are investigating much shorter rotation cycles. The harvesting schedule would have to be adjusted to avoid flowering (terminal growth of banagrass and sugarcane ceases once flowering occurs), which takes place during the winter and early spring in stands exceeding four months of age. Two types of systems for harvesting and transporting banagrass have been tested in Hawaii: (1) sugarcane billet harvesting systems and (2) forage harvesting systems. The billet harvesting system had been tried on a fairly large scale, approaching 400 hectares (1000 acres), at the former Waialua Sugar Company on Oahu, more than a decade ago. Both billet sugarcane harvesters and forage harvesters are commercial but their application to Hawaii conditions would require additional evaluation to determine the best set of technology options to serve both crop production (adaptability to terrain, field efficiency, harvesting throughput, etc.) and conversion facility (feedstock particle size, moisture content, etc.) requirements. It is anticipated that banagrass would be ratooned multiple times before being replanted.

Technology Gaps

Most of the practices presently being used for growing and harvesting banagrass have been extrapolated from sugarcane production and have not been optimized for banagrass. Major technology gaps for banagrass include breeding and selecting superior cultivars, establishing crop management practices specifically tailored to banagrass, and developing better harvesting and transporting systems.

4.3 Eucalyptus

(This section on Eucalyptus was taken largely from Friday (2006))

Eucalyptus trees, originally from Australia, were brought to Hawaii as a prospect for commercial timber production after the 1960’s. Various species have been introduced into the state and can be found on at least six of the major inhabited islands. Eucalypts generally prefer temperate to tropical regions with sufficient rainfall that is distributed throughout much the year. There are possibly 600 species of *Eucalyptus* worldwide; more than 90 (not including ornamental species) have been planted in Hawaii. The most commonly planted species in Hawaii are *E. botryoides, E. camaldulensis, E. citriodora, E. deglupta, E. globulus, E. grandis, E. microcorys, E. paniculata, E. pilularis, E. resinifera, E. robusta, E. saligna,* and *E. sideroxylon.*

The most productive species grow best in areas of moderate to high rainfall (>110 cm [>45 inches]). Other species grow well on lands having as little as 50 cm (20 inches) of rainfall. Eucalyptus typically is not irrigated; species are usually selected to match rainfall at the particular location. Eucalypts tolerate acid soils. Some species are adapted to warm temperate regions and in Hawaii grow at elevations up to 2000 meters (7000 feet). Above this, moisture becomes severely limiting. The most productive sites in Hawaii are below 1000 meters (3000 feet) elevation.

If trees are planted on abandoned canelands, heavy rollers would be used to cut and crush cane and other vegetation. If the area is covered with very heavy vegetation or brush, a tractor equipped with a bulldozer blade could be used. The blade is held above the ground to knock down heavy brush so that a harrow or roller can crush the material. On some lands, a tractor equipped with wide-gauge shoes would be used to pull a heavy-duty, off-set cutaway harrow. After clearing, herbicide spray could be applied if the vegetation returns before planting. Tree seedlings are planted about two weeks after herbicide spraying.

Young trees do not compete well with weeds, especially in fertile soils. The critical period of development is two to three months after planting, when regrowth of a previous crop or weeds compete with the tree seedlings. Weeds should be kept under control with one application of herbicide prior to planting and two or three applications following planting. Post-planting weed control is performed with manual backpack sprayers or using tractor-mounted sprayers. At the early stage, trees are sensitive to herbicide so care should be taken to avoid contact between the herbicide and the young plants.

Tests have show that *Eucalyptus* responds well to fertilization, particularly to nitrogen. *Eucalyptus* grown on oxisols has shown phosphorus deficiency. Intercropping *Eucalyptus* with the nitrogen-fixing legume *Falcataria moluccana* (common name albizia) greatly improved growth and production of the *Eucalyptus* over chemically fertilized trees on the Hamakua coast.

Optimal harvesting age varies with species and environments, but normally is around seven or eight years. The harvesting operation for trees would be fully mechanized using commercially available equipment. A feller buncher unit, capable of cutting 0.35 m (1 foot) diameter stems, could be used to harvest standing trees. In this system, stems are sheared at the base using hydraulic shears located at the base of the feller buncher. Clean shearing would be required to minimize stump damage for good coppice regrowth. Most production scenarios, however, favor replanting over coppicing. Following tree felling, skidder/forwarders would collect the felled trees and transport them as logs, to hauling units or to centralized in-field locations where the trees would be chipped. In-field chipping units would chip the whole trees and discharge the chips into wood chip vans.

Technology Gaps

As noted above, a large number of Eucalyptus species have been planted in Hawaii; while there is opportunity for yield improvement through better selection of species for particular environments, the increases probably will not be dramatic. The most significant technology gap associated with Eucalyptus involves selecting appropriate harvesting and transporting systems that are well suited to Hawaii's challenging terrain and other conditions.

4.4 *Leucaena*

(Much of this section on *Leucaena* was taken from Brewbaker (1980))

Leucaena leucocephala is a nitrogen-fixing tree or shrub, originating in Mexico and Central America. It was introduced to Hawaii as fodder. "Giant" *Leucaena* is a tree form that shares many of the traits of the more common forms of *L. leucocephala*, but does not seed and has larger stems. *Leucaena* is a drought tolerant species and is usually found in lower elevations in locations having lower rainfall. *Leucaena* grows well in neutral or slightly acid soils, and does poorly in very acid soils. With proper management, the giant *Leucaena* tree grows at a rapid pace from transplanting to mature height, growing roughly one meter (3 feet) per month during the first five months, and >15 meters (50 feet) height and 10 cm (4 inches) diameter in six years. The University of Hawaii at Manoa continues to perform research on this crop.

Nitrogen, Potassium and, possibly, Phosphorus, would be required at planting, but only K and possibly, P, would be required after planting, as *Leucaena* is nitrogen fixing. The response of *Leucaena* to P is not very well known.

Giant *Leucaena* can be established directly from sown seeds or from transplanted seedlings grown to age, 3 to 4 months. Most likely, as an energy crop, this plant species would be grown from transplants. It is anticipated that ~10,000 trees per hectare (~4000 trees per acre) would be optimal for an energy plantation.

When cut down, the tree can produce a cluster of branches to 10 meters (30 feet) in length within one year; however, if planted in a dense stand and harvested regularly, it can be maintained for decades as a low shrub.

Brewbaker (1980) considered five alternative harvesting and transporting systems for giant *Leucaena*. The swathe-felling mobile chipper was proposed as the best methods for harvesting *L. leucocephala* in Hawaii because it is capable of felling trees and chipping them directly in the field with minimal manpower. Other mechanized harvesters like feller bunchers, grapple skidders and roadside chippers require more skilled operators and are better suited to larger trees planted at lower densities.

Technology Gaps

Technology gaps in *Leucaena* production are similar to Eucalyptus; however, because *Leucaena* has not been produced in large quantities in Hawaii, in addition to selecting appropriate harvesting and transporting systems, additional research would be needed to optimize crop management practices.

4.5 Jatropha

(Much of this section on *Jatropha* was taken from Duarte and Paull (2006))
Jatropha curcas L. (Euphorbiaceae) most likely originated in the Mexican - Central American region. It is known in English as Barbados nut, castor oil, Chinese castor oil, curcas, fig nut, physic nut, pig nut, purging nut, and wild oil nut. It has been spread world-wide as a medicinal plant into tropical regions. The plant readily establishes itself and is regarded as an invasive weed in a number of countries. This perennial monoecious species is a shrub or small tree (6 m [20 feet]) with spreading branches.

Jatropha nuts are high in protein and fat; however, they contain an albumin poison, toxalbumen cursin, and a toxin, curcasin, which makes eating them potentially fatal. There has been much interest in non-toxic varieties of *Jatropha* that, potentially, could provide byproducts, such as animal feed, which could make the economics of *Jatropha* production and conversion into biofuels more attractive. The literature reports the availability of such edible (non-toxic) varieties of *J. curcas* (e.g., see Makkar, 2009).

The succulent species can be found in locations ranging from dry tropic to moist subtropical to wet tropical forests. It grows best in temperatures ranging from 20 to 28°C (70 to 80°F), and can be found from sea level to 1500 m (5000 feet) elevation. Its adaptability to drier tropical climates and poorer soils makes this oil bearing species an attractive energy crop for application to marginal agricultural lands in Hawaii. Crop research is presently being conducted on this crop by the University of Hawaii at Manoa and by the Hawaii Agriculture Research Center.

The tree can be propagated from cuttings and seeds. The cuttings root readily. Seeds germinate in about 10 days. The best time to start in the field is at the beginning of the rainy season. The young plant is sensitive to weed competition during establishment, although, normally, tillage is not needed (only the area around the plants needs to be cleaned). Planting densities of 2 x 2 m (6 x 6 feet), 2.5 x 2.5 m (8 x 8 feet), and 3 x 3 m (10 x 10 feet) have been recommended. The plant should be hedged and pruned to maintain its shape and has a productive life of 40 to 50 years. As a hedge, the planting distances should range from 15 to 25 cm (6 to 10 inches).

The *Jatropha* plant produces a fruit measuring about 3 cm (1.25 inches) in diameter that contains an oil bearing kernel. In developing countries, the fruit is harvested by hand, but mechanical harvesting would be required in any commercial operation in Hawaii. At present, *Jatropha*'s flowering is not synchronized and this results in fruit at various stages of maturity being present on the plant at any given time. Methods to address asynchronous flowering could include plant breeding, cultural practices, or selective harvesting. The latter would require development of harvesting equipment that removes only ripe fruit and does not disturb immature fruit and flowers. Given that the oil bearing kernel is only a small fraction of the mature fruit weight, the harvesting equipment might also remove the kernel and return the fruit pulp to the field surface as mulch. Use of the fruit pulp as a byproduct could justify whole fruit harvesting. Modified mechanical harvesting equipment for blueberries and olives have been proposed for *Jatropha* harvesting, however, to date, no performance test data have been published.

Technology Gaps

Jatropha presently is in the R&D stage of development in Hawaii. Superior varieties need to be identified and sound management practices have yet to be developed for that crop. The availability of non-toxic varieties of *Jatropha* could improve the economics of biofuel production by providing a seed meal that is rich in protein, which could be used to generate an animal feed byproduct. Mechanical harvesting systems need to be developed.

4.6 Oil Palm

The African oil palm, *Elaeis guineensis*, is an economically important crop for many developing countries in the humid tropics. It is the highest yielding and highly profitable oil crop and is relatively easy to grown by large plantations and small farmers alike (Soh *et al*., 2008). The oil palm originated in West Africa but has since been planted successfully in tropical regions within 20 degrees of the equator. Malaysia and Indonesia, combined, produce roughly 80% of the world's output of palm oil, however, that species is an important export oil crop for a number of countries (Rieger, 2009).

Oil palm grows best in hot, wet tropical lowlands that receive at least 180 cm (70 inches) of rain or mechanical irrigation per year, evenly distributed throughout the year. Temperatures below 24°C (75°F) depress growth. Though some varieties of oil palm are being evaluated in Hawaii by the University of Hawaii at Hilo and others, presently no varieties of oil palm have been reported as being superior in Hawaii's subtropical environments.

Oil palm is propagated by seed. Commercial seeds, produced typically by companies that specialize in palm breeding, are mixtures of hybrids derived from parents that are non-true inbreds. Consequently, considerable genetic variability exists among commercial palms.

Typical commercial plant density is ~140 trees per hectare (~60 trees per acre), in triangular grids, ~10 meters (~30 feet) apart (Rieger, 2009). During the first three years, little or no fruit is obtained and plantations are often intercropped with other crops.

Oil palm flowers are produced in dense clusters and are primarily insect-pollinated. Oil palm trees grow to 20-25 meters (60-80 feet) tall, though rarely approach 10 meters (30 feet) in commercial production owing to harvesting limitations, bearing fruits in bunches. The fruit takes five to six months to mature from pollination to maturity. Fruit bunches can weigh 10 to 40 kilograms (20 to 90 pounds). Each fruit contains a single seed (the palm kernel) surrounded by a soft oily pulp. Oil is extracted from both the pulp of the fruit and the kernel.

There are no commercial, mechanical harvesters for oil palm. Oil palm fruit bunches are hand harvested in countries where oil palm is grown commercially. Trees must be visited every 10-15 days, as bunches ripen throughout the year. Harvesting has been semi-mechanized with power cutters and cherry-picker type lifts, but not fully mechanized.

Palm fronds and kernel meal are processed for use as livestock feed.

Technology Gaps
There are major technology gaps with oil palm. No commercial varieties of oil palm are known to be well suited for Hawaii's subtropical environment. Irrigation water requirements for oil palm are very high, which could pose a significant strain on Hawaii's water resources. Mechanical systems that are capable of harvesting oil palm fruit bunches need to be developed.

4.7 Microalgae
(Much of this section on microalgae was taken from Csordas (2001))
Microalgae typically are unicellular aquatic organisms, although some can form chains. These organisms function as nutrient recyclers and lie at the base of many food chains in aquatic ecosystems. The aquaculture industry relies extensively on such autotrophic microorganisms as live feed for commercially valuable filter feeding organisms such as shrimp and clams. Presently, considerable research on microalgae is being conducted by private industry and the University of Hawaii at Manoa.

Various growth chambers, or photobioreactors, have been tested and used in culturing microalgae. Production systems differ in the manner in which nutrients, cells and light are cycled into the system.

Open production systems are open to the ambient environment; closed systems have barriers aimed, in part, to prevent contamination by the surrounding. Open systems typically cost less to operate and maintain than closed systems; however, outdoor algae production systems are more susceptible to the introduction of undesired algae species and other contaminants. Open systems have been used commercially mainly for algal strains that grow in very harsh environments, such as high salinity or extreme pH, which reduces the likelihood of contamination by other undesirable aquatic organisms.

Ponds are sometimes used for mass cultivation of algae. There are three common algal pond designs, each having its own method for mixing the algae: Circular ponds with mechanical arms or air bubbles for mixing are one type of system used. Raceways with paddle wheels to push the algae through their channels are sometimes used in the aquaculture industry. A sloped raceway type pond with a circulating pump is another system that works to keep the algae from settling. Closed photobioreactors are being used commercially to produce microalgae for nutraceutical applications, though commercial closed systems generally have been quite small in scale. Mera Pharma New (which acquired Aquasearch) and Cyanotech have successfully produced microalgae in large closed photobioreactors in Kailua-Kona on the island of Hawaii, though production costs are believed to be far too high for producing microalgae targeted to the energy market. One major engineering challenge in producing microalgae is overcoming the shading problem in large photobioreactors. Use of fiber optics to overcome the shading problem has been a subject of much R&D, though might not be practical for bioenergy applications.

Microalgae production systems are normally classified as batch, semi-continuous, or continuous, depending on how often cells are removed from the system and how nutrients and carbon dioxide are added to enhance growth rate. A batch system requires harvesting all algae from the system once a desired cell density is reached. Batch systems are considered the most reliable because the cultures are not kept longer than necessary to produce the desired cell density or product characteristic. Semi-continuous cultures are partially harvested after the desired cell density is obtained. The desired combination of nutrients and cells can then be added for the next growth cycle. Harvesting and replenishing nutrients occurs continuously in a continuous system. In principle, continuous systems can be more efficient, and provide a higher rate of production over time than batch or semi-continuous systems; however, maintaining cell densities and nutrients at target levels can be complex and costly.

As with the terrestrial energy crops described above, harvesting has a major impact on the economics of producing and processing microalgae. Harvesting microalgae is costly because: (1) individual cells normally vary widely in size; (2) algae cells have low specific gravity, making them difficult to settle quickly; (3) algae culture normally is very dilute. Various harvesting techniques have been used for algae: Straining, filtration, flocculation, centrifugation, and foam fractionation have been employed.

Microstrainers or fabrics with micrometer-sized pores have been used to harvest algae. These often have very slow throughputs and require backwashing to unclog the material. Sedimentation has been used for separating larger sized (>100 μm) particles; longer settling times make that method impractical for harvesting smaller particles. To increase settling rates, flocculants have been used, though flocculants often change the chemical properties of algae, which could be problematic for certain end uses. Centrifugation is a reliable technique for extracting algae from the growth medium, though centrifuges are costly and consume much power. Foam fractionation is an adsorptive bubble separation technique that selectively transfers microscopic particles and dissolved materials from liquid cultures to flowing gas bubbles that gather at the air–liquid interface, which can then be removed. Foam fractionation has been tested in Hawaii and has been shown to be a promising technique to facilitate the harvesting of microalgae.

Technology Gaps

There are enormous technology gaps in algae production. These include developing (1) improved strains of algae that do not present invasive species risks, (2) large photobioreactors that allow for efficient penetration of sunlight, (3) more effective methods to distribute carbon dioxide and nutrients in water, and (4) better and more energy-efficient methods to harvest and separate microalgae from water.

5. Bioenergy Conversion Technologies

This section provides a description of bioenergy conversion technologies and includes information on their resource requirements, yields, and potential impacts.

5.1 Fermentation based ethanol production.

Figure 2 shows the conversion step for producing ethanol from sugarcane and molasses. Sugarcane is mechanically pressed to produce a sugar-rich juice. The juice is primarily composed of sucrose, a 12-carbon fermentable sugars that are readily converted into ethanol by yeast *Saccharomyces cerevisiae*. Ethanol is recovered by distillation. Molasses, a by-product from the sugar processing plant can also be fermented to ethanol. Molasses however needs dilution prior to fermentation.

The enzymes present in the yeast, namely sucrase or invertase first convert disaccharides such as maltose or sucrose ($C_{12}H_{22}O_{11}$) into simpler carbohydrate (monosaccharides) such as glucose and fructose ($C_6H_{12}O_6$). These monosaccharides are then converted into ethanol and carbon dioxide by enzyme zymase. Sugarcane molasses contains about 49.2% sucrose. Again above two enzymes are responsible for its conversion to ethanol. The biochemical reactions involved in ethanol production are shown by the flowing two equations:

$$C_{12}H_{22}O_{11} + H_2O \rightarrow 2C_6H_{12}O_6 \qquad (1)$$

$$2C_6H_{12}O_6 \rightarrow 4CH_3CH_2OH + 4CO_2 \qquad (2)$$

Based on stoichiometry, one mole of sucrose produces four moles of ethanol and four moles of carbon dioxide. Thus, theoretically 163 gallons of ethanol can be produced per ton of sucrose [(4x46 kg ethanol/342 kg sucrose) x (1/0.789) (L/kg) x (gal/3.785 L) x (907 kg/ton)]. Under normal plant operating conditions, a yield of 141 gallons of ethanol per ton of sucrose can be expected from sugarcane, and molasses a byproduct of sugarcane and sugar beet can produce up to of 69.4 gallons ethanol per ton of molasses (USDA, 2006).

The conversion of sugar-to-ethanol is a mature technology. There are still opportunities for further improvement in the economics especially in value-added processing of co-products, such as vinasse, bagasse and carbon dioxide that are considered low or negative value byproducts.

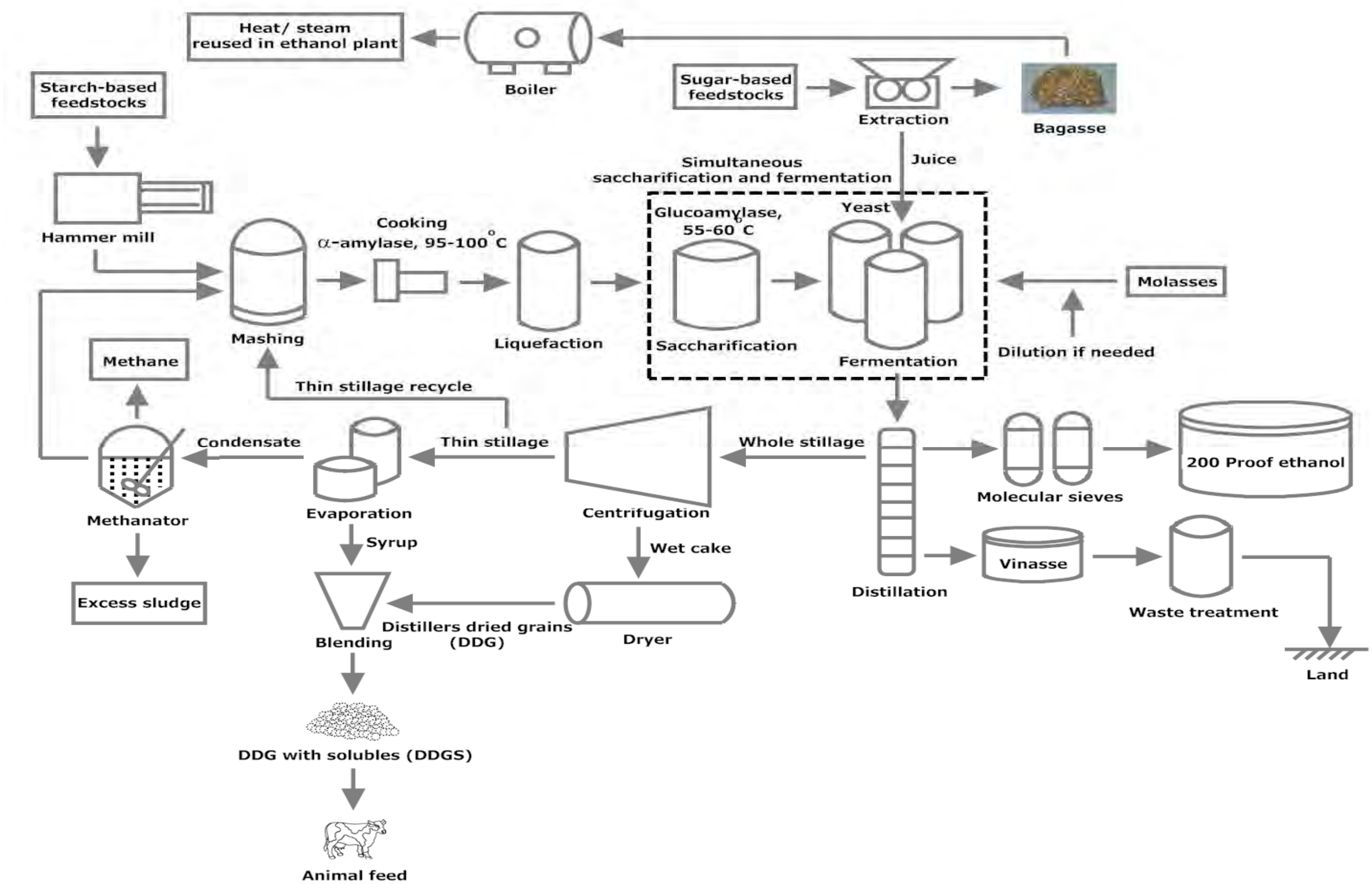

Figure 2. Schematic diagram for ethanol production from sugar and starch-based feedstocks

By-products of Sugarcane-to-Ethanol Plants

The byproducts of sugarcane mills that convert sugarcane juice to raw sugar are molasses and bagasse. Sugarcane juice and molasses can be converted into fuel alcohol. Thus, the major byproducts of sugarcane-to-ethanol process are: bagasse, vinasse and carbon dioxide. Value-added processing of these by-products becomes extremely important for sustainability of sugarcane-to ethanol plants.

Bagasse: The fibrous sugarcane residue remains after sugar juice extraction is known as bagasse. On a dry wt. basis, one ton of sugarcane produces nearly 140 kg of bagasse. Bagasse generally has the following characteristics: moisture 45-50%, cellulose 19-27%, hemicellulose 11-15%, and lignin 7-13% (Pandey et al., 2000). Typically, bagasse is used for production of steam and generation of electricity for in-plant use and excess is sold to local utility company. Sugarcane bagasse is a lignocellulosic biomass which has a potential for liquid biofuel production. One dry ton of sugarcane bagasse can potentially produce up to 80 gallons of ethanol. The cellulosic-to-ethanol technology is still in early stage of development and thus there is considerable uncertainty on the economics of process. The surplus bagasse could be also used as a raw material in paper and pulp, acoustic board, pressed wood, and animal feed productions (Paturau, 1989; Dominguez et al., 1996; Pessoa et al., 1997).

Vinasse: The liquid fermentation by-product following the recovery of ethanol is known as vinasse. The important characteristics of vinasse are presented in Table 1. Vinasse is typically dark colored, with high solids and organic matter contents, and strong acidic properties (Goldemberg et al., 2008). Due to these characteristics, vinasse is of significant environmental concern if not properly treated prior to being discharged to the environment. Sugarcane-ethanol plants produce about 16.3 gallons of vinasse per gallon of ethanol (Saha et al., 2005). Finding an appropriate use for vinasse is critically important for the sustainability of sugarcane ethanol in Hawaii. Since vinasse contains nutrients, e.g. nitrogen, phosphate, potassium, sucrose and yeast cells, it could be a source of fertilizer in cropland. Brazil for example, currently uses vinasse for irrigation, and application at a rate of 30,000 m^3 vinasse/km^2 showed no damaging effect on groundwater. However, converting vinasse into high-value product would improve the overall economics of sugarcane ethanol.

Table 1. Characteristics of vinasses of sugar-based feedstocks.

Parameters	Cane juice[a]	Cane molasses[a]	Beet molasses[a]	Sweet sorghum[b]
pH	4.04±0.49	4.46±0.35	5.35±1.02	4.5
Chemical oxygen demand (COD) (g L^{-1})	30.4±8.2	84.9±30.6	91.1±38.9	80
Biochemical oxygen demand (BOD) (g L^{-1})	16.7±3.4	39.0±10.8	44.9±21.7	46
Total solids (g L^{-1})	-	100[c]	-	30
Total nitrogen (mg L^{-1})	628±316	1229±639	3569±2694	800
Total phosphorus (mg L^{-1})	130±110	187±350	163±66	2000
Sulfate (mg L^{-1})	1356±1396	3478±2517	3716±2015	-
Potassium (mg L^{-1})	1952±1151	5124±3120	10030±6322	-

Sources: Modified from [a]Wilkie *et al.* [26]; [b]de Menezes[27]; [c]Harada *et al.*[32]

Carbon dioxide: CO_2 is one of the major fermentation by-products. Based on stoichiometry, four moles of CO_2 is produced for every mole of sucrose fermented to ethanol. This corresponds to 466.7 kg CO_2 per ton of sucrose [(4x44 kg CO_2/342 kg sucrose) x (907 kg/ton)]. CO_2 can be captured and refined for use in carbonated beverages and dry ice. It can also be used as a carbon source for algal production.

Status of Sugarcane-to-Ethanol Plants in the United States

Currently no commercial sugarcane-to-ethanol plant exists in the United States. Economics certainly has been the major factor for this as corn-based ethanol can be produced at nearly half the price of sugarcane ethanol. Based on a USDA report, the cost of producing ethanol from sugarcane was estimated around $2.40 per gallon based on 2003-2004 sugarcane market and estimated processing costs. The feedstock cost alone accounted for nearly 62% ($1.48 per gallon) of the total production cost. The corn-ethanol production cost was just 1.05 per gallon from corn dry milling plants. Molasses ethanol production however showed fairly competitive price of $1.27 per gallon ethanol with feedstock cost of $0.91 per gallon ethanol. The estimated production costs of ethanol from different sugar-based feedstocks are summarized in Table 2. For comparison, the table also shows the production cost of sugarcane ethanol in Brazil.

Table 2. Summary of estimated ethanol production costs (US$/gallon of ethanol)

Cost items	US sugarcane	US molasses	US corn dry milling[a]	Brazil sugarcane
Feedstock costs	1.48	0.91	0.53	0.30
Processing costs	0.92	0.36	0.52	0.51
Total cost	2.40	1.27	1.05	0.81

Sources: Adapted from USDA report (2006)

In terms of capital cost, it is estimated that a 20-MGY (million gallon per year) sugarcane ethanol plant would cost in the range of $2.10-2.20 per gallon of annul capacity. The capital cost would be significantly lower if an ethanol plant is added into an existing sugarcane mill that can utilize the sugacane juice or molasses. The cost would be fairly comparable to that of corn dry milling ethanol plants, which cost around $1.50 per gallon of annual capacity (USDA report, 2006). It is important to point out that the economics of producing ethanol from sugar-based feedstock is primarily governed by the market price of gasoline. The instability in petroleum price has been a major factor for the commercialization of sugarcane-to-ethanol plant in the United States.

Sugarcane Ethanol in Hawaii

Although, sugarcane yield is the highest in Hawaii among all sugarcane producing states (Florida, Louisiana and Texas) due to a 2-yr crop cycle in the United States, Hawaii's sugar production contributes only 7% of the US production due to declining acreage. Hawaiian Commercial and Sugar Company (HC&S) located in Maui will be the only remaining sugarcane processing plant in Hawaii after 2009. Several factors contributed to the declining sugar production in Hawaii:

- High production cost due to labor and energy costs
- Transportation costs of sugar from Hawaii to the mainland

- Increase land values due to commercial and residential development
- Availability of sugar in low cost from imports and alternative domestic sweeteners such as high-fructose corn syrup (HFCS)

Hawaii also provides a unique opportunity for sugarcane ethanol due to its geographical isolation from the mainland. The high energy cost coupled with transportation cost of raw sugars may favor sugarcane ethanol in Hawaii compared to Mainland. Thus, HC&S is exploring the economic viability of sugarcane ethanol production in Hawaii with interested third parties (name omitted due to confidentiality agreement).

Vinasse, which is a high organic strength by-product, can possibly be converted into protein-rich animal feed. Research is currently underway at University of Hawaii to develop protein-rich fish meal from vinasse, which has a niche market in the Pacific islands. Another option is to digest it anaerobically to produce highly combustible methane gas for on-site electricity generation. Excess electricity may be sold to the local utilities. The USDA report did not give credit to the value of vinnase. Table 3 provides the total energy value of vinasse from a 20-MGY sugar-cane ethanol plant if it is converted to methane gas through anaerobic digestion.

Table 3. Summary of estimated energy production from methane gas

Items	Value
Vinasse generation	16gal/gal ethanol
Methane yield	0.3 m^3/kg COD_{rem}
COD removal efficiency	70%
Total daily vinasse generation	$(16 \times 20 \times 10^6)/365 = 3,318\ m^3$
COD concentration in vinasse	30g/L (for sugarcane juice)
Total daily COD produced	30 kg/m^3x3,318 m^3 = 99,540 kg
Total daily COD removed	99,540 x 0.70 = 69,678 kg
Daily methane produced	0.3 x 69678 = 20,903 m^3
Energy value of 1 m^3 of methane	35,310 Btu
Total energy produced	20,904 x 35,310 = 738 MBtu

Sources: Adapted Khanal (2008)

The daily energy produced would be nearly 2,000 MBtu, if molasses is employed for ethanol production due to higher COD concentrations. Thus, a pilot-scale study should be conducted to accurately examine the costs of production and to determine the credits of by-products.

5.2 Starch-based Feedstocks

The dominant feedstock for ethanol in the United States is corn (*Zea mays* L.), which accounts for over 95% of total ethanol production (McAloon, 2007). For tropical countries like Thailand, cassava (*Manihot esculenta*) has been the most promising crop for ethanol production (Sriroth and Piyachomkwan, 2005). Although ethanol in the US is commercially produced from corn, grain sorghum [*Sorghum bicolor* (L.) Moench] has also been used interchangeably with corn in Nebraska and Kansas facilities. Unlike sugar-based feedstocks, starch-based feedstocks cannot be directly fermented to ethanol. Starch hydrolysis, liquefaction and saccharification are required to produce fermentable sugars after the feedstocks are milled and mashed. The ethanol process from starch-based feedstocks is represented in Figure 2.

Starch-to-ethanol Conversion Efficiency

The ethanol conversion efficiency of starch-based feedstock can be calculated as illustrated below:

$$H(C_6H_{10}O_5)_nOH \xrightarrow[\text{water}]{\text{Amylolytic enzyme}} n\ C_6H_{12}O_6 \xrightarrow{\text{Yeast}} 2n\ CH_3CH_2OH + 2n\ CO_2 \qquad (1)$$

Starch	Glucose	Ethanol	Carbon dioxide
162 (n)	180 (n)	46 (2n)	44 (2n)
100%	111.11%	56.79%	54.32%

The conversion efficiency is calculated from the theoretical yield of 56.79 g of ethanol from 100 g starch (e.g., 1 g of starch is hydrolyzed into 1.11 g of glucose, and 1 mole of glucose is converted into 2 moles of ethanol). Thus, the theoretical ethanol yield per bushel (56 lbs) of corn (75% starch) is 3.63 gallons [(56 lbs/bushel) x (0.454 kg/lbs) x (0.5679 kg ethanol/kg starch) x (75kg starch/100 kg corn) x (1/0.789 kg/L) x (gal/3.785L)]. This is equivalent to 490.7 L of ethanol per dry ton of corn. The ethanol yield of dry-grind mill varies from 2.6 to 2.8 gallon/bushel of corn. Thus, the conversion efficiency is around 71.6 to 77%. This corresponds to an actual ethanol yield of 351.0 to 378.0 L/dry ton of corn. Similarly for cassava chips with a starch content of 69.7%, the maximum ethanol yield is 456 L/dry ton cassava [(2000lbs/ton) x (0.5679 lb ethanol/lb starch) x (69.7 lb starch/100 lb cassava) x (1/1.7358 lb/L)]. The actual ethanol yield is around 400L ethanol/dry ton of cassava chips. Sorghum grains contain 50 to 75% starch and the ethanol yield is within the periphery of corn (Dahlberg, 2007).

Corn

Background

Although corn is best known worldwide from USA Corn-Belt hybrids, it is actually a tropical plant. It has taken a century of breeding to make corn well-adapted and productive in the temperate climates (Troyer, 2006). The commonly used corn for ethanol production is the yellow dent corn *(Zea mays* var. *indentata)*, also known as commodity corn. The corn kernel is primarily starch (75% on dry wt basis), which contains alpha-linked glucose monomers. Enzymes such as alpha-amylase and glucoamylase are used to breakdown starch to glucose for fermentation to ethanol. One bushel of corn (56 lbs) yields 2.6 to 2.8 gallons of ethanol and about 17.4 lbs of distillers dried grain with solubles (DDGS) in dry corn-milling plants (http://www.ers.usda.gov/AmberWaves/April06/Features/Ethanol.htm)

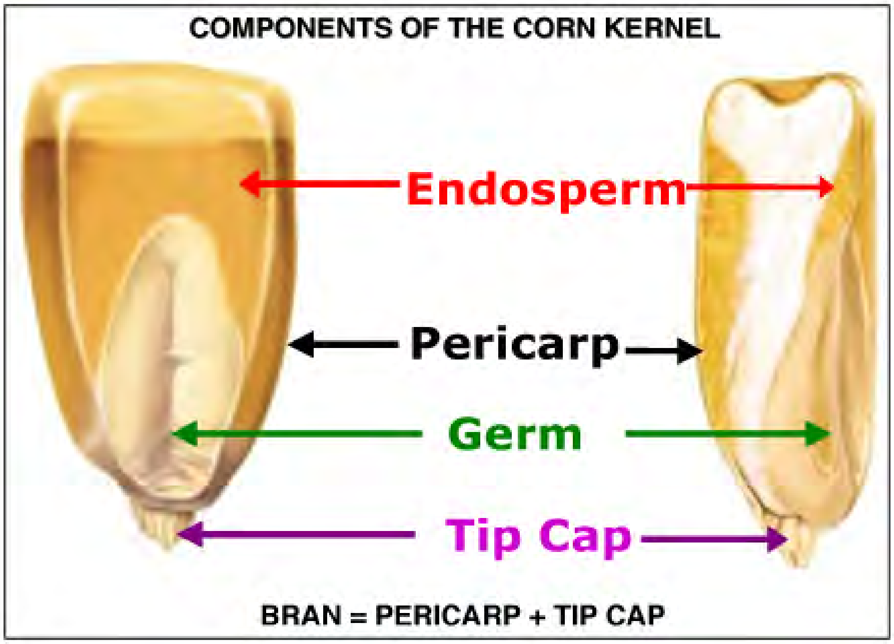

Figure 3. Components of the corn kernel
(Source: www.cerealprocess.com/images/corn-components.jp)

The corn kernel consists of four major components: hull or pericarp, endosperm, germ and tip cap as shown in Figure 3. The endosperm is primarily starch, the corn's energy storage, and protein for germination. The pericarp or hull is made of cellulosic material and protects the kernel from microorganisms and insects. The tip cap is the point where the kernel and cob are connected. It is the passage for water and minerals to enter the kernel. The composition of corn kernels is presented in Table 4.

Table 4. Composition of yellow dent corn kernel (percent dry wt. basis)

Component	Kernel percent	Starch	Protein	Oil	Ash	Sugars	Fiber
Endosperm	82.9%	88.4%	8.0%	0.8%	0.3%	0.6%	1.9%
Germ	11.0%	11.9%	18.4%	29.6%	10.5%	10.8%	18.8%
Bran coat	5.3%	7.3%	3.7%	1.0%	0.8%	0.3%	86.9%
Tip cap	0.8%	5.3%	9.1%	3.8%	1.6%	1.6%	78.6%
Whole kernel	100%	75.0%	8.9%	4.0%	1.5%	1.5%	8.9%

(Source: http://www.bungenorthamerica.com/news/pubs/03_Bunge_Milling_Process_Diagram.pdf)

Tropical Corn Hybrids

The development of ethanol production in Hawaii would be entirely contingent on the use of tropical hybrids. The best publicly available are from Hawaii Foundation Seeds 12 (HFS) and CIMMYT. Excellent commercial hybrids of Pioneer (DuPont), Syngenta, and Monsanto (and a few other corporations) occur abroad, but could not be imported into Hawaii and would have to be produced here. Commercial seeds represent 15% of the cost of US corn production, partly due to the use of transgenics. HFS seeds at $2/lb would be much cheaper.

Average Yields

Due to its ideal climatic condition, Hawaii provides a unique opportunity for year-round growing season. Monthly plot plantings for four years at Waimanalo averaged 155 bushels per crop acre of grain, or 472 bushels per acre per year. Outstanding hybrids (H1015, H1035) showed an average yield of 175 bus/A per crop, and regularly exceed 200 bus/acre in summer trials without fungicides or insecticides. Yields were found to vary significantly during the year in Hawaii. Extreme lows represent short days and overcast conditions of the winter months. The variation is less extreme in premier leeward regions based on studies of monthly plantings (Brewbaker, 2003). However, in the corn-belt in the Midwest, one acre of land produced about 154 bushels of corn in 2008 (RFA Outlook, 2009). The significantly higher yield provides an opportunity for Hawaii to explore the potential of corn-ethanol.

Ethanol and Corn Used

As of May 2009, the United States has nearly 161 corn-based biorefineries with an operation capacity of 10.5 billion gallons per year, and 19 more plants are under construction or expansion (Renewable Fuels Association, http://www.ethanolrfa.org/industry/locations/). Based on 2008 corn production data, the United States used 3,026.0 million bushels of corn for ethanol production from total available corn of 14,362 million bushels, which means about 21% of the corn was diverted for ethanol production (RFA Outlook, 2009).

Water Requirement

Water requirement for corn-to-ethanol plants can be divided into two categories: Water needed for corn production (agronomic requirement) and water needed for corn-starch conversion to ethanol (conversion requirement).

Agronomic water requirement: The agronomic water requirement depends on the regions of the United States. Over 95% of the corn farm is not irrigated at all. According to the 2003 USDA Farm and Ranch Survey, corn grain consumes on average 1.2 acre-feet of water per acre of land with an average corn yield of 178 bushels per acre. This corresponds to a water consumption of 785 gallons per gallon of ethanol produced (Aden, 2007).

Conversion water requirement: A significant amount of water is needed for corn-starch conversion to ethanol. Although both wet-and dry-milling processes are used for ethanol production, the latter contribute to over 80% of ethanol production in the United States and is discussed here.

Despite the name, dry-grind plants require large amounts of water. The annual water consumption of a typical 50-million gallon per year (MGY) dry-grind ethanol plant ranges from 150 to 300 million gallons (Stanich, 2007); equivalent to 3 to 5 gallons per gallon of ethanol produced or over 1.2 acre-feet. Groundwater is the primary source of water for corn-ethanol plants in the corn-belt. Water consumption varies from plant to plant with production capacity, plant age, intake water quality, process efficiency and control (e.g. water treatment, cooling tower, chiller, boiler, distillation, centrifugation), and house-keeping practices. Water consumption also varies with season, with larger volumes being used in the summer due to greater evaporative losses. Water drawn into the plant and used for the above described processes is termed “consumptive use” water, that is, the water consumed in the process, loss during evaporation/drying, reject from reverse osmosis (RO) units, and water that leaves with products such as DDGS and ethanol. Water used for cooling tower and boiler blowdowns, effluent/liquid discharges and internal recycling are not considered part of the total water demand.

Many dry-grind ethanol plants claim to be closed-loop (zero discharge) with regard to water use, and in fact most process wastewaters do get recycled in the plant. However, many plants use reverse osmosis (RO) as part of the production process, and the RO waste stream contains a high level of total dissolved solids (TDS). A significant dilution of RO reject is usually necessary prior to discharge.

Harvesting Technology

Corn grain harvesting has been fully mechanized in developed countries. Current practice of corn grain harvesting is to separate the desired product from other plant residues (i.e. corn kernels from cob, husk, leaves and stalks). This separation process is known as threshing. A combine harvester, also known as a combine is employed to achieve both harvesting and threshing of corn grain. Such equipment mainly recovers the grain and major parts of the plants are left in the field. The total grain loss from a combine is as low as 1-3% (Brown, 2003).

With significant interests in cellulosic ethanol, there is a need to revisit the design of a combine that harvests both grain and biomass (stover and cob) in a single-pass. Research is currently underway by team of researchers at Iowa State University and University of Wisconsin in this direction.

Corn-Based Ethanol Production

Corn-based ethanol is commercially produced in the United States by dry-grind milling and wet milling processes. The former however accounts for the majority of ethanol production (> 80%). In wet milling, various parts of the corn kernel (i.e. starch, protein, fiber, and oil) are separated prior to fermentation. Thus, a multitude of products such as ethanol, starch, high fructose corn syrup, corn oil, and corn gluten meal are produced by wet milling plant. Wet milling plants have higher capital costs, but provide greater operational flexibility in comparison to dry-grind plants. Dry-grind plants produce ethanol as a major product and distillers dried grain with solubles (DDGS) as the only by-product, which is sold as an animal feed. Since dry-grind ethanol plants account for the large majority of U.S. ethanol production because of its lower capital and operating costs, it is discussed in greater detail in this section. A typical dry-grind ethanol plant has a production capacity of 50 million gallon per year (MGY). Wet milling plants on the other hand have production capacity as much as twice that of dry-grind plants due to scale of economy. Modified dry milling is a relatively new development that incorporates some aspects of both wet and dry mill technologies.

Dry-Grind Ethanol Process

A dry-grind process is illustrated in Figure 2. The whole corn is ground in a hammer mill or roller mill and then mixed with water to form a mash. The mash is cooked in a jet cooker at 80 to 90^{o}C (215-220^{o}F) for 15 to 20 min. A small amount of the enzyme alpha-amylase is added during jet cooking to assist liquefaction. Additional alpha-amylase is added during secondary liquefaction, which occurs for 90 min at 95^{o}C (220^{o}F). The cooked mash is then cooled to 60^{o}C (140^{o}F) and mixed with the enzyme glucoamylase to convert the starch to fermentable sugars, a process known as saccharification. This saccharified mash is fermented with yeast (*Saccharomyces cerevisiae*) to produce ethanol. In most plants, saccharification and fermentation occur simultaneously (Simultaneous-Saccharification and Fermentation (SSF)) to minimize the inhibition of enzyme activity and the yeast cells by the product (sugar). Fermentation is usually conducted at pH of 4.8-5.0 and a temperature of 37^{o}C (90^{o}F) for 48h. The fermented mash, often referred to as beer, is distilled to produce a 95% ethanol product by volume (or 190 proof). Dehydration of the 95% ethanol using molecular sieves, which preferentially retain the water while allowing the ethanol to pass, further purifies the product to 99.5% (~200 proof). The fermentation residues are referred to as whole stillage, which is centrifuged to obtain wet cake. The wet cake is passed through a series of dryers to obtain distiller's dry grains (DDG). Thin stillage is the liquid portion obtained from centrifugation. A portion of the thin stillage is dehydrated by evaporation to obtain syrup. The syrup is blended with DDG to form distiller's dried grains with soluble - DDGS. The remainder of the thin stillage is often recycled as process water.

Kansas based ICM, Inc. is well known for designing and building dry-grind ethanol plants in the United States. The details can be found at *http://www.icminc.com*/.

Recent modifications of the dry-grind process include processing at reduced temperatures and pre-fractionation for recovery of germ and fiber prior to fermentation. This process has undergone extensive investigation by researchers at the University of Illinois (Singh et al., 2001). The reduced temperature or non-cooking process uses a special enzyme that works effectively at low temperatures. *STARGEN^{TM} 001* is such an enzyme, developed by Genencor International. *STARGEN^{TM} 001* contains *Aspergillus kawachi* alpha-amylase expressed in *Trichoderma reesei,* and a glucoamylase from *Aspergillus niger* that functions synergistically to hydrolyze starch into glucose. There are several full-scale modified dry-grind plants currently in operation in the U.S. Since there is no cooking step involved in the process, the thin stillage is not directly recycled upstream. It is sterilized by boiling to eliminate any possibility of bacterial contamination.

South Dakota-based POET (formerly known as Broin) is responsible for developing the turn-key project, design, engineering, construction and management of their non-cooking ethanol plants (*http://www.poetenergy.com/)*.

Co-Products from Dry-grind Corn Ethanol Plants

The co-products of dry-grind ethanol plants that convert corn starch to ethanol are whole stillage and carbon dioxide. Currently, whole stillage is subjected to centrifugation to separate the solid fraction known at wet cake and thin stillage. The wet cake is then dried and blended with syrup obtained from thin stillage to generate distillers dried grains with solubles (DDGS). DDGS is currently sold as a nutritious livestock feed. The market price of DDGS ranges from $100-150 per dry ton. Some studies also reported direct burning of DDG following pelletization/briquetting for energy generation (Rottinghaus and Bern, 2008; Schill, 2008)

Whole stillage: Whole stillage or simply stillage is the main residues following ethanol recovery from the dry-grind corn ethanol process. One-third of corn remains as dissolved and suspended organics in stillage. Consequently, stillage contains high organic matter as reflected in a total chemical oxygen demand (TCOD) about 200 g/L with a total solids content of over 11% (Khanal, 2008). The detail characteristics of stillage are given in Table 5. The volume of stillage generated by a typical 50-MGY dry-grind ethanol plant is 600 to 700 gal/min (136 to 159 m^3/h). The whole stillage is centrifuged to obtain a solid stream known as wet cake, which is then dried to obtain distillers dried grains (DDG) as discussed below.

Table 5. Characteristics of stillage from a typical dry-grind ethanol plant

Parameters	Whole stillage	Thin stillage
Total solids (TS)*, %	11.4	6.1
Volatile solids (VS)*, %	10.7	5.3
VS/TS ratio	0.93	0.87
Total suspended solids (TSS)*, %	9.5	2.1
Volatile suspended solids (VSS)*, %	9.4	2.1
TCOD, g/L	203	94
SCOD, g/L	48	41
COD/VS ratio	1.9	1.8
pH	4.46	4.46
VFA, mg/L as acetic acid	2,390	1,310
Alkalinity, mg/L as $CaCO_3$	0	0
Carbohydrate**, mg/L as glucose	10,700	13,600
TKN, mg/L as N	4,020	1,720
NH_3-N**, mg/L	18.5	32.1
TP, mg/L as P	1,331	1,292

*1% = 10,000 mg/L
**Tested on soluble portion of the sample
Source: Khanal, 2008

Thin stillage: The whole stillage is generally centrifuged. The centrate is known as thin stillage. A typical typical 50-MGY dry-grind ethanol plant generates 500 to 600 gal/min (114 to 136 m^3/h) of thin stillage. On a per bushel basis, 13-16 gallon thin stillage is generated. The typical characteristics of thin stillage are presented in Table 5. Thin stillage also contains very high levels of total solids and COD. Around 40 to 60% of thin stillage gets directly recycled upfront in mash preparation. The remaining portion is evaporated to form syrup and is mixed with DDG to form distillers dried grains with solubles (DDGS).

***Distillers Dried Grains with Solubles (DDGS)*:** DDGS essentially is the only co-product of dry-grind ethanol plant. Dry-grind mill generates about 17.4 lbs of DDGS per bushel of corn. The U.S. dry mill ethanol refineries, which make up the majority of ethanol production, generated nearly 23 million metric ton of distiller's grains in 2008. (Renewable Fuels Association, (http://www.ethanolrfa.org/industry/resources/coproducts/)).
Stillage contains protein, minerals, fat and fiber, and are concentrated during the production process to produce DDGS. Its nutrient composition is listed in Table 6. The unique nutrient composition of protein, fat, highly digestible fibers, and minerals provided in the product can be well utilized as a nutritious livestock feed. Both dairy and beef cattle have been the main consumers of DDGS. Lately, larger quantities of DDGS are being used in the feed rations of hogs and poultry. The feeding rates are 46, 42, 3 and 10% of DDGS for dairy, beef, poultry, and swine, respectively.

Table 6. Composition of distillers' dried grains with solubles (DDGS)

	Kim *et al.*	Rai *et al.*	Belyea *et al.*	Spiehs *et al.*	Thale[r]
Moisture content (% total)	-	-	-	11.1	-
Dry matter content (% total)	88.9	-	-	88.9	87-93
Crude protein	27.3	25-30	31.3	30.2	23-29
Crude fiber	-	-	10.2	8.8	9.1
Crude fat	14.5	8 12	11.9	10.9	3 12
Starch	-	-	5.1	-	-
Phosphorus	-	-	-	-	0.77
Lysine	1.0	-	-	-	0.59-0.89
ADF	-	-	17.2	16.2	-
Ash	4.7	-	4.6	5.8	-

All values are % dry basis except where otherwise noted.
* ADF = acid detergent fiber

Carbon dioxide: CO_2 is one of the major ethanol fermentation by-products. Based on stoichiometry (eq. 1), 54.32 kg of carbon dioxide is generated through the fermentation of 100 kg starch. Thus, the theoretical CO_2 production per bushel (56 lbs) of corn (75% starch) is 10.36 kg [(56 lbs/bushel) x (0.454 kg/lbs) x (0.5432 kg CO_2/kg starch) x (75kg starch/100 kg corn)]. This is equivalent to 370 kg of CO_2 per dry ton of corn. In an actual plant, about 16-17 lbs of CO_2 is generated per bushel of corn. CO_2 can be captured and refined for use in carbonated beverages and dry ice. It can also be used as a carbon source for algal production. Iowa recently funded over $2 million to BioProcess Algae for the commercialization of algae technology for biofuel production at a southwest Iowa ethanol plant. The algal-to-biofuel will utilize the CO_2 generation from the fermentor of a corn-ethanol plant.

Wastewater/Liquid Streams from Corn-ethanol Plant

Many dry-grind ethanol plants are considered zero discharge with regard to water use, and in fact most process wastewaters do get recycled in the plant. However, many plant use reverse osmosis (RO) as part of the production process, and the RO waste stream contains a high level of total dissolved solids (TDS). A significant dilution of RO reject is usually necessary prior to discharge.

Major liquid streams from a dry-grind plant include thin stillage, evaporative condensate, clean-in-place (CIP) wash water, blow downs from the cooling tower and boiler, RO rejects, and miscellaneous wash waters. A brief discussion of these streams follows.

Thin stillage: Thin stillage contains very high levels of total solids and COD. Its characteristics are dependent upon the fermentation and distillation processes, and the type and efficiency of solid-liquid separation. About 40 to 60% of thin stillage gets directly recycled in mash preparation. A remaining portion is evaporated to form syrup. Some plants evaporate the entire thin stillage stream.

Condensate: Condensate is the liquid stream recovered from the evaporation of thin stillage. Condensate volume ranges from 200 to 250 gal/min for a 50-MGY plant when 50% of thin stillage is evaporated. The condensate contains significant levels of dissolved organics, primarily weak organic acids such as acetic, lactic, propionic and butyric acids. The COD varies from 2 to 8 g/L with a pH of 4 to 5. Acetic acid appears to be the major acid in most condensate samples. The evaporated condensate lacks many essential nutrients needed for successful biological treatment.

Wash water*:* This stream is generated from the clean-up, pipe flushing, and rinsing of process vessels. CIP is one of the major components of the stream that mainly contains alkali solution (4 to 5% NaOH) and fermented mash. Because this waste stream has a high pH (10-12), it is often used to adjust pH in an upflow anaerobic sludge blanket (UASB) reactor or to optimize yeast propagation.

Blowdowns from boiler and cooling tower: Boiler blowdown is relatively clean and is directly recycled in the process. Cooling tower blowdown may contain some microbes due to atmospheric exposure, but is relatively free from organic matter, and is discharged to a receiving stream or lake.

Cost Analysis of Corn-ethanol in the United States

Corn-ethanol is sold at competitive price in the continental U.S. with federal tax credits of $0.51/gallon. The feedstock cost shows significant variations ranging from $1.90/bushel in 2005 to $2.00-3.50/bushel in 2006 (McAloon, 2007). In 2007 and 2008, the feedstock price crossed $4.00/bushel. The capital cost for a corn-based ethanol plant is around $1.50/gallon of annual capacity based on 20 MGY plant (USDA Report, 2006). Table 7 shows the summary of various costs in corn-ethanol production.

Table 7. Summary of estimated ethanol production costs

Cost items	Unit	2005 Cost	Corn Wet milling	Corn dry milling
		(McAloon, 2007)	USDA Report (2006)	
Capital costs	$/gal annual capacity	2.00	-	$1.50
Feedstock costs	$/bu	1.90	-	
Corn cost	$/gal	0.69	0.40	0.53
Processing costs	$/gal	0.51	0.63	0.52
Total cost	$/gal	1.20	1.03	1.05

Corn Ethanol in Hawaii

Although, Hawaii's tropical climate provides a significant edge over the temperate corn-belt, corn production is mainly limited to sweet corn or seed corn. Some of the major barriers for corn-ethanol in Hawaii are:

- High production costs due to labor and energy costs
- Increase land values due to commercial and residential development
- Lack of logistics for co-product utilization

For sustainable corn-ethanol industries, the market for co-products, which contributes up to 20% of total revenue generation (Khanal, 2008), must be locally available. DDG/DDGS or wet cake is the major co-product of dry-grind ethanol plants and has largely been sold as livestock feed. More recently, these materials have also been pelletized or briquetted for energy products. In Hawaii, the sales of livestock products (beef, dairy, eggs and pork) declined by nearly 39% in the last two decades (Hawaii Department of Agriculture, 2007). Thus, the market for co-product is quite limited. This can mainly be attributed to lack of animal feeding operations, slaughterhouse facilities, and distribution network for meat products. Revitalization of Hawaii's livestock industry would improve co-product economics and food security as well as acting to increase availability of animal byproducts such as fats, oils, and grease.

The current model of a 50-MGY plant in the corn-belt cannot be applied to Hawaii. Small-scale (0.5 to 1-MGY) corn-ethanol biorefineries would only be a feasible option provided that close-loop system as depicted in Figure 4 is adopted.

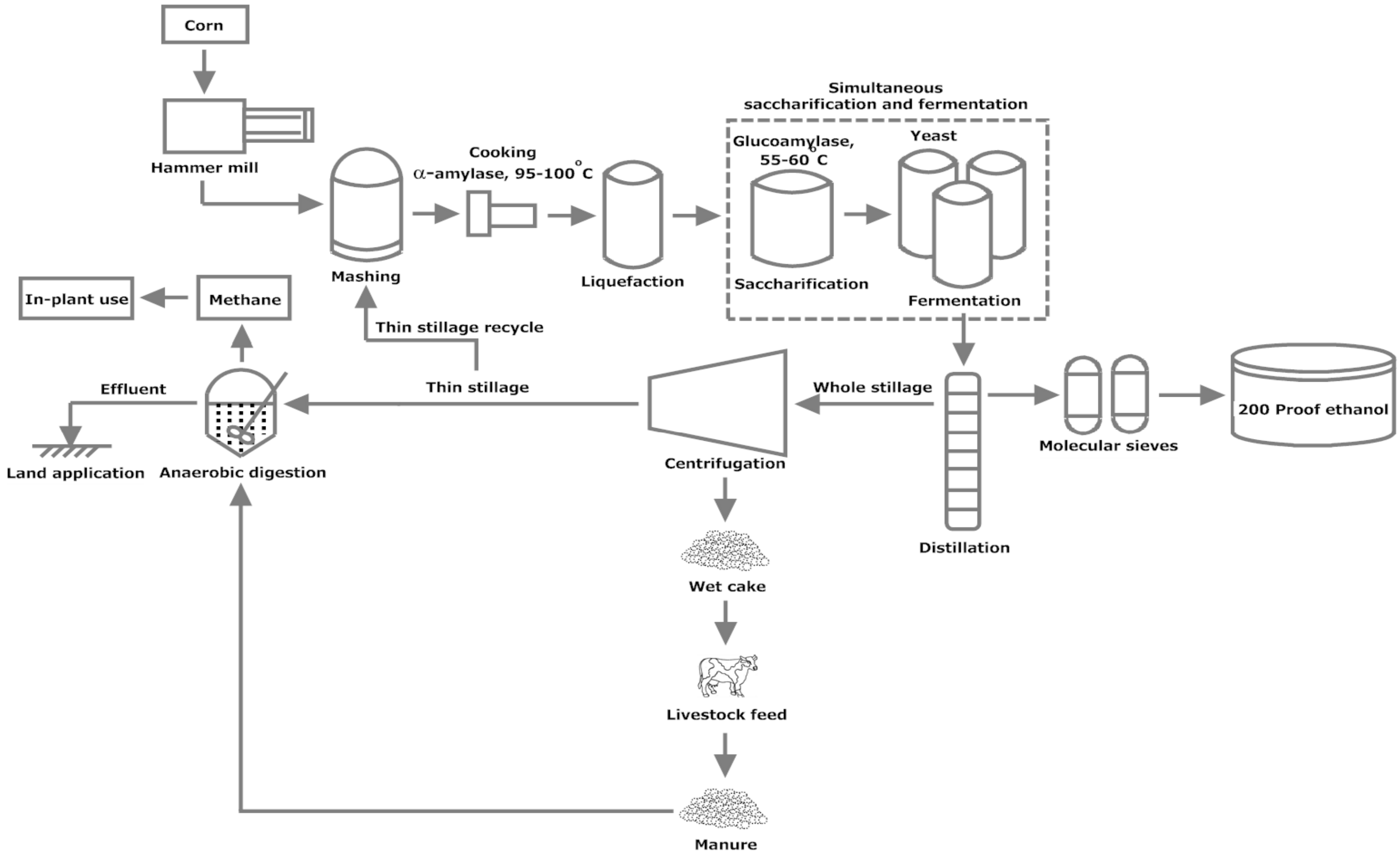

Figure 4. Integrated farm-scale corn-ethanol biorefinery

Such biorefineries operate similar to a large-scale dry-grind mill; but with fewer unit processes/operations. In addition, the liquid stream (part of the thin stillage) is anaerobically digested to produce biogas for in-plant energy generation. The effluent is then land applied. Such bio-refinery has to be integrated with livestock production (dairy/beef cattle or swine) so that the co-product can be fed wet directly without further processing. The manure produced is anaerobically digested to generate methane gas and the digested slurry is land applied to supplement nutrients (N and P). Table 8 provides calculations showing the land area requirement for 1-MGY corn-ethanol plan.

Table 8. Land area requirement for 1-MGY dry-grind plant.

Items	Value
Corn yield in Hawaii	150 to 200 bushel/per crop/acre
Annual corn yield at 2.5 crops/year	437.5 bushel/acre
Corn needed for 1MGY plant @ 2.8 gallon/bushel	357,143 bushels
Land area requirement for 1MGY plant	~820 acre

Recent economic analysis showed a feedstock production cost of $2.56 per gallon ethanol. The study assumed a yield of 360 bushels per year with a conversion factor of 2.7 gallons of ethanol/bushel. Figures used were for the calendar year 2006 (Personal communication, Dr. John F. Yanagida). This cost analysis may not be applicable for mini-biorefinery proposed here.

Cassava

Background

Cassava (*Manihot esculena*) is a starch-rich feedstock and is primarily grown in a tropical climate. Although originally from the Amazon region of Central America, it is widely grown in South East Asia and Africa as a food commodity. The plant is also known by different names such as Yuca, Manioc, Mandioca, Maniok or Tapioca. Cassava can be grown in all-types of soils. Ideally sandy loam and loamy sand soils provide excellent conditions for cassava root formation. Importantly, it can be planted in lands where other crops cannot be grown economically (Sriroth and Piyachomkwan, 2008). The major cassava producing nations are Nigeria, Brazil, Thailand, Indonesia and Congo. The world Cassava production was nearly 218 million tons in year 2006.

Figure 5. Pictures of cassava plants (A) and cassava tubers (B)

Cassava contains relatively low protein and other nutrients. Thus it could serve as an ideal feedstock for ethanol production. Additionally, it can be grown in otherwise infertile land with minimal input of chemicals, such as fertilizers, herbicides and insecticides; making it one of the cheapest agro-based feedstocks (Hill and Hay, 2004). The typical composition of cassava chips is shown in Table 9.

Table 9. Composition of cassava chips

Composition	**Percentage**
Starch	69.7
Moisture	12.0
Fiber	3.4
Sand/silica	2.4
Others	12.5

Source: Nitayavardhana et al. (2008)

Average Yields

The cassava yield shows a considerable variation depending on several factors including soil types, nutrient and water availability. The fresh root yield of 90 ton/hectare was reported for adequate moisture and optimum fertilizer input (Moore, 2005). Fresh cassava roots may contain moisture level of 50 to 70%. Dai et al. (2006) reported a cassava root yield of 13,333 kg/hectare with a moisture content of 13%. The yield of various cassava varieties in Thailand is given in Table 10.

Table 10. Cassava root yield at different stages of growth (ton/hectare)

Varieties	Time of Harvest (months)			
	6	8	10	12
R1	24.0	20.5	24.6	29.8
R5	35.8	25.9	35.2	41.8
R60	22.3	21.2	26.8	34.7
R90	27.0	21.1	26.6	34.9
KU50	29.2	19.8	27.8	34.9
CMR 33-57-81	38.2	29.7	41.9	51.1

Source: Santisopasri et al. (2001).

Water Requirement

The water requirement for cassava-to-ethanol plants can be divided into two categories: Water needed for cassava production (agronomic requirement) and water needed for cassava-starch conversion to ethanol (conversion requirement).

Agronomic water requirement: Cassava is considered to be a drought-tolerant plant. Published data showed that cassava plants can be grown without irrigation (Nyugen et al., 2007). The plants, however, require a certain level of soil moisture during the early stage of plantation. A minimum rainfall of 1,000 mm/year could still sustain the growth (Sriroth and Piyachomkwan, 2008).

Conversion water requirement: A significant amount of water is needed for cassava-starch conversion to ethanol. Root cleaning is the first-step in preparing cassava conversion to ethanol, which consumes a large amount of water. Both wet-and dry-milling processes similar to corn-ethanol plants are employed. The latter is widely used due to lower capital and operating costs. The water requirement is very similar to corn-ethanol plants.

Harvesting Technology

Cassava is primarily grown in developing countries, where the labor supplies are abundant at a reasonably low cost. The harvesting is done manually as illustrated in Figure 6. The harvesting cost was around $ 65.07 per hectare in 2005 in Thailand (Sriroth and Piyachomkwan, 2008). A mechanized harvesting system similar to potato harvesting can be used with some modification.

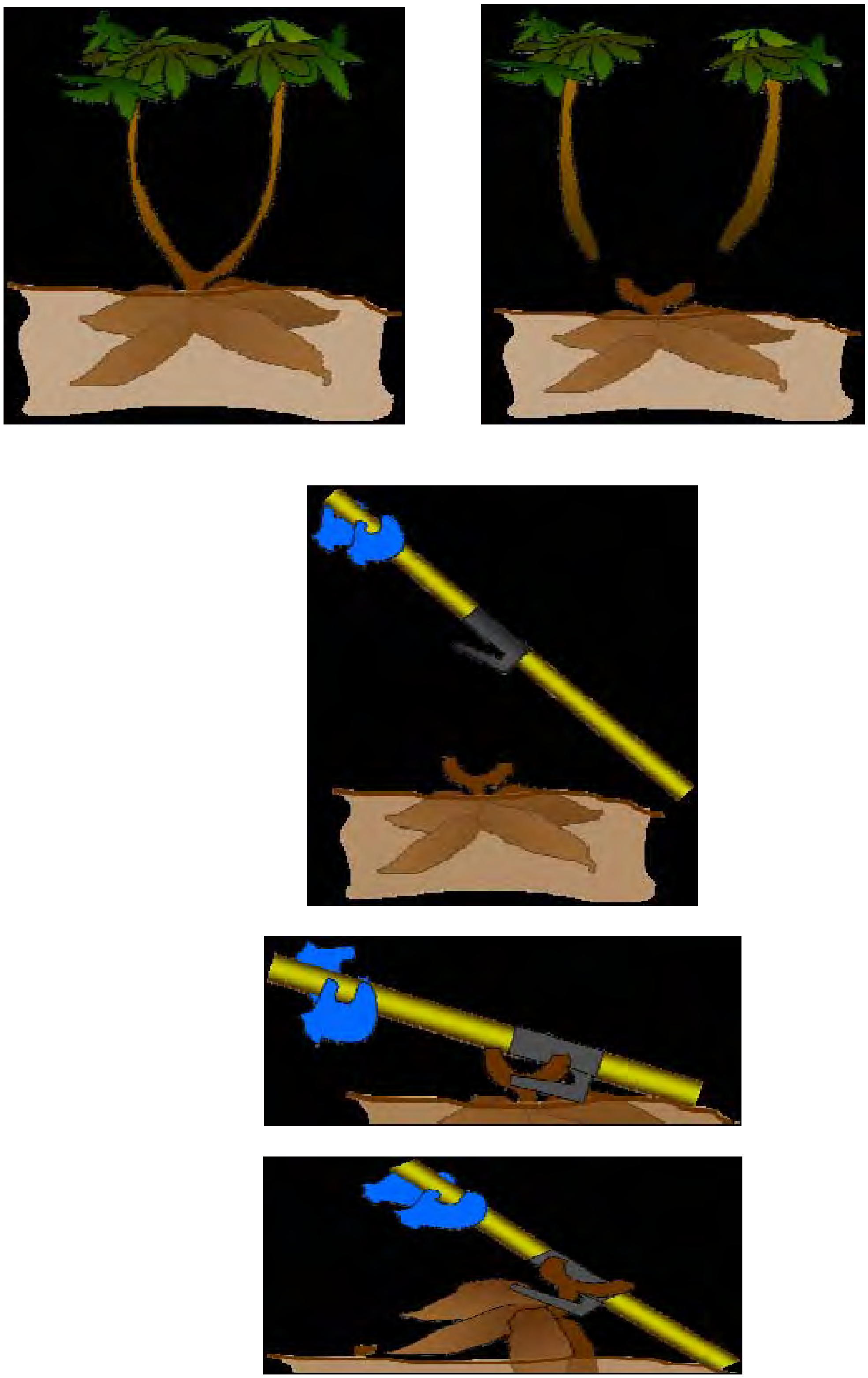

Figure 6. Harvesting of cassava roots in Thailand.

Cassava-Based Ethanol Production

Cassava roots contain nearly 70% starch on a dry wt. basis. Similar to corn-starch, cassava-starch molecules contain long chains of glucose molecules connected by alpha 1-4 linkages. Enzymes, alpha-amylase and glucoamylase, are needed to break down long chain carbohydrate into simple sugars (glucose).

There are some additional preprocessing steps that are essential for converting cassava roots into ethanol. The roots require thorough cleaning before conversion into ethanol. Although fresh roots can be directly used for ethanol production during harvest season, drying is often needed for offseason use due to a high water content of around 60 to 70%. The cassava chips are generally spread outdoor for sun drying.

To produce cassava chips, fresh cassava roots are chopped into small pieces and sun dried without washing. A separator is then used to clean cassava roots to remove sand and dirt. Dried cassava chips are preferred for the following reasons:

- Dry cassava chips are lighter compared to cassava roots. They can be easily transported to the plant site or within the plant.
- Due to a lower moisture content (< 14%), cassava chips can be stored for a longer period and during off-season use.
- Dry chips can be converted into ethanol using a dry-grind process similar to matured corn grains, thus minimizing the production cost.

Waste/Residues from Cassava Ethanol Process

The co-product from cassava-ethanol plants, stillage (or wet cake or DDGS), is not as nutritious as that of corn-ethanol. The only protein available in DDGS is from residual yeast cells. There are several ways to utilize the residues:

Anaerobic digestion of whole stillage to produce biogas and its subsequent use for on-site energy production is often considered a viable alternative. The digested residues could be land applied to supplement nutrients. Energy recovered from biogas showed a favorable net energy value (NEV) [NEV is defined as the difference between the energy content of ethanol and the amount of net energy inputs in the fuel production cycles] of cassava ethanol in Thailand (Nguyen et al., 2007). The details of anaerobic digestion of stillage for biogas production can be found in Khanal (2008).

The whole stillage can be centrifuged to produce a wet cake, which contains a moisture content of 50% that can be directly burned to produce heat/electricity for in-plant use. The centrifugate known as thin stillage can be anaerobically digested to produce methane gas for heat/electricity generation.

Wet cake can be further dried to produce dry-cake similar to DDGS and use as livestock feed.

Cost Analysis of Cassava-ethanol

Cassava is not commonly grown in the United States. The cost-analyses are based on studies conducted in Asian countries. For example in China, the total production cost excluding raw material costs was reported around $1.01/gal. In Thailand, the total production cost was found to be around $ 0.83/gal. The feedstock cost is expected to be stabilized at $35/dry ton (or $0.33/gallon ethanol) (Sriroth and Piyachomkwan, 2008).

5.3 Biochemical Conversion of Lignocellulose Feedstocks into Ethanol

Biochemical conversion essentially uses biocatalysts such as enzymes and microbes, and heat and chemicals to convert biomass into biofuel. In principle, the key steps involved in biochemical conversions of lignocellulosic biomass to ethanol are similar to current grain-starch conversion to ethanol in dry-milling process. Lignocellulosic biomass conversion however poses several different technical challenges as outlined here:

1. Starch-based feedstock does not require comprehensive pretreatment except milling, mashing and jet-cooking. Lignocellulosic biomass due to its heterogeneity and crystallinity, provide structural rigidity. Thus, the biomass must be subjected to pretreatment to disrupt strong bonds during biochemical conversions.
2. Starch can be hydrolyzed to fermentable sugars by using simple enzymes: amylases. Lignocellulosic feedstocks, however, require complex enzymes, cellulases, which are a cocktail of several types of enzymes.
3. Conventional ethanol fermentation is carried out by yeast *Saccharomyces cerevisiae* which mainly ferments glucose. *Lignocellulose-derived sugars contain a mixture of* 5 and 6-carbon sugars. Thus, novel microbial catalysts are needed for efficient fermentation of mixed sugar streams, especially hemi-cellulose-derived xylose.

The biochemical pathway consists of three steps: pretreatment, enzyme hydrolysis and fermentation. The biomass needs preprocessing, primarily size reduction, prior to conversion. In addition, biomass-derived hydrolysates also need conditioning such as pH adjustment, detoxification and lignin removal. Product separation, recovery of other byproducts, and value-added processing are other important steps in this type of processing. The biofuel industries essentially adopt a biorefinery concept similar to petroleum refineries. The various steps involved in different biochemical conversion technologies are illustrated in Figure 7.

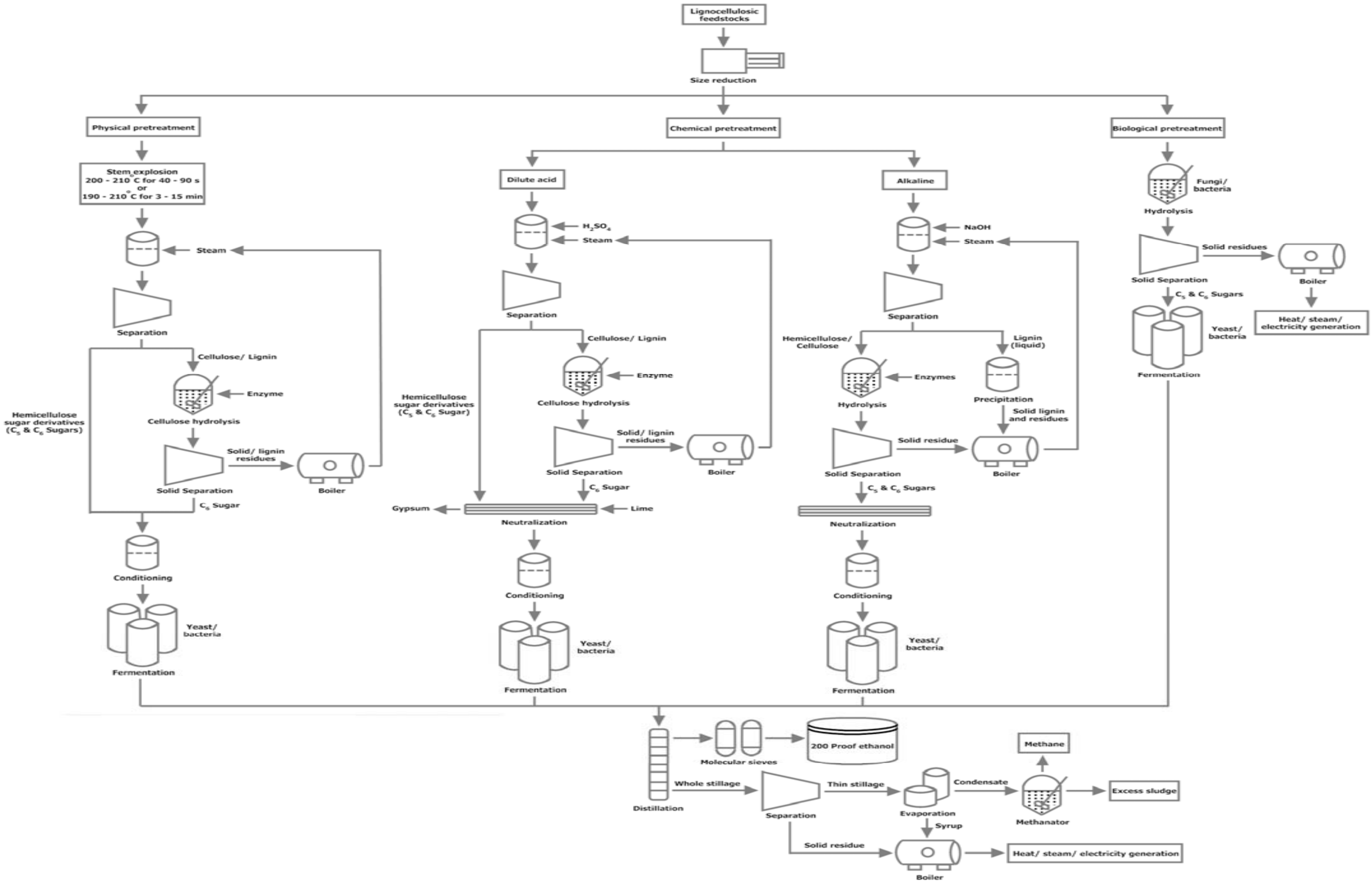

Figure 7. Various steps in biochemical conversion process (Adapted from Nitayavardhana and Khanal, 2009)

Lignocellulose Biomass Pretreatment

Several techniques have been developed to promote structural destabilization of lignocellulosic biomass collectively known as pretreatment. Thus the main objective of pretreatment is to expose cellulose and hemicelluloses to enzymes for efficient enzyme hydrolysis. Pretreatment is probably the most important and critical step in biochemical conversion of lignocellulosic biomass to ethanol.

Goals of Pretreatment Processes

As discussed above, the main objective of pretreatment is to prepare the biomass for efficient downstream processing. Currently, there is no particular preferred biomass pretreatment technology. Therefore, it is important to select the technology that fulfills the most if not all of the performance goals outlined below (IEA Bioenergy, 2008; Johnson and Elander, 2008):

- maximize the yields of both C-5 and C-6 sugars for downstream processing with minimal degradation of produced sugars;
- facilitate the recovery of lignin as a high-value product;
- minimize the formation of inhibitory soluble chemicals including furfural, hydroxymethylfurfural, organic acids and phenolic compounds in the hydrolyzate for downstream enzyme hydrolysis and fermentation;
- be capable of effectively accommodating diverse feedstocks without significant change in process or the product quality;
- require little or no preprocessing steps, e.g. size reduction by grinding, milling, pulverizing etc.;
- have a high degree of simplicity;
- utilize low cost chemicals with minimal generation of waste streams;
- utilize less energy and have low capital and operating costs.

Lignocellulosic Biomass Structure

For the efficient pretreatment of lignocellulosic biomass, understanding the biomass structure is extremely important. The feedstocks discussed earlier are all categorized as lignocellulosic biomass, which implies that the majority of their structural components consist of hemicellulose, cellulose, and lignin. The relative quantities of these compounds however, are highly variable depending on species of the crop, but generally they contain about 35-50% cellulose, 20-35% hemicellulose, 10-25% lignin, and a remaining percentage consisting of protein, ash and oils (Liu et al., 2008). Of these constituents, cellulose and hemicellulose are of considerable interest in the generation of bioethanol on biochemical conversion.

Cellulose is a structural polymer of lignocellulosic plants that is composed of a six-carbon sugar, glucose, in $\beta(1\rightarrow4)$ glycosidic bonds. It is important to note that the efficient enzymatic conversion of biomass to fermentable sugars is primarily governed by the accessibility of $\beta(1\rightarrow4)$ glycosidic bonds in cellulose to cellulase enzymes. Unlike cellulose, hemicellulose is a heterogeneous polymer that consists of five and six-carbon sugars. The sugar backbone of hemicellulose is typically formed by polymers of the five-carbon xylose, with side chains of other pentose and hexose sugars: arabinose, mannose, and galactose. Hemicellulose is amorphous and weaves around linear strands of cellulose to increase structural stability. Lignin, a highly complex phenolic compound thought to arise from the free radical polymerization of an alcohol and varying methoxyl constituents (Ramos, 2003), forms cross-linking bonds with hemicellulose and effectively acts as glue . This lignin-hemicellulose interaction is often described as a protective sheath that encases strands of cellulose (Mousdale, 2008). The conceptual arrangement of these components in lignocellulosic biomass in depicted in Figure 8. This protective sheath is widely known to have recalcitrant properties that inhibit a collection of enzymes, called cellulases, from digesting structural polysaccharides into their single (monomeric) sugar constituents. Thus, the pretreatment of biomass is required to destabilize the internal structure and subsequently increase the accessibility of enzymes to cellulose.

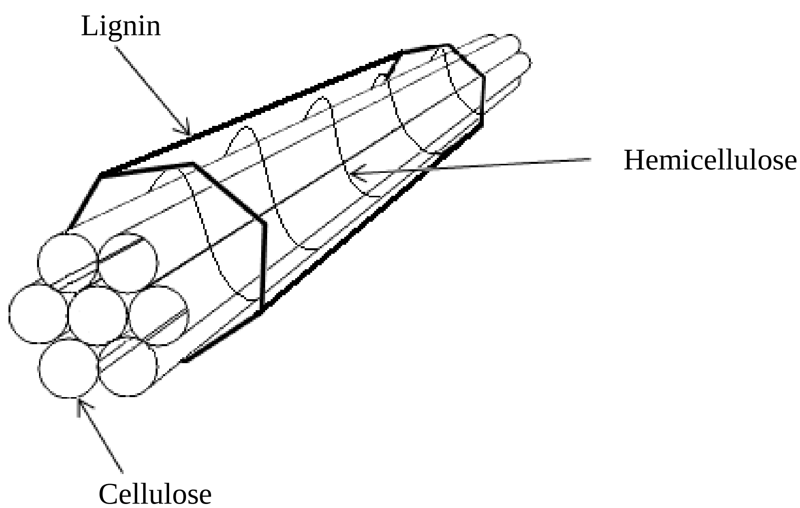

Figure 8. Strands of cellulose encased hemicellulose and lignin
(Adapted from Takara et al., 2009).

Pretreatment Technologies

A seemingly infinite number of pretreatment strategies have been developed and tested with new methods being reported frequently. It is often hard to compare one technology with another due to non-uniformity in the treatment conditions. A USDOE funded Biomass Refining *Consortium for Applied Fundamentals and Innovation (CAFI)* recently evaluated different pretreatment methods undertaken by researchers in North America. The aim of the study was to obtain a comparative process performance and economic data for leading pretreatment technologies. The details can be found in Wyman et al. (2005).

The pretreatment options can be grouped into four main categories: 1) physical, 2) chemical, 3) biological, and 4) a combination of methods (hybrid).

Physical pretreatments

Physical pretreatments attempt to destabilize the structure of biomass without chemical or microbial assistance. Intensive size reduction commonly known as comminution involves various physical means of size reduction such as ball milling (wet, dry and vibratory processes), attrition milling, compression milling, and wet or dry disk refining. High energy cost associated with the mechanical equipment is the major issue with comminution method (Johnson and Elander, 2008).

Steam explosion without chemical addition is another physical pretreatment method. In this method, lignocellulosic biomass is saturated with steam at an elevated temperature and pressure. After a predetermined residence time, the biomass chamber is quickly (and violently) decompressed. Because high temperatures and pressures are used, sugar degradation is unavoidable. A careful balance between temperature, pressure and time must be maintained to ensure that glucose and xylose do not degrade into 5-hydroxymethylfurfural (HMF) and furfural, respectively. HMF and furfural have inhibitory effects on microbial species and affect ethanol fermentation. Ruiz et al. (2008) examined the effect of steam explosion on sunflower stalks; an agricultural residue that is typically burned. The authors reported a maximum yield of 2 2g of total sugars per 100 g of raw material; corresponding to 40.7% of the sugar content within the stalks with steam explosion conducted at 210°C.

In steam-explosion pretreatment, a hydrolysis reaction is catalyzed by the release of organic acids produced from acetyl functional group associated with hemicelluloses. The generated acid facilitates lignin solubilization and hydrolysis of hemicellulose. The highest release of xylose from hemicellulose is no more than 65% of the theoretical value due to severe sugar degradation during non-catalyzed steam explosion reaction (Johnson and Elander, 2008). Often steam explosion studies are conducted with addition of chemicals such as sulfur dioxide and sulfuric acid to improve the yield of sugar release. Steam explosion pretreatment has been found effective for many different biomass feedstocks; but has been less effective with softwoods.

Autohydrolysis pretreatments including liquid hot water batch and liquid hot water percolation are similar to steam explosion pretreatment except that the sudden decompression is not applied. In liquid hot water pretreatment, cellulose hydrolysis is achieved at very high temperature of 260^{o}C; whereas hemicellulose hydrolysis is achieved at a lower temperature range of 22-230^{o}C. The sugar released in the liquid stream in the latter case is mainly in oligomeric form. It therefore requires further hydrolysis using either enzyme or acid to produce fermentable (monomeric) sugars. Although, liquid hot water pretreatment eliminates the needs of catalyst and expensive corrosive-resistant reactor, the cost saving is offset by lower sugar yields and the need of enzyme hydrolysis step.

Chemical pretreatment

There are two common types of chemical pretreatments, acid and base that are commonly employed for biomass pretreatment. Dilute acid and alkali take advantage of the chemical properties of lignocellulosic biomass to promote structural destabilization. Although numerous variations exist, dilute acid is often conducted at low concentrations of sulfuric acid and elevated temperatures. The primary targets of acid and base pretreatments are hemicellulose and lignin, respectively. Because hemicellulose is composed of a xylose backbone with branching sugar moieties, its chemical bonds are more easily hydrolyzed under mild acidic conditions. The sugar mono or oligomers are effectively solubilized in the liquid fraction of dilute acid and can be fermented into ethanol. The removal of hemicellulose from the solid fraction helps to unravel the biomass structure and increases the accessibility of cellulases to cellulose. Ballesteros et al. (2008) examined the effects of sulfuric acid on herbaceous Mediterranean species, Cardoon, using dilute conditions 0.1-0.2% (w/w). A maximum enzymatic hydrolysis yield of 81% was obtained at a 0.11% (w/w) sulfuric acid concentration at 200°C and a 10% (w/v) loading.

Similarly, dilute concentrations of alkali can be combined with elevated temperatures to selectively solubilize lignin portions of biomass and promote structural destabilization. The common alkali substances include but are not limited to ammonia, lime, sodium hydroxide, and potassium chloride. A pilot-scale operation investigated the scale-up of lime pretreated wheat straw. It was found that 16.7 kg of pretreated wheat straw could produce up to 1.7 kg of ethanol (Maas et al., 2008).

Biological pretreatment

Biological conversions of biomass utilize either fungal or bacterial species to break down lignocellulosic components. Commonly, wood-rot fungal species are exploited for their degradative capabilities. Shrestha et al. (2008) found that when the fungal species *Phanerochaete chrysosporium* was cultivated under solid substrate conditions, there was a relatively low yield of ethanol (3g per 100 g of fiber) compared to the expected 9 g of ethanol per 100 g of corn fiber. It was suggested that this difference was due in part to the fungal consumption of released sugars. Another study found higher yields upon combining fungal degradation of rice straw with ammonia fiber explosion (AFEX). Rice straw is commonly used as a substrate for edible mushroom production and has little value after mushroom harvesting. Balan et al. (2008) discovered that more than 98% of the glucan and 75% of the xylan can be converted into fermentable sugars after pretreatment and hydrolysis.

Hybrid pretreatment

Combinations of the varying pretreatment strategies can be used to enhance the hydrolysis of fermentable sugars from lignocellulosic biomass. Some of the recent innovations have been wet-oxidative alkali pretreatment, microbial-AFEX pretreatment, sulfur dioxide-impregnated steam explosion and alkali-microwave pretreatment.

Comparison of Different Pretreatment Technologies

As discussed above, a wide range of pretreatment technologies are at different stages of development. There is no ideal or preferred pretreatment method currently available for diverse feedstocks. Table 11 summarizes different pretreatment methods. The merits and demerits of different pretreatments are presented in Table 12.

Table 11. Summary of prospective pretreatment methods.

Pretreatment Method	Process	Feedstock	Temperature	Enzyme Loading	Yields	Inhibitor Generation	Limitations	Reference
Physical	Hot water washing	Corn stover	190°C	15 FPU/g glucan	90% glucose	Yes	Large water requirement, high temperature	(Mosier et al., 2005)
Chemical	Dilute sulfuric acid	Corn stover	140°C	60 FPU/g glucan	93% total sugars	Yes	Cost of equipment, need for neutralization	(Lloyd and Wyman, 2005)
	Ammonia Recycle Percolation	Corn stover	190°C /170°C	10 FPU/g glucan	92.5% glucose	Negligible	Requires two stages – increased cost/space	(Kim and Lee, 2005)
Biological	*Pleurotus ostreatus* (plus AFEX)	Rice straw	100°C	15 FPU/g glucan	>98% glucose	Negligible	Extremely slow and require hybrid pretreatments	(Jones et al., 2008)
Hybrid	Ammonia fiber expansion	Corn stover	90°C	60 FPU/g glucan	100% glucose and 80% xylose	Negligible	Ammonia cost and recovery	(Teymouri et al., 2005)
	Wet-oxidative lime	Corn stover	55°C	15 FPU/g cellulose	91.3% glucose and 51.8% xylose	Negligible	Slow, possible mass transfer limitations with oxygen	(Kim and Holtzapple , 2005)
	Acid-steam explosion	Corn stover	190°C	15 FPU/g glucan	85% glucose	Yes	Inhibitor generation, equipment cost	(Zimbardi et al., 2007)
	Microwave-assisted alkali	Switch-grass	190°C	15-20 FPU/g glucan	99% releasable sugars	Not reported	Energy costs of microwave, possible scale-up setbacks	(Hu and Wen, 2008)

Table 12. Merits and demerits of important pretreatment technologies

Pretreatment Technologies	**Merits**	**Demerits**
Physical	• Capable of handling coarse or larger size biomass • Eliminates the need of corrosive chemicals • Simplicity in operation • Generates little or none inhibitory chemicals	• Lower yield of sugars • Extremely high energy requirement for mechanical equipments • Requires additional pretreatment step
Dilute acid	• Abundant published data available for techno-economic analysis • Effective for diverse feedstocks • Effective in achieving high sugar yields via both hemicellulose hydrolysis and enzyme hydrolysis of cellulose fraction	• Requires costly acid-resistant bioreactor. • Requires downstream acid neutralization • Degrades sugars due to extreme condition • Generates inhibitory degradation products that could be toxic to fermentation microbes
Steam explosion	• Eliminates the need of extremely corrosion resistant equipment and reactor • Capable of handling high solids loadings • Suitable for hard woods	• Sugar degradation due to steam explosion reaction • Generation of soluble inhibitory products • Less effective on soft woods • Requires washing of pretreated biomass or conditioning of hydrolyzate to remove inhibitory products
AFEX	• Highly effective on agri-residues and herbaceous crops • Sugars are not degraded • High sugar yield • No generation of inhibitory chemicals	• Hemicellulose is not hydrolysed. Thus, both cellulose and hemicellulose fraction need to be hydrolyzed • High capital cost associated with capturing and recycling of ammonia

Enzymatic Hydrolysis

Many proposed full-scale lignocellulose ethanol plants plan to employ biochemical route. Although enzymes or acid can be used to facilitate the release of monomeric sugars from pretreated biomass, the former one is the preferred method due to low cost of enzymes, better sugar yield and less input of chemicals. Thus enzymatic hydrolysis is considered to be an integral part of biochemical method for ethanol production. Acid pretreatment does solubilize hemicellulose into monomers, which leaves behind lignin and cellulose. Unlike starch-based feedstocks where a single family of amylases is needed to hydrolyze starch to ethanol, cellulose hydrolysis requires a cocktail of several enzymes, cellulases for effective conversion of cellulose into fermentable sugars. The cellulase enzymes are typically produced by wood-rot fungi *Trichoderma reesei*. Other fungal species such as *Penicillin Funiculosum* and *Aspergillus niger* have also been extensively used for cellulose production. The cellulase production by these fungal species is already operating at pilot or industrial scales. Several other cellulase producing fungal species are *Trichoderma spp., Penicillium spp., Fusarium spp., Aspergillus spp., Chrysosporium pannorum,* and *Sclerotium rolfsii* (Philippidis, 1994). Bacteria also produce enzymes that are capable of hydrolyzing cellulose. Several cellulase producing bacteria are *Acidothermus cellulolyticus, Micromonospora bispora, Bacillus sp., Cytophaga sp., Streptomyces flavogriseus, Thermomonospora fusca, Thermomonospora curvata, Clostridium stercorarium and Clostridium thermocellum,* and *Ruminococcus albus* (Philippidis, 1994). Termites and other wood-feeding insects (e.g. beetles) are also able to digest lignocellulosic biomass (Watanabe et al., 1998).

The effective enzyme hydrolysis of lignocellulosic biomass requires stepwise removal of hemicelluloses or lignin prior to cellulose breakdown into fermentable sugars. Even though enzyme systems are available for degradation of lignin and hemicelluloses, chemical pretreatments, acid/alkaline are usually adopted for their removal (Saha, 2003). Dilute acid pretreatment usually hydrolyzes hemicelluloses to its sugar constituents, with the residues containing cellulose and lignin. The lignin can either be extracted with organic solvents like ethanol, butanol or formic acid prior to enzyme hydrolysis, or alternatively, hydrolysis of cellulose with lignin present is carried out. The enzymatic hydrolysis of cellulose is a key operation in biochemical conversion, which determines the quality and quantity of the end-product obtained, thus impacting the downstream processing.

Cellulase Enzyme

It is important to point-out that cellulase is not a single enzyme, but a cocktail of several enzymes. The depolymerization of cellulose requires three types of enzymes: (a) endo-β-1,4-glucanases (EG), (b) exo-β-1,4-glucanases (cellobiohydrolase) (CBH), and (c) β-1,4-glucosidases. Table 13 shows major cellulase enzyme systems, their specificity, and end products. Even though all cellulases act on chemically identical bonds, the β-1,4-linkage between two glucose units, they differ in terms of their site of attack on the cellulose chain. They are accordingly classified into two distinct groups: endoglucanases, the enzymes that act in the middle of the cellulose chain and exoglucanases, enzymes that act at either end of the cellulose chain.

(a) **<u>Endo-β-1,4-glucanases:</u>** The endoglucanases (EG) randomly cut into cellulose chains, thereby producing shorter cello-oligomers, also called cellodextrins, which can be further degraded by exoglucanases. EG accounts for between 15-20% of the extracellular protein when *T. reesei* is cultivated on cellulose. Endoglucanases are mainly active on amorphous (or less-ordered) parts of cellulose-producing soluble oligomers. Cellobiohydrolase comprises between 35 and 85% of the extracellular protein produced by *T. reesei*.

(b) **<u>Exo-β-1,4-glucanases (cellobiohydrolase) (CBH):</u>** Cellobiohydrolase cleavages predominantly produces cellobiose units from either the reducing or non-reducing the ends of cellulose chains and cello-oligosaccharides (Maija et al., 2003). While CBH mainly acts on crystalline regions of cellulose, there are conflicting accounts of the specificity of the enzyme in regards to its source and favored substrate (Wood, 1989).

(c) **<u>β-glucosidases:</u>** The third type of enzymes, namely β-glucosidases, make up less than 1% of extracellular protein produced by *T. reesei*; a majority being intracellular. The fungal and bacterial β-glucosidases hydrolyze cellobiose and a range of other β-glucosides, producing glucose. While the term β-glucosidase is taken almost synonymously with cellobiase, these enzymes act more readily with higher oligomers than on cellobiose (Marsden et al., 1985). This enzyme generally governs the overall cellulolytic process and is considered to be a rate-limiting step in the enzyme hydrolysis of cellulose because the accumulation of cellobiose inhibits both endogluconase and cellobiohydrolase activities. β-glucosidase activity is also subjected to end-product (glucose) inhibition.

Table 13 Major cellulase enzyme systems, their specificity, and end products

Action	Trivial names	Systematic names	Substrate	Bonds hydrolyzed	Reaction products
Endo	Cellulase, endoglucanase	1,4-β-D-glucan-4-Glucanohydrolase	Cellulose, 1,3-1,4- β -Glucans	1,4- β	1,4- β -dextrins, mixed 1,3-1,4- β -dextrins
Exo	Cellobio-hydrolase	1,4- β -D-glucancellobio-hydrolase	Cellulose, 1,3-1,4- β -Glucans	1,4- β	Cellobiose
Exo	Cellobiase	β –Glucosidase	β-D-glucosides	1,4- β 1,3- β 1,6- β	Glucose

(*Adapted from Maija et al., 2003.*)

Challenges of Enzyme Hydrolysis

The effectiveness of enzyme hydrolysis is very much dependent on the degree of disruption of lignin-cellulose-hemicellulose interactions during pretreatment with minimal generation of inhibitory soluble products. Thermal and chemical (acid/alkaline) pretreatments make the cellulose more readily accessible to enzymes by opening up cleavage sites. Such pretreatments also cause redeposition of thermally labile lignin that obscure the access of cellulase enzymes to cellulose. One recent study revealed a loss of enzymatic saccharification efficacy of up to 20% due to the surface deposition of lignin droplets on thermal/acid-pretreated biomass (Selig et al., 2007). The presence of lignin interferes with the enzyme hydrolysis by either blocking the enzymes access to cellulose or irreversibly binding the enzymes. Extreme chemical pretreatment is often needed to break lignin-cellulose-hemicellulose interactions for efficient enzyme digestion. Such pretreatment also generates soluble inhibitory products (such as acetic acid, furfural, hydroxymethylfurfural, formic acid, phenolic compounds etc.) (Hodge et al., 2008). Cellulose hydrolysis is also subjected to product inhibition. For example, the product cellobiose inhibits the enzymes endogluconase and cellobiohydrolase, while an accumulation of glucose inhibits the enzyme β-glucosidase. End-product inhibition can be alleviated by combining enzyme hydrolysis and fermentation known as simultaneous saccharification and fermentation (SSF). Commercial grain-ethanol process adopts SSF to minimize product inhibition.

Some of the major barriers to commercialization of enzyme hydrolysis of cellulose are:

- Substrate and product inhibitions
- Thermal inactivation
- Low product yield
- High cost of enzymes

Cost of Enzymes

The cost of enzymes is one of the major contributors to ethanol production costs in cellulosic ethanol. Commercial cellulase typically lacks the enzyme β-glucosidase. β-glucosidase prevents the accumulation of cellobiose which otherwise inhibits the enzymes, endogluconase and cellobiohydrolase. Thus addition of β-glucosidase is needed in enzyme solutions, subsequently increasing costs. The cost of enzyme has gone by nearly 20-fold in recent years. A significant effort toward enzyme cost reductions is a result of a US DOE grant to two major enzyme producers: Genencor and Novozymes. In recent years, enzymes went from $0.50 per gallon of ethanol to $0.10-$0.30 per gallon of ethanol (Hettenhaus et al., 2002). Another study reported enzyme costs of around $0.25/gallon for lignocellulosic feedstock in California (Williams et al., 2007). For the economic viability of cellulosic ethanol, the enzyme cost should be $0.045-0.09. For corn-based ethanol plants, the enzyme cost is just around $0.03-0.04/gallon ethanol. Thus, further cost reductions are still needed for economic viability of lignocellulose-ethanol plants. Enzyme recycling may be adopted to hydrolyze multiple batches of substrate and may reduce the overall enzyme cost. This can be achieved by immobilizing enzymes on an inert carrier.

Fermentation

The commercial yeast *Saccharomyces cerevisiae* is the most preferred microbial catalyst for ethanol fermentation due to its adaptability and tolerance. *S. cerevisiae* can effectively ferment hexoses such as glucose, but it cannot ferment pentoses such as xylose and arabinose. Lignocellulosic biomass yields a mixture of pentose and hexose sugars, and several inhibitory soluble compounds including organic acids, furan derivatives and phenolic compounds formed during pretreatment. Lignocellulosic biomass such as hardwood and agri-residues contain 5 to 20% pentose sugars - xylose and arabinose. Xylose is often the most abundant pentose sugar in hydrolyzate. Thus research efforts are directed towards developing microbial catalysts capable of fermenting 5-carbon sugars.

Xylose-fermenting microbes include bacteria, yeast and micro-fungi. Anaerobic bacteria can ferment pentoses, but are inhibited by very low concentrations of sugar and ethanol. Yeast, *Pichia stipitis*, can also ferment xylose into ethanol with reasonably high yields. The yeast is, however, inhibited by the soluble products generated during pretreatment. Fungi are more tolerant to toxic compound; but the rate is slow (Hahn-Hägerdal et al., 2006). There is no known natural microbe capable of fermenting 5- and 6-carbon sugars simultaneously. Recent efforts have focused on genetically engineered microbes with the capacity of fermenting a mixed sugar stream effectively. *Escherichia coli* and *Klebsiella oxytoca* are two examples of microbes engineered to ferment pentose by inserting ethanologenic genes from *Zymomonas mobilis.* Xylose-fermenting *S. cerevisiae* was generated by introducing genes for xylose-metabolizing enzymes from *P. stipitis* and xylose-fermenting *Zymomonas mobilis* was generated by introducing genes for xylose-metabolizing enzymes from *E. coli.*

In addition to fermenting a mixed sugar stream, the microbes should also be able to tolerate the inhibitory compounds formed during pretreatment. Thus prior detoxification of inhibitory compounds is needed for effective fermentation.

Process Integration

A greater degree of process integration is already in practice for starch-based feedstock where all unit processes/operations have been optimized to reduce the production cost of ethanol and maximize the recovery of value-added products. For lignocellulosic feedstock, there are considerable unknowns involved in the overall selection of processes. For example, pretreatment types, the choice of co-products/value-added products govern the selection of processes in downstream processing. Since cellulosic-ethanol is still at the pre-commercialization stage, it requires significant research and feasibility demonstrations to develop the most efficient process. The process integration needs careful consideration with respect to the following issues:

Value-added products: The generation of high-value products from residues/wastes of cellulosic-ethanol plant may require multiple separate steps/processes to form a biorefinery. Some of the co-products include lignin, stillage, and carbon dioxide. The co-products could be subjected to value-added processing. In a larger biochemical processing facility (~10,000 dMt/day), a substantial amount of lignin (1,500 to 2,000 tonnes/day) is generated. Thus, a separate medium-sized gasification plant can be set-up for lignin conversion into ethanol through a thermochemical route (Foust et al., 2008). Lignin may also be burned in a boiler for the production steam to satisfy factory power and process energy requirements.

Two-stage fermentation: One of the major challenges with cellulosic ethanol is the fermentability of a mixed sugar stream in the hydrolyzate. Microbial catalysts require different optimal conditions to achieve maximum yields from pentose and hexose sugars. Therefore, a two-stage fermentation process may maximize the production yield because each unit could be optimized independently. It may also provide the opportunity to convert part of sugars into high-value products. For example, pentose sugars can be converted into xylitol or levulinic acid (IEA Bioenergy, 2008).

Simultaneous saccharification and fermentation (SSF): SSF is well adopted in starch-based ethanol. The same concept can also be applied in cellulosic ethanol provided that pentose-sugar does not inhibit hexose fermentation. Similarly, the use of thermophilic bacteria can also provide an opportunity to simultaneously ferment 5- and 6-carbon sugars in SSF.

Biofuel Yield

The overall conversion efficiency of biomass to bioenergy is around 35%. The efficiency can be improved with recovery and inclusion of heat/power and by-products in the system (IEA Bioenergy, 2008). Biochemical pathway is expected to yield around 70 to 90 gallon of ethanol per dry ton of biomass (Foust et al., 2008). It is important to note that the yield is highly depended on feedstock types, and pretreatment methods among others.

Co-Products from Lignocellulosic Ethanol Plants

Ethanol is essentially the major product. Co-products are the residues generated in the processes and are additional revenue sources. For example, co-products in corn-ethanol plants account for 20 to 30% of total revenue generation (Khanal, 2008). Thus a recovery of value-added products is extremely important for the sustainability of a biofuel biorefinery. Some of the co-products from lignocellulosic ethanol plant include:

Lignin: Lignin, which represents the third largest fraction of lignocellulosic biomass (10-30% of biomass), is not convertible into fermentable sugars. It is therefore extremely important to recover and convert biomass-derived lignin into high-value products to maintain economic competitiveness of cellulosic-ethanol processes, which includes either direct burning of lignin in a gasifier or conversion into syngas for synthesis into biofuels. Lignin separation is also important to prevent inhibitory effects in downstream processing such as enzyme hydrolysis. The lignin from pretreated residues is recovered typically by precipitation (Lora and Glasser, 2002). The lignin recovered is largely insoluble in water under neutral or acidic conditions. It is soluble in organic solvents and in aqueous alkali, and it can be recovered with a low content of contaminants such as sugars and ash. Some lignins originating from the development of various biomass conversion processes have been available. Among these were commercial lignins including Sucrolin and Angiolin, produced on pilot-scale from residuals of the industrial production of furfural from sugarcane bagasse. Currently, there are a number of lignin-based products in the development stage from cellulosic-ethanol processes (Lora and Glasser, 2002).

<u>Stillage:</u> A substantial quantity of stillage is derived from lignocellulosic ethanol plants. For every liter of ethanol produced, 11.1 liters of stillage is generated. Generally, stillage has a relatively low pH (5.35±0.53) and high organic matters (with COD 61.3±40 g L^{-1} and BOD, 27.6±15.2 g L^{-1}) (Wilke et al., 2002). The authors reported the following characteristics of stillage: total nitrogen, 2787±4554 mg L^{-1}; total phosphorus, 28±30 g L^{-1}; sulfate, 651±122 g L^{-1}. Significant increases in ethanol production will require an effective solution for residue management. Value-added processing is essential for the sustainability of an ethanol plant. The cellulosic-based ethanol stillage is not as nutritious as corn-based stillage. Thus other alternative applications of stillage need to be examined. The solids following ethanol recovery can be separated through centrifugation. The solid cake is then sent to boiler for heat/steam generation. The liquid stream (centrifugate) can be anaerobically digested to produce methane gas, which can be burnt for energy recovery. The treated effluent can be recycled for in-plant use.

Water/Wastewater Treatment and Recycling

Water demand in cellulosic ethanol plant will be one of major issues. It takes about 4 gallons of water to produce one gallon of ethanol in a typical corn based ethanol plant. There have been debates on the enormous water demand in ethanol biorefineries, in which the numbers are tremendously increasing. At a later stage, the maturity and establishment of cellulosic biofuel refineries will demand even greater amounts of water: ~ 6 gallon water for every gallon of ethanol produced. It is therefore critical to consider an adequate supply and optimized usage of water in all biorefineries (Alen, 2007).

Recycling of water back to the processing stages in a biorefinery may be one possibility for minimizing water consumption, but it may be limited by the solid, organic and hazardous contents present in the wastewater. The wastewater from such refineries cannot be treated at municipal treatment facility because of its inherent characteristics, the geography of most biorefineries and inadequate processing infrastructures at a local authority. Onsite wastewater treatment and water recycling schemes benefit the biorefinery by: (1) reducing the requirement of fresh water, (2) installing proprietary standard treatments, subsequently increasing revenue by reducing treatment costs while raising energy (e.g. biogas and solid fuel) generation, and (3) limiting pollution to water bodies.

Cost Analysis of Lignocellulosic-ethanol

Few literatures regarding the current economic feasibility of biomass pretreatment and the overall production of bioethanol exist due to the complexity of the analysis and the large number of variables that change from year to year. The current estimated production costs of cellulosic ethanol show a considerable variation ranging from \$2.27- \$4.92 per gallon. The cost may go down to as low as \$0.95 to \$1.32 with further measures in cost reduction (IEA Bioenergy, 2008). Some of the factors influencing the overall cost of cellulosic ethanol are:

- Feedstock cost
- Processing cost (including labor cost, pretreatment cost and other chemical costs)
- Enzyme cost
- Energy cost
- Revenue generation from by-products
- Current petroleum price

Different feedstock costs are reported in the literature ranging from $25 to $50 per dry ton. Foust et al. (2008) reported that a feedstock cost of $35/dry ton (based on 2002 dollars) could provide economically viable lignocellulosic biorefinery, of which $10 was allocated for grower payments (to cover the actual value of biomass). The remaining amount covered feedstock supply system costs. The expanding cellulosic-ethanol plant may drastically increase the demand of feedstock thereby raising the feedstock cost. There is certainly an upper limit that biorefinery industries can afford to pay to remain competitive in the market. This will essentially stabilize the cost in a long-term.

Foust et al. (2008) reported the production cost of around $1.31 per gallon ethanol. This is equivalent to $1.91 per gallon gasoline after considering the ethanol energy content of 2/3 in comparison to gasoline. In another feasibility study, Williams et al. (2007) reported ethanol production costs of $1.67/gallon assuming feedstock costs of $ 44/dry Mg at a plant in California. The plant capital cost was assumed to be $2.88 per gallon-annual capacity.

Eggeman and Elander (2005) defined the minimum ethanol selling price (MESP) as the retail price of ethanol that generates a net zero value for the present worth of a project when cash flows are discounted 10% after tax. The authors used the MESP to compare the performances of the following types of pretreatments: dilute acid, hot water, AFEX, ARP and lime, and compared it with an ideal case and a control. Using the fourth year of operation for comparison, it was suggested that dilute acid pretreatment of biomass may be the most viable due to its lower plant level cash cost and subsequently lower MESP (about $1.35). The comparison however, is highly speculative since a number of factors must be considered for a rigorous economic analysis of biomass processing, like biomass-specific structural recalcitrance and fermentable sugar content.

Recently, Sendich et al. (2008) revaluated the feasibility of AFEX pretreatment of corn stover in response to a paper published in 2005, which predicted a minimum ethanol selling price (MESP) of about $1.41 per gallon of ethanol. Sendich et al. (2008) proposed that the utilization of an improved ammonia recovery system and reduced ammonia loadings could reduce the MESP to $1.03 per gallon for simultaneous saccharification and fermentation processes (SSF). It was further suggested that the replacement of SSF by consolidated bioprocessing (CBP), which eliminates the need to purchase enzymes, would reduce the MESP to as low as $0.80 per gallon.

The feedstock, enzymes and biomass pretreatment are three of the biggest contributors to ethanol production costs and have subsequently been a subject of research for decades. The feedstock, in particular, contributes up to 35.5% of the final cost of ethanol (Piccolo and Bezzo, 2009). Improvements in technology however, have the potential to reduce expenses significantly and increase the viability of biorefineries. In recent years, enzymes went from \$0.50 per gallon of ethanol to \$0.10-\$0.30 per gallon of ethanol (Hettenhaus et al., 2002), but further cost reductions are still required. Biomass pretreatment-associated costs reflect the strategies employed, but estimates for current technologies are around \$0.11 per gallon of ethanol. The National Resources Defense Council (NRDC) suggests that cost reductions of 22%, 65%, and 89% can be made to feedstock, pretreatment, and enzyme related costs as the bioethanol technology matures; the result being a final cost of \$0.63 per gallon of ethanol with mature ethanol processing compared to the presently achievable \$1.26 per gallon of ethanol (Greene and Mugica, 2005).

The capital cost of lignocellulosic-ethanol production depends on types of pretreatment adopted. Although no significant difference in capital costs was found among different pretreatments as depicted in Table 14, there is a significant need to cut-down the pretreatment cost.

Table 14. Capital cost for various pretreatments for biochemical conversion

Pretreatment types	Total fixed capital \$ M	Annual plant capacity MGY	Fixed capital cost \$/gallon
No pretreatment	200.3	9	22.26
Dilute acid	208.6	56	3.71
Hot water	200.9	44	4.58
Steam-explosion	190.4	53	3.60
AFEX	211.5	57	3.71
ARP	210.9	46	4.54
Lime	163.6	49	3.33
Ideal pretreatment	162.5	64	2.50

Adapted from IEA Bioenergy (2008)

Current Status of Cellulosic-ethanol Facilities

Considerable efforts are being made towards commercialization of cellulosic ethanol. Several pilot and demonstration plants are under development or in operation.
Some of the well known biofuel industries are the major players in the development of 2nd generation fuel. For example, Poet (formerly Broin), which operates a network of 26 plants, is aiming for cellulosic ethanol using corn-cob, fiber and corn stover at Emmetsburg, Iowa. For the 125-MGY plant, 25% of ethanol will be produced from the cellulosic feedstock. The biorefinery is projected to start in 2011. Iogen, an enzyme producer based in Ottawa Canada has been running a 40 t/day pilot-scale cellulosic ethanol using wheat straw and corn stover.

Some of these biorefineries under development/construction are summarized in Table 15.

Table 15. Cellulosic-ethanol plants under development/construction

Company	**Location**	**Capacity**	**Technology**	**Feedstock**
Abengoa Bioenergy LLC	Colwich, KS Hugoton, KS York, NE	11.36 mgy 11.6 mgy 11.6 mgy	Bio-chemical	Corn cobs, corn stover, switchgrass, wheat straw, milo stubble, and other biomass
AE Biofuels	Butte, MT	small scale	Ambient Temperature Cellulose Starch Hydrolysis	Switchgrass, grass seed, grass straw, and corn stalks
Bluefire Ethanol	Corona, CA Lancaster, CA	18 mgy 3.1 mgy	Arkenol Process Technology (Concentrated Acid Hydrolysis Technology Process)	Municipal solid waste
California Ethanol + Power, LLC	Brawley, CA	55 mgy		Local Imperial Valley grown sugarcane; facility powered by sugarcane bagasse
Coskata	Madison, PA	40,000 gal/yr	Biological fermentation technology; proprietary microorganisms and efficient bioreactor designs in a three-step conversion process that can turn most carbon-based feedstock into ethanol	Any carbon-based feedstock, including biomass, municipal solid waste, bagasse, and other agricultural residue
DuPont Danisco Cellulosic Ethanol LLC	Vonore, TN	250,000 gal/yr	Enzymatic hydrolysis technology	switchgrass, corn stover, corn fiber, and corn cobs
Iogen Biorefinery Partners LLC	Shelley, ID	18.49	Bio-chemical	Wheat straw
POET	Scotland, SD Emmetsburg, IA	20,000 gal/yr 31.25 mgy	BFRAC™ separates the corn starch from the corn germ and corn fiber, the cellulosic casing that protects the corn kernel	Corn fiber, corn cobs, and corn stalks
Verenium	Jennings, LA Highlands County, FL	1.4 mgy 36 mgy	C5 and C6 fermentations	sugarcane bagasse, specially-bred energy cane, high-fiber sugar cane

Company	Location	Capacity	Technology	Feedstock
Range Fuels Inc.	Soperton, GA	20 mgy	Two-step themo-chemical process	Wood chips (mixed hardwood)
Ecofin LLC	Washington County, KY	1.3 mgy	Solid state fermentation process developed by Alltech	Corn cobs
ICM	St. Joseph, MO Shelley ID	1.51 mgy 18 mgy	Enzyme technology	Switchgrass, forage sorghum, corn stover, wheat straw, barley straw, and rice straw
Lignol Innovations	Grand Junction, CO	2.50 mgy	Biochem-organosolve	Woody biomass, agricultural residues, hardwood, and softwood
Mascoma	Monroe, TN	2.01 mgy	Bio-chemical bio-refineries	Switchgrass and hardwoods
Mascoma/New York State Energy Research and Development Authority/New York State Department of Agriculture and Markets	Rome, NY	5 mgy	"Consolidated bioprocessing" refinery would use genetically modified bacteria to break down and ferment local wood chips	Lignocellulosic biomass, including switchgrass, paper sludge, and wood chips
Mascoma/Michigan Economic Development Corporation/Michigan State University/Michigan Technological University	Chippewa County, MI	40 mgy	"Consolidated bioprocessing" refinery would use genetically modified bacteria to break down and ferment local wood chips	Lignocellulosic biomass, including switchgrass, paper sludge, and wood chips
Pacific Ethanol	Boardman, OR	2.7 mgy	BioGasol	Wheat straw, stover, poplar residuals

Company	Location	Capacity	Technology	Feedstock
RSE Pulp	Old Town, ME	2.19	Bio-chemical bio-refineries	Woodchips (mixed hardwood)
Verenium	Jennings, LA	1.40	Bio-chemical bio-refineries	Bagasse, energy crops, agricultural residues, wood residues

(Adapted from IEA Bioenergy, 2008, 2009 Ethanol Outlook Report http://www.ethanolrfa.org/industry/outlook/)

Cost Analysis of Cellulosic Ethanol in Hawaii

The major lignocellulosic feedstocks (e.g. guinea grass, banagrass, eucalyptus, and leucaena) for ethanol production in Hawaii are discussed in an earlier section. More reliable yield data based on field-scale studies are currently lacking. Most of the estimates are based on studies conducted on experimental plots under controlled conditions (Ogoshi, 2008). In a recent study, Yanagida et al. (2008) examined the economic feasibility of three cellulosic feedstocks (e.g. banagrass, Eucalyptus, and Leucaena) for Hawaii and compared the feedstock cost per gallon of ethanol, break-even price of feedstock, and break-even price of ethanol. From Table 16, it is apparent that banagrass and Leucaena have the lowest feedstock cost per gallon of ethanol.

Table 16. Comparison of biofuel yields, feedstock cost/gallon for biofuel crops

Crop	Biomass yield (ton/ac/year)	Conversion factor (gal/ton biomass)	Ethanol (gal/ac/year)	Feedstock cost ($/gallon)
1. Sugarcane	23.8	19.5	464.1	$ 2.01
2. Banagrass	21.5	67	1440.5	$ 0.88
3. Eucalyptus	7.8	65	507	$ 1.56
4. Leucaena	8.8	65	572	$ 0.83

Adapted from (Yanagida et al., 2008)

Net returns (based on feedstock price) and the break-even prices for feedstock are not available for Eucalyptus and Leucaena due to lack of reliable feedstock price data. Of the remaining feedstocks reported, only banagrass showed a positive net return per acre (Table 17). For these feedstocks, high production costs are primarily due to field operation costs (fertilizer, pesticides and other chemical applications) as well as harvesting costs. With improved yields, the cost component can be reduced and net returns can also be improved. It should also be noted that the conversion technology for cellulosic-ethanol is still under development. Thus, production costs may not accurately reflect the industrial practice and the results should be interpreted with caution.

Table 17. Summary of production, costs, gross revenues and net revenue for sugar and selected cellulosic feedstocks for Hawaii.

Cost items	Unit	Sugarcane	Banagrass	Eucalyptus	Leucaena
Net revenue (per acre)	acre/year	-$119.61	$538.75	N/A	N/A
Break-even price of feedstock	$/ton	$39.27	$58.80	N/A	N/A
Break-even price of ethanol	$/gallon	$3.08	$2.24	$3.18	$2.45

Adapted from (Yanagida et al., 2008)

Other lignocellulosic feedstocks such as guinea grass, energy cane and sweet sorghum may be more attractive for biofuel production due to better yield. Studies are currently underway to examine their yields under different environmental and soil conditions in large-scale demonstration plot in Big Island.

5.4 Pyrolysis

Pyrolysis, is a process in which biomass is heated rapidly to 450 to 500°C in the absence of oxygen. The biomass feedstock decomposes and when the products are brought to ambient conditions, the result is a mixture of solid char, permanent gases, and liquid phase. Pyrolysis processes are designed to maximize the production of the liquid called bio-oil or pyrolysis oil. The yield of bio-oil from wood and paper range from 60 to 80% (weight) and 75 to 93% (weight), respectively, correlating with cellulose content of the biomass material. Char and permanent gases account for 4 to 30% and 2 to 20%, respectively, of the initial feedstock mass. The composition of bio-oil is approximately 20-25% water, 25-30% water insoluble pyrolytic lignin, 5-12% organic acids, 5-10% non-polar hydrocarbons, 5-10% anhydrosugars, and 10-25% other oxygenated compounds (Anon, 2001; Oasmaa and Peacocke, 2001; Oasmaa *et al*., 1997). Bio-oil has a heating value of ~7,500 BTU per lb, similar to that of most solid biomass fuels at 10 to 12% moisture. As a liquid fuel, bio-oil has an energy density of ~75,500 BTU per gallon, about 55% of the value for fuel oil. A summary of bio-oil characteristics for Ensyn's RPT™ Process is provided in Table 18 for a variety of feedstocks.

Commercial pyrolysis units are available from two Canadian companies, Ensyn Corporation of Ottawa and DynaMotive Energy Systems Corporation of Vancouver. Pyrolysis oils have commercial markets, mainly as liquid smoke that is applied to meat products. Red Arrow International LLC of Manitowoc, Wisconsin, is perhaps the best known company marketing this product. Bio-oil may also be used as a chemical intermediate that can be fractionated into its chemical constituents and sold to chemical markets, although this is not currently practiced commercially. Energy products show potential but have seen limited implementation at commercial scales (Freel and Graham, 2000). Red Arrow uses bio-oil to satisfy 6 MW_{th} of industrial energy demand at their manufacturing facility. Bio-oil has also been cofired with coal in a grate-fired, utility boiler in Wisconsin near Red Arrow's manufacturing facility. Minor modifications were performed on the boiler to allow injection of steam-atomized bio-oil in the over-fire area above the grate. The bio-oil accounted for 5% of the total fuel energy input and emission and performance evaluations concluded that there were no noticeable changes compared to coal.

Table 18. Typical bio-oil yield and quality from Ensyn RTP™ Process

Feedstock	Wood	Bark	Bagasse	Corn Fiber	Mixed Paper
Typical Product Yields[1] (weight %)					
Bio-Oil	71-80	60-67	75-81	71-76	71-93
Char	12-20	16-28	12-14	7-14	4-20
Gas	5-12	8-17	5-10	10-17	2-12
Bio-Oil Higher Heating Value					
BTU per lb	6,800-8,400	7,780-8,900	7,670-8,350	7,100-8,250	6,700-8,000
BTU per gal	75,500	81,500	79,500	73,500	74,000

[1] Yields are on an ash-free basis

With additional processing bio-oil can be used in combustion turbines. In boilers, bio-oil does not provide energy advantages over firing biomass directly, as any gain in efficiency is more than offset by the energy expended to produce the bio-oil. The potential advantage of bio-oil in steam boiler applications is that it generally has a greater energy density (BTU per ft^3) than the parent biomass material which can be useful if it is necessary to transport fuel from point of production to point of use. There are clear advantages for using bio-oil in combustion turbines and other power generation systems that have higher conversion efficiency than steam-based units and cannot use biomass directly. The use of bio-oil in higher efficiency units will need to address technical challenges. The composition and fuel properties of bio-oil differ considerably from commonly used petroleum-based fuels for which most conversion technologies were developed. Depending on the feedstock and the type of fast pyrolysis method employed, bio-oil composition may also vary significantly. These differences should be taken into consideration in the selection of bio-oil-fired power generation units (Anon, 2001; Anon, 2001a).

Bio-oil may also be upgraded to produce clean transportation fuels using unit operations typically found in an oil refinery. This pathway for bioenergy development could potentially take advantage of existing refinery conversion infrastructure and the products would be compatible with distribution equipment. Hydroprocessing would remove oxygen from the bio-oils compounds using high pressure hydrogen in the presence of catalyst to produce hydrocarbon compounds (NSF, 2008).

Orenda, a division of Magellen Aerospace, is offering combustion turbine units fired on bio-oils. An Orenda representative, Ron Tingle, visited the state seeking opportunities for a biomass fueled installation (Tingle, 2005). In preparing this report, Mr. Tingle was contacted for an update on Orenda's activities. Orenda has teamed with Dynamotive to develop an energy project located at a hardwood floor manufacturing facility near Toronto. The facility will convert 100 ton per day of wood waste to produce 70 tons of bio-oil, 10 tons of char, and 10 tons of permanent gases. The unit is nearly ready to commission, and in full operation will produce 2.5 MW of electricity from Orenda's OGTS2500 combustion turbine and supply 12,000 tons of process steam per hour. The total project cost is estimated at $10.7 million for engineering design, equipment supply, construction, and commissioning. Mr. Tingle also mentioned that he has been in contact with another pyrolysis unit developer that is working on a smaller portable unit that can be used in forest thinning operations. The bio-oil could then be transported to a centrally-located, power plant. The Orenda combustion turbine unit can also be relocated within the constraints imposed by grid access for power distribution and access to required operating utilities. Although not proven technology, this portable pyrolysis unit could be considered for use in alien species eradication efforts.

Byproduct char produced by pyrolysis can be burned as an energy source to provide necessary process heat. Recent interest has developed around the use of carbonized biomass as a soil amendment to improve soil quality and as a means of carbon sequestration.

5.5 Gasification

Gasification is the partial oxidation of a solid fuel to form a combustible gas. Generally, the goal of a gasification process is to simultaneously maximize the solid fuel carbon conversion and the heating value of the product gas. Air and steam are commonly used oxidizers when electricity is the desired end product. Oxygen can also be used but the additional expense required to produce a concentrated oxygen stream for the process limits this option to applications where the product gas is to be used to synthesize higher-valued chemical compounds.

The composition of biomass varies depending on the species and local growing and harvesting conditions. Nonetheless, on a dry mass basis, biomass typically contains about 48% carbon, 6% hydrogen, and 42% oxygen with the remainder composed of inorganic elements. The fraction of each component varies depending on the type of biomass. Wood for example typically has very little (~0.5%) inorganic material whereas grass species may have ~5%. When subjected to proximate analysis, biomass typically contains ~80% volatile matter and 15% fixed carbon. The volatile matter is classified as the amount of fuel mass which is driven off as a gas when a sample is heated in an inert environment. Complete oxidation using air to produce carbon dioxide and water follows the reaction;

$$\overbrace{CH_{1.5}O_{0.7}}^{Biomass} + 1.025\overbrace{(O_2 + 3.7N_2)}^{Air} \longrightarrow CO_2 + 0.75H_2O + 3.79N_2$$

This reaction defines a stoichiometric air-fuel ratio of ~5.6 (mass basis) for biomass combustion, neglecting the mass of ash in the fuel. Boilers are often operated with rates of excess air from 30% to 100% of stoichiometric, (air-fuel ratios of 7.3 to 11.3 (mass basis)), to ensure complete combustion and control temperature. Air blown gasifiers typically operate at about 30% of stoichiometric air (air-fuel ratio of 1.7 (mass basis)) and produce gas composed of CO_2, CO, H_2, H_2O, CH_4, N_2, and higher hydrocarbon compounds. The mixture of these components will vary depending on the gasifier technology employed. Air blown gasifiers are directly heated in that some portion of the fuel reacts with the oxygen and provides the heat required to volatilize or gasify the remainder. Steam may also be fed to an air-blown gasifier to moderate temperatures near the air injection point and to improve carbon conversion and gas quality by increasing the rate of the reaction:

$$\mathrm{C}_{\mathrm{solid}} + \mathrm{H_2O}_{\mathrm{steam}} \longrightarrow \mathrm{CO} + \mathrm{H_2}$$

Product gas from air blown gasifiers has a higher heating value in the range of 100 to 135 BTU per ft^3 [1]. A typical gas composition is shown in Table 19. A typical dry gas yield for an air-blown gasification system is ~32 dry ft^3 per lb of dry fuel. Note that this includes the nitrogen input from the fluidizing air.

Table 19. Typical gas composition from pressurized air blown biomass gasifier.

Gas Component	Air Blown	Steam Blown
H_2	9	22.2
CO	14.1	43.2
CH_4	9	15.8
CO_2	19.2	13.5
N_2	47.4	
Higher Hydrocarbons	1.3	5.5

Most of the development efforts currently under way which seek to match biomass gasifiers to combustion turbines have selected bubbling or circulating fluidized bed technologies for the gasification reactor. Schematics of these two types are shown in Figure 9. Fluidized beds contain fine, inert particles of sand or alumina which have been selected for size, density and thermal characteristics. As gas is forced through the bed from below with increasing velocity, a point is reached when the frictional force between particle and gas counterbalances the weight of the particle. This is the point of minimum fluidization, and increases in gas flow rate beyond this point result in bubbling and channeling of the fluid through the bed media. Bubbling fluidized beds are operated in this regime. As shown in Figure 9 (a), the bubbling fluidized bed reactor design includes a larger diameter section at the top, called the disengagement zone, which reduces the flow velocity allowing unreacted fuel and bed particles to return to the lower section of the reactor. Continued increases in gas flowrate beyond minimum fluidization velocity reach a point where the terminal velocity of char and bed particles is exceeded and particles become entrained in the gas flow. Circulating fluidized beds are operated in this manner and particles exiting from the top of the reactor are separated from the gas flow in a cyclone and returned to the bed. In both types of fluidized beds, the inert particles are initially heated at start-up and then serve as an ignition source and thermal energy carrier at steady state conditions. Table 20 provides a comparison of bubbling and circulating fluidized bed characteristics.

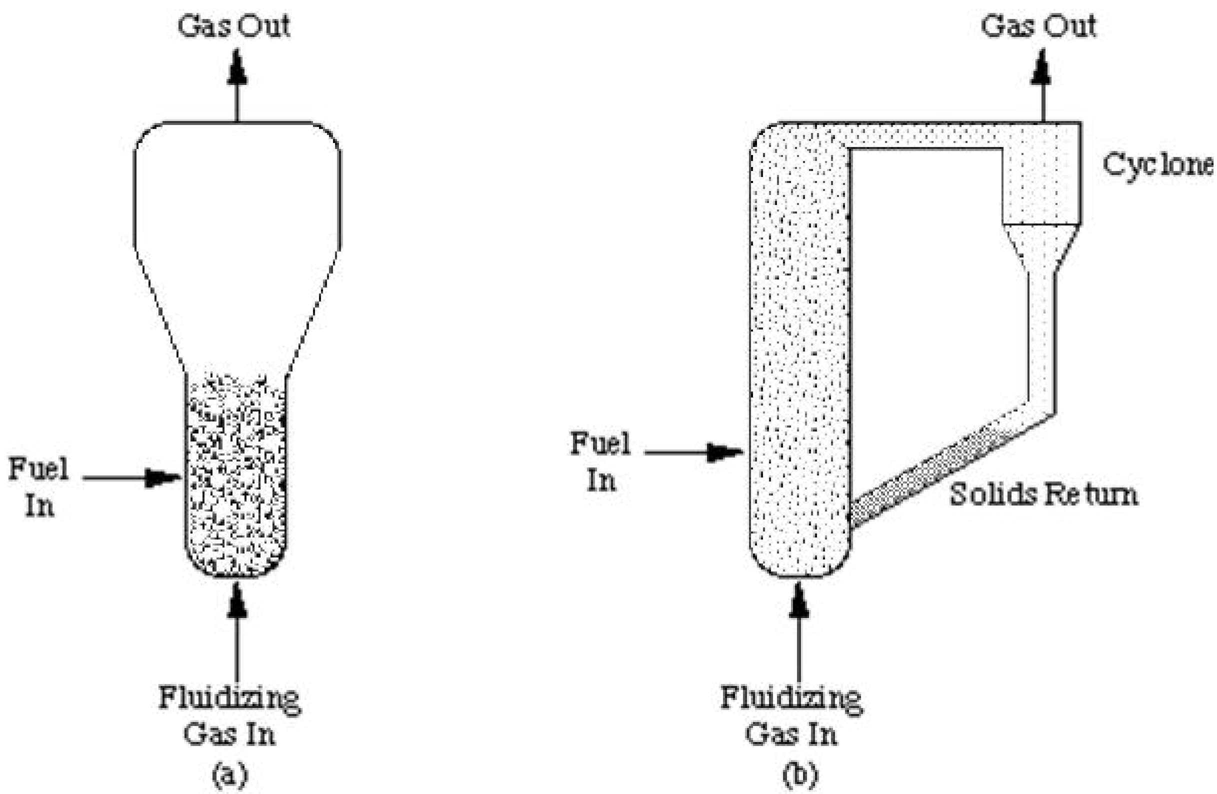

Figure 9. Schematics of bubbling (a) and circulating (b) fluidized bed gasifiers.

Table 20. Comparison of circulating and bubbling fluidized beds [2].

	Circulating Fluidized Bed	Bubbling Fluidized Bed
Gas Solid Reaction	Suitable for rapid reactions. Recirculation of small particles is crucial.	Yields a uniform product gas. Large bubble size may result in gas bypass through bed.
In-Bed Temperature Distribution	Temperature gradients in direction of solid flow; may be minimized by sufficient circulation of solids.	Exhibits a nearly uniform temperature distribution throughout the reactor.
Particles	Size of fuel particles determined by minimum transport velocity. High velocities may result in equipment erosion.	Ability to accept a wide range of fuel particle sizes including fines.
Heat Exchange and Transport	Heat exchange less efficient than bubbling fluidized bed, but high heat transport rates possible due to high heat capacity of bed material.	Provides high rates of heat transfer between inert material, fuel, and gas.
Conversion	High conversion possible.	High conversion possible.

Indirectly heated fluidized bed gasifier technology has also been developed. One variant of this is shown in Figure 10. Fuel is fed to a circulating fluidized bed gasifier containing hot bed material which uses low pressure steam as the fluidizing agent. Without oxygen present, the fuel is pyrolyzed and the volatiles react with steam producing a combustible gas. Pyrolysis is the thermal decomposition of fuel to form a mixture of gases when heated in the general temperature range from 200 to 600°C. With no oxygen present and limited amounts of heat, carbon conversion from solid to gas is incomplete, resulting in a mixture of char and bed material being entrained from the gasifier. This mixture of solids is separated from the product gas in a cyclone and directed to a second circulating fluidized bed which is blown with air and operated as a combustor, yielding a stream of flue gas and hot bed material. A second cyclone disengages the hot solids and they are returned to the gasifier to provide the heat required for fuel pyrolysis and reactions between fuel volatiles and steam. This system effectively decouples the gasification reactions from the combustion reactions, yielding product gas with a small amount of nitrogen compared to an air blown gasifier and a heating value of ~400 BTU/ft^3. Typical gas composition for an indirectly heated gasifier is shown in Table 19 and dry gas yields for this process are ~12 ft^3 of dry gas per lb of dry biomass (Bain *et al.*, 1997).

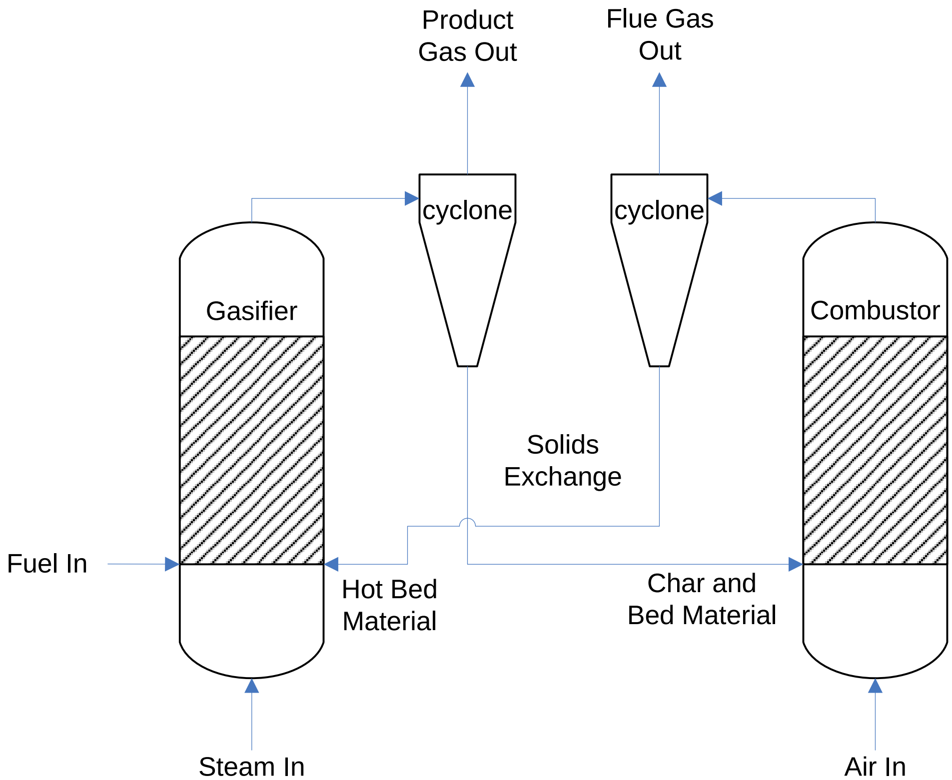

Figure 10. Schematic of indirectly heated fluidized bed gasifier.

5.5.1 Gasification for Power Generation

In a biomass integrated gasifier, combined cycle (BIGCC) application, the product gas would be fired in a combustion turbine to generate electricity in a topping cycle. The hot exhaust products are directed through a heat recovery steam generator (HRSG) and steam raised in this manner is used in a steam turbine to generate additional electricity in a bottoming cycle and to satisfy motive and thermal requirements at the installation. The use of a gas turbine requires the fuel gas and combustion air stream to be pressurized, typically to a minimum of 300 psi, depending on the design of the machine. Two configurations have been developed for meeting these requirements while integrating the gasifier with the power block. The first involves pressurizing the gasifier, maintaining pressure through gas conditioning equipment, and feeding the conditioned product stream to the combustor of the gas turbine. The second approach is to operate the gasifier and gas conditioning equipment at nominally atmospheric pressure, then compress the product gas to satisfy turbine requirements. The former approach is shown schematically in Figure 11. To date, no known BIGCC units are operating commercially.

The inputs to the system shown in Figure 11 include the biomass fuel, air, water, and materials such as catalysts or sorbents required in the gas conditioning block. Outputs from the system will include ash from the biomass fuel (typically 1-2% of the dry fuel input), electricity, and flue gas composed primarily of nitrogen, oxygen, and carbon dioxide. Flue gas also contains pollutants, particulate matter and permanent gas species, and these emissions are regulated by state and federal laws that require installation of best available control technology.

An alternative approach to generating power with product gas is to remove the combustion turbine from the system and directly fire the product gas in a boiler to generate steam. This approach is commercial, see for example http://www.primenergy.com/Gasification_idx.htm.

Smaller scale biomass gasification power projects (5 kW to 5 MW) using reciprocating engines are under commercial development in the U.S., India, and Europe. A plant at Skive in Denmark recently commissioned a bubbling fluidized bed with a fuel feed rate of 100 ton per day and an net electricity output of 5 MW from three reciprocating engine generator sets. The technical challenges encountered by the project developers for this plant included "scaling-up from pilot to commercial facilities, a lack of pre-existing long-term data and integrated plant control, missing detail from design information, and a long and costly commissioning period requiring extensive measurement and testing."

Minutes and presentations of a recent meeting of the International Energy Agency's biomass gasification task display the depth and breadth of the current activities related to this technology (see http://www.gastechnology.org/webroot/app/xn/xd.aspx?it=enweb&xd=iea/taskminutes.xml).

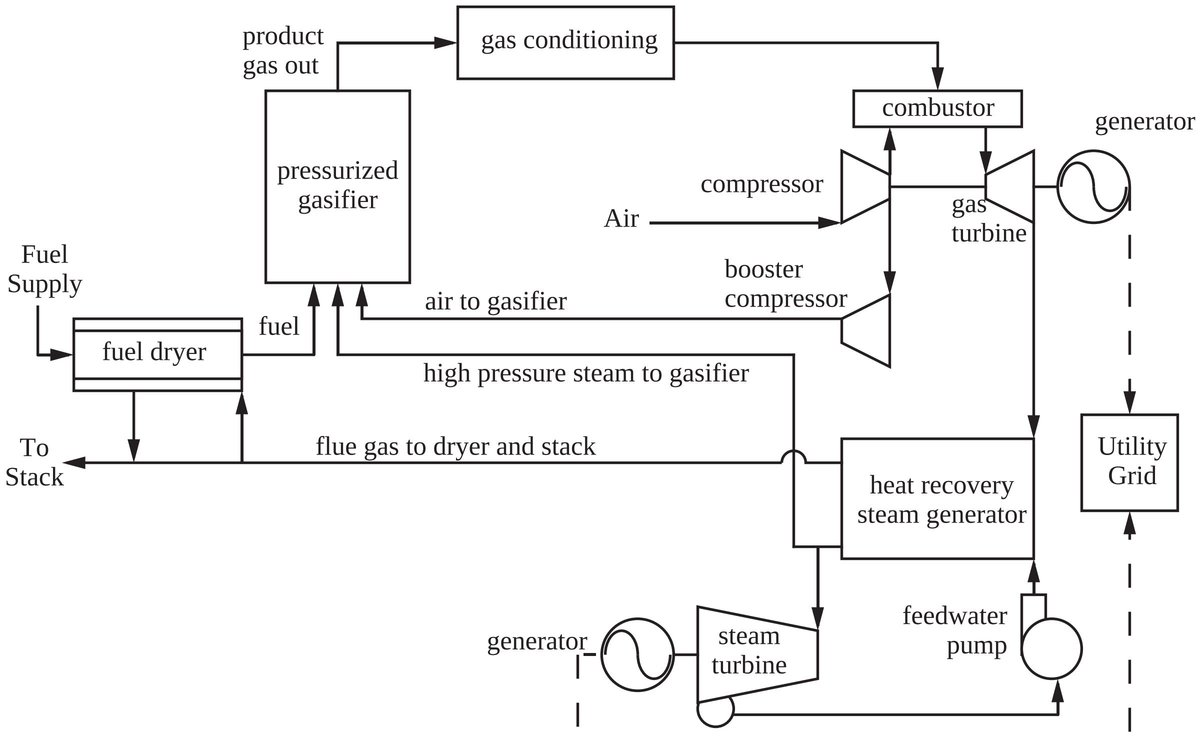

Figure 11. Schematic of pressurized biomass integrated gasifier combined cycle power system.

5.5.2 Gasification for Synthesis of Fuels and Chemicals

A variety of fuels and chemicals can be synthesized from gas rich in hydrogen and carbon monoxide commonly called syngas. Syngas containing a prescribed ratio of these two building block molecules is passed over a catalyst at specified conditions of temperature and pressure to synthesize target compounds. The basic concept of a catalyst reaction is that (1) the reactants (H_2 and CO) adsorb on the catalyst surface, (2) the reactants are rearranged in the adsorbed state to produce the desire product, and (3) the product is desorbed from the catalyst surface. Note that the catalyst is not consumed in the reaction. Hydrogen is also produced from the purification of syngas. The most common energy resource used for syngas production is natural gas (primarily methane) but it can be produced from any hydrocarbon material or biomass. A recent report by the National Renewable Energy Laboratory (Spath and Dayton, 2003) reviewed possible fuel and chemical products that might be produced from biomass via gasification and included hydrogen, Fischer Tropsch liquids, ammonia, methanol, dimethyl ether (DME), acetic acid, formaldehyde, methyl tert-butyl ether (MTBE), ethanol, and mixed higher alcohols as shown in Figure 12. Their review concluded that the best product to pursue were hydrogen and methanol and that ethanol from syngas could potentially be cost competitive but needed to be demonstrated at larger scales.

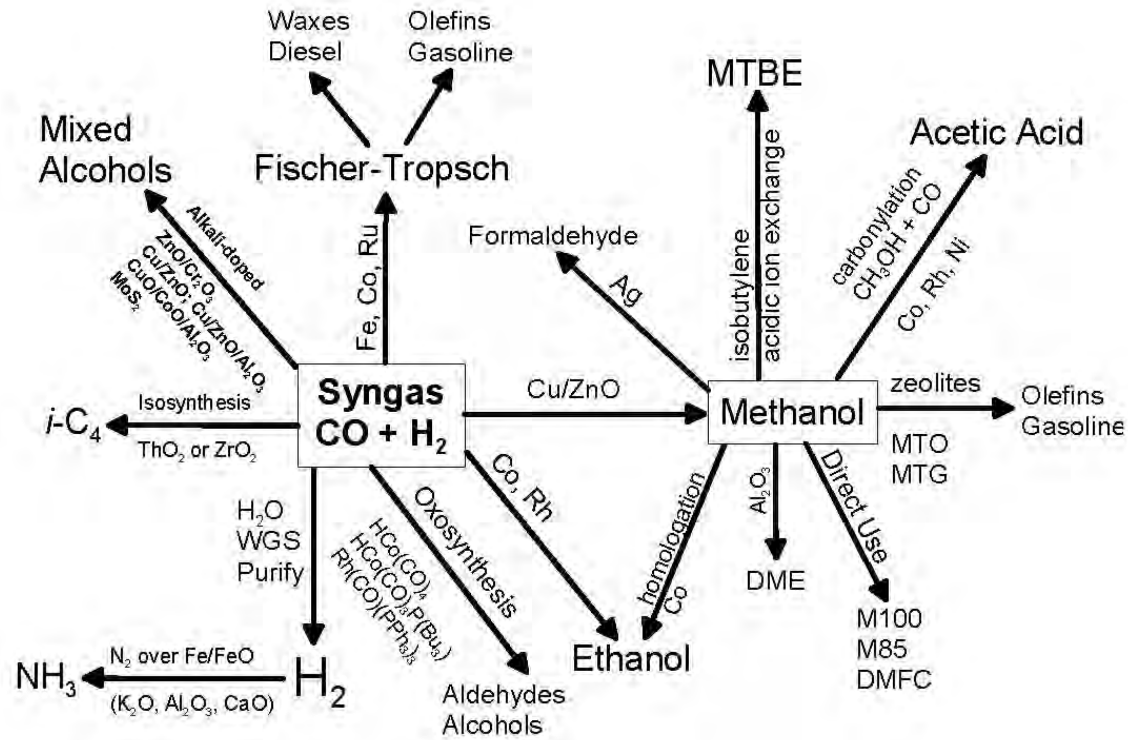

Figure 12. Potential fuel and chemical products from syngas (adapted from Spath and Dayton, 2003).

Fischer-Tropsch synthesis has primarily been focused on the production of synthetic diesel, often called FT diesel. The advantage of FT diesel is its compatibility with wetted materials in the distribution and end use sectors. FT diesel normally has a narrower range of molecules than diesel products refined from petroleum and has fewer contaminants, particularly sulfur species. This enables diesel engines to be tuned for better performance and reductions in emissions of particulate matter and oxides of nitrogen, both criteria pollutants.
http://www.nrel.gov/vehiclesandfuels/npbf/gas_liquid.html

SunFuels Hawaii LLC is a biomass to energy company based in Kamuela on Hawaii island that seeks to develop biomass to liquid fuels based on the Choren technology (www.choren.com). Choren is a leading gasification company now developing the first commercial facility in Europe to produce synthetic SunDiesel™ fuel. Choren's fuel development is backed by minority partners Royal Dutch Shell and automakers Daimler and Volkswagen.

ClearFuels Technology, a local company, has licensed a process technology from Pearson Technology Inc. to produce synthesis gas. The process has been demonstrated at a scale of 5 tons biomass per day at Pearson's pilot plant in Aberdeen, Mississippi and a 20 ton biomass per day demonstration unit is currently under development. Syngas will be converted to a variety of products including naptha, Fischer Tropsch diesel, Fischer Tropsch aviation fuel, and ethanol (Shleser, 2009). An agreement between ClearFuels and Rentech will use Rentech's process to produce Fischer Tropsch products.

Most of the hydrogen produced in Hawaii is generated from crude oil in the refining process. Current hydrogen use in Hawaii is mainly limited to use in the refineries, as a coolant in large turbo generators, and in small volume, specialty chemical applications. Hydrogen does not represent a large, near-term market that could be entered from production via biomass, however, pursuit of niche markets may provide entry points at smaller scales.

Ethanol, methanol, and dimethyl ether (a methanol derivative) all have potential for entry into local transportation, power generation, or fuel gas markets. Ethanol has immediate local markets as a transportation fuel in the state-mandated E10 gasoline blend, provided it can be produced and sold at a price that is competitive with imported ethanol. Methanol is a commodity chemical, one of the top 10 chemicals produced globally. It can be used directly as a fuel in spark ignited engines or blended with gasoline. Methanol has been used in the past as a ground transportation fuel in several demonstration programs, e.g., in California and in Hawaii, but is not widely used commercially as a primary fuel today because of its higher cost (relative to gasoline), toxicity, and corrosiveness. Methanol is more corrosive than most other fuels, thus requires special storage and delivery equipment. Methanol will dissolve many of the gasketing and fuel-delivery materials used in gasoline engines (Owen and Coley, 1995). DME can be derived from methanol. It is primarily used as an intermediate in the chemical industry and as a propellant for aerosol cans. DME is a liquid at modest pressures and can be used as a cooking fuel, thereby having potential as a locally-produced, biofuel replacement for LPG or propane. DME also has potential as a diesel fuel substitute, having a cetane number comparable to diesel fuel. Use in diesel engines would require modification to the fuel delivery system.

5.6 Direct Combustion of Biomass

Direct combustion of biomass for power generation has a long history in Hawaii. Sugar companies have used bagasse as fuel to generate steam for mechanical, thermal, and electrical power. At present, no power plant in the state is operated using a dedicated fuel supply system, i.e. biomass grown only for fuel production. Conventional biomass power generation units combust the fuel in a water wall boiler, raising steam that is used in a turbogenerator to produce electricity. Units are necessarily limited in size by the supply of fuel that can be economically delivered to the plant with transportation costs serving as a major factor. Biomass power plants developed in the 1980's in California using urban wood waste and agricultural residues were typically sized at 25 MW. Larger facilities (~50 MW) exist such as the McNeill Generating Station in Burlington, Vermont, fueled with waste wood from the forest industries and Okeelanta Power in South Bay, Florida, fueled with bagasse and waste wood. Hawaiian Commercial & Sugar (HC&S) on Maui typically produces 29 MW of electricity to satisfy internal demand and exports ~10 MW to Maui Electric Co. In addition to the bagasse produced from sugar milling, HC&S uses coal as a supplemental fuel for periods when the mill is not operating or is at reduced processing capacity (Jakeway, 2006). HC&S also operates hydropower generating units that contribute to their production total.

At least two companies, Hamakua Biomass Energy and Hu Honua are reportedly pursuing power generation facilities on the Hamakua coast fueled with wood from tree plantations. Both companies seek to use conventional, steam based, solid fuel combustion units.

Direct combustion, steam-based, biomass power plants are a mature technology. Modern units include grate fired and fluidized bed units. The later boiler units installed at sugar mills in Hawaii were grate fired units operating at pressures of 450 to 900 psi. Many of the biomass power plants installed in California in the last 25 years were fluidized bed combustors selected for their tolerance of a wide range of fuels.

Recovery and utilization of low grade heat from biomass power plants can improve overall fuel efficiency. Opportunities that can be economically exploited often depend on co-locating heat demands with power generating stations. Sugar factories in Hawaii have long cogenerated electricity, motive power, and process heat.

Utilities in Hawaii currently fuel some of their power plants with residual fuel oil, an oil refinery product, and have expressed interest in displacing this fuel source with a renewable surrogate such as crude vegetable oil. This may require modification of the steam generating units to make efficient use of the fuel and to adhere to emission standards. This approach to biofuel implementation has the advantage of allowing existing generating assets to continue operating rather than requiring construction of new facilities. A 30 day demonstration test firing vegetable oil in commercial steam units owned by Hawaiian Electric is scheduled for late 2009.

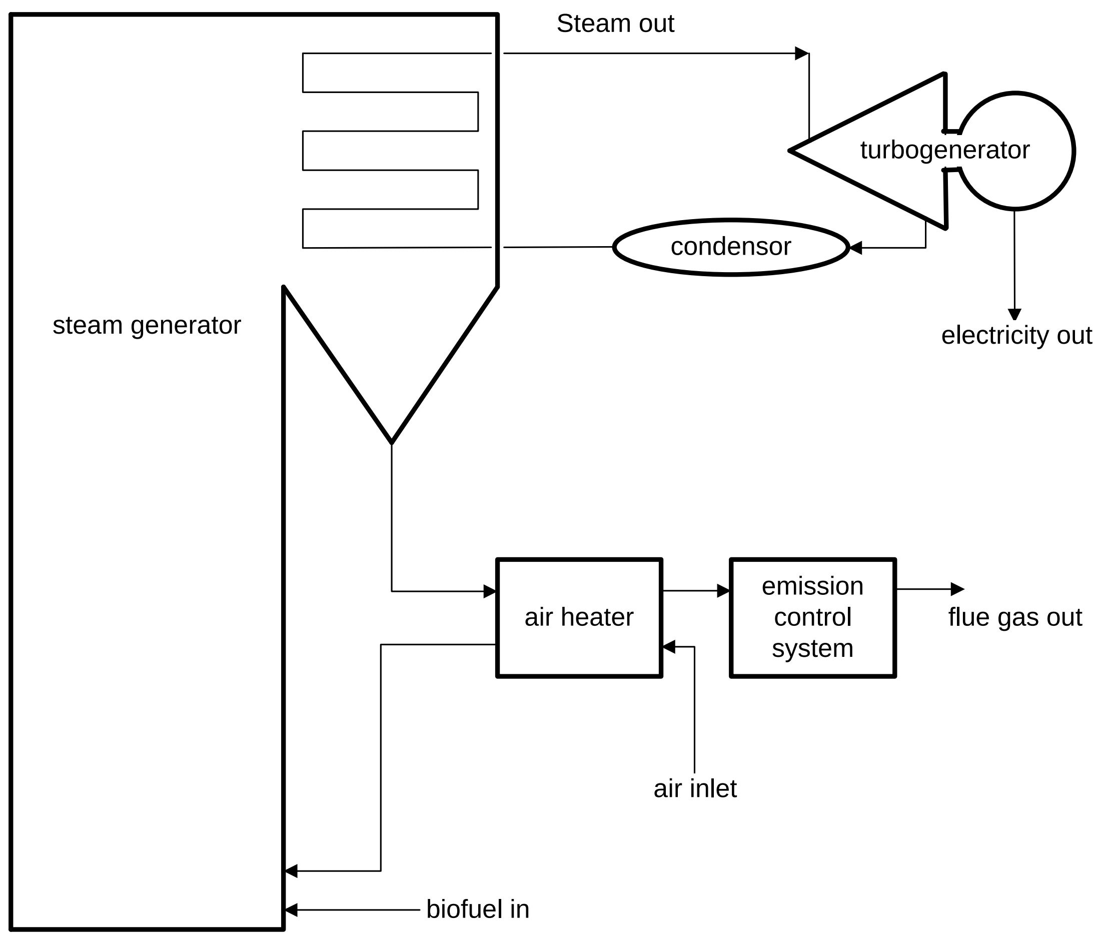

Figure 13. Schematic of direct combustion system

The inputs to the system shown in Figure 13 include the biomass fuel, air, and water. Outputs from the system will include ash from the biomass fuel (typically 1-2% of the dry fuel input), electricity, and flue gas composed primarily of nitrogen, oxygen, and carbon dioxide. Flue gas also contains pollutants, particulate matter and permanent gas species, and these emissions are regulated by state and federal laws that require installation of best available control technology.

5.7 Renewable Diesel from Plant Oils or Animal Fats

5.7.1 Biodiesel (renewable diesel via transesterification of vegetable oil)

Biodiesel can be produced from vegetable oils, animal fats, or recycled restaurant grease. Converting cooking oil and restaurant grease to biodiesel eliminates the need to dispose of these wastes, and creates a commercial product that reduces air emissions and decreases dependence on imported fossil fuels (Sheehan *et al*., 1998; Mittelbach, 1996; Anon, 2003b; Tyson, 2001).

Biodiesel has properties similar to those of petroleum-based diesel fuel with several notable exceptions. Biodiesel is virtually free of sulfur, ring molecules, and aromatics often associated with its fossil counterpart (Sheehan *et al*., 1998; Mittelbach, 1996). Biodiesel also has slightly lower energy density than petroleum diesel.

Biodiesel is composed of fatty acid methyl esters, derived from medium length (C16-C18) fatty acid chains. Biodiesel is produced by esterification of these fatty acids, which are found in vegetable and animal fats. Oil reacts with ethanol or methanol and a lye catalyst in a process called transesterification, to produce biodiesel (Sheehan *et al*., 1998; Tyson, 2001). The major byproduct of the transesterification process is glycerin, which is separated from the biodiesel fuel. Glycerin that is not removed in the separation step can cause problems with filter plugging, injector deposition, and cold weather operation, and can build-up in storage and fueling systems. Maximum levels of both free glycerin and total glycerin are stipulated in ASTM standard D6751, Standard Specification for Biodiesel Fuel (B100) Blend Stock for Distillate Fuels. Blends of biodiesel with petroleum diesel are identifies as B5 for 5% biodiesel content, B20 for 20 biodiesel content, etc.

Biodiesel use has also increased as a result of growing public awareness and greater availability of the fuel. Biodiesel should become increasingly competitive as petroleum supplies dwindle and the technology for producing biodiesel improves. Although generally more expensive, the price of biodiesel has, at times, approached that of petroleum diesel. A non-scientific survey of pump prices of biodiesel in urban Honolulu on June 23, 2009, found that B99.99, B20, and petroleum diesel were selling for $3.88 per gallon, $3.78 per gallon, and $2.97 per gallon, respectively.

Biodiesel, its use, and effect on diesel engines have been researched extensively, though mainly for transportation applications. Most studies report that biodiesel performs comparably to diesel fuel. Operators report no noticeable changes in vehicle performance. Tests have also shown that replacing diesel fuel with biodiesel dramatically reduces particulate matter, carbon monoxide, and net carbon dioxide emissions, and eliminates sulfur emissions. On the down side, biodiesel usually is more costly, has a slightly lower energy density, and produces higher NO_x emissions than diesel fuel (Lue *et al*., 2001; Yamane and Shimamoto, 2001; Graboski *et al*., 1999).

The production of biodiesel from vegetable oils and animal fats is a mature technology. Inputs to the production process include the oil feedstock, methanol, and catalysts. The outputs include the biodiesel product, a crude glycerin byproduct that may contain small amounts of water, methanol, and catalyst. Technologies to process crude glycerin to value added products are approaching commercial status using streams generated from large biodiesel production facilities on the mainland and in Europe. Value added processing of crude glycerin from biodiesel production in Hawaii is an area of current research interest. Processes appropriate for smaller scale and products with local markets are under consideration.

Pacific Biodiesel operates two biodiesel production facilities in Hawaii with used cooking oil and grease trap waste as feedstocks. Annual production is roughly 700,000 gallons.

5.7.2 Green Diesel (renewable diesel via hydrotreating vegetable oil)

Green diesel is a term used to describe renewable diesel fuel produced via the UOP/Eni Ecofining™ process. The process uses plant oils as feedstock and converts the triglycerides and free fatty acids (FFA) components to produce a paraffin rich product according to the reaction:

$$\text{Triglyceride/FFA} + H_2 \xrightarrow[\textit{catalyst}]{} \text{Paraffin} + H_2O/CO_2$$

Oxygen present in the triglycerides and FFA are removed by catalytically reacting them with hydrogen over a catalyst (Kalnes et. al, 2009)

On a mass basis, the process requires roughly 100 parts of vegetable oil and 1 to 4 parts H_2 as input. The product contains 75 to 85% Green diesel, 5% propane, 0 to 2% butane, and less than 1 to 7% naptha (mass basis). The Green diesel product has a heating value of 44 MJ/kg, comparable to ultra low sulfur diesel (ULSD) fuel, and a cetane number in the range of 70 to 90, roughly double that of ULSD fuel. The specific gravity of Green diesel is slightly lower than ULSD, 0.78 vs. 0.84, resulting in a roughly 7% lower energy density per unit volume.

UOP projects that commercial plants will open in Europe in 2010. A similar process is also under development by UOP to produce synthetic paraffinic kerosene that can be used as a green jet fuel.

5.8. Anaerobic Digestion for Biogas Production

5.8.1 Background

Anaerobic digestion is a biological process in which microorganisms degrade the organic matters such as polysaccharides, proteins and lipids into gaseous fuel especially methane gas under oxygen-free environment. The anaerobic microorganisms are ubiquitous in natural environment such as bottom of lakes, marsh land, etc. Various organic wastes such as food wastes, organic fraction of municipal solid wastes, animal manure, high strength wastewater, wastewater sludge etc. are the ideal candidates for anaerobic digestion. The organic matters present in wastewater or solids are degraded by several groups of microorganisms through a number of metabolic stages into biogas ($CH_4 + CO_2$). The biogas composition varies according to types of waste with methane (50 to 75% by volume) and carbon dioxide (25 to 50%) being the major components. Methane is a valuable resource that can be used to produce electricity.

5.8.2 Anaerobic Conversion Process

The complex organic matters are degraded into simple soluble substrates by the fermentative anaerobic microbes using exo-enzymes excreted by microbes. This step is commonly known as hydrolysis or liquefaction. The fermentative bacteria ferment the soluble products of the first step into volatile fatty acids (VFAs) and hydrogen, carbon dioxide and ethanol among others. This step is known as acidogenesis. These VFAs along with ethanol are converted into acetic acid, hydrogen and carbon dioxide. This acetic acid producing step is known as acetogenesis. Finally, acetic acid, hydrogen and carbon dioxide are converted into methane gas and the process is known as methanogenesis. For high solids wastes, hydrolysis is a rate-limiting step, whereas methanogenesis is the rate-limiting step for soluble waste stream. Figure 14 shows the anaerobic conversion pathway.

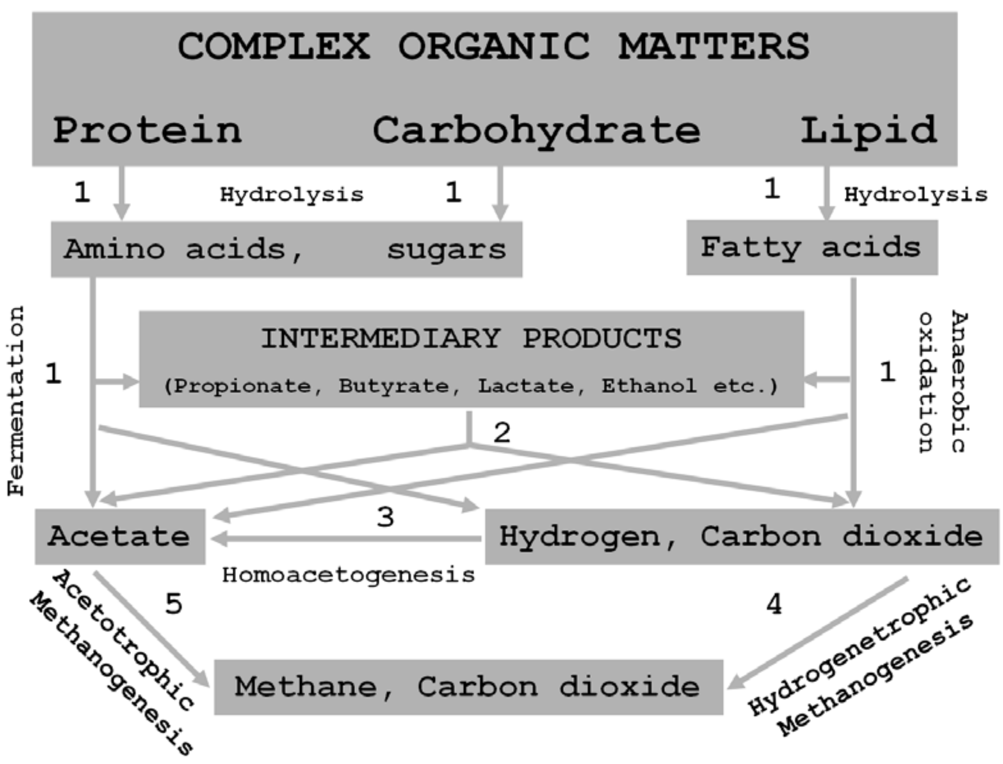

Figure 14. Anaerobic bioconversion of complex organic matter (Adapted from Khanal, 2008).

5.8.3 Biogas Yield

Biogas yield depends on many factors. Waste characteristic and organic content are probably the most important factors governing biomass yield. The biomass yield can be estimated based on chemical composition of the substrates. As a rule of thumb, theoretically, 1 kg of organic matter (as chemical oxygen demand (COD)), generates 0.35 m^3 of methane gas. Often chemical composition of waste is not known. The best way to find the methane yield would be conducting a lab-scale anaerobic digestibility study. The biogas yields for some important feedstocks are summarized in Table 21.

Table 21.   Biogas yields and methane contents of common wastes (Adapted from Khanal, 2008)

Feedstocks	**Total Solids**	**Volatile Solids**	**Biogas Yield**[1]	**CH_4 Content**
	%DS	% of DS	m^3/kg VS	%
Garden wastes	60 - 70	90	0.20 – 0.50	NA
Pig Slurry	3 – 81	70 - 80	20 – 40	0.25 – 0.50
Cow Slurry	5 – 12	75 - 85	20 – 30	0.20 – 0.30
Chicken Slurry	10 – 30	70 - 80	>30	0.35 – 0.60
Grass silage	15 - 25	90	0.56	NA
Fruit wastes	15 - 20	75	0.25 – 0.50	NA
Food wastes	10	80	0.50 – 0.60	70 - 80
Municipal sludge	4-6	70-80	0.5 - 0.7	55-70

I NA – not available

5.8.4 Biogas Impurities

Methane is not the only gaseous product of anaerobic digestion. It also produces many different impurities that may affect the downstream processing. Some of these impurities include hydrogen sulfide, moisture, carbon dioxide and siloxanes. These impurities must be removed prior to their utilization as fuel. Although carbon dioxide is not an impurity per se, it does lower the heating value of the fuel. Power generation equipment can handle 30 to 50% (by volume) of CO_2 in the biogas. Hydrogen sulfide is a major culprit in biogas, which is extremely reactive corrosive gas. Sulfide can be removed through absorption using iron sponge, water scrubbing or biological oxidation. Siloxanes are organic silicon polymers that are present in a wide range of commercial personal care, industrial medical and even in food products. Oxidation of these compounds in gas utilization equipment produces abrasive solids. These compounds can be removed by using two methods: low-temperature drying system; and (2) graphite molecular sieve scrubbers.

5.8.5 Biogas Utilization

Biogas has been traditionally used as a boiler fuel for steam generation. The common alternative applications of biogas are:

- Biogas for electricity generation. This includes engine generators, turbine generators, microturbines and fuel cells.
- Biogas as vehicle fuel
- Digester gas for cooking and lighting.

The summary of biogas power generation with different equipment is given in Table 22.

Table 22. Power generation from biogas using different systems (Adapted from Khanal, 2008)

Parameter	**Engine Generator**	**Turbine Generator**	**Microturbine**	**Fuel Cell**
System Size				
Unit Size, kW[a]	150-3000	> 1000	30-300	200
Appropriate Plant Size	Small to mid-size	Large	Small	Small
Performance				
Efficiency, %	30-35	25-30	25-30	35-40
Estimated heat recovery potential as a percentage of fuel input, %	40-45	30-35	30-35	40-45
Overall System Efficiency, %	70-80	55-65	55-65	75-85
Typical Costs				
Installed Cost, $US/kW[b]	1,200-1,500	1,500-2,000	1,500-2,000	4,000-6,000
Maintenance, $US/kWh[c]	0.010-0.025	0.005-0.018	0.005-0.018	0.005-0.025

[a]Capacity is approximate and will vary with supplier.
[b]Installed costs vary with and type and amount of auxiliary equipment and the type of structure.
[c]Maintenance costs are dependent on the quality of gas used. Costs are based on supplier service contracts.

5.8.6 Anaerobic Digestion in Hawaii

Anaerobic digestion is a mature technology and can be easily adopted to the tropical conditions. The abundance of waste materials/residues coupled with lack of disposal option, provides an excellent opportunity to adopt anaerobic digestion technology for bioenergy production and waste remediation. Based on a recent assessment of Hawaii's biomass and bioenergy resources (Turn et al., 2002), the types of wastes and thier quantities are summarized in Table 23.

Table 23. Biowastes produced in different county of Hawaii (Adapted from Turn et al., 2002)

Waste types	Tons/yr	Hawaii	Maui	Kauai	Honolulu
Swine manure	Dry	410	540	180	1,560
Poultry litter	dry				8,300
Pineapple processing wastes	dry		7,500		
Food waste[1]	As received	24,000	15,000	5,800	90,000
Municipal sludge[2]	dry	183	3352	246	16,576

[1]Amount entering landfills
[2]Included municipal solids waste value

A recent survey conducted by Okazaki et al (2008) estimated that there were 8,253 registered food establishments in Hawaii during 2004-2005. The annual food waste generation was estimated to be about 336,000 tonnes. The food waste can be readily digested to produce biogas that can be used for electricity generation.

6. Technology Development Status

The conversion technologies identified in Figure 1 and their development status, characterized as pilot plant, demonstration scale, or commercial are summarized in Table 24. Technology development typically follows a path beginning with initial discovery in the laboratory and proceeding through a series of increasingly large scale systems to arrive at a commercial process. This approach is used to identify and solve problems at smaller and less costly scales prior to investing in a commercial unit and thereby reduce risk. Risks associated with developing new technologies are also reduced by using private/public partnerships to fund the construction and operations of smaller scale plants. Increases in scale for the purposes of technology verification often progress by factors of ~10. Pilot, demonstration, and commercial facilities might be constructed at scales on the order of <10, 100, and 1000 tons per day.

Ethanol production from sugar and starch are commercial technologies that are currently used for production from sugar cane and corn, respectively. Pilot plants for the production of ethanol from fiber have been constructed by several companies and by the National Renewable Energy Laboratory. A demonstration project of up to 33 ton per day has been constructed by a Canadian company, Iogen, and the U.S. Department of Energy (Voith, 2009) is cofunding several other demonstration projects for this technology.

Biofuels Digest recently published a listing of top 50 companies in the bioenergy field (Lane, 2008). The rational behind this ranking as provided by the publication was (Lane, 2008a),

> "The most important measure was the quality of the intellectual property owned or developed by the company. The more unique, the more compelling, and more talked-about, the better. Companies that hid their IP in the cellar (nothing wrong

with that - Coke has done it for years), had a tougher time getting into the rankings or getting a high position.

The second most important measure was the due diligence done on the company by public and private investors. A dollar invested in a company is a powerful form of voting one's belief in the business model, the management, and the IP. Especially if those dollars are personal dollars. So investments by VC - especially those who are known to do very good due diligence, were valued highly. Corporate dollars too, although they don't always represent a personal investment. Even public dollars are of immense value - all the four original recipients of DOE dollars for cellulosic demonstration-scale plants (well, originally there were six, but two dropped out) are highly ranked this year.

The third measure was measurable progress towards commercialization – although companies are at different stages in their evolution. Early-stage companies were measured against typical early-stage milestones, while later-stage companies had more overtly commercial benchmarks such as revenues and growth rates."

Table 24. Characterization of the development status of biomass conversion technologies

	Pilot	Demonstration	Commercial	Appropriate for HI?
Ethanol from Biochemical Route				
Sugar			X	Y
Starch			X	Y
Fiber[1]	X	x		Y
Gasification				
Heat			X	Y
Power	X	X		Y
Combined Cycle	X	X		Y
IC Engine	X	X		Y
Steam based			X	Y
Synfuels	X	X		Y
Pyrolysis[2]				
Bio-oil production			X	Y
Charcoal production		X	X	Y
Bio-oil production for fuels	X	x		Y
Combustion			X	Y
Renewable diesel via transesterification of vegetable oil			X	Y
Renewable diesel via hydrotreating of vegetable oil	X	X		Y
Anaerobic Digestion				
Heat			X	Y
Power			X	Y
Biogas production via cracking of fats, oil, and grease	X			

[1] Demonstration projects for cellulosic ethanol production currently underway
[2] Pyrolysis for bio-oil production as food ingredient is at commercial scale but use of bio-oil for energy other than combustion applications remains at pilot scale

The companies included in the list are summarized in Table 25. Also included is the URL for each company website, a brief description of their technology, their product, and the stage of technology development. This information is included in the report to provide a sense of the current status of the bioenergy industry from a national perspective.

Table 25. Top 50 bioenergy companies as identified by Biofuels Digest (Lane, 2008) [status codes: L=lab scale, D=demonstration scale, C=commercial]

	Company	Web Site	Technology	Product	Status
1.	Coskata	www.coskata.com/	Biomass gasification with microbial conversion of syngas	Ethanol	L
2	Sapphire Energy	www.sapphireenergy.com/	Photosynthetic micro-organisms	Green crude/green gasoline	L
3	Virent Energy Systems	www.virent.com	Aqueous phase reforming of sugars or fiber with catalytic conversion	fuels, gases, chemical	L
4	POET	www.poetenergy.com	Hydrolysis and fermentation of corn	ethanol	C
5	Range Fuels	www.rangefuels.com	Biomass gasification with catalytic conversion of syngas	Ethanol	D
6	Solazyme	www.solazyme.com	Marine microbes	Fuels, chemicals, high valued products	L
7	Amyris Biotechnologies	www.amyris.com	Conversion of plant biomass (sugars) using engineered micro-organisms	Hydrocarbon fuels, high valued products	L
8	Mascoma	www.mascoma.com	Microbially based conversion of biomass	Cellulosic ethanol	L
9	Dupont Danisco Cellulosic Ethanol	www.ddce.com	Alkaline pretreatment, enzymatic hydrolysis, fermentation	Cellulosic ethanol	L
10	UOP	www.uop.com	Catalyst producer	Fuels, chemicals, high valued products	C
11	ZeaChem	www.zeachem.com	Biochemical production of ethyl acetate, lignin gasification to produce hydrogen; ethyl acetate + hydrogen to produce ethanol	Ethanol and other chemicals	L
12	Aquaflow Bionomic	www.aquaflowgroup.com	Wild strains of algae grown on waste water	Jet fuel	L
13	Bluefire Ethanol	bluefireethanol.com	Dilute acid hydrolysis of biomass with fermentation	Ethanol	D
14	Novozymes	www.novozymes.com	Enzyme, micro-organism, and protein producer	Ethanol and other high value products	C
15	Qteros	www.qteros.com	Microbial production of ethanol from fiber	Ethanol	L
16	Petrobras	www2.petrobras.com.br/ingles/	Veg. oil and animal fat and oil seed for biodiesel, fermentation of sugarcane for ethanol	Biodiesel and Ethanol	C
17	Cobalt Biofuels	www.cobaltbiofuels.com/	Fermentation of various feedstocks	Biobutanol	L
18	Iogen	www.iogen.ca	Cellulosic – from agricultural residue	Ethanol	D
19	Synthetic Genomics	www.syntheticgenomics.com/	Genomic solutions to global energy and environmental challenges	Next generation fuels and chemicals	L
20	Abengoa Energy	www.abengoabioenergy.com/sites/bioenergy/en/	Hydrolysis and Fermentation of sugar cane, wheat, barley, corn and sorghum for Ethanol, soy and palm for biodiesel	Ethanol Biodiesel	C
21	KL Energy	www.klprocess.com/	Cellulosic, sugar and grain fermentation	Ethanol	D

	Company	Web Site	Technology	Product	Status
22	INEOS	www.ineos.com/index.php	Municipal solid waste, organic commercial waste and agricultural residues are superheated and off gases fed through bacteria	Ethanol	L
23	GreenFuel	www.greenfuelonline.com/	Algae	Fuels	L
24	Vital Renewable Energy Company	www.vrec.com.br/	Sugar cane fermentation	Ethanol	C
25	LS9	www.ls9.com/	Sugar cane fermentation and cellulosic conversion of biomass	Fuels, chemicals	D
26	Raven Biofuels	www.ravenbiofuels.com/	Cellulosic two stage acid hydrolysis of bio matter	Ethanol and chemicals	L
27	Gevo	www.gevo.com/	Fermentation	Fuels and chemicals	L
28	St1 Biofuels Oy	www.st1.eu/index.php?id=2386	Fermentation of food industry side steams (dough, potatoes etc…), biowaste	Ethanol	C
29	Primafuel	www.primafuel.com/	Service and technology provider	Biorefineries	C
30	Taurus Energy	www.taurusenergy.eu/EN/	Cellulosic biowaste conversion	Ethanol	L
31	Ceres	www.ceres.net/	Produce low carbon non-food energy crops	Seeds for bioenergy crops	C
32	Syngenta	www.syngenta.com/en/index.html	Agribusiness helping farmers grow more with less	Seeds and agrichemicals	C
33	Aurora Biofuels	www.aurorabiofuels.com/	Algae	Biodiesel	L
34	Bionavitas	www.bionavitas.com/	Algae	Biodiesel	L
35	Algenol	www.algenolbiofuels.com/	Algae	Ethanol	L
36	Verenium	www.verenium.com/	Cellulosic biomass	Ethanol	D
37	Simply Green	www.seacoastbiofuels.com/	Biofuels distributer	Biodiesel blends	C
38	Carbon Green	www.carbongreenllc.com/	Carbon credit management		C
39	SEKAB	www.sekab.com/	Cellulose to ethanol	Ethanol, chemicals	C
40	Osage Bioenergy	www.osagebioenergy.com/	Barley feedstock	Ethanol	L
41	Dynamotive	dynamotive.com/	Fast pyrolysis of biomass	Fuels, Biochar	C
42	Sustainable Power	www.sustainablepowercorp.us/	Hydrolysis / pyrolysis	Fuels	C
43	ETH Bioenergia	www.eth.com/website/default.asp	Sugar, fuel, energy	Ethanol	C
44	Choren	www.choren.com/en/	Gasification/PO/FT	Biodiesel	D
45	OriginOil	www.originoil.com/	Quantum fracturing algae	Fuels, chemicals	D
46	Propel Fuels	www.propelfuels.com/content/	Fuel stations in CA	Biodiesel and E85	C
47	GEM Biofuels	www.gembiofuels.com/	Supply jatropha-based feedstock		C
48	Lake Erie Biofuels	www.lakeeriebiofuels.com/	Transesterification and acid esterification	Biodiesel 45 Million gallons/yr	C

	Company	Web Site	Technology	Product	Status
49	Cavitation Technologies	www.cavitationtechnologies.com/	Produce biodiesel with flow-trough nano-cavitation technology	Sell turnkey conversion systems	C
50	Lotus/Jaguar – Omnivore	www.biofuelsdigest.com/blog2/2008/08/13/lotus-jaguar-to-debut-omnivore-multi-biofuel-engine-with-higher-mpg-than-gasoline/	Multi-Biofuels two-stroke single cylinder motor		D

All of the bioenergy technologies reviewed in this section have potential application in Hawaii but all are not expected to be commercial. The utility of the technologies will depend on completion of technology development for those that are not yet fully commercial and the availability of suitable, cost competitive, sugar, starch, fiber, and oil feedstock resources. Questions of appropriate scale for the technologies will also need to be addressed and will evolve as fossil fuel supplies dwindle and efficiency and conservation serve to reduce energy product demand. A concomitant enhanced appreciation for energy security and economic benefits derived from local production of bioenergy products can be expected to foster policy support.

7. Technology Task Recommendations

A number of recommendations have been developed based on stakeholder input and information collected in preparing this task and include:

1. The State should continue a bioenergy technology assessment activity that can provide updated information on the status of bioenergy conversion pathways and estimates of energy return on investment (EROI) for bioenergy value chain components.

2. Mechanized harvesting is a common theme across bioenergy crops. The State should fund a faculty position (s) in this area to work with industry, conduct research as needed, and evaluate harvesting technologies for application in Hawaii.

3. Support demonstration project development along the bioenergy value chain including energy crop production, transportation and logistics, and processing and conversion technologies. The State should develop funding mechanisms to leverage federal and private funds and support demonstration projects.

4. The State should provide support to industry for preliminary feasibility studies of selected energy crop x conversion alternatives to identify the most promising technology pathways and the resource requirements for those pathways.

5. The State should provide low-or-no cost land leases and expedited permitting to support pre-commercial bioenergy demonstration projects.

6. Hawaii should establish a bioenergy/biofuel development fund to support research, and technology development and demonstration where the University of Hawaii, other research organizations, and Hawaii-based industries should be encouraged to jointly participate.

7. Funds should be allocated to support training manpower in the field of bioenergy/biofuel technology.

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Appendix 1

Summary Notes from Technology Session at April 2, 2009 Stakeholder Meeting

Disclaimer: These notes were prepared by the Hawaii Bioenergy Master Plan Stakeholders Meeting facilitators (Hawai'i Alliance of Nonprofit Organizations) to document information and opinions offered by the stakeholder participants during the meeting breakout sessions. They do not reflect or state views of, or information provided by, the Hawaii Department of Business, Economic Development and Tourism, the University of Hawaii, the U.S. Department of Energy or the project team.

Technology Breakout Session Notes

Hawaii Bioenergy Master Plan Stakeholders Meeting
April 2, 2009

1. **Where do you see the greatest technology gaps in the production of biomass feedstocks?** *Participants were asked to brainstorm their ideas. The participants then grouped similar ideas and labeled each. They then voted to identify which group was the greatest technology gap.*

Harvesting and Extraction (25 votes)

- Harvesting and extraction technologies don't exist for all feedstocks
  - There is also the issue of human labor versus technology
- What kinds of gaps? Gaps in technology or gaps in what should be? Individual projects will determine what should be. How to harvest is a technology gap, excluding human labor. The master plan will not determine the best match of crop to technology.
  - There is a considerable gap to prove gasification process feasibility and technology.
- Eucalyptus is low technology. How to maximize yield by harvesting technique is important. Then how to convert it to high grade biofuel, e.g., biodiesel. This is second/third cycle productivity.
- In Hawaii currently we use oil. The missing piece is going directly from oil into combustion without converting first into biodiesel. We need to consider this option.
- Jatropha is good for oil but it leaves a toxic residue. We need technology that leads to nontoxic residue so it can be used for other purposes.
- The Philippines has conversion, but we're not sure how it will go in Hawaii. There is economic risk for farmers. Can the State take that risk?

Selection and Development of Feedstocks (21 votes)

- Does it include GMO?
- We need to identify which crops produce multiple income streams to ensure success. We should start with multiple income stream crops first, and then move to mono-use crops.
- Expand to other products; each has its own needs.
- There are many micro-climates in Hawaii and this affects how well crops will grow. It also affects the technology gap, which crops for which spots, different species to use, etc.
- What are the gaps to using human and other waste?
- What about future cycles and long-term sustainability of all crops.

Economics/Business Model (15 votes)

- Ethanol for flexi-fuel vehicles is not common on the market. We are focusing on ethanol, with a limited market.
- This is tied to the issue of multiple income streams. Gaps address what technology is missing in order to go through the steps on the chart [provided to participants]. The State can identify technology to get grant monies to develop those technologies.
- Technology exists to change waste streams to value streams. The State could help with developing markets locally.
- We do not have a good economic plan or long-term game plan at this point. We need to secure money, identify which crops to pursue first, and attract outside money and talent.

Byproduct/Secondary Development (13 votes)

- Four to 5 technologies are required to get algae through the chart path. Algae > oil > transether > biodiesel? There is also spent algal biomass > methane (through anaerobic digestion that proves at high volume).
    - Algal strain selection is a limiting factor because of concerns about invasive species impact on the local environment.
    - CO_2 or flue gas goes into ponds. Technology is needed at a low cost for CO_2/flue gas separation and extraction.
    - We also need technology to dewater for algae.
    - Algae > oil where we are competing.
    - Solid sludge at the end could compost, in theory.
- Jatropha is good for oil but it leaves a toxic residue. We need technology that leads to nontoxic residue so it can be used for other purposes.

Integration of Technologies (6 votes)

- Biomass feedstock has low density energy content. Financial feasibility depends on on-site conversion or concentration, and then move to get transportation efficiencies.

Carbon Footprint/Land Productivity (6 votes)

- Energy input is required to grow crops. How do we move away from fossil-based fertilizers to improve financial costs and environmental costs?
- Social, economic, environmental concerns in sustainability.
- Greenhouse gas measuring net carbon footprint.

Other Comments:

- What is limiting factor of growing algae for higher yield for biodiesel?
- Are you getting the information you need? What do we need to get to target yield?
- Protect from alien species and disease control.

2. **What are the greatest areas of risk or uncertainty regarding bioenergy technologies?**
   Participants were asked to brainstorm their ideas.

Economic Feasibility & Risk
- Uncertainty of fossil fuel prices.
- Economic failure
- Prices and market size
- Uncertain state incentives
- Economies of scale
- Ability to use total capacity of plant to reduce cost
- Scale up or down capability

Technology
- Abandonment of technology and/or crop if not viable
- Existing combustion technology's ability to handle new alternative feedstocks
- Investing in technology development
- Development rate of technology to commercial use
- Compatibility with emerging engine technologies, not as biofuel friendly
- Mechanism to compare technologies now versus the future, grow versus sell

Land Use
- Land intensive technologies
- Land development needs
- Competing uses of land

Environmental Concerns
- Environmental conditions changing over time
- Bioterrorism, disease
- Level of pollution capping

Crops
- Unknown commercial yields of crops
- Abandonment of technology and/or crop if not viable

Public Support
- Buy-in from people for large-scale
- Changing and/or lack of public support

Processing
- "Run" time and quantities, flexibility of processing plans
- Timing/ location/ sizing of processing facilities

Infrastructure

- Compatibility with existing infrastructure in Hawaii
- Flexibility to use different feedstocks in same plant

Other

- Viability of secondary products
- End product quality/ consistency/ shelf-life
- Enough raw materials

3. What types of bioenergy demonstration projects would be most useful to reduce risks?
Participants were asked to brainstorm their ideas.

Crop/Feedstock Trials

- Feedstock trials by island and by microclimate
- Farmer operated/managed feedstock trials, not just university
- Demonstration of oils, properties before biofuel process
- Different growing technologies, less carbon-fertilizer based, under research now

Production/Extraction/Conversion Technology

- Engineering of production/harvest technologies across different feedstocks
- Different extraction technologies especially oil crops
- Gasification plant to test engineering, materials, feedstocks and other conversion processes
- Diversified versus consolidated points of production; many small versus few large plants

Infrastructure Changes

- Integrate with existing infrastructure, use existing not replace/ recapitalize
- Need to upgrade grid
- Plug in new module to existing technologies and distribution systems; re-purpose infrastructure
- Existing refineries (expertise, facilities), blending.

Scalability

- By-product, scale appropriate to Hawaii
- Scalability from demonstration to commercial
- Work with landowners early for siting and scaling

Marketable By-Products

- Secondary products as substitute for high-value applications
- Market (local) for byproducts
- Suitability of byproducts for power generation, other uses (e.g., animal feed)

Harvesting Projects

- Harvest/crush mill demonstration to determine yields
- Engineering of production/harvest technologies across different feedstocks

Other

- Fundamental energy and mass balance over process. What power needed for process? What is the best case?
- Demonstrate what is here today
- Storage, transport, blending, shelf-life of end products
- Characteristics of emissions when consumed
- Need information from existing operations, studies, projects; gather and analyze, consolidate and review
- Life cycle analysis from feedstock to end use

4. **In the next 2-3 years, what policy changes would address the gaps and reduce the risks for bioenergy technologies?** *Participants were asked to brainstorm their ideas.*

Incentives

- Pay premiums, preference for in-state produced fuel crops
- Public risk (some) for private demonstration project
- Invent, via tax credits, bonds; also longer-term incentives, beyond 5 years
- Link carbon emissions to financial incentives
- Utilities (energy companies) now middle person, incentives for both the utility and the developer – the utility to become an economic partner; incentives for all stakeholders for mutual benefits
- Incentives for agriculture to grow and to use biomass/biofuels; put incentives up front to reduce costs along entire chain
- Close cycle using bioenergy to make bioenergy; pay premiums tying incentives to carbon content (California low carbon fuel standard)

Land & Water Use Policies

- Land use changes (temporary) to allow demonstration project
- Including many land use policies – competition, highest use, allocation priorities, zone uses unclear, land prices vary, different authorities
- Water use policies similar issue

Oil-Related

- Heavy tax on imported oil
- Fossil fuel based inputs into biofuel production, so not completely separate payment from price of oil
- Allow bioenergy electricity projects to receive electricity payments partially delinked from price of oil; state law says must be delinked, change law

Other

- Demonstration facility needs temporary permitting, fast-track for demonstration scale, not huge EIS
- Stand-alone energy-only department within State and University of Hawaii
- PUC handling of renewable energy, does it properly recognize value
- Biofuels and bioenergy defined as renewable energy for portfolio standards
- Other models involve large companies
- Better information for policymakers on how commercialized technologies; a credible source regarding developmental versus commercial, where it is used, and how it is used elsewhere

Hawaii Bioenergy Master Plan

Permitting

Marc. M. Siah & Associates, Inc.
Manfred J. Zapka, Ph.D., P.E.

December 2009

Executive Summary

Hawaii's bold and far reaching visions for a secure and sustainable energy future require an expeditious and broad implementation of clean and renewable energy applications including biofuels. Stakeholders in Hawaii's bioenergy industry, however, have identified Hawaii's permitting regime as a main obstacle to capital investment in the sector and successful implementation of promising bioenergy projects in the state. To meet its clean energy goals, Hawaii cannot afford the perception that investment and green energy initiatives are hindered by a lack of support from State and County permitting agencies.

To mitigate this problem, state leadership has called for swift improvements in permitting processes with passage of legislative measures affecting State and County permitting agencies. Several of these agencies have commenced implementation of process improvements, examples of which are provided in this report that show utilization of innovative online tools.

With the passage of HB 1464, HD 3, SD2, CD1, the 2009 State Legislature provided for expansion of the scope of the Renewable Energy Facility Siting Process, which regulates permitting of renewable energy facilities above certain thresholds for electricity generation and biofuel production capacities. The Renewable Energy Facility Siting Process prescribes process facilitation and establishes a maximum time period for government agencies to review a permit application. This should provide potential investors in renewable energy projects some assurance that their permit applications will be processed in a timely manner and with a maximum guaranteed time for processing the permit request.

While the changes in permitting of renewable energy facilities should provide significant improvements, the permitting regime could and probably must be further improved in the future to accommodate the large scope of renewable energy development required to move Hawaii closer to the Hawaii Clean Energy Initiative goal of 70 percent clean energy by 2030. The report suggests additional project management measures and the extensive use of online systems as means of further improvements.

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1. Challenges of Permitting in a Rapidly Changing Energy Panorama

Evolving global environmental and energy challenges require rethinking of and possible departure from existing modes of public governance and business operation. There is a near universal acceptance that there ought to be fundamental changes in our use of natural resources in order to combat the growing danger of climate change and global warming. The curbing of greenhouse gas emissions has become a centerpiece of international cooperation and national governance. Strategies for combating related emissions include efforts to promulgate renewable forms of fuels, referred to as biofuels or renewable fuels.

Besides the need to curb greenhouse gas emissions, our national energy security requires the rethinking of our energy use patterns and technologies for energy generation and conversion. Hawaii imports large amounts of crude oil to satisfy nearly 90 percent of the state's energy demands for transportation and electricity generation. This high dependence on petroleum greatly exposes Hawaii to global oil supply and price variations. Over the past years the global oil market has shown significant volatility with a massive price spike and extraordinarily high oil prices in the middle of 2008. Although oil prices have receded in the months following the 2008 spike, similar or even greater market volatility can be expected for years to come. A recent study by McKinsey International (McKinsey, 2009) suggests that under certain conditions a global crude oil supply shortfall with a resulting increase in oil prices could develop as early as 2010 or 2013.

The IEA's Executive Summary of the World Energy Outlook 2008 starts with the stark observation that "*The world's energy system is at a crossroads. Current global trends in energy supply and consumption are patently unsustainable — environmentally, economically, socially. But that can — and must — be altered; there's still time to change the road we're on.* "(IEA, 2008)

Over the past three decades, successive administrations in the State of Hawaii have initiated programs to lower Hawaii's high oil dependency in favor of more diverse energy sources, particularly renewable and clean energy sources. Current plans to drastically slash Hawaii's oil dependencies have introduced a high level of commitment to transform the state's energy supply towards clean energy forms and scaling back the use of petroleum.

State government has statutorily made a commitment to supply up to 20% of all transportation fuel from alternative fuel sources. Under the Hawaii Clean Energy Initiative, the State endeavors to supply up to 70% of all its energy demand from clean energy as early as 2030. These initiatives require enormous resolve, investment and commitment to introduce innovative energy technologies, to train a workforce with new (energy) skill sets and to advocate changed general consumer behaviors towards energy.

Fundamental technological changes in energy generation and consumption cannot materialize overnight. They require a substantial amount of implementation time and patience. A 2005 Science Application International (SAIC 2005) report sponsored by the U.S. Department of

Energy points out that it takes between 10 to 20 years to transform an oil-centered energy supply to alternative sources such as renewable sources. Time is of the essence in the coming energy transformation for Hawaii. The state's comprehensive and expeditious energy transition will require administrative support on many levels of State and County government.

With Hawaii at the cross-roads of an unprecedented and comprehensive energy transformation, all stakeholders in the business community, State and County governments, and the public at large, need to cooperate to take advantage of evolving opportunities in the renewable energy field. While the business community recognizes the great opportunities for investment in renewable energy projects in the state, they should be able to concentrate on entrepreneurial skills to overcome the many business challenges that endanger successful completion of renewable energy projects and they should not have to spend avoidable efforts and resources to cope with unnecessarily complex and inefficient permitting processes. State and County administrations can greatly support much-needed renewable energy projects proposed by innovative investors or public interest groups through supporting expeditious permitting.

While the opportunities for biofuels remain very promising, in the end, biofuels will have to compete with petroleum fuels, the fuel of choice for the past decades during which a vast infrastructure for end-use applications was developed. Future technology breakthroughs should help to make biofuels an economic fuel choice, in addition to being a preferred fuel to mitigate global warming. Similar to any developing industry, investments in production and infrastructure for biofuels present a high degree of risk due to potential regulatory hurdles.

Most biofuel projects require construction and operation permits. Often the permitting process is long and arduous, especially when innovative agricultural, process, and conversion technologies are involved, which may not be familiar or routine to the permitting agencies. In order to promote a regulatory environment that supports capital investment for development of biofuel projects, governmental agencies, especially on the state and county levels, should facilitate and expedite permitting processes to reduce regulatory uncertainty and time for project completion.

Government permitting agencies are faced with the challenge of balancing requests for expedited permitting for important energy projects with their responsibility to protect the public and environment from potential adverse impacts. On one hand, the permitting agencies have the obligation to thoroughly scrutinize the projects and ensure safeguards so that the project has no adverse environmental and social impacts. On the other hand, the duration of the permitting process should not cause failure of renewable and environmentally beneficial energy projects that support a sustainable life style in Hawaii.

DBEDT estimates the number of permits that may be required for a renewable energy project could reach as high as 109, as is illustrated in Figure 1. (DBEDT, 2009 A) In presenting the high number of permits required for energy projects in Hawaii, DBEDT refers to Hawaii's permitting regime as THE hindrance to projects and investments in Hawaii. (DBEDT, 2009 B) Furthermore, it is suggested that Hawaii has a historically poor reputation among investors due to uncertainty in the permitting process.

	Env. Review	Env. Impact	Const/ Op	Land Use/ Zoning	Total
Federal	3	15	3	2	23
State	2	19	16	17	54
County	1	3	10	18	32
Total	6	37	29	37	109

Figure 1 List of permits that may be required for renewable energy projects in

While governmental policies and business initiatives actively endeavor to establish Hawaii as an international leader in renewable and clean energy, "permitting barriers" are allegedly hampering urgently needed investment and entrepreneurial initiative to bring forward Hawaii's vision of a clean and sustainable energy future.

An answer to this "permitting challenge" is to increase the efficiency of and to expedite the permitting process in order to lower the risks for the project sponsors, while safeguarding a thorough environmental and regulatory review.

2. Overview of Existing Permits and Regulations Applicable to Bioenergy Projects

Proposed bioenergy projects in Hawaii are developed in a regulatory environment that is administered by Federal, State and County agencies. Each of these agencies reviews different aspects of the project and issues various permits required for the construction and operation of a bioenergy project. The number of permits required for a biofuel project can vary depending on the scope of the project, its anticipated environmental and social impacts, its location within certain zoning districts or certain special management areas, to list a few of many permitting conditions.

While permitting can delay or sometimes derail energy projects, permits are important safeguards to protect the community and the environment from potential harm and adverse impacts. In these important functions, permits ensure better enforcement of the state's progressive environmental laws in order to protect valuable social and natural resources and to preserve Hawaii's beauty for future generations.

The approval or denial of certain permits can mean the success or failure of potential projects. The rejection of crucially important permits and a subsequent lengthy appeal process, or a lengthy permitting process over several years can lead to economic failure of a project which may be important to the energy future of the state. Some critics perceive a lack of transparency, accountability and permit process clarity. The main risks to an energy project are the unpredictability of the permitting process and its outcome. Precious financial and human resources of start-up or expanding energy companies could be unproductively spent while waiting for permits that might not be approved. In an economic environment where financial assets are difficult to obtain and credit is tight, companies must look for ways to secure and conserve project funding.

2.1 Federal Regulations Governing Bioenergy Projects

The following paragraphs list the main regulations administered by federal agencies, which may be applicable to Hawaii's bioenergy projects, depending on the specific technologies used. These regulations are typically administered by agencies such as the Environmental Protection Agency (EPA), Department of Transportation, US Army of Corp of Engineers, and others. Many of the federally instituted regulations discussed below are also enforced by agencies on the State and County levels.

Energy Independence and Security Act of 2007 was passed to move the United States toward greater energy independence and security, to increase the production of clean renewable fuels, and introduce other energy saving and greenhouse reducing measures. The bill provides that the volume of biofuels added to gasoline is required to increase to 36 billion gallons by 2022, up from 4.7 billion gallons in 2007. The EPA is responsible for implementation of the Renewable Fuel Standard Program (RFS).

National Environmental Policy Act (NEPA): If federal money is used in construction of a bioenergy facility or any associated facilities, such as an access road, infrastructure, or water supply, then the project is subject to the National Environmental Policy Act (NEPA). NEPA requires preparation of Environmental Assessments and Environmental Impact Statements for review by various regulatory agencies, neighborhood boards, concerned citizens and others from the public at large. Significant impacts that are identified and determined to be unavoidable may require mitigation to reduce or minimize their potential environmental or human health impacts.

Renewable Fuel Standard (RFS) Program applies to facilities that produce 10,000 gallons or more of renewable fuel per year. Producers with less than 10,000 gallons may also choose to comply as well. Some of the requirements are:

- Fuel and Fuel Additive Registration System (FFARS) program
- Generate, transfer and record Renewable Identification Numbers (RINs)
- Abide by Blending Requirements

Clear Air Act (CAA) defines ambient air quality standards for pollutants from numerous and diverse sources which are considered harmful to public health and the environment. The CAA defines air quality standards for certain pollutants called “criteria” pollutants, such as particulate matter, carbon monoxide, sulfur dioxide, nitrogen oxides, lead and ozone. Regulations distinguish attainment areas where the air quality meets the standards and non-attainment areas where it does not. An area may be an attainment area for one pollutant and a non-attainment area for another. The Clean Air Act requires that certain permits be obtained to minimize impacts from air emissions for the construction and the operational phases of a bioenergy facility.

A CAA pre-construction permitting program is known as the <u>new source review program</u>. Two kinds of pre-construction permits may apply:

<u>Major construction permitting</u> comprises two major construction permits:

Prevention of Significant Deterioration: A threshold of 250 tons per year for critical pollutants applies for new plants, as well as other thresholds applicable to the net increase in pollutants. Permits issued require installation of the Best Available Control Technology (BACT), air quality analysis, impact analysis, and public involvement.

Non-attainment New Source Review: Permits are required where the source is in an area that is not in attainment with the national ambient air quality standards; also called a “non-attainment area." Here any source that emits more than 100 tons per year of identified pollutants is considered a major source. Mitigating involves installation of measures to achieve the lowest achievable emission rate and other measures.

<u>Minor Construction permits</u> do not require prevention of significant deterioration or non-attainment new source review permits. Minor construction permits contain conditions that will limit the source’s emissions to the threshold rates to avoid becoming subject to the prevention of significant deterioration or non-attainment new source review regulations.

<u>CAA New Source Performance Standards</u> apply to certain elements of the bioenegy facility, such as process vessels, Volatile Organic Liquid Storage Vessels, coal handling plants, grain handling, Synthetic Organic Chemical Manufacturing Industry (SOCMI) Equipment spills or leaks. The New Source Performance Standards establishes required performance targets for equipment and control devices that will be installed.

<u>CAA - National Emission Standards for Hazardous Air Pollutants</u> apply if construction/modification of a bioenergy plant involves demolition or renovation of any existing public or commercial structures. New and existing facilities that fall within this permit criteria and are major sources of hazardous air pollutants are subject to the Maximum Achievable Control Technology (MACT) Standards.

<u>Clean Air Act Air Operating permits</u> must be acquired within some period (often 12 months) after the bioenergy facility begins operation. The operating permit is generally issued for a

specific time period (usually for five years) rather than the life of the operating unit. CAA Air Operating Permits are issued for two possible operating scenarios:

1. Major Source Title V Air Permits. The Title V operating permit is a comprehensive permit that compiles all of the applicable state and federal regulatory requirements, construction permit provisions, and recordkeeping, reporting, testing, and monitoring requirements into one permit. The permit applies if potentially emitted quantities of criteria pollutants are greater than a threshold rate (e.g. 100 tons per year) or they are major sources of hazardous air pollutants.

2. Minor Source Air Permits regulate plants that operate at capacities below the threshold of 100 tons per year of critical pollutants.

<u>The CAA-Risk Management Program</u> establishes standards to prevent catastrophic accidents involving extremely hazardous chemicals. Bioenergy facilities of any size have a "general duty to prevent releases, and to minimize the consequences of accidental releases which do occur." Implementing "Best Practices" helps facilities to comply with this law.

Pollution Prevention Act regulates the practice of eliminating or reducing waste at its source. The focus is on efforts to stop something from becoming waste in the first place. Pollution prevention measures include modifying production processes, the promotion of the use of non-toxic or less-toxic substances as well as implementing re-use of materials rather than introducing them into the waste stream. Best practices are becoming important for the attainment of the objectives of the Pollution Prevention Act.

Clean Water Act (CWA) regulates emissions and impact mitigation during construction and operation of a bioenergy facility.

<u>During the construction phase</u> the following CWA regulations apply:

- CWA 404 Permits / wetland: Permits under Section 404 of the Clean Water Act address the discharges of dredged or fill material into waters of the United States, such as wetlands, streams, rivers, lakes, bays, etc.

- CWA stormwater construction permits control possible environmental impacts due to land disturbance caused by construction (i.e., clearing, grading, and excavating) that could lead to serious environmental harm in water bodies both nearby and downstream from the site runoff. The permits must be obtained before any construction activities for discharges to waters of the U.S. from any construction activity that disturbs one acre or more of land. Permits require implementation of stormwater pollution prevention measures to control discharges of sediment and other pollutants from the site during construction activities.

- CWA permit for construction of a wastewater facility is required for the construction of any type of wastewater collection, treatment or holding system to meet limits established in a wastewater disposal permit.

- CWA Safe Drinking Water Permits are required if the bioenergy facility is regarded as a Public Water System, e.g. the plant derives drinking water from sources other than public water supplies. Permits include water use and well construction permits.

- CWA Underground Injection Control permits regulate injection of fluids underground for disposal through a wide array of injection techniques. A permit is required if a bioenergy facility disposes of storm water, cooling water, industrial or other fluids into the subsurface via an injection well, uses an on site sanitary waste disposal system, e.g. septic tank system, for sanitary or other waste streams.

- A range of programs protect ground water, such as the Ground Water Protection Strategy, Source Water Protection Program, Sole Source Aquifer Program, and Wellhead Protection Program.

During the operational phase the following CWA regulations apply:

Bioenergy facilities require permits for the disposal of process related wastewater and/or stormwater that might be contaminated by the plant operation.

There are three types of wastewater discharge permits, depending on the mode of disposal.

- Direct discharge to receiving waters is regulated by the National Pollutant Discharge Elimination System (NPDES) permit in terms of volume and type of water quality discharged into a receiving water body, such as lake, river or stream or into a conveyance, such as a culvert, or pipe that discharges into the receiving water body.

- Discharge to a Municipal Wastewater Treatment Plant: A permit issued by the County regulates the discharge to a municipal wastewater treatment plant. Where pretreatment is required, the permit would regulate the extent of required pre-treatment.

- Land Application for Wastewater Disposal is typically regulated by NPDES permits.

Discharges from facilities typically require individual NPDES permits including a pollution prevention plan, to control, monitor and report discharges of pollutants from the facilities during operation.

Spill Prevention, Control and Countermeasure Regulations are to prevent discharges of oil into navigable waters or adjoining shorelines and for reporting of spills so that mitigating measures can be implemented.

General NPDES permits are necessary for storm water discharges during construction at the facilities.

Safe Drinking Water Act regulates certain uses of water supply and underground discharges.

Public Water System permits are required for water supply systems to facilities with capacities over threshold rate (e.g. more than 25 people for more than 60 days per year). Permitting needs include regulations for water use, well construction, operator qualifications and testing.

Underground Injection permits are required for disposal of storm water, cooling water, industrial or other fluids into the ground via an injection well or if the facility operates an onsite waste disposal system that receives sanitary or other discharges.

Resource Conservation and Recovery Act (RCRA) regulates solid and hazardous waste. Each plant is responsible for determining if each waste stream is hazardous and managing it appropriately if it is hazardous.

Some of the hazardous materials used in the operation of a bioenergy facility may include:

- Spent filter media such as diatomaceous earth and resins can spontaneously combust.
- Waste methanol and waste glycerin
- Spent or unused catalyst
- Wastewater -- If it contains a listed hazardous waste or exhibits a hazardous characteristic, it must be managed as a hazardous waste until treated and/or disposed in the CWA permitted process.
- Spent or unwanted laboratory chemicals
- Used oil

Emergency Planning and Community Right-to-Know Act requires facilities with regulated chemicals above threshold planning quantities to prepare comprehensive emergency response plans. The regulations require reporting of spills of hazardous chemicals which are above a certain volume.

Reporting Hazardous Chemical Storage – Tier II requires facilities to report any hazardous chemical or extremely hazardous chemical that is stored at the facility in excess of the designated threshold planning quantity. There are chemicals, such as methanol and hexane, that may be used in biofuel facilities that fall under this requirement.

Toxic Release Inventory Reporting is required for bioenergy facilities that manufacture, process or otherwise use any listed toxic chemicals, or chemical categories in excess of threshold quantities.

There are other federal permits and regulations that may apply to the development and operation of bioenergy facilities, such as permits by the U.S. Army Corp of Engineers, US Department of Interior or US Department of Energy. Furthermore, the construction and operation of biofuel facilities might be subject to national or international standards such as regulatory provisions set forth by US Department of Labor, Occupational Safety & Health Administration (OSHA), the International Fire Code (IFC) or the U.S. Flood Insurance Act, to name but a few important standards and laws.

Finally, it must be recognized that bioenergy projects may be critical infrastructure installations that require due protection against act of terrorism. In the pre-9/11 world most of the regulations for energy installations centered on environmental protection, occupational safety and the safeguarding against impacts from fires and spills. In the post-9/11 world energy installations could prove to be preferred targets for terrorist attacks since the presence of highly flammable or hazardous substances could increase the impact of any attack. Therefore, permits for bioenergy installations might also have to comply with regulatory provisions of the Department of Homeland Security, such as Chemical Facilities Anti-Terrorism Standards (CFATS) and Maritime Transportation Security Act (MTSA).

2.2 State Regulations Governing Bioenergy Projects

Many federal regulations described in Section 3.1 are implemented by the State of Hawaii, either in their entirety or with changes that reflect the unique situation of Hawaii.

State of Hawaii agencies administer the regulations and permits that may apply to the construction and operation of bioenergy facilities. Several governing regulations and permits are as follows:

Department of Health, Clean Air Branch administers the permit process for air pollution control permits falling under the federal regulations of the Clean Air Act. On the state level these permits are administered under the legal authority of Chapter 342B, Hawaii Revised Statutes and Hawaii Administrative Rules, Title 11. Air Pollution Control Permits are required prior to constructing, reconstructing, modifying, or operating a stationary air pollution source. Covered Source Permits are subject to a federal performance or control technology standard. Noncovered sources are all other stationary sources that are not covered sources.

Department of Health, Clean Water Branch administers the National Pollutant Discharge Elimination System (NPDES) permit program for the U.S. Environmental Protection Agency. The NPDES permitting system regulates discharges of water and water with two permit categories, individual and general permits. An individual permit is a permit awarded to an individual facility based on specific facility information (e.g., type of activity, nature of discharge, receiving water quality). A general permit is an NPDES permit that covers several facilities that have the same type of discharge and are located in a specific geographic area, thus avoiding individual permitting processes. Under the NPDES Program, all facilities which discharge pollutants from any point source into waters of the United States are required to obtain NPDES permits. The NPDES covers point and non-point sources emitted from municipal and non-municipal sources.

Department of Health, Office of Solid and Hazardous Waste Branch administers permits that regulate the handling of solid waste and related impacts.

The Office of Environmental Quality administers the review of environmental impacts under the legal authority of Chapter 343, Hawaii Revised Statutes (HRS). Construction and operation of bioenergy facility may require a formal environmental review, such as an Environmental Assessment or a full Environmental Impact Study in order to attest that the proposed bioenergy facility does not cause significant environmental impact.

Department of Land and Natural Resources administers a range of permits and regulatory actions, such as special use of conservation land, conditional use permit, historical reviews, stream channel alterations, work in ocean waters, special management area use permit, well construction permits, among others.

Land use in the State of Hawaii is regulated by four categories of land use districts - Urban, Rural, Agricultural and Conservation.

- Land in the Urban District is characterized by “city-like” concentrations of people, structures and services. This district also includes vacant areas for future development.

- Land in the Rural District typically feature small farms intermixed with low-density residential lots.

- Land in Agricultural District is for the cultivation of crops, aquaculture and agriculture-support activities, raising livestock, timber cultivation, land with significant potential for agriculture uses as well as some energy applications. While the permitted energy facilities in the agricultural districts have been mostly wind energy, recent legislation allows a wider use for energy, including bioenergy facilities.

- Land in the Conservation District comprises existing forest, water reserve zones, protected areas for watersheds and water sources, scenic and historic areas, parks, wilderness, open space, recreational areas, habitats of plants and wildlife. Use of land in the Conservation District is regulated by the State Department of Land and Natural Resources.

The Land Use Commission establishes and regulates district boundaries for the entire state. The commission's primary goal is safeguarding that state concerns are addressed and considered in the land use decision-making process. The commission acts on petitions for boundary changes submitted by State and county agencies as well as private developers and landowners. The commission decides on the award of special use permits within the Agricultural and Rural Districts.

Permits to Cross or Enter the State Energy Corridor are required for construction within or crossing the established Energy Corridor, such as laying additional pipelines for biofuel. The permit is administered by the Department of Transportation.

The Department of Transportation regulates work performed upon a state highway as well as installing, relocation and widening of access to state highways.

A Historic Review must be performed for any proposed construction, alteration or improvement that will affect a historic or cultural site that is eligible to be listed, or is listed, on the Hawaii Register of Historic Places. The review is performed from the Historic Preservation Branch of the Hawaii State Department of Land Natural Resources.

Other regulations on the State level may also apply to the permitting process for bioenergy projects. For example, the Public Utilities Commission (PUC), regulates all franchised or certificated public service entities operating in the state, such as energy, petroleum, telecommunications, transportation and water/wastewater. The PUC monitors petroleum and biofuel use through the Petroleum Industry Monitoring, Analysis and Reporting (PIMAR) Program. Fuel companies, including biofuel companies, have to be part of this comprehensive report system.

2.3 County Regulations Governing Bioenergy Projects

Many aspects of the construction and operation of bioenergy facilities fall under the general requirements and procedures for land development projects in the four counties of Hawaii. Permits have to be secured for most actions involved. While there are slight differences in the process of getting the permits in the different counties, most of the underlying ordinances and permit requirements are very similar.

The following lists several permits that may apply to the construction and operation of biofuel installations. Several other permitting requirements may exist, depending on the location of the proposed project and the nature of the proposed bioenergy facility. Apart from the land use ordinances, all referred to permits are listed in alphabetical order. These major permits, which are potentially required, serve to illustrate the wide range of activities that require review and acceptance at the county level.

Land Use Ordinances regulate permitted activities in the different land use zones of the counties. Land uses in the different zones are either permitted or conditional use permit can be obtained following a review process. There are approximately 20 different land use zone districts defined on the county level (compared to four land use districts on the state level). Changes of land use zone designation are possible through Zone Change applications. Depending on the State and County land use district and zone designation, county agencies can approve re-zoning (often an environmental review in accordance with Chapter 343, HRS, is required) or, if State land use districts do not allow the specific land use, both State and County agencies must approve the zone change.

<u>Building permits</u> are required for any construction, modification or demolishment of any building or structure.

Combustible and flammable <u>tank installation permits</u> are required to install, modify and operate fuel tanks or containers of combustible or flammable liquid, having a capacity over a certain threshold (e.g. 60 gallons and more)

<u>Connection to storm sewer permit</u> regulates the connection to the municipal sewer system. For industrial facilities, such as bioenergy facilities also require the NPDES permit for connection.

<u>Discharge effluent permits</u> are required for any discharge into the municipal storm water system. A construction-dewatering permit is required for discharging water resulting from

construction operation into municipal storm water systems or onto public right-of-way. A NPDES permit might also be required.

Environmental Impact Review, either an EA or EIS, might be required, if "triggering" events apply, for certain developments.

Flood Determination Reviews are required for all proposed developments within General Flood Plain Districts.

Grading permits are generally required for site development work that includes grubbing, grading and stockpiling. When the area is larger than a threshold size (e.g. 1 acre) a temporary erosion control plan must be prepared in order to limit the magnitude of soil erosion and possible run-off into receiving waters.

Industrial Wastewater Discharge permits are required for discharge into the municipal sewer systems. The industrial wastewater must be meet requirements for the type and volume of wastewater discharges. Certain requirements apply for pretreatment, peak flow discharges, location of the discharge and prohibition of certain wastewater discharges.

Trenching permits are generally required for breaking up, disturbing and digging under a public right-of-way,

Sewer connection permits are required for connecting to the municipal sewer system.

A Sign permit is required to install, alter or relocate any signs.

Street Usage permits are required for all construction work performed on county roads, including streets, highways, roads, driveways and sidewalks. Construction related parking and street closures are also covered in this permit.

Temporary Use permits might be required for construction staging areas for bioenergy facilities.

Variances from building, electrical, plumbing and fire codes might be required for bioenergy facilities.

Water use and water system permits are required for connecting to the municipal water supply.

2.4 Summary of Existing Permits and Regulations

Table 1 lists the main Federal, State and County permits and regulations that have to be considered in the development, construction and operation of bioenergy installations in the State of Hawaii. The wide range of possible configurations of bioenergy projects requires a broad array of permits and regulations to be considered. It has to be pointed out that, of course, not all bioenergy projects would be subject to such a wide range of permits and regulations.

Table 1 lists the name of the permit or regulatory provision and provides short descriptions of these. The table further indicates if the permit or regulation would be enforced on a Federal, State or County level. While the permitting requirements in the four counties are basically identical, permitting on the county level is processed in different departments, since the department structure in the four counties varies.

Table 1 List of main permits and regulations to be considered in the development, construction and operation of bioenergy installations in the State of Hawaii

Table 1: List of main permits and regulations to be considered in the development, construction and operation of bioenergy installations in the State of Hawaii.

Type of permit or regulatory action	Short description	Federal Agency	State agency	County Agencies			
				C&C of Honolulu	Maui County	Hawaii County	Kauai County
Aboveground Storage Tank (AST) permit; construction and operation	Regulates possible emissions from tank storage facilities		State Department of Health				
Air quality from General Agricultural Operations	Regulates air emission from agricultural operations		State Department of Health				
Boiler (pressure vessel) permit	Regulates the construction and operation of pressure vessels and boilers and enforces applicable standards.		State Department of Labor				

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Type of permit or regulatory action	Short description	Federal Agency	State agency	County Agencies			
				C&C of Honolulu	Maui County	Hawaii County	Kauai County
Bridge and Causeway Permit	Regulates the construction of a bridge or causeway or the modification of an existing bridge or causeway across navigable waters of the US.	U.S. Department of Homeland Security - US Coast Guard					
Building Permit:	Permit required to erect, construct, enlarge, repair, demolish or otherwise alter a building, structure, fence, retaining wall,			Department of Planning and Permitting	Department of Public Works	Department of Public Works	Department of Public Works

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Type of permit or regulatory action	Short description	Federal Agency	State agency	County Agencies: C&C of Honolulu	Maui County	Hawaii County	Kauai County
	etc.; perform any electrical or plumbing work; work on sidewalk or driveway in public right-of-way.						
Burn Permit (agricultural burning)	Regulates any agricultural burning		State Department of Health				
Clean Air Act (air permits)	Regulate the constructing, modifying or operating of stationary air pollution sources.		State Department of Health				
o Covered source permit	Covered source permits regulate major sources of air		State Department of Health				

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Type of permit or regulatory action	Short description	Federal Agency	State agency	County Agencies: C&C of Honolulu	Maui County	Hawaii County	Kauai County
	emissions and sources that are subject to a federal performance or control standard.						
o Uncovered source permit	Noncovered sources are all other stationary sources that are not covered sources.		State Department of Health				
o Major construction permit	Regulates the construction of a major source (e.g. above threshold emission); includes Prevention of Significant		State Department of Health				

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Type of permit or regulatory action	Short description	Federal Agency	State agency	County Agencies			
				C&C of Honolulu	Maui County	Hawaii County	Kauai County
	Deterioration (PSD) and requires Best Available Control technology						
o Minor consecution permit	Regulates the construction of a minor source (e.g. below threshold emission)		State Department of Health				
o Major Source Title V Operating Permit	Title V operating permits regulate the operation of a major source (e.g. above a threshold emission) in one comprehensive permit Permits		State Department of Health				

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Type of permit or regulatory action	Short description	Federal Agency	State agency	County Agencies			
				C&C of Honolulu	Maui County	Hawaii County	Kauai County
	are enforceable documents.						
o Minor Source Operating Permit	Regulates the operation of a minor source (e.g. below a threshold emission)		State Department of Health				````
Chemical facilities anti-terror standards (CFATS)	Regulates measures to ensure the security and safety on facilities, including facilities that produce or handle listed chemicals, energy facilities and others installations.	U.S. Department of Homeland Security					

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Type of permit or regulatory action	Short description	Federal Agency	State agency	County Agencies			
				C&C of Honolulu	Maui County	Hawaii County	Kauai County
Clean Water Act (SECTION 404); Permits for Discharges of Dredged or Fill Material into the Waters of the United States.	Regulates the discharge of dredged and filled materials into waters of the US, incl. wetlands, streams, rivers, lakes, and bays.	U.S. Army Corp of Engineers, U.S. Environmental Protection Agency					
Coastal Zone Management Program, Federal consistency	Requires review and regulatory actions to ensure that projects needing federal permit are consistent with Hawaii's Coastal Zone Management Program		Office of State Planning				
Combustible and	Regulates the			Honolulu Fire	Department of	Fire	Fire

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Type of permit or regulatory action	Short description	Federal Agency	State agency	County Agencies			
				C&C of Honolulu	Maui County	Hawaii County	Kauai County
flammable liquids tank installations permits	installation, replacement or otherwise handling of any container with combustible or flammable liquid over 60 gallons.			Department	Fire and Public Safety	Department	Department
Community Noise Permit	Regulates noise from a stationary source as a temporary measure or if source has Best Available Noise Control technology		State Department of Health				
Conditional Use Permit (CUP)	Regulates conditional uses that might be			Department of Planning and Permitting	Planning Department	Planning Department	Planning Department

Table 1: List of main permits and regulations to be considered in the development, construction and operation of bioenergy installations in the State of Hawaii.

Type of permit or regulatory action	Short description	Federal Agency	State agency	County Agencies			
				C&C of Honolulu	Maui County	Hawaii County	Kauai County
	permitted in specific zoning districts in accordance with land use regulations; here only type 2 (e.g. significant impacts) are the most likely to consider.						
Conservation District Use Permit	Regulates any use within the State Conservation District		State Department of Land and Natural Resources				
Construction Noise Permit	Regulates construction related noise (this is a subset of Community		State Department of Health				

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Type of permit or regulatory action	Short description	Federal Agency	State agency	County Agencies			
				C&C of Honolulu	Maui County	Hawaii County	Kauai County
	Noise Permit)						
Construction Dewatering Permit	Regulates discharge of water resulting from construction operation onto public-right-of-way of municipal stream sewer system (if discharge is into State waters NPDES is required)			Department of Planning and Permitting	Department of Public Works	Department of Public Works	Department of Public Works
County Roadway Right-of-Way Permit (Street Usage Permit)	Regulates work conducted on County highways and roadways			Department of Transportation Services	Department of Public Works	Department of Public Works	Department of Public Works
Development Plan	Regulates any			Department of	Planning	Planning	Planning

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Type of permit or regulatory action	Short description	Federal Agency	State agency	County Agencies			
				C&C of Honolulu	Maui County	Hawaii County	Kauai County
Amendments	land use activity that is not in accordance with the Development Plan through amendments			Planning and Permitting	Department	Department	Department
Discharge Effluent Permit	Regulates any effluent discharge other than storm water onto public right-of-way or municipal storm sewer; NPDES might be required if significant impact is assumed.			Department of Environmental Services	Department of Public Works	Department of Public Works	Department of Public Works
Driveway Permits	Regulates the construction of			Department of Planning and	Department of Public Works	Department of Public Works	Department of Public

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Type of permit or regulatory action	Short description	Federal Agency	State agency	County Agencies			
				C&C of Honolulu	Maui County	Hawaii County	Kauai County
	a driveway in the public right-of-way			Permitting			Works
Effluent Discharge - Zone of mixing	Regulates effluent discharge into a receiving water where water quality standards for this area would be violated.		State Department of Health				
Electrical Permit	Regulates all plumbing work in new construction and modifications to existing structures; could be granted under construction /			Department of Planning and Permitting	Department of Public Works	Department of Public Works	Department of Public Works

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Type of permit or regulatory action	Short description	Federal Agency	State agency	County Agencies			
				C&C of Honolulu	Maui County	Hawaii County	Kauai County
	building permit						
Energy Corridor Permit	Regulates any construction within or crossing the established energy corridor.		State Department of Transportation				
Environmental Impact Statement (EIS) County	EIS might be required for projects that use County land or funds, lands within SMA, Special Districts or within a historical site.			Department of Planning and Permitting or other C&C agencies	Planning Department	Planning Department	Planning Department
Environmental Impact Statement (EIS) NEPA	EIS might be required for projects that use federal	Federal Agency involved in the projects					

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Type of permit or regulatory action	Short description	Federal Agency	State agency	County Agencies			
				C&C of Honolulu	Maui County	Hawaii County	Kauai County
	funds or need a federal permit or represents a federal action with significant impact.						
Environmental Impact Statement (EIS) State	EIS might be required for projects that use State land or funds; lands within State Conservation District, shoreline area, for general plan amendments.		State Office of Environmental Quality Control				
ESA Section 10 Permit	Regulating the use of federal land in relation to the	U.S. Department of Interiors, Fish and Wildlife					

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Type of permit or regulatory action	Short description	Federal Agency	State agency	County Agencies			
				C&C of Honolulu	Maui County	Hawaii County	Kauai County
	"incidental take" (taking, disturbing, etc) of habitat for endangered species according to ESA.	Service					
FAA Notice of Construction, permit for construction in navigable airspace	Regulates any construction that would affect navigable airspace, e.g. tall structures in special areas.	Federal Aviation Administration					
Flood Hazard Districts, Development Permits	Regulates developments in areas that are designated flood hazard areas.		State Dept. of Land and Natural Resources				

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Type of permit or regulatory action	Short description	Federal Agency	State agency	County Agencies			
				C&C of Honolulu	Maui County	Hawaii County	Kauai County
Flood Hazard Districts, Variance Permits	Flood hazard variances can be granted to deviate from flood district requirements of county land use regulations.			Department of Planning and Permitting	Planning Department	Planning Department	Planning Department
General Plan Amendments	General plan amendments might be required for land uses.			Department of Planning and Permitting	Planning Department	Planning Department	Planning Department
Grading Permit	Grading permit is required for any cut and fill activities; all other regulatory requirements have to be met before grading			Department of Planning and Permitting	Department of Public Works	Department of Public Works	Department of Public Works

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Type of permit or regulatory action	Short description	Federal Agency	State agency	County Agencies			
				C&C of Honolulu	Maui County	Hawaii County	Kauai County
	permit is approved.						
Groundwater Use Permit	Regulates the use of groundwater in a designated ground water management area.		State Department of Land and Natural Resources				
Grubbing and Stockpiling	Grubbing and stockpiling permit is required for any related activities; all other regulatory requirements have to be met before permit is approved.			Department of Planning and Permitting	Department of Public Works	Department of Public Works	Department of Public Works
Hazardous waste; storage, treatment	Regulates processes in	U.S. Environmental	State Department of				

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Type of permit or regulatory action	Short description	Federal Agency	State agency	County Agencies			
				C&C of Honolulu	Maui County	Hawaii County	Kauai County
and disposal	regard to storage, treatment and disposal of hazardous waste; regulates measures to mitigate wastes; regulates documentation and registration	Protection Agency	Health				
Historical Site Review	Regulates construction and alterations projects that affect historic sites that are listed in the Hawaii Register of Historic		State Department of Land and Natural Resources				

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Type of permit or regulatory action	Short description	Federal Agency	State agency	County Agencies			
				C&C of Honolulu	Maui County	Hawaii County	Kauai County
	Places.						
Industrial Wastewater Discharge Permit	Regulates the discharge of industrial wastewater into the county sewer system			Department of Environmental Services	Department of Public Works	Department of Environmental Management	Department of Public Works
Maritime Transportation Security Act (MTSA)	Regulates the marine transport and transfer of fuel	U.S. Department of Homeland Security - US Coast Guard					
Natural Area Reserves Use Permit (special use permit)	Regulates activities within the Natural Area Reserves to allow actions that would otherwise prohibited		State Department of Land and Natural Resources				
NPDES permits							

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Type of permit or regulatory action	Short description	Federal Agency	State agency	County Agencies			
				C&C of Honolulu	Maui County	Hawaii County	Kauai County
o General NPDES permits	Regulates effluent discharges into receiving waters based on General Permit Coverage that are issued under NPDES General Permits; there are 11 general permit cases in Hawaii, such as Storm water associated with industrial activity and construction activities, effluent from leaking underground storage tank		State Department of Health				

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Type of permit or regulatory action	Short description	Federal Agency	State agency	County Agencies			
				C&C of Honolulu	Maui County	Hawaii County	Kauai County
	remedial activities, cooling water (below a threshold flow rate), hydrotesting waters, construction activity dewatering effluent, wastewater from petroleum bulk stations, terminals and well drilling activities, discharges from recycled water systems , discharges from recycled water systems,						

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Type of permit or regulatory action	Short description	Federal Agency	State agency	County Agencies			
				C&C of Honolulu	Maui County	Hawaii County	Kauai County
	storm water and certain non-storm water discharges (small MS4s)						
o Individual NPDES permits	Regulates effluent discharges into receiving waters based on case-by-case reviews that are not covered under the general permits		State Department of Health				
Ocean Work Permit	Regulates any work in ocean waters surrounding the State		State Department of Land and Natural Resources				
Oversize and	Regulates			Department of	Department of	Department of	Department

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Type of permit or regulatory action	Short description	Federal Agency	State agency	County Agencies			
				C&C of Honolulu	Maui County	Hawaii County	Kauai County
Overweight Vehicle Permit, County Permit	traffic caused by oversize and overweight vehicles on County highways and roadways.			Transportation Services	Transportation	Public Works	of Public Works
Oversize and Overweight Vehicle Permit, State Permit	Regulates traffic caused by oversize and overweight vehicles on State highways and roadways		State Department of Transportation				
Pesticides and chemigation; storage transport and application of pesticides	Regulates the use, storage, transport, application and disposal of pesticides (in accordance		State Department of Health				

Table 1: List of main permits and regulations to be considered in the development, construction and operation of bioenergy installations in the State of Hawaii.

Type of permit or regulatory action	Short description	Federal Agency	State agency	County Agencies			
				C&C of Honolulu	Maui County	Hawaii County	Kauai County
	with the Federal Insecticide, Fungicide, and Rodenticide Act)						
Plan Review, (County Land Use Regulations)	A plan review use approval is required for certain agricultural activities and processing facilities			Department of Planning and Permitting	Planning Department	Planning Department	Planning Department
Plumbing Permits	Regulates all plumbing work in new construction and modifications to existing structures; could be granted under				Department of Public Works	Department of Public Works	Department of Public Works

Table 1: List of main permits and regulations to be considered in the development, construction and operation of bioenergy installations in the State of Hawaii.

Type of permit or regulatory action	Short description	Federal Agency	State agency	County Agencies			
				C&C of Honolulu	Maui County	Hawaii County	Kauai County
	construction / building permit						
Public Utilities Commission (PUC)	The Public Utilities Commission (PUC) regulates all franchised or certificated public service companies operating in the State; prescribes rates, tariffs, charges and fees.						
Public Water System Permit	Regulates the installation and operation of individual water supply systems with a		State Department of Health				

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Type of permit or regulatory action	Short description	Federal Agency	State agency	County Agencies			
				C&C of Honolulu	Maui County	Hawaii County	Kauai County
	capacity over a certain capacity						
Renewable Fuel Standard Program	Regulates the creation, transfer and documentation of Renewable Identification Numbers (RIN) for all companies and entities that produce, import, and trade with biofuels.	U.S. Environmental Protection Agency					
Sewer System, Connection to County Sewer System	Regulates any connections or re-connections to any municipal			Department of Environmental Services	Department of Public Works	Department of Public Works	Department of Public Works

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Type of permit or regulatory action	Short description	Federal Agency	State agency	County Agencies			
				C&C of Honolulu	Maui County	Hawaii County	Kauai County
	sewer system.						
Sewer Connection, Modification and Expansion	Regulates, extension of a sewer into un-sewered area, over sizing of a sewer system to allow for future development, and construction of relief sewer systems.			Department of Environmental Services	Department of Public Works	Department of Public Works	Department of Public Works
Sign Permit	Regulates the installation, construction, modification and relocation of any sign.			Department of Planning and Permitting	Department of Public Works	Department of Public Works	Department of Public Works
Solid Waste Management Permit	Regulates activities related to the		State Department of Health				

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Type of permit or regulatory action	Short description	Federal Agency	State agency	County Agencies			
				C&C of Honolulu	Maui County	Hawaii County	Kauai County
	disposal of solid waste						
Special Management Area Use Permit	Regulates any development within designated special management area.			Department of Planning and Permitting	Planning Department	Planning Department	Planning Department
Special use permit in the State Agriculture District (HRS, 2005 as amended)	Regulates developments and land uses (here energy and biofuel related) within agricultural district that would be otherwise prohibited		State Land Use Commission				
Spill and Emergency	Regulates	U.S.	State				

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Type of permit or regulatory action	Short description	Federal Agency	State agency	County Agencies			
				C&C of Honolulu	Maui County	Hawaii County	Kauai County
Response Plan for Fuel Systems	what emergency responses have to be planned and what response measures have to be provided to combat fuel spills	Environmental Protection Agency	Department of Health				
State Highway Work Permit	Regulates work conducted on State highways and roadways		State Dept. of Transportation				
State Clean Water Certification 401, Water Quality Certification	Regulates any activity in State waters that would result in any form of discharge, such as		State Department of Health				

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Type of permit or regulatory action	Short description	Federal Agency	State agency	County Agencies			
				C&C of Honolulu	Maui County	Hawaii County	Kauai County
	discharge of dredged and fill material (must also have a US Army Corp of Engineers CWA 404 permit) construction of bridges and dams across navigable waters, ocean dumping, etc.						
State Incidental Take License	Regulates activities in the State that may affect endangered species in Hawaii; State incidental take permit is		State Department of Land and Natural Resources				

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Type of permit or regulatory action	Short description	Federal Agency	State agency	County Agencies			
				C&C of Honolulu	Maui County	Hawaii County	Kauai County
	required in addition to the Federal permit (ESA Section 10 Permit).						
State Highways Conducting Engineering/Survey, Maintenance and Inspection Work Upon State Highways	Regulates work conducted on State highways and roadways related to non-construction work, such as engineering, maintenance and inspection.		State Department of Transportation				
State Highways Right-of-entry	Regulates the construction of any roadway and driveway entries to State highways and		State Department of Transportation				

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Type of permit or regulatory action	Short description	Federal Agency	State agency	County Agencies			
				C&C of Honolulu	Maui County	Hawaii County	Kauai County
	roadways.						
State Land Use District Boundary Amendments	Regulates amendments to the State land use districts as defined by the State Land Use Commission.						
o for land parcels larger than 15 acres	Regulates amendments to change the State land use districts classification of land parcels larger than 15 acres and any reclassification of Conservation Districts.		State Land Use Commission				

Table 1: List of main permits and regulations to be considered in the development, construction and operation of bioenergy installations in the State of Hawaii.

Type of permit or regulatory action	Short description	Federal Agency	State agency	County Agencies			
				C&C of Honolulu	Maui County	Hawaii County	Kauai County
o for land parcels of 15 acres and less	Regulate all amendments of land parcels that are smaller than 15 acres and are not within Conservation Districts.			Department of Planning and Permitting	Planning department	Planning Department	Planning Department
Stream Channel Alteration Permit (SCA)	Regulates any type of alteration work inside the ordinary high water marks of a continuously flowing stream.		State Department of Land and Natural Resources				
Stream Diversion Works Permit (SDWP) ..	Regulates any work in conjunction with diverting stream water		State Department of Land and Natural Resources				

Table 1: List of main permits and regulations to be considered in the development, construction and operation of bioenergy installations in the State of Hawaii.

Type of permit or regulatory action	Short description	Federal Agency	State agency	County Agencies			
				C&C of Honolulu	Maui County	Hawaii County	Kauai County
	by installing or construction an artificial or natural structure.						
Street Usage Permit	Regulates work on public right-of-way, such as any construction work on County streets, highways, roads, driveways, etc. ; parking in conjunction with construction; street closure in conjunction with construction .			Department of Transportation Services	Department of Public Works	Department of Public Works	Department of Public Works

Table 1: List of main permits and regulations to be considered in the development, construction and operation of bioenergy installations in the State of Hawaii.

Type of permit or regulatory action	Short description	Federal Agency	State agency	County Agencies			
				C&C of Honolulu	Maui County	Hawaii County	Kauai County
Sustainable Communities Plan Amendment	Sustainable Communities plan amendments might be required for land uses.			Department of Planning and Permitting	Planning department	Planning Department	Planning Department
Surface Water Use Permit	Regulates the withdrawals from surface waters.		State Department of Land and Natural Resources				
Temporary use permit	Regulates uses and structures of temporary nature and which might have a significant impact on surrounding areas, such as off-site construction			Department of Planning and Permitting	Department of Public Works	Department of Public Works	Department of Public Works

Table 1: List of main permits and regulations to be considered in the development, construction and operation of bioenergy installations in the State of Hawaii.

Type of permit or regulatory action	Short description	Federal Agency	State agency	County Agencies			
				C&C of Honolulu	Maui County	Hawaii County	Kauai County
	storage yard, etc.						
Trenching permit	Regulates all activities related to excavating in public right-of-way.			Department of Planning and Permitting	Department of Public Works	Department of Public Works	Department of Public Works
Underground Injection Control (UIC) Permit	Regulates any form of underground effluent discharge, such as from underground injection systems. Permit is required to construct, operate, modify or		State Department of Health				

Table 1: List of main permits and regulations to be considered in the development, construction and operation of bioenergy installations in the State of Hawaii.

Type of permit or regulatory action	Short description	Federal Agency	State agency	County Agencies			
				C&C of Honolulu	Maui County	Hawaii County	Kauai County
	otherwise utilize an injection well.						
Underground Storage Tank Permit	Regulates the construction and operation of underground storage tanks with a capacity of over 1,100 gallons.		State Department of Health				
Utility Service Requirements, Electricity	Regulates infrastructure requirements for connection to the public electric grid.			Hawaiian Electric Company	Maui Electric Company	Hawaii Electric Light Company	Kauai Island Utility Cooperative
Utility Service Requirements, Water	Regulates infrastructure requirements for connection to the public			Honolulu Board of water Supply	Department of Water Supply	Department of Water Supply	Water Department

Table 1: List of main permits and regulations to be considered in the development, construction and operation of bioenergy installations in the State of Hawaii.

Type of permit or regulatory action	Short description	Federal Agency	State agency	County Agencies			
				C&C of Honolulu	Maui County	Hawaii County	Kauai County
	water system.						
Variance from Building, electrical, plumbing and fire codes	Regulates all instances when building, electrical, plumbing and fire code would not be met in a development or structure.			Department of Planning and Permitting; Fire Department	Department of Public Works	Department of Public Works	Department of Public Works
Variance from Pollution Controls	Regulates all instances when any emissions or discharges of pollutants or noise would exceed applicable standards and rules.		State Department of Health				
Wastewater	Regulates the		State				

Table 1: List of main permits and regulations to be considered in the development, construction and operation of bioenergy installations in the State of Hawaii.

Type of permit or regulatory action	Short description	Federal Agency	State agency	County Agencies: C&C of Honolulu	Maui County	Hawaii County	Kauai County
Treatment System Permit	construction and operation of individual wastewater treatment facilities; e.g. where the wastewater source would not be connected to the municipal sewer system.		Department of Health				
Water Connection/Facilities Charges.	Regulates under what condition a water user can be connected to the municipal water supply system.			Honolulu Board of water Supply	Dept. of Water Supply	Dept. of Water Supply	Water Department
Water Use Permit (WUP)	Regulates withdrawals of		State Department of				

Table 1: List of main permits and regulations to be considered in the development, construction and operation of bioenergy installations in the State of Hawaii.

Type of permit or regulatory action	Short description	Federal Agency	State agency	County Agencies			
				C&C of Honolulu	Maui County	Hawaii County	Kauai County
	water from any surface or ground water management area		Land and Natural Resources				
Well Construction / Pump Installation Permit,	Regulates the construction of water wells and the installation of water pumps to extract water.		State Department of Land and Natural Resources				
Wellhead Protection	Regulates activities around a well where such activities might affect the quality of the water. Measures are designed in conjunction		State Department of Health				

Table 1: List of main permits and regulations to be considered in the development, construction and operation of bioenergy installations in the State of Hawaii.

Type of permit or regulatory action	Short description	Federal Agency	State agency	County Agencies			
				C&C of Honolulu	Maui County	Hawaii County	Kauai County
	with the Safe Drinking Water Act to protect public drinking water supplies.						
Zoning Change	Regulates changes of land use zone districts to allow land uses that are otherwise not permitted under the land use ordinances.			Department of Planning and Permitting	Planning Department	Planning Department	Planning Department
Zoning Waivers for public uses and public Utilities	Regulates waivers to the requirements under the land use ordinance for certain public or			Department of Planning and Permitting	Planning Department	Planning Department	Planning Department

Table 1: List of main permits and regulations to be considered in the development, construction and operation of bioenergy installations in the State of Hawaii.

Type of permit or regulatory action	Short description	Federal Agency	State agency	County Agencies			
				C&C of Honolulu	Maui County	Hawaii County	Kauai County
	utility installations.						

2.5 Permits and Regulations Along the Bioenergy Value Chain

The bioenergy total value chain has the following three main components:

Feedstock Production: Growing or collecting of biomass that will be converted to bioenergy. This biomass is then transported to the bioenergy conversion facility.

Bioenergy Conversion Facility: Converting the biomass to a physical state that can be used by most consumers. Biomass can be converted to liquid or gaseous products that power engines for transportation or electricity generation. Biomass can also be converted to heat to provide process heat or to power thermal power plants.

Bioenergy Distribution: Liquid biofuels are typically used in vehicles or thermal powerplants. The distribution system for liquid biofuels typically involves conveyance through pipelines, transport in bulk marine tankers or tanker trucks and storage in fuel tanks. Gaseous biofuel products are typically converted to electricity in thermal powerplants that are in close proximity to the gasification plants. Solid biofuels are typically transported by truck or railway from the feedstock production facility to conversion plants, where the solid biofuel is converted to electricity or process heat.

Permitting and regulatory requirements vary at different stages in the value chain. Table 2 illustrates a "Permitting Matrix" with three rows and columns. The matrix defines what group of permits and regulations are applicable in different phases of the value chain. Table 3 names the permits and regulations that are applicable for facilities belonging to feedstock production, bioenergy conversion and biofuel distribution.

Table 2 Definition of Permitting Matrix

Areas of biofuel value chain	Land - Use Zoning permits		Construction permits		Operating permits	
	issues	permits	issues	permits	issues	permits
Feedstock production	Land use zoning / districts at state and county levels; special management areas; flood zones and other zoning issues as they pertain to the development of bioenergy feedstock resources.		Permitting requirements relative to specific development for the feedstock agricultural areas, including soil erosion, runoff, grading, etc. ; permitting requirements for ancillary facilities.		Permitting needs for the operation of the feedstock resources, including water usage, feed stock storage, handling of solid waste, handling of hazardeous products etc.	
Bioenergy conversion	Land use zoning / districts at state and county levels; special management areas; flood zones and other zoning issues as they pertain to the development of biofuel conversion facilities		Permitting needs for site preparation and the construction of the biofuel facilities, including control of runoff, soil erosion, solid waste handling, air pollution, traffic, etc.		Permitting needs for the operation of the biofuel facility, including water usage allocation, wastewater disposal, storage of hazardous agents, air pollution impacts, process equipment operation, storage of process relevant agents, storage of refined agents, etc.	
Distribution of biofuel / bioenergy	Land use zoning / districts at state and county levels; special management areas; flood zones and other zoning issues as they pertain to the development of biofuel distribution infrastructure		Permitting needs during site preparation and the construction of the biofuel distribution infrastructure.		Permitting needs for operation of the biofuel distribution infrastructure components; including operation permits for land and marine transport, fuel handling, fire protection, spill mitigation, etc.	

Table 3 Bioenergy Feedstock production – List of possible permits required for a range of project settings.

Table 3 Bioenergy Feedstock production – List of possible permits required for a range of project settings.

Land Use permits and regulations	Construction permits and regulations	Operation permits and regulations
Review land use ordinances in regards to zoning at federal, State and County levels, such as, Special Management Areas, flood zones and other zoning issues as they pertain to the development of bioenergy feedstock resources	Permitting needs relative to specific development for the feedstock production area, including soil erosion, runoff, grading, water issues, construction impacts, use and storage of certain process products or pesticides, etc.	Permitting needs for the operation of the feedstock resources, including water usage, feed stock storage, noise, storm water runoff, etc.
Coastal Zone Management Program, Federal consistency Conditional Use Permit (CUP) Conservation District Use Permit Development Plan Amendments Environmental Impact Statement (EIS) County Environmental Impact Statement (EIS) NEPA Environmental Impact Statement (EIS) State ESA Section 10 Permit Flood Hazard Districts, Development Permits Flood Hazard Districts,	Aboveground Storage Tank (AST) permit; construction and operation Air quality from General Agricultural Operations Bridge and Causeway Permit Building Permit: Burn Permit (agricultural burning) CAA permits: Covered source permit Uncovered source permit Minor construction permit Clean Water Act (SECTION 404) Combustible and flammable liquids tank installations permits Community Noise Permit Construction Noise Permit	Aboveground Storage Tank (AST) permit; construction and operation Air quality from General Agricultural Operations Burn Permit (agricultural burning) CAA permits: Covered source permit Uncovered source permit Minor Source Operating Permit Combustible and flammable liquids tank installations permit Community Noise Permit Construction Noise Permit Hazardous waste; storage, treatment and disposal

Table 3 Bioenergy Feedstock production – List of possible permits required for a range of project settings.

Land Use permits and regulations	Construction permits and regulations	Operation permits and regulations
Variance Permits General Plan Amendments Historical Site Review Natural Area Reserves Use Permit (special use permit) Plan Review, (County Land Use Regulations) Special Management Area Use Permit Special use permit in the State Agriculture District (HRS, 2005 as amended) State Incidental Take License State Land Use District Boundary Amendments - for land parcels larger than 15 acres - for land parcels of 15 acres and less Sustainable Communities Plan Amendment Zoning Change Zoning Waivers for public uses and public Utilities	Construction Dewatering Permit County Roadway Right-of-Way Permit (Street Usage Permit) Discharge Effluent Permit Driveway Permits Effluent Discharge - Zone of mixing Electrical Permit Energy Corridor Permit Environmental Impact Statement (EIS) County Environmental Impact Statement (EIS) NEPA Environmental Impact Statement (EIS) State Grading Permit Groundwater Use Permit Grubbing and Stockpiling Historical Site Review General NPDES permits Individual NPDES permits Oversize and Overweight Vehicle Permit, County Permit Oversize and Overweight Vehicle Permit, State Permit Pesticides and chemigation; storage transport and application of pesticides Plumbing Permits Sewer System, Connection to County Sewer System Sewer Connection, Modification and Expansion Sign Permit State Highway Work Permit State Clean Water	Maritime Transportation Security Act (MTSA) General NPDES permits Pesticides and chemigation; storage transport and application of pesticides Sign Permit Solid Waste Management Permit Wastewater Treatment System Permit Water Connection/Facilities Charges. Water Use Permit (WUP) Well Construction / Pump Installation Permit, Wellhead Protection

Table 3 Bioenergy Feedstock production – List of possible permits required for a range of project settings.		
Land Use permits and regulations	**Construction permits and regulations**	**Operation permits and regulations**
	Certification 401, Water Quality Certification State Highways Conducting Engineering/Survey, Maintenance and Inspection Work Upon State Highways State Highways Right-of-entry Stream Channel Alteration Permit (SCA) Stream Diversion Works Permit (SDWP) .. Street Usage Permit Surface Water Use Permit Temporary use permit Trenching permit Underground Injection Control (UIC) Permit Utility Service Requirements, Electricity Utility Service Requirements, Water Variance from Building, electrical, plumbing and fire codes Variance from Pollution Controls Well Construction / Pump Installation Permit, Wellhead Protection	

Table 4 Bioenergy Conversion Facility (with all ancillary facilities) – List of possible permits required for a range of project settings.

Table 4 Bioenergy Conversion Facility (with all ancillary facilities) – List of possible permits required for a range of project settings.		
Land Use permits and regulations	**Construction permits and regulations**	**Operation permits and regulations**
Review land use ordinances in regards to zoning at federal, State and County levels, such as, Special Management Areas, flood zones and other zoning issues as they pertain to land use the biofuel conversion facilities	Permitting needs for site preparation and the construction of the biofuel facilities, including control of runoff, soil erosion, solid waste handling, air pollution, traffic, etc.	Permitting needs for the operation of the biofuel facility, including water usage allocation, wastewater disposal, storage of hazardous agents, air pollution impacts, process equipment operation, storage of process relevant agents, storage of refined agents. etc.
Coastal Zone Management Program, Federal consistency Conditional Use Permit (CUP) Conservation District Use Permit Development Plan Amendments Environmental Impact Statement (EIS) County Environmental Impact Statement (EIS) NEPA Environmental Impact Statement (EIS) State ESA Section 10 Permit Flood Hazard Districts, Development Permits Flood Hazard Districts, Variance Permits General Plan Amendments	Aboveground Storage Tank (AST) permit; construction and operation Boiler (pressure vessel) permit Bridge and Causeway Permit Building Permit: Burn Permit (agricultural burning) Covered source permit Uncovered source permit Major construction permit Minor construction permit Clean Water Act (SECTION 404) Combustible and flammable liquids tank installations permits Community Noise Permit Construction Noise Permit Construction Dewatering Permit County Roadway Right-of-Way Permit (Street	Aboveground Storage Tank (AST) permit; construction and operation Boiler (pressure vessel) permit Burn Permit (agricultural burning) Covered source permit Uncovered source permit Major Source Title V Operating Permit Minor Source Operating Permit Chemical facilities anti-terror standards (CFATS) Combustible and flammable liquids tank installations permits Community Noise Permit Construction Noise Permit Hazardous waste; storage, treatment and disposal Industrial Wastewater Discharge Permit Maritime Transportation

Table 4 Bioenergy Conversion Facility (with all ancillary facilities) – List of possible permits required for a range of project settings.

Land Use permits and regulations	**Construction permits and regulations**	**Operation permits and regulations**
Historical Site Review Natural Area Reserves Use Permit (special use permit) Plan Review, (County Land Use Regulations) Special Management Area Use Permit State Incidental Take License State Land Use District Boundary Amendments for land parcels larger than 15 acres for land parcels of 15 acres and less Sustainable Communities Plan Amendment Zoning Change Zoning Waivers for public uses and public Utilities	Usage Permit) Discharge Effluent Permit Driveway Permits Effluent Discharge - Zone of mixing Electrical Permit Energy Corridor Permit Environmental Impact Statement (EIS) County Environmental Impact Statement (EIS) NEPA Environmental Impact Statement (EIS) State FAA Notice of Construction, permit for construction in navigable airspace Grading Permit Groundwater Use Permit Grubbing and Stockpiling Hazardous waste; storage, treatment and disposal Historical Site Review Industrial Wastewater Discharge Permit General NPDES permits Individual NPDES permits Ocean Work Permit Oversize and Overweight Vehicle Permit, County Permit Oversize and Overweight Vehicle Permit, State Permit Pesticides and chemigation; storage transport and application of pesticides Plumbing Permits Public Water System Permit Sewer System, Connection to County Sewer System Sewer Connection,	Security Act (MTSA) General NPDES permits Individual NPDES permits Pesticides and chemigation; storage transport and application of pesticides Public Utilities Commission (PUC) Public Water System Permit "Renewable Fuel Standard Program " Sign Permit Solid Waste Management Permit Underground Injection Control (UIC) Permit Underground Storage Tank Permit Utility Service Requirements, Electricity Utility Service Requirements, Water Variance from Building, electrical, plumbing and fire codes Variance from Pollution Controls Wastewater Treatment System Permit Water Connection/Facilities Charges. Water Use Permit (WUP) Well Construction / Pump Installation Permit, Wellhead Protection

Table 4 Bioenergy Conversion Facility (with all ancillary facilities) – List of possible permits required for a range of project settings.		
Land Use permits and regulations	**Construction permits and regulations**	**Operation permits and regulations**
	Modification and Expansion Sign Permit State Highway Work Permit State Clean Water Certification 401, Water Quality Certification State Highways Conducting Engineering/Survey, Maintenance and Inspection Work Upon State Highways State Highways Right-of-entry Stream Channel Alteration Permit (SCA) Stream Diversion Works Permit (SDWP) .. Street Usage Permit Surface Water Use Permit Temporary use permit Trenching permit Underground Injection Control (UIC) Permit Underground Storage Tank Permit Utility Service Requirements, Electricity Utility Service Requirements, Water Variance from Building, electrical, plumbing and fire codes Variance from Pollution Controls Wastewater Treatment System Permit Well Construction / Pump Installation Permit, Wellhead Protection	

Table 5 Bioenergy Distribution Facility (with all ancillary facilities) – List of possible permits required for a range of project settings.

Table 5 Bioenergy Distribution Facility (with all ancillary facilities) – List of possible permits required for a range of project settings.		
Land Use permits and regulations	**Construction permits and regulations**	**Operation permits and regulations**
Review land use ordinances in regards to zoning at federal, State and County levels, such as, Special Management Areas, flood zones and other zoning issues as they pertain to the development of bioenergy distribution infrastructure.	Permitting needs during site preparation and the construction of the bioenergy distribution infrastructure.	Permitting needs for operation of the bioenergy distribution infrastructure components; including operation permits for land and marine transport, fuel handling, fire protection, spill mitigation, etc.
Coastal Zone Management Program, Federal consistency Conditional Use Permit (CUP) Development Plan Amendments Environmental Impact Statement (EIS) County Environmental Impact Statement (EIS) NEPA Environmental Impact Statement (EIS) State ESA Section 10 Permit Flood Hazard Districts, Development Permits Flood Hazard Districts, Variance Permits General Plan Amendments Historical Site Review	Aboveground Storage Tank (AST) permit; construction and operation Bridge and Causeway Permit Building Permit: Covered source permit Uncovered source permit Major construction permit Minor construction permit Clean Water Act (SECTION 404) Combustible and flammable liquids tank installations permits Community Noise Permit Construction Noise Permit Construction Dewatering Permit County Roadway Right-of-Way Permit (Street Usage Permit) Discharge Effluent Permit Driveway Permits	Aboveground Storage Tank (AST) permit; construction and operation Covered source permit Uncovered source permit Major Source Title V Operating Permit Minor Source Operating Permit Chemical facilities anti-terror standards (CFATS) Combustible and flammable liquids tank installations permits Community Noise Permit Construction Noise Permit Hazardous waste; storage, treatment and disposal Industrial Wastewater Discharge Permit Maritime Transportation Security Act (MTSA) General NPDES permits Individual NPDES permits

Table 5 Bioenergy Distribution Facility (with all ancillary facilities) – List of possible permits required for a range of project settings.

Land Use permits and regulations	**Construction permits and regulations**	**Operation permits and regulations**
Maritime Transportation Security Act (MTSA) Natural Area Reserves Use Permit (special use permit) Plan Review, (County Land Use Regulations) Special Management Area Use Permit State Incidental Take License State Land Use District Boundary Amendments for land parcels larger than 15 acres for land parcels of 15 acres and less Sustainable Communities Plan Amendment Zoning Change Zoning Waivers for public uses and public Utilities	Effluent Discharge - Zone of mixing Electrical Permit Energy Corridor Permit Environmental Impact Statement (EIS) County Environmental Impact Statement (EIS) NEPA Environmental Impact Statement (EIS) State ESA Section 10 Permit FAA Notice of Construction, permit for construction in navigable airspace Grading Permit Groundwater Use Permit Grubbing and Stockpiling Hazardous waste; storage, treatment and disposal Historical Site Review Industrial Wastewater Discharge Permit Maritime Transportation Security Act (MTSA) General NPDES permits Individual NPDES permits Ocean Work Permit Oversize and Overweight Vehicle Permit, County Permit Oversize and Overweight Vehicle Permit, State Permit Pesticides and chemigation; storage transport and application of pesticides Plumbing Permits Public Water System Permit Sewer System, Connection to County Sewer System Sewer Connection,	Pesticides and chemigation; storage transport and application of pesticides Public Utilities Commission (PUC) Public Water System Permit "Renewable Fuel Standard Program" Sign Permit Underground Injection Control (UIC) Permit Underground Storage Tank Permit Utility Service Requirements, Electricity Utility Service Requirements, Water Variance from Building, electrical, plumbing and fire codes Variance from Pollution Controls Wastewater Treatment System Permit Water Connection/Facilities Charges. Water Use Permit (WUP) Well Construction / Pump Installation Permit, Wellhead Protection

Table 5 Bioenergy Distribution Facility (with all ancillary facilities) – List of possible permits required for a range of project settings.		
Land Use permits and regulations	**Construction permits and regulations**	**Operation permits and regulations**
	Modification and Expansion Sign Permit State Highway Work Permit State Clean Water Certification 401, Water Quality Certification State Highways Conducting Engineering/Survey, Maintenance and Inspection Work Upon State Highways State Highways Right-of-entry Stream Channel Alteration Permit (SCA) Stream Diversion Works Permit (SDWP) .. Street Usage Permit Surface Water Use Permit Temporary use permit Trenching permit Underground Injection Control (UIC) Permit Underground Storage Tank Permit Utility Service Requirements, Electricity Utility Service Requirements, Water Variance from Building, electrical, plumbing and fire codes Variance from Pollution Controls Wastewater Treatment System Permit Well Construction / Pump Installation Permit, Wellhead Protection	

3. Hawaii Bioenergy Stakeholders Opinion about Permitting

In formulation and compilation of this Master Plan, stakeholders in the bioenergy industry gave inputs regarding the current status and future needs of bioenergy related permitting. The following paragraphs discuss perceived shortcomings of the existing permitting framework and proposed measures to streamline the permitting process in order to make it more transparent, effective and expeditious, as expressed by stakeholders.

3.1 Perceptions of Existing Permitting

Stakeholder input about different aspects of permitting has been categorized and is presented hereafter in the order of importance in which the aspects were raised:

<u>The process efficiency of the existing permitting is poor:</u>

The perceived weaknesses of the existing permitting process were expressed as follows:

- The permitting process lacks clear structure; with permit processing either concurrent or consecutive, there needs to be a clear indication in what order the permits are processed; while some agencies offer lists of required permits other agencies do not offer such lists. Reducing number of permits, where possible would be helpful.
- One-stop permitting; the roles of a facilitator or a project manager would be helpful to expedite the permitting process
- Timeline and expediting required; Deadlines would be helpful to gauge the project progress; need accountability of where the permitting process stands and if there are undue delays; there is need for expedited permitting; especially smaller or start-up energy companies, which want to invest in energy projects in Hawaii have to spend too much of their precious resources while waiting for the permitting process to be completed.
- Lack of cooperation between permitting agencies; lack of cooperation between agencies cost additional time and efforts

<u>Basic understanding about bioenergy is lacking:</u>

The question that biofuels solve environmental and energy security problems apparently needs to be addressed and clear guidelines have to be established and made public. It has to be clearly stated that there might be benefits and disadvantages to biofuels. Since Hawaii's leadership has declared biofuels and bioenergy as top priorities, there needs to be a clear communication as to why biofuel are essential for the state and why there is an urgent need for a buying-in at all levels of State and County administrations.

Increase the demand for bioenergy:

The increased demand for bioenergy will increase bioenergy investments and projects. This increase in number of projects will result in a strong need for streamlined permitting processes; on the other hand, the absence of bioenergy projects will make the need for streamlined processes moot. Here again, the goal set forth by Hawaii's leadership that calls for greater share of clean and renewable energy in the State energy supply, has to be embraced by Hawaii's businesses, community and governmental agencies so that more bioenergy projects can be realized. The goal of a large bioenergy industry in Hawaii needs to be fully anchored in the fabric of the governmental administrations in order to attract investment through an effective and expeditious permitting regime.

Transparency is needed in the permitting process:

The permitting process seems to lack transparency. Not only are bioenergy policy making actions by the state not transparent, the permitting process itself lacks transparent process guidelines.

Agency staffing and training:

The staff at the reviewing agencies must have access to an appropriate knowledge base to effectively process permits in areas that involve innovative technologies. Training should be provided to increase expertise in subject areas where needed.

Other aspects:

Stakeholders attested a political bias towards certain companies or individuals and called for the urgent need that the permitting process be free from political considerations. There seems to be a reluctance of State and County agencies to consult with external agencies that have the expert knowledge necessary for competent and expeditious permitting. Procedurally the permitting process must not be terminated or "reset" to the start, due to "significant" changes in the project. It is not atypical for projects going through the planning phase to experience changes in scope, technology or process. Since "significant" changes would cause termination or at least "resetting" of the permitting process, the agencies have to use transparency of what constitutes "significant".

3.2 Proposed Elements of Streamlined Permitting

The following measures and policies were proposed by the stakeholders. The order in which they are presented does not reflect a preference or importance of such improvements.

The permitting process needs to be more effective through measures such as presented below:

- Stakeholders recognize the need for thorough permitting but prefer an improved permitting process. Stakeholders want a permitting process that thoroughly scrutinizes possible environmental and social impacts; fundamental changes to strict permitting are not desired. This notwithstanding, the process of permitting needs a major overhaul requiring streamlining and transforming. The main aspects that need revamping are clear and easy to follow process steps such as, mitigating inefficiencies at the interfaces between agencies and individual permits, informing the process participants, formulating and controlling milestones for expeditious permitting and having clear accountability of all stakeholders involved.
- Business planning for a proposed project must allocate adequate time to obtain all necessary permits. Significantly surpassing the allocated time allowance for permitting could place the business rationale for the bioenergy project into jeopardy. Therefore it is imperative to clearly state the targeted time for completing the different permitting steps and to assign accountability for completing the permitting steps in time.
- The criteria for approval must be made clearer to all process participants involved. Subjectivity in the process must be eliminated by clearly stating the expectations and the reasons for denial of the permit. Clear accountability of the agencies would help to make the process more transparent.
- The community needs to be involved in the process. Businesses must be more pro-active in informing the community early in the process. There needs to be a process step that qualifies a “quality of public comments”, and ensures that public comments truly reflect the needs and opinions of the community and not a small group of community members.
- There should to be clear and conclusive leadership directive that communicates the urgent need of bioenergy to state’s communities and to all stakeholders in the permitting process involved. Conflicts that might arise between environmental concerns, business concerns, cultural concerns and societal concern need to be resolved so that Hawaii can effectively move towards a bioenergy future.
- Cooperation among different agencies in the state and with out-of-state agencies and experts ought to be encouraged. Cooperation of agencies in the state would increase the efficiency of the permitting process by avoiding redundant and repetitive steps in the permitting process. Cooperation with out-of-state agencies or experts would increase the knowledge base and would enable the definition of realistic benchmarks for a streamlined permitting process. Since there appears an increased push in other states towards reforming permitting, Hawaii could greatly benefit from experiences gained in other parts of the nation. Agencies might need to relinquish some of their “jurisdiction” to other agencies in an effort to combine oversight of permitting between agencies and avoid redundancy.
- The staffs of agencies as well as permit applicants require training and information in administrative as well as in technology or subject knowledge. In the evolving bioenergy industry innovations are happening fast and the flow of

information needs to be encouraged. The permitting process needs to be transformed from an adversarial to a more collaborative process approach. If the permitting involves advanced scientific or technical knowledge, a peer review process might be helpful.

- The need for Hawaii to implement renewable energy and biofuels must be seen in a larger statewide energy situation. Biofuels are only part of the solutions and not all biofuels appear to be “good”. Neighboring islands will have to share in the burden of implementing bioenergy but might not necessarily require the high level of biofuel as is envisioned for Oahu.

4. Strategies for Expedited Permitting

The need to foster economic development and expeditiously implementing renewable energy projects has caused some regional and state governments in the US to streamline existing permitting procedures and reduce time and effort in the permitting for certain projects that are deemed beneficial for the state, region and community.

While the efforts of streamlining permitting are applicable to a broad range of economic development projects, renewable energy development projects are generally receiving a prominent status. A web search conducted in April and May of 2009 has revealed the following elements of expedited and streamlined permitting, which could also be implemented in Hawaii:

- Expedited permitting is a major goal for many agencies but substantial time will be required by agencies to change their permitting processes towards a new permitting paradigm. Since pressing economic development and renewable energy implementation needs cannot wait until new permitting is universally accepted and implemented thoroughly by the organizations, certain projects should qualify for preferential permitting treatment. The decision whether a project qualifies for expedited permitting might be based on general procedural qualifiers or on case-by-case decisions.

- The permitting procedures should be defined as an efficient work process that encompasses work schemes of all participating agencies and stresses proactive cooperation between the agencies and the applicant. Where present permitting processes might already lead to efficient permitting within individual agencies, it is paramount to facilitate the cooperation between agencies to remove redundancies in permits and information required for individual permits.

- The creation of a central contact point is seen as advantageous in order to efficiently communicate between applicants and permit awarding agencies. The central contact point would act as a facilitator who can help the applicant to reduce the burden of providing redundant information and keep the permitting project on a tight schedule.

- Each permit awarding agency should assign a point of contact that communicates between the central point of contact and the agencies that are part of the permitting process. The points of contacts within the agencies should also be responsible to establish and maintain efficient intra-agency communication for all permitting.

- There should be a pooled information repository where the applicant can deposit information that could then be used by different permits. This information repository would reduce the burden of the applicant to provide similar information to different agencies and for different permits.

- The permitting process should be accomplished within a certain time period. All agencies should endeavor to finish their permitting work within that time frame. A range from 90 to 180 days has been identified by different state and county agencies for certain permit types. Certain unforeseen circumstances (i.e. non availability of information) might preclude the targeted permitting period but permitting should be completed as expeditiously as possible

- The use of e-permitting is encouraged. The use of an online self-application for certain permits may be justified.

- Another venue for an expanded use of the Internet is an online permitting process with progress tracking and online exchange of information. Such an e-permitting process would define permitting milestones and would process milestone tracking. The applicant and all other process participants could get real time information about the status of the project and if the project permitting is on schedule.

- There should be a mechanism to inform applicants about what steps and in what order these steps need to be carried out in the permitting process.

- Agencies should continuously train existing and new staff in the expedited permitting.

5. Efficient Permitting in Hawaii

Hawaii's legislature has emphasized the significance of streamlining and prioritizing the permitting process to provide predictability to private companies and to encourage their commitment of substantial amounts of capital, time, and effort necessary to develop renewable energy projects. The "Hawaii Integrated Energy Policy of 1991" found that the "permits and approvals that may be required for the development and siting of energy facilities ... can take up to seven years for a single project." [Hawaii 2007 Legislature SB 987].

In an effort to make the permitting process for renewable projects more efficient, transparent and predictable, Hawaii has enacted several legislative measures. The following amendments to the Hawaii Revised Statutes (HRS) reflect recent legislative initiatives, starting with the 2007 legislative session. These legislative measures were enacted establishing specific permitting processes and process roles to support aligning Hawaii's energy policy laws with the State's energy goals.

Section 46-19.4, HRS, calls for priority permitting processes for renewable energy projects. All agencies shall provide priority handling and processing for all county permits required for renewable energy projects.

Section 196-1.5, HRS, calls for a priority permitting process for renewable energy projects. All agencies shall provide priority handling and processing for all State permits required for renewable energy projects.

Section 226-18, Objectives and policies for facility systems – energy, paragraph c(10), calls for priority handling and processing for all State and County permits required for renewable energy projects.

Efforts to improve the efficiency in permitting should address two aspects of the permitting process:

Improving the permitting process within the permitting agency: The individual permitting agency is responsible to streamline the permitting process through internal standards and expediting measures. Permitting agencies can improve process efficiency of internal workflow by defining standard procedures (e.g. as illustrated in flow diagrams), assigning a project leader and improving communication between the internal agency work group and with the applicant. Using web-based communication and administration tools can significantly speed up the process and avoid repetitive actions with predefined procedures. For example, some permitting agencies in Hawaii do offer online permit applications and tracking for certain permits.

Improving the permitting process by coordinating efforts of all permitting agencies: In most cases bioenergy facilities require a range of permits issued by more than one permitting agency. In such cases managing or facilitating the overall permitting process can significantly improve the efficiency of interagency cooperation.

5.1 Examples of Internal Agency Efficiency Measures

Permitting agencies in Hawaii are tasked to make permitting more efficient, transparent and less time consuming. The actual extent of improvements of internal agency process improvements might not be visible to the public because these efforts are conducted by internal workgroups. However, permitting process improvements are presently being developed and implemented in various departments. Three examples of transparent and efficient permitting are illustrated in the following.

Example One, Commission of Water Resource Management, State Department of Land and Natural Resources.
The permit portal page is shown in Figure 2 [DLNR, 2009 A]. Presently, processes for five permits are described in depth in downloadable PDF. The flowcharts offer a clear overview of all steps in the process of obtaining a permit. Figure 3 shows a partial flow diagram of the stream channel alteration permit (SCAP) process [DLNR, 2009 B].

Example Two, Kauai County Building Permits Online! the building permit tracking portal of e-Gov Kauai is shown below, Figure 4. The functions provide tracking of the permit status and also offer online help in the permitting process.

Example Three, City and County of Honolulu, Department of Planning and Permitting (DPP), Interactive GIS Maps and Data: This extensive and powerful GIS system (Figure

5) is a great help for permitting related activities. The new and updated GIS system provides parcel maps and other information using site address, tax map key, geocode address or intersection, park name, and GPS coordinates. The system also provides Cultural & Demographic, Public Safety, Zoning & Regulatory, Structures & Facilities, Fema Flood & Hydrography, and Utilities information.

Figure 2 Screen-print of online permit portal of Hawaii Commission on Water Resource Management, DLNR [DLNR, 2009 A]

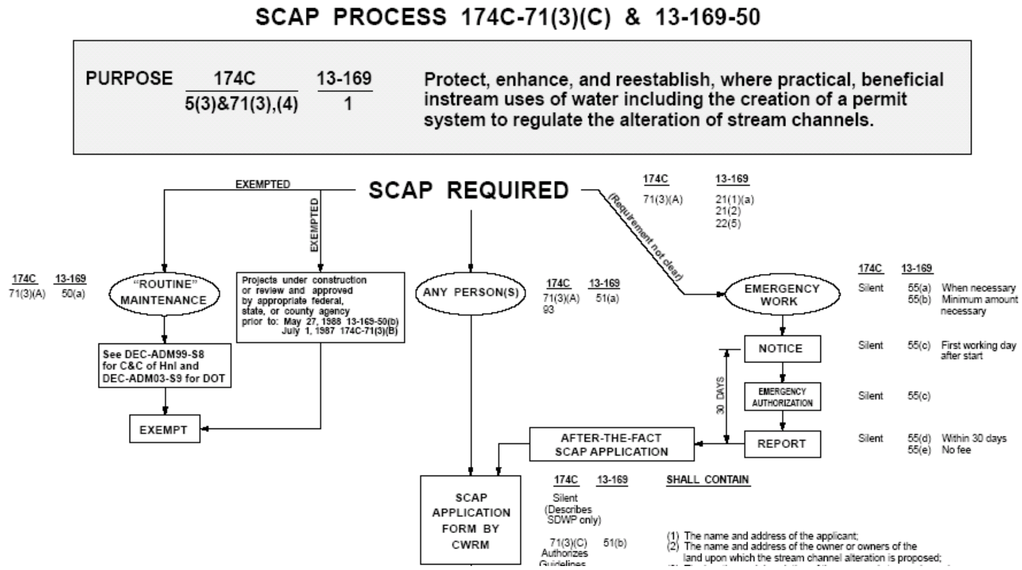

Figure 3 Flow diagram of stream channel alteration permit (SCAP) process;

Figure 4 Screen-print of Kauai County Building Permits Online! Portal

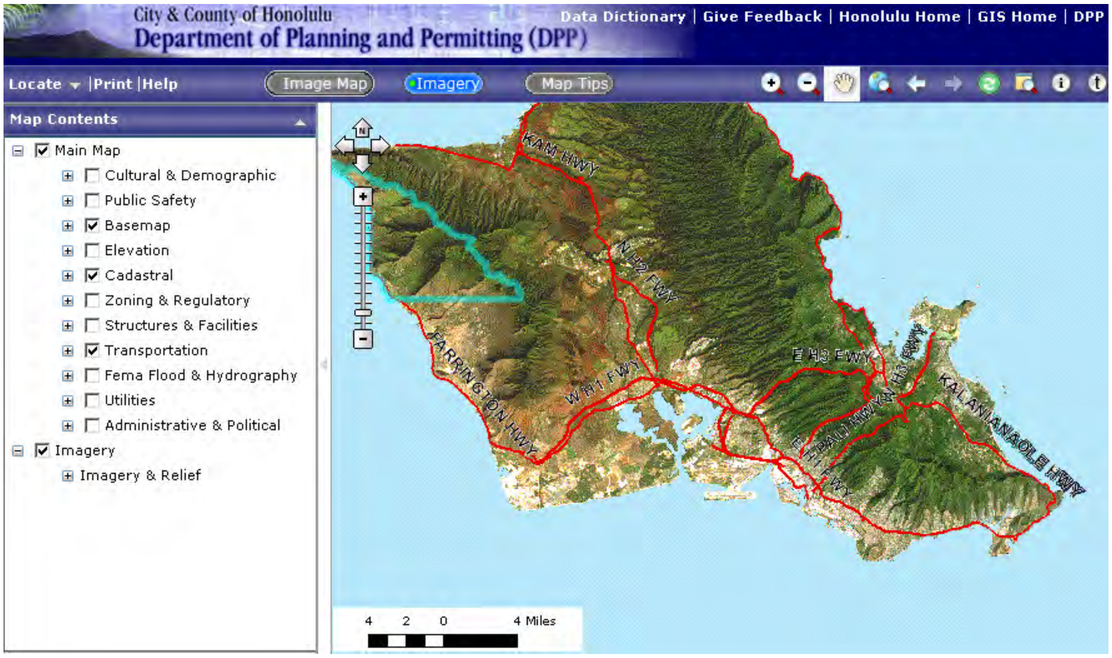

Figure 5 Screen-print of interactive GIS maps and data portal, City and County of Honolulu, Department of Planning and Permitting (DPP) [DPP, 2009].

5.2 Coordinating the Bioenergy Permitting Process

Coordination of the overall permitting process for bioenergy facilities can significantly improve the efficiency and shorten the length of the overall permitting process. Chapter 201N, HRS, establishes the Renewable Energy Facility Siting Process (REFSP) that provides a permitting and regulatory framework for the construction of renewable energy facilities in the state with a rated electricity generation capacity greater than 200 MW. In the 2009 legislative session, HB 1464 HD3 SD2 CD1 was passed to amend Chapter 201N, HRS, to allow renewable energy facilities with rated energy generation capacities of greater than 5 MW and less than 200 MW, and biofuel production capacities of larger than 1 million gallons per year, to apply for the REFSP process.

In the current form of the REFSP, biogas facilities are not specifically recognized as renewable energy facilities. Stakeholders have pointed out that facilities which convert feedstock into gaseous fuels, referred to a biogas, should also qualify for permitting under the REFSP rules. Often biogas facilities provide gaseous fuel from renewable sources exclusively to power plants. In these cases the power rating of the power plant can be used to qualify the facility as a renewable energy facility for permitting under REFSP. There might be cases, however, when biogas is produced to provide renewable fuel for other applications than generating power. In such cases the threshold for REFSP eligibility would need to be also expressed in cubic feet of volume of biogas per time period (e.g. Mcf per year) or in terms of heat content (e.g. Mbtu), so that biogas facilities could use REFSP permitting.

Section 201-12.5, HRS, established by Act 208, SLH 2008, defines the role of a Renewable Energy Facilitator. Legislation was passed in the 2009 session to increase the range of responsibilities of the Renewable Energy Facilitator to encompass permitting related to land use, renewable energy process equipment, electricity transmission from the facility to the utility grid, and any required on-site infrastructure. Beside other responsibilities to initiate the permitting process under Section 201N, HRS, the Renewable Energy Facilitator is in charge of coordination of renewable energy projects and day-to-day management of the REFSP. This wide range of responsibilities gives the Renewable Energy Facilitator a central role in the permitting of most of renewable energy projects in the State of Hawaii.

Section 201N-3, HRS, provides that the Energy Resource Coordinator (Coordinator), defined in Section 196-3, HRS, as the Director of the Department of Business, Economic Development, and Tourism, “develops and establishes a permit plan application format and procedure to ensure a timely review to obtain required permits and approvals for renewable energy facilities”. While the decision to award or deny permits is retained by the State or county agencies, the REFSP gives the Coordinator the legal leverage to force a decision to either grant or deny permits by not later than 18 months after the approval of a complete permit application.

Since environmental impact statements (EIS) might be required for many renewable energy facilities, with typical completion times between one to two years, the time to complete the entire permitting process for a renewable energy facility could potentially be reduced to around two-and-a-half to three-and-a-half years. Although such permitting time might still be considered “long”, the REFSP process promises a significant shortening of completion time for permitting of renewable energy facilities in the State of Hawaii.

While the specific format and procedure for the permit plan may be subject to the discretion of the Energy Resource Coordinator, Figure 6 shows the basic process flow diagram of the Renewable Energy Facility Siting Process as described in Section 201N, HRS. The basic steps in the Renewable Energy Facility Siting Process as shown in Figure 6 are as follows:

1. At the start of the process, a determination is made whether a renewable energy facility (REF) qualifies for the REFSP. A REF with an electricity generating capacity of larger than 200 MW is required to follow the process. A REF with electricity generating capacity of more than 5 MW or a biofuel production capacity of larger than one million gallons per year may apply for the process. All renewable energy facility projects that do not qualify due to the capacity criteria, or where the applicant qualifies but does not apply for consideration, are not subject to the REFSP process.

2. After qualifying, the REF project for the REFSP, the Coordinator assesses a fee to be paid by the applicant for permit related services to be provided by DBEDT, other participating agencies or external consultants (should DBEDT decide to retain them). The Coordinator sets the fees. The Renewable Energy Facilitator (REFac) then holds a pre-application meeting to discuss all steps and required actions for the permitting process. If the renewable energy facility project requires a full environmental review, the final EA or EIS has to be accepted before the permit application is accepted by DBEDT. In accordance with Section 201N, HRS, DBEDT is the accepting agency for final environmental impact statements that are prepared by an applicant or an agency for any REF.

3. After the final EIS is accepted, the permit plan application is completed and accepted. A notice that the permit application is accepted is published in the bi-weekly "Environmental Notice" of the Office of Environmental Quality Control (OEQC). Furthermore, the Renewable Energy Facilitator notifies the agencies involved in the permitting process that the permit application is complete and that the agencies can officially commence permitting related work; although agencies are allowed to start earlier, if they choose to do so.

4. Subsequently, the permit plan for the project is developed, which contains all remaining required steps of the permitting process, including a list of all permits to be obtained. The permit plan is then made public and posted on the DBEDT web-site. The permit plan is considered a "working document" that facilitates communication between the participating parties and also involves and informs the public.

5. The Renewable Energy Facilitator works with and advises all agencies to ensure expeditious permitting. If, after twelve months after the acceptance of the completed permit plan application, an agency has not decided on approval of the permit, the REFac is to notify the agencies and request cooperation or clarification in resolving outstanding issues. If after 18 months after the acceptance of the completed permit plan application an agency has still not completed the permitting process the permit is then awarded by default. This completes the permitting process.

DBEDT, therefore, can play an important and central role in the permitting process for virtually all renewable energy facility projects in the state that meet the capacity criteria. By following the DBEDT administered REFSP process the applicant is in the position to compel a decision by the permitting agencies not later than 18 months after the acceptance of the completed permit plan application.

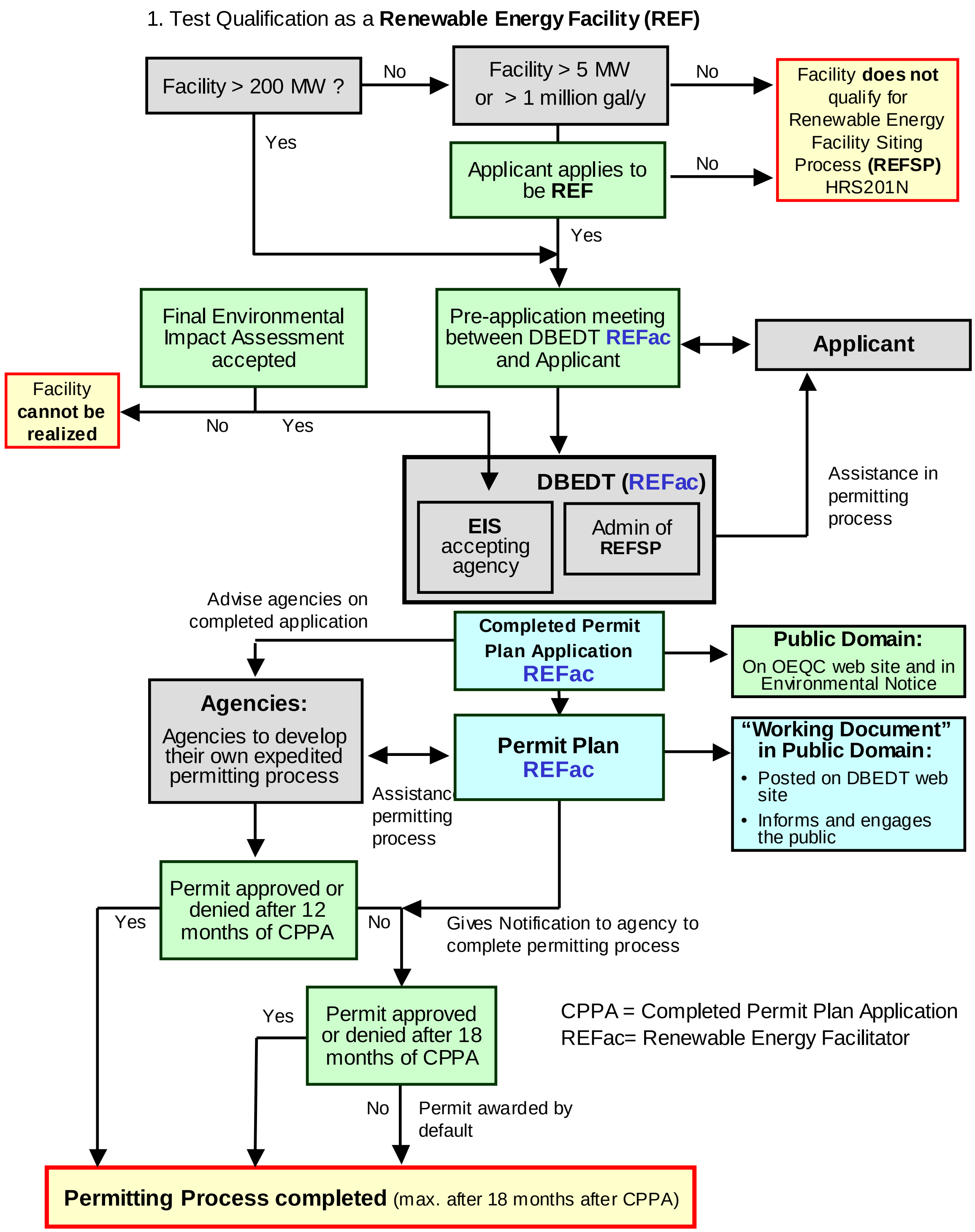

Figure 6 Basic process diagram of the renewable energy facility siting process (REFSP) as defined in Chapter 201N, HRS

6. Recommended Further Improvements in Permitting

The efficient, expeditious and transparent permitting approach that is envisioned to ensure the development of a strong clean and renewable energy industry for Hawaii is in the process of evolving, as workflow improvements of the permitting process within permitting agencies are being developed and implemented and a strong overall permitting framework with sanctioning authority has become law.

Further recommended measures could entail a continuing effort to improve internal agency permitting workflow and using effective project management to coordinate project tasks between different permitting agencies and the applicant and ensure that the project progress is on track.

However, merely developing workflow improvements and policies aimed at changing the permitting process is only one part of the solution. Like in every “organizational change” or “reengineering” situation the human factor is at least as important to the positive outcome of change as the well intended and well designed processes. Estimates of failed “process reengineering” can be as high as 70% (Hammer, 1993 and Salvendy, 2001). Many change and re-engineering initiatives fail since too much emphasis is placed on managing “up and down” and not “managing across”.

One of the most difficult challenges for implementation teams is that long-standing habits have to be changed in order to fully embrace new organizational processes. A successful organizational change effort requires therefore strategies to ensure “buy-in” from all process participants. Important steps of such change strategies include building of motivation, creation and communication of a clear vision, empowering others to act on the vision, consolidation of improvements and finally institutionalizing the new approaches (Kotter, 1996).

In the Renewable Energy Facility Siting Process, the role of a Renewable Energy Facilitator might face challenges in coordinating the organizational efforts and getting “buy-in” from all agencies involved while serving as an authority in cases of non-compliance. The legal authority automatically bestows leverage to speed up the permitting process; yet an authoritative role might also hinder free flowing communication between project participants, especially when there are unexpected problems in the project progress.

The expeditious development of a strong renewable energy and bioenergy industry in Hawaii will surely and significantly benefit from the already existing measures to expedite permitting of renewable energy projects. With the accelerating pace and scope of new energy systems and movement towards bold energy goals in Hawaii, State and County agencies will also have to adopt supportive processes. An important aspect of every re-engineering effort is the aspect that improvement is a “continuous improvement”. Processes that work well will be strengthened and processes that require further streamlining will be optimized accordingly.

The following possible future variation of a permitting process scenario would emphasize project management tools for interagency permitting cooperation and a different project role for the facilitator.

In this process variation, a structured inter-agency permitting workflow is described in which communication and data exchange between the permitting agencies is enhanced by an online data repository and online process management tools. Figure 7 shows a proposed expedited permitting process for biofuel projects. The main elements of the proposed process, such as different task responsibilities, sub-processes and conditional process flows are shown in the process schematic in Figure 7 and are briefly discussed below.

1. The Applicant is the representative of the sponsor of a bioenergy project. The Applicant, upon understanding the possible different permitting procedures available, applies to a “Permit Facilitator” for consideration of an expedited permitting process.

2. The Permit Facilitator might have different project responsibilities than the Renewable Energy Facilitator, as described in Section 201-12.5, HRS. The Permit Facilitator could be a consultant, either an internal state or county government consultant or a private consultant hired by the Applicant. The Permit Facilitator would act as a central contact point for pre-application consultations or for subsequent project permitting. Two different professionals could represent the function of Permit Facilitator in the pre-application and permitting project phases. There would be fees involved for professional services rendered by the Permit Facilitator.

3. The pre-application meeting would determine if the Applicant could use expedited permitting for the proposed bioenergy project. If NO, e.g. if it is determined that the Applicant cannot use the expedited permitting process for the bioenergy project, the Applicant would have to use a regular permitting process or the Applicant would have the opportunity to appeal the negative decision on a case-by-case review with a Permitting Ombudsman.

4. If YES, e.g. it would be determined that the Applicant could use expedited permitting for the proposed bioenergy project, and the Permit Facilitator would call an initial permitting project meeting to bring together the different permitting agencies and the Applicant. At this point the project scope and targeted timeline would be established and documented in a format that clearly notes what permits, from what agencies are required and when the different permit steps in the overall permitting process should be completed.

5. The project framework would indicate clear process ownership for different process steps. The project process would further indicate what information the Applicant is required to provide by what time and to what extent online self-certification options would be available for certain permit types.

6. The online Project Information Pool would be made available for expeditious collection and transfer of required information. The scope of the required information would be defined by the different agencies. The Applicant would be requested to furnish the specified information by a certain time in order to allow for on-time permitting. Rather than sending the required information to the agencies that request them the Applicant could deposit the information on a central data server. Different agencies involved in the permitting could draw information from the central project information pool, thereby avoiding redundant information requests to the Applicant.

7. The different agencies would name their own point of contact, who would maintain communication with the permit facilitator. The agencies could cooperate among each other and could decide to reduce permitting review on a number of overlapping issues. While the individual overlapping permits would not be eliminated, a portion of the permitting work might be avoidable by accepting overlapping decision making and consideration of information that would be used multiple times for different permits.

8. The Permit Facilitator would create and maintain the project online Log, which would contain a web-based portal for all project related communication. A function of the online project Log could also be a tracking of milestones so that project participants could be informed about the status of the permitting. To the extent that permitting includes confidential information, part of the project data would not be in the public domain.

9. Possible online self-certification processes could be made available by agencies for certain permits, which do not need individual and lengthy discretionary permitting review.

The proposed Project Information Pool would serve as a central repository for permitting process information. The Project Information Pool would serve in two functions, (1) as a <u>project-planning tool</u> where the agencies define the number and type of permits required and the supportive information that they require for individual review. The required permits and supporting information would be indicated using hyperlinked data management; furthermore all points of contact would be specified in hyperlinked media, (2) as a <u>project process management tool</u>, where the applicant deposits password protected data online and data is withdrawn selectively by the agencies. Furthermore the status of the project, e.g. the completed milestones for every individual permit and the overall project milestone status would also be presented.

Figures 6-2 and 6-3 show the Project information Pool and define project roles in more detail, respectively.

Figure 8 indicates the structure and working process of the Project Information Pool. The agencies would define the scope of supportive information that is required for permitting. When setting up the permitting project the agencies could choose from a predefined permit catalogue. As illustrated in Figure 8, information could be shared between agencies. This manner of information chunking and sharing between agencies could significantly reduce the burden of the Applicant to furnish information multiple times for different permits.

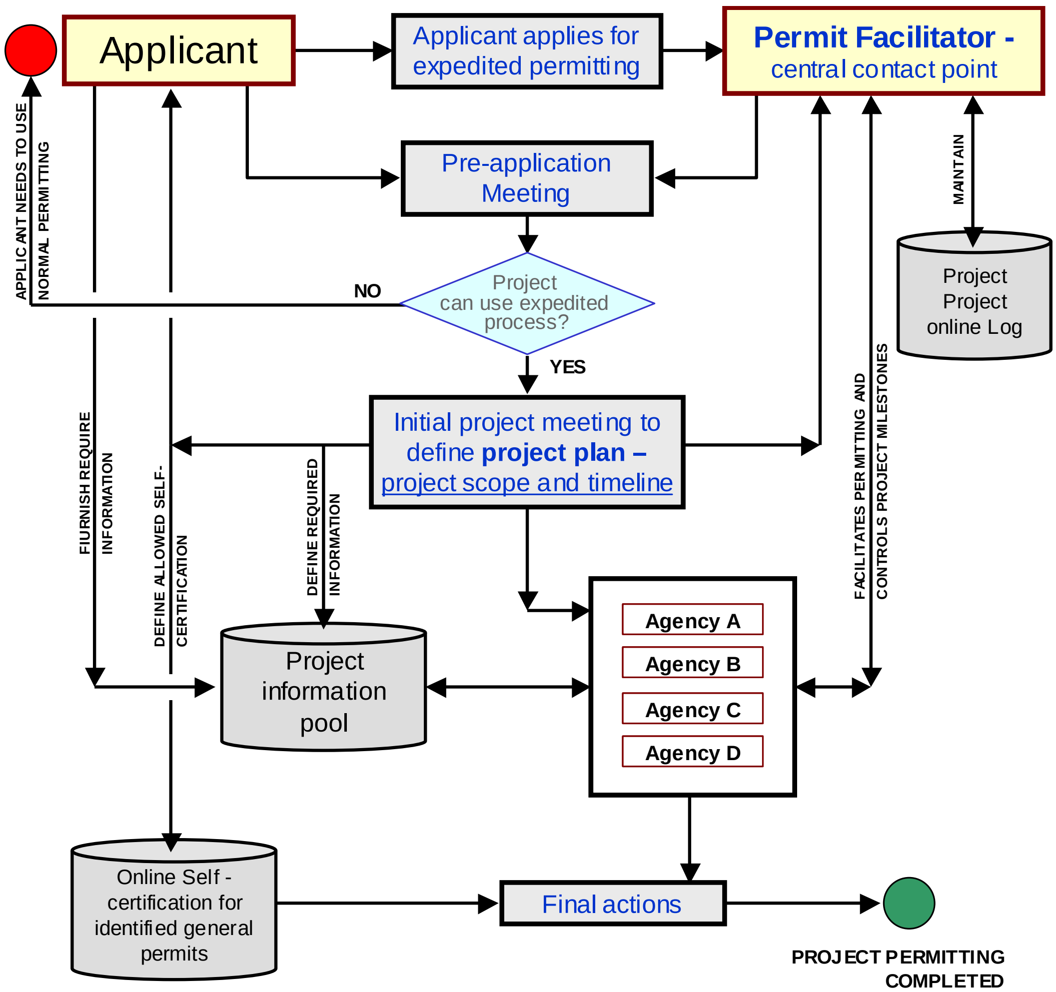

Figure 7 Proposed Expedited Permitting Process

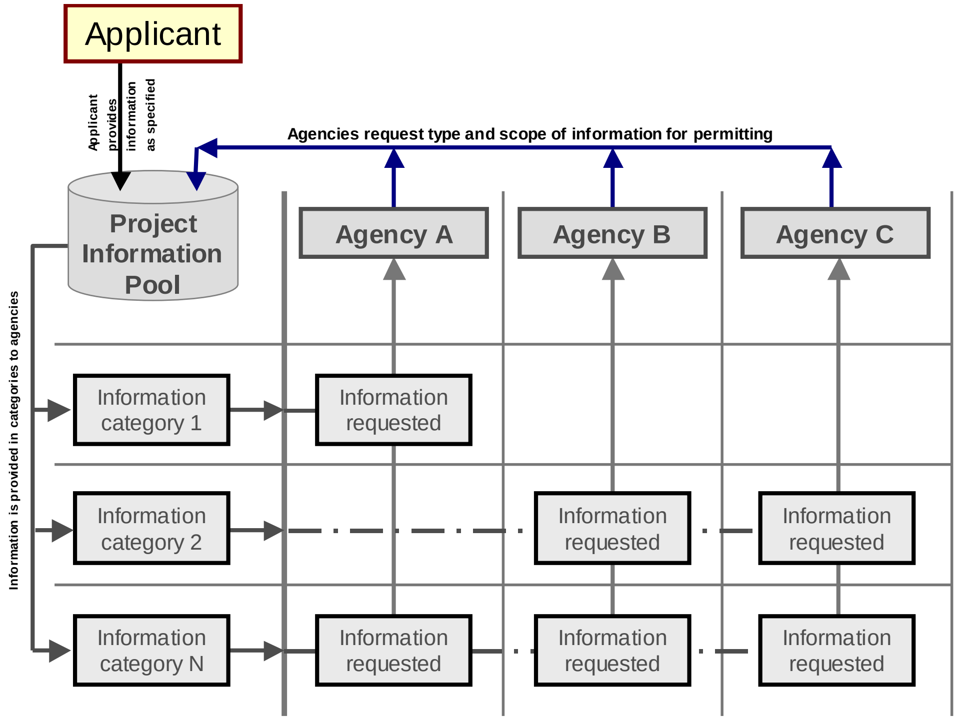

Figure 8 Project information pool for proposed expedited permitting process

Figure 9 shows different roles in the proposed expedited permitting process:

The State or County governments could designate a Permitting Ombudsman. The ombudsman would be tasked with neutral or impartial dispute resolution in cases where the permitting agencies and applicant cannot find a mutually acceptable agreement to contentious permitting issues. The Ombudsman, furthermore, could offer neutral interpretation of the intended regulatory objective if difficulties in the expedited permitting process arose. The Ombusdman would not be part of the regular permitting project work, but rather would be an outside authority to seek conflict resolution based on existing provisions (e.g. on a maximum permitting time as stated in statutes).

The Applicant would be the representative of the project sponsor for which expedited permitting is sought. The Applicant would work closely with the Permit Facilitator. The project communication related to the process progress and requirements would be primarily through the Permit Facilitator, while the Applicant would communicate directly with the different Agencies if there is need for clarification and data submittal. The Applicant would deposit the required information in the Project Information Pools, which would be available to all project participants.

The Permit Facilitator would be the central contact point of the expedited permitting process. The Permit Facilitator would have two functions: (1) to communicate with the Applicant in the pre-application phase and determine if the project is eligible for expedited permitting, (2) if the project is eligible for expedited permitting, the Permit Facilitator would work with the Applicant in all phases of the application process to ensure an efficient permitting process, would bring together all required agencies, and would enable efficient data exchange and project milestone monitoring, so that the permitting process could be completed on time.

Each agency would define their own Agency Point-of-Contact (POC) to facilitate the communication with other agencies, the permit facilitator and the Applicant.

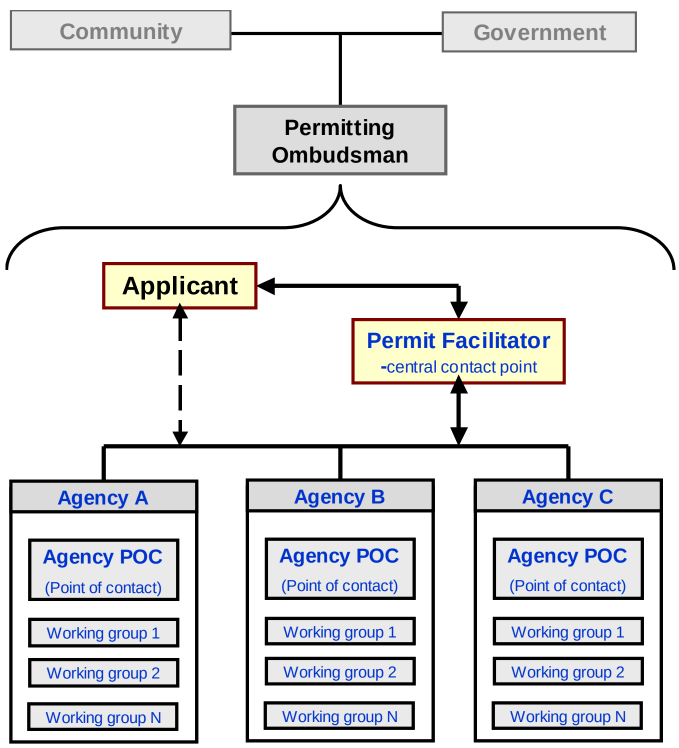

Figure 9 Process Roles in Proposed Expedited Permitting Process

7. Illustrative Example of Proposed Permitting System Documentation

This section presents an illustrative example of the proposed permitting documentation procedure. The logistical mainstay of the proposed expedited permitting system for bioenergy facilities would be an online information system, which would summarize the required permits for the particular bioenergy project and provide hyperlinked access to agency web-servers and to the Project Information Pool webserver.

The illustrative permitting example of a bioenergy facility is a hypothetical biofuel storage tank facility, which could store refined biofuels, unrefined feedstock and/or secondary process products and liquid process waste. Because of the range of possible liquid substances stored various permits could apply. The lists in Tables 6 through 8, shown below, therefore might contain permits and regulatory obligations, which would be redundant in the actual permitting. The purpose of the lists is to illustrate a workflow of the expedited permitting system that is aided by online information management tools.

In the proposed system the type of lists in Table 6 through 8 could be created for online web-serving either by manual or automatic means. In a manual editing mode, the online lists would be created manually, with a project lead creating hyperlinks and depositing documents into the Project Information Pool. In automatic mode, the preferred way, the different permits with all required downloadable information and forms, could be created within a predefined database and the individual permits would then be placed into the project space by "drag-and-drop".

The three lists of the storage tank permitting example illustrate permits and regulatory obligation for three project phases, (1) site development, (2) facility construction and (3) facility operation are shown in Tables 6, 7 and 8, respectively.

The different columns in these lists show the following:

A. A description of the project activity
B. The name of the permit or the regulations that has to be followed
C. The primary agency responsible for permitting or enforcement
D. The legislation that governs the permit or regulation (with links to access background information)
E. Links Point-of-contact and links to download permitting forms and information
F. The Status of project milestones (with linked access to threaded communication)

Table 6 Illustrative Example of Proposed Permitting System Documentation Hypothetical Biofuel Tank Farm – Permits for Site Development

Example: Biofuel Tank Farm - List of possible permits
(not complete listing of possible permits)

Site development:
The site for the biofuel tank farm is developed in conjunction with the applicable Land Use Ordinances and zone adjustment procedures, if applicable.

Activity	Permit & Appication name	Regulatory Authority approve & review	Legislation; download info. & forms	Contact download forms	Project actions milestone status
Zone change: if LUO does not allow for tank farm constrution & operation on state and county level	Zoning adjustmens	County Dept. of Land Utilization	Land Use Ordinance	contact POC: download inform.	click for status
	State Land Use Distric Boundary Amendments	State land Commission	HRS 205; HAR 15	contact POC: download inform.	click for status
Environmental Assessments (EA) or Environmental Impact Statements (EIS)	EIS on County Level	County Dept. of Land Utilization - Planning Department	HRS 205 & 343 HAR 11 - 200	contact POC: download inform.	click for status
	EIS on State Level	varies - State or county agency which is responsible for approval	HRS 343 HAR 11 - 200	contact POC: download inform.	click for status
	EIS on Federal level	federal agency that funfs or in whose jurisdiction project falls	National Environmental Policy Act	contact POC: download inform.	click for status
Conditional use of land under LUO if significant impact requires review	conditional use permit	County Dept. of land Utilization	HRS 46 LUO	contact POC: download inform.	click for status
Use of agricultural land	Special use permit for agricultural land	State Land Use & Planning Commission	HRS 205	contact POC: download inform.	click for status
Constructions flood zone	Development in flood hazrad districts	County Dept. of land Utilization	U.S. national Flood Insurance Act	contact POC: download inform.	click for status
Review if constrcution site is of historical & cultural significance	Historic Site Review	State Dept. of Land and natural Resources; Historic Preservation Div.	HRS 6	contact POC: download inform.	click for status
Construction in Special Management Are District	Special Management Area Use permit	County Dept. of Land Utilization	HRS 205 & 364	contact POC: download inform.	click for status
other permits and regulatory obligations possible					

Table 7 Illustrative Example of Proposed Permitting System Documentation
Hypothetical Biofuel Tank Farm – Permits for Facility Construction

Example: Biofuel Tank Farm - List of possible permits
(not complete listing of possible permits)

Facility construction:
The the construction of a biofuel tank & pumping facility will require the following permits and adherence to regulatory obligations.

Activity	Permit & Appication name	Regulatory Authority approve & review	Legislation; download info. & forms	Contact download forms	Project actions milestone status
Constrcution of a structure of building	building permit	County Building Department	HRS 444 & 464 County rules	contact POC: download inform.	click for status
Grading and earcth movement	Grading, gubbing and stockpiling permit	County Dept. of Public Works	HRS 180 County rules	contact POC: download inform.	click for status
Installation of tanks that contain combustible & flammable liquid	Combustible & flammable liquids tank installation permit	County Fire Department	HRS 132 County Rules National Fore Protection Assoc.	contact POC: download inform.	click for status
Construction new are modifying existing access to state highway	Work on State Highway permit	State Dept. of Transportation	HRS 264	contact POC: download inform.	click for status
Construction work that includes digging in or disturbing public right-of-way	Trenching Permit	County Dept of Public Works	County rules	contact POC: download inform.	click for status
Dewatering a constrcution site	Constrcution dewatering permit	County Dept of Public Works	County rules	contact POC: download inform.	click for status
Effluent discharge of construction run-off	NPDES stormwater runoff permit	State Dept. of Health	Clean Water Act HRS 342D	contact POC: download inform.	click for status
Constrcution performed on County streets, highways, paths, sidewalks, etc.	Street Usage permit	County Dept. of Transportation Services	HRS 286 County rules	contact POC: download inform.	click for status
Temporary use of land for constrcution staging or constrcution yard	Temporay Use permit	County Dept. of Land Utilization	County rules	contact POC: download inform.	click for status

Table 7 Illustrative Example of Proposed Permitting System Documentation Hypothetical Biofuel Tank Farm – Permits for Facility Construction (page 2 of 2)

Activity	Permit & Appication name	Regulatory Authority approve & review	Legislation; download info. & forms	Contact download forms	Project actions milestone status
Discharge of dredged or fill material into waters of the United States	CWA 404 permit	U.S. Army Corp of Engineers	CWA 404 CFR 33, 320	contact POC: download inform.	click for status
Installing a well for water supply	Well construction permit	State Dept. of Land and Natural Resources	HRS 174	contact POC: download inform.	click for status
Drawing water for construction from municipal water supply system	Water use permit	Board of Water Supply	County rules	contact POC: download inform.	click for status
Ambient air quality during construction	Major construction permitting:	EPA	CAA	contact POC: download inform.	click for status
Installation of process equipment that is in conformance with CAA	CAA New Source Performance Standards	EPA	CAA	contact POC: download inform.	click for status
Regulations under the Renewable Fuel Standard Law	RFS standards	EPA	Renewable Fuel Standard (RFS) under Energy Policy Act of 2005; Clean Air Act as amended	contact POC: download inform.	click for status
Federal regulstions about storage and handling hazardous fuels and chemicals	RCRA standards	EPA	Resource Conservation and Recovery Act	contact POC: download inform.	click for status
other permits and regulatory obligations possible					

Table 8 Illustrative Example of Proposed Permitting System Documentation
Hypothetical Biofuel Tank Farm – Permits for Facility Operation

Example: Biofuel Tank Farm - List of possible permits
(not complete listing of possible permits)

Facility opertion:
The operation of a biofuel tank & pumping facility will require the following permits and procedural obligations.

Activity	Permit & Appication name	Regulatory Authority approve & review	Legislation; download info. & forms	Contact; download forms	Project actions milestone status
Discharge of effluent during operation	Discharge to into a water body: NPDES permit	State Dept. of Health	Clean Water Act HRS 342D	contact POC: download required supportive inform.	click for status
	Discharge to wastewater treatment plant: NPDES permit	State Dept. of Health	Clean Water Act HRS 342D	contact POC: download required supportive inform.	click for status
Wastewater discharge to municpal sewer system	Sewer connection permits	County Dept. of Public Works	County rules	contact POC: download required supportive inform.	click for status
Discharge of industrial wastewater into the county sewer system	Industrial wastewater discharge permit	County Dept. of Public Works	County rules	contact POC: download required supportive inform.	click for status
Discharge of wastewater through an underground injection system (e.g. septic tank)	Undergournd injection control permit	State Dept. of Health	Clean Water Act HRS 342D	contact POC: download required supportive inform.	click for status
Connection to municipal water supply system	Water and water system development permit	Water supply authority (I,e, HNL Board of Water Supply	HRS 54	contact POC: download required supportive inform.	click for status
Operating a well for water supply	Well operation permit	Commision of Water Resources	HRS 174	contact POC: download required supportive inform.	click for status
Discharge or emission that exceeds applicable standards	Variance form pollution controls	State Dept. of Health	HRS 342D	contact POC: download required supportive inform.	click for status

Table 8 Illustrative Example of Proposed Permitting System Documentation
Hypothetical Biofuel Tank Farm – Permits for Facility Operation (page 2 of 2)

Activity	Permit & Appication name	Regulatory Authority approve & review	Legislation; download info. & forms	Contact; download forms	Project actions milestone status
Discharging airborne substances during operation	Major Source Title V Air Permits	State Dept. of Health	CAA HRS 342D	contact POC: download required supportive inform.	click for status
Operation of underground storage tank	Underground Storage Tank Permit	State Dept. of Health	Resource Conservation and Recovery Act (RCRA); HRS 11	contact POC: download required supportive inform.	click for status
Regulations under the Renewable Fuel Standard Law	RFS standards	EPA	Renewable Fuel Standard (RFS) under Energy Policy Act of 2005; Clean Air Act as amended	contact POC: download required supportive inform.	click for status
Federal regulations about storage and handling hazardous fuels and chemicals	RCRA standards	EPA	Resource Conservation and Recovery Act	contact POC: download required supportive inform.	click for status
Emergency planning requirements for pollution and fire control, documenting hazardous chemical inventory and report on toxic chemical release	Operating permits and Provisions under the EPCRA	EPA	Emergency Planning and Community Right to Know Act (EPCRA)	contact POC: download required supportive inform.	click for status
other permits and regulatory obligations possible					

8. Conclusion and Recommendations

The development and implementation of renewable energy projects, and specifically renewable biofuels, is of utmost importance to Hawaii. Presently Hawaii relies on petroleum for about 90% of its energy needs and has one of the highest per capita oil consumption rates in the world. The global oil market has been volatile for the past several years and sobering predictions by mainstream oil analysts warn of possible increasingly tight global oil supplies and high future oil prices starting as soon as in the next 2 to 5 years. Therefore time is of the essence to transform Hawaii's energy system towards more diversity of the state's energy supply.

Hawaii's leadership has developed bold visions of fundamentally transforming Hawaii's energy in the next two decades to provide up to 70 percent clean energy by 2030. Innovation at this staggering implementation scope and speed requires changes in the way governmental agencies work with developers of renewable energy facilities in the permitting of such projects.

The present permitting regime in Hawaii is seen by investors as the main hindrance to investment in Hawaii. Measures to streamline the permitting regime in Hawaii are therefore crucial to improve the attractiveness of Hawaii as a good place to invest in clean energy.

Improvements in Hawaii's permitting regime should involve new workflow processes within State and County permitting agencies as well as efficient interagency cooperation. While internal agency process improvements are ongoing and have resulted in numerous noticeable improvements, Hawaii's legislature has recently established the Renewable Energy Facility Siting Process that provides an overall permitting framework for renewable energy facilities above a certain capacity. Projects that qualify for the Renewable Energy Facility Siting Process will have a prescribed maximum time for permitting of 18 months, excluding the EIS process. An enforceable maximum time for permitting should provide investors some certainty that their permitting applications will be processed in a timely manner.

Innovative permitting approaches, such as the Renewable Energy Facility Siting Process, are laying important administrative foundations for expeditious development of a strong renewable energy industry in Hawaii.

While these new approaches to permitting of renewable energy facilities are timely and very important for Hawaii's secure and clean energy future, it is to be expected that Hawaii's permitting regime will require further changes in the years to come, in order to correct processes that lack efficiency improvements.

This report proposes possible further improvements to permitting for renewable energy facilities described in sections 4-7 above. The proposed further improvement of permitting process would build on past accomplishments and recent legislative actions and would emphasize interagency cooperation in permitting project management and innovative online management tools.

It is felt that a structured and transparent interagency permitting framework working in concert with Hawaii's permitting agencies' own internal efficiency standards, is an appropriate administrative support to ensure the healthy growth of a strong renewable energy and bioenergy industry in Hawaii.

While progressive procedures and policies are the foundations to transform the permitting regime, human aspects in the organizations are the drivers that make re-engineering efforts successful and ensure that effective permitting strategies will become institutionalized.

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Abbreviations and Acronyms

AST	Aboveground Storage Tank
CAA	Clear Air Act
CFATS	Chemical Facilities Anti-Terrorism Standards
CUP	Conditional Use Permit
CWA	Clean Water Act
DBEDT	Hawaii State Department of Business Development and Tourism
DLNR	Hawaii State Department of Land and Natural Resources
DOH	Hawaii State Department of Health
DOT	Hawaii State Department of Health
DPP	City & County of Honolulu Department of Planning and Permitting
EA	Environmental Assessment
EIS	Environmental Impact Statement
EISA	Energy Independence and Security Act
EPA	U.S. Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FFARS	Fuel and Fuel Additive Registration System
GIS	Geographic Information Systems
I-2	Intensive Industrial Zone
IEA	International Energy Agency
IFC	International Fire Code
HAR	Hawaii Administrative Rules
HRS	Hawaii Revised Statutes
LUO	Land Use Ordinance
MTSA	Maritime Transportation Security Act
MW	Mega watts
NEPA	National Environmental Policy Act
NPDES	National Pollutant Discharge Elimination System
OEQC	Office of Environmental Quality Control.
OSHA	Occupational Safety & Health Administration
PIMAR	Petroleum Industry Monitoring, Analysis and Reporting
POC	Point-of-Contact
PUC	Public Utilities Commission
RCRA	Resource Conservation and Recovery Act
REF	Renewable Energy Facility
REFac	Renewable Energy Facilitator
REFSP	Renewable Energy Facility Siting Process
RFS	Renewable Fuel Standard
RIN	Renewable Identification Numbers
SAIC	Science Application Corporation International
SCAS	Stream Channel Alteration Permit
SDWA	Safe Drinking Water Act
SDWP	Stream Diversion Works Permit
SOCMI	Synthetic Organic Chemical Manufacturing Industry

TRIR	Toxic Release Inventory Reporting
UIC	Underground Injection Control
WUP	Water Use Permit

Hawaii Bioenergy Master Plan

Financial Incentives And Barriers; And Other Funding Sources

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Executive Summary

The goal of this section of the Hawaii Bioenergy Master Plan is to identify and evaluate financial incentives and barriers at points along the bioenergy industry value chain (feedstock production, feedstock logistics, conversion, distribution, and end use) and their potential impact on the production of biofuels at levels sufficient to contribute a significant renewable energy resource to the State of Hawai‘i.

This section provides a comprehensive list of the financial barriers and incentives to entry and operation in the biofuel industry in the State of Hawai‘i. The scope covers both Federal and State financial instruments, including the American Recovery and Reinvestment Act of 2009. It includes discussion of innovative public and private financing vehicles for alternative energy and greenhouse gas (GHG) emissions reductions. The analysis was conducted through a legislative scan, stakeholder interviews, and surveys. Appendices summarize existing State and federal biofuel incentives, legislation proposed during the 2009 Hawai’i legislative session, and policies for other Pacific region states and for selected countries.

A historic overview of biofuels legislation and industry activity provides a backdrop for the understanding of Hawai‘i’s present landscape. Hawai‘i biofuels initiatives date back to the mid-1970s, following a period of rapid fossil fuel price inflation. While biofuels have been used for electricity generation and transportation fuels, the development of a Hawai’i industry has been slow. There does not currently exist local production or refining of Hawai‘i grown feedstock other than the long-established use of bagasse for electricity production.

This study analyzes the key threats to bioenergy across the value chain. Briefly, biofuels investors appear not to be confident in long-run profitability given challenges that they face in land acquisition, competition from energy substitutes (e.g. electric vehicles), highly concentrated purchasers, and fragmented State support.

<u>The following recommendations are provided:</u>

- Frame Hawai‘i’s bioenergy strategy around vital State interests. Energy security and greenhouse gas emissions reduction targets could provide justification for bioenergy support.
- Design a priori measurement and monitoring mechanisms to evaluate alternative individual projects based on State interests, particularly for the distribution of land leases.
- Act swiftly to capture funding made available through the American Recovery and Reinvestment Act of 2009, though recognize the funding would need to be balanced by sustained sources to carry the operation year after year.

- Consider House Concurrent Resolution 195 (HCR 195) and the subsequent recommendations of the Hawai‘i Energy Policy Forum (HEPF). Further study is required to determine the most appropriate incentives at each part of the biofuels value chain. In particular, analysis is needed to determine: Locations for biomass project; Options for leasing state land for fuel crop development; Opportunities for state and county governments and private investors to secure federal grants to support the development of fuel crops and the conversion of fuel crops to generate electricity; and feasibility of setting up a revolving fund as a mechanism to provide incentives necessary to stimulate investment in fuel crops and the conversion of fuel crops to generate electricity.

- Establish a sub-committee of people with a mix of public and private experience raising capital for infrastructure and energy projects to put together the specific financial incentives to support the Hawaii Bioenergy Master Plan (HBMP). The sub-committee should, at a bare minimum, evaluate the incentive concepts proposed by HEPF in their response to HCR 195 (Appendix G).

- Create a dedicated office that will maintain an up-to-date list of State and Federal incentives, and provide guidance for prospective business owners in biofuel on how to apply for incentives (grants, loans, tax credits, etc.). This office could also be the resource that guides business owners on the steps needed to valuate the environmental credits from the project. Perhaps this office could even provide business planning guidance. For example, a biomass power plant will likely be eligible for a waiver from the competitive bid process to provide HECO electricity. However, the waiver is for a period of 4 months. That is a prohibitively short period of time to get all the aspects of a plant’s operations lined up for negotiation of a power purchase agreement with the utility.

- Coordinate and make transparent the process for land acquisition for biofuel feedstock producers. Bioenergy and land use policy involves multiple State agencies (DLNR, DHHL, DOA, DBEDT). Biofuels may be perceived as competing with other land uses, such as food production and residential development. The State interest in bioenergy should be articulated relative to competing interests.

- Reconcile investor’s concern for exit strategies with biofuels incentives. “What are the business options if ethanol demand falls?” “What are my exit strategies?” “What other outlets exist for large ethanol stocks if transportation demand tanks?” Biofuels investors' decisions are typically based on 10-20 years for biofuel refinery plants.

- Align a flex fuel ethanol-based transportation strategy with the emergence of potential new transportation modes, including rail, and vehicle technologies, such as electric and hybrid vehicles. The State and counties are committed to alternative transportation strategies, and the role of biofuels should be assessed in that context.

- Synergize the biofuels master plan with the Hawai‘i Clean Energy Initiative goals. A higher profile for both will likely lead to more Federal dollars.

- Investigate Renewable Identification Number (RIN) market opportunities stemming from the Federal Renewable Fuel Standard (RFS). At present, Hawai‘i is opted-in to the Federal RFS. (Anon. 2008d) While further study is required, opportunities may exist to establish a complete, localized bioenergy value chain in Hawai‘i’s using the Federal RFS. One resource we suggest to investigate is the RINMARK exchange (http://www.rinxchange.com/).

- Facilitate the measurement and monitoring of greenhouse gas emissions. An approach might include mandatory reporting through The Climate Registry (TCR). TCR sets consistent and transparent standards to calculate, verify and publicly report greenhouse gas emissions

- Coordinate biofuels policy with State goals to reduced GHG emissions. GHG emission reductions have actualized and perceived economic value in current and proposed initiatives to mitigate anthropogenic climate change. Provide research, education, and outreach on the role that biofuels might play relative to other strategies.

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Introduction

"Biomass is the single renewable resource that has the potential to supplant our use of liquid transportation fuels now and help create a more stable energy future." (Anon, 2008a)

Overview

Act 253, Session Laws of Hawai'i 2007, called for the development of a Hawai'i Bioenergy Master Plan (HBMP) to manage Hawai'i's transition to energy self-sufficiency based in part on biofuels for power generation and transportation. The University of Hawai'i Economic Research Organization's Energy and Greenhouse Gas Solutions (EGGS) group was retained by the Hawai'i Natural Energy Institute (HNEI) to prepare an evaluation of the financial incentives and barriers to developing and using biofuels in Hawai'i, as well as identifying other sources of available funding. (Task 8)[1].

Rationale

Identifying and evaluating the current financial incentives and barriers are critical to the HBMP. As indicated by the U.S. Department of Energy's (DOE) *Biomass: Multi-Year Program Plan*, "growth of (the biofuel) industry is currently constrained by limited infrastructure, high production costs, competing energy technologies, and other market barriers. Market incentives and legislative mandates are helping to overcome some of these barriers." (Anon, 2008a) Knowledge of existing financial barriers and those incentives designed to overcome the obstacles will facilitate how to move bioenergy development and use forward in Hawai'i.

Background

The State of Hawai'i has been active in pursuing biofuels since the 1970s, promoting research and development as well as passing legislation to overcome market barriers. To give context to the present challenges and initiatives in place for Hawai'i that relate to the financial incentives and barriers, a brief review of the activities around biofuels in Hawai'i is useful.

The 1973 oil embargo of Organization of Arab Petroleum Exporting Countries (OAPEC) led crude oil prices to rapidly quadruple. (Anon, 2008b) Hawai'i, highly dependent on imported oil, responded in 1974 with Act 235 (SLH 1974) that established the Hawai'i Natural Energy Institute along with the State Program for Energy Planning and Conservation, and the Natural Energy Laboratory of Hawai'i Authority. The goals of Act 235 (SLH 1974) were to (1) diminish Hawai'i's total dependence on imported fossil fuels; (2) meet the state's increasing energy demands with little or no environmental

[1] Task Objective under Memorandum of Agreement Scope of Work for Task 8 of the Hawaii Bioenergy Master Plan project: To identify and evaluate financial incentives and barriers at points along the bioenergy production value chain (feedstock production, feedstock logistics, conversion, biofuel distribution, and end use) and their potential impact on the production of biofuels at levels sufficient to contribute a significant renewable energy resource to the State. To provide information, analysis, and recommendations related to this evaluation.

degradation; and (3) contribute to the technology base for finding solutions to the national and global energy shortage.

In 1980, two organizations proposed full-scale feasibility studies in Hawaiʻi to produce ethanol from molasses - C. Brewer and Company and Pacific Resources, Incorporated (owner of Hawaiʻi Independent Refinery, Inc.). (Shleser, 1994) Following completion of the study, C. Brewer and Company chose not to construct a facility, but released an often quoted press release stating, “We have put a great deal of time, effort and expense into ethanol ... but we cannot invest $15 million in capital to produce a product we cannot be assured of marketing within the Hawaiian market as we have no gasoline stations of our own.” (Shleser, 1994) This finding, almost three decades ago, pointed to the need for industry coordination

In 1993, the Hawaiian Sugar Planters Association, led by Robert V. Osgood and Nicklos S. Dudley, published *Comparative Studies of Biomass Yields for Tree and Grass Crops Grown for Conversion to Energy*. They concluded that at 1993 fuel prices it was not profitable to produce, deliver and process biomass fuels for electricity production exclusively from grasses or trees. (Osgood, et al., 1993) Osgood and Dudley indicated that the State should focus on higher value products including fuel alcohols, chemical feedstocks, paper pulp and manufactured lumber and veneer over using biomass for combustion. (Osgood, et al., 1993)

In his 1994 report on ethanol production in Hawaiʻi, Robert Shleser documents experts claiming, “during the last two to three years there has been more progress in the technology for the conversion of lignocellulosic materials to ethanol than in the previous twenty years.” (Shleser, 1994) Fifteen years later, this research into this technology is still being conducted.

Following the National Energy Policy Act of 1992, which required increasing alternative fuel use starting in 1994, Act 199 (SLH 1994) was signed into law in Hawaiʻi requiring gasoline to contain 10% ethanol. Despite its passage, legal, technical, logistical, and economic challenges delayed this mandate from going into effect until April 2006. Chapter 486E, Hawaiʻi Revised Statutes (HRS), repealed and replaced by Chapter 486J in 1997, indicated that the director of the Department of Business, Economic Development, and Tourism (DBEDT) has the authority to allow sale of gasoline that does not meet the ethanol content requirement:

a) To the extent that sufficient quantities of competitively-priced ethanol are not available to meet the minimum requirements of this section; or

b) In the event of any other circumstances for which the department determines compliance with this section would cause undue hardship.

These exclusion clauses and the delay in enforcing Act 199 are indicative of the barriers to biofuel development and growth in Hawaiʻi. Now that the ethanol mandate has been implemented, Hawaiʻi’s decades long experience can be instructive of barriers to biofuels growth and development at different points along the biofuels value chain.

In 2002 at a Hawai‘i Ethanol Workshop, Maurice Kaya (then Administrator of DBEDT’s Energy, Resources and Technology Division) outlined the existing incentives to ethanol, in addition to the mandate set in 1994: (Kaya, 2002)

- Ethanol Production Credit
  - equivalent to $0.30/gallon fuel-grade ethanol produced
  - credit for up to 15 million gallons per year per facility
  - available up to 8 years if investment was less than $50 million; up to 10 years for investment greater than $50 million
  - Facility must be in Hawai‘i and in production before January 1, 2012.
- Exemption from 4% state excise tax on retail sales
  - Fuel mixture consisting of at least 10% biomass-derived alcohol
  - Applies to E10 and E85
  - Exemption terminates on December 31, 2006
- Reduced highway taxes on E85
  - Alternate fuels subject to 0.5 effective state highway tax of diesel fuel
  - applies to E85
  - Does not apply to E10 or oxy-diesel

Kaya indicated that the obstacle to the implementation of the ethanol requirement was largely at the refinery level. (Kaya, 2002) For gasoline to be sold, the fuel had to meet the American Society for Testing and Materials (ASTM) specification D4814 - Standard Specification for Automotive Spark-Ignition Engine Fuel. In Hawai‘i, gasoline could not have a Reid vapor pressure (RVP) greater than 11.5 pounds per square inch (psi). (Kaya, 2002) A testing report indicated the gasoline RVP range at 9.7-11.4 psi and adding ethanol to this gasoline would likely result in out-of-spec fuel for Hawai‘i. (Kaya, 2002) Quoting Kaya, “Bottom line: in Hawai‘i, refiner participation is necessary.”

As additional support for industry development, in 2002, HNEI provided a *Bioenergy and Biomass Resource Assessment* for the State of Hawai‘i in which then current stocks of animal wastes, forest products residues, agricultural residues, and urban wastes were evaluated for their energy potentials. (Turn, et al., 2002a) In the same year, HNEI completed the *Analysis of Hawai‘i Biomass Resources for Distributed Energy Applications*, also for the State. It indicated use of macadamia nut shells and sugarcane bagasse for distributed generation applications (DER), but also concluded that the potential for other biomass use in DER depends “on the local, national, and/or international market economics and the policy and regulatory environment.” (Turn, et al., 2002b)

Stillwater Associates further described the existing challenges in 2003 in an assessment of the impact of blending of ethanol into Hawai‘i’s gasoline pool on the overall fuel balance, refinery economics, and gasoline distribution costs. Among other items, Stillwater Associates concluded that (Gieskes, et al., 2003)

- The local refineries would incur a loss through reduced gasoline demand, which would force them to produce and export more naptha at lower margins.
- Vapor pressure changes to gasoline due to the added ethanol would require refineries to modify operations and spend capital on distillation and storage facilities.
- Most of the locally produced ethanol should be exported to California to provide a market of suitable scale. This would provide benefits to the local economy through agriculture,

ethanol plant investment and renewable power generation, but minimize losses in local excise tax revenue (incentive in place at the time) and minimize higher gasoline expenditures.

- Ultimately, large scale ethanol production could generate up to $100 million in annual revenues, add as much as $300 million to the Hawai‘i economy and add up to 200 new jobs.

Following considerable public dialogue about these conclusions and the readiness of Hawai‘i to implement the 10% ethanol blending requirement, in September 2004, Governor Lingle signed the administrative rule providing for implementation of the mandate. (Anon, 2004) The oil companies were cited as supportive of the use of ethanol, in general, but concerned about the expense of modifying their operations being passed on to the consumer, and the lack of any locally produced ethanol. (Natarajan, 2004a) Ethanol proponents indicated that with the mandate going into effect eighteen months from the signing of the rule, they had ample time to develop local production. (Natarajan, 2004b) At least three ethanol production projects were in development at the time, with other projects in an incubation phase. (Natarajan, 2004a)

Also in 2004, the Federal Volumetric Ethanol Excise Tax Credit (VEETC) was created as part of H.R. 4520, the American Jobs Creation Act of 2004. This incentive provided a tax credit of $0.51 per gallon of ethanol that is blended with gasoline.

As the April 2006 effective date of the Hawai‘i ethanol mandate approached, it was the petroleum companies that were ready. On March 2, 2006, Aloha Petroleum announced it had received 5 million gallons of ethanol from Jamaica that it planned to blend. Aloha Petroleum was cited as spending $3 million in equipment and plant modifications to make the gasoline blend. (Anon, 2006a) From the initial 5 million gallons blended, the VEETC likely resulted in a $2.55 million credit for Aloha. On March 13, 2006, Chevron announced it had completed its first new blending facility in Honolulu, and that three more facilities would open soon in Hilo, Port Allen, and Kahului. (Anon, 2006b) Later in 2006, Chevron Corp. rolled out a new biofuels unit, citing that worldwide, the company blends about 300 million gallons of ethanol into its gasoline. (Scanlon, 2006) This could result in a VEETC of $153 million per year within the US. Further indicating the momentum shift for the petroleum companies, Aloha Petroleum wanted to install pumps for E85 for $100,000 a site, but safety concerns stalled the effort. (Anon, 2006c)

Meanwhile, ethanol production in Hawai‘i has been non-existent. Projects discussed in the period leading up to the 2004 signing have yet to produce any fuel. (Anon, 2008c)

Given the resistance to Act 199 (SLH 1994) by the petroleum industry, why has the petroleum industry been the most progressive component of the biofuels value chain? What barriers were overcome and by what incentives? The answer may have little to do with biofuel incentives.

Unrelated to national or local biofuel development efforts, the 1990 amendment of the Federal Clean Air Act, originally passed in 1963, mandated that oxygenating agents be added to gasoline to reduce pollution from vehicle exhaust. Methyl tertiary butyl ether (MTBE) use quickly rose from 83,000 barrels/day in 1989 to 161,000 barrels/day in 1994 to more than 260,000 barrels/day in 2002. (Anon, 2000) Refineries favored MTBE over other oxygenating agents (such as ethanol) due to its superior blending properties, lower cost, and ease of distribution and storage. (Nersesian, 2006) In the late 1990s, concerns began to rise over MTBE being detected in drinking water supplies, and research indicated that lab animals were developing cancer when exposed to the compound. (Anon) States moved to ban MTBE and lawsuits began to be filed. The federal government moved to develop a position on the claims and decided to phase out MTBE. (Anon, 2000) The Energy Policy Act of 2005 originally sought to ease the country off MTBE by: 1) including language to limit liability for the MTBE manufacturers against lawsuits; 2) extending the phase out period to 2014; and 3) providing $2 billion transition assistance. (Dingell, et al., 2005) These provisions were removed before passage, ultimately leaving an immediate and large risk exposure for MTBE manufacturers and the refineries that used the product. The oil industry rapidly switched over to ethanol to protect itself from the risk exposure in 2006. (Swanson, 2008)

In 2006, in addition to the 10% ethanol mandate going into effect, the following events transpired:

- The State supported analysis for both ethanol production (Keffer, et al., 2006) and biodiesel crop production (Poteet, 2006);
- Act 240, signed in 2006, established a State alternative fuel standard (AFS) for highway fuel demand – 10% by 2010; 15% by 2015; and 20% by 2020;
- Act 162 (SLH 2006) amended the Renewable Portfolio Standard (RPS) to include definitions of biogas, biomass and biofuels as forms of renewable energy (RE) among other RE sources, and gave the Public Utilities Commission (PUC) the authority to assess penalties on utilities that fail to meet the RPS (among other powers);
- House Concurrent Resolution 195 (HCR 195) was adopted by the Legislature, "Encouraging Hawai'i's landowners, investors, county governments, and regulated electric utilities to pursue development and conversion of fuel crops for electricity generation, and requesting the Hawai'i Energy Policy Forum to make recommendations."

HCR 195 specifically requested the following to be addressed:

1. Financial incentives that may be necessary to stimulate development of fuel crops and the conversion of fuel crops to generate electricity, including incentives to reduce the risk of falling oil prices for investors;
2. The most suitable locations for undertaking biomass projects independent from, or in conjunction with, municipal solid waste-to-energy programs;
3. Options for leasing state land for fuel crop development;
4. Opportunities for state and county governments and private investors to secure federal grants to support the development of fuel crops and the conversion of fuel crops to generate electricity; and

5. The feasibility of setting up a revolving fund as a mechanism to provide incentives necessary to stimulate investment in fuel crops and the conversion of fuel crops to generate electricity.

The response to HCR 195 eventually contributed to the language of Act 253, SLH 2007, and the articulation of the Hawai‘i Bioenergy Master Plan.

Objectives

The primary objective of this work is to develop an up-to-date, comprehensive list of financial barriers and active financial incentives in the area of growing a biofuel industry in the State of Hawai‘i to assist with an understanding of appropriate financial incentives for industry support. This includes existing Hawai‘i State and Federal incentives, relevant incentives from the Federal American Recovery and Reinvestment Act of 2009, as well as bills proposed during the 2009 Hawai‘i Legislative Session.

Another focus of this work is to describe the perceptions of the investment capital sector towards biofuel projects. The goal of government incentives and mandates is to ultimately direct the flow of investment capital to a targeted area, not to create industries dependent on continuing government support.

This work also includes describing the increasing activity in the development and use of innovative public and private financing vehicles for alternative energy and greenhouse gas (GHG) emissions reductions. Two examples in particular will be discussed: 1) the renewable identification numbers (RIN) market created from the Federal 2007 Renewable Fuels Standard program; and 2) the American Clean Energy and Security Act of 2009. This bill, introduced at the Federal level by Waxman and Markey, describes a renewable energy standard, an energy efficiency standard and GHG cap and trade program, all with market incentives that include biofuels.

Lastly, this work aims to deliver a set of recommendations on how the HBMP can incorporate this information and analysis.

Scope

Lying clearly within the scope of this issue area (Task 8) of the HBMP project are the existing and proposed federal and Hawai‘i mandates and incentives. Also included are relevant mandates and incentives from other states and countries.

Given the structure of the HBMP team, however, it would be redundant for the scope of this work to reach too far into the particulars of any given point along the value chain. The subject of financial barriers, financial incentives, and funding sources permeates all points along the bioenergy value chain. In light of the independent, extensive analysis by other parties of the HBMP team, the scope of this work will consider and analyze the value chain primarily from the perspective of an investor, and not include the details of technical challenges, resource limitations, permitting and labor.

Finally, given that Act 253 was enacted in 2007, the scope of data collection will be largely confined to sources produced and made available from 2006 to the beginning of April 2009.

Area of study

The area of study is framed by the questions:

- *What is the perspective of private investment capital on biofuels in general and in Hawaiʻi?*
- *What are the perceived, present financial barriers to growing a biofuels industry in Hawaiʻi, and what are the available Hawaiʻi and federal financial incentives for a local biofuels industry?*
- *What relevant financial incentives exist in other states? Internationally?*
- *How well do these components align?*
- *What are the existing Hawaiʻi and federal activities that relate to developing a local biofuels industry?*
- *What additional funding sources could be pursued, particularly in light of innovative financial instruments used for renewable energy and GHG abatement?*

Key information sources

To answer the questions framing this study, information was gathered from a variety of sources. Reports from academic sources, non-governmental organizations, and government offices were evaluated that address biofuel development and associated policies. Presented below are the reports found to be most relevant:

1. *Hawaiʻi Biofuels Summit Technical Synopsis*. Rocky Mountain Institute, September 28, 2006
2. *Hawaiʻi Biofuels Summit Briefing Book*. Rocky Mountain Institute, August 8, 2006
3. *Final Report in Response to House Concurrent Resolution 195*. Hawaiʻi Energy Policy Forum, April 9, 2007
4. *Policy Gap Analysis: Findings and Policy Recommendations for the Biomass Sector*. Biomass Research and Development Initiative (BRDI), February 21, 2007
5. *Biomass Multi-Year Program*, Office of the Biomass Program Energy Efficiency and Renewable Energy, U.S. Department of Energy, March 2008
6. *Assessment of Existing Hawaiʻi Biomass Feedstocks*. Black & Veatch Corporation, May 2008 (Draft)
7. *National Biofuels Action Plan.* Biomass Research and Development Board, October, 2008
8. *Biofuel Economics and Policy for Washington State.* Yoder, J., R. Shumway, et al. 2008

In general, an exhaustive review of international, national and state programs and legislation related to biofuel development produced considerable data on both barriers and incentives. This included directly accessing government legislation portals (e.g. www.capitol.hawaii.gov) to assess the exact language of relevant bills.

List of Incentives

Existing Hawai‘i incentives	Appendix A
Existing Federal incentives	Appendix B
Relevant incentives from American Recovery and Reinvestment Act of 2009	Appendix C
Proposed Hawai‘i legislation relevant to biofuels	Appendix D
Selected incentives from other states	Appendix E
Selected incentives from other countries	Appendix F
Financial incentives described in HCR 195	Appendix G

Activities engaging stakeholders and experts

Stakeholders

A list of relevant stakeholders was provided by HNEI, which had received and updated a record from the State of Hawai‘i DBEDT. In addition to using this resource, stakeholders and experts were directly engaged at two separate meetings, by survey, and in individual conversations. A description of the events and data collection process, and a summary of the resulting information are presented below.

Stakeholder meetings

February 13, 2009 - The Hawai‘i Science & Technology Council held a “Tech Download” event titled: *Biotechnology: Feeding, Fueling and Healing Hawai‘i -Policy Challenges for a Sustainable Economy*.

This event focused on bioenergy with three members of the Hawai‘i biofuel community presenting and participating in a panel discussion: Robert King, Founder, Pacific Biodiesel; Michael Poteet, Agronomist, Hawai‘i Agriculture Research Center; and Paul Zorner, CEO, Hawai‘i Bioenergy. The audience included investors, DBEDT officials, University of Hawai‘i administrators and researchers, and business leaders. At the beginning of the event, an opportunity was provided to announce the objective of Task 8 of the Bioenergy Master Plan project to the active stakeholders present.

The panel discussed challenges along the value chain, citing technology constraints of second and third generation biofuels, present local biofuel feedstock shortages, and equipment needs. When directly asked what incentives could work in Hawai‘i and what incentives had worked elsewhere, the panel did not have an answer. The most concrete opinion and insight gathered from the event was from a retired, French investment banker who had attended looking for investment opportunities. When chased down in the parking lot, he indicated biofuels, in general, were not an attractive investment given the unproven technology, high costs, and high risks. He favored solar investments.

April 2, 2009 – HNEI hosted a *Hawai‘i Bioenergy Master Plan Stakeholders Meeting* co-sponsored by the U.S. Department of Energy and DBEDT

In support of developing the HBMP a stakeholder meeting was held. Hawai‘i bioenergy stakeholders were invited to learn about the progress of the HBMP, and provide input during facilitated breakout sessions. The parties responsible for the eleven tasks of the HBMP developed questions for bioenergy stakeholders. These questions were grouped into larger themes by the HBMP project coordinators and facilitators to be addressed during the breakout sessions.

Two breakout sessions were devoted to addressing:

1. What are the primary barriers that inhibit the economic feasibility and competitiveness of locally grown biofuels?
2. In the next two-years, what financial incentives will create economic feasibility and encourage the competiveness of locally grown biofuels?
3. In the next 2-3 years, what policy changes will create economic feasibility and encourage the competiveness of locally grown biofuels?
4. The biofuel industry is often seen as a way to change communities dependent on agricultural land or that have some connection to the land. Please share examples you know of that demonstrate the impact of the biofuels industry on rural communities.
5. What best practices would you recommend to assure a win/win experience for biofuel industries and rural/agricultural regions of Hawai‘i? How can we minimize negative impacts and optimize positive impacts?

A summary of the stakeholder discussion on these questions was generated by the event facilitators and is in Appendix H. Upon receipt of this account, a series of tables and observations were compiled aligning existing Hawai‘i and Federal incentives with perceived barriers to biofuels development (see Appendix I).

Survey

A survey was designed then distributed to a number of available potential bioenergy producers, feedstock producer and suppliers, and producers of bioenergy as a byproduct of higher value products. Respondents were asked to rank the level of risk associated with the various stages of the supply chain including: feedstock, production, distribution and end use, on a scale of 1-7, with 7 as very risky. A sample of the survey is in Appendix J.

A summary of the riskiest areas of the value chain identified in the survey is below (Table 1). Risks are grouped according to the role of the respondent.

Table 1: Summary of risk identified through survey

Feedstock	Conversion	Distribution	End use
Bioenergy Producer			
Real Estate	Feedstock-product spread vs. fixed cost	Product spread vs. fixed costs	Biofuel cost vs. Petroleum
Production	Tenure of off-take contract vs. debt		
Lead-time for feedstock vs. market demand	Security of feedstock supply/ availability/ liquidity		

Producer of Energy as Byproduct			
	Feedstock	Product vs. Fixed costs	
Producer and Supplier of Feedstock			
Labor	Duration of fed tax credit	Duration of fed tax credit	Credit worthy suppliers
Real estate	Tenure of off take contract vs. debt	Investment recovery of biofuels infrastructure	
Production	Security of feedstock supply/ availability/ liquidity	Credit worthy suppliers	
Water	Credit worthy off takers		

Feedback from the surveys indicates that financial incentives are extremely important to the future of bioenergy on the island. One survey respondent noted, “You can’t have a biofuels market without incentives.” Other respondents also expressed the importance of building a sustainable industry and one respondent gave specific information about “wanting to make sure they can pay a living wage, keep Hawai‘i green, have a zero carbon footprint and enhance a non-tourism place for the economy.” Other sentiments included confusion over “where we are in these incentives.” It was also suggested by one respondent that the primary difficulty in building anything is finding equity money stating, “We need to persuade independent investors to invest in Hawai‘i. There is a perception that Hawai‘i is unfriendly to business. It’s 90 percent about process. What matters is that you go through all the hoops…particularly with the EIS system.” Some perceive the process challenge as a mechanism to stop projects, not protect the environment.

In-Depth Interview

In May, 2009 the team sought feedback from the Hawai‘i biofuel community, particularly from those active in developing projects in both ethanol production and electricity generation from biomass. Stakeholders were given a list of perceived barriers developed from the April 2 stakeholder meeting and asked to comment about how they may or may not affect a biofuels operation in Hawai‘i. Four main points surfaced:

1. The High Technology Investment Tax Credit (Act 221) is not a practical incentive for many biofuels, especially first generation ethanol. Non-fossil fuel qualifiers must meet criteria for innovative research (41D IRS Code). Given that it is unlikely that production of first generation ethanol will require innovative research, the incentive will not apply and proven biofuel technologies cannot take advantage of this important incentive.

2. The State General Excise Exemptions/ Enterprise Zones and Federal Volumetric Ethanol Excise Tax Credit are beneficial.

3. Though the competitive bidding process for providing power to the electric utility theoretically provides a market for Hawai‘i biofuel ventures, the process appears as a significant barrier. For biofuel companies to move forward they either have to meet a capacity requirement or receive a waiver of competitive bid. To bid

outright, a prospect must demonstrate it can meet capacity, competitively. The lack of biopower production thus far in Hawai‘i is exacerbated by the requirement to make a bid outright. As mentioned previously, the prospect can apply for a waiver, which when granted allows four months to put a proposal together. Under a waiver, the applicant must negotiate a purchase agreement with the utility, which is largely contingent on being able to meet capacity. Thus, the prospect needs to source and close on a feedstock contract, demonstrate its plant can operate and deliver to the utility, and lock down all other operational needs prior to getting a purchase agreement – all within a four month period. This process requires a significant amount of capital, which is difficult to finance because there is no chance of getting a purchase agreement prior to demonstrating that capacity can be met. The circular nature of the challenge has been a significant barrier to biofuel prospects participating in the competitive bidding process even with the waiver clause.

4. Related to point three, it is the feedstock provider that faces the most severe constraints upon entering the market. Current market conditions and financial incentives do not presently provide a viable prospect for start-up feedstock producers. The challenge for a farmer is meeting costs to establish operations (land, equipment, fertilizer, greenhouse, etc.). To finance, the farmer needs a purchase agreement from a buyer. The feedstock buyer requires guaranteed delivery, which the farmer can't provide without, at a bare minimum, land. To lease land, the land-owner needs a robust tenant with a purchase agreement. Here, again, is the circular nature of the challenge.

Other funding sources/information

For the purposes of this report "other funding sources" has been defined as private investment capital and innovative market mechanisms that add value to bioenergy development.

Private investment capital

A perspective on private capital and investments in biofuels is provided by Michael Swanson, Senior Agricultural Economist with Wells Fargo Bank described the challenge facing biofuels in the eyes of an investor (Swanson 2008). According to Swanson, biofuels providers are offering a commodity that is not differentiated in the marketplace. Thus, biofuel provided will be 'price takers' and will not be in a position to set a premium price above the general market price. The key to success in commodity markets, according to Swanson (2008), is to be the low cost supplier.

Swanson indicates a number of competitive pressures facing new entrants into the biofuels industry. The prices for biofuels crops are sensitive to alternative fuel prices, which fluctuate. Other considerations are the intra-industry competitiveness for local growers. Key factors include competitive advantage in terms of growing conditions, proprietary technology, raw materials, and economies of scale. Quality soil, growing days, and water are all key for growing cellulosic crops.

According to Swanson (2008), the demand for biofuels and thus the price and profitability of the industry depend on several factors. Crude oil price fluctuations impact biofuels profitability. Higher federal fuel efficiency standards also diminish demand for biofuels, as do mass transit and electric vehicles. Foreign suppliers of biofuels will also place downward pressure on prices.

Renewable energy trading: Renewable Identification Numbers

The most relevant, concrete example of innovative markets adding value to biofuels comes through the Renewable Fuels Standard (RFS) created by the Energy Independence and Security Act of 2007 (EISA). EISA set mandated levels for 2008 through 2022 for various types of renewable fuel to be blended with diesel and gasoline. The ultimate per annum goal is thirty-five billion gallons ethanol and one billion gallons biodiesel. The U.S. Environmental Protection Agency (EPA) tracks and enforces this mandate through the use of Renewable Identification Numbers (RINs). RINs are issued at the point of production or import. (Wisner, 2009a) When a RIN-issued batch of ethanol is blended into gasoline, the blender turns the RIN into the EPA to demonstrate compliance. (Wisner, 2009a) If a blender has excess RINs, beyond what is required for the mandate, the excess can be sold to another blender to apply to the current year's mandate or banked for future use. (Wisner, 2009a)

RINs are currently traded on an internet-based exchange called RINMARK, operated by Renewable Trading Services, LLC, though not exclusively.

Ron Kotrba described in the Ethanol Producer Magazine (April, 2009) one way this system could channel investment to ethanol plants: (Kotrba, 2009)

> According to Bill Day, corporate spokesman for Valero Energy Corp., the oil refiner's 2008 overall production averaged 1.19 million barrels per day of "gasoline and related blend stocks" equaling roughly 18.2 billion gallons a year. The U.S. EPA has declared that this year's RFS is 11.1 billion gallons, which equals 10.21 percent volume ethanol blend requirement for each of the obligated parties. Assuming Valero's 2009 gasoline production projections are similar to its 2008 production its share of the 10.21 percent would come to about 1.9 billion gallons of ethanol blending in 2009.
>
> Valero could purchase renewable identification number (RIN) credits to satisfy its obligation. If the oil refiner were to only purchase RINs to satisfy its RFS obligation and blended zero ethanol into its supplies—an unrealistic scenario but interesting to entertain, nevertheless—figuring a historically high RIN credit price of 15 cents per credit, the oil refiner could pay $285 million in RIN credit accumulations to satisfy its obligation for 2009. Instead, Valero proposes to pay $280 million for capital assets that, year after year, will continue to help it internally meet obligations under the RFS. It is also interesting to note that the five VeraSun plants in question have a cumulative nameplate capacity of 560 MMgy, which could satisfy between a quarter and a third of Valero's ethanol blending obligations for 2009. The five ethanol plants at $280 million with a 560 MMgy cumulative production capacity could amount to the oil company paying only 50 cents per installed gallon of production capacity.

Kotrba indicated the numerous idled U.S. ethanol plants, poor ethanol blend margins, and the 2008 year-end reporting deadline approaching quickly on Feb. 28, 2009, have together caused RIN prices to skyrocket. (Kotrba, 2009)

At present, Hawai‘i is opted-in to the Federal RFS. (Anon. 2008d) While further study is required, opportunities may exist to establish a complete, localized bioenergy value chain in Hawai‘i's using the Federal RFS. One resource we suggest to investigate is the RINMARK exchange (http://www.rinxchange.com/).

Biofuels and greenhouse gas emissions reductions

The largest, clearest signal that there will be funding opportunities for biofuels from quantified greenhouse gas emissions reductions comes from observing the U.S. Department of Agriculture (USDA) over the past few years. In late 2006, USDA issued a regulation "to broaden the use of private sector markets for environmental goods and services through emerging voluntary market mechanisms such as environmental credit trading and voluntary reporting registries. USDA believes market-based environmental stewardship can encourage competition, spur innovation, and achieve environmental benefits, while helping USDA constituents comply with environmental regulations." The regulation continues to clearly identify its strategy of including "environmental credits" as a means to promote agriculture (Copy of Regulation in Appendix K).

Even more indicative of the USDA's aggressive pursuit of market mechanisms for agriculture is the naming of the USDA as the regulating body of GHG offsets in rural and agricultural areas in HR 2454, American Clean Energy and Security Act (ACESA). Legislation is moving quickly, with the regulation of GHGs a high priority of President Obama. HR 2454 passed the U.S. House of Representatives on June 26, 2009.

ACESA establishes a "cap and trade" system in which emissions of greenhouse gases would be capped overall and allowances for such emissions either given away to polluters or sold. The Congressional Quarterly Fact Sheet states, "the bill provides agribusinesses with unique opportunities to make money in a renewable energy market, through such activities as […] growing crops suitable for the production of biofuels. The bill even provides assistance to agricultural enterprises during a transition to a renewable energy market by providing them with free emissions allowances." (Hannett, 2009)

According to stakeholders, a key component of a recent biofuel power purchase agreement grants a Hawai'i utility ownership of "environmental credits" from the biofuel operation. Clearly, utilities understand the potential future importance of greenhouse gas emissions offsets and other environmental benefits of biofuels, and place a monetary value on environmental credits today.

Act 234 (SLH 2007) commits the State to reduce GHGs to 1990 levels by the year 2020. Currently the State's GHG Emissions Reduction Task Force is working to provide an action plan that would include market-based mechanisms. In any policy involving biofuels, the HBMP should encourage careful measurement and monitoring of greenhouse gas emissions. As supported by the USDA, an approach might include GHG reporting through a registry, like The Climate Registry (TCR). TCR, of which Hawai'i is a founding member, is a nonprofit collaboration among North American states, provinces, territories and Native Sovereign Nations that sets consistent and transparent standards to calculate, verify and publicly report greenhouse gas emissions into a single registry. The Registry supports both voluntary and mandatory reporting programs and provides comprehensive, accurate data to reduce greenhouse gas emissions.

Findings

In very simple terms, the largest barrier to biofuels growth is the uncertainty of whether an investment in bioenergy can be profitable at each of the stages in the biofuels value added chain: biofuels feedstock production, conversion, distribution, and end-use. A review of these barriers, back through the value chain, is summarized below.

From the perspective of end-users, Hawai‘i grown biofuels are a commodity and should be substitutable with other transportation energy sources, such as foreign biofuels and petroleum. With new advances in automotive technologies, plug-in hybrid vehicles are creating an opportunity for electricity to substitute or even replace gasoline and diesel in a portion of the state's vehicles. Federal and State mandates and regulations may advance improved vehicle fuel efficiency standards, greenhouse gas emissions standards, or other environmental policies that impact consumer demand. The end use demand for biofuels thus remains subject to competition and uncertainty, with market prices being determined by global market forces as well as government policy.

Small market size and geographic isolation from competitors confines the current number of refineries to Chevron and Tesoro. In addition, the Hawaiian Electric Company plans to import vegetable oil or biodiesel for power production. The concern of the State's two refineries is the cost of Hawai‘i grown biofuels as an input relative to other fuels, the volume available, and the reliability of supply. Foremost are several risks. Refineries are concerned about lost revenues from petroleum refining due to biofuels displacement and managing the profitability of their existing petroleum refining operations. Refineries must reliably provide power and fuel to end users, and at reasonable costs as determined by their regulators and competitive pressures. Refineries face fluctuating oil prices, ranging from as high as $140 to current price of ~$70. To some degree, biofuels and petroleum fuels are interchangeable. Refineries also face fixed costs in adapting plants and equipment to specific fuel types or blends, such as ethanol sourcing to meet the E10 mandate. With high fixed costs and other sources of volatility, their success in the marketplace requires the ability to earn profits to compensate for market risks. Among these volatilities are concerns over the certainty of feedstock supply and consumer markets.

Biofuels producers that are considering entering the Hawai‘i market face a highly-specialized, niche market. With a limited number of buyers (refineries and other distributors), biofuels producers must demonstrate that their fuel is the preferred option (cost, quality, or other criteria) and that it can be provided reliably. They must demonstrate sufficient supply to justify an investment by distributors into specialized equipment and technologies. Biofuels producers face additional challenges on the supply side:

1. Investments in plants and equipment are costly and generally require financing.
2. Production technologies are often specific to selected feedstock and cannot be easily adapted.
3. If demand from the limited number of buyers is not consistent or sustainable, biofuel producers are faced with very limited exit options.

What are the alternative uses for facilities? To give context to these points, a June 2009 report entitled, “The Ethanol Crisis,” the author described that current ethanol production exceeds demand under the Energy Independence Security Act of 2007 federal mandate and will likely exceed demand past 2012. (Wisner, 2009)

At the beginning of the value added chain are feedstock growers. In Hawaiʻi, biofuel farmers will face challenges shared by farmers everywhere, such as volatility in weather, labor cost and availability, and commodity price fluctuations. Hawaiʻi’s agribusiness environment provides unique opportunities and challenges. One positive aspect is that Hawaiʻi supports a year round growing season. However, several factors tend to undermine the cost competitiveness of biofuel crops in Hawaiʻi. Land costs are relatively high, and land ownership is highly concentrated. Labor costs are also much higher than would be the case in competing supply markets, such as Brazil or Jamaica. Feedstock producers face establishment costs (Greenhouse, farming equipment, etc) that may require financing. However, it is difficult for producers to obtain credit in markets that are not established, where purchase agreements are not in place.

The current environment for biofuels development in Hawaiʻi is most constrained in the feedstock and production areas. The strongest consensus among stakeholders is on the following four points.

1. The High Technology Investment Tax Credit (Act 221) is not a practical incentive for many biofuels, especially first generation ethanol. Non-fossil fuel qualifiers must meet criteria for innovative research (41D IRS Code). Given that it is unlikely that production of first generation ethanol will require innovative research, the incentive will not apply and proven biofuel technologies cannot take advantage of this important incentive.

2. The State General Excise Exemptions/ Enterprise Zones and Federal Volumetric Ethanol Excise Tax Credit are beneficial.

3. Though the competitive bidding process for providing power to the electric utility theoretically provides a market for Hawaiʻi biofuel ventures, significant problems are outstanding. For biofuel companies to move forward they either have to meet

a capacity requirement or receive a waiver of competitive bid. To bid outright, a prospect must demonstrate it can meet capacity, competitively. The lack of biopower production thus far in Hawaiʻi is exacerbated by the requirement to make a bid outright. As mentioned previously, the prospect can apply for a waiver, which when granted allows four months to put a proposal together. Under a waiver, the applicant must negotiate a purchase agreement with the utility, which is largely contingent on being able to meet capacity. Thus, the prospect needs to source and close on a feedstock contract, demonstrate its plant can properly operate and deliver power to the utility, and lock down all other operation needs, prior to getting a purchase agreement by the end of the four month period. This process requires a significant amount of capital, which is difficult to finance because there is no chance of getting a purchase agreement prior to demonstrating that capacity can be met. The circular nature of the challenge has been a significant barrier to biofuel prospects participating in the competitive bidding process even with the waiver clause.

4. Related to point three, we conclude that it is the feedstock provider that faces the most severe constraints upon entering the market. Current market conditions and financial incentives do not presently provide a viable prospect for start-up feedstock producers. The challenge for a farmer is meeting his/her establishment costs (land, equipment, fertilizer, greenhouse, etc.). To finance, the farmer needs a purchase agreement from a buyer. The feedstock buyer requires guaranteed delivery, which the farmer can't provide without, at a bare minimum, land. To lease land, the land-owner needs a robust tenant with a purchase agreement. Here, again, is the circular nature of the challenge.

Vertical integration of land ownership, feedstock production, and conversion facility operation, a typical model for plantation agriculture in Hawaii, could serve to reduce the barriers identified in (3) and (4) above.

In general, a number of key economic threats to the viability of biofuels are identified.

- First, the current economic recession and the recently high prices of fuel are likely to dampen demand for transportation fuels for some time to come.
- Second, hybrid, electric, and hydrogen cars are increasingly becoming available with technologies that provide alternatives to liquid transportation fuels. Hawaiʻi has made ambitious infrastructure commitments to the electric car platform. Again, investors may question biofuel forecasts that do not include these initiatives.
- Third, mass transit and the introduction of rail will also change the transportation infrastructure in ways that impact fuel demand.
- Fourth, locally grown feedstock will compete with biofuel imports that may be lower priced.
- Fifth, biofuel entrepreneurs do not have confidence in the profitability of feedstock or fuel production under current conditions.

In reviewing the events that led up to Hawaii's rollout of the ethanol mandate, it became evident that a liability risk related to human health greatly contributed to U.S. refineries adopting ethanol blending. (Swanson, 2008) MTBE was the preferred oxygenating additive until lawsuits surfaced citing impacts on drinking water and carcinogenic properties. EPAct 2005 abruptly exposed the petroleum refiners to litigation risk, prompting a rapid switch to ethanol. Regardless the extent to which Hawaii used or did not use MTBE, EPAct 2005 dramatically altered ethanol markets. (Swanson, 2008, Wisner, 2009b) For the refineries, this influence was perhaps more significant than the ethanol mandates that went into effect at the same time in 2006. It is not clear if petroleum companies are committed to the ethanol mandates or whether they will fight them in the future. For example, the Pacific Business News article describes House Bill 1271, passed during the 2009 Hawaii legislative session, also known as the the "Barrel Tax Bill." (Kalani, 2009) The author writes that the legislation would suspend the state's ethanol law for three years, however, this language was not included in the bill that eventually passed. Though it is unclear why the language was originally included, this point is raised to illustrate the uncertainty of ethanol demand based on the State's E10 mandate.

As a stakeholder in the HBMP, SunFuels Hawaiʻi, LLC submitted a letter to the HBMP team dated June 8, 2009. Among a variety of insights and perspectives offered, the discussion of the importance to the biofuels investment community of establishing appropriate, specific, data-driven targets is worth highlighting. Like other Hawaiʻi biofuel stakeholders encountered during this study, SunFuels Hawaiʻi is not requesting incentives, but a clear, well thought out, transparent plan (and process) in which to invest their money. Synergizing the goals of the Hawaiʻi Clean Energy Initiative, the Global Warming Solutions Act (Act 234 SLH 2007), and the HBMP may provide the stability investors are seeking.

One general note on a method of evaluating the economics of biofuels, energy return on investment (EROI) analyses can present biofuels as unattractive, though results can vary depending on method, crop type, and fuel. An EROI, also referred to as net energy, is either expressed as a unit-less number or ratio of energy returned to society per energy required to get that energy.(Hall et al., 2009) An EROI of greater than 1 means there is a net gain of energy. Hall et al. argue corn-based ethanol has very low net energy yields (e.g. Hall et al. (2009) where corn ethanol EROI is less than 3:1.(2009) However, these metrics vary, especially when considering 2nd and 3rd generation sources. For example, Hammerschlag's 1990-2006 review (2006) presents that though corn ethanol yields an EROI of 0.84-1.65, cellulosic ethanol EROI's range from 4.40-6.61. Schemer et al. (2008) demonstrate switchgrass yields 500% more renewable energy than energy consumed in its production and has significant environmental benefits, as estimated by net GHG emissions as well as soil conservation benefits. HBMP should plan for the transition to higher yields of 2nd and 3rd generation biofuels to maximize EROI.

In conclusion, this study compiled a comprehensive list of financial incentives that are now available to Hawaiʻi biofuels industry from State and Federal sources. The policy landscape in other U.S. states, and foreign countries is also included to illustrate alternative options that Hawai‘i might consider. Financial barriers were cataloged and an investor’s perspective of these obstacles is provided. Along with a perspective of private capital, a description of innovative financial instruments is supplied.

Recommendations for the Hawaii Bioenergy Master Plan:

Frame Hawai‘i’s bioenergy strategy around vital State interests. Energy security and greenhouse gas emissions reduction targets could provide justification for bioenergy support.

Design *a priori* measurement and monitoring mechanisms to evaluate alternative individual projects based on State interests, particularly for the distribution of land leases.

Act swiftly to capture funding made available through the American Recovery and Reinvestment Act of 2009, though recognize the funding would need to be balanced by sustained sources to carry the operation year after year.

Consider House Concurrent Resolution 195 (HCR 195) and the subsequent recommendations of the Hawai‘i Energy Policy Forum (HEPF). Further study is required to determine the most appropriate incentives at each part of the biofuels value chain. In particular, analysis is needed to determine: Locations for biomass project; Options for leasing state land for fuel crop development; Opportunities for state and county governments and private investors to secure federal grants to support the development of fuel crops and the conversion of fuel crops to generate electricity; and feasibility of setting up a revolving fund as a mechanism to provide incentives necessary to stimulate investment in fuel crops and the conversion of fuel crops to generate electricity.

Establish a sub-committee of people with a mix of public and private experience raising capital for infrastructure and energy projects to put together the specific financial incentives to support HBMP. The sub-committee should, at a bare minimum, evaluate the incentive concepts proposed by HEPF in their response to HCR 195 (Appendix G).

Create a dedicated office that will maintain an up-to-date list of State and Federal incentives, and provide guidance for prospective business owners in biofuel on how to apply for incentives (grants, loans, tax credits, etc.). This office could also be the resource that guides business owners on the steps needed to valuate the environmental credits from the project. Perhaps this office could even provide business planning guidance. For example, a biomass power plant will likely be eligible for a waiver from the competitive bid process to provide HECO electricity. However, the waiver is for a period of 4 months. That is a prohibitively short period of time to get all the aspects of a plant’s operations lined up for negotiation of a power purchase agreement with the utility.

Coordinate and make transparent the process for land acquisition for biofuel feedstock producers. Bioenergy and land use policy involves multiple State agencies (DLNR, DHHL, DOA, DBEDT). Biofuels may be perceived as competing with other land uses, such as food production and residential development. The State interest in bioenergy should be articulated relative to competing interests.

Reconcile investor's concern for exit strategies with biofuels incentives. "What are the business options if ethanol demand falls?" "What are my exit strategies?" "What other outlets exist for large ethanol stocks if transportation demand tanks?" Biofuels investors' decisions are typically based on 10-20 years for biofuel refinery plants.

Align a flex fuel ethanol-based transportation strategy with the emergence of potential new transportation modes, including rail, and vehicle technologies, such as electric and hybrid vehicles. The State and counties are committed to alternative transportation strategies, and the role of biofuels should be assessed in that context.

Synergize the biofuels master plan with the Hawai‘i Clean Energy Initiative goals. A higher profile for both will likely lead to more Federal dollars.

Investigate Renewable Identification Number (RIN) market opportunities stemming from the Federal Renewable Fuel Standard (RFS). At present, Hawai‘i is opted-in to the Federal RFS. (Anon. 2008d) While further study is required, opportunities may exist to establish a complete, localized bioenergy value chain in Hawai‘i's using the Federal RFS. One resource we suggest to investigate is the RINMARK exchange (http://www.rinxchange.com/).

Facilitate the measurement and monitoring of greenhouse gas emissions. An approach might include mandatory reporting through The Climate Registry (TCR). TCR sets consistent and transparent standards to calculate, verify and publicly report greenhouse gas emissions

Coordinate biofuels policy with State goals to reduced GHG emissions. GHG emission reductions have actualized and perceived economic value in current and proposed initiatives to mitigate anthropogenic climate change. Provide research, education, and outreach on the role that biofuels might play relative to other strategies.

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Appendix A:

Existing Hawai‘i State Incentives as of June 2009

High Technology Business Investment Tax Credit [§235-110.9]
Value Chain: Most likely Conversion
Status: Expires on December 31, 2010.
Incentive type: Tax Credit
Description:

- The tax credit shall be as follows:
  - In the year the investment was made, 35 per cent;
  - In the first year following the year in which the investment was made, 25 per cent;
  - In the second year following the investment, 20 per cent;
  - In the third year following the investment, 10 per cent; and
  - In the fourth year following the investment, 10 per cent;
- Of the investment made by the taxpayer in each qualified high technology business, up to a maximum allowed credit:
  - $700,000 in the year the investment was made;
  - $500,000 in the first year following the year in which the investment was made;
  - $400,000 in the second year following the year in which the investment was made;
  - $200,000 in the third year following the year in which the investment was made;
  - And $200,000 in the fourth year following the year in which the investment was made.

Tax Credit for Research Activities [§235-110.91]
Value Chain: Most likely Conversion
Status: Expires on December 31, 2010.
Incentive type: Tax Credit
Description:

- Income tax credit for qualified research activities equal to the credit for research activities provided by section 41 of the Internal Revenue Code and as modified by this section.

Alcohol Fuels Excise Tax Exemption [§237-27.1]
Value Chain: Distribution or End Use
Status: Shall be repealed on June 30, 2009
Incentive type: Tax Credit
Description:

- There shall be exempted from and excluded from the measure of the taxes imposed by this chapter all of the gross proceeds arising from the sale of alcohol fuels for consumption or use by the purchaser and not for resale.

Ethanol Facility Tax Credit (EFTC) [§235-110.3]
Value Chain: Conversion
Status: Qualifying ethanol production facilities must be in operation prior to January 1, 2017.
Incentive type: Tax Credit (refundable)
Description:

- For each qualified ethanol production facility, the annual dollar amount of the ethanol facility tax credit during the 8 year period shall be equal to 30 per cent of its nameplate capacity if the nameplate capacity is greater than 500,000 but less than 15,000,000 gallons. A taxpayer may claim this credit for each qualifying ethanol facility; provided that:
  - The claim for this credit by any taxpayer of a qualifying ethanol production facility shall not exceed 100 per cent of the total of all investments made by the taxpayer in the qualifying ethanol production facility during the credit period;
  - The qualifying ethanol production facility operated at a level of production of at least 75 per cent of its nameplate capacity on an annualized basis;
  - The qualifying ethanol production facility is in production on or before January 1, 2017; and
  - No taxpayer that claims the credit under this section shall claim any other tax credit under this chapter for the same taxable year.

Farm and Aquaculture Sustainable Projects Loan [§219-6 (H)]
Value Chain: Feedstock Production; Feedstock Logistics
Status: Effective Date: 7/1/2008 - Still Effective.
Incentive type: State Loan Program
Description:

- Class H: Aquaculture sustainable project loans shall provide for:
  - The purchase, construction, or improvement of essential farm buildings, including the improvement of existing farm buildings related to the project;
  - The improvement of land that may be required by the project;
  - The purchase of equipment and payment of any related expenses, including materials, labor, and services;
  - Operating expenses associated with the project; or
  - The liquidation of indebtedness incurred for any of the foregoing purposes.
- The loans shall be for an amount not to exceed $1,500,000 or 85% of the project cost, whichever is less, and for a term not to exceed 40 years.

State Business Tax Credit / Enterprise Zones [§209E-10]
Value Chain: Across
Status: TBD.
Incentive type: Tax Credit
Description:

- Except for the general excise tax, the credit shall be:
  - 80 per cent of the tax due for the first tax year,
  - 70 per cent of the tax due for the second tax year,
  - 60 per cent of the tax due for the third year,
  - 50 per cent of the tax due the fourth year,
  - 40 per cent of the tax due the fifth year,
  - 30 per cent of the tax due the sixth year, and
  - 20 per cent of the tax due the seventh year;
- Any tax credit not usable shall not be applied to future tax years. Tax credits provided for in this section shall only apply to taxable income of a qualified business attributable to the conduct of business within the enterprise zone. In addition, any qualified business shall be entitled to a tax credit against any taxes due the State in an amount equal to a percentage of unemployment taxes paid. The amount of the credit shall be equal to
  - 80 per cent of the unemployment taxes paid during the first year,

- 70 per cent of the taxes paid during the second year,
- 60 per cent of the taxes paid during the third year,
- 50 per cent of the taxes paid during the fourth year,
- 40 per cent of the taxes paid during the fifth year,
- 30 per cent of the taxes paid during the sixth year, and
- 20 per cent of the taxes paid during the seventh year;

- Tax credits provided for in this section shall only apply to the unemployment tax paid on employees employed at the qualified business' establishment or establishments located within the enterprise zone.

State general excise exemptions / Enterprise Zones [§209E-11]
Value Chain Target: Across
Status: TBD
Incentive type: Tax Exemption
Description:

- Any qualified business is exempt from the payment of general excise taxes on the gross proceeds from the manufacture of tangible personal property, the wholesale sale of tangible personal property, the engaging in a service business by a qualified business, or the engaging in research, development, sale, or production of all types of genetically-engineered medical, agricultural, or maritime biotechnology products;
- The exemption shall extend for a period not to exceed 7 years;

Reduced Tax Rates for Alternative Fuels [§243-4]
Value Chain: Distribution
Status: Shall be repealed and reenacted on December 31, 2009.
Incentive type: Favorable Rates of Taxation
Description:

- With respect to alternative fuels, the only tax collected shall be:
  - Every distributor of any alternative fuel for operation of an internal combustion engine shall pay a license tax to the department of one-quarter of 1 cent for each gallon of alternative fuel sold or used by the distributor;
  - Every distributor, in addition to the tax required under paragraph 1 of this subsection, shall pay a license tax to the department for each gallon of alternative fuel sold or used by the distributor for operating a motor vehicle or motor vehicles upon the public highways of the State at a rate proportional to that of the rates applicable to diesel oil, rounded to the nearest one-tenth of a cent, as follows:
    - Ethanol, 0.145 times the rate for diesel;
    - Methanol, 0.11 times the rate for diesel;
    - Biodiesel, 0.25 times the rate for diesel;
    - Liquefied petroleum gas, 0.33 times the rate for diesel; and
    - For other alternative fuels, the rate shall be based on the energy content of the fuels as compared to diesel fuel, using a lower heating value of 130,000 BTU per gallon as a standard for diesel, so that the tax rate, on an energy content basis, is equal to one-quarter the rate for diesel fuel.

Appendix B:

Existing Federal Incentives

Biorefinery Project Grants
Value Chain: Conversion
Status: Still Effective.
Incentive type: Research Grants
Description:

- Provides funds for cooperative biomass R&D for the production of fuels, electric power, chemicals, and other products;
- Variable qualified applicant and authorization year to year, depending on program goals in a given year;

Alternative Fuel Excise Tax Credit
Value Chain: Distribution; End Use
Status: Expires on December 31, 2009.
Incentive type: Tax Credit
Description:

- Available for alternative fuel that is sold for use or used as a fuel to operate a motor vehicle;
- A tax credit in the amount of $0.50 per gallon;
- Qualified alternative fuels: Compressed natural gas (based on 121 cubic feet), Liquefied natural gas, Liquefied petroleum gas, Liquefied hydrogen, P-Series fuel, Liquid fuel derived from coal through the Fischer-Tropsch process, and Compressed or liquefied gas derived from biomass;
- Not allowed if an incentive for the same alternative fuel is also determined under the rules for the ethanol or biodiesel tax credits;
- Expires December 31, 2009, except for liquefied hydrogen which expires September 30, 2014;

Alternative Fuel Infrastructure Tax Credit
Value Chain: Distribution
Status: Expires on December 31, 2010.
Incentive type: Tax Credit
Description:

- Available for the cost of installing alternative fueling equipment placed into service after December 31, 2005;
- Qualified alternative fuels: natural gas, liquefied petroleum gas, hydrogen, electricity, E85, or diesel fuel blends containing a minimum of 20% biodiesel;
- Amount is up to 30% of the cost, not to exceed $30,000, for equipment placed into service before January 1, 2009.
- Amount is up to 50% not to exceed $50,000, for equipment placed into service on or after January 1, 2009.
- Allowed to use the credit towards each location for those who install equipment at multiple sites;
- A tax credit of up to $1,000, which increases to $2,000 for equipment placed into service after December 31, 2008 for consumers who purchase residential fueling equipment;

- The maximum credit amount of $200,000 for hydrogen fueling equipment placed into service after December 31, 2008, and before January 1, 2015;

Alternative Fuel Mixture Excise Tax Credit
Value Chain: Distribution
Status: Expires on December 31, 2009.
Incentive type: Tax Credit
Description:

- A tax incentive on the sale or use of the alternative fuel blend (mixture) for use as a fuel in the blender's trade or business;
- A tax credit in the amount of $0.50 per gallon of alternative fuel used to produce a mixture containing at least 0.1% gasoline, diesel, or kerosene;
- Qualified alternative fuels: compressed natural gas (based on 121 cubic feet), liquefied natural gas, liquefied petroleum gas, liquefied hydrogen, P-Series fuel, liquid fuel derived from coal through the Fischer-Tropsch process, and compressed or liquefied gas derived from biomass;
- Not allowed if an incentive for the same alternative fuel is also determined under the rules for the ethanol or biodiesel tax credits;
- Expires on December 31, 2009, except for liquefied hydrogen, which expires September 30, 2014;

Biodiesel Income Tax Credit
Value Chain: Distribution; End Use
Status: Expires on December 31, 2009.
Incentive type: Tax Credit
Description:

- A taxpayer that delivers pure, unblended biodiesel (B100) into the tank of a vehicle or uses B100 as an on-road fuel in their trade or business may be eligible for an incentive in the amount of $1.00 per gallon of biodiesel, agri-biodiesel, or renewable diesel;
- Qualified fuel: biodiesel, agri-biodiesel, and/or renewable diesel content (Renewable diesel is defined as liquid fuel derived from biomass);

Biodiesel Mixture Excise Tax Credit
Value Chain: Distribution
Status: Expires on December 31, 2009.
Incentive type: Tax Credit
Description:

- A biodiesel blender may be eligible for a tax incentive in the amount of $1.00 per gallon of pure biodiesel, agri-biodiesel, or renewable diesel blended with petroleum diesel to produce a mixture containing at least 0.1% diesel fuel.

Cellulosic Biofuel Producer Tax Credit
Value Chain: Conversion
Status: Expires on December 31, 2012.
Incentive type: Tax Incentive
Description:

- A cellulosic biofuel producer may be eligible for a tax incentive in the amount of up to $1.01 per gallon of cellulosic biofuel.

- If the cellulosic biofuel also qualifies for alcohol fuel tax credits, the credit amount is reduced to $0.46 per gallon for biofuel that is ethanol and $0.41 per gallon if the biofuel is not ethanol.
- Under current law, only qualified fuel produced in the U.S. between January 1, 2009, and December 31, 2012, for use in the U.S. may be eligible.

Volumetric Ethanol Excise Tax Credit (VEETC) [by the American Jobs Creation Act of 2004; §301]
Value Chain: Distribution
Status: Expires on December 31, 2010.
Incentive type: Tax Credit
Description:

- An ethanol blender may be eligible for a tax incentive in the amount of $0.45 per gallon of pure ethanol (minimum 190 proof) blended with gasoline.

Special Depreciation Allowance for Cellulosic Biomass Ethanol Plant Property [by the Tax Relief and Health Care Act of 2006, §209]
Value Chain: Conversion
Status: Expires on December 31, 2012.
Incentive type: Depreciation Allowance
Description:

- A taxpayer may take a depreciation deduction of 50% of the adjusted basis of a new cellulosic ethanol plant in the year it is put in service;
- Only applicable to cellulosic ethanol plants that break down cellulose through enzymatic processes;
- Any portion of the cost financed through tax-exempt bonds is exempted from the depreciation allowance;
- Only applicable to plants acquired after December 20, 2006, and placed in service before January 1, 2013. Any plant that had a binding contract for acquisition before December 20, 2006, does not qualify;

Business and Industry (B&I) Guaranteed Loans
Incentive type: Federal Loan Program
Description:

- This program provides guarantees for up to 90% of a loan made by a commercial lender. Loan proceeds may be used for working capital, machinery and equipment, buildings and real estate, and certain types of debt refinancing.
- Approximately $1 billion in loans are guaranteed annually.

Biomass Research and Development Initiative [by the Biomass R&D Act of 2000, §307; extended and mandatory appropriations provided by the Farm Bill 2002, §9008; extended and funding authorization expanded by the EPA 2005, §941]
Status: Effective by the end of 2015.
Incentive type: Grant
Description:

- Grants are provided for biomass research, development, and demonstration projects;
- Eligible projects include ethanol and biodiesel demonstration plants;
- Currently authorized at $200 million per year;

Small Agribiodiesel Producer Credit [by the EPA 2005, §1345]
Status: Expires on December 31, 2009.
Incentive type: Tax Credit
Description:

- A small agri-biodiesel producer may be eligible for a tax incentive in the amount of $0.10 per gallon of agri-biodiesel.
- A small producer is one that has, at all times during the tax year, not more than 60 million gallons of productive capacity of any type of agri-biodiesel.
- Agri-biodiesel is defined as diesel fuel derived solely from virgin oils, including esters derived from corn, soybeans, sunflower seeds, cottonseeds, canola, crambe, rapeseeds, safflowers, flaxseeds, rice bran, mustard seeds, and camelina, and from animal fats; renewable diesel does not qualify for the credit.
- The incentive applies only to the first 15 million gallons of agri-biodiesel produced in a tax year.

Small Ethanol Producer Credit [by the Omnibus Budget Reconciliation Act of 1990, §11502; extended by the American Jobs Creation Act of 2004, §301; expanded by the EPA 2005, §1347]
Status: Expires on December 31, 2010.
Incentive type: Tax Credit
Description:

- A small ethanol producer may be eligible for a tax incentive in the amount of $0.10 per gallon of ethanol.
- A small producer is one that has, at all times during the tax year, not more than 60 million gallons of productive capacity of any type of alcohol.
- The incentive applies only to the first 15 million gallons of ethanol produced in a tax year.

Renewable Diesel Tax Credit [by the EPA 2005]
Status: In effect until 2010.
Incentive type: Tax Credit
Description:

- Amends the biodiesel tax credits to include renewable diesel fuel, which is derived from biomass by a thermal depolymerization process;
- The credit is $1 per gallon of renewable diesel.

Credit for Installation of Alternative Fueling Stations [by the EPA 2005; §1342]
Value Chain: Distribution
Status: TBD
Incentive type: Credit
Description:

- Permits taxpayers to claim a 30% credit for the cost of installing clean-fuel vehicle refueling property to be used in a trade or business of the taxpayer or installed at the principal residence of the taxpayer. 85% of the volume must consist of ethanol, natural gas, compressed natural gas, liquefied natural gas, liquefied petroleum gas, and hydrogen. Any mixture of diesel fuel and biodiesel must contain at least 20% biodiesel.

Biomass Commercial Use Grant Program [by the EPA 2005; §210(b)]

Value Chain: End Use
Status: Authorized from 2006 to 2016.
Incentive type: Grant
Description:

- Authorizes placement of grants to improve the commercial value of forest biomass for electric energy, useful heat, transportation fuels, and other commercial purposes;
- Biomass commercial use grants may be made to any person in a preferred community that owns or operates a facility that uses biomass as a raw material to produce electric energy, sensible heat, or transportation fuels;
- To help offset the purchase cost of biomass, a qualified entity may receive up to a $20 per green ton for biomass delivered.

Bioenergy Program – University Biodiesel Program [by the EPA 2005; §932(e)]
Value Chain: End Use
Status: Authorized from 2007 to 2009.
Incentive type: Grant
Description:

- $213 million for FY2007, $251 million FY2008, and $274 million for FY2009 authorized to carry out all Bioenergy Programs.
- This program establishes a demonstration program for electric generation facilities owned by institutions of higher education. It shall examine the feasibility of operating diesel electric power generators using biodiesel grades as high as B100.

Advanced Biofuel Technologies Program [by the EPA 2005; §1514]
Value Chain: Conversion
Status: Authorized from 2005 to 2009.
Incentive type: Grant
Description:

- $110 million per year from FY2005 through FY2009 authorized.
- This program is established to demonstrate advanced technologies for the production of alternative transportation fuels. Funding will be granted to programs that demonstrate 4 or more different conversion technologies for cellulosic biomass ethanol and to programs that demonstrate 5 or more technologies for co-producing value-added bioproducts resulting from the production of biodiesel.

Biobased Fuels and Products Outreach and Education Program [by the EPA 2005; §947]
Value Chain: Conversion
Status: Authorized from 2006 to 2010.
Incentive type: Grant
Description:

- $1 million per year from FY2006 through FY2010 authorized.
- This establishes a program to provide training and technical assistance for feedstock producers to promote producer ownership, investment, and participation in operating biobased processing facilities. It would also provide public education and outreach on biobased fuels and product for consumers.

Cellulosic Biofuel Production Incentives [by the EPA 2005; §942]
Value Chain: Conversion

Status: The first year when annual biofuel production is 1 billion gallons or when the EPA 2005 has been in effect for 10 years (whichever comes first).
Incentive type: Grant/Award
Description:

- This program serves as an incentive to accelerate annual cellulosic biofuels production to 1 million gallons by 2015 and to ensure that small feedstock producers and rural businesses are participants in the cellulosic biofuel industry;
- Awards a production incentive on a per gallon basis of cellulosic biofuels;

Cellulosic Biomass Ethanol and Municipal Solid Waste Loan Guarantee Program [by the EPA 2005; §1510]
Value Chain: Coversion
Status: Effective until 2015.
Incentive type: Federal Loan Program
Description:

- The program authorizes loan guarantees for up to 80% to private institutions for the cost of constructing facilities to process MSW and cellulosic biomass into fuel ethanol and other commercial byproducts;
- Private lending institutions must guarantee loans for biofuel plant construction and each project must have a 30 million gallon capacity;

DOE Loan Guarantee Program [by the EPA 2005, Title XVII]
Value Chain:
Status: Still Effective; Expires 09/30/2011
Incentive type: Federal Loan Program
Description:

- Energy Policy Act of 2005 (EPAct 2005) authorized DOE to issue loan guarantees for projects that "avoid, reduce or sequester air pollutants or anthropogenic emissions of greenhouse gases; and employ new or significantly improved technologies as compared to commercial technologies in service in the United States at the time the guarantee is issued." $10 billion originally authorized
- Three categories: (1) manufacturing projects, (2) stand-alone projects, and (3) large-scale integration projects that may combine multiple eligible renewable energy, energy efficiency and transmission technologies in accordance with a staged development scheme.
- The American Recovery and Reinvestment Act of 2009 (H.R. 1), enacted in February 2009, extended the authority of the DOE to issue loan guarantees and appropriated $6 billion for this program. Under this act, the DOE may enter into guarantees until September 30, 2011. The act amended EPAct 2005 by adding a new section defining eligible technologies for new loan guarantees. Eligible projects include renewable energy projects that generate electricity or thermal energy and facilities that manufacture related components, electric power transmission systems, and innovative biofuels projects. Funding for biofuels projects is limited to $500 million. Davis-Bacon wage requirements apply to any project receiving a loan guarantee.

Farm Bill 2008
Value Chain: Across
Status: Govern Federal farm programs for 2008-2012;
Incentive type: Federal Act (Collection of Grants, Loans, Taxes, Incentives)

Description:

- Forest Biomass for Energy: Authorizes appropriation of $15 million annually for FY 2009-12;
- Biofuels Infrastructure Study: Requires Secretaries of Agriculture, Energy, and Transportation and Administrator of Environmental Protection Agency to jointly conduct a comprehensive biofuels infrastructure study;
- Biomass Research and Development: Provides mandatory CCC funding of $118 million for FY 2009-12. Authorizes additional $35 million annually FY 2009-12;
- Biodiesel Fuel Education Program: Extends program, with CCC funding remaining at $1 million annually for FY 2008-12;
- Bioenergy Program for Advanced Biofuels: Mandates a total of $300 million in CCC funding for FY 2009-12. Authorizes appropriations of $25 million annually for FY 2009-12;
- Biorefinery Assistance: Mandates $75 million in funding for FY 2009 and $245 million in FY 2010 through CCC, for cost of loan guarantees, until expended. No mandatory funding specified for grant program. Authorizes appropriations of $150 million annually for FY 2009-12;
- Biorefinery Assistance: Authorizes competitive grants to assist development and construction of demonstration-scale biorefineries that convert renewable biomass to advanced biofuels. Grants may not exceed 30% of project cost. Authorizes loan guarantees to fund development, construction, and retrofitting of commercial-scale biorefineries. Loan guarantees of up to 90% of principal and interest may not exceed $250 million and are limited to 80% of project costs.
- Biobased Markets Program: Mandates total funding through CCC of $1 million for FY 2008 and $2 million annually for FY2009-12 for testing and labeling of biobased products. Authorizes appropriations of additional funding of $2 million annually for FY 2009-12.
- Biomass Crop Assistance Program: Establishes a program to support establishment and production of eligible crops for conversion to bioenergy, and to assist agricultural and forest landowners with collection, harvest, storage, and transportation of these crops to conversion facility. Assistance includes:
  - payments for up to 75% of cost of establishing an eligible crop;
  - annual payments to support production;
  - matching payments of up to $45/ton for 2 years for collection, harvest, storage, and transportation to a biomass conversion facility;
- Contract terms are up to 5 years for annual and perennial crops and up to 15 years for woody biomass.
- Repowering Assistance: Authorizes payments to encourage existing biorefineries to replace fossil fuels used to produce heat or power for operation of the biorefinery. Payments would be made for installation of new systems that use renewable biomass or for new production of energy from renewable biomass. Mandatory funding of $35 million through CCC for FY 2009, until expended. Authorizes appropriations of $15 million annually FY 2009-12.
- Bioenergy Research: Revises Sun Grant Research Initiative; Grant Information Analysis Center will support regional centers and produce annual report. Authorizes $75 million annually for FY 2008-12.
- Credit for Production of Cellulosic Biofuel: Provides temporary cellulosic biofuels production tax credit of up to $1.01/gallon through Dec 31, 2012.
- Modification of Alcohol Credit: Reduces tax credits to 45 cents/gallon in calendar year after annual production or importation of ethanol reaches 7.5 billion gallons.

Sun Grant Research Initiative Act of 2003
Value Chain: Across
Status: Effective until 2010;
Incentive type: Research Grants
Description:

- Provision established by Sun Grant Research Initiative Act of 2003;
- Established 5 regional sun grant research centers based at Land Grant universities;
- Intent was to foster collaboration between USDA, Department of Energy, and Land Grant universities in developing and disseminating biobased energy technologies;
- Authorized appropriations of $25 million in FY2005, $50 million in FY2006, and $75 million for each of FY2007-10;

Rural Business Enterprise Grants (RBEG)
Value Chain: Across
Status: Still Effective;
Incentive type: Federal Grant Program
Description:

- RBEG provides grants to finance and facilitate development of small and emerging private rural business enterprises. The grant is awarded to a third party to assist a business; grant funds do not go directly to the business.
- Approximately $40 million in each of FY2005 through FY2007; $38.7 million for FY2008;

U.S. Department of Treasury - Renewable Energy Grants
Incentive Type: Federal Grant Program (H.R. 1: Div. B, Sec. 1104 & 1603 (The American Recovery and Reinvestment Act of 2009))
Status: Effective 1/1/2009 – 01/01/2014 for biomass
Description:

- The grant is equal to 30% of the basis of the property for qualified facilities. Qualified facilities include wind energy facilities, closed-loop biomass facilities, open-loop biomass facilities, geothermal energy facilities, landfill gas facilities, trash facilities, qualified hydropower facilities, and marine and hydrokinetic renewable energy facilities.
- Terms: Grant applications must be submitted by 10/1/2011. Payment of grant will be made within 60 days of the grant application date or the date property is placed in service, whichever is later.

Renewable Energy Production Tax Credit
Value Chain: Distribution; End Use
Incentive Type: Tax Credit
Status: Enacted 1992. Updated February 17, 2009. Facility must be in service by 12/31/2013
Description:

- The federal renewable electricity production tax credit (PTC) is a per-kilowatt-hour tax credit for electricity generated by qualified energy resources and sold by the taxpayer to an unrelated person during the taxable year
- The February 2009 legislation revised the credit by: (1) extending the in-service deadline for most eligible technologies by three years (two years for marine and hydrokinetic resources); and (2) allowing facilities that qualify for the PTC to opt instead to take the federal business energy investment credit (ITC) or an equivalent cash grant from the U.S.

Department of Treasury. The ITC or grant for PTC-eligible technologies is generally equal to 30% of eligible costs.
- Closed-loop biomass credit = $0.021/kwh
- Open-loop biomass credit = $0.01/kwh
- Open-loop biomass, geothermal, small irrigation hydro, landfill gas and municipal solid waste combustion facilities placed into service after October 22, 2004, and before enactment of the Energy Policy Act of 2005, on August 8, 2005, are only eligible for the credit for a five-year period.
- Open-loop biomass facilities placed in service before October 22, 2004, are eligible for a five-year period beginning January 1, 2005.

Business Energy Investment Tax Credit
Value Chain: Across
Incentive Type: Tax Credit
Status: Credit eligible for systems in service before 12/31/2016
Description:
- The American Recovery and Reinvestment Act of 2009 (H.R. 1) allows taxpayers eligible for the federal renewable electricity production tax credit (PTC) to take the federal business energy investment tax credit (ITC) or to receive a grant from the U.S. Treasury Department instead of taking the PTC for new installations. The new law also allows taxpayers eligible for the business ITC to receive a grant from the U.S. Treasury Department instead of taking the business ITC for new installations.
- Significantly, The American Recovery and Reinvestment Act of 2009 repealed a previous limitation on the use of the credit for eligible projects also supported by "subsidized energy financing." For projects placed in service after December 31, 2008, this limitation no longer applies. Businesses that receive other incentives are advised to consult with a tax professional regarding how to calculate this federal tax credit.

Qualified Energy Conservation Bonds
Status: H.R.1; Div.B; Sec.1112 (American Recovery and Reinvestment Act of 2009);
Effective Date: 04/07/2009
Incentive type: Federal Loan Program
Description:
- The Energy Improvement and Extension Act of 2008, enacted in October 2008, authorized the issuance of Qualified Energy Conservation Bonds (QECBs) that may be used by state, local and tribal governments to finance certain types of energy projects. QECBs are qualified tax credit bonds, and in this respect are similar to new Clean Renewable Energy Bonds or CREBs.
- Energy Improvement and Extension Act of 2008 and The American Recovery and Reinvestment Act of 2009, enacted in February 2009, expanded the allowable bond volume to $3.2 billion. In April 2009 the IRS issued Notice 2009-29 providing interim guidance on how the program will operate and how the bond volume will be allocated.
- The advantage of these bonds is that they are issued -- theoretically -- with a 0% interest rate. The borrower pays back only the principal of the bond, and the bondholder receives federal tax credits in lieu of the traditional bond interest. The tax credit may be taken quarterly to offset the tax liability of the bondholder. The tax credit rate is set daily by the U.S. Treasury Department; however, energy conservation bondholders will receive only 70% of the full rate set by the Treasury Department under 26 26 USC § 54A. Credits exceeding a bondholder's tax liability may be carried forward to the succeeding tax year, but cannot be refunded. Energy conservation bonds differ from traditional tax-exempt

bonds in that the tax credits issued through the program are treated as taxable income for the bondholder.

- In contrast to CREBs, QECBs are not subject to a U.S. Department of Treasury application and approval process. Bond volume is instead allocated to each state based on the state's percentage of the U.S. population as of July 1, 2008. Each state is then required to allocate a portion of its allocation to "large local governments" within the state based on the local government's percentage of the state's population. Large local governments are defined as municipalities and counties with populations of 100,000 or more. Large local governments may reallocate their designated portion back to the state if they choose to do so. IRS Notice 2009-29 contains a list of the QECB allocations for each state and U.S. territory.
- The definition of "qualified energy conservation projects" is fairly broad and contains elements relating to energy efficiency capital expenditures in public buildings; renewable energy production; various research and development applications; mass commuting facilities that reduce energy consumption; several types of energy related demonstration projects; and public energy efficiency education campaigns (see H.R. 1424 for additional details). Renewable energy facilities that are eligible for CREBs are also eligible for QECBs.

Tribal Energy Program Grant

USDA - Rural Energy for America Program (REAP) Grants and Loans
Value Chain: Across
Incentive Type: Grant
Status: Enacted 5/13/2002. Effective FY2003. Updated May, 2008
Description:

- Updated by The Food, Conservation, and Energy Act of 2008 (H.R. 2419), enacted by Congress in May 2008.
- Promotes energy efficiency and renewable energy for agricultural producers and rural small businesses through the use of (1) grants and loan guarantees for energy efficiency improvements and renewable energy systems, and (2) grants for energy audits and renewable energy development assistance.
- Congress has allocated funding for the new program in the following amounts: $55 million for FY 2009, $60 million for FY 2010, $70 million for FY 2011, and $70 million for FY 2012.
- 96% of funding dedicated to grants and loan guarantees for energy efficiency improvements and renewable energy systems.
- Available to agricultural producers and rural small businesses to purchase renewable energy systems (including systems that may be used to produce and sell electricity), to make energy efficiency improvements, and to conduct relevant feasibility studies.
- Eligible renewable energy projects include wind, solar, biomass and geothermal; and hydrogen derived from biomass or water using wind, solar or geothermal energy sources.
- Grants are limited to 25% of a proposed project's cost, and a loan guarantee may not exceed $25 million. The combined amount of a grant and loan guarantee may not exceed 75% of the project’s cost.
- A minimum of 20% of the funds available for these incentives will be dedicated to grants of $20,000 or less.

Clean Renewable Energy Bonds (CREBs)
Value Chain: Across

Status: Enacted 10/03/2008. Effective 04/07/2009. Application due 08/04/2009
Incentive type: Federal Loan Program
Description:

- The Energy Improvement and Extension Act of 2008 (Div. A, Sec. 107) allocated $800 million for new Clean Renewable Energy Bonds (CREBs). In February 2009, the American Recovery and Reinvestment Act of 2009 (Div. B, Sec. 1111) allocated an additional $1.6 billion for new CREBs, for a total new CREB allocation of $2.4 billion
- May be used by certain entities -- primarily in the public sector -- to finance renewable energy projects.
- Qualifying technologies is generally the same as that used for the federal renewable energy production tax credit (PTC).
- CREBs may be issued by electric cooperatives, government entities (states, cities, counties, territories, Indian tribal governments or any political subdivision thereof), and by certain lenders.
- CREBs are issued -- theoretically -- with a 0% interest rate.
- Public power providers, governmental bodies, and electric cooperatives are each reserved an equal share (33.3%) of the CREBs allocation.
- The borrower pays back only the principal of the bond, and the bondholder receives federal tax credits in lieu of the traditional bond interest.

Qualifying Advanced Energy Project Investment Tax Credit
Description:

- Tax credit to encourage the development of a U.S.-based renewable energy manufacturing sector. In any taxable year, the investment tax credit is equal to 30% of the qualified investment required for an advanced energy project that establishes, re-equips or expands a manufacturing facility that produces any of the following:
  - Equipment and/or technologies used to produced energy from the sun, wind, geothermal or "other" renewable resources
  - Fuel cells, microturbines or energy-storage systems for use with electric or hybrid-electric motor vehicles
  - Equipment used to refine or blend renewable fuels
  - Equipment and/or technologies to produce energy-conservation technologies (including energy-conserving lighting technologies and smart grid technologies)
- Qualified investments generally include personal tangible property that is depreciable and required for the production process. Other tangible property may be considered a qualified investment only if it is an essential part of the facility, excluding buildings and structural components.
- The U.S. Treasury Department will issue certifications for qualified investments eligible for credits to qualifying advanced energy project sponsors. In total, $2.3 billion worth of credits may be allocated under the program. After certification is granted, the taxpayer has one year to provide additional evidence that the requirements of the certification have been met and three years to put the project in service.
- In determining which projects to certify, the U.S. Treasury Department must consider those which most likely will be commercially viable, provide the greatest domestic job creation, provide the greatest net reduction of air pollution and/or greenhouse gases, have great potential for technological innovation and commercial deployment, have the lowest levelized cost of generated (or stored) energy or the lowest levelized cost of reduction in energy consumption or greenhouse gas emissions, and have the shortest project time. The U.S. Treasury Department, in consultation with the U.S. Department of Energy, must

create additional specific program guidelines and the application process by August 16, 2009.
- Any taxpayer receiving this credit may not also receive business energy investment tax credit.

Renewable Energy Production Incentive (REPI)

Description:

- Established by the federal Energy Policy Act of 1992, the federal Renewable Energy Production Incentive (REPI) provides incentive payments for electricity generated and sold by new qualifying renewable energy facilities. Qualifying systems are eligible for annual incentive payments of 1.5¢ per kilowatt-hour in 1993 dollars (indexed for inflation) for the first 10-year period of their operation, subject to the availability of annual appropriations in each federal fiscal year of operation. REPI was designed to complement the federal renewable energy production tax credit (PTC), which is available only to businesses that pay federal corporate taxes.
- Qualifying systems must generate electricity using solar, wind, geothermal (with certain restrictions), biomass (excluding municipal solid waste), landfill gas, livestock methane, or ocean resources (including tidal, wave, current and thermal). The production payment applies only to the electricity sold to another entity. Eligible electric production facilities include not-for-profit electrical cooperatives, public utilities, state governments and political subdivisions thereof, commonwealths, territories and possessions of the United States, the District of Columbia, Indian tribal governments or political subdivisions thereof, and Native Corporations.
- Payments may be made only for electricity generated from an eligible facility first used before October 1, 2016. Appropriations have been authorized for fiscal years 2006 through fiscal year 2026. If there are insufficient appropriations to make full payments for electricity production from all qualified systems for a federal fiscal year, 60% of the appropriated funds for the fiscal year will be assigned to facilities that use solar, wind, ocean, geothermal or closed-loop biomass technologies; and 40% of the appropriated funds for the fiscal year will be assigned to other eligible projects. Funds will be awarded on a pro rata basis, if necessary.

Appendix C:

American Recovery and Reinvestment Act of 2009 (ARRA 2009)

Recovery Act - Demonstration of Integrated Biorefinery Operations
Funding: Estimated total of $787 million
Open Date: 05/06/2009
Close Date: 06/30/2009
Funding Organization: Biomass Program
Funding Number: DE-FOA-0000096
Description

- The intent of this Funding Opportunity Announcement (FOA) will be to select integrated biorefinery projects that have the necessary technical and economic performance data that validates their readiness for the next level of scale-up. In general, integrated biorefineries employ various combinations of feedstocks and conversion technologies to produce a variety of products, with the main focus on producing biofuels and bioproducts. Co- or by-products can include additional fuels, chemicals (or other materials), and heat and power. For the purpose of this FOA, the term integrated biorefinery is a facility that uses an acceptable feedstock (as defined in the FOA), to produce a biofuel or bioproduct as the primary product (as defined in the FOA) and may produce other products including additional fuels, chemicals (or other materials), and heat and power as co-products. These integrated biorefineries would produce, as their primary product, a liquid transportation fuel that supports, depending on topic area, meeting the advanced, renewable or advanced biofuels portion of the Energy Independence and Security Act of 2007 (EISA) Renewable Fuel Standards (RFS) or, depending on topic area, a bioproduct that substitutes for petroleum-based feedstocks and products.
- $480 Million Solicitation for Integrated Pilot- and Demonstration-Scale Biorefineries
  - Projects to validate integrated biorefinery technologies that produce advanced biofuels, bioproducts, and heat and power in an integrated system, thus enabling private financing of commercial-scale replications.
  - DOE anticipates making 10 to 20 awards for refineries at various scales and designs, all to be operational in the next three years. The DOE funding ceiling is $25 million for pilot-scale projects and $50 million for demonstration scale projects.
- $176.5 Million for Commercial-Scale Biorefinery Projects
  - $176.5 million will be used to increase the federal funding ceiling on two or more demonstration- or commercial-scale biorefinery projects that were selected and awarded within the last two years.
  - The goal of these efforts is to reduce the risk of the development and deployment of these first-of-a-kind operations. These funds are expected to expedite the construction phase of these projects and ultimately accelerate the timeline for start up and commissioning.
- $110 Million for Fundamental Research in Key Program Areas
  - Expand the resources available for sustainability research through the Office of Science Bioenergy Research Centers and establish a user-facility/small-scale integrated pilot plant ($25 million)

    - Create an advanced research consortium to develop technologies and facilitate subsequent demonstration of infrastructure-compatible biofuels through a competitive solicitation ($35 million)
    - Create an algal biofuels consortium to accelerate demonstration of algal biofuels through a competitive solicitation ($50 million).
    - This funding will help to develop cutting-edge conversion technologies, including generating more desirable catalysts, fuel-producing microbes, and feedstocks.
  - $20 Million for Ethanol Research
    - The Biomass Program is planning to use $20 million of the Recovery Act funding in a competitive solicitation to achieve the following:
    - Optimize flex-fuel vehicles operating on high octane E85 fuel (85% ethanol, 15% gasoline blend)
    - Evaluate the impact of higher ethanol blends in conventional vehicles
    - Upgrade existing refueling infrastructure to be compatible with fuels up to E85.

Recovery Act Funding for Expansion of Infrastructure for Ethanol Blends

Value Chain:
Status: Expected to announce summer of 2009
Incentive Type:
Description:

  - DOE Office of the Biomass Program to issue Funding Opportunity Announcements (FOA) related to intermediate ethanol blends.
  - This special advance notice is intended to provide potential applicants the opportunity to develop partnerships and begin the process of gathering data to prepare their applications. No applications or questions will be accepted at this time.
  - It will be open for 60 days.
  - The purpose of this prospective FOA is to increase the availability and use of potential ethanol blends up to 85 percent ethanol.
  - Two areas of interest have been identified to increase both the awareness and the use of ethanol blends for transportation.
  - Topic Area 1: Refueling Infrastructure for Ethanol Blends
    - DOE will be seeking cost-shared projects to expand the infrastructure at retail fueling locations to accommodate gasoline-ethanol blends. Expected projects may include modifications, upgrades or expansions of existing infrastructure at retail stations, or the installation of new equipment to accommodate blends of ethanol.
  - Topic Area 2: Education and Outreach for Ethanol Blends
    - DOE is seeking projects which will increase public awareness of the benefits, safety, and use requirements of ethanol blends. Projects are sought which will present accurate, unbiased, factual information on ethanol to targeted audiences. Proposed projects will be expected to include detailed plans with identified metrics for measuring the effectiveness of the education effort.
  - This Special Notice is intended to provide potential applicants advance notice of two upcoming Office of the Biomass Program Funding Opportunity Announcements. Prospective applicants should begin developing partnerships, formulating ideas, and gathering data in anticipation of the issuance of these FOAs. Please do not respond or submit questions in response to this Special Notice.

Recovery Act Funding of Development of Algal Biofuels and Advanced Fungible Biofuels

Value Chain:

Status: Expected to announce summer of 2009
Incentive Type:
Description:

- DOE Office of the Biomass Program to issue Funding Opportunity Announcements (FOA) related to algal and advanced biofuels.
- This special advance notice is intended to provide potential applicants the opportunity to develop partnerships and begin the process of gathering data to prepare their applications. No applications or questions will be accepted at this time.
- Open for 90 days
- The purpose of this prospective FOA is to address the interface between fundamental and applied research in these respective areas by utilizing consortiums with the necessary expertise to effectively and efficiently develop algal and advanced fungible biofuels technologies.
- DOE will not be seeking to construct new facilities but leverage existing capabilities and resources to the maximum extent possible.
- Expects to fund projects over multiple years.
- Two topic areas will be included in the FOA.
- Topic Area 1: Algal Biofuels Research and Development
  - The primary objective of this topic area is to develop cost effective algae based biofuels that are competitive with their petroleum counterparts. The research and development will focus on the following five key barriers as identified in DOE's National Algal Biofuels Roadmap:
    - Feedstock Supply: Strain development and cultivation;
    - Feedstock Logistics: Harvesting and extraction;
    - Conversion/Production: Accumulation of intermediate and synthesis of fuels and co-products;
    - Infrastructure: Fuel testing and standardization; and
    - Sustainable Practices: Life-cycle and economic analyses, siting, and resources management.
  - Consortium Details:
    - DOE seeks the formation of partnerships in this area because a suite of technologies is required for algal biofuels commercialization and because cost sharing can maximize the leveraging of public funds. Consortiums may include leading scientists from an appropriate mix of academia, government and/or non-government laboratories, user facilities (e.g. the Joint Genome Institute), non-profit organizations, and private industry. Additionally, the consortiums should seek to utilize 'best-in-class' technologies, and engage end users and other field experts outside the traditional disciplines of science and engineering.
    - At a minimum, the partnerships should have the expertise to address the following aspects:
      - Fundamental strain biology as it relates to cultivation;
      - Process engineering and modeling;
      - Algae processing (harvesting and intermediates extraction) and resource management; and
      - Production of value added co-products.
    - The ideal partnerships will have existing facilities that enable technology demonstration and analytical measurements of the integrated process at larger than bench-scale. The development effort will support three years with the intent of accelerating technology development.
- Topic Area 2: Advanced Fungible Biofuels

    - The primary objective of this topic area is to develop technology pathways leading to cost effective (compared to petroleum based fuels) conversion of biomass to advanced biofuels other than cellulosic ethanol with particular interest in bio-based hydrocarbon fuels, e.g. green gasoline and diesel. The technology pathways proposed can employ biological, thermochemical, and/or chemical conversion of cellulosic or non-food natural oil based feedstocks. This effort will focus on the development of cost competitive, infrastructure-compatible, advanced fungible biofuels, such as green gasoline and green diesel in an 'accelerated-to-market' timeframe. The areas of research could include the following:
        - Chemical conversion of cellulosic sugars;
        - Selective thermal processing technologies;
        - Utilization of petroleum refining technology for conversion of biocrude;
        - Catalyst specificity and lifetime;
        - Engineering designs;
        - Biomass processing catalyst development; and
        - Biomass-to-liquids (fuels) catalyst development.
    - The development effort will support three years with the intent of accelerating the technology development. The resulting advanced fungible biofuel should be of a high energy density and compatible with existing hydrocarbon fuel distribution and end use systems.
    - Consortium Details:
        - In order to efficiently and effectively develop and deploy advanced fungible biofuels, a consortium of partners is needed.
        - Consortiums may include leading scientists from academia, government and/or non-government labs, non-profit organizations, and private industry that can bring a multidisciplinary, collaborative approach to solving the scientific barriers associated with making cost effective biomass-derived hydrocarbon compatible fuels.
        - Because the research will lead to deployment of the technologies, it will be necessary to engage industry and other partners to cost share to maximize the leveraging of public funds.
        - The consortiums will need to involve an organizational teaming effort where the teams bring unique capabilities that provide a synergy to the overall development effort.
- This Special Notice is intended to provide potential applicants advance notice of two upcoming Office of the Biomass Program Funding Opportunity announcements. Prospective applicants should begin developing partnerships, formulating ideas, and gathering data in anticipation of the issuance of these FOAs. Please do not respond or submit questions in response to this Special Notice.

DIVISION A - Appropriations Provisions

- Rural Business Programs: $150 million for guaranteed business and industry loans and for rural business enterprise grants.
- National Science Foundation:
    - $2.5 billion for Research and Related Activities
    - $100 million for Education and Human Resources
    - $400 million for Major Research Equipment and Facilities Construction.
- Energy Efficiency and Renewable Energy: $16.8 billion in total, of which:

    - $3.2 billion for Energy Efficiency and Conservation Block Grants; of which $400 million shall be awarded on a competitive basis.
    - $3.1 billion for State Energy Program.
- Innovative Technology Loan Guarantee Program: $6 billion for loan guarantees for renewable technologies and transmission technologies.
- Small Business Loans: $636 million for the Business Loans Program of which $5 million is for microloans and $630 million to implement fee reductions and new loan guarantee authorities (up to 90%) for Section 7(a) loans. Loan guarantees may not be issued under this section after the date 12 months after the date of enactment of this Act.
- State and Tribal Assistance Grants:
    - Diesel Emissions Reduction: $300 million for Diesel Emissions Reduction Act competitive grants. The Agency may make awards for meritorious proposals submitted under competitions initiated within the last 18 months.
- Training and Employment Services: $3.95 billion for workforce programs. Of which $750 million for competitive grants for worker training in high growth and emerging industries. Of which $500 million is for projects to prepare workers for careers in energy efficiency and renewable energy.

DIVISION B - Tax, Unemployment, Health, State Fiscal Relief, and Other Provisions

- Long-term Extension and Modification of Renewable Energy Production Tax Credit: Extends the placed-in-service date closed-loop biomass; open-loop biomass; geothermal; small irrigation; hydropower; landfill gas; waste-to-energy; and marine renewable facilities for three years (through December 31, 2013).
- Temporary Election to Claim the Investment Tax Credit in Lieu of the Production Tax Credit: Facilities may elect to claim the investment tax credit instead of the production tax credit. Eligible facilities: Facilities that produce electricity from wind, closed-loop biomass, open-loop biomass, geothermal, small irrigation, hydropower, landfill gas, waste-to-energy, and marine renewable.
- Repeal Subsidized Energy Financing Limitation on the Investment Tax Credit: Repeals the subsidized energy financing limitation on the investment tax credit to allow businesses and individuals to qualify for the full amount of the investment tax credit even if such property is financed with industrial development bonds or through any other subsidized energy financing.
- Clean Renewable Energy Bonds ("CREBs"): Authorizes $1.6 billion of new clean renewable energy bonds to finance facilities that generate electricity from wind; closed-loop biomass; open-loop biomass; geothermal; small irrigation; hydropower; landfill gas; marine renewable; and trash combustion facilities.
- Qualified Energy Conservation Bonds: Authorizes $2.4 billion of qualified energy conservation bonds to finance State, municipal and tribal government programs and initiatives designed to reduce greenhouse gas emissions.
- Tax Credits for Alternative Refueling Property: For 2009 and 2010, the Act increases the 30% alternative refueling property credit for businesses (capped at $30,000) to 50% (capped at $50,000).
- Industrial Development Bonds (IDB): The proposal amends the definition of manufacturing facility eligible for tax exempt bond financing to any facility used in the manufacturing, creation, or production of tangible or intangible property.
- Advanced Energy Investment Credit: Establishes a new 30% investment tax credit for facilities engaged in the manufacture of advanced energy property through a competitive bidding process. The Secretary of may allocate up to $2.3 billion in credits. Advanced energy property includes technology for the production of renewable energy, energy

storage, energy conservation, efficient transmission and distribution of electricity, and carbon capture and sequestration.

- Treasury Department Energy Grants in Lieu of Tax Credits: Taxpayers may receive a grant from the Treasury Department in lieu of the production tax credit or investment tax credit. This grant will operate like the current-law investment tax credit. The Treasury Department will issue a grant in an amount equal to 30% of the cost of the renewable energy facility within sixty days of the facility being placed in service or, if later, within sixty days of receiving an application for such grant.

Appendix D

Proposed State Legislation Promoting Biofuels:

2009 Regular Session; House Bills Introduced[2]:

HB 211
- o Report Title: Public Land Leases; Renewable Energy
- o Relating to: Public Lands
- o Description:
  - – Allows DLNR to enter into leases of public lands for renewable energy projects and receive as all or partial consideration an equity participation in the renewable energy entity
- o Summary:
  - – Adding a new section: "§171- Renewable energy production; lease by negotiation; equity participation. (a) Anything to the contrary contained in this chapter notwithstanding, the board may lease public lands to a lessee for use in projects involving the generation of renewable energy: (1) Through negotiations; …"

HB 224
- o Report Title: Renewable energy siting; preferential process
- o Relating to: The Renewable Energy Facility Siting Process
- o Description:
  - – Creates a preferential and expediting permit plan application process for renewable energy producers of scale
- o Summary:
  - – The purpose of this Act is to create an expedited and preferential application process for renewable energy providers of scale, and to create a fixed deadline for permit approvals and an incentive to expedite them.
  - – Adding a new section: "§201N- A Preference in siting assistance. (a) Permit plan applications for renewable energy facilities that: (1) cost $750,000,000 or more; …"

HB 245
- o Report Title: Renewable Energy Facilities; Conservation and Agricultural Districts; Special Management Areas
- o Relating to: Renewable Energy Facilities
- o Description:
  - – Allows the development of renewable energy facilities on conservation and agricultural districts and special management areas; provided that the facilities comply with all applicable regulatory laws. (SD1)
- o Summary:
  - – Adding a new section: "§201N- Conservation and agricultural districts; special management areas; allowed use. (a) Notwithstanding any law to the contrary, the siting, development, construction, and operation of a renewable energy facility may be allowed within a conservation or agricultural district or special management area…"

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[2] Last updated: April 22, 2009

- This Act shall take effect on July 1, 2009.

HB 246

- Report Title: Renewable Energy; Biodiesel Feedstock; Appropriations
- Relating to: Biodiesel Feedstock
- Description:
  - Appropriation for Hawai‘i county economic opportunity council for operation of laboratory and research farm expansion for the Hawai‘i biotech tissue culture center to mass produce biodiesel feedstock
- Summary:
  - There is appropriated out of the general revenues of the State of Hawai‘i the sum of $3,000,000 for fiscal year 2009-2010, or so much thereof as may be necessary, as a grant and subsidy under chapter 42F, HRS, to the Hawai‘i county economic opportunity council, as follows:
    1. $1,800,000 for operational expenses for the Hawai‘i biotech tissue culture center to the end of the first cycle of mass propagation and point of sale to mass produce non-genetically-modified organism, superior, high yielding jatropha curas biodiesel feedstock; and
    2. $1,200,000 to expand the existing 8,500 square foot laboratory to 25,000 square feet to significantly raise production from an estimated 2.2 plantlets per year to 20,000,000 plantlets per year over a three year period.
  - This Act shall take effect on July 1, 2009.

HB 277

- Report Title: alternative Energy Utilities in Schools; Grants; Appropriation
- Relating to: Alternative Energy
- Description:
  - Appropriates funds to make grants available to public schools for the purchase of alternative energy utilities for public school campuses in the state.
- Summary:
  - There is appropriated out of the general revenues of the State of Hawai‘i the sum of $_____ or so much thereof as may be necessary for fiscal year 2009-2010 to make available grants to public schools for the purchase of alternative energy utilities for public school campuses in the state.
  - This Act shall take effect on July 1, 2009.

HB 279

- Report Title: Renewable Energy Branch; Appropriation
- Relating to: Energy
- Description:
  - Establishes the renewable energy branch in the department of business, economic development, and tourism to coordinate and promote renewable energy initiatives. Strengthens existing renewable energy and planning provisions. Provides for staffing, and, subject to federal funding, project managers to oversee energy projects funded by federal grants. Appropriates funds. (SD1)
- Summary:
  - The purpose of this Act is to support the renewable energy industry in Hawai‘i by:

1. **1.** Establishing a renewable energy branch in the department of business, economic development, and tourism to coordinate and promote renewable energy initiatives;
2. **2.** Strengthening laws supporting energy diversification, long-term provision of dependable energy services, and use of diverse energy technologies;
3. **3.** Providing adequate resources for the support of the renewable energy industry, and for comprehensive energy planning, in the department of business, economic development, and tourism.

- Adding a new section: "§201- Renewable energy branch; establishment. (a) There is established a renewable energy branch within the department. (b) Branch functions shall include but not be limited to: (1) Renewable energy resource assessments, technical analyses, and resource development functions, including design, management, and completion of systematic analysis of existing and proposed energy resource programs; …
- Amended to read as follows: "§196-4 Powers and duties … (12) Formulate a systematic process, including the development of requirements, to identify geographic areas that are rich with renewable energy resource potential that can be developed in a cost-effective and environmentally benign manner and designate these areas as renewable energy zones; (13) Develop and recommend incentives, plans, and programs to encourage the development of renewable energy resource projects within the renewable energy zones; (14) Assist public and private agencies in identifying utility transmission projects or infrastructure required to accommodate and facilitate the development of renewable energy resources; (15) Assist public and private agencies, in coordination with the department of budget and finance, in accessing the use of special purpose revenue bonds to finance the engineering, design, and construction of transmission projects and infrastructure that are deemed critical to the development of renewable energy resources; (16) Develop the criteria or requirements for identifying and qualifying specific transmission projects and infrastructure that are critical to the development of renewable energy resources, including providing assistance in accessing the use of special purpose revenue bonds to finance the projects or infrastructure; …"
- This Act shall take effect on July 1, 2009.

HB 422

- Report Title: Renewable Energy Technologies Income Tax Credit
- Relating to: Taxation
- Description:
  - Amends the renewable energy technologies income tax credit to make the credit refundable for certain taxpayers, prohibit special allocations of the credit by pass-through entities, and prevents passive activity losses from including a depreciation deduction
- Summary:
  - Amended by amending subsection (d) to read as follows: "(d) Section 704 of the Internal Revenue Code (with respect to a partner's distributive share) shall be operative for purposes of this chapter; except that section 704(b)(2) shall not apply to: … (5) Allocations of the renewable energy technologies income tax credit allowed under section 235-12.5."
  - This Act, upon its approval, shall apply to taxable years beginning after December 31, 2008.

HB 487

- Report Title: Hawai‘i Clean Energy Initiative (HCEI); Electric Generation and Delivery

- Relating to: Hawai‘i Clean Energy Initiative - Electric Generation and Delivery
- Description:
  - Establishes electric generation and delivery initiatives necessary for and contributing to the transition of Hawai‘i’s energy sector to 70% non-petroleum energy sources by 2030
- Summary:
  - The purpose of this Act is to provide a first step in aligning Hawai‘i’s energy policy laws with the State’s energy goals. For Hawai‘i to realize energy independence and economic stability, the transformation of its energy system must encompass changes to: (1) Hawai‘i’s policy or regulatory framework; (2) System-level technology development and integration; (3) Financing or capital investment; and (4) Institutional system planning.

HB 488

- Report Title: Hawai‘i Clean Energy Initiative (HCEI) - Energy Efficiency
- Relating to: Hawai‘i Clean Energy Initiative - Energy Efficiency
- Description:
  - Establishes energy efficiency initiatives necessary for and contributing to the transition of Hawai‘i’s energy sector to 70% non-petroleum energy sources by 2030
- Summary:
  - Adding a new section to HRS: "§A-A Energy efficiency portfolio standard. The State shall set an energy efficiency portfolio standard with the goal of off-setting forecasted load growth in the electricity sector from 2009 to 2030. The statewide target shall be 4300 gigawatt-hours of electricity savings by 2030. …"
  - Adding a new section to HRS: "§A-A Energy efficiency studies and planning. The public benefits fee administrator shall appropriate $500,000 from the public utilities commission special fund to conduct energy efficiency assessments to identify current energy use patterns in this State and areas of greatest potential for energy efficiency savings. The assessments shall include end use research regarding Hawai‘i’s homes, businesses, and other utility customers. The energy potential assessments shall identify and recommend energy efficiency programs to target. The assessments shall be forwarded to the legislature, the public utilities commission, the energy resources coordinator, and the utilities. The assessments shall be completed by December 31, 2010. …"
  - Adding a new section to HRS: "§A-A On-bill financing for energy efficiency and renewable energy. (a) By December 31, 2009, the public utilities commission shall institute a rule governing the on-bill financing program, to be administered by the public benefits fee administrator, and shall adopt rules pursuant to chapter 91 to effect the program’s goals of changing out inefficient refrigerators, installing solar water heaters, and installing photovoltaic systems."
  - Adding a new section to HRS: "§A-A Consumer Information. The public benefits fee administrator shall develop programs and information to educate financial institutions, realtors, mortgage brokers, and consumers on the economics of energy efficient properties, including savings over the life-cycle of such properties."
  - Adding a new section: "§235-A Tax credit for a net zero energy building. (a) There shall be allowed to each taxpayer who owns a net zero energy building fixed to real property located in the state an income tax credit which shall be deductible from the taxpayer's net income tax liability, if any, imposed by this chapter only for the first taxable year in which the building meets the definition of net zero energy building. (b) The amount of the credit shall be: (1) For a building that is up to 1000 square feet, the tax credit shall be $9.00 per square foot; (2) For a building that is more than 1000 square feet but less than 4,000 square feet, the tax credit shall be $6.00 per square foot; (3) For a building that is more than 4,000 square feet, the tax credit shall be $3.00 per square foot for a maximum

credit of $50,000. … (g) This section shall apply to taxable years beginning after December 31, 2009, and shall not apply to taxable years beginning after December 31, 2019. …"

HB 489

- Report Title: Hawai‘i Clean Energy Initiative In Transportation Energy
- Relating to: Hawai‘i Clean Energy Initiative In Transportation Energy
- Description:
  - Establishes transportation energy initiatives necessary for the transition of Hawai‘i's transportation energy sector from almost completely dependent on petroleum towards the use of efficient, stable, secure, renewable, non-petroleum energy sources by 2030
- Summary:
  - Adding a new section: "§235-A Electric vehicle charging; income tax credit. (a) There shall be allowed to each taxpayer subject to the taxes imposed by this chapter a tax credit for code compliant electric vehicle charging infrastructure installed and placed in service in the State that shall be deductible from the taxpayer's net income tax liability. The tax credit may be claimed for the taxable year in which the code compliant electric vehicle charging system is placed in service in the State. (b) The amount of the credit shall be seventy per cent of the cost of the electric vehicle charging system or $500 per electric vehicle charge point of the system, whichever is less. … (i) This tax credit applies to electric vehicle charging systems placed in service after July 1, 2009 and before January 1, 2016."
  - Adding a new section: "§235-B Alternative fuel refueling; income tax credit. (a) There shall be allowed to each taxpayer subject to the taxes imposed by this chapter a tax credit for any alternative fuel refueling infrastructure installed and placed in service in the State that shall be deductible from the taxpayer's net income tax liability. The tax credit may be claimed for the taxable year in which the alternative fuel refueling infrastructure is placed in service. (b) The amount of the credit shall be thirty per cent of the cost of the alternative fuel refueling infrastructure or $10,000, whichever is less. … (j) This tax credit applies to alternative fuel refueling infrastructure placed in service after July 1, 2009 and before January 1, 2016."
  - Adding a new section to HRS: "§A-A Designation of parking spaces for electric vehicles. … Such spaces shall be designated, clearly marked, and enforced by December 31, 2010"
  - Adding a new section: "§291-A Parking spaces reserved for electric vehicles; penalties. (a) Beginning January 1, 2011, any person who parks a non-electric vehicle in a space designated and marked as reserved for electric vehicles shall receive a warning. (b) Beginning July 1, 2011,… shall be fined not less than $50 nor more than $100 and pay any costs incurred by the court related to assessing the fine. … "
  - Adding a new section to HRS: "§A-A Requirement for electric vehicle charging capability. Electric vehicle charging capability shall be required on all new single family housing units constructed after January 1, 2015…."
  - Adding a new section: "§237-A Exemption of sale or lease of certain vehicles. (a) Beginning January 1, 2010, and expiring December 31, 2015, there shall be exempted from the measure of the taxes imposed by this chapter all of the gross proceeds arising from the sale or lease of new or used light duty motor vehicles classified as alternative fuel vehicles and fuel economy leader vehicles. …"
  - Adding a new section to HRS: "§A-A Transportation energy transformation grant fund. (a) There is established a special fund to be designated as the transportation energy transformation grant fund.… (e) Subject to the availability of funds and the standards in this chapter, grants for approved electric vehicles shall be provided to purchasers of

electric vehicles intended to be integrated intelligently with the electrical grid and licensed for use on Hawai‘i's highways, as follows: (1) Beginning January 1, 2010, and expiring December 31, 2010: up to $4000 per vehicle; limited to the first 500 vehicles. (2) Beginning January 1, 2011, and expiring December 31, 2011: up to $3500 per vehicle; limited to the first 1000 vehicles. (3) Beginning January 1, 2012, and expiring December 31, 2013: up to $2500 per vehicle; limited to the first 2000 vehicles per year. (4) Beginning January 1, 2014, and expiring December 31, 2015: up to $2000 per vehicle; limited to the first 2500 vehicles per year. (5) Beginning January 1, 2016, and expiring December 31, 2021: up to $500 per vehicle; limited to the first 10000 vehicles per year. …"

- Amended to read as follows: [Ethanol is substituted with Biofuel] "§235-110.3 Biofuel facility tax credit. (a) … (b) As used in this section: "Biofuel" means ethanol, biodiesel, diesel, jet fuel, or other liquid fuel meeting…"
- Amended to read as follows: "§251-2 Rental motor vehicle and tour vehicle surcharge tax. … c) For the period of January 1, 2010, through December 31, 2015, up to two hundred alternative fueled light duty motor vehicles per rental car fleet shall be exempt from the rental motor vehicle surcharge tax…."
- Amended to read as follows: "§103D-1012 Biofuel preference. … (g) Beginning January 1, 2012, all state-owned diesel vehicles and equipment are required to be fueled with blends of biomass-based diesel, subject to the availability of the fuel, and so long as the price is no greater than twenty per cent more per gallon than the price of conventional diesel"
- Adding a new section: "§196-A Alternative fuel vehicle requirement for private fleets. (a) Beginning January 1, 2012, each fleet operator controlling more than fifty light duty motor vehicles in the state shall, when replacing its light duty motor vehicles or expanding its fleet, acquire increasing percentages of vehicles capable of operating on non-petroleum energy sources, including electric vehicles, flexible fuel vehicles, or other alternative fuel vehicles. (b) At least four per cent of all new light duty motor vehicles acquired by a fleet operator in the state during calendar year 2012 shall be alternative fuel vehicles. This percentage shall increase by four per cent per year, reaching seventy-six per cent in the calendar year 2030…"
- Adding a new section: "§196-A Alternative fuel light duty motor vehicle sales requirement. (a) Beginning January 1, 2015, each motor vehicle dealer with sales of more than fifty light duty motor vehicles per year in Hawai‘i shall increase the percentages of new and used light duty motor vehicle sales represented by vehicles capable of operating on non-petroleum energy sources, including electric vehicles, flexible fuel vehicles, or other alternative fuel vehicles, as follows: (1) Ten per cent of its annual light duty motor vehicle sales for each calendar year between January 1, 2015 and December 31, 2019; (2) Twenty per cent of its annual light duty motor vehicle sales for each calendar year between January 1, 2020 and December 31, 2024; (3) Fifty per cent of its annual light duty motor vehicle sales for each calendar year between January 1, 2025 and December 31, 2029; and (4) Seventy-five per cent of its annual light duty motor vehicle sales for each calendar year after January 1, 2030…"

HB 490

- Report Title: Energy
- Relating to: Tax incentives for renewable energy
- Description:
  - Increases incentives for renewable energy; repeals prohibition on taking solar tax credit for developers.

- Summary:
  - Section 235-12.5 HRS, is amended: "Renewable energy technologies; income tax credit. … This credit shall be available for systems installed and placed in service in the State after June 30, 2003. …"
  - This bill increases the tax credit from 35 percent to 50 percent (of the actual cost or a fixed value based on the property type, whichever is less) for solar thermal energy systems and photovoltaic energy systems and from 20 percent to 35 percent (of the actual cost or a fixed value based on the property type, whichever is less) for wind-powered energy systems. It also introduces a new tax credit, equal to 50 percent of the actual cost or $750,000, whichever is less, for the wave energy systems in commercial properties.
  - This Act shall take effect upon its approval and shall apply to taxable years beginning after December 31, 2008.

HB 546

- Report Title: Net Energy Metering; Renewable Energy; Electricity; Public Utilities Commission
- Relating to: renewable energy
- Description:
  - Removes the capacity limit for net energy metering and increases eligible customer-generator capacity to one megawatt. Permits existing net metered customers to remain with net metering program once alternative credits or compensation mechanisms are created. Allows an eligible customer-generator to generate up to one hundred kilowatts before the eligible customer-generator must gain public utilities commission approval of safety and performance standards.
- Summary:
  - Amending section 269-101, to read: "… 'Eligible customer-generator' means a metered residential or commercial customer, including a government entity, of an electric utility who owns and operates, leases, or purchases electricity from a solar, wind turbine, biomass, or hydroelectric energy generating facility, or a hybrid system consisting of two or more of these facilities" …

HB 589 (Act 173; Enacted in 07/07/2009)

- Report Title: Renewable Energy Project; Subdivisions
- Relating to: renewable energy facilities
- Description:
  - Exempts leases and easements for renewable energy projects from subdivision requirements; defines "subdivision requirements"; requires agencies to accept instruments for recording and filing. Sunsets 6/30/2013. (SD2)
- Summary:
  - Adding a new section: "§201N- Exemption from subdivision requirements. (a)… (1) Lands within the agricultural or conservation state land use district may be leased; and (2) Easements may be created and granted over lands within the agricultural or conservation state land use district, for the purpose of developing and financing a renewable energy project or access to a renewable energy project that is a permitted use in the district, even if the leased land or easement area has not been subdivided as a separate subdivided lot or easement… (b)… (4) Mortgages and other security interests may be granted with respect to any lease or easement created pursuant to this section, and the holders of such mortgages or other security interests may foreclose upon the lease or easement covered and otherwise enforce the terms of the mortgage and security documents, subject to

compliance with applicable laws other than subdivision requirements… (d) The exemption from subdivision requirements authorized by this section shall only apply to leases and easements that meet the following requirements and shall be subject to the following limitations:… (2) The lease shall have an initial term of at least twenty years;…"
- This Act shall take effect upon its approval; provided that section 4 of this Act shall take effect on July 1, 2013; provided further that sections 2 and 3 of this Act shall be repealed on June 30, 2013.

HB 591 (Act 185; Enacted in 07/15/2009)

- Report Title: Renewable Energy; Agricultural Activities; Preferential Rates
- Relating to: Public Utilities
- Description:
  - Authorizes preferential rates for the purchase of renewable energy produced in conjunction with agricultural activities. (SD2)
- Summary:
  - Adding a new section: "§269 Preferential renewable energy rates; agricultural activities. It is the policy of the State to promote the long-term viability of agriculture by establishing mechanisms that provide for preferential rates for the purchase of renewable energy produced in conjunction with agricultural activities. The public utilities commission shall have the authority to establish preferential rates for the purchase of renewable energy produced in conjunction with agricultural activities…"

HB 619

- Report Title: Public Utilities; Renewable Energy Zones
- Relating to: Public Utilities
- Description:
  - Directs the public utilities commission to prepare a study on the creation of renewable energy zones and report its findings to the legislature.
- Summary:
  - The public utilities commission shall prepare a study on the feasibility of establishing renewable energy zones that are free from regulation by the public utilities commission.
  - "Renewable energy zone" means a designated area or facility in which energy may be generated from renewable resources in privately-owned generation facilities and distributed to users by way of transmission infrastructure that is separate from power transmission infrastructure owned or operated by a public utility.
  - The public utilities commission shall include procedures and qualifications for designating an area or a facility as a renewable energy zone, and it shall make recommendations for areas and facilities that should be designated as renewable energy zones.
  - The public utilities commission shall report its findings and recommendations to the legislature no later than twenty days prior to the convening of the regular session of 2010.

HB 738

- Report Title: Tax exemptions; Direct generation of electricity using fuel cells, hydrogen, biomass, wind, the sun, the ocean, geothermal energy, waste heat, hydroelectric power, or landfill gas
- Relating to: Tax exemptions
- Description:

- Exempts from the general excise tax and use tax all equipment used directly in the generation of electricity using fuel cells, hydrogen, biomass, wind, the sun, the ocean, geothermal energy, waste heat, hydroelectric power, or landfill gas.
- Summary:
  - Adding a new section: "§237- Exemption for certain machinery and equipment used directly in the generation of electricity. (a) The tax imposed under this chapter shall not apply to sales of machinery and equipment used directly in the generation of electricity using fuel cells, hydrogen, biomass, wind, the sun, the ocean, geothermal energy, waste heat, hydroelectric power, or landfill gas as the principal source of power, or to sales of or charges made for labor and services rendered with respect to the installation of such machinery and equipment; provided that the purchaser develops with such machinery, equipment, and labor a facility capable of generating not less than two hundred watts per day of electricity and provides the seller with an exemption certificate in a form and manner prescribed by the department…"
  - Adding a new section: "§238- Exemption for certain machinery and equipment used directly in the generation of electricity. …" (Same as chapter 237).
  - This Act shall take effect on January 1, 2010; provided that it shall be repealed on December 31, 2014.

HB 816

- Report Title: Renewable Energy
- Relating to: Energy
- Description:
  - Prohibits the permitting after 12/31/12 of any new electrical generation facility that uses fossil fuels to generate electricity. Requires all electrical generation facilities to produce electricity from renewable energy by 1/1/25.
- Summary:
  - Adding a new section: "§196- Electrical generation facilities; fossil fuels; prohibition. (a) After December 31, 2012, no permit shall be issued for the construction or operation of an electrical generation facility that produces electrical energy primarily from the combustion of any type of fossil fuel. (b) No later than January 1, 2025, all electrical generation facilities in the State shall generate electrical energy primarily from renewable energy."
  - Amended to read as follows: "§269-7.5 Certificates of public convenience and necessity… (f) After December 31, 2012, no certificate shall be issued to any applicant for the operation of a new electrical generation facility that produces electrical energy primarily from the combustion of any type of fossil fuel. (g) After January 1, 2025, the commission shall revoke any certificate that was previously issued to a public utility for the operation of an electrical generation facility that produces electrical energy primarily from the combustion of any type of fossil fuel if that facility has not been converted or retrofitted to generate electrical energy primarily from renewable energy."

HB 820

- Report Title: Department of Planning and Sustainability; Establishment
- Relating to: Sustainability
- Description:
  - Creates a department of planning and sustainability by combining the office of planning, commission on water resource management, energy resources coordinator responsibilities, agribusiness development corporation, land use

commission, office of environmental quality control, and Hawaii community development authority.

- Summary:
  - Chapter 26, HRS, is amended by adding a new section: "§26-   Department of planning and sustainability. (a) The department of planning and sustainability shall be headed by a single executive to be known as the director of planning and sustainability. The department shall:
    (1) Undertake statewide long-range planning and sustainability activities;
    (2) Undertake energy development and management;
    (3) Provide sustainability research and analysis; and
    (4) Encourage, develop, and implement plans for Hawaii's agriculture and food supply, land use, community development and housing, economy, environment, energy, natural resources, lifestyle, and culture through programs established by law.
    (b) The following are placed in the department of planning and sustainability for administrative purposes as defined by section 26-35: the agribusiness development corporation, commission on water resource management, duties and responsibilities of the energy resources coordinator, Hawaii community development authority, land use commission, office of environmental quality control, office of planning, and any other boards and commissions as provided by law."
  - This Act shall take effect on July 1, 2011; provided that section 12 shall take effect on July 1, 2009.

HB 1052

- Report Title: Hawaii Clean Energy Initiative; Electric Generation and Delivery.
- Relating to: Hawaii's Clean Energy Initiative in Electric Generation and Delivery
- Description:
  - Establishes electric generation and delivery initiatives necessary for and contributing to the transition of Hawaii's energy sector to 70 percent non-petroleum energy sources by 2030.
- Summary:
  RENEWABLE PORTFOLIO STANDARDS
  - Section 269-92 HRS, is amended by amending subsections (a) and (b) to read as follow: "a) Each electric utility company that sells electricity for consumption in the State shall establish a renewable portfolio standard of:
    (1) Ten per cent of its net electricity sales by December 31, 2010;
    (2) Fifteen per cent of its net electricity sales by December 31, 2015;
    (3) Twenty-five per cent of its net electricity sales by December 31, 2020; and
    (4) Forty per cent of its net electricity sales by December 31, 2030.
    b) … (4) The public utilities commission shall not approve applications to build new additional fossil-based electric generation units with rated capacity greater than two megawatts."

  ENERGY RESOURCES COORDINATOR
  - Section 196-4 HRS, is amended to read as follows: "Powers and duties. Subject to the approval of the governor, the coordinator shall: …
    (12) Formulate a systematic process including the development of requirements, to identify geographic areas that are rich with renewable energy resource potential which can be developed in a cost-effective and environmentally benign manner, and designate such areas as renewable energy zones;

(13) Develop and recommend incentives plans and programs to encourage the development of renewable energy resource projects within the renewable energy zones;
(14) Assist public and private agencies in identifying the utility transmission projects or infrastructure that are required to accommodate and facilitate the development of renewable energy resources;
(15) Assist public and private agencies in coordination with the department of budget and finance in accessing use of special purpose revenue bonds to finance the engineering, design, and construction of transmission projects and infrastructure that are deemed critical to the development of renewable energy resources;
(16) Develop the criteria or requirements for identifying and qualifying specific transmission projects or infrastructure that are critical to the development of renewable energy resources, and which the energy resources coordinator will assist in accessing the use of special purpose revenue bonds to finance such projects or infrastructure; …"

RENEWABLE ENERGY PERMITTING

- Section 201N-1 HRS, is amended by amending the definition of "renewable energy facility" to read as follows: ""Renewable energy facility" or "facility" means a new facility located in the State with the capacity to produce from renewable energy at least two hundred megawatts of electricity; provided that biofuel production facilities of at least one million gallons per year and electricity production facilities with capacities between five and two hundred megawatts may apply to the coordinator for designation as renewable energy facilities, with such designation to be at the sole discretion of the coordinator. …"

HB 1053

- Report Title: Hawaii Clean Energy Initiative; Energy Efficiency.
- Relating to: Hawaii's Clean Energy Initiative in Energy Efficiency
- Description:
  - Establishes energy efficiency initiatives necessary for and contributing to the transition of Hawaii's energy sector to 70 percent non-petroleum energy sources by 2030.
- Summary:

  ENERGY EFFICIENCY
  - The HRS is amended by adding a new section: "§ Energy efficiency portfolio standard. The State shall set an energy efficiency portfolio standard with the goal of off-setting forecasted load growth in the electricity sector from 2009 to 2030. The statewide target shall be 4,300 gigawatt-hours of electricity savings by 2030. The interim targets, and any island by island targets, shall be set by the public utilities commission. The public utilities commission shall identify the parties who are responsible for each element of the standard and set incentives and penalties based on performance by each entity. Renewable substitution, including but not limited to solar water heating and sea water air conditioning, shall count toward this standard."

HB 1054

- Report Title: Hawaii Clean Energy Initiative; Transportation.
- Relating to: Hawaii's Clean Energy Initiative in Transportation Energy
- Description:
  - Establishes transportation energy initiatives necessary for the transition of Hawaii′s transportation energy sector from almost completely dependent on

petroleum towards the use of efficient, stable, secure, renewable, non-petroleum energy sources by 2030.

- o Summary:

  TRANSPORTATION ENERGY INFRASTRUCTURE
  - – Chapter 235 HRS, is amended by adding a new section: "§235-__ Electric vehicle charging; income tax credit. … (b) The amount of the credit shall be 70 per cent of the cost of the electric vehicle charging system or $500 per electric vehicle charge point of the system, whichever is less. …"
  - – Chapter 235 HRS, is amended by adding a new section: "§235-__ Alternative fuel refueling; income tax credit. … b) The amount of the credit shall be 30 per cent of the cost of the alternative fuel refueling infrastructure or $10,000, whichever is less. …"

  TRANSPORTATION ENERGY INCENTIVES
  - – The HRS is amended by adding a new section: "§___-__ Transportation energy transformation grant fund. (a) There is established a special fund to be designated as the transportation energy transformation grant fund. …"
  - – Section 235-110.3 HRS, is amended to read as follows: "§235-110.3 Biofuel facility tax credit.

    (a) … For each qualified biofuel production facility, the annual dollar amount of the biofuel facility tax credit during the 8-year period shall be equal to 30 percent of its nameplate capacity if the nameplate capacity is greater than 500,000 gallons. A taxpayer may claim this credit for the first 15 million gallons of capacity of each qualifying biofuel facility; provided that….

    (b) … "Biofuel" means ethanol, biodiesel, diesel, jet fuel, or other liquid fuel meeting the relevant fuel specifications of ASTM International (formerly ASTM, the American Society for Testing and Materials). …"

  TRANSPORTATION ENERGY REQUIREMENTS
  - – Section 103D-1012 HRS, is amended to read as follows: "Biofuel preference. (a) … Contracts for the purchase of diesel fuel or boiler fuel shall be awarded to the lowest responsible and responsive bidders, with preference given to bids for biofuels or blends of biofuel and petroleum fuel. (b) When purchasing fuel for use in diesel engines, the preference shall be 20 per cent per gallon of 100 per cent biomass-based diesel. For blends containing both biomass-based diesel and petroleum-based diesel, the preference shall be applied only to the biomass-based diesel portion of the blend. (c) When purchasing fuel for use in boilers, the preference shall be 20 per cent per gallon of 100 per cent biofuel. For blends containing both biofuel and petroleum-based boiler fuel, the preference shall be applied only to the biofuel portion of the blend. … (g) Beginning January 1, 2012, all state-owned diesel vehicles and equipment are required to be fueled with blends of biomass-based diesel, subject to the availability of the fuel, and so long as the price is no greater than twenty per cent more per gallon than the price of conventional diesel."

HB 1197

- o Report Title: Alcohol Fuels; Renewable Fuel Standard
- o Relating to: ALCOHOL FUELS
- o Description:
  - – Improve Hawaiʻi's economic and energy security position by establishing a preference for locally produced alcohol fuels.
- o Summary:

- Amended to read as follows: "§237-27.1 Exemption of sale of alcohol fuels. … The exemption shall apply to alcohol fuels utilized to meet the State's renewable fuel standard and shall be administered based on the local alcohol fuel production capacity for that tax year, as determined by the department of business, economic development, and tourism"
- Act 209 Session Laws of Hawaiʻi, 2007 is amended by amending section 6 to read as follows: "SECTION 6. This Act shall take effect on July 1, 2007; provided that section 2 of this Act shall be repealed on June 30, 2015" (It was 2009 before).

HB 1271

- Report Title: Food and Energy Security
- Relating to: Government
- Description:
  - Makes various amendments, establishes various initiatives, and appropriates funds to promote economic development for local food and energy businesses, ensure Hawaii is energy and food self-sufficient and sustainable to the maximum extent feasible, and help Hawaii's natural resources and humankind adapt and be resilient to the inevitable challenges brought on by climate change. (HB1271 CD1)
- Summary:
  - The purpose of this Act is to:
    - (1) Promote economic development for local food and energy businesses by establishing necessary funding, guidance, and infrastructure;
    - (2) Ensure Hawaii is energy and food self-sufficient and sustainable to the maximum extent feasible; and
    - (3) Plan for and implement measures to help Hawaii's natural resources and humankind adapt and be resilient to the inevitable challenges brought on by climate change caused by carbon dioxide and other greenhouse gas emissions from burning fossil fuels.
  - Section 201-12.8 HRS, is amended: "Energy security special fund; uses. (a) There is created within the state treasury an energy security special fund, which shall consist of:
    - (1) The portion of the environmental response, energy, and food security tax specified under section 243-3.5; (2) … (b) … moneys from the fund may be used for no other purposes except for …:
    - (1) To support the Hawaii clean energy initiative program, including its energy division and projects that ensure dependable, efficient, and economical energy, promote energy self-sufficiency, and provide greater energy security for the State;
    - (2) To fund the renewable energy facilitator pursuant to section 201-12.5 and any other positions necessary for the purposes of paragraph (1) as determined by the legislature; and
    - (3) To fund, to the extent possible, the greenhouse gas emissions reduction task force, climate change task force, grants-in-aid to the economic development boards of each county, and grants-in-aid to economic development agencies of each county to meet the stated objectives of the Hawaii clean energy initiative program."
  - Section 243-3.5 HRS is amended by amending its title and subsection (a) to read:
    "Environmental response, energy, and food security tax; uses. (a) … there is hereby imposed a state environmental response, energy, and food security tax of $1.05 on each barrel or fractional part of a barrel of petroleum product sold by a distributor to any retail dealer or end user, other than a refiner, of petroleum product; provided that:
    - (1) 5 cents of the tax on each barrel shall be deposited into the environmental response revolving fund …;

(2) 55 cents of the tax on each barrel shall be deposited into the energy security special fund …;
(3) 10 cents of the tax on each barrel shall be deposited into the energy systems development special fund …; and
(4) 35 cents of the tax on each barrel shall be deposited into the agricultural development and food security special fund ….

The tax imposed by this subsection shall be paid by the distributor of the petroleum product."

– Chapter 141 HRS is amended by adding a new section: "§141- Agricultural development and food security special fund; …

(c) … moneys in the special fund may be expended for the following purposes:
(1) The awarding of grants to farmers for agricultural production or processing activity;
(2) The acquisition of real property for agricultural production or processing activity;
(3) The improvement of real property, irrigation systems, and transportation networks necessary to promote agricultural production or processing activity;
(4) The purchase of equipment necessary for agricultural production or processing activity;
(5) The conduct of research on and testing of agricultural products and markets;
(6) The promotion and marketing of agricultural products grown or raised in the state;
(7) Any other activity intended to increase agricultural production or processing that may lead to reduced importation of food, fodder, or feed from outside the state."

HB 1277

- Report Title: DLNR; Renewable Energy Producer; Public Notice; Public Lands; Lease
- Relating to: Renewable Energy Producers
- Description:
  - Requires that the board of land and natural resources conduct public hearings prior to awarding a lease of public land to a renewable energy producer.
- Summary:
  - Section 171-95 HRS is amended to read as follows: "Disposition to governments, governmental agencies, public utilities, and renewable energy producers. (a) Notwithstanding any limitations to the contrary, except as provided in subsection (d) with regard to leases for renewable energy producers, the board of land and natural resources without public auction, may:

(1) Sell public lands at a price and on other terms and conditions…;
(2) Lease to the governments, agencies, public utilities, and renewable energy producers public lands for terms up to, but not in excess of, 65 years at rental…;
(3) Grant licenses and easements…;
(4) Exchange public lands with the governments and agencies; (5, 6) … (b) …

(c) For the purposes of this section, "renewable energy producer" means:
(1) Any producer of electrical or thermal energy produced by wind, solar energy, hydropower, landfill gas, waste-to-energy, ocean thermal energy conversion, cold seawater, wave energy, biomass, including municipal solid waste, biofuels or fuels derived from organic sources, hydrogen fuels derived primarily from renewable energy, or fuel cells where the fuel is derived primarily from renewable sources… or
(2) Any grower or producer of plant or animal materials used primarily for the production of biofuels or other fuels; provided that….

(d) The board may lease or renew a lease of public lands to renewable energy producers under subsection (a)(2) only pursuant to a public process that includes public notice under section 1-28.5 providing other interested renewable energy producers opportunity to participate in the process; provided that the renewable energy producer shall be required to submit as part of the proposal for the board's evaluation, as assisted by the DBEDT, the following: … (some other documents)"

HB 1305

- Report Title: Taxation
- Relating to: Taxation
- Description:
  - Establishes a non-refundable tax credit for the manufacture of renewable energy technology devices.
- Summary:
  - Adding a new section: "§235-A Renewable energy technology manufacturer; income tax credit. (a)… The amount of the credit shall be _____ per cent of qualified production costs…"
  - This Act shall take effect upon its approval and shall apply to taxable years beginning after December 31, 2008.

HB 1368

- Report Title: Renewable Energy; Biomass; Appropriation
- Relating to: Renewable Energy
- Description:
  - Makes an appropriation for the relocation and establishment of a pilot plant for the conversion of biomass into liquid transportation fuel and electricity.
- Summary:
  - The Hawaiʻi Economic Opportunity Council requires seed funding in the amount of $580,000 for the purchase of the pilot plant and the relocation and reassembly of the plant on the island of Hawaiʻi. With successful field testing, the pilot project can be expanded into a commercial venture for private investors.
  - There is appropriated out of the general revenues of the State of Hawaiʻi the sum of $580,000 or so much thereof as may be necessary for fiscal year 2009-2010 for establishment of a pilot biomass conversion plant on the island of Hawaiʻi to convert biomass and methane gases in landfills into liquid transportation fuel and electricity.
  - This Act shall take effect on July 1, 2009.

HB 1458

- Report Title: Renewable Energy Technology Systems Loans
- Relating to: Renewable Energy
- Description:
  - Establishes the Renewable Energy Technology Systems Loan Program to provide loans to homeowners to purchase and install renewable energy technology systems, that shall be secured by the property upon which the system is installed, and repaid using the savings realized from use of the renewable energy technology system.
- Summary:
  - Adding a new part to Chapter 196: "PART . RENEWABLE ENERGY TECHNOLOGY SYSTEMS LOAN PROGRAM

        - §196-A Definitions …
        - §196-B Renewable energy technology systems loan program. (a) … The purpose of the loan program is to enable the department to make direct loans to eligible homeowners, as determined by the department, who seek to purchase and install renewable energy technology systems on their property. …
        - §196-C Renewable energy technology systems loan revolving fund …"
    - "There is appropriated out of the general revenues of the State of Hawai‘i the sum of $ or so much thereof as may be necessary for fiscal year 2009-2010 to be deposited into the renewable energy technology systems loan revolving fund created in section 196-C, Hawai‘i Revised Statutes."
    - This Act shall take effect on July 1, 2009.

HB 1464 (Act 155; Enacted in 06/25/2009)

- Report Title: Renewable Energy; Energy Efficiency
- Relating to: Energy Resources
- Description:
    - Provides for and encourages renewable energy use and development, and energy efficiency. Prohibits electric utilities from increasing generating capacity using fossil fuels. Increases requirements for renewable energy portfolio standard. Expands duties of energy resources coordinator. Allows businesses that produce electricity using certain renewable energy resources to qualify for enterprise zone benefits. Effective date is 7/1/2046. (SD2)
- Summary:
    - Adding a new section: "§342B- Fossil fuel electricity generating facilities. (a) Effective July 1, 2009, no new covered source that is owned or operated by an electricity-generating public utility with a rated capacity of more than two megawatts shall be permitted to generate electricity from fossil fuel sources; provided that electric utility cooperative associations shall be exempt from the requirements of this subsection until July 1, 2015. (b) Effective July 1, 2009, no covered source that is owned or operated by an electricity-generating public utility with a rated capacity of more than two megawatts and existing on July 1, 2009, except for an electric utility cooperative association, shall be modified in any manner that allows it to use more fossil fuel as a source of electricity generation than is allowed under its permit as of July 1, 2009. No covered source that is owned or operated by an electric utility cooperative association with a rated capacity of more than two megawatts and existing on July 1, 2009 shall be modified in any manner that allows it to use more fossil fuel as a source of electricity generation than is allowed under its permit as of July 1, 2015."
    - Section 269-92 HRS, is Amended: "(a) Each electric utility company … shall establish a renewable portfolio standard of:
      (1) 10% of its net electricity sales by December 31, 2010;
      (2) 15% of its net electricity sales by December 31, 2015;
      (3) 25% of its net electricity sales by December 31, 2020; and
      (4) 40% of its net electricity sales by December 31, 2030.

      (b) The public utilities commission may establish standards for each utility that prescribe what portion of the renewable portfolio standards shall be met by specific types of renewable energy resources; provided that:
      (1) Prior to January 1, 2015, at least 50% of the renewable portfolio standards shall be met by electrical energy generated using renewable energy as the source, and after December 31, 2014, the entire renewable portfolio standard shall be met by electrical generation from renewable energy sources;

(2) Beginning January 1, 2015, electrical energy savings shall not count toward renewable energy portfolio standards;
(3) Where electrical energy is generated or displaced by a combination of renewable and nonrenewable means, the proportion attributable to the renewable means shall be credited as renewable energy;
(4) Where fossil and renewable fuels are co-fired in the same generating unit, the unit shall be considered to generate renewable electrical energy (electricity) in direct proportion to the percentage of the total heat value represented by the heat input value of the renewable fuels; and
(5) Effective July 1, 2009, the public utilities commission shall not approve any application by a public utility to build a new generation facility … that uses fossil fuel as the source of electricity generation; provided that, between July 1, 2009 and July 1, 2015, the public utilities commission may approve an application when the application is submitted by an electric utility cooperative association…"

- Section 201-12.5 HRS is amended: "… (b) The renewable energy facilitator shall have the following duties:
  (1) Facilitate the efficient permitting of renewable energy projects, including:
  (A) The land parcel on which the facility is situated;
  (B) Any renewable energy production structure or equipment;
  (C) Any energy transmission line from the facility to a public utility's electricity system;
  (D) Any on-site infrastructure necessary for the production of electricity or biofuel from the renewable energy site; …"
- Section 201N-1 HRS is amended by: ""Renewable energy facility" or "facility" means a new facility located in the state with the capacity to produce from renewable energy at least 200 megawatts of electricity; provided that an electricity production facility with a capability between 5 megawatts and 199 megawatts of electricity and a biofuel production facility with a capacity to produce 1 million gallons or more annually may apply to the coordinator for designation as a renewable energy facility."
- The HRS is amended by adding the following new section: "§ Energy-efficiency portfolio standards. (a) The public utilities commission shall establish energy-efficiency portfolio standards that will maximize cost-effective energy-efficiency programs and technologies. (b) The energy-efficiency portfolio standards shall be designed to achieve 4300 gigawatt-hours of electricity use reductions statewide by 2030; … (e) Beginning in 2015, electric energy savings brought about by the use of renewable displacement or off-set technologies, including solar water heating and seawater air conditioning district cooling systems, shall count toward this standard."
- Chapter 235 HRS is amended by adding two new sections: "§235-A Electric vehicle charging infrastructure; income tax credit. … " (As explained in HB 489, HB 1054, SB 1202) and "§235-B Alternative fuel refueling infrastructure; income tax credit. … " (As explained in HB 489, HB 1054, SB 1202)
- Section 103D-412 HRS is amended to read as follows: "Light-duty vehicle requirements. … (b) Beginning January 1, 2010, all state and county entities, when purchasing new vehicles, shall seek vehicles with reduced dependence on petroleum-based fuels that meet the needs of the agency. Priority for selecting vehicles shall be as follows:
  (1) Electric or plug-in hybrid electric vehicles;
  (2) Hydrogen or fuel cell vehicles;
  (3) Flexible fuel vehicles;
  (4) Hybrid electric vehicles; or

(5) Vehicles that are identified by the USEPA … as being among the top performers for fuel economy in their class."

– This Act shall take effect on July 1, 2009.

HB 1468

- Report Title: Renewable Energy
- Relating to: Renewable Energy
- Description:
  - Establishes comprehensive measures for increasing the production and use of renewable energy in the State.
- Summary:
  - This bill asks for some slight modifications on Renewable Portfolio Standards, Net Energy Metering, Energy Resources Coordinator, Renewable Energy Resources, Renewable Energy Facilitator and Renewable Energy Permitting in almost the same way which is already explained in HB1052.

HB 1650

- Report Title: Electric-Powered Motor Vehicles
- Relating to: Energy
- Description:
  - Requires 25 per cent of all consumer motor vehicles to be electric-powered by January 1, 2020. Requires the Hawaii Energy Policy Forum to develop a regulatory scheme to implement this policy.
- Summary:
  - The purpose of this Act is to: "(1) Require 25% of all consumer motor vehicles to be electric-powered by January 1, 2020;he state enterprise zones program was established to promote private sector business growth, and to facilitate the revitalization of certain communities within the state through various measures such as regulatory flexibility and tax incentives. …"
  - "There is appropriated out of the general revenues of the State of Hawaii the sum of $ or so much thereof as may be necessary for fiscal year 2009-2010 for the Hawaii energy policy forum to develop a regulatory scheme to implement the policy requiring that 25% of all consumer motor vehicles be electric-powered by January 1, 2020."
  - This Act shall take effect on July 1, 2009.

HB 1682

- Report Title: Enterprise Zone (EZ) Program
- Relating to: State Enterprise Zones
- Description:
  - Allows LLCs and renewable energy producers to qualify for EZ benefits; extends EZ tax benefits for manufacturing and agricultural businesses, for an additional seven years; allows receipts, sales, and employees of a business's establishments in all EZs within one county to count towards EZ qualifications; exempts payments for construction for a business approved for enrollment in the EZ Program from the general excise tax. (HB1682 HD1)
- Summary:
  - The state enterprise zones program was established to promote private sector business growth, and to facilitate the revitalization of certain communities within the state through various measures such as regulatory flexibility and tax incentives.

- The purpose of this Act is to improve the state enterprise zone program by, among other things:
    1. Allowing limited liability companies to be included under the definitions of "qualified businesses" and "service businesses";
    2. Extending the enterprise zone tax credits and exemptions, for businesses engaged in manufacturing tangible personal property or in producing or processing agricultural products, for an additional seven years;
    3. Allowing the receipts, sales, and employees of a business's establishments in all enterprise zones located within the same county to count toward qualification requirements.
- This Act shall take effect on July 1, 2112.

HB 1704

- Report Title: Energy Independence; Government-Industry Consortium
- Relating to: Economic Development
- Description:
    - Directs the energy resources coordinator to establish a government-industry consortium for funding, research, and development of renewable energy resources.
- Summary:
    - SECTION 1. … The purpose of this Act is to create an energy initiative that will:
        (1) Lead the development and demonstration of transformational new energy technologies, including both space and terrestrial solar energy solutions;
        (2) Demonstrate that Hawaii is a leader in renewable energy development;
        (3) Implement a portfolio of visionary short-term and long-term energy solutions;
        (4) Create profitable high-quality new business opportunities for innovative technology-based start-up firms in Hawaii;
        (5) Establish Hawaii as a world-class leader in sustainable energy education, research, development, demonstrations, manufacturing, and operations; and
        (6) Enable Hawaii to achieve energy self-sufficiency within a generation, setting an example for the rest of the world.
    - SECTION 2. (a) The energy resources coordinator shall establish a government-industry consortium which shall:
        (1) Establish Sustainable Energy Innovation, LLC, …;
        (2) Seek federal and private industry funding for renewable energy technology research;
        (3) Develop and demonstrate advanced energy technology projects and testing in Hawaii…;
        (4) Provide funding for qualified small business ventures to work on projects in partnership with the UH and other universities, corporations, and the international community to rapidly establish renewable energy technologies and businesses; and
        (5) Assist the UH to develop new curricula for advanced sustainable energy economics and systems and to lead the education of the next generation of researchers, engineers, and technicians.
    - There is appropriated out of the general revenues of the State of Hawaii the sum of $1,000,000 or so much thereof as may be necessary for fiscal year 2009-2010 and $2,000,000 or so much thereof as may be necessary for fiscal year 2010-2011 for the organization and operations of the government-industry consortium pursuant to section 2 of this Act.
    - This Act shall take effect on July 1, 2009.

HB 1810

- Report Title: Energy Efficiency
- Relating to: Energy Efficiency
- Description:
  - Directs the public utilities commission to establish energy efficiency portfolio standards. Directs the public benefits fee administrator to review energy use patterns and develop an energy efficiency plan. Directs the energy resources coordinator to review energy efficiency in building construction and recommend amendments to county building codes and the state building code. Requires the state building code to contain provisions of the International Energy Conservation Code and directs counties to adopt those provisions. Allows for the review of energy efficiency in existing state buildings and directs the energy resources coordinator to establish energy efficiency guidelines for retro-commissioning and retrofits. Requires existing state buildings to be retro-commissioned no less than every five years. Requires the energy resources coordinator to publish an annual energy efficiency report. Requires energy performance contracts for retro-commissioning to meet energy efficiency standards. Expands the pay as you save pilot program to include photovoltaic energy systems and refrigerator exchanges. Directs the public benefits fee administrator to develop and implement a program to encourage residential retail electricity customers to replace inefficient household appliances with ENERGY STAR appliances. Provides a net zero energy building tax credit to builders of residential or commercial buildings that produce enough energy that is equal to or greater than the energy consumed by the occupants of the building. Directs the public utilities commission to establish a consumer information program on energy efficient properties. Allows a taxpayer who claims the low-income household renter's tax credit to transfer the credit to the taxpayer's landlord.

HB 1811

- Report Title: Transportation Energy
- Relating to: Transportation Energy
- Description:
  - Establishes a comprehensive approach to increasing the use of alternative fuel vehicles in the State, including state procurement of alternative fuel vehicles, tax incentives, and infrastructure requirements.
- Summary:
  - Adding a new section: "§196-B Transportation energy transformation grant fund. (a) There is established in the state treasury a special fund to be designated as the transportation energy transformation grant fund into which shall be deposited appropriations made by the legislature to the fund… (e) Subject to the availability of funds and the standards in this section, grants for approved electric vehicles shall be provided to purchasers of electric vehicles intended to be integrated intelligently with the electrical grid and licensed for use on highways in the State, as follows: (1) Beginning January 1, 2010, and expiring December 31, 2010: up to $4,000 per vehicle limited to the first five hundred vehicles that are approved; (2) Beginning January 1, 2011, and expiring December 31, 2011: up to $3,500 per vehicle limited to the first one thousand vehicles that are approved; (3) Beginning January 1, 2012, and expiring December 31, 2013: up to $2,500 per vehicle limited to the first two thousand vehicles per year that are approved; (4) Beginning January 1, 2014, and expiring December 31, 2015: up to $2,000 per vehicle limited to the first two thousand five hundred vehicles that are approved per

year; and (5) Beginning January 1, 2016, and expiring December 31, 2021: up to $500 per vehicle limited to the first ten thousand vehicles that are approved per year…."
- There is appropriated out of the general revenues of the State of Hawaiʻi the sum of $3,750,000 or so much thereof as may be necessary for fiscal year 2009-2010 to be deposited into the transportation energy transformation grant fund.
- There is appropriated out of the transportation energy transformation grant fund the sum of $3,750,000 or so much thereof as may be necessary for fiscal year 2009-2010 to implement the purposes of the transportation energy transformation grant fund.

HB 1843

- Report Title: Renewable Energy
- Relating to: Renewable Energy
- Description:
  - Establishes comprehensive measures for increasing the production and use of renewable energy in the State. Effective 1/1/2020. (HB1843 HD2)
- Summary:

  PART I (RENEWABLE PORTFOLIO STANDARDS)
  - Adding a new section: "§196- New electrical generation facility; permit prohibition. No state or county agency shall issue a permit to any applicant for the construction or operation of a new electrical generation facility that produces electrical energy solely from the combustion of any type of fossil fuel; provided that, under extraordinary circumstances, as determined by the commission, a certificate may be issued."
  - Section 269-7.5 HRS, is Amended: " Certificates of public convenience and necessity. … (f) No certificate shall be issued to any applicant for the construction or operation of a new electrical generation facility that produces electrical energy solely from the combustion of any type of fossil fuel; provided that, under extraordinary circumstances, as determined by the commission, a certificate may be issued."

  PART II (ENERGY RESOURCES COORDINATOR)
  - Section 196-4 HRS, is amended: "Powers and duties. Subject to the approval of the governor, the coordinator shall: …
    (12) Formulate a systematic process, including the development of requirements, to identify geographic areas that contain renewable energy resource potential that may be developed in a cost-effective and environmentally benign manner and designate these areas as renewable energy zones;
    (13) Develop and recommend incentive plans and programs to encourage the development of renewable energy resource projects within the renewable energy zones;
    (14) Assist public and private agencies in identifying the utility transmission projects or infrastructure that are required to accommodate and facilitate the development of renewable energy resources;
    (15) Assist public and private agencies in coordination with the department of budget and finance in accessing use of special purpose revenue bonds to finance the engineering, design, and construction of transmission projects and infrastructure that are deemed critical to the development of renewable energy resources;
    (16) Develop the criteria or requirements for identifying and qualifying specific transmission projects or infrastructure that are critical to the development of renewable energy resources and for which the energy resources coordinator shall assist in accessing the use of special purpose revenue bonds to finance; and…"

  PART III (RENEWABLE ENERGY RESOURCES)
  - Section 209E-2 HRS, is amended: ""Qualified business" means any corporation, partnership, or sole proprietorship authorized to do business in the state that is … and is

engaged in … (D) Biogas, including landfill and sewage-based digester gas; … (G) Biomass, including biomass crops, agriculture and animal residues and wastes, and solid waste; (H) Biofuels; ..."

PART IV (RENEWABLE ENERGY FACILITATOR)

- Section 201-12.5 HRS, is amended: "(b) The renewable energy facilitator shall have the following duties: (1) Facilitate the efficient permitting of renewable energy projects[;], including: (A) The land parcel on which the facility is situated; (B) Any renewable energy production structure or equipment; (C) Any energy transmission line from the facility to a public utility′s electricity system; and (D) Any on-site infrastructure necessary for the production of electricity or biofuel from the renewable energy site;… "

PART V (RENEWABLE ENERGY PERMITTING)

- Section 201N-1 HRS, is amended: ""Renewable energy facility" or "facility" means a new facility located in the state with the capacity to produce from renewable energy between five megawatts and two hundred megawatts of electricity or a biofuel production facility with a capacity to produce one million gallons annually…"

This Act shall take effect on January 1, 2020; provided that section 11 shall take effect on July 1, 2020.

2009 Regular Session; Senate Bills Introduced:

SB 50 (Act 19, Special Session 1)

- Report Title: DLNR; Renewable Energy Producer; Public Notice; Public Lands; Lease
- Relating to: Renewable Energy Producers
- Description:
  - Sets terms and conditions for leases of public lands to renewable energy producers, including requiring a public hearing, project completion, design, and financing documentation, and limitations on terminating or altering existing leases of public lands affected. (CD1)
- Summary:
  - Chapter 171 HRS is amended by adding a new section: "§171- Renewable energy producers; lease of public lands without public auction. (a) The board may lease or renew a lease of public lands to renewable energy producers, as defined in section 171-95, without public auction only pursuant to a public process that includes public notice under section 1-28.5 providing other interested renewable energy producers opportunity to participate in the process; … provided further that the renewable energy producer shall be required to submit as part of the proposal for the board's evaluation, as assisted by the DBEDT, the following:
    (1) A timeline for completion of the project;
    (2) A description of a financial plan for project financing;
    (3) A description of the conceptual design of the project;
    (4) A description of the business concept for the project; and
    (5) A description of landscape and acreage requirements including public and private lands. "

SB 69

- Report Title: Renewable Energy; Biodiesel Feedstock; Appropriations
- Relating to: Biodiesel feedstock
- Description:

   - Appropriation for Hawai‘i county economic opportunity council for operation of laboratory and research farm expansion for the Hawai‘i biotech tissue culture center to mass produce biodiesel feedstock.
- Summary:
   - There is appropriated out of the general revenues of the State of Hawai‘i the sum of $3,000,000 for fiscal year 2009-2010, or so much thereof as may be necessary, as a grant and subsidy under chapter 42F, HRS, to the Hawai‘i county economic opportunity council, as follows: (1) $1,800,000 for operational expenses for the Hawai‘i biotech tissue culture center to the end of the first cycle of mass propagation and point of sale to mass produce non-genetically-modified organism, superior, high yielding jatropha curas biodiesel feedstock;

SB 199

- Report Title: Sunset; Repeal Tax Credits
- Relating to: Taxation
- Description:
   - Sunsets and repeals all tax credits for taxable years beginning after 12/31/10. (SD1)
- Summary:
   - §235 HRS, is amended by adding two new sections to be appropriately designated and to read as follows:
      - §235- Tax credits; repeal; carryover unaffected. The ability to claim a tax credit that has not been exhausted in subsequent taxable years shall not be affected by the repeal date of that tax credit. The exhaustion of tax credits in subsequent taxable years shall be governed by the specific provisions of each tax credit.
      - §235- Tax credits; legislature; two-thirds vote. Effective July 1, 2009, the enactment of legislation establishing any tax credit shall require a two-thirds vote of the members to which each house of the legislature is entitled.
   - §235-12.5 (Renewable energy technologies; income tax credit), Hawai‘i Revised Statutes, is repealed. … §235-110.3 (Ethanol facility tax credit), Hawai‘i Revised Statutes, is repealed. …

SB 464 (Act 154, Enacted in 06/25/2009)

- Report Title: Renewable Energy Technologies Income Tax Credit
- Relating to: Taxation
- Description:
   - Amends the renewable energy technologies income tax credit to encourage use of solar and wind energy systems and to permit a portion of the excess of the credit over payments due to be refunded to the taxpayer in certain circumstances. Reduces the tax credit for certain energy systems used to meet substitute renewable energy technology requirements for single-family residential properties. (SB464 CD2)
- Summary:
   - Section 235-12.5 HRS is amended: "Renewable energy technologies; income tax credit.
     (a) … The tax credit may be claimed as follows:
     (1) For each solar energy system: 35% of the actual cost or the cap amount determined in subsection (b), whichever is less; or
     (2) For each wind-powered energy system: 20% of the actual cost or the cap amount determined in subsection (b), whichever is less; …
     (k) This section shall apply to eligible renewable energy technology systems that are installed and placed in service on or after July 1, 2009."

- This Act shall take effect on July 1, 2009, and shall apply to taxable years beginning after December 31, 2008.

SB 467

- Report Title: Renewable Energy; DBEDT Division
- Relating to: Renewable Energy
- Description:
  - Establishes a renewable energy branch in the department of business, economic development, and tourism to coordinate and promote renewable energy initiatives. (SD1)
- Summary:
  - The purpose of this Act is to support the renewable energy industry in Hawaii by:
    (1) Establishing a renewable energy branch in the department of business, economic development, and tourism to coordinate and promote renewable energy initiatives;
    (2) Strengthening statutes supporting energy diversification, a longer term view of what is reasonable in energy planning, and utilization of energy technologies; and
    (3) Providing adequate resources for the support of the renewable energy industry, and for comprehensive energy planning, in the department of business, economic development, and tourism.
  - Chapter 201 HRS is amended by adding new section: "§201- Renewable energy branch; established. (a) … (b) Branch functions shall include, but not be limited to:

    (1) Renewable energy resource assessments, technical analyses, and resource development functions, including design, management, and completion of systematic analysis of existing and proposed energy resource programs; evaluation of analyses conducted by government agencies and other organizations; formulation of plans for the optimum development of Hawaii's renewable energy resources; and the development and management of programs to encourage private and public exploration, research, and commercial development of renewable energy resources;

    (2) Project facilitation functions, including the development and implementation of programs to facilitate the efficient permitting of renewable energy projects;

    (3) Renewable energy partnership and outreach functions, including participation in renewable and sustainable energy evaluation and demonstration projects, outreach, and other activities to promote technically, economically, and environmentally feasible technologies and projects;

    (4) Renewable energy resource, technology, and project viability consultant functions, including serving as a consultant to the governor, public agencies, and private industry on matters related to the utilization of Hawaii's renewable energy resources; and

    (5) Research, reporting, implementation, and support of renewable and transportation energy related statutes, laws, acts, rules, regulations, and initiatives."
  - This Act shall take effect on July 1, 2009.

SB 489

- Report Title: Providers of Electricity; Agricultural Producers; Alternative Energy
- Relating to: Energy
- Description:
  - Authorizes PUC to establish a preferential rate structure for electricity provided by agricultural producers from renewable energy sources. Also authorizes the establishment of a renewable energy credits trading program and credits for environmental services.
- Summary:

- The purpose of this Act is to establish new policies relating to the purchase of electricity produced by agricultural producers.
- Section 269-94 HRS is amended: "Waivers, extensions, and incentives: … (b) The public utilities commission may provide incentives to encourage electric utility companies to exceed their renewable portfolio standards, to meet their renewable portfolio standards ahead of time, or both, including but not limited to:
  (1) Preferential rates for producers associated with agricultural activities in accordance with subsection (c);
  (2) Renewable energy credits trading programs which establish a value for all of the attributes associated with renewable energy production; and
  (3) Credit for environmental restoration activities such as improving air and water quality, flood control, wildlife habitat restoration and preservation, and carbon sequestration."
- This Act shall take effect on July 1, 2009.

SB 511

- Report Title: Biodiesel; Market Stimulation
- Relating to: Biodiesel
- Description:
  - Provides various market stimulation incentives for the development of biodiesel, including making state agricultural lands available for biodiesel fuel crops.
- Summary:
  - §171- Lease of agricultural lands for crops used in the production of biodiesel fuel.
  - §103D-1012, HRS, is amended by amending subsections (a), (b), and (c) to read as follows: … (Biodiesel preference)
  - §235-7, HRS, is amended by amending subsection (a) to read as follows: (a) There shall be excluded from gross income, adjusted gross income, and taxable income: … (14) One hundred per cent of income derived from the operation of an oil seed crushing facility that processes oil seed produced or grown in the State for biodiesel production in the State.
  - This Act shall take effect on January 1, 2010; provided that the amendments made to section 235-7(a), HRS, by section 3 of this Act, shall not be repealed when that section is repealed and reenacted on January 1, 2013, pursuant to section 3 of Act 166, Session Laws of Hawai‘i 2007.

SB 512

- Report Title: Biofuels Facility; Nameplate Capacity; Gallons Produced
- Relating to: Taxation
- Description:
  - Amends the definition of nameplate capacity for biofuels facilities and revises the allowable tax credit to be equal to 40 cents per gallon of biofuel produced. (SD1)
- Summary:
  - §235-110.3 Biofuel facility tax credit: For each qualified biofuel production facility, the annual dollar amount of the biofuel facility tax credit during the eight-year period shall be equal to 40 cents per gallon produced if the nameplate capacity of the qualified biofuel production facility is greater than five hundred thousand gallons but less than fifteen million gallons.

SB 558

- Report Title: Energy Resources; Alternate Energy
- Relating to: Energy Resources
- Description:
  - Encourages the use of competitively-priced ethanol produced in Hawaiʻi from locally grown renewable feedstocks or waste materials, when available; specifies that "alternate fuels" shall not include imported fuels.
- Summary:
  - The purpose of this Act is to promote the use of local energy sources, which will reduce the State's reliance on imported fuels.
  - §196-9(c)(4) Purchase alternative fuels and ethanol blended gasoline when available; provided that sufficient quantities of competitively-priced ethanol produced in Hawaiʻi from locally grown renewable feedstocks or waste materials are available;
  - §196-42 State support for achieving alternate fuels standards. … For purposes of the alternate fuels standard, ethanol produced from cellulosic materials shall be considered the equivalent of 2.5 gallons of noncellulosic ethanol. "Alternate fuels" shall have the same meaning as … provided further that it shall not include imported fuels.

SB 870

- Report Title: Hawaiʻi Clean Energy Initiative; Electric Generation and Delivery
- Relating to: Hawaiʻi′s Clean Energy Initiative in Electric Generation and Delivery
- Description:
  - Establishes electric generation and delivery initiatives necessary for and contributing to the transition of Hawaiʻi's energy sector to 70 percent non-petroleum energy sources by 2030.
- Summary:
  - §269-92, HRS, is amended to read as follows: … [(a)3,4 and (b)1 have increased the renewable portfolio standards of electricity generation]
  - §196-4, HRS, is amended to read as follows: … (13) Develop and recommend incentives plans and programs to encourage the development of renewable energy resource projects within the renewable energy zones; … (15) Assist public and private agencies … in accessing use of special purpose revenue bonds to finance the engineering, design, and construction of transmission projects and infrastructure that are deemed critical to the development of renewable energy resources;
  - §209E-2, HRS, is amended by amending the definition of ″qualified business″ to read as follows: "Qualified business" means any corporation … (4) Engaged in development or production of fuels or thermal energy or electrical energy from renewable resources, including: Wind; The sun; Falling water; Biogas, including landfill and sewage-based digester gas; Geothermal; Ocean water, currents and waves; Biomass, including biomass crops, agriculture and animal residues and wastes, and solid waste; Biofuels; and Hydrogen produced from renewable energy sources.

SB 871

- Report Title: Hawaiʻi Clean Energy Initiative; Energy Efficiency
- Relating to: Hawaiʻi′s Clean Energy Initiative in Energy Efficiency
- Description:
  - Establishes energy efficiency initiatives necessary for and contributing to the transition of Hawaii's energy sector to 70 percent non-petroleum energy sources by 2030.
- Summary:

- – § Energy efficiency portfolio standard. … The statewide target shall be 4,300 gigawatt-hours of electricity savings by 2030. … The administrator will submit annual reports to the public utilities commission by March 1 of each year, beginning March 1, 2010, reporting energy efficiency savings achieved during the previous calendar year.
- – § Energy efficiency studies and planning. The public benefits fee administrator shall expend $500,000 from the public benefit fee to conduct energy efficiency assessments to identify current energy use patterns in this State and areas of greatest potential for energy efficiency savings. … The assessments shall be completed by December 31, 2010.
- – § 235-_____ Tax credit for a net zero energy building. (a) … (b) The amount of the credit shall be:
  (1) For a building that is up to 1000 square feet, the tax credit shall be $9.00 per square foot;
  (2) For a building that is more than 1000 square feet but less than 4,000 square feet, the tax credit shall be $6.00 per square foot;
  (3) For a building that is more than 4,000 square feet, the tax credit shall be $3.00 per square foot for a maximum credit of $50,000.

SB 872

- o Report Title: Hawaiʻi Clean Energy Initiative; Transportation
- o Relating to: Hawaiʻi's Clean Energy Initiative in Transportation Energy
- o Description:
  - – Establishes transportation energy initiatives necessary for the transition of Hawaiʻi′s transportation energy sector from almost completely dependent on petroleum towards the use of efficient, stable, secure, renewable, non-petroleum energy sources by 2030.
- o Summary:
  - – §237- Exemption of sale or lease of certain vehicles (Beginning January 1, 2010, and expiring December 31, 2015)
  - – §___-__ Transportation energy transformation grant fund.
  - – §235-110.3 HRS, is amended to read as follows: Biofuel facility tax credit.
  - – §251-2 Rental motor vehicle and tour vehicle surcharge tax: … (c) For the period of January 1, 2010, through December 31, 2015, up to two hundred alternative fueled light duty motor vehicles per rental car fleet shall be exempt from the rental motor vehicle surcharge tax.
  - – §103D-412 Light duty motor vehicle requirements: (a) The procurement policy for all agencies purchasing or leasing light duty motor vehicles shall be to reduce dependence on petroleum for transportation energy. Beginning January 1, 2010, all state and county entities shall, when purchasing new vehicles, seek vehicles with reduced dependence on petroleum-based fuels.
  - – §103D-1012 Biofuel preference: … (g) Beginning January 1, 2012, all state-owned diesel vehicles and equipment are required to be fueled with blends of biomass-based diesel, subject to the availability of the fuel, and so long as the price is no greater than twenty per cent more per gallon than the price of conventional diesel.
  - – §196- Alternative fuel vehicle requirement for private fleets. (a) Beginning January 1, 2015, each fleet operator controlling more than fifty light duty motor vehicles in the State shall, when replacing its light duty motor vehicles or expanding its fleet, acquire increasing percentages of vehicles capable of operating on non-petroleum energy sources, including electric vehicles, flexible fuel vehicles, or other alternative fuel vehicles. (b) At least four per cent of all new light duty motor vehicles acquired by a fleet operator in the State during calendar year 2015 shall be alternative fuel vehicles. This percentage shall

increase by four per cent per year, reaching sixty-four per cent in the calendar year 2030. …

SB 1037

- Report Title: Electric Vehicles; Energy Efficient Industry Development
- Relating to: Transportation energy initiatives
- Description:
  - Develops a suitable infrastructure to develop the electric vehicle industry in Hawaiʻi.
- Summary:
  - §235- Alternative fuel refueling infrastructure; income tax credit. (a) Each individual or corporate taxpayer that files a corporate net income tax return for a taxable year may claim a tax credit under this section against the Hawaiʻi state corporate net income tax. The tax credit may be claimed for alternative fuel refueling infrastructure installed and placed in service during the taxable year. The tax credit may be claimed as follows: For taxable years ending before January 1, 2016, an income tax credit will be allowed for the purchase and installation of alternative fuel refueling infrastructure. The allowable credit shall be up to thirty per cent of the installed cost of the alternative fuel refueling infrastructure or $25,000, whichever is less.
  - §103D-412 Light-duty vehicle requirements. (a) The procurement policy for all agencies purchasing or leasing light duty vehicles shall be to reduce dependence on petroleum for transportation energy. Beginning January 1, 2010, when purchasing new vehicles, all State and county agencies shall seek vehicles with reduced dependence on petroleum-based fuels.

SB 1186

- Report Title: Renewable Energy Opportunity Zones
- Relating to: Renewable energy opportunity zones
- Description:
  - Requires the director of business, economic development, and tourism, in consultation with the renewable energy opportunity zone advisory committee to: designate renewable energy opportunity zones, determine the types of energy generation for such zones, determine the number of zones and the period of zones, perform required environmental impact statements for zones, and expedite issuance of county permits.
- Summary:
  - The intent of the Legislature is to have the groundwork prepared in anticipation of the entry of qualified businesses that are willing and able to invest in the State to develop renewable energy resources by having certain areas in the respective counties designated as renewable energy opportunity zones, approved for certain types of renewable energy generation, with all the necessary environmental impact statements performed and in place, and by expediting the issuance of necessary county permits, in consultation with the respective counties through their active participation in an advisory committee.
  - The HRS is amended by adding a new chapter (Renewable Energy Opportunity Zones).
    - § -1 The purpose of this chapter is to reduce the State's dependence on imported oil and increase the State's energy self-sufficiency by providing for the establishment of renewable energy opportunity zones. …
    - § -9 State business tax credit.
    - § -10 State general excise and use tax exemptions.
    - § -11 Local incentives.

SB 1202 (Act 156; Enacted 06/25/2009)

- Report Title: Transportation; Energy Efficient Vehicles
- Relating to: Transportation energy initiatives
- Description:
  - Establishes the development of non-fossil fuel transportation as a state policy goal. Provides tax credits for the purchase and installation of electric vehicle charging infrastructure and alternative fuel refueling infrastructure. Requires the designation of parking spaces for electric vehicles. Requires state and county agencies to follow a priority list when purchasing energy-efficient vehicles, including electric vehicles. Requires the director of transportation to furnish information to the energy resources coordinator on the use of electric vehicles in the State. Requires the department of transportation to develop a plan for electric vehicle infrastructure. (SD1)
- Summary:
  - Chapter 235 HRS, is amended by adding two new sections: … §235-B Alternative fuel refueling infrastructure; income tax credit. (a) Each individual or corporate taxpayer that files an individual or corporate net income tax return for a taxable year may claim a tax credit under this section against the Hawaiʻi state individual or corporate net income tax. … (shall apply to taxable years beginning after December 31, 2008).
  - §103D-412 HRS, is amended to read as follows: Light-duty vehicle requirements. (a) The procurement policy for all agencies purchasing or leasing light-duty vehicles shall be to reduce dependence on petroleum for transportation energy. (b) Beginning January 1, 2010, all state and county entities, when purchasing new vehicles, shall seek vehicles with reduced dependence on petroleum-based fuels that meet the needs of the agency.

SB 1231

- Report Title: Renewable Energy; Biomass; Appropriation
- Relating to: Renewable Energy
- Description:
  - Makes an appropriation for the relocation and establishment of a pilot plant for the conversion of biomass into liquid transportation fuel and electricity.
- Summary:
  - The Hawaiʻi County Economic Opportunity Council has an agreement with Aggregate Energy, LLC of Idaho for the development of a pilot project on the island of Hawaiʻi to convert biomass and methane gases found in landfills into synthetic liquid transportation fuel and electricity.
  - The Hawaiʻi Economic Opportunity Council requires seed funding in the amount of $580,000 for the purchase of the pilot plant and the relocation and reassembly of the plant on the island of Hawaiʻi. With successful field testing, the pilot project can be expanded into a commercial venture for private investors.
  - This Act shall take effect on July 1, 2009.

SB 1234

- Report Title: Food and Energy Security
- Relating to: Government
- Description:
  - Establishes the Hawaii energy and food security authority to plan, coordinate, and address Hawaii's energy and food security needs. Repeals the state program for energy planning and conservation. Imposes the environmental response and energy and food security tax. Makes the executive director of the authority the energy resources

coordinator. Repeals the energy resources coordinator duties. Abolishes the agribusiness development corporation on 7/1/2011.

- Summary:
  - The HRS is amended by adding a new chapter: "HAWAII ENERGY AND FOOD SECURITY AUTHORITY

    § -2 Establishment of the Hawaii energy and food security authority; purpose. … (b) The purpose of the Hawaii energy and food security authority shall be to promote and achieve energy independence and food security in Hawaii. Its duties shall include but not be limited to:

    (1) Developing, implementing, and monitoring long-range plans to achieve energy independence and food security in Hawaii;

    (2) Promoting and accelerating renewable energy, energy efficiency, and energy self-sufficiency initiatives to lead towards energy independence for Hawaii;

    (3) Developing and promoting local agricultural markets, to achieve food self-sufficiency and security for Hawaii;

    (4) Administering the Hawaii energy and food security fund, established in section -9;

    (5) Coordinating energy and food security activities and programs, including competitive grant programs, targeted tax credits, infrastructure development and other incentive programs; and

    (6) Engaging in workforce development, and marketing and business development activities that promote energy and food self-sufficiency, to facilitate public-private partnerships with other public agencies, the private sector and non-governmental organizations.

    § -9 Energy and food security fund. (a) There is established the energy and food security fund, into which shall be deposited: (1) A portion of the revenues from the environmental response and energy and food security tax, as provided by section 243-3.5; (2) … "
  - Section 243-3.5 HRS is amended: "§243-3.5 Environmental response and energy and food security tax; uses. (a) In addition to any other taxes provided by law, subject to the exemptions set forth in section 243-7, there is hereby imposed a state environmental response and energy and food security tax of $1 on each barrel or fractional part of a barrel of petroleum product sold by a distributor to any retail dealer or end user, other than a refiner, of petroleum product; provided that:

    (1) 5 cents of the tax on each barrel shall be used pursuant to section 128D-2 to address concerns relating to drinking water;

    (2) 47.5 cents of the tax on each barrel shall be used pursuant to section -9 to address energy and food security issues; and

    (3) 47.5 cents of the tax on each barrel shall be used pursuant to section 163D-17 to address food security issues.

    The tax imposed by this subsection shall be paid by the distributor of the petroleum product."

SB 1247

- Report Title: Tax Credits; Tax Exemptions; Evaluation; Report
- Relating to: The economy
- Description:
  - Requires the department of taxation, with the assistance of the department of business, economic development, and tourism, to evaluate certain tax credits and tax exemptions and report to the legislature. Requires the department of taxation to give

recommendations prior to the mandate for those tax credits and tax exemptions to sunset. (SD2)

- Summary:
  - The purposes of this Act are to institute an ongoing program of evaluation of those tax credits and tax exemptions that have no sunset dates, require the department of taxation and department of business, economic development, and tourism to compile the necessary information to enable the legislature to evaluate tax credits and exemptions with consistent standards, and to sunset those credits and exemptions that the department of taxation and legislature do not believe should be extended. Over time, as economic conditions change, different combinations of tax credits and tax exemptions serve as the State's key tools to promote or discourage particular behavior among residents and businesses. For existing tax credits and tax exemptions that have a sunset date, the purpose of this Act is to require the department of taxation, with the assistance of the department of business, economic development, and tourism, to compile accurate information on their usage and whether they are fulfilling the purposes for which they were adopted, as well as providing solid returns on public investment.

SB 1258

- Report Title: Renewable Energy
- Relating to: Renewable Energy
- Description:
  - Establishes electric generation and delivery initiatives necessary for and contributing to the transition of Hawai‘i's energy sector to seventy per cent non-petroleum energy sources by 2030. (SD1)
- Summary:
  - The purpose of this Act is to provide a first step in aligning Hawai‘i's energy policy laws with the State's energy goals. For Hawai‘i to realize energy independence and economic stability, the transformation of its energy system must encompass changes to: (1) Hawai‘i's policy or regulatory framework; (2) System-level technology development and integration; (3) Financing or capital investment; and (4) Institutional system planning.

SB 1303

- Report Title: Energy Independence; Government-Industry Consortium
- Relating to: Energy Independence
- Description:
  - Directs the energy resources coordinator to establish a government-industry consortium for funding, research, and development of renewable energy resources. (SD1)
- Summary:
  - The legislature finds that a focused new initiative is needed to establish Hawai‘i as one of the principal leaders in research, commercialization, and application of new ground-based and space-based energy technologies. The purpose of this Act is to create such energy initiative.
  - The energy resources coordinator shall establish a government-industry consortium which shall: … (2) Seek federal and private industry funding for renewable energy technology research; …

SB 1307

- Report Title: Transportation Energy
- Relating to: Alcohol Fuels

- Description:
  - Improve Hawai‘i's economic and energy security position by establishing a preference for locally produced alcohol fuels.
- Summary:
  - §237-27.1 HRS, is amended to read as follows: Exemption of sale of alcohol fuels. (a) … The exemption shall apply to alcohol fuels utilized to meet the State's renewable fuel standard and shall be administered based on the local alcohol fuel production capacity for that tax year, as determined by the department of business, economic development, and tourism. …

SB 1612

- Report Title: Transportation Energy
- Relating to: Transportation Energy
- Description:
  - Establishes Land Transportation Modernization Special Fund if fees and tax increases are triggered. (SD1)
- Summary:
  - Chapter 248 HRS is amended by adding a new section: "§248 Land transportation modernization special fund. …" The expenditure purposes are not specifically determined and listed yet.

SB 1634

- Report Title: Transportation; Planning; Energy Efficiency; Tax Credit
- Relating to: Transportation
- Description:
  - Includes in the State's potential growth policy research and development of non-fossil fuel and energy efficient modes of transportation; provides tax credits for the installation of electric vehicle charging infrastructures and alternative fuel refueling infrastructures; establishes penalties for parking in electric vehicle parking spaces; requires agencies purchasing light-duty vehicles to consider electric, hybrid, then hydrogen options.
- Summary:
  - Section 226-10 HRS, is amended to read as follows: … (b) To achieve the potential growth activity objective, it shall be the policy of this State to: … (12) Foster the research and development of non-fossil fuel and energy efficient modes of transportation.
  - Chapter 235, Hawai‘i Revised Statutes, is amended by adding two new sections:
    - §235-A Electric vehicle charging infrastructure; income tax credit. (a) … The tax credit may be claimed for code compliant electric vehicle charging infrastructure installed and placed in service in the State after January 1, 2010, and prior to the close of the taxable year. The tax credit may be claimed as for taxable years ending before January 1, 2012, for the purchase and installation of electric vehicle charging infrastructure. The credit shall be seventy per cent of the installed cost of the electric vehicle charging system or $1,000 per electric vehicle charge point of the system, whichever is less.
    - §235-B Alternative fuel refueling infrastructure; income tax credit. (a) … The tax credit may be claimed for alternative fuel refueling infrastructure installed and placed in service during the taxable year. The tax credit may be claimed for taxable years ending before January 1, 2016, for the purchase and installation of alternative fuel refueling infrastructure. The credit shall be thirty per cent of the installed cost of the alternative fuel refueling infrastructure or $25,000, whichever is less.

Appendix E

Selected programs from other states:
Biofuel Related Tasks/Projects/ Programs/Incentives:[3]

Alaska

- o Alaska Energy Authority
  - Mission: Reduce the cost of energy in Alaska
  - Programs:
    (1) Alternative Energy (Biomass Energy; …)
    (2) Loan Programs (Bulk Fuel Revolving Loan Fund, …)
    (3) Renewable Energy Grant Program (Renewable Energy Fund, …)
    (4) …
- o Barged in diesel runs power to a range of $0.21-0.80/kWh
- o Alaska Energy Inventory 2007 Funding - $500,000
- o Development of Renewable Energy Atlas and Inventory (with major biomass component)
- o Development of Alaska roadmaps (e.g. Alaska Rural Energy Plan, Railbelt Energy Plan)
- o Alaska Wood Energy Development Task Group
- o "Fish Oil Biodiesel" development project

Idaho

- o Idaho Office of Energy Resources
  - Biodiesel Activities and Efforts
    - Funding: The Idaho Legislature appropriated $690,000 for fiscal year FY2008 and anticipates an additional $1.6 million for FY2009 through 2012, for a total of $2.3 million over the 5-year period. The legislation directed the Office of Energy Resources to administer the funds.
- o A long biodiesel history
- o Fueling station grants - $690,000 – for E-85 and biodiesel
- o Pacific Ethanol - $380,000 infrastructure grant for 50 MGY plant
- o National Biodiesel Education Program – At University of Idaho (since 1979)
- o Idaho Roadmap – Idaho Energy Plan 2007 by State Legislature

Montana

- o Montana Department of Environmental Quality
  - Montana Biomass Energy Program
- o Ethanol mandate with 40 MGY trigger & Renewable Electricity Std.
- o Tax incentives
- o Strong biofuels program (ethanol & biodiesel) – State working group

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[3] "Regional and State Biomass Assessments, Analysis & Roadmaps Leading to Projects: Lessons Learned", David Sjoding, Pacific Regional Biomass Energy, 16 October 2008.

- BioPower and BioHeat/CHP – Fuels for Schools ($450,000) & Woody Biomass Work Group
- Roadmap: Climate Change Action Plan – Biomass/biofuels prominent
- Fuel testing lab at Havre, MT - $250,000 for equipment

Oregon
- Oregon Departments of Energy, Agriculture & Forestry
  - Oregon's Business Energy Tax Credit (BETC): provides a 50% credit for the capital costs of biofuels and bioenergy projects
  - Per-Unit Biomass Credits: are available for several types of biofuel and bioenergy feedstocks. The credits rates for biomass are
    - <u>$.05 per pound for oilseed crops</u>
    - <u>$.90 per bushel for grain crops (corn is excluded, and wheat is eligible only after January 1, 2009)</u>
    - <u>$.10 per gallon for virgin oil or alcohol delivered for production in Oregon from Oregon-based feedstock</u>
    - <u>$.10 per gallon for used cooking oil or waste grease</u>
    - <u>$10.00 per wet ton for wastewater biosolids</u>
    - <u>$10.00 per green ton for woody biomass collected from nursery, orchard, agricultural, forest, or rangeland property in Oregon, including but not limited to prunings, thinning, plantation rotations, log landing or slash resulting from harvest or forest health stewardship</u>
    - <u>$10.00 per green ton for grass, wheat straw, or other vegetative biomass from agricultural crops</u>
    - <u>$5.00 per wet ton for yard debris and municipally generated food waste</u>
    - <u>$5.00 per wet ton for animal manure and rendering offal</u>
  - Energy Trust of Oregon's Biopower Program: provides financial incentives to help support development of biopower projects that use organic waste to generate electricity.
  - Producing Biodiesel or Ethanol in Oregon: A Guide to Permits, Licenses, Incentives and Resources
  - Utah Biodiesel Supply Tutorial
- Oregon roadmap: Renewable Energy Action Plan April 2005 (strong bioenergy section)
- Renewable Portfolio Standard (RPS)/ Renewable Fuels Standard (RFS) - 2007
- "Biomass Inventory" Development (with routine updates)

Washington
- Washington State Bioenergy Project
  - A multi-agency work group staffed from Washington Departments of CTED, Ag, Ecology & Washington State University Extension Energy Program
- Washington State Biofuel Laws and Incentives:
  - Production
    - <u>Tax Incentives</u>
      - <u>Reduced B&O rate provided for manufacture of wood biomass, alcohol or biodiesel fuels, or biodiesel feedstocks</u>

        - Anaerobic digester construction and operation are exempt from retail sales and use taxes.
        - Equipment, labor and associated services for power production greater than 200w from various renewable energy sources are exempt from retail sales and use taxes.
        - Land, buildings and equipment used for anaerobic digestion, manufacturing alcohol, biodiesel and wood biomass fuels, or biodiesel feedstock are exempt from property and leasehold taxes for six years following the date the facility becomes operational.
    - Financial Assistance
        - The Energy Freedom Program is established to provide financial support for projects converting farm products, wastes, cellulose, or biogas directly into electricity or biofuel or other coproducts. Expires June 30, 2016.
- Distribution & Use
    - Tax Incentives
        - Sales to and use of non-highway biodiesel and biodiesel blends by farm fuel users are exempt from retail sales and use tax.
        - Sales and use of equipment used for retail sale of E85 and biodiesel blends of B20 or higher are exempt from retail sales and use tax. Sales of fuel delivery vehicles are exempt if at least 75% of the fuel is E85 or biodiesel blend of B20 or higher. Expires July 1, 2015.
        - Sales of equipment used for retail sale or use of wood biomass fuel blends containing at least 20% wood biomass fuel are exempt from retail sales tax. Sales of fuel delivery vehicles are exempt if at least 75% of the fuel is wood biomass fuel blends containing at least 20% wood biomass fuel. Expires July 1, 2009.
        - Retailers of biodiesel, E85 and wood biomass fuel eligible for B&O deduction. Expires July 1, 2015.
    - Financial Assistance
        - The Green Energy Incentive Account is established within the Energy Freedom Program to provide financial support for projects supporting development of a biofuels refueling network along the interstate corridors. Expires June 30, 2016.

- Renewable Portfolio Standard (RPS)/ Renewable Fuels Standard (RFS) - 2006
- Biomass Inventory 12/2005
- Feedstock Characterization 07/2007
- Energy Freedom Program: grants for bioenergy capital projects
- Biennial operating bioenergy budget
- Washington roadmap (Nine legislative studies underway)
- Center for Bioproducts & Bioenergy (WSU & PNNL)
- Beyond Waste Program (Organic waste to resources)

Appendix F

Selected promotions/financial incentives for biofuels in other countries

England

- Green Fuels Challenge
  - In the run up to Budget 2001, the Government will invite British industry to develop proposals for practical alternative fuels.
- Non-Fossil Fuel Obligation
  - Before the introduction of the Renewables Obligation, the Non-Fossil Fuel Obligation (NFFO) was the Government's major instrument for encouraging growth within the renewable energy industry. The NFFO applied in England and Wales. In Scotland and Northern Ireland, the Renewables Obligation (Scotland) (ROS) or the Northern Ireland NFFO (NI-NFFO) applied. The NFFO assisted the industry by providing premium payments for renewables-generated electricity over a fixed period, with contracts being awarded to individual generators.
- Renewables Obligation
  - The Renewables Obligation (RO) is the Government's main mechanism for supporting generation of renewable electricity.
  - The Renewables Obligation requires licensed electricity suppliers to source a specific and annually increasing percentage of the electricity they supply from renewable sources. The current level is 9.1% for 2008/09 rising to 15.4% by 2015/16.
  - The Obligation requires suppliers to source an annually increasing percentage of their sales from renewables. For each megawatt hour of renewable energy generated, a tradable certificate called a Renewables Obligation Certificate (ROC) is issued.
  - Suppliers can meet their obligation by:
    (1) acquiring ROCs
    (2) paying a buy-out price equivalent to £35.76/megawatt hour in 2008/09 and rising each year with retail price index;or
    (3) a combination of ROCs and paying a buy-out price.

    When a supplier chooses to pay the buy-out price, the money they pay is put into the buy-out fund. Following the end of an Obligation period, the buy-out fund is recycled to electricity suppliers presenting ROCS.
- Emissions Trading Scheme for GHG
  - The European Emissions Trading Scheme (EU ETS) has been introduced across Europe to encourage businesses to reduce greenhouse gas emissions. Defra has appointed the Environment Agency to regulate the scheme in England and Wales and we therefore raise charges to recover the costs of doing this work.

Italy

- Biomass Implementation Programme
- Fiscal incentives at biodiesel for transport
- Tax exemption of Biodiesel for heating purposes

Netherlands

- Fiscal instruments and green funds and agreements in various sectors of the bioenergy chain
- Demand and willingness to pay for green electricity

Appendix G

Final Report in Response to House Concurrent Resolution 195

Prepared by
The Hawai‘i Energy Policy Forum
April 9, 2007

This document is the final report by the Hawai‘i Energy Policy Forum (Forum) in response to House Concurrent Resolution 195 (HCR 195) adopted by the 2006 Legislature: “Encouraging Hawai‘i's landowners, investors, county governments, and regulated electric utilities to pursue development and conversion of fuel crops for electricity generation, and requesting the Hawai‘i Energy Policy Forum to make recommendations.”

HCR 195 required the Forum to issue recommendations on:

1. Financial incentives that may be necessary to stimulate development of fuel crops and the conversion of fuel crops to generate electricity, including incentives to reduce the risk of falling oil prices for investors;

2. The most suitable locations for undertaking biomass projects independent from, or in conjunction with, municipal solid waste-to-energy programs;

3. Options for leasing state land for fuel crop development;

4. Opportunities for state and county governments and private investors to secure federal grants to support the development of fuel crops and the conversion of fuel crops to generate electricity; and

5. The feasibility of setting up a revolving fund as a mechanism to provide incentives necessary to stimulate investment in fuel corps and the conversion of fuel crops to generate electricity.

In support of the objective of diversifying Hawai‘i’s energy system, two events were held in 2006: Governor Lingle convened the Biofuels Summit; and a stakeholder group including state, federal, private sector, and academia representatives organized the Hawai‘i Agriculture Bioenergy Workshop to explore the potential for a domestic bioenergy and biofuels future. Both events were held with the recognition that initiating a bioenergy industry in Hawai‘i must first address a diverse and very complex set of issues that involves many public and private stakeholders.

These two activities also demonstrated the effectiveness of facilitated collaboration and pointed to the value of coordination in the development of supply, production capability, and infrastructure - each requiring long independent lead times - which enables greater understanding and support by both public and private stakeholders.

In addition to the summit and workshop, the Forum gratefully acknowledges the assistance of the Department of Business, Economic Development and Tourism (DBEDT). DBEDT agreed to assist the Forum with its report to the Legislature. DBEDT engaged the Rocky Mountain Institute (RMI) to produce a report, Biomass – and Biofuels – to – Power to provide recommendations for the Forum to consider in preparation of its response to the Legislature. We thank DBEDT for its financial support to this effort.

The Forum developed its recommendations and report based on the above data and submitted it for vetting by the entire Forum membership. The recommendations herein are thus based in part on recommendations made in the RMI report and also on comments received from DBEDT, other Forum members and other interested parties, as well as a review of the outcomes from the Governor's Biofuels Summit and the Bioenergy Workshop.

Based on its analysis of these inputs, the Forum is pleased to make the following recommendations:

Forum Recommendations

1. Develop a State of Hawaiʻi Bioenergy Master Plan

While HCR 195 did not request an evaluation of the need for a Hawaiʻi Bioenergy Master Plan (HBMP), the Forum determined that such a Plan was both the logical outcome of the other recommendations that follow, and the Forum's proposed vehicle for addressing the issues that have been raised during the course of its evaluation.

- Objective: Given the complexity, diverse stakeholder groups, capital investment requirements, land-use and water supply issues, and supporting infrastructure requirements, the Forum recommends that a comprehensive Bioenergy Master Plan be developed with the objective of establishing a new bioenergy industry in Hawaiʻi.
- Responsibility: The Director of DBEDT, as the State Energy Resources Coordinator, should take the lead in developing the plan. (Reference: Chapter 196, Hawaiʻi Revised Statutes)
- Schedule: Because of the complexity and diverse interests involved, development of the plan should include the various stakeholder representatives and with sufficient resources and time (2 years) to prepare and vett the plan, including any supporting studies required to provide required data. A progress report should be delivered to the legislature at the start of the 2008 session. The final plan should be submitted to the 2009 Legislature.

- Scope: The plan should be action-oriented and should address (but not be limited to) the following issues:
    - Setting specific objectives, milestones, and timelines such that progress can be measured against clear metrics;
    - Water resources;
    - Land resources;
    - Distribution infrastructure for both marine and land;
    - Labor resources;
    - Technology to develop bioenergy feedstock and biofuels;
    - Permitting issues;
    - Financial incentives and barriers, and other funding issues;
    - Business partnering;
    - Policy requirements necessary for implementation of the master plan; and
    - Identification and analysis of the impacts of transitioning to a bioenergy economy.
- Resources: - Sufficient personnel and financial resources must be allocated to prepare the plan. Funding should be available to conduct the necessary studies, using both internal and external DBEDT resources, and to gather necessary data (example: survey of irrigation systems). While the Forum defers to the administering agency, it recommends adequate funding at the level of $1,000,000 over two years. However, both the detailed scope of work and the budget should be determined as the initial task of the HBMP. An updated budget should then be provided as part of the interim report at the end of the first year.
- Consultation: The plan should be developed with input from all interested stakeholders through the use of workshops, working groups, other means of coordination and communication, and, if appropriate, outside consultant services.

2. HCR 195 Requirement #1 – Financial Incentives

HCR 195 requested recommendations on financial incentives that may be necessary to stimulate development of fuel crops and the conversion of fuel crops to generate electricity, including incentives to reduce the risk of falling oil prices for investors.

- Recommendation: The Forum recommends that a system of financial incentives be developed. This should be an outcome of the Bioenergy Master Plan.
- Options development & analysis: Develop a variety of options, identify the advantages and disadvantages of each option, and attempt to quantify the impact through the development of financial models and conducting in-depth analysis.
- Gaming: To avoid unintended consequences, conduct "gaming" analysis to see how the incentive packages could be manipulated.
- Control and Feedback: Develop protocols for data requirements and models to determine the effectiveness of the incentives.

- Flexibility: Incentives must be designed so that they have the flexibility to be throttled back or ramped up to match market forces and the situation.
- Initial Options: The HEPF recommends that the Departments of Business, Economic Development & Tourism (DBEDT) coordinate with the following government departments and agencies to conduct in-depth analyses of the merits of the incentive package options listed below: Agriculture, Taxation, the Public Utilities Commission, and the Division of Consumer Advocacy. This analysis should be part of the Bioenergy Master Plan development work.

* *Incentive #1: Two-pronged sliding scale production tax credit, consisting of:*

Component #1: Links the current State de-taxation of biofuels to in-state feedstock production and quantity of biofuel in the blended product. The purpose of this incentive is to provide protection for Hawaiʻi's farmers given the market risks for investing in growing biofuel feedstocks and to focus Hawaiʻi taxpayer incentives on support for Hawaiʻi-based business; and

Component #2: Creates a state-level sliding-scale subsidy that goes to zero when oil prices are high, and increases when oil prices are low, effectively creating a hedge for consumers and a price floor for producers.

* *Incentive #2: Agriculture Infrastructure tax credit & Master Plan.*

Investment tax credit focused on building Hawaiʻi's irrigation systems. This is modeled on a similar credit being designed through the Department of Agriculture's Important Agricultural Lands' incentive program. A general fund appropriation should be considered.

* *Incentive #3: Distribution Infrastructure Investment Tax Credit & Master Plan.*

Investment tax credit focused on building Hawaiʻi's a bioenergy distribution network in cooperation with stakeholders. This includes bioenergy storage, pipelines, marine and land transport, and terminal infrastructure. The overall scope and the implementation of the infrastructure required to support a biofuels industry would be an outcome of the overall Hawaiʻi Bioenergy Master Plan. The level of investment tax credit required to support implementation would be an outcome of the Bioenergy Master Plan. A general fund appropriation should be considered.

* *Incentive #4: Research & Development Funding.*

Significant Hawaiʻi-specific research and development is needed to investigate potential biodiesel crop cultivars and micro-algae, improved varieties of sugar cane, new harvesting techniques, appropriate energy crops, and enhanced product utilization. Such an effort should be subsidized by the state through a grant fund that can be accessed by either public or private sector entities (HB 1003 HD3 and

SB 1943 SD1). The focus of the R&D effort should be defined in the Bioenergy Master Plan.

* *Incentive #5: Biodiesel Producer's Credit.*
The Hawai‘i Bioenergy Master Plan should include an evaluation of a state producer's credit for biodiesel that mirrors the state ethanol producer's credit.

3. HCR 195 Requirement #2 – Coordination of biomass projects and municipal solid waste-to-energy programs

HCR 195 requested recommendations on the most suitable locations for undertaking biomass projects independent from, or in conjunction with municipal solid waste-to-energy programs. The factors that should be considered in determining the location of biomass operations, specifically:

* Distance from biomass feedstocks;
* Distance from electric load centers;
* Interconnection issues; and
* Locations of landfills/transfer stations.
* County MSW programs

The actual siting of projects will require in-depth analysis and should be included in the Hawai‘i Bioenergy Master Plan effort, with adequate resources for assessing the various factors in location determination. It will likely require the assistance of outside consultants to execute properly and in the detail required to formulate concrete action items. The plan will also require close coordination with the counties which actually control the MSW.

4. HCR 195 Requirement #3 – Options for Leasing State Land for Fuel Crop Development

HRS §171-95 allows the Department of Lands and Natural Resources (DLNR) to lease public land to renewable energy producers for up to 65 years without public auction. There is ambiguity as to whether a person growing a fuel crop is a renewable energy producer.

- Recommendation #1: To enable feedstock producers to lease lands, HRS 171-95 should be amended to explicitly include feedstock producers in the definition of “renewable energy producer.”

- Recommendation #2: Amend HRS §171-95 to offer preferential rent prices for start-up biofuel crop growers.

- Recommendation #3: Provide an expedited review of permits for leasing state lands for growing biofuel crops.

5. HCR 195 Requirement #4 – Opportunities for state and county governments and private investors to secure federal grants to support the development of fuel crops and the conversion of fuel crops to generate electricity.

To facilitate and support the development of this industry, information on currently available grants and other opportunities should be easily accessible to interested investors and producers. It is therefore recommended that DBEDT maintain a comprehensive inventory of federal, state, and other opportunities and post the information on a suitable website. Additionally, it might also maintain a data base of contact addresses and send out email notifications as changes in funding opportunities occur.

6. HCR 195 Requirement #5 – Feasibility of setting up a revolving fund to provide incentives to stimulate investment in fuel crops and the conversion of fuel crops to generate electricity.

Based on examples of successful revolving loan funds described in the RMI report, a revolving loan fund is feasible; and the Forum thus recommends the establishment of a Hawai‘i Bioenergy Revolving Fund (“HBRF”) (Reference HB 1003 HD3). The HBRF would allow Hawai‘i entrepreneurs to transcend barriers associated with financing innovative projects and should target two (2) areas:

- Credit-worthiness: Lack of credit-worthiness particularly characterizes small and/or new entrepreneurs. Given the capital-intensity of the conversion and the storage/distribution segments of the biofuels/biomass value chain, small and/or new entrepreneurs would mostly be present in the agricultural segment of the biofuels value chain.

- Small-scale farming & biodiesel: Whereas crops grown to produce ethanol generally require large tracts of land and industrial-scale agriculture, biodiesel can often be grown at a small scale. Because of the smaller scale, these producers might struggle to find the necessary financing, and are therefore an ideal target for a revolving loan fund.

7. Additional Forum Recommendation – Assistance to Potential Local Growers

DBEDT should include in support of the HBMP, investigations and analyses of:

- The total cost per ton to grow and deliver alternative energy crops to bioenergy converters; and
- The need for local cooperatives for sharing of information, equipment, facilities, etc.

Appendix H:

HNEI April 2, 2009 Stakeholder Meeting Notes

Financial Incentives and Economic Impacts

1. What are the primary financial barriers that inhibit the economic feasibility and competitiveness of locally grown biofuels? *Participants were asked to brainstorm their ideas.*

    Costs

    - Price of oil
    - High cost of capital structure for bio-refineries
    - High cost of land, labor, energy, feedstock
    - Price at the pump is affected by taxes or the lack thereof
    - Cost of labor – is it a barrier or benefit? For example, agriculture wages are lower on the chart. The whole process of end-product might be a challenge against the Third World Market
    - Some operations have unionized labor and they do have living wages
    - There is an assumption about the work ethic of Hawai‘i is that that we don’t work very hard. People may presume they have to double labor costs
    - Cost to get the product to the end-user where it will be used. Cost of distribution
    - Cost of resources: politically, water, fertilizer
    - Critical mass – it’s hard to make a large economic plant for a small population

    Tax Credits/Incentives

    - Tax incentives – inconsistent funding. It is difficult to get funders to invest without an assurance of incentives, future, etc.
    - There aren’t consistent tax credits across all types of biofuel crops. That is a Federal and State issue
    - Some rules have changed on tax credits
    - We should look at the breakdowns project by project to figure out maximum tax breaks. What works elsewhere won’t necessarily work in Hawai‘i
    - Tax structure – pyramiding, off-set by tax incentives for biofuel growth

    Large Landowners

    - The availability of land to grow crops is limited to some large landowners. If they want to make money, they’ll diversify to other investments
    - Lack of commitment by large landowners
    - Looking for “silver bullet” vs. smaller scale production here that would fully benefit the state. “Large” doesn’t have to be “economically viable”

    Getting Buy-In/Investment

    - Is this a risk people are willing to put money into?

- Size – large $ are easier to get than small $
- There's an extremely widely held perception by institutions that it's difficult to do business in Hawai'i, from a regulatory standpoint. They don't want to invest here

Inexpensive Alternatives

- Cheap alternatives
- Cheap imports – competition (e.g., ethanol – already has existing infrastructure)

Recession

- The recession affects ability to raise funds
- The recession caused competition to get large amount of funds out there. People are more willing to invest in different areas at this time because of the market

Determining Which Crops to Invest In

- Some crops involve more labor than others. We need to examine this to determine which crops to invest in
- We lack a sense of direction regarding which crops we're going to be growing – it's hard to get investment if we don't know

Other Comments

- Fragmented distribution of available land
- Time is money – permitting process is time consuming
- Three-fifths of all biofuels went to Europe – totally changed dynamic in U.S.

2. In the next 2-3 years, what financial incentives will create economic feasibility and encourage the competitiveness of locally grown biofuels? *Participants were asked to brainstorm their ideas.*

Tax Incentives

- Monetize tax incentives; direct check at completion of project vs. tax credit
- Create tax credit incentives for growers and large landowners
- Need tax support for biofuels – but mandating is problematic

Other State Incentives

- Hope Hawai'i projects attract Stimulus Funding – deadline is May 29. Grants.gov is a resource. It is helpful if the State commits funding – matching funds are needed for the Federal funds
- Look at requiring vehicles that come here be able to use these fuels; educate consumers to make these changes

- Mechanism for fast-tracking permitting and new facilities might create better financial environment

Incentives for Co-Use/Co-Products

- Incentives across co-products need parity to make whole operation financially feasible
- There is a bill in the Legislature now looking at food and biofuels at same time and creating incentives for both rather than as competitors against each other

Financing Options/Incentives

- It is a 15-20 year financial commitment. If the State could guarantee a bridge (2 years) between balloon and re-financing and support corrections that needed to be made in operations over balloon time. This will allow for better chance of refinancing
- Hawaiʻi Clean Energy Initiative restructures debt on the balance sheet

Investor Incentives

- The State bundles projects into a size appealing to investors
- We need a clear definition on how the State handles these things, i.e., what will PUC do? Pay attention to everything the investment community is looking for – we need to shore up the process

Preference for Locally-Grown Biofuels

- A clearly stated and quantified preference for locally-grown biofuels – especially the State of Hawaiʻi using them in vehicles and facilities. This helps to calculate price advantage.
- Look at State procurement code for preference for buying local

Wheeling

- Bio-energy side, not just for biofuels. Also transportation. Feed-in tariff/wheeling
- Wheeling for biofuel-produced electricity instead of selling power to HECO for 50% of what they sell it for, can sell at 80%

Other Comments

- Some kind of incentive to landowners to put land in biofuel production vs. other kinds of development
- Act 221 – keep it alive and meaningful. 100% payback over 5 years

3. In the next 2-3 years, what policy changes will create economic feasibility and encourage the competitiveness of locally grown biofuels?
Participants were asked to brainstorm their ideas.

Hybrid Model

- The Hybrid Model is not totally tied to the price of oil, but somewhat tied; that could decrease over time. Using liquid fuels and electricity
- Integrated refineries producing both liquid and electricity. What role can public State and County play? What contribution can State make (lands, subsidies) to decrease the footprint required?

Tax Issues

- Carbon content of different biofuels. Local biofuels might have an advantage. Create premium for carbon advantaged biofuel. Create a carbon tax at State and national levels.
- Policy changes towards taxation of local fuels e.g., road tax. Price matters. State can shift their priorities by taxation policies. (That's how we can fund the bridge.)

Create Effective Storage System

- State should go after stimulus money to enable a decent battery (could be thermal, etc.) or environmentally sound storage system (e.g., Maui system is not able to store energy for use at another time). Need energy storage system for electricity especially
- On storage – non-storability hasn't been resolved internationally. Value of biofuel: can offset the intermittent nature of solar and wind.

Education/Shifting Perspectives

- Shift idea of change – change is good, should not be resisted. Doing things, not just talking
- Separate bad from good biofuels, attributes would go a long way towards community acceptance.

Other Comments

- Structuring stand-by Purchase of Power Agreements to accommodate night or low-end times, when solar or wind are not being used. Create the ability to bring power online or offline as needed. May help to incentivize
- Mandate use of biofuel for State vehicle fleets – would stimulate demand
- Note: electric vehicles are good, but if they plug into grid the it is a problem because the grid is powered by fossil fuels
- Bioenergy Master Plan is a great first step. Let's look at what the appropriate role of biofuels is in our energy future. Develop a roadmap where technology developments are expected. This helps at the policy level and decreases infighting
- Transparency at all levels of Road Map/Plan
- There is a bill in the Legislature now – looking at food and biofuels at same time – incentives for both rather than as competitors against each other
- Everyone is looking at their portfolio needs. If investors are assured they'll realize their investment, it'll increase investment. Shows State and County commitment to create loaning scenario without worry

- Policy changes within the university – Research and Development areas to enhance economic viability

4. *Original Question:* The Biofuel industry is often seen as a way to revitalize rural communities. Please share examples you know of that demonstrate the impact of the biofuel industry on rural communities. *Participants asked the Task Leader for clarification on this question.*

    - There are positives and negatives: Community support, opposition. This question targets change in the sense of "revitalizing" communities. This doesn't always happen. Is it more useful to ask about *any* impact?

    As a result, the Task Leader and group agreed to an amended question:

    Revised Question: The Biofuel industry is often seen as a way to change communities dependent on agricultural land or that have some connection to the land. Please share examples you know of that demonstrate the impact of the biofuel industry on these communities. *Participants were asked to brainstorm their ideas.*

    - If not for Kamehameha Schools buying Hamakua Sugar, that land would have been gentrified
    - Growing back to large scale agriculture, tens of thousands of acres. Need major placeholder for agricultural lands
    - Many rural communities – plantation model – huge community camps. The centralization happened when ag opportunities decreased. The job opportunities that were once there when they were plantation communities diminished. Biofuel is one way to incorporate the ag industry back into communities.
    - Impact on food security, i.e., if local biofuels are available, they can fuel equipment that can produce food locally (create available power)
    - Create more employment, increase local jobs, but trying to site a facility is not easy – it can be controversial
    - Level out income – more diversity of income, spread out over year, increase stability
    - Ability to keep family together in farming and related enterprises. Looking to train talent here – mechanical, fabricators, operators, increase opportunities for job skills learning. Not just jobs, but what they represent
    - Spin off industries from a large core ag operation, e.g, rum – trash goes to cattle farmers
    - Tourism associated with biofuel start to finish. People interested in ag tours and there is not much of that here now. Could be adjunct to biofuels
    - If we have a healthy ag industry tied together with biofuels it can contribute to critical mass. Irrigation systems, knowledge, training, fertilizers made from biofuels. Reframe Food vs. Fuel to Plants vs. Pavement
    - Absent of viable ag enterprises, we can't preserve ag nature of any plant – turns into payment

- Compatible land use that supports energy and agriculture
- This would create an increase in the use of roads, particularly by large vehicles. An advantage is that we could convert half of traffic to transportation of non-explosive ag products and we'd be better off. In other words, increase vehicles, decrease "bombs"
- Energy independence for communities – possibility? Depends on economies of scale
- Amount of pesticides/herbicides being used on biofuel crops could be high or low, depending on what used

5. What best practices would you recommend to assure a win/win experience for biofuel industries and rural/agricultural regions of Hawaiʻi? (How can we minimize negative impacts and optimize positive impacts?) *Participants were asked to brainstorm their ideas.*

<u>Water Management</u>

- Water delivery infrastructure – purchase water to support community, e.g., Kula (like "wheeling")
- The issue about water tables is that our state doesn't have a sophisticated water table system throughout all islands.
- Cleaning of water with nutrients – if irrigating to clean water, can possibly grow something ("Phytoremediation," e.g., plant in Pearl Harbor), ways to re-use water
- Hawaiʻian Electric is re-using water through "RO" – reverse osmosis
- We need to work more aggressively to stop water runoff, minimizing runoff to ocean, and reefs, replenish water tables in aquifers, perhaps produce power, use dams to capture water and minimize loss and runoff
- Hamakua Coast – is there a way to use runoff water (stop it?). This is a policy issue
- Plant biofuel crops in areas that could contain or border some of water runoff. Manage plantings to minimize runoff

<u>Co-Use</u>

- Look at Food and Biofuels at the same time – incentives for both rather than compete (Bill in Legislature now)
- Food/Fuel working together. Specific example – 2 industries come together and share irrigation costs and integrate operations. Ecosystem benefits
- There may be increased opportunity for biomass to solve some problems on agricultural land and produce a product, e.g., like salvaging bush (the devil's in the details on this)

<u>Community Engagement</u>

- Engage the community – first and foremost. Crucial, especially if public lands. Must have the support, endorsement and desire of community

- A model that includes all pieces would allow decision analysis capabilities within State to see how pieces fit together. Take system to community to increase understanding and get input, help them see where important connection points are, and how it can benefit or interfere. Allows for increased discussion.
- Development of leadership and communities – rely on transparency

Other Comments

- Educate legislators and policy makers – make sure they understand details we're discussing today. Can't assume policy-makers understand
- Land stewardship policies – what the impact of different planting will be – harvest methodologies. Major potential negative impact
- Fully integrated system – feed, fuel, lumber products – everything put together – social aspect, keep community viable, e.g., byproducts from one becomes feedstock for another
- Ensure this industry can generate enough revenue to support a critical mass. Otherwise, we will lose young people who move away from the State. Real jobs for people. Must support other economies in State. Can't just benefit a small group of people or large landowners
- Align selves with State's initiative toward sustainability, degrees in sustainability at college level
- Biofuels from feedstock to production – resources for Best Practices:
    - International: Roundtable on Sustainable Biofuels
    - National: Sustainable Biodiesel Alliance
- A philosophical question – what else can we bring here? Issue of diverse solutions
- Can stabilize the price fluctuations of electricity
- Can stop money from flying out the door to BP and Shell (related to transportation)

Appendix I:

Obstacles were grouped into seven primary categories: 1) Costs, 2) Tax credits/ incentives, 3) Large landowners, 4) Getting buy-in investment, 5) Inexpensive alternatives, 6) Recession, 7) Crop selection. The barriers were then matched to existing and proposed State and Federal incentives.

Barrier:TAX / FINANCIAL INCENTIVES

FINANCIAL BARRIERS	STATE-EXISTING	TYPE	STATE- PROPOSED	TYPE	NATIONAL-EXISTING	TYPE
Tax incentives	High Tech Business Investment Tax Credit	Tax Credit	Energy; SPRBS; BioEnergy Hawai‘i, LLC	Special purpose revenue bonds	Alternative Fuel Excise Tax Credit	Tax Credit
	Tax Credit for Research Activities	Tax Credit	Biofuels Facility; Nameplate Capacity; Gallons Produced	Tax credit	Biodiesel Income Tax Credit	Tax Credit
	Ethanol Facility Tax Credit (EFTC)	Tax Credit (refundable)			Small Agribiodiesel Producer Credit	Tax Credit
	State general excise exemptions / Enterprise Zones	Tax Exemption			Small Ethanol Producer Credit	Tax Credit
	State Business Tax Credit / Enterprise Zones	Tax Credit			Volumetric Ethanol Excise Tax Credit (VEETC)	Tax Credit
	Reduced Tax Rates for Alternative Fuels	Favorable Rates of Taxation			Renewable Diesel Tax Credit [by the EPA 2005]	Tax Credit
					Special Depreciation Allowance for Cellulosic Biomass Ethanol Plant Property	Depreciation Allowance
					Farm Bill 2008	Federal Grant Program/Tax Credit
Inconsistencies in financial across different crops			Renewable Energy; Biodiesel Feedstock; Appropriations (HB 246)	Grant and Subsidy		

Perceived barriers not addressed by current or proposed incentives:

- Inconsistencies in financial incentives across different crops
- Inconsistent funding
- Inconsistencies over supply chain
- Tax structure

- Changing tax credits

Barrier: Cost

FINANCIAL BARRIERS	STATE-EXISTING	TYPE	STATE- PROPOSED	TYPE	NATIONAL-EXISTING	TYPE
High cost of capital structure for bio-refineries	Ethanol Facility Tax Credit (EFTC)	Tax Credit (refundable)	Renewable Energy; Biomass; Appropriation	Funding	Biorefinery Project Grants	Research Grants
	State general excise exemptions / Enterprise Zones	Tax Exemption			Cellulosic Biofuel Producer Tax Credit	Tax incentive
	State Business Tax Credit / Enterprise Zones	Tax Credit			Cellulosic Biomass Ethanol and MSW Loan Guarantee Program	Federal Loan Program
					Business and Industry (B&I) Guaranteed Loans	Federal Loan Program
					Farm Bill 2008	Federal Grant Program/ Tax Credit
					Improved Energy Technology Loans	Loan
High cost of land, energy, feedstock	Farm and Aquaculture Sustainable Projects Loan	State Loan Program	Renewable Energy; Biodiesel Feedstock; Appropriations	Grant and Subsidy	Biomass Commercial Use Grant Program	Grant
			Biodiesel; Market Stimulation	Market stimulation incentives	Cellulosic Biofuel Production Incentives	Awards
			Public Land Leases; Renewable Energy	Land availability		
Price at the pump is affected by taxes or the lack thereof	Alcohol Fuels Excise Tax Exemption	Tax Exemption			Biodiesel Income Tax Credit	Tax Credit
	Reduced Tax Rates for Alternative Fuels	Favorable Rates of Taxation				
Transporting product to end-user			Electric Vehicles; Energy Efficient Industry Development	Tax credit	Alternative Fuel Infrastructure Tax Credit	Tax Credit
			Transportation; Energy Efficient Vehicles	Tax credit	Credit for Installation of Alternative Fueling Stations	Credit
			Hawaiʻi Clean Energy Initiative In Transportation Energy (HB 489)	Tax credit		

Perceived barriers not addressed by current or proposed incentives:

- Price of oil

- Cost of labor/ unionized labor/ non-livable wages
- Cost of resources
- Critical mass

Barrier: LARGE LAND OWNERS

FINANCIAL BARRIERS	STATE- EXISTING	TYPE	STATE- PROPOSED	TYPE	NATIONAL- EXISTING	TYPE
Lack of commitment by large landowners			Public Land Leases; Renewable Energy	Land availability		
			Renewable Energy Facilities; Conservation and Agricultural Districts; Special Management Areas	Land availability		

Perceived barriers not addressed by current or proposed incentives:
- Availability of land is limited to some large landowners
- Large vs. smaller scale production

Barrier: GETTING BUY-IN/ INVESTMENT

FINANCIAL BARRIERS	STATE- EXISTING	TYPE	STATE- PROPOSED	TYPE	NATIONAL- EXISTING	TYPE
Risks			Renewable Energy Opportunity Zones	Investment Encouragement	Business and Industry (B&I) Guaranteed Loans	Federal Loan Program
			Enterprise Zone (EZ) Program	Promote private sector business growth		

Perceived barriers not addressed by current or proposed incentives:
- Large money is easier to get than small money
- Time is money permitting process

Barrier: INEXPENSIVE ALTERNATIVES

FINANCIAL BARRIERS	STATE- EXISTING	TYPE	STATE- PROPOSED	TYPE	NATIONAL- EXISTING	TYPE
Cheap alternatives			Hawai‘i Clean Energy Initiative; Transportation	Mandatory rules promoting Alter. Fuels		
			Hawai‘i Clean Energy Initiative In Transportation Energy	Mandatory rules promoting Alter. Fuels		

Cheap imports			Energy Resources; Alternate Energy	Promote the use of local energy sources		

Barrier: RESEARCH

FINANCIAL BARRIERS	STATE-EXISTING	TYPE	STATE-PROPOSED	TYPE	NATIONAL-EXISTING	TYPE
Lack of General knowledge about bioenergy			Hawai‘i Clean Energy Initiative (HCEI) - Energy Efficiency (HB 488)	Special Funds for Research and Public Awareness Programs	Biodiesel Engine Testing Program [by the EPA 2005]	Grants
					Biomass Commercial Use Grant Program	Grant
					Bioenergy Program – University Biodiesel Program	Grant
					Advanced Biofuel Technologies Program	Grant
					Farm Bill 2008	Federal Grant Program/Tax Credit
					Biobased Fuels and Products Outreach and Education Program	Grant
					Sun Grant Research Initiative Act of 2003	Research Grants

Barrier: CROP SELECTION

FINANCIAL BARRIERS	STATE-EXISTING	TYPE	STATE-PROPOSED	TYPE	NATIONAL-EXISTING	TYPE
Lack sense of direction in crop selection					Biomass Research and Development Initiative	Grants

Perceived barriers not addressed by current or proposed incentives:

- Variation in labor requirement, crop by crop basis

The two categories with the highest number of accompanying incentives were “Cost” and “Tax Credits/ Incentives.” For barriers, stakeholders cited the high cost of capital structure for bio-refineries, high cost of land, energy and feedstock, price at the pump is affected by taxes or the lack thereof, and transporting product to end-user. These barriers are seemingly addressed by the Ethanol Tax Credit, State General Excise Exemptions/ Enterprise Zones, Farm and Aquaculture Sustainable Projects Loan, Alcohol Fuels Tax Exemption and the Reduced Tax Rates for Alternative Fuels.

Regarding “Tax/ Financial Incentives,” stakeholders found that they could not rely on the tax incentives and also that the funding incentives were inconsistent across different crops. It appears that, with regard to the tax incentives in place (High Tech Business Investment Tax Credit; Tax Credit for Research Activities, Ethanol Facility Tax Credit, State General Excise Exemptions/ Enterprise Zones; State Business Tax Credit/ Enterprise Zones; Reduced Tax Rates for Alternative Fuels), the experience of the stakeholders suggests that, despite the large number of incentives, they are insufficient for development and/or growth of a biofuels business.

There were several barriers within these two categories that were not addressed by any existing or proposed incentives. These include the price of oil; cost of labor/unionized labor/ non-livable wages; cost of resources (assumed to be feedstock); critical mass; inconsistencies in financial incentives across different crops; inconsistent funding; inconsistencies over supply chain; tax structure; and changing tax credits.

There were far fewer incentives for barriers within the categories Large Land Owners, Getting Buy-In/ Investment, and Inexpensive Alternatives.

The category “research” and its barrier- lack of general knowledge about bioenergy- was addressed by several existing Federal incentives, but by only one proposed State incentive and no existing State incentives.

The category “crop selection” and its barrier- lack of sense of direction in crop selection- was aligned with one existing Federal incentive. The barrier- variation in labor requirement, crop-by-crop basis- was not addressed.

Incentives are heavy in the conversion and distribution phases of the supply chain and limited in the feedstock production phase.

Appendix J

Sample Survey

On a scale of 1-7 please rate the level of significance of these risks to biofuel production, **7 being a very significant risk and 1 being not a very significant risk.** Please highlight the number that represents the appropriate level.							
Feedstock Production							
Price Risks							
Labor availability							
Known	1	2	3	4	5	6	7
Unknown	1	2	3	4	5	6	7
Real estate market price pressure	1	2	3	4	5	6	7
Production- imported feedstack spread vs. fixed cost	1	2	3	4	5	6	7
Water costs	1	2	3	4	5	6	7
Contract Risks							
Lead time for feedstock vs. market deman(security of deman)	1	2	3	4	5	6	7
Climate change/seasonality vs, demand	1	2	3	4	5	6	7
Biofuel Production							
Price Risks							
Feedstock-product spreads vs. fixed costs	1	2	3	4	5	6	7
Duration of federal tax credits	1	2	3	4	5	6	7
By product market	1	2	3	4	5	6	7
size and pricing	1	2	3	4	5	6	7
Contract Risks							
Tenure of off-take contract vs. debt	1	2	3	4	5	6	7
Secruity of feedstock supply/ availability/ liquidity	1	2	3	4	5	6	7
Credit worthy off-takers	1	2	3	4	5	6	7
Distribution and Storage							
Price Risks							
Product spread vs. fixed cost	1	2	3	4	5	6	7
Duration of federal tax credits	1	2	3	4	5	6	7
Contract Risks							
Investment recovery of biofuels infrastructure (terminals/ stations)	1	2	3	4	5	6	7
Credit worthy suppliers	1	2	3	4	5	6	7
End Use							
Price Risks							
Biofuels cost vs. pertroleum fuel	1	2	3	4	5	6	7
Duration of federal tax credits	1	2	3	4	5	6	7
Contract Risks							
Credit-worthy suppliers	1	2	3	4	5	6	7

Appendix K

U.S. DEPARTMENT OF AGRICULTURE DEPARTMENTAL REGULATION
Number: 5600-003
SUBJECT: USDA Roles in Market-Based Environmental Stewardship
DATE: December 20, 2006
OPI: Natural Resources Conservation Service

PURPOSE This regulation sets forth the policy of the United States Department of Agriculture (USDA) with regard to actions that enable the application of scientifically sound market based environmental stewardship approaches to improve environmental quality at a lower cost to society and to establish a departmental coordination council to facilitate activities necessary to implement this policy.

SPECIAL INSTRUCTIONS/CANCELLATIONS This Departmental Regulation will be in effect until superseded.

BACKGROUND Market-based environmental stewardship approaches provide market participants flexibility to undertake actions that have the lowest cost. Many market-based approaches have been shown to result in more cost-effective achievement of natural resource conservation and environmental goals compared to traditional regulatory approaches and to accelerate the rate of environmental improvements. Market-based approaches and voluntary reporting registries may include many environmental factors including greenhouse gases, water, air, wetlands, and wildlife habitat.* *Mechanisms may include credit trading, insurance, mitigation banking, competitive offer-based auctioning, and eco-labeling.

POLICY The U.S. Department of Agriculture (USDA) seeks to broaden the use of private sector markets for environmental goods and services through emerging voluntary market mechanisms such as environmental credit trading and voluntary reporting registries. USDA believes market-based environmental stewardship can encourage competition, spur innovation, and achieve environmental benefits, while helping USDA constituents comply with environmental regulations. Effective private sector markets require consistent, well-defined, and quantifiable environmental goods and services. USDA actions should help to enable the application of scientifically sound market-based environmental stewardship approaches to improve environmental quality at a lower cost to society. This includes developing and evaluating tools and methods to encourage participation. Given this, USDA managers are encouraged to employ flexibility when addressing specific goals and objectives that can facilitate USDA constituents' participation in private sector environmental market initiatives. Accordingly, it is the policy of USDA to:
A) Cooperate with other Federal departments, as well as Tribal, State, and Local government and nongovernmental organizations in:

(1) Establishing a role for agriculture and forestry in providing environmental offsets and enhancements; and

(2) Developing accounting practices and procedures for quantifying environmental goods and services.

B) Facilitate consistent, efficient, and effective agency level policies, programs, and activities to enable USDA constituents and partners to take advantage and promote awareness of environmental stewardship markets.

C) Promote use of environmental credit trading and voluntary reporting registries, as well as other environmental market-based stewardship approaches, to help fulfill USDA natural resource conservation missions and improve environmental quality within the scope of agency authorities.

D) Develop, test, and evaluate innovative tools and methods, including those for identifying and quantifying environmental impacts, which support market-based environmental stewardship.

E) Encourage and conduct research and technology development to assess and improve the understanding and management of natural resources and conservation practices, and systems, and to ensure that policy and programs have a firm scientific basis.

F) Conduct outreach, education, technology transfer, and partnership building activities with USDA constituents and others, using long established and proven institutional arrangements, as well as establishing new innovative partnerships to enlist the involvement of interested USDA constituents and others in market-based environmental stewardship.

G) Foster knowledge within USDA agencies of environmental stewardship markets. This policy does not create any right or benefit, or trust responsibility, substantive or procedural, enforceable by a party against the United States, its agencies or instrumentalities, its officers or employees, or any other person.

This policy does not alter or amend any requirement under statute, regulation, or Executive Order. This policy applies only to USDA agencies and programs and does not affect State, Local or Tribal laws, procedures, or regulations.

USDA MARKET-BASED ENVIRONMENTAL STEWARDSHIP COORDINATION COUNCIL

This policy hereby establishes the USDA Market-Based Environmental Stewardship Coordination Council. The Council will be chaired by the Under Secretary for Natural Resources and Environment. Membership will be comprised of the Under Secretary for Research, Education, and Economics; Under Secretary for Farm and Foreign Agricultural Services; Under Secretary for Rural Development; the Chief Economist; the General Counsel; and other officers as may be deemed appropriate by the Council. The Council will facilitate Departmental activities necessary to implement the Department Policy as established by this memorandum. Council members may identify executive level designees.

To carry out the activities identified and approved by the Council, the Council will establish a work group comprised of appropriate agencies and offices that they determine have roles in implementing this policy. The work group may include, but not be limited to, representatives from the following agencies and offices: Agricultural Research Service; Cooperative State Research, Education, and Extension Service; Economic Research Service; Forest Service; Farm Service Agency; Natural Resources Conservation Service; Office of the Chief Economist; and, Office of General Counsel. The work group will report to leadership within these agencies and offices respectively, as identified by the Council, and this leadership group will report to the Council.

The member Mission Areas, Offices, and Agencies of the Council are to contribute personnel, administrative, and programmatic resources as needed, and determined by them consistent with their delegated authorities and appropriations, to carry out these duties.

Hawaii Bioenergy Master Plan

Business Partnering

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December 2009

Executive Summary

In order for Hawaii to have a productive bioenergy industry, successful partnering amongst industry "players" is essential. This section of the Hawaii Bioenergy Master Plan specifically evaluates facilitating the bioenergy industry through partnerships across and between sectors of the bioenergy value chain, and partnership with other organizations that control access to critical resources such as land and water.

Hawaii's bioenergy industry is in its infancy. Research found that a significant number of Partners demonstrate interest and intent—especially in the area of bioenergy conversion/processing— but most Partners have not yet reached the stage of commercial production. From a business partnership perspective, the following was noted:

- Partnering between various processes within the value chain is required for the vast majority of models identified.

  For the purposes of this report, a model is an example of the bioenergy production value chain that has differing partnership-handoff points/roles.

- More Partners are needed to fulfill identified functions. Many of the Partners are not necessarily associated with the bioenergy industry and thus the industry would benefit from a facilitator who can identify and match potential partners in the process chain.

- A greater number of Partners is needed in the Growing Processes area. Independent producers of bioenergy feedstock (biostock) are rare. Among the models with nearer term biostock production capability, a vertical integration was commonly found whereby the organization controls the processing and develops the biostock.

- Facilitative partnerships should be viewed on a per-island basis due to the economic obstacles of interisland shipping. One notable exception is in the transportation and distribution of liquid biofuels where there may be existing infrastructure.

- More information on production capacity (growing and processing) is needed and would greatly facilitate partnership identification and Partner planning.

The following represent key recommendations for advancing the bioenergy industry in Hawaii:

- **Provide "first-mover" incentives**
  In order to motivate the industry and build capacity in functions supporting the bioenergy industry, the State can provide incentives for early implementation of bioenergy production.

- **Develop and maintain a bioenergy Partner database**
  A database of Partners, similar to the Bioenergy Partner Catalog in this report, would facilitate identification of partners for organizations without complete vertical integration, and assist with the identification of opportunities to fill the gaps in the bioenergy industry. This would benefit the State, in its industry facilitation efforts, as well as the private sector Partners.

- **Provide incentives to growers**
  Qualitative and quantitative information collected for this report indicates a need for greater capacity in bioenergy feedstock production. The objective of encouraging greater growing capacity can be approached from either end of the bioenergy value chain, but the authors believe that incentivizing growers directly is more effective for this objective.

- **Facilitate partnerships through a matchmaker**
  The State can significantly encourage necessary bioenergy partnerships through the creation of a position or program that facilitates such partnerships by identifying and encouraging needed Partners, introducing appropriate Partners, and acting as an industry advocate and government liaison.

Contents

Introduction

Topic overview/background

There has been significant interest in bioenergy production in Hawaii for many years, in part due to the favorable environmental conditions for growing energy crops, relatively high energy costs, high dependence on imported fossil fuels, and large inventories of agricultural land sitting idle due to the decline of sugarcane and pineapple production. In addition, increasing concern for the environment and recent erratic oil prices have served to add urgency to seeking alternative energy solutions for Hawaii.

This concern, however, is not reflected in the level of bioenergy output in the state. The bioenergy industry faces many obstacles and the State--in recognition of the importance of this industry and challenges facing it--has mandated[1] the development of a Hawaii Bioenergy Master Plan (HBMP) to determine ways to facilitate development of the industry. This section of the HBMP specifically evaluates facilitating the bioenergy industry through partnerships within and between sectors of the bioenergy value chain, and partnership with other organizations that control access to critical resources such as land and water.

Bioenergy value chain (Biomass Research and Development Board, 2008)

Why this area is important to development of the Bioenergy Master Plan

A healthy bioenergy industry requires coordination and integration across the value chain and beyond. As examples: Without access to suitable land, biomass feedstock cannot be grown in economically feasible volumes; without reliable supplies of feedstock from growers, biomass convertors cannot justify investments in production facilities or produce consistent amounts of bioenergy; without an effective distribution system for the bioenergy product, end users cannot consume the bioenergy.

Interdependencies such as these are particularly critical during the formation of an industry. Without an already-established industry with partners in place, potential bioenergy participants are often unable or unwilling to move forward with their plans due to missing or insufficient partners—essentially a "chicken-and-egg" issue. As an example: A biomass converter may require knowing they will have a source of feedstock

[1] Act 253, Part III, Section 4, SLH 2007

prior to investing/implementing, while a farmer may need to know he has a market for the crop before investing/planting. In order for Hawaii to have a meaningfully productive bioenergy industry, successful partnering amongst industry "players" is essential.

Objectives

The objectives of this report are:

- To identify and evaluate business partnering arrangements at points along the value chain (feedstock production, feedstock logistics, conversion, bioenergy distribution, and end use) that can contribute to the production of bioenergy at levels sufficient to contribute a significant renewable energy resource to the state.
- To provide information, analysis, and recommendations related to this evaluation.
- To capture a significant portion of the models and partners in bioenergy production and produce information useful for identifying partnering opportunities from existing Hawaii-based organizations, as well as identifying needed partners.

Scope of work/activities

In order to identify bioenergy partnering arrangements for Hawaii's bioenergy industry, the authors first established a set of working definitions and framework with which to describe the data captured. This approach is detailed below:

Framework of bioenergy business partnering

A framework (below) of bioenergy production process and requirements was developed to capture and describe the Models[2] and role(s) of Partners, and subsequently validated with project leaders[3] and Dr. Charles Kinoshita[4].

Grow Bioenergy Feedstock (Biostock)													Process Biostock Into Bioenergy Product												Byproduct Value Conversion						Transport							
SubProcesses						Requirements							SubProcesses					Requirements							Sub		Requirements				Sub			Requirements				
Field Prep	**Planting**	**Irrigation**	**Cultivation**	**Harvesting**	**Collect/Transport to Processor**	Capital	Labor	Technical expertise	Water	Permits/Regulation	Community acceptance	Land	**Receive Biostock**	**Preprocessing**	**Pay Producer/ Aggregator**	**Convert to Bioenergy Product**	**Prep for Delivery**	Technical Expertise	Permits/ Regulations	Capital	Labor	Land	Community acceptance	Biostock Supply/Consistency	**Remove Byproducts**	**Payment**	Capital	Labor	Infrastructure	Permits/ Regulations	**Receive Bioenergy Consumable**	**Transport**	End User Ability to Use	Capital	Labor	Product volume & consistency	Infrastructure	Permits/ Regulations

Bioenergy Partnering Framework

2 "Models" – Examples of bioenergy production value chains that have differing partnership-handoff points/roles in the Framework.
3 Scott Turn and Priscilla Thompson, Hawaii Natural Energy Institute, University of Hawaii
4 Associate Dean of Academic Affairs, College of Tropical Agriculture and Human Resources, University of Hawaii

Descriptions of functions of the Framework

Grow Bioenergy Feedstock (Biostock)

- Field Preparation – Land clearing and grading; tillage
- Planting – Propagating and/or establishing biostock material (typically plants)
- Irrigation – Delivering irrigation water from the source to the crop
- Cultivation – Activities involved with maintaining growth such as fertilization and weed control
- Harvesting – Reaping the energy crop (biostock product)
- Collect/Transport to Processor – Aggregating the biostock product from one or more growers and delivering to the processor
- Capital – Fulfills/helps fulfill the requirement of startup capital and/or subsidizes operating capital for the Grow Biostock process
- Labor – Fulfills/helps fulfill the labor requirement of Grow Biostock process
- Technical expertise – Provides technical expertise to facilitate the Grow Biostock process
- Water – Provides water for biostock irrigation
- Permits/Regulation – Provides, facilitates, or enforces permits/laws/regulations required by operators in the Grow Biostock process
- Community acceptance – Facilitates acceptance of the Grow Biostock operation by the community in which it operates
- Land – Provides land for the Grow Biostock process

Process Biostock into Bioenergy Product

- Receive Biostock – Takes delivery of raw biostock
- Preprocessing (possibly geographically distributed) – Activities to prepare the raw biostock for Conversion, such as cleaning, milling, and oil extraction
- Pay Producer/ Aggregator – Paying for the raw biostock
- Convert to Bioenergy Product – Converting the biostock into commercial bioenergy product(s), using methods such as transesterification, hydrolysis, fermentation, pyrolysis, gasification, or combustion
- Preparation for Delivery – Activities after conversion to prepare the bioenergy product for delivery such as loading trucks
- Technical Expertise – Provides technical expertise to facilitate the Process Biostock Into Bioenergy Product process
- Permits/ Regulations – Provides, facilitates, or enforces permits/laws/regulations required by operators in the Process Biostock Into Bioenergy Product process

- Capital – Fulfills/helps fulfill the requirement of startup capital and/or subsidizes operating capital for the Process Biostock Into Bioenergy Product process
- Labor – Fulfills/helps fulfill the labor requirement of Process Biostock Into Bioenergy Product process
- Land – Provides land for conversion facilities
- Community Acceptance – Facilitates acceptance of the Process Biostock Into Bioenergy Product operation by the community in which it operates
- Biostock Supply/ Consistency – Assists with consistency of biostock supply volumes and properties, as a biostock aggregator might do

Byproduct Value Conversion (residue streams from the *Process Biostock into Bioenergy Product* process that are not intended for bioenergy production: glycerin, stillage, etc.)
- Remove Byproducts – Physically removing the byproducts from the conversion facility
- Payment – Either paying for the conversion of byproducts or paying the byproduct remover, as in a tipping fee
- Capital – Fulfills/helps fulfill the requirement of startup capital and/or subsidizes operating capital for the Byproduct Value Conversion process
- Labor – Fulfills/helps fulfill the labor requirement of Byproduct Value Conversion process
- Infrastructure – Provides physical infrastructure to facilitate removal and value conversion
- Permits/ Regulations – Provides, facilitates, or enforces permits/laws/regulations required by operators in the Byproduct Value Conversion process

Transportation and Distribution (of commercial bioenergy product)
- Receive Consumable Bioenergy – Takes delivery of bioenergy product
- Transport – Delivers bioenergy product from conversion facility to end user or distribution points
- End User Ability to Use – Alters bioenergy product for end use, as in splash mixing ethanol with gasoline
- Capital – Fulfills/helps fulfill the requirement of startup capital and/or subsidizes operating capital for the Transportation and Distribution process
- Labor – Fulfills/helps fulfill the labor requirement of Transportation and Distribution process
- Infrastructure – Provides physical infrastructure to transport and/or store bioenergy products

- Product Volume & Consistency – Assists with consistency of biostock supply volumes and properties, as a bioenergy distributor might do
- Permits/ Regulations – Provides, facilitates, or enforces permits/laws/regulations required by operators in the Transportation and Distribution process

Models - Definition

"Models" – *Examples of bioenergy production value chains that have differing partnership-handoff points/roles in the Framework.*

Partners – Definition

"Partners" – *(primarily) Hawaii organizations that fulfill, intend to fulfill, or would logically fulfill functions of the Framework.*

Identification of stakeholders, experts, information sources

Stakeholders, experts, and information sources for this task were identified as follows (see *References* for detailed listings):

- Stakeholders – From bioenergy Stakeholder meeting[5] hosted by the Hawaii Natural Energy Institute of the University of Hawaii (HNEI) as well as Partners captured in the Bioenergy Partner Catalog.
- Experts – Recommendations for Subject Matter Experts (SMEs) were solicited from the HNEI project team leaders and Dr. Charles Kinoshita. Subsequent SME contact resulted in identification of additional SMEs.
- Information Sources – Interviews with SMEs, Partner websites, Partner data validation, Internet research, articles and other publications.

Areas of study

The focus of the research for this report was to identify business partnering models and partnerships that would facilitate bioenergy industry growth in Hawaii. To this end, Models and Partners were researched and documented within the Framework described above. A Hawaii-based focus was used for Partner identification, and to a lesser degree Model identification.

For each of the Models, the team sought the following information:

- Advantages and shortcomings
- Participants (partners) in the Model, including location, and name and type of organization (cooperative, government agency, private firm, etc.) where possible
- Roles each participant played within the Framework
- Bioenergy feedstock crop involved
- Bioenergy conversion technology involved

[5] "Hawaii Bioenergy Master Plan Stakeholders Meeting," April 2, 2009, Japanese Cultural Center

- Bioenergy end product
- Major byproducts of the primary conversion process
- Government subsidies or other incentives received
- General description and other notes about the Model
- Example(s) of organizations identified with the Model
- Source of the Model information captured

For each of the Partners, the team sought the following information:

- Company name
- Website address
- Contact name, phone number, and email
- City, State, and Island (if Hawaii) of operations
- Role(s) the partner plays within the Framework
- Bioenergy feedstock crop produced (if applicable)
- Bioenergy conversion technology used (if applicable)
- Bioenergy end product produced (if applicable)
- Capacity of production (acres grown or annual conversion capacity)
- Status of operations (production or in planning)
- Company description/notes
- Source of the Partner information captured

Activities undertaken

Between January 2009 and May 2009, the project team endeavored to fulfill the objectives of this project through the following activities:

Summary

1. Established an understanding of the project objective, scope, and protocols.
2. Developed a structure for describing the bioenergy business partnering environment and opportunities for the bioenergy industry.
3. Collected information from experts, stakeholders, and secondary research.
4. Developed a listing of bioenergy business partnering models.
5. Developed a catalog of Hawaii bioenergy business partners.
6. Analyzed the collected information to identify opportunities for facilitating a bioenergy industry in Hawaii through business partnerships.
7. Formally documented the activities, data, analysis, and recommendations.

Project Management

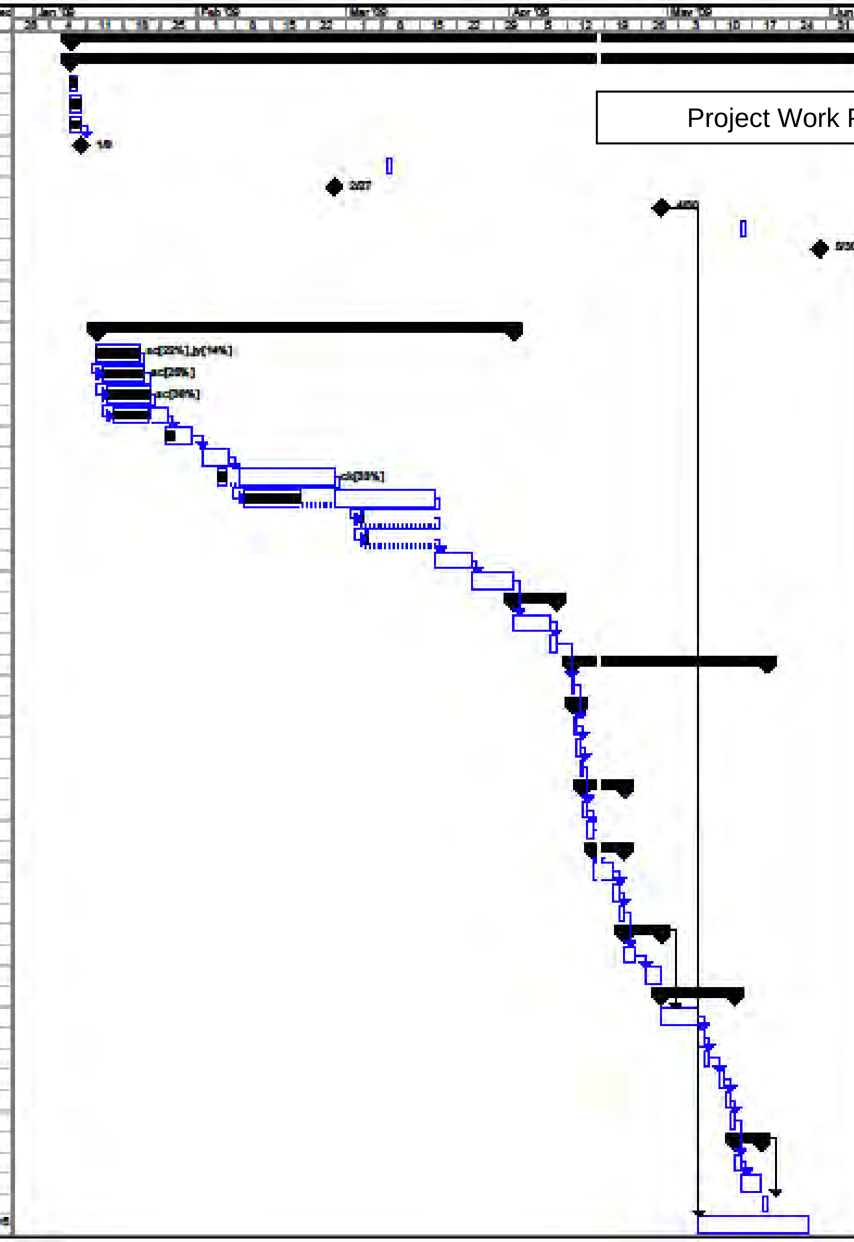
Members of the Agribusiness Incubator Program of the University of Hawaii (AIP) and Dr. Charles Kinoshita met with HNEI project leaders to discuss assisting HNEI with development of the Hawaii Bioenergy Master Plan (HBMP). HNEI divided the HBMP into Tasks, one of which was labeled as Task 9: Business Partnering. AIP agreed to develop the report for Task 9 and formed a project team consisting of two members of AIP, with Dr. Kinoshita serving an advisory role.

To manage this project (the research and development of the Business Partnering report), the team:

- Confirmed requirements, communication methods, and scope of the project. Significant clarifications of scope included the focus on Hawaii-based Partners and inclusion of key bioenergy conversion byproducts.
- Developed a detailed work plan (see *Project Work Plan* diagram below):

Project Work Plan

ID	Task Name	Duration	Start	Finish	Predec
1	Task 8: Business Partnering	258 days	1/8	12/14	
2	Project administration	258 days	1/8	12/14	
3	Clarify scope, definitions, deliverables	1 day	1/8	1/8	
4	Develop workplan	2 days	1/8	1/9	
5	Develop proposal	2 days	1/8	1/9	
6	Proposal signoff	0 days	1/9	1/9	5
7	Task focus meeting	1 day	3/9	3/9	
8	Progress report	0 days	2/27	2/27	
9	Final draft task report	0 days	4/30	4/30	
10	Integration meeting	1 day	5/15	5/15	
11	Final task report	0 days	5/30	5/30	
12	Draft Plan stakeholder review meeting	1 day	7/1	7/1	
13	Final draft plan meeting	1 day	10/15	10/15	
14	Final plan meeting	1 day	12/14	12/14	
15	Gather and document information	54 days	1/13	4/1	
16	Develop information gathering approach	5 days	1/13	1/20	
17	Identify processes and subprocesses	5 days	1/14	1/21	16
18	Identify process requirements	5 days	1/15	1/22	17
19	Identify existing partnering models in Hawaii and beyond	5.25 days	1/16	1/26	18
20	Identify other partnering models/opps	5 days	1/26	1/30	19
21	Identify potential partners for each requirement	5 days	2/2	2/6	20
22	Identify stakeholders, technical experts, and information sources	15 days	2/5	2/26	21
23	Seek expert feedback on identified models/opps	25 days	2/10	3/17	22
24	Incorporate feedback into processes and subprocesses	10 days	3/4	3/17	23
25	Incorporate feedback into process requirements	9 days	3/5	3/17	24
26	Incorporate feedback into documentation of existing partnering models	5 days	3/18	3/24	25
27	Incorporate feedback into documentation of other partnering models/opps	5 days	3/25	4/1	26
28	Make recommendations	6 days	4/2	4/9	
29	Promote each step in value chain to support hypothetical biofuel use	5 days	4/2	4/8	27
30	Any other support of the objectives of this Task and/or Plan	1 day	4/9	4/9	29
31	Produce report (draft)	27 days	4/13	5/19	
32	Abstract/Executive summary	0.5 days	4/13	4/13	30
33	Introduction	1 day	4/13	4/14	
34	Overview/background	0.5 days	4/13	4/13	32
35	Why areas is important to master plan	0.5 days	4/14	4/14	34
36	Objectives	0.5 days	4/14	4/14	35
37	Scope of work/activities	6 days	4/15	4/22	
38	Identification of stakeholders, experts, info sources	1 day	4/15	4/15	36
39	Areas of study	1 day	4/16	4/16	38
40	Activities undertaken	4 days	4/17	4/22	
41	Research and analysis	2 days	4/17	4/20	39
42	Meetings/surveys	1 day	4/21	4/21	41
43	Other	1 day	4/22	4/22	42
44	Findings	5 days	4/23	4/29	
45	Summary of data collected	2 days	4/23	4/24	43
46	Analyses (status, trends, data constraints)	3 days	4/27	4/29	45
47	Recommendations for Master Plan	10 days	4/30	5/13	
48	Actions and policy initiatives (including Task List guidance?)	5 days	4/30	5/6	44
49	Budget	1 day	5/7	5/7	48
50	Timeline	1 day	5/8	5/8	49
51	Lead organization	1 day	5/11	5/11	50
52	Potential funding source	1 day	5/12	5/12	51
53	Recommendations for further research (new)	1 day	5/13	5/13	52
54	Appendices	3 days	5/14	5/18	
55	Stakeholder list/meeting participants	1 day	5/14	5/14	53
56	Analyses, tables, figures, supporting information	2 days	5/15	5/18	55
57	References	1 day	5/19	5/19	54
58	Final Task Plan Report	15 days	5/7	5/27	9FS+5

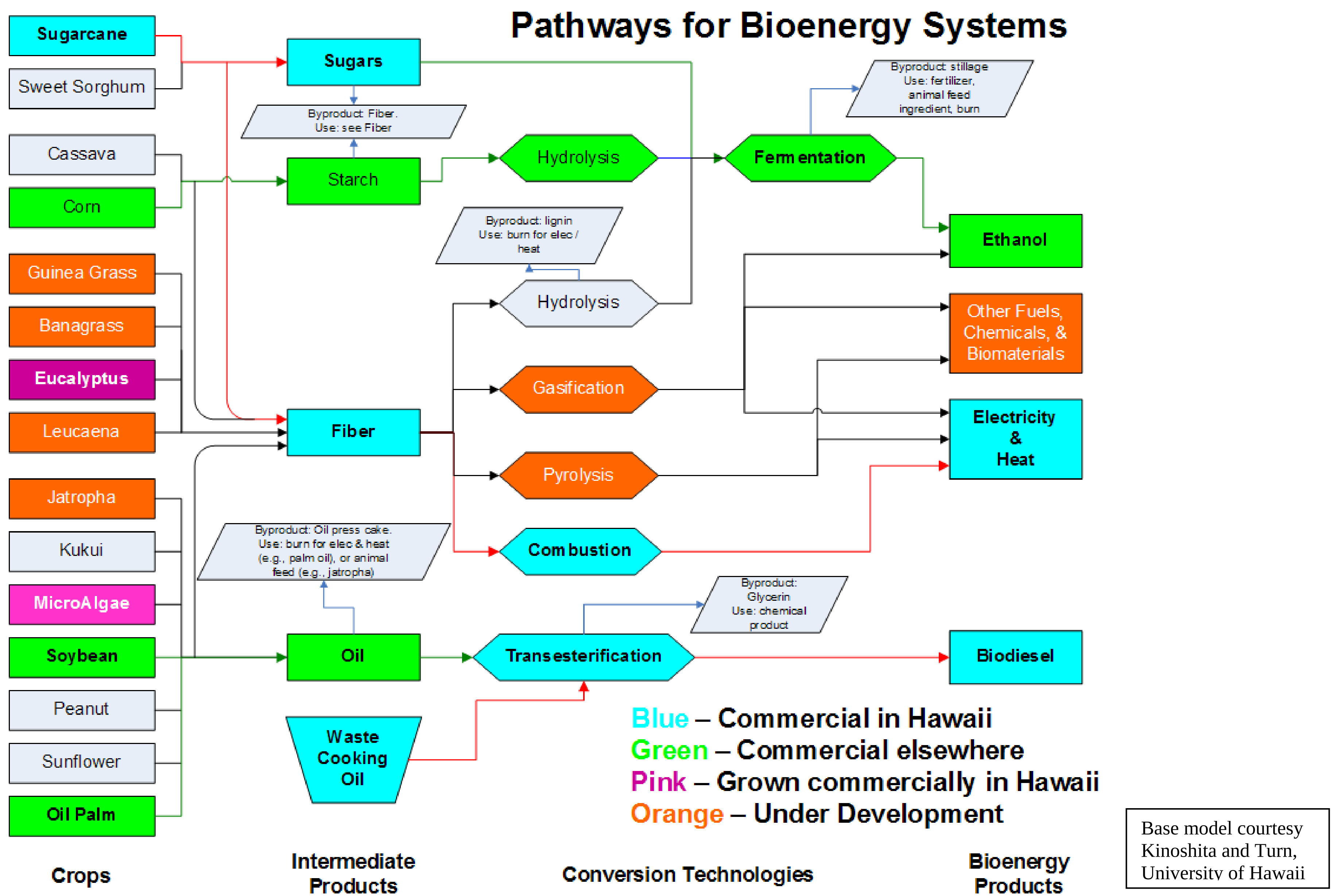


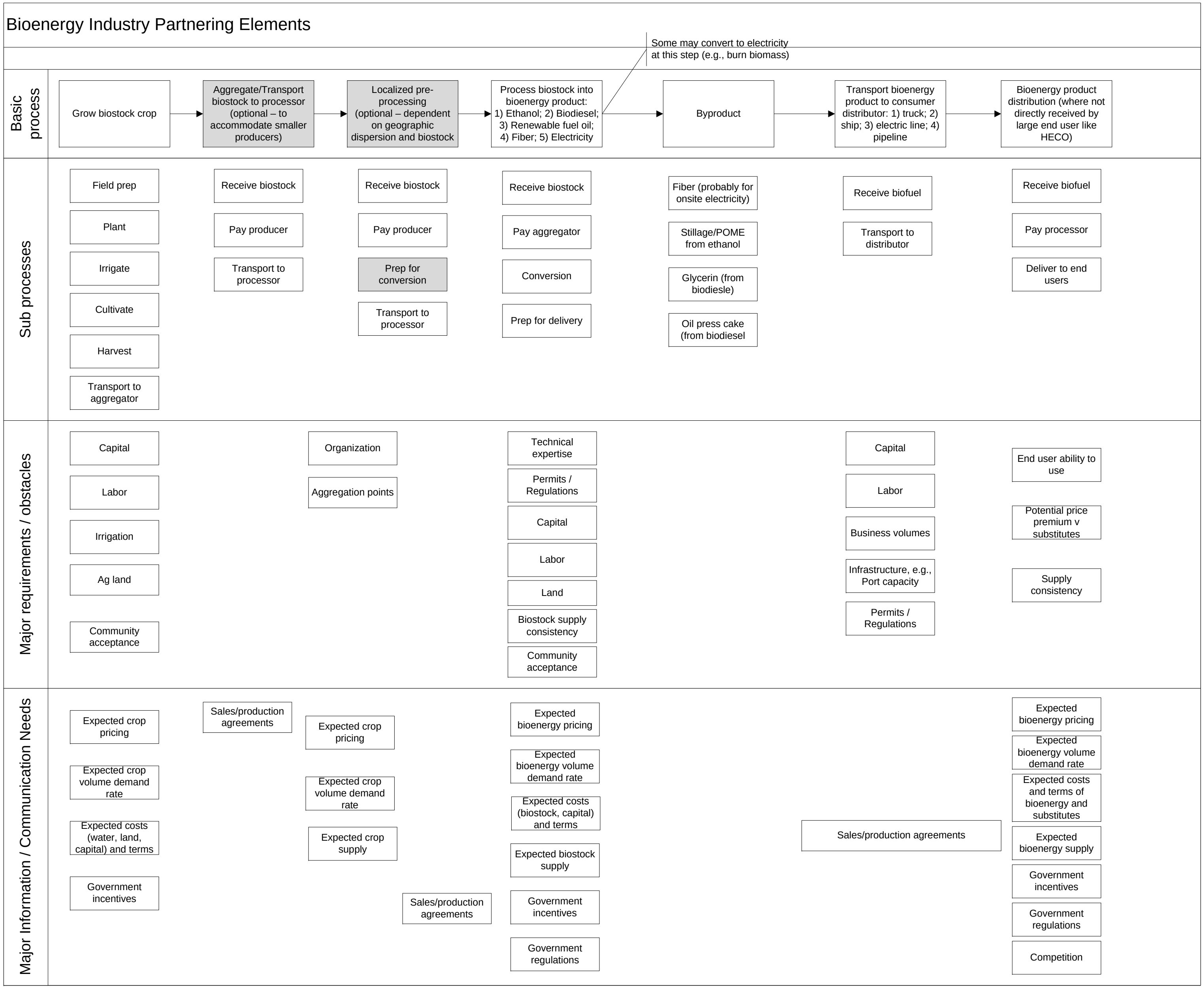
Research and Analysis – Approach

The team then established a foundation for shared understanding and a framework for the approach by performing the following activities:

- Discussed bioenergy value chain and models with project lead.
- Developed and validated a definition of Models and Partners.
- Expanded upon an existing model *Pathway for Bioenergy Systems*[6] with subsequent validation to identify characteristics (types, uses, related conversion technologies, processes) of bioenergy production byproducts and the scope of byproducts in this report (see *Pathways for Bioenergy Systems* diagram below).
- Developed and validated a process map of bioenergy production and key requirements (see *Bioenergy Business Partnering Elements* diagram below) in order to identify the handoff opportunities in the overall process, the significant requirements of each major process area, and the communication requirements between process owners. Validated the accuracy and intended use in identifying and describing business partnering.
- Developed a bioenergy production Framework to graphically (via a matrix) describe the bioenergy production process and requirements, Partners, and Models.
- Documented and validated an approach to capture information using the developed definitions and Framework, and the methods for analyzing the captured data to craft recommendations for this report:
    - Models are used to identify business partnering opportunities, and indicate successful models of business partnering. Specific Partners identified in the Models enhance the catalog of known and potential Partners.
    - A catalog of Partners allows for identification of imbalances in the number and capacity of Partners in various areas of the bioenergy value chain in order to suggest areas of relative weakness.

[6] Kinoshita and Turn, University of Hawaii


Pathways for Bioenergy Systems
Sugarcane
Sweet Sorghum
Cassava
Corn
Guinea Grass
Banagrass
Eucalyptus
Leucaena
Jatropha
Kukui
MicroAlgae
Soybean
Peanut
Sunflower
Oil Palm
Sugars
Byproduct: Fiber. Use: see Fiber
Starch
Fiber
Byproduct: Oil press cake. Use: burn for elec & heat (e.g., palm oil), or animal feed (e.g., jatropha)
Oil
Waste Cooking Oil
Hydrolysis
Fermentation
Byproduct: stillage Use: fertilizer, animal feed ingredient, burn
Byproduct: lignin Use: burn for elec / heat
Hydrolysis
Gasification
Pyrolysis
Combustion
Byproduct: Glycerin Use: chemical product
Transesterification
Ethanol
Other Fuels, Chemicals, & Biomaterials
Electricity & Heat
Biodiesel
Blue – Commercial in Hawaii
Green – Commercial elsewhere
Pink – Grown commercially in Hawaii
Orange – Under Development
Crops
Intermediate Products
Conversion Technologies
Bioenergy Products
Base model courtesy Kinoshita and Turn, University of Hawaii


Bioenergy Industry Partnering Elements
Some may convert to electricity at this step (e.g., burn biomass)
Basic process
Grow biostock crop
Aggregate/Transport biostock to processor (optional – to accommodate smaller producers)
Localized pre-processing (optional – dependent on geographic dispersion and biostock
Process biostock into bioenergy product: 1) Ethanol; 2) Biodiesel; 3) Renewable fuel oil; 4) Fiber; 5) Electricity
Byproduct
Transport bioenergy product to consumer distributor: 1) truck; 2) ship; 3) electric line; 4) pipeline
Bioenergy product distribution (where not directly received by large end user like HECO)
Sub processes
Field prep
Plant
Irrigate
Cultivate
Harvest
Transport to aggregator
Receive biostock
Pay producer
Transport to processor
Receive biostock
Pay producer
Prep for conversion
Transport to processor
Receive biostock
Pay aggregator
Conversion
Prep for delivery
Fiber (probably for onsite electricity)
Stillage/POME from ethanol
Glycerin (from biodiesle)
Oil press cake (from biodiesel
Receive biofuel
Transport to distributor
Receive biofuel
Pay processor
Deliver to end users
Major requirements / obstacles
Capital
Labor
Irrigation
Ag land
Community acceptance
Organization
Aggregation points
Technical expertise
Permits / Regulations
Capital
Labor
Land
Biostock supply consistency
Community acceptance
Capital
Labor
Business volumes
Infrastructure, e.g., Port capacity
Permits / Regulations
End user ability to use
Potential price premium v substitutes
Supply consistency
Major Information / Communication Needs
Expected crop pricing
Expected crop volume demand rate
Expected costs (water, land, capital) and terms
Government incentives
Sales/production agreements
Expected crop pricing
Expected crop volume demand rate
Expected crop supply
Sales/production agreements
Expected bioenergy pricing
Expected bioenergy volume demand rate
Expected costs (biostock, capital) and terms
Expected biostock supply
Government incentives
Government regulations
Sales/production agreements
Expected bioenergy pricing
Expected bioenergy volume demand rate
Expected costs and terms of bioenergy and substitutes
Expected bioenergy supply
Government incentives
Government regulations
Competition

Research and Analysis – Data collection

Based on the shared understanding developed above, the team then developed data collection tools and collected relevant information from a variety of sources by performing the following activities:

- Developed and validated a *Bioenergy Model/Partner Capture* form (see *Appendix - Bioenergy Production Models - Model Capture Form*) to define the information to capture for each model. Form was used to capture bioenergy production models in Hawaii and beyond and includes:
    - Identification of the source of the information
    - Name of the model
    - Biostock crop, bioenergy end product, and byproducts involved
    - Relative advantages of this model identified
    - Relative disadvantages of this model identified
    - Description of the model
    - Sources of any subsidies to the model
    - Partners in the model, their location, type of organization (e.g., cooperative or private business), and the functions they performed within the Framework. Where a number of participants in a Model serve the same function, they are identified as a single Partner (i.e., 20 independent growers providing bioenergy feedstock may be listed as a single "Independent Growers" Partner for that Model).

- Developed and validated a *Bioenergy Business Partner Information Gathering Form* (see *Appendix - Bioenergy Business Partners - Bioenergy Partner Catalog Capture Form*) to define the information to capture for each partner. Form was used to document current and potential bioenergy partners in Hawaii and includes:
    - Organization Name
    - Contact information (contact name, phone, email, website)
    - Location (city, island, state)
    - Products (specific biostock or bioenergy products)
    - Status (currently performing or intent to perform the functions described)
    - Product Capacity (acres of biostock, units of measure for bioenergy)
    - Description (brief company description)
    - Functions performed within the Framework

- Performed interviews with project leaders, experts identified by project leaders (see *References – Subject Matter Experts*), Dr. Kinoshita, and other SMEs to collect information using the *Bioenergy Model/Partner Capture* form (see *Meetings and/or Surveys* section below for further detail). Interviewees did not limit discussion to Models and Partners and thus other information/opinions/perspectives were also captured.

- Captured Model and Partner data at the Stakeholder meeting by distribution of data collection forms, verbal solicitation, and topic-specific breakout sessions. Here again, participants in breakout sessions provided information that, while not specifically related to Models and Partners, added context and perspectives that were captured and appear in this report in the *Appendix – Stakeholders - Stakeholder meeting data (Business Partnering Breakout Sessions)* section.

- Solicited Model and Partner data through emails to Stakeholder meeting attendees and invitees. The then-current collections of Models and Partners were made publicly available on the HNEI website as well as the related data capture forms for validation and feedback (www.hnei.hawaii.edu/bmpp/stakeholders.asp).

- Through Web searches and review of literature, identified and recorded Model and Partner information (see *References - Publications and Internet Sources*).

<u>Research and Analysis – Information Extraction</u>

The collected data was compiled in two documents: one for the various Models (see *Appendix – Bioenergy Production Models – Model Data*) and one for the Partners (see *Appendix – Bioenergy Business Partners – Bioenergy Partner Catalog*). Information from the data collection (including interviews and Stakeholder breakout sessions) informed and influenced the team's recommendations for business partnering.

The Bioenergy Partner Catalog was created in a spreadsheet format to facilitate sorting, counting, and comparing the data. From this data the team was able to identify gaps in Partner capacity that, if closed, would strengthen Hawaii's bioenergy industry. In addition, the spreadsheet format would facilitate migration of the data to a database, a key element in one of the recommendations.

<u>Meetings and/or Surveys</u>

Multiple meetings/interviews were held with SMEs for this report and a joint Bioenergy Stakeholder meeting was held to provide access to stakeholders for all contributors to the HBMP, as well as provide information and a feedback opportunity to the stakeholders. The SMEs are listed in the *References* section and the stakeholder meeting agenda is listed in *Appendix – Stakeholder Meeting Agenda*.

Findings

Summary of data collected

<u>Models</u>

13 Models were identified (see *Appendix – Bioenergy Production Models – Model Data*). These are labeled:

- Algae-Based Transportation Fuel Model
- Biodiesel from Oil Seeds Model
- Community-Based Waste Cooking Oil Model
- Cooperative Growing (Australian) Model
- Cooperative Model
- Cooperative-Based Biodiesel Model
- Generic Fiber to Electricity (common) Model
- Generic Sugar/Starch to Ethanol (common) Model
- Imported Seed Oil Model
- Lihue Plantation Model
- Sugar Plantation Model
- Thermal Gasification Model
- Vertically Integrated Model

An average of just over four Partners was involved in each model, with a minimum of two and a maximum of seven Partners. Not coincidentally, perhaps, this corresponds with the number of major processes (four) in the Framework. More assuredly, it is clear that a number of Partners are required for the complete bioenergy value chain.

Note that where a number of participants in a Model serve the same function, they are counted as a single Partner (i.e., a Model that has 20 independent growers providing bioenergy feedstock counts the growers as a one Partner). Consider also that the Partner count is very likely underestimated in the Requirements subareas of the Framework due to the lack of detailed information on many Models and the variety of organizations typically required to fulfill the diversity of requirements.

Given the significant number of partnerships required for the bioenergy value chain and the complexity of most business partnerships, facilitating the identification of appropriate partners and the partnering itself would contribute significantly to the development of a meaningful bioenergy industry in Hawaii.

Partners

56 Partners were identified (see *Appendix – Bioenergy Business Partners – Bioenergy Partner Catalog*). Statistics based on data captured about these Partners are listed in the following tables:

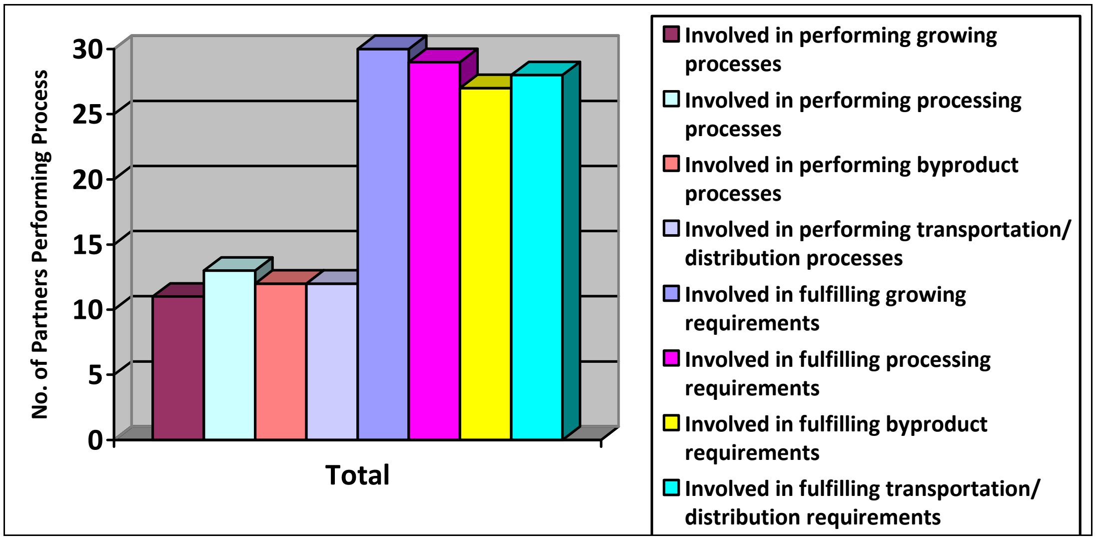
Table 1 (below) shows the number of Partners who participate in the subareas of the Framework. As stated above, there are a larger number of Partners needed to serve the diversity of the Requirements subareas, and consequently we find 2.4 times more Partners participating in these subareas versus the Process subareas.

Table 1: Summary of Framework Function Participation by Status

Criteria	Currently Performing	Intend to Perform	Total
Status of performing functions of the Framework	39	17	56
Involved in performing **growing** processes	8	3	11
Involved in fulfilling **growing** requirements	27	3	30
Involved in performing **processing** processes	5	8	13
Involved in fulfilling **processing** requirements	21	8	29
Involved in performing **byproduct** processes	4	8	12
Involved in fulfilling **byproduct** requirements	19	8	27
Involved in performing **transportation/distribution** processes	10	2	12
Involved in fulfilling **transportation/distribution** requirements	26	2	28

Figure 1 (below) graphically illustrates the data in Table 1, grouped by Processes and Requirements subareas. This reveals a surprising degree of parity of Partner participation across Framework major processes, for both Processing as well as Requirements subareas.

Figure 1: Comparison of Total Participation by Framework Major Process Area



Due to the unexpected parity demonstrated in Figure 1, the team analyzed the data with the addition of a qualitative filter: Instead of counting Partners who have any participation, only those Partners who perform/intend to perform a significant portion (greater than 50% of listed functions) of Process subareas were counted. Table 2 (below) contains the result of this analysis.

Table 2: Significant Process Participation by Status

Criteria	Currently Performing	Intend to Perform	Total
Involved in performing **growing** processes	4	3	7
Involved in performing **processing** processes	3	8	11
Involved in performing **byproduct** processes	3	7	10
Involved in performing **transportation/distribution** processes	10	1	11

Figure 2 graphically illustrates the relative weakness in number of Partners in the Growing process subarea. This is confirmed by SME feedback, as well as the team's observation that organizations with meaningful participation in the Growing processes are almost exclusively the same organizations that expect to Process the biostock into bioenergy.

Figure 2: Comparison of Significant Participation by Framework Major Process Area

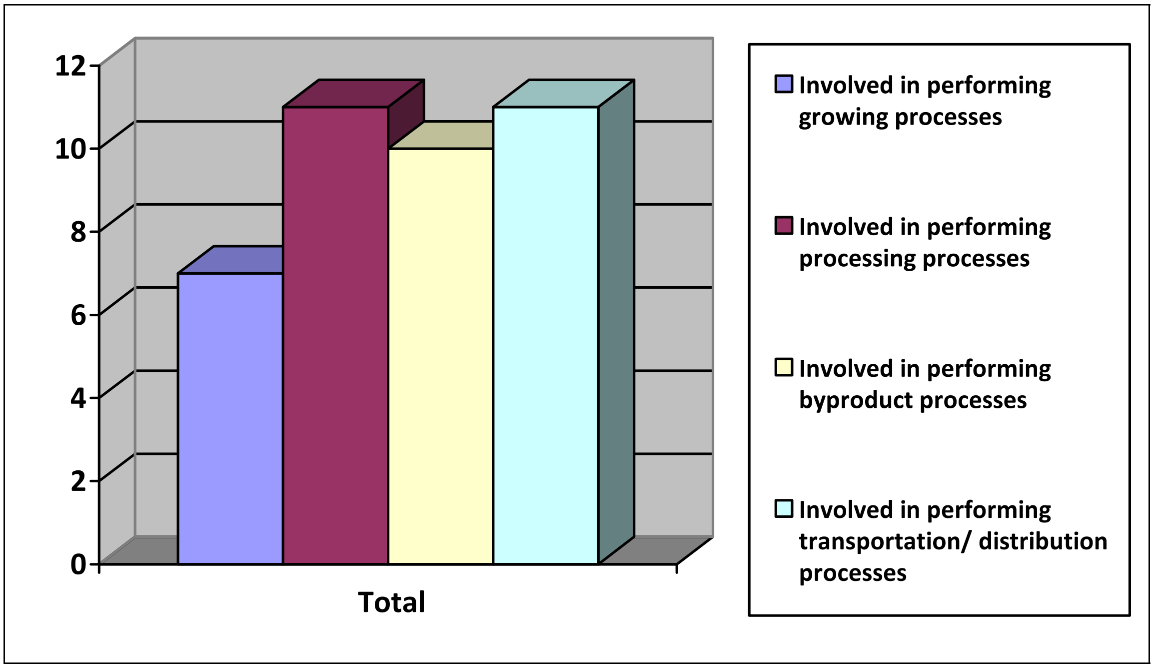


Table 3 lists the number of Process (versus Requirement) Partners by island and major process. The last column is a count of all partners for that island, including Requirement Partners. Note that the counts include both Partners 'Currently Performing' and 'Intending to Perform'.

Table 3: Major Process Partner Participation by Island

Service Area	Process Partners, by Major Process				Process and Requirement Partner Totals
	Grow	Process	Byproduct	Transport	
Hawaii	3	4	4	4	9
Lanai	0	0	0	0	1
Kauai	1	1	1	1	6
Maui	3	4	4	6	11
Oahu	3	4	3	4	12
Statewide	1	0	0	1	16

Table 4 details Partner counts for each of the functions of the Framework, by island. It is expected that interisland transportation of the biostock to conversion facilities (and to a lesser degree the handoffs between other major processes) presents economic obstacles that would indicate a per-island bioenergy value chain.

Table 4: Function Coverage by Island

	Grow BioEnergy Feedstock (Biostock)												
	SubProcesses						**Requirements**						
Island	**Field Prep**	**Planting**	**Irrigation**	**Cultivation**	**Harvesting**	**Collect/Transport to Processor**	Capital	Labor	Technical expertise	Water	Permits/Regulation	Community acceptance	Land
Hawaii	2	2	1	2	2	2	4	2	3	1	3	1	2
Kauai	1	1	1	1	1	1	3	1	1	0	2	1	3
Lanai	0	0	0	0	0	0	0	0	0	0	0	0	1
Maui	2	2	2	2	2	3	5	3	3	2	3	3	4
Oahu	1	1	2	1	1	2	4	2	5	1	3	2	3
Statewide	0	0	0	0	0	1	5	2	1	0	4	0	3
TOTAL	6	6	6	6	6	9	21	10	13	4	15	7	16

	Process Biostock Into Bioenergy Product											
	SubProc					**Requirements**						
Island	**Receive Biostock**	**Preprocessing**	**Pay Producer**	**Convert to Bioenergy Product**	**Prep for Delivery**	Technical Expertise	Permits/ Regulations	Capital	Labor	Land	Community acceptance	Biostock Supply/Variety Consistency
Hawaii	3	3	3	4	3	4	4	5	4	3	3	3
Kauai	1	1	1	1	1	1	2	3	1	3	1	1
Lanai	0	0	0	0	0	0	0	0	0	1	0	0
Maui	4	4	4	4	4	4	4	6	4	5	4	4
Oahu	3	3	3	4	3	4	4	5	3	4	3	3
Statewide	0	0	0	0	0	0	4	5	2	3	0	0
TOTAL	11	11	11	13	11	13	18	24	14	19	11	11

	Byproduct Value Conversion						**Transport**						
	SP		**R**				**SP**		**R**				
Island	**Remove Byproducts**	**Payment**	Capital	Labor	Infrastructure	Permits/ Regulations	**Receive Bioenergy Consumable**	**Transport**	End User Ability to Use	Capital	Labor	Product volume & consistency	Infrastructure
Hawaii	4	2	5	4	3	3	3	4	3	4	3	5	4
Kauai	1	1	3	1	1	2	1	1	1	3	1	1	1
Lanai	0	0	0	0	0	0	0	0	0	0	0	0	0
Maui	4	4	6	4	4	4	6	6	4	8	6	6	6
Oahu	3	3	5	3	4	4	4	4	4	6	4	5	5
Statewide	0	0	5	2	0	4	1	1	1	6	3	1	1
TOTAL	12	10	24	14	12	17	15	16	13	27	17	18	17

The team had intended to report on Partner capacities of major functions (acres of biostock production capacity, millions of gallons of ethanol production per year, etc.) but could not gather sufficient data points from Partners for meaningful reporting. This data would be useful in:

- Developing capacity comparisons between major processes (growing vs. conversion) for a high level view of capacity mismatches.
- Identifying capacity gaps between specific biostock crops and conversion technologies that can utilize the biostock.

Continued effort to collect this data is critical if answers to these questions are desired.

Analyses – Status, Trends, Data Constraints

Hawaii's bioenergy industry is in its infancy. While a significant number of Partners demonstrate interest and intent—especially in the area of bioenergy conversion/processing — most Partners have not yet reached the stage of commercial production. From a business partnership perspective, the following key points are indicated by the research findings (including interviews and stakeholder feedback):

- Partnering between subprocesses is required for the vast majority of Models and, especially at this stage of the industry, would benefit from a facilitator that identifies and matches appropriate Partners.

- There is a relatively greater number of Partners needed to fulfill the functions of the Requirements subareas (land, water, etc.). These Partners are not necessarily associated with the bioenergy industry and thus the industry would benefit from a facilitator for identification of Requirements Partners for the Subprocess Partners.

- A greater number of Partners are needed in the Growing Processes. Independent producers of bioenergy feedstock (biostock) are rare. More commonly found among the models closest to production is a vertical integration with the organization controlling the processing also developing the biostock.

- Facilitative partnerships should be viewed on a per-island basis due to the economic obstacles of interisland shipping. One notable exception is in the transportation and distribution of liquid biofuels if infrastructure already exists.

- More information on production capacity (growing and processing) is needed and would greatly facilitate partnership identification and Partner planning. It is likely that the lack of information is exacerbated by the nascent nature of the Partner businesses.

- It is evident to the authors that a lack of partnerships is a significant obstacle to industry traction at this stage of the industry. The problem is colloquially known as a “chicken-and-egg” problem: Investment in and construction of conversion facilities are pending certainty of biostock supply; potential suppliers of biostock (growers) await a known buyer (processors) before committing to planting; potential investments in distribution modifications await a bioenergy product to distribute. A few Partners with vertically integrated operations and assets, or control thereof, are positioned to overcome this obstacle and would be sensible targets for “first mover” incentives to encourage commercial implementation. This may provide benefits to other Partners if the implementation produces critical mass in areas to which they have access.

Recommendations for Bioenergy Master Plan:

Actions and policy initiatives

As this report was mandated by the State of Hawaii, the recommendations herein assume actions performable by the agents of the State of Hawaii. The recommendations are further focused by the objective of: Increasing the amount of bioenergy production in the State through facilitation of business partnering. Finally, specific financial incentives and permit facilitation are covered elsewhere in the HBMP, therefore, these recommendations define the targets for the incentives.

1. **<u>Provide "first-mover" incentives</u>**

   In order to overcome the "chicken and egg" phenomenon and build capacity in functions supporting the bioenergy industry, the State can provide incentives for early implementation of bioenergy production. The selection of incentives is best determined by the Partners themselves, but this can be generally assumed to include incentives that reduce the risk of being pioneers (financial risk, risk of legal/regulatory setbacks, etc.). Examples might include: A floor on the price of imported oil; loan guarantees or bonds; purchase commitments for the bioenergy products, and; clarification/development of laws and regulations. Closely related is Recommendation 3, as Growing Partners/biostock production is a common bottleneck in the value chain in Hawaii.

   The objective of these incentives is to encourage quick implementation, thus some incentives should have an expiration date. Identification of likely Partners (facilitated by the Partner Database—see Recommendation 2) and criteria for qualifying for the incentives should include "shovel readiness[7]" and capacity. Furthermore, the State should initially work with a County to focus on developing the Partners on a single island that contribute to a productive value chain.

2. **<u>Develop and maintain a bioenergy Partner database</u>**

   A database of Partners, similar to the Bioenergy Partner Catalog in this report, would facilitate identification of partners for organizations without complete vertical integration, and assist with the identification of opportunities to fill the gaps in the bioenergy industry. This would benefit the State, in its industry facilitation efforts, as well as the private sector Partners.

   As previously noted, capacity information is largely absent from the Bioenergy Partner Catalog therefore a continuing effort to collect this (and other) information would provide the data to answer questions that are critical for bioenergy industry partnerships.

[7] The speed with which the Partner can implement and be in commercial production, including considerations of resources and partnerships already in place, i.e., how much of the Framework is ready or near ready to perform.

The database should have the following characteristics:

- Publically accessible via the Internet
- Regularly updated/maintained (a one-time effort will likely result in an obsolete, and therefore undependable/unutilized tool)
- Minimally contain the following information:
    - Organization Name
    - Contact information (contact name, phone, email, website)
    - Location (city, island, state)
    - Products (specific biostock or bioenergy products)
    - Status (currently performing or intent to perform P+R functions described)
    - Product Capacity (acres of biostock, units of measure for bioenergy)
    - Description (brief company description)
    - Functions performed within the Framework
- Allow for submission of new Partners and updates of existing Partner data. Ideally a gatekeeper function can receive, review, and vet the new information before the database is updated (see Recommendation 4). Completeness of the submission is critical and should be part of the acceptance criteria
- Allow for multi-parameter reporting functionality (e.g., find all partners that do X Framework function with capacity of Y on the island of Z)

3. **Provide incentives to growers**

Qualitative and quantitative information collected for this report indicate a need for greater capacity in bioenergy feedstock production. The objective of encouraging greater growing capacity can be approached from either end of the bioenergy value chain[8], but the authors believe that incentivizing growers directly is more effective for this objective. Incentives at upstream points in the value chain can be powerful forces for development of the industry, but the trickle-down effect on the growers would be slower, "watered down" by the upstream absorption of incentives, and less tangible and understood by the growers.

A powerful incentive for organizations fulfilling the Growing process would be one that assures a market for the bioenergy crop. The State could implement a purchase program (targeted at slightly below market rates to avoid competing with private industry) for surplus crops, with restrictions on annual volumes and the duration of the program. Depending on the crop, the purchased products would be stored, or preprocessed (e.g., oil extracted) with the resulting product stored for future sale to bioenergy Processing Partners.

[8] One end being the consumer use, or "pull" demand, the other being the growing of biostock.

Uncertainty surrounding crop selection can be reduced through State support of Hawaii-specific crop research and crop-specific incentives (e.g., market assurance). Research can be accelerated by greatly minimizing the number of crops receiving research funding, as determined by a science and industry panel. The objective, related to Recommendation 1, should be accelerated implementation versus optimal selection.

4. **Facilitate partnerships through a matchmaker**
   The State can significantly encourage necessary bioenergy partnerships through the creation of a position or program that facilitates such partnerships by identifying and encouraging needed Partners, introducing appropriate Partners to each other, and acting as an industry advocate and government liaison.

   The position/program would also have responsibility for as many of the State-supported bioenergy programs as is practicable, which would help to ensure an aligned and focused bioenergy effort. Finally, the Partner Database of Recommendation 2 should be maintained by this position/program.

In general, the State is well positioned to fulfill functions in the Requirements subareas of the Framework (land, water, regulations, etc.) and can thereby be a valuable Partner in a private-public partnership to facilitate the bioenergy industry in Hawaii.

Budget

The following budget represents estimates for the cost of the recommendations. Note that certain incentives are not specified and thus the budgeted amount does not necessarily reflect need but is at an amount estimated to provide impact.

Recommendation	CY2010	CY2011	CY2012	CY2013	CY2014	CY2015	6 yr Total
First mover incentives[9]	$2,000k	$3,000k	$1,000k	$0	$0	$0	$6,000k
Partner database[10]	$60k	$20k	$20k	$20k	$20k	$20k	$160k
Grower incentives[11]	$850k	$1,350k	$1,000k	$1,000k	$850k	$0	$5,050k
Bioenergy program/ matchmaker[12]	$200k	$200k	$200k	$200k	$200k	$200k	$1,200k

[9] Assumption of cost of incentives and reflecting expiration of incentives
[10] Hardware and development first year, 0.25 FTE maintenance/connectivity/technology refresh thereafter
[11] Purchase program capped at $1.5M per year for 5 years, plus $350k annual research funding. Low first year payments due to ramp up of acreage.
[12] 2.0 FTE plus overhead, to end upon sufficient industry maturation

Timeline

The timeline for implementation of recommendations is front-weighted for acceleration of impacts. Dark grey indicates implementation; light grey indicates duration of programs.

Recommendation	CY2010	CY2011	CY2012	CY2013	CY2014	CY2015
First mover incentives						
Partner database						
Grower incentives						
Bioenergy program/ matchmaker						

Lead organization

Per Recommendation 4, a new position or program should be created to head these efforts. This position or program would logically come under the Department of Business, Economic Development, and Tourism (DBEDT) as the programs are expected to be of limited term with a developmental focus.

Potential funding source

Funding the recommendations in this economic environment will be challenging, but the economic and environmental importance of a healthy bioenergy industry, combined with the partnership obstacles the industry faces, indicates funding at some level to address the partnership issues. Logical funding sources would include:

- Barrel Tax increase on imported oil
- U.S. Department of Energy (the recommendations are initiatives and do not require ongoing operational funding)
- Economic Development Agency (the recommendations are initiatives and do not require ongoing operational funding)

Appendices

Stakeholders

On April 2, 2009, HNEI hosted a Bioenergy Master Plan Stakeholders meeting to bring together relevant stakeholders to learn about, and provide input to, the Hawaii Bioenergy Master Plan. For the Business Partnering task, two breakout sessions were held to gather feedback on two broad questions (identified below). The sessions were moderated and recorded (data below) and included members of the project team.

Of the 78 meeting participants, 35% completed surveys, from which the following are derived:

- Attendees self-identified affiliation breakdown

Industry	9.1%
Farmer	6.1%
Conversion	9.1%
Distribution	6.1%
End Use	9.1%
Other	6.1%
Government	0.0%
State	15.2%
County	0.0%
Federal	0.0%
Non-Profit	3.0%
Research	24.2%
Student	0.0%
Other	12.1%

- Attendees self-reporting participation in the breakout session for Business Partnering: 9.1%

Other stakeholders who provided information and feedback outside of the Stakeholder Meeting included SMEs listed in the *Reference* section.

Stakeholder meeting data (Business Partnering Breakout Sessions)

Session 1

1. **Please identify examples of partnerships between companies and/or governments or other organizations that have facilitated bioenergy production.** *Participants were asked to share their knowledge.*

   Current Partnerships

   - *Agreement to purchase power on Kauai; utility on Kauai.*

1. *Strategic partnership to save sugar (Gay & Robin, Pacific West Energy)*
    - *This involved land issues, water, and asset acquisition*
    - *This provides other uses for land such as sugar bioenergy versus GMO crops*
2. *Wood chips to gasify*
    - *There are financing issues and land issues*
3. *Algae based partnership that captures CO2 from generation*
    - *This involves Hawaii Bioenergy (landowner consortium) for biodiesel for Federal DARPA contract*

- *Power purchase agreement Maui Electric with HC&S Sugar.*

Developing Partnerships

- *Negotiating with Big Island producers also is in development.*
- *Possible micro-algae development on Maui using CO2 from stacks.*

Research Partnerships

- *UH Hilo and HARC are seeing money for biocrop research from HECO. The money is for 3 years, plus another 3 years possible.*
- *Shell "Cellana" joint venture to do research at NELHA to develop algae as biofuel. This involves growing, extracting, and processing. This project is with university researchers who have intellectual property rights.*
- *There was some small scale project with EPA funding - Pacific Biodiesel and Oceanic Institute were involved. They were working with crops with high oil content to make biodiesel. They gave the press cake to Oceanic Institute for animal feed. This increases the value chain with other co-products. EPA and Honolulu Clean Cities nonprofit own the oil press equipment which is still at Makapuu. They were working with kukui and coconut. Someone will buy the equipment since it is the only industrial scale press in Hawaii. Now they are working on what crops will work and grow well in Hawaii.*
- *What is commercial link between projects and academics? Need to capture this information, additional details; catalog models/ partner opportunities, will be living document to share with each other and legislators to fill gaps; incentive to contribute.*

Past Partnerships

- *25 years ago Lihue Plantation Company, Kauai Electric and Foster Wheeler, a generator vendor, worked in partnership. Foster Wheeler built a 23 megawatt facility free for first power revenues. This was a three-way win – Lihue Plantation got upgraded, Foster Wheeler sold the unit and got revenues, and Kauai Electronic got energy to its grid. It was the first time* *in world. Since then Lihue Plantation shut down and Kauai Electric sent the boiler to the Philippines.*

2. **What business partnering opportunities do you see in the next 2-3 years for bioenergy production in Hawaii?** *Participants were asked to brainstorm their ideas.*

- *There are many land opportunities*
    - *The partnerships are hard to build and maintain because of competing uses for the land - solar, biomass, cattle*
    - *We need to work together to maximize use of resources*
    - *Kauai County is just starting sustainability plan development*
- *It would be helpful for counties to develop master plans to balance competing interests and uses of resources (e.g., state lands).*
    - *This would create industry and help us move forward*
    - *Crops just for bioenergy are hard to be cost-effective*
    - *We need to use state funds that don't need huge return*
- *Who will farmers be and how will they operate?*
    - *We need the government to be involved, e.g., supply labor to help small-scale farmers*
    - *It is hard to get land and get moving*
    - *Farmers are not usually partners. We focus on conversion first, and then look for someone to grow, e.g. "we have a cement factory, now we need rock quarry." We need farmers involved early in development, but that is hard to do.*
- *Big Island non-native forests are mandated for non-power use.*
- *The State should be more supportive of power use of resources.*
- *To grow biomass for energy is not economically feasible, but if we use biomass already in the ground it could be economically feasible. Unfortunately, current policy works against that use.*
- *The State should help with research to identify which crops to plant and where (islands, microclimates) in a more coordinated approach -*
    - *We need state-funded trials*
    - *Jatropha, palm, malungai/malunggay have been tried on a small scale*
- *We need a technology knowledge partner to identify viable crops.*
- *Crops, harvesting and land often go together. Crops are not grown on a large scale in Hawaii. Growers partner with harvest equipment companies. They*

tend to identify farm layout needs and how to harvest with mechanics rather than with human labor.

- *We need low energy and low labor crops for Hawaii.*
- *Money or critical mass can solve many of these issues. Sometimes the issues are economic issues; sometimes we need partners; sometimes it is other non-economic issues, e.g., land.*
- *Water infrastructure is an issue. Many are falling into disrepair. We have to think about what is the replacement cost? It takes millions of dollars to refurbish water infrastructure versus billions of dollars to replace them. Owners should try to salvage them. But there is a small window of opportunity to save those resources.*
- *Kauai's priority is to create the industry. Kauai spent $100 million on a boiler to spark the industry. Either state or private initiative can set up.*
- *Maui is committing to biofuels to meet laws. We (MECO) test this next year for 30 days to prove the technology. Should it be palm oil? Algae? Jatropha? How will these work in our system? We are creating a market for others to come in. Is a buying program enough incentive?*
- *Our market seems ready, but upstream is less ready. Who/where are the aggregation points? E.g., oil press owner talking about co-ops: should farmers own equipment to control production, or should it be a private venture? Co-ops are difficult to work well.*
- *It would help to have land use guidelines. We need to identify spots where people get attractive arrangements to grow specific crops, e.g., long-term crops like trees. Biofuel crops are a very specific land use application and should not be fighting with other agricultural uses. It depends on when the land lease is available and who got it.*

Session 2

1. **Please identify examples of partnerships between companies and/or governments or other organizations that have facilitated bioenergy production.** *Participants were asked to share their knowledge.*

<u>Current Partnerships</u>

- *High Technology Development Corporation is a state agency with incubators to help high technology start-ups with consulting.*

<u>Developing Partnerships</u>

- *What is GasCo's interest? Is it to produce surrogate SNG from biomass? Is it to offset petroleum demands? Is it to replace fossil fuel feedstocks? We are looking at opportunities for use of biofuels to incorporate into current streams, gas or other forms. We are looking at how to keep costs down for consumers.*

- *There is greater efficiency using gas to heat water than using electricity. It has a lower carbon footprint than solar with backup. We want to tell legislators "we are renewable."*
  - *GasCo has a mini-refinery with many capabilities. We don't need a full-scale demonstration with their smaller plant.*
  - *We are seeking partners. It would be helpful to have a catalog of players.*
  - *There is a project trying to catalog players - who, what, crop, scale.*
  - *Viability also depends on by-products. GasCo might be interested in methane from algae production.*
- *Informal talks between GasCo and UH have occurred, but no formal partnership has formed yet.*
- *There is an existing refinery infrastructure. We want to integrate in biofuels. Partners are being sought with capital and technology knowledge to use their physical infrastructure (e.g., refinery for transportation fuel; use biofuels to make alternative oil stocks). The goal is to become more renewable, although this is in early development.*
- *Kunia Group is a model to provide seed stock to large scale algae growth. This needs CO2, water (salt and fresh), fertilizer, and seed stock at front end of production. It could partner with larger companies to take by-products growing at lab on a pilot scale. They could offer seed stock and consulting services.*
- *An agricultural/ industrial chemical supplier could partner to grow crops and provide supplies. E.g., BEI (Brewer) could the facilitate by-product use or possibly be a potential intermediary.*
- *Partnering in wood high value products and biomass for fuel to use in production of high value, e.g., half a tree for high value and half a tree for energy. Also uses for the leftovers, from problem to opportunity. We could be ready 90 days after funding is secured and products and energy purchase agreements are in place. We have it from steam boiler to dry wood in our current plan.*

Other Discussion

- *Grow > produce > convert > distribute is the process here in Hawaii and elsewhere. Some of this is occurring now and some is phantom in design.*
- *I am hearing about interdependencies, but people are working in silos. There is a lack of communication, a disconnect. It is partly because we don't know who is doing what. There is no formal mechanism to communicate and share what is ongoing.*
- *There are some issues with confidentiality. We need agreements in order to share.*

- *There is an incentive to share in catalog and make oneself available for matchmaking by identifying gaps and mismatches in capacity for legislature to address.*
- *A catalog for master planning. Is there a mechanism for limited or restricted access and participation? I can see a catalog on a website. Some of the information would need to be public. We would want them to input directly where they can put in partial information (only that which they are willing to share).*

2. **What business partnering opportunities do you see in the next 2-3 years for bioenergy production in Hawaii?** *Participants were asked to brainstorm their ideas.*

- *Partner in making electricity. Does the local power supplier have adequate capacity (e.g., transmission lines)? They need more development of infrastructure to expand. It is hard for an electric company to fund capital to accommodate capacity purchase. They are obligated to buy alternative/independent power, but it is very complicated. They are good at avoiding NUGs (non-utility generators). It's hard to enforce.*
- *Align incentives between utilities and independent power products. Utilities do have some champions. Don't regulate but align incentives.*
- *Landowners are not very enthusiastic to use their land for biofuel. They are waiting for others to step up first. It is a stand-off of who will make a bold investment of money, time, and courage. The utilities are regulated and can't be bold. Landowners are trusts with obligations to stakeholders. They tend to be conservative.*
- *We need to understand what projects, who is involved, and connect with them. It depends on which technologies.*
- *We need something to happen beyond talk. This has been happening for long time. We need to facilitate the development of the industry - logistics, infrastructure, permits.*
- *We need to link three disparate worlds that don't talk together – 1) agriculture; 2) entrepreneurial/technology/venture capital, literally hundreds are working on this, but much is not viable until the future; and, (3) traditional fossil fuel infrastructure.*
- *Total vertical integration worked in past. Some are working now.*
- *A "renewable portfolio" can be counted multiple times along its stream. It is part of aligning incentives. This is driven by a company wanting to make money with biofuels. Ideally it is economic-driven.*

- *The big gap is in technology development. Now alternative energy is more expensive than fossil fuel energy. We have to think about how to meet the aspirations of federal mandates but still keep shareholders happy.*
- *Hawaii is so small. It lowers the odds that one player will step out boldly. We worry as the first mover whether we are a leader or a fool. There should be incentives to encourage the first steps.*
- *China now or the US before could just do it - without permits. It is very complex and hard to be entrepreneurial with so many barriers. It takes $3 million in permits for a $1 million plan.*
- *All the steps along the value chain must be coordinated.*
- *Military lands have different permitting. There are many other bureaucratic barriers. The military has federal regulations, but not state regulations.*

Stakeholder Meeting Agenda

Hawaii Bioenergy Master Plan
Stakeholders Meeting
April 2, 2009
7:30 am – 4:30 pm
Japanese Cultural Center, Mānoa Ballroom

AGENDA

Time	Activities	Presenter
7:30 am	**Registration and Continental Breakfast**	
8:00 am	**Welcome & Overview**	**Scott Turn**
8:15 am	**Team Updates** • *Land & Water Resources* • *Environmental Impacts* • *Permitting* • *Technology*	**Aly El-Kadi &** **Richard Ogoshi** **Andrew Tomlinson** **Manfred Zapka** **Scott Turn**
9:15 am	**Process Instructions**	**Lily Bloom Domingo**
9:30 am	**Break & Move to Breakout Rooms**	
9:45 am	**1st Session**	
10:45 am	**Break & Move to 2nd Topic**	
11:00 am	**2nd Session**	
11:45 am	**Lunch**	
12:45 pm	**Team Updates** • *Labor* • *Distribution Infrastructure* • *Financial Incentives* • *Economic Impacts* • *Business Partnering*	 **James Spencer** **Manfred Zapka** **Denise Konan** **Makena Coffman** **Steven Chiang**
2:00 pm	**Break & Move to Breakout Rooms**	
2:15 pm	**3rd Session**	
3:15 pm	**Break & Move to 4th Breakout Session**	
3:30 pm	**4th Session**	
4:15 pm	**Move to Main Hall**	
4:20 pm	**Closing Remarks**	**Scott Turn**

Analyses, tables, figures, supporting information

A Scenario for Biofuel Production

Two data sources were used to arrive at a bioenergy scenario for the purposes of the Hawaii Bioenergy Master Plan (HBMP). These sources included the 2007 fuel consumption values for transportation and power generation and the Hawaii Clean Energy Initiative agreement signed between the State of Hawaii and Hawaiian Electric Industries utility companies. Table 1 summarizes the 2007 fuel consumption levels by county. Table 2 presents the Hawaii Bioenergy Master Plan bioenergy scenario based on 20% displacement of the 2007 fuel use from Table 1 and the bioenergy components of the renewable energy commitments identified in the HCEI agreement.

Table 1. 2007 Fuel Consumption by County/Island in million gallons per year

	Honolulu	Maui	Lanai	Molokai	Hawaii	Kauai	State
Transportation Fuel Use							
Gasoline	286.7	65.6			80.6	35.7	468.6
Diesel Oil (non-hwy)	186.2	11.7			14.8	22.3	235.0
Diesel Oil (hwy use)	25.4	9.2			13.2	4.8	52.7
Aviation fuel	114.9	66.2			31.6	17.4	230.1
Power Generation							
Fuel Oil	340.1	19.8			33.0		393.0
Diesel	4.1	57.2	2.4	2.8	11.8	34.6	112.9

Data obtained from State of Hawaii Monthly Energy Trends (Department of Business, Economic Development & Tourism, 2009).

Table 2. Bioenergy use scenario by county/island to guide HI bioenergy master plan activities (liquid fuels in 10^6 gal per yr, solid fuels in dry tons per yr).

	Honolulu	Maui	Lanai	Molokai	Hawaii	Kauai	State
Transportation Fuel Use							
Ethanol (20% of 2007 Gasoline Volume)	57.3	13.1	0.0	0.0	16.1	7.1	93.7
Biodiesel (non-hwy use) (20% of 2007 Non-Hwy Diesel Oil Volume)	37.2	2.3	0.0	0.0	3.0	4.5	47.0
Biodiesel (hwy use) (20% of 2007 Hwy Use Diesel Oil Volume)	5.1	1.8	0.0	0.0	2.6	1.0	10.5
Power Generation Use (20% of 2007 power generation use)							
Renewable Fuel Oil	68.0	4.0	0.0	0.0	6.6	0.0	78.6
Biodiesel	0.8	11.4	0.5	0.6	2.4	6.9	22.6
Power Generation Use Based on HCEI Agreement							
Simple cycle biofueled CT-1 (110 MW), CIP (under construction)	6						6.0
Distributed generation biofueled (8 MW) at HNL airport[1]	0.665						0.665
DG biofueled (30 MW) various substations[1]	2.5						2.5
Simple cycle biofueled CT-2 (110 MW), CIP	6						6.0
DG mixed renewables (100 MW) on	8.5						8.5

military property[1]							
Pulehu Energy (6 MW) on Maui operating on forest residues[2]		38,000					38,000
Hamakua Biomass (25 MW) or Hu Honua Biomass (22 MW), wood[2]					160,000		160,000
Totals							
Ethanol	57.3	13.1	0.0	0.0	16.1	7.1	93.7
Biodiesel Oil	66.8	15.6	0.5	0.6	8.0	12.3	103.7
Renewable Fuel Oil	68.0	4.0	0.0	0.0	6.6	0.0	78.6
Fiber		38,000			160,000		198,000

[1] Based on 1,000 hours of operation annually
[2] Based on 85% plant availability, 20% plant efficiency, wood higher heating value of 19 MJ/kg

Bioenergy Production Models

<u>Model Capture Form</u>

Business Model/Partner Capture	Grow Bioenergy Feedstock (Biostock)													Process Biostock Into Bioenergy Product												Byproduct Value Conversion						Transport							
Source:	SubProcesses						Requirements							SubProcesses					Requirements							Sub		Requirements				Sub			Requirements				
Model name: Crop: Conversion type: End product: Byproduct:	Field Prep	Planting	Irrigation	Cultivation	Harvesting	Collect/Transport to Processor	Capital	Labor	Technical expertise	Water	Permits/Regulation	Community acceptance	Land	Receive Biostock	Preprocessing	Pay Producer/ Aggregator	Convert to Bioenergy Product	Prep for Delivery	Technical Expertise	Permits/ Regulations	Capital	Labor	Land	Community acceptance	Biostock Supply/Consistency	Remove Byproducts	Payment	Capital	Labor	Infrastructure	Permits/ Regulations	Receive Bioenergy Consumable	Transport	End User Ability to Use	Capital	Labor	Product Volume & consistency	Infrastructure	Permits/ Regulations
Partner/Location: Organization type:																																							
Partner/Location: Organization type:																																							
Partner/Location: Organization type:																																							
Partner/Location: Organization type:																																							
Partner/Location: Organization type:																																							
Partner/Location: Organization type:																																							
Partner/Location: Organization type:																																							

Advantages	Disadvantages	Description / Notes / What would be needed to make this work here?
		Subsidies

Model Data

	Grow Bioenergy Feedstock (Biostock)													Process Biostock Into Bioenergy Product												Byproduct Value Conversion						Transportation and Distribution							
Model	SubProcesses						Requirements							SubProcesses					Requirements							Sub		Requirements				Sub		Requirements					
	Field Prep	Planting	Irrigation	Cultivation	Harvesting	Collect/Transport to Processor	Capital	Labor	Technical expertise	Water	Permits/Regulation	Community acceptance	Land	Receive Biostock	Preprocessing	Pay Producer/ Aggregator	Convert to Bioenergy Product	Prep for Delivery	Technical Expertise	Permits/ Regulations	Capital	Labor	Land	Community acceptance	Biostock Supply/Consistency	Remove Byproducts	Payment	Capital	Labor	Infrastructure	Permits/ Regulations	Receive Bioenergy Consumable	Transport	End User Ability to Use	Capital	Labor	Product volume & consistency	Infrastructure	Permits/ Regulations
Vertically Integrated Model																																							
Partner 1 (HC&S)																																							
Partner 2 (MECO)																																							
Cooperative Model																																							
Partner 1 (Grower Coop)																																							
Partner 2 (Processor)																																							
Partner 3 (HELCO)																																							
Cooperative Growing (Australian) Model																																							
Partner 1 (Multiple Farmers)																																							
Partner 2 (Processor)																																							
Partner 3 (Contractors)																																							
UNKNOWN																																							

	Grow Bioenergy Feedstock (Biostock)													Process Biostock Into Bioenergy Product												Byproduct Value Conversion						Transportation and Distribution							
Model	SubProcesses						Requirements							SubProcesses					Requirements							Sub		Requirements				Sub		Requirements					
	Field Prep	**Planting**	**Irrigation**	**Cultivation**	**Harvesting**	**Collect/Transport to Processor**	Capital	Labor	Technical expertise	Water	Permits/Regulation	Community acceptance	Land	**Receive Biostock**	**Preprocessing**	**Pay Producer/ Aggregator**	**Convert to Bioenergy Product**	**Prep for Delivery**	Technical Expertise	Permits/ Regulations	Capital	Labor	Land	Community acceptance	Biostock Supply/Consistency	**Remove Byproducts**	**Payment**	Capital	Labor	Infrastructure	Permits/ Regulations	**Receive Bioenergy Consumable**	**Transport**	End User Ability to Use	Capital	Labor	Product volume & consistency	Infrastructure	Permits/ Regulations
Community-Based Waste Cooking Oil Model																																							
Partner 1 (Various Restaurants)										n/a																													
Partner 2 (Pacific Biodiesel)																																							
Partner 3 (Transport Companies)																																							
Partner 4 (Various Fuel Distributors)																																							
Partner 5 (Various Investors																																							
Partner 6 (JV Northwest)																																							
Partner 7 (State or Private Landowner)																																							
Cooperative-Based Biodiesel Model																																							
Partner 1 (Various Farmers)																																							
Partner 2 (Oil Processor)																																							
Partner 3 (Pacific Biodiesel)																																							
Partner 4 (Various Fuel Distributors)																																							
Partner 5 (Various Investors																																							
Partner 6 (JV Northwest)																																							
Partner 7 (State or Private Landowner)																																							
Imported Seed Oil Model																																							
Partner 1 (Out of state oil supplier)																																							
Partner 2 (Electrical utility)																																							

	Grow Bioenergy Feedstock (Biostock)													Process Biostock Into Bioenergy Product												Byproduct Value Conversion						Transportation and Distribution							
Model	**SubProcesses**						**Requirements**							**SubProcesses**					**Requirements**							**Sub**		**Requirements**				**Sub**		**Requirements**					
	Field Prep	**Planting**	**Irrigation**	**Cultivation**	**Harvesting**	**Collect/Transport to Processor**	Capital	Labor	Technical expertise	Water	Permits/Regulation	Community acceptance	Land	**Receive Biostock**	**Preprocessing**	**Pay Producer/ Aggregator**	**Convert to Bioenergy Product**	**Prep for Delivery**	Technical Expertise	Permits/ Regulations	Capital	Labor	Land	Community acceptance	Biostock Supply/Consistency	**Remove Byproducts**	**Payment**	Capital	Labor	Infrastructure	Permits/ Regulations	**Receive Bioenergy Consumable**	**Transport**	End User Ability to Use	Capital	Labor	Product volume & consistency	Infrastructure	Permits/ Regulations
Generic Sugar/Starch to Ethanol (common) Model																																							
Partner 1 (grower)																																							
Partner 2 (convertor)																																							
Partner 3 (byproduct)																																							
Partner 4 (ethanol dist)																																							
Generic Fiber to Electricity (common) Model																																							
Partner 1 (grower)																																							
Partner 2 (convertor)																																							
Partner 3 (utility)																																							
Thermal Gasification Model																																							
Partner 1 (grower)																																							
Partner 2 (ClearFuels)																																							
Partner 3 (transportation)																																							
Sugar Plantation Model																																							
Partner 1 (sugar co)																																							
Partner 2 (ClearFuels)																																							
partner 3 (ethanol fermenter)																																							
Partner 4 (byproduct)																																							

	Grow Bioenergy Feedstock (Biostock)													Process Biostock Into Bioenergy Product												Byproduct Value Conversion						Transportation and Distribution							
Model	SubProcesses						Requirements							SubProcesses					Requirements							Sub		Requirements				Sub		Requirements					
	Field Prep	**Planting**	**Irrigation**	**Cultivation**	**Harvesting**	**Collect/Transport to Processor**	Capital	Labor	Technical expertise	Water	Permits/Regulation	Community acceptance	Land	**Receive Biostock**	**Preprocessing**	**Pay Producer/ Aggregator**	**Convert to Bioenergy Product**	**Prep for Delivery**	Technical Expertise	Permits/ Regulations	Capital	Labor	Land	Community acceptance	Biostock Supply/Consistency	**Remove Byproducts**	**Payment**	Capital	Labor	Infrastructure	Permits/ Regulations	**Receive Bioenergy Consumable**	**Transport**	End User Ability to Use	Capital	Labor	Product volume & consistency	Infrastructure	Permits/ Regulations
Partner 5 (transportation)																																							
Algae-Based Transportation Fuels Model																																							
Partner 1 (Defense Advanced Research Projects Agency)																																							
Partner 2 (Science Applications International Corporation)																																							
Partner 3 (General Atomics)																																							
Partner 4 (HBE)																																							
Partner 5 (Military)																																							
Lihue Plantation Model																																							
Partner 1 (Lihue Plantation)																																							
Partner 2 (Foster Wheeler)																																							
Partner 3 (Citizens Utility)																																							
Biodiesel from Oil Seeds Model																																							
Partner 1 (Pacific Biodiesel)																																							
Partner 2 (Oceanic Institute)																																							
Partner 3 (Honolulu Clean Cities)																																							
Partner 4 (Environmental Protection Agency)																																							
Partner 5 (Multiple Growers)																																							

Model	Crop	Conversion Type	End Product	Byproduct	Subsidies	Description/Notes	Advantages	Disadvantages	Source
Vertically Integrated Model	sugar cane	hydrolysis, fermentation, combustion	ethanol (not currently), heat/electricity	stillage	HI tax credit for ethanol production; HI GET exemption for E10 or greater; HI highway tax reduced for transport of E85. Demand subsidized by HI mandate of use of E10	HC&S grows sugar, owns land (or leases from related companies), generates electricity from combustion of bagasse and is positioned to do conversion to ethanol. East Maui Irrigation provides water. A&B owns these companies as well as the trucking, farm operation, and shipping (sugar). MECO buys electricity from HC&S and distributes to end users. State of HI provides tax credits and incentives.	Control and cooperation across the value chain, control over land and water, internal "buyer" for bioenergy product (electricity) State and federal tax credit possibility.	Accounting for value of goods and services across business units/companies can be muddied. Risk borne by single company.	Charles Kinoshita
	sugar cane	hydrolysis, fermentation, combustion	ethanol (not currently), heat/electricity	stillage	HI tax credit for ethanol production; HI GET exemption for E10 or greater; HI highway tax reduced for transport of E85. Demand subsidized by HI mandate of use of E10	Kauai Island Utility Co-op. in Lihue on the island of Kauai, Hawaii, entered into a power purchase agreement with Pacific West Energy LLC in Kaumakani, Hawaii, to purchase electricity from Pacific West Energy's planned 20-megawatt sugarcane bagasse-fired power generation facility, according to the co-op. The biomass-to-energy plant will complement Pacific West Energy's planned 12 MMgy ethanol facility that will use sugarcane as its feedstock. Pacific West Energy announced that it will lease land and other assets from sugar producer Gay & Robinson Inc. to grow sugarcane. Pacific West Energy is currently in the process of seeking significant third-party investment to fund the next stages of the Kauai project, including construction, the company said.		Land owner may want to lease land to competing industries.	Steven Rymsha
	sugar cane eucalyptus sweet sorghum	hydrolysis, fermentation, combustion	ethanol (not currently), heat/electricity	stillage	HI tax credit for ethanol production; HI GET exemption for E10 or greater; HI highway tax reduced for transport of E85. Demand subsidized by HI mandate of use of E10	Hawaii BioEnergy (HBE) also considering this model. Various businesses and individuals would form a partnership to perform growing, processing, and byproduct conversion. Ethanol would be sold to mid tier petroleum company and energy sold to electric company. Also considering cellulosic ethanol to reduce footprint requirements.	Targeting brownfield lands for transition ease. Cellulosic ethanol production can reduce land, facility, and capital, requirements.	Current partners do not own suitable land for production. New technology increases risk. Production timeframe is long.	Mawae Morton

Model	Crop	Conversion Type	End Product	Byproduct	Subsidies	Description/Notes	Advantages	Disadvantages	Source
Cooperative Model	sugar cane	hydrolysis, fermentation, combustion	ethanol (not currently), heat/electricity	stillage, sugar, molasses	HI tax credit for ethanol production; HI GET exemption for E10 or greater; HI highway tax reduced for transport of E85. Demand subsidized by HI mandate of use of E10	Coop (United Cane Planters' Cooperative) members grow feedstock and deliver to processing facility. Coop owned processing plant and shared farm equipment. Coop and Mauna Kea Agribusiness formed joint venture non-profit (Hilo Coast Processing Co.) to perform harvesting and processing. HCPC ran the plant and determined crop harvesting schedule amongst members. HELCO was buyer of electricity. Example above is no longer in operation.	Lower costs through economies of scale and shared costs, growers have additional participation in value chain, more consistent supply, allows small growers to participate, shared risk	Significant effort for cooperative to maintain member compliance/participati on	Charles Kinoshita
Cooperative Growing (Australian) Model	Sugar cane	hydrolysis, fermentation, combustion	ethanol (not currently), heat/electricity	stillage, sugar, molasses		Coop members grow feedstock. Contractor harvests for multiple coop members. Processor owns and runs plant and determines crop harvesting schedule for coop.	Coop can negotiate with processor as a unit, processor ensures more consistent supply, low investment for coop	Significant effort for cooperative to maintain member compliance/participati on, coop does not participate in higher levels of value chain	Charles Kinoshita
Community-Based Waste Cooking Oil Model	Waste cooking oil	transesterifica tion	biodiesel	glycerin		Feedstock (used cooking oil) produced by food service and other organizations not purposely producing the feedstock for bioenergy production. Collection of feedstock performed by processor and/or independent agents. Processor converts to biodiesel and makes available at the processing facility, delivers directly to customers, or provides to independent distributors. Example: Pacific Biodiesel	Flexible sourcing and preexisting sources for feedstock. Feedstock otherwise a waste product. End product can be accepted by wide variety of users	Limited sources of large feedstock supplies. Byproducts have limited market in Hawaii	Pacific Biodiesel
Cooperative-Based Biodiesel Model	Oil producing crops	transesterifica tion	biodiesel	glycerin, methane		Oil from feedstock extracted by grower or miller and delivered to processor. Processor converts to biodiesel and makes available at the processing facility, delivers directly to customers, or provides to independent distributors. Example: Pacific Biodiesel (not in Hawaii)			Pacific Biodiesel
Imported Seed Oil Model	Oil producing crops	none	vegetable oil	none		Vegetable oil shipped into Hawaii. Biostock growth and oil extraction performed by independents or vertically integrated provider of the oil. Oil is burned directly for heat/steam to produce electricity and distributed through preexisting electrical grid.	No conversion process required.	Feedstock (vegetable oil) currently imported.	HECO

Model	Crop	Conversion Type	End Product	Byproduct	Subsidies	Description/Notes	Advantages	Disadvantages	Source
Generic Sugar/Starch to Ethanol (common) Model	sugar cane, corn	hydrolysis, fermentation, combustion	ethanol, heat/electricity	stillage	HI tax credit for ethanol production; HI GET exemption for E10 or greater; HI highway tax reduced for transport of E85. Demand subsidized by HI mandate of use of E10				
Generic Fiber to Electricity (common) Model	Various sources of fiber, including bagasse	Combustion, pyrolysis, gasification	electricity			If fiber is combusted or pyrolized, heat is used for boilers or turbines to generate electricity. Pyrolisys and gasification methods produce other products with commercial value.	Fiber is often a byproduct of other value extraction and can generate electricity for onsite use as well as distributing to electric utility		HECO
Thermal Gasification Model									
Sugar Plantation Model									
Algae-Based Transportation Fuels Model	algae	transesterifica tion	jet fuel	protein		Currently no production. In research only. Science Applications International Group and General Atomics, two San Diego-based defense contractors have received federal grants totaling nearly $35 million to drive down the cost of making jet fuel from algae. General Atomics and SAIC received the contracts from the Pentagon's Defense Advanced Research Projects Agency, or DARPA. It is the military's research and development funding arm and is seeking biofuel alternatives for military aircraft, which make up a significant percentage of the $6 billion the military spends on fuel annually. HBE would assist in research and consulting on product commercialization.	Jet fuel is a high value product. Minimal footprint requirement. Limited restrictions on type of water needed (brackish, wastewater, fresh, and salt are feasible). Multiple growers can provide biocrop.	Requires large quantity of CO2. Still in testing phase.	Mawae Morton

Model	Crop	Conversion Type	End Product	Byproduct	Subsidies	Description/Notes	Advantages	Disadvantages	Source
	algae	transesterification	biodiesel	protein		Currently no production. In research only. HR BioPetroleum, Alexander & Baldwin, Inc., Hawaiian Electric Company and Maui Electric Company have signed a memoranda of understanding to pursue the joint development of a commercial-scale microalgae facility on Maui to produce lipid oil for conversion to biodiesel and other valuable products, such as animal feed. Under the agreements: HR BioPetroleum will be responsible for overall project management, including obtaining financing, and construction and operation of the microalgae facility. Alexander & Baldwin will provide strategically located land, adjacent to Maui Electric's Ma'alaea Power Plant, to site the algae production ponds and processing plant, and may provide equity capital to the project. Hawaiian Electric and Maui Electric companies will lead in determining the permitting and construction needs for piping to carry stack gases containing carbon dioxide, which the algae consume, from the Ma'alaea plant to an adjacent algae facility.			Press release
Lihue Plantation Model	sugar cane	hydrolysis, fermentation, combustion	sugar heat/electricity	stillage, sugar, molasses		Old Model; No longer in operation Lihue Plantation had an established sugar operation. Foster Wheeler, an international power equipment supplier, built a power processing facility for Lihue Plantation. The plantation was able to use the facility to power its operations. Additional generated power was sold to Citizens Utility with revenues over a pre-determined period going to Foster Wheeler.	Foster Wheeler provided financing on processing facility. Foster Wheeler was able to build a processing facility and generate revenues without a land investment (Lihue Plantation provided land).		Charles Kinoshita

Model	Crop	Conversion Type	End Product	Byproduct	Subsidies	Description/Notes	Advantages	Disadvantages	Source
Biodeisel from Oil Seeds Model	Oil producing crops	transesterification	biodiesel	glycerin, methane, animal feed	Grant received from EPA was used for research and purchase of oil press.	Currently no production. In research phase. The EPA funded a project to explore and evaluate plant species currently growing in Hawai'i to determine their suitability for producing biodiesel. The information gathered from the project will be valuable for identifying which crops already growing in Hawai'i might have the greatest potential to support large scale biodiesel production in Hawai'i. Crops evaluated included coconut, kukui, jatropha and castor. The plant material of each crop will be analyzed to determine oil extraction yields, potential byproducts, biodiesel processing characteristics, fuel quality potential and emission profiles. An oil press was also purchased with grant funds and resides at Oceanic Institute. Oil extraction methods were also studied. The plant material by-product from the extracting process, or press cake, will be studied by Oceanic Institute to determine its potential as an ingredient in fish or animal feeds to help support Hawaii's livestock industries. After the study, the oil press may be purchased by Pacific Biodiesel for commercial use, obtaining biostock from multiple growers.	Initial research and funding by government grant. Oil press usage and outcomes tested prior to purchase.		Bryan Collins

Bioenergy Business Partners

Bioenergy Partner Catalog Capture Form

Bioenergy Business Partner
Information Gathering Form

Partners are organizations that perform, intend to perform, or should perform bioenergy processes and/or requirements. Please tell us about your organization and the role it plays in bioenergy production in Hawaii.

General Information

Organization Name: ____________________ Organization Website URL: ____________________

Contact Name: ____________________ Contact Phone Number: ____________________

Contact Email: ____________________

Brief Company Description: ____________________

Place an "x" under each portion(s) of the bioenergy process that your company performs (see back for descriptions of each):

Grow Bioenergy Feedstock (Biostock)													Process Biostock Into Bioenergy Product													Byproduct Value Conversion						Transportation and Distribution							
SubProcesses (SP)						Requirements (R)							SP					R							SP		R				SP		R					
Field Prep	Planting	Irrigation	Cultivation	Harvesting	Collect/Transport to Processor	Capital	Labor	Technical expertise	Water	Permits/Regulation	Community acceptance	Land	Receive Biostock	Preprocessing (possibly distributed)	Pay Producer/Aggregator	Convert to Bioenergy Product	Prep for Delivery	Technical Expertise	Permits/Regulations	Capital	Labor	Land	Community acceptance	Biostock Supply/Consistency	Remove Byproducts	Payment	Capital	Labor	Infrastructure	Permits/Regulations	Receive Bioenergy Consumable	Transport	End User Ability to Use	Capital	Labor	Product volume & consistency	Infrastructure	Permits/Regulations

Location

Where is your bioenergy process or requirement conducted?

City, State: ____________________ Island: ____________________

Products

Indicate the specific biostock or bioenergy product that your company produces: ____________________

Status (select one)

❑ Currently performing the functions described above ❑ Intend to perform the functions described above

Capacity

Acres of biostock grown: ____________________ Annual bioenergy production capacity: ____________________

Fax completed form to the Agribusiness Incubator Program at (808) 956-3547 or via email agincubator@ctahr.hawaii.edu.
Direct questions to Janel Yamamoto or Steven Chiang at (808) 956-3530.
For current examples, see www.hnei.hawaii.edu/bmpp/stakholders.asp

Bioenergy Partner Catalog

	Grow BioEnergy Feedstock (Biostock)													Process Biostock Into Bioenergy Product												Byproduct Value Conversion						Transport							
	SubProcesses						Requirements							SP					R							SP		R				SP		R					
Organization Name	**Field Prep**	**Planting**	**Irrigation**	**Cultivation**	**Harvesting**	**Collect/Transport to Processor**	Capital	Labor	Technical expertise	Water	Permits/Regulation	Community acceptance	Land	**Receive Biostock**	**Preprocessing**	**Pay Producer**	**Convert to Bioenergy Product**	**Prep for Delivery**	Technical Expertise	Permits/ Regulations	Capital	Labor	Land	Community acceptance	Biostock Supply/Variety Consistency	**Remove Byproducts**	**Payment**	Capital	Labor	Infrastructure	Permits/ Regulations	**Receive Bioenergy Consumable**	**Transport**	End User Ability to Use	Capital	Labor	Product volume & consistency	Infrastructure	Permits/ Regulations
A&B Properties, Inc.	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x
Agricultural Leadership Foundation of Hawaii								x														x							x							x			
Aloha Green LLC																																							
Aloha Petroleum, Ltd.																																x	x	x	x	x	x	x	x
ARCADIS			x				x		x		x						x		x	x	x							x		x	x				x		x	x	
BEI Hawaii																																							
BioEnergy Systems of Hawaii																																							
BlueEarth Biofuels LLC														x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Board of Water Supply										x																													
Castle and Cooke													x										x																
Chevron Hawaii																																x	x	x	x	x	x	x	x
City & County of Honolulu							x				x									x	x							x			x				x				x
Clean Fuels Development Coalition - Hawaii Chapter																																							
ClearFuels Technology														x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x								
College of Tropical Agriculture and Human Resources									x																														
County of Hawaii							x				x									x	x							x			x				x				x
County of Kauai							x				x									x	x							x			x				x				x
County of Maui							x				x									x	x							x			x				x				x
Diamond Head Renewable Sources																																							

Organization Name	Grow BioEnergy Feedstock (Biostock)													Process Biostock Into Bioenergy Product												Byproduct Value Conversion						Transport							
	SubProcesses						Requirements							SP					R							SP		R				SP		R					
	Field Prep	Planting	Irrigation	Cultivation	Harvesting	Collect/Transport to Processor	Capital	Labor	Technical expertise	Water	Permits/Regulation	Community acceptance	Land	Receive Biostock	Preprocessing	Pay Producer	Convert to Bioenergy Product	Prep for Delivery	Technical Expertise	Permits/ Regulations	Capital	Labor	Land	Community acceptance	Biostock Supply/Variety Consistency	Remove Byproducts	Payment	Capital	Labor	Infrastructure	Permits/ Regulations	Receive Bioenergy Consumable	Transport	End User Ability to Use	Capital	Labor	Product volume & consistency	Infrastructure	Permits/ Regulations
Gay and Robinson Sugar Co.													x										x																
Grove Farm Company							x						x								x		x					x							x				
Hawaii Agribusiness Development Corp																																							
Hawaii Agriculture Research Center									x																														
Hawai'i BioEnergy, LLC																																							
Hawaii Department of Agriculture							x				x		x							x	x		x					x			x				x				x
Hawaii Department of Business, Economic Development and Tourism							x				x									x	x							x			x				x				x
Hawaii Department of Land and Natural Resources							x				x		x							x	x		x					x			x				x				x
Hawaii Electric Light Company, Inc.																																x	x	x	x	x	x	x	x
Hawaii Farm Bureau Federation																																							
Hawaiian Commercial and Sugar Company	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x		x	x		x	x	x	x	
Hawaiian Electric Company, Inc.																																x	x	x	x	x	x	x	x
Hawaiian Islands Bioenergy	x	x			x	x	x		x					x	x	x	x	x	x		x	x		x	x	x		x	x	x			x				x	x	
Hawaiian Mahogany Inc.	x	x	x	x	x	x	x	x	x		x	x	x																										
HR Biopetroleum, Inc.	x	x	x	x	x	x	x	x	x		x	x	x																										
Hu Honua Bioenergy	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x								
Imperium Renewables														x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x								
Kai Bioenergy Corp.				x			x	x	x	x	x		x				x		x	x	x	x	x			x		x	x								x		
Kamehameha Schools							x						x								x		x					x							x				
Kauai Island Utility Cooperative																																x	x	x	x	x	x	x	x
Kuehnle Agrosystems									x																														
Matson Navigation						x																																	
Maui Economic Development Board																																							

	Grow BioEnergy Feedstock (Biostock)													Process Biostock Into Bioenergy Product												Byproduct Value Conversion						Transport							
	SubProcesses						Requirements							SP					R							SP		R				SP		R					
Organization Name	**Field Prep**	**Planting**	**Irrigation**	**Cultivation**	**Harvesting**	**Collect/Transport to Processor**	Capital	Labor	Technical expertise	Water	Permits/Regulation	Community acceptance	Land	**Receive Biostock**	**Preprocessing**	**Pay Producer**	**Convert to Bioenergy Product**	**Prep for Delivery**	Technical Expertise	Permits/ Regulations	Capital	Labor	Land	Community acceptance	Biostock Supply/Variety Consistency	**Remove Byproducts**	**Payment**	Capital	Labor	Infrastructure	Permits/ Regulations	**Receive Bioenergy Consumable**	**Transport**	End User Ability to Use	Capital	Labor	Product volume & consistency	Infrastructure	Permits/ Regulations
Maui Electric Company																																x	x	x	x	x	x	x	x
Maui Land and Pineapple Company							x						x								x		x					x							x				
Maui Planning Commission											x									x											x								x
OmniGreen Renewables																																							
Pacific BioDiesel						x	x	x	x			x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	
Pacific West Energy LLC														x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x								
RealGreen Power LLC																																							
Society for Human Resource Management - Hawaii Chapter								x														x							x							x			
Sunfuels Hawaii LLC														x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x								
Tesoro Hawaii																																x	x	x	x	x	x	x	x
The Gas Company														x		x	x			x			x	x	x								x						
Tradewinds Forest Products	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x								
US Biodiesel Group																																							
U.S. Department of Energy							x				x									x	x							x			x				x				x

A&B Properties, Inc.

Website: www.alexanderbaldwin.com
Contact:
Phone:
Email: cloomis@abprop.com
Location: Puunene, Hi
Island: Maui
Product: Electricity
Status: **Currently performing**
Capacity, Acres:
Capacity, Bioenergy: annually
Source: *http://www.alexanderbaldwin.com/our-company/history.php*
See at beginning of catalog for Framework functions
A&B Properties, Inc. is a diversified real estate commercial and development company, which is comprised of land stewardship, planning, entitlement and development to enhance the value of the A&B's lands, in keeping with community needs.
A&B owns over 89,000 acres throughout Hawaii.

Agricultural Leadership Foundation of Hawaii

Website: www.agleaderhi.org
Contact:
Phone:
Email: office@agleaderhi.org
Location: State, HI
Island: Statewide
Product: n/a
Status: **Currently performing**
Capacity, Acres:
Capacity, Bioenergy: annually
Source: *http://www.agleaderhi.org/index.htm*
See at beginning of catalog for Framework functions
The Agricultural Leadership Foundation of Hawaii recognizes that a healthy, thriving, sustainable agricultural sector is an important component of Hawaii's future. As such, they focus on those in agriculture who will help to lead by providing a Agricultural Leadership Training Program and offering other conferences and training opportunities.

Aloha Green LLC

Website: www.alohagreen.com
Contact:
Phone:
Email: info@alohagreen.com
Location: Hamakua, HI
Island: Hawaii
Product: Biodiesel
Status: **Intend to perform**
Capacity, Acres:
Capacity, Bioenergy: annually
Source: *http://alohagreen.com/home.htm*
See at beginning of catalog for Framework functions
The vision of Aloha Green is to serve as a positive catalyst for economic-sustainability and revitalization of the Village communities along the Hamakua Coastal Region.
Unconfirmed: the company plans to buy jatropha seedlings to produce biodiesel.

Aloha Petroleum, Ltd.

Website: www.alohagas.com
Contact:
Phone:
Email: inquiries@alohagas.com
Location: ,
Island: Oahu
Hawaii
Product: Biodiesel
Status: **Currently performing**
Capacity, Acres:
Capacity, Bioenergy: annually
Source: *http://www.alohagas.com/biodiesel.html*
See at beginning of catalog for Framework functions
Aloha purchases B-100 or 100% biodiesel from Pacific Biodiesel.
The highest demand in the Hawaii market today is for B-20. This is a blend of 20% B-100 and 80% diesel fuel. Aloha blends only with ultra low sulphur diesel fuel which is no greater than 15 ppm sulphur (parts per million). Aloha supplies several private companies and government agencies with B-20.

ARCADIS

Website: www.arcadis-us.com
Contact: Bret Harper
Phone: 808-522-0365
Email: bret.harper@arcadis-us.com
Location: Honolulu, HI
Island: Oahu
Product: Ethanol
Status: **Currently performing**
Capacity, Acres:
Capacity, Bioenergy: 500,000 gal/yr annually
Source: *Organization Provided*
See at beginning of catalog for Framework functions
ARCADIS is an international company providing consultancy, engineering and management services in infrastructure, environment and buildings, to enhance mobility, sustainability and quality of life. ARCADIS develops, designs, implements, maintains and operates projects for companies and governments.

BEI Hawaii

Website: www.beihawaii.com
Contact: Jim Mistysyn
Phone: 808-532-7430
Email: jmistysyn@beihawaii.com
Location: State, HI
Island: Statewide
Product: n/a
Status: **Currently performing**
Capacity, Acres:
Capacity, Bioenergy: annually
Source: *Organization Provided*
See at beginning of catalog for Framework functions
Largest supplier of industrial and agricultural chemicals and fertilizers in Hawaii. Currently bring in products internationally in bulk isotainers, totes, drums, supersacks, bags and smaller units. In many cases, we perform discharge deliveries into customer storage. Have excellent transportation relationships and logistic capabilities to support required time and cost factors. Potential also exists for sale of process byproducts.

BioEnergy Systems of Hawaii

Website: www.bioehawaii.com
Contact:
Phone:
Email: http://www.bioehawaii.com/contactus.html
Location:
Island:
Product:
Status:
Capacity, Acres:
Capacity, Bioenergy: annually
Source: *http://www.bioehawaii.com/aboutus.html*
See at beginning of catalog for Framework functions
Our mission is to create and operate renewable energy production facilities that meet both environmental and energy needs in Hawaii. Bio Energy concentrates on biomass fueled systems to take advantage of biomass fuel's steady and sustainable availability.
Bio Energy also concentrates on waste biomass that otherwise would end up in our landfills or cause other environmental problems to keep its cost of fuel and the energy that it produces as low as possible. In this way, Bio Energy can help keep our cost of electricity or other energy products stable with local sources of fuel while helping to resolve some of Hawaii's ongoing environmental problems.

BlueEarth Biofuels LLC

Website: www.blueearthbiofuels.com
Contact: Landis Maez
Phone: 388-5433
Email: Landis.Maez@BlueEarthHawaii.com
Location: Kahului, HI
Island: Maui
Product: Biodiesel from vegetable oils
Status: **Intend to perform**
Capacity, Acres:
Capacity, Bioenergy: 120 million gallons annually
Source: *Organization Provided*
See at beginning of catalog for Framework functions
Owners, Operators and Developers of Utility/Industrial scale biofuels facilities. BlueEarth Biofuels has for the past 2 years been developing a 120

million gallon per year biodiesel production facility on Maui to fuel MECO's internal combustion power generation assets.

Board of Water Supply

Website: www.hbws.org
Contact:
Phone:
Email: csawai@hbws.org
Location: Honolulu, HI
Island: Oahu
Product: n/a
Status: **Currently performing**
Capacity, Acres:
Capacity, Bioenergy: annually
Source: *http://www.hbws.org/cssweb/display.cfm?sid=1065*
See at beginning of catalog for Framework functions
The Board of Water Supply (BWS) manages O'ahu's municipal water resources and distribution system.

Castle and Cooke

Website: www.castlecookehawaii.com
Contact:
Phone:
Email: mtakemoto@castlecooke.com
Location: Mililani, HI
Island: Oahu
Lanai
Product: n/a
Status: **Currently performing**
Capacity, Acres:
Capacity, Bioenergy: annually
Source:
http://www.renewableenergyworld.com/rea/news/article/2009/01/castle-cooke-and-sunpower-open-1-2-mw-solar-system-in-hawaii-54434
See at beginning of catalog for Framework functions
Castle & Cooke, Inc. was incorporated to be the successor to the real estate and resort business of Dole Food Company, Inc. The Company is engaged in three principal businesses: residential real estate, commercial real estate and resorts.

Castle & Cooke is committed to helping the state of Hawai'i achieve energy independence. With the dedication of Hawai'i's largest solar farm, we are delivering on our commitment by bringing clean solar energy to the people of Lana'i.

Chevron Hawaii

Website: www.chevron.com
Contact:
Phone:
Email: alchee@chevron.com
Location: State, HI
Island: Statewide
Product: Ethanol
Status: **Currently performing**
Capacity, Acres:
Capacity, Bioenergy: annually
Source: *http://www.chevron.com/deliveringenergy/biofuels/*
See at beginning of catalog for Framework functions
As part of Chevron's strategy to invest in renewable energy technologies, we have formed a business unit to advance technology and pursue commercial opportunities related to the production and distribution of advanced biofuels. We are actively investing in the acceleration of the scientific, technical and commercial breakthroughs necessary to bring nonfood biofuels to large-scale commercial production.

City & County of Honolulu

Website: www.honolulu.gov
Contact:
Phone:
Email: achung@honolulu.gov
Location: Honolulu, HI
Island: Oahu
Product: n/a
Status: **Currently performing**
Capacity, Acres:
Capacity, Bioenergy: annually
Source: *Hawaii Directory of Sustainable Energy*
See at beginning of catalog for Framework functions
Governing body for the city and county of Honolulu.

Clean Fuels Development Coalition - Hawaii Chapter

Website: www.cleanfuelsdc.org
www.cleanfuelshawaii.org
Contact:
Phone:
Email: info@cleanfuelshawaii.org
Location: ,
Island:
Product: n/a
Status:
Capacity, Acres:
Capacity, Bioenergy: annually
Source: *Hawaii Directory of Sustainable Energy*
See at beginning of catalog for Framework functions

Clean Fuels Hawai‘i (CFH) is a nonprofit organization established to promote the development and utilization of clean-burning fuels that can reduce dependence on imported oil, improve Hawai‘i's economy, and maintain air quality. CFH has a broad base of support within the energy, environment, health, technology, agriculture and automotive sectors. These diverse interests are drawn together out of their common interest in developing clean fuels for Hawai‘i.

ClearFuels Technology

Website: www.clearfuels.com
Contact:
Phone:
Email: eric@clearfuels.com
Location: Aiea, HI
Island: Oahu
Product: Biodiesel
Jetfuel
Ethanol
Status: **Intend to perform**
Capacity, Acres:
Capacity, Bioenergy: annually
Source: *http://www.clearfuels.com/*
See at beginning of catalog for Framework functions

ClearFuels Technology Inc's mission is to produce clear clean renewable fuels such as ethanol, methanol, hydrogen and synthetic gas from sustainable cellulosic biomass using advanced thermochemical technologies.

ClearFuels focus is on the sugarcane platform, the source of over half the world's ethanol. Clearfuels Technology is integrating its highly efficient thermochemical production of cellulosic ethanol from bagasse and cane trash with the established fermentation processes of producing ethanol from sugarcane. Lester Brown of the Earth Policy Institute explains that sugarcane ethanol has an energy ratio of 1 to 8. This means that for each unit of energy required to transform sugarcane into ethanol, 8 times as much energy is created. For corn this ratio is 1 to 1.3 and for cellulose it is 1 to 4. By integrating thermochemical production of ethanol and syngas from cellulose in the form of bagasse and cane trash, with existing sugar mills and sugar fermentation facilities, ClearFuels' biorefineries are expected to produce more ethanol per acre of sugarcane with lower carbon dioxide emissions per gallon. The resulting integrated facilities also retain the flexibility to vary the production of ethanol, sugar and power to optimize economic returns in response to market conditions.

College of Tropical Agriculture and Human Resources

Website: www2.ctahr.hawaii.edu/ctahr2001
Contact: Andrew G. Hashimoto
Phone: 956-8234
Email: aghashim@ctahr.hawaii.edu
Location: State, HI
Island: Statewide
Product: n/a
Status: **Currently performing**
Capacity, Acres: n/a
Capacity, Bioenergy: n/a annually
Source: *Hawaii Directory of Sustainable Energy*
See at beginning of catalog for Framework functions

Conducts research and educational programs that support tropical agricultural systems that foster viable communities, a diversified economy and a healthy environment.

County of Hawaii

Website: www.hawaii-county.com/
Contact:
Phone:
Email: jtesta@co.hawaii.hi.us
Location: Hilo, HI
Island: Hawaii
Product: n/a
Status: **Currently performing**
Capacity, Acres:
Capacity, Bioenergy: annually
Source: *Hawaii Directory of Sustainable Energy*
See at beginning of catalog for Framework functions
The department provides proactive leadership to enhance the quality of life and sustainability of the Big Island's communities in the areas of agriculture, tourism, energy, economic development, film, community development and information resources.

County of Kauai

Website: www.kauai.gov/OED
Contact:
Phone:
Email: btokioka@kauai.gov
Location: Lihue, HI
Island: Kauai
Product: n/a
Status: **Currently performing**
Capacity, Acres:
Capacity, Bioenergy: annually
Source: *Hawaii Directory of Sustainable Energy*
See at beginning of catalog for Framework functions
Governing body for the county of Kauai.

County of Maui

Website: www.co.maui.hi.us/mayor/economic
Contact:
Phone:
Email: deidre.tegarden@mauicounty.gov
Location: Wailuku, HI
Island: Maui
Product: n/a
Status: **Currently performing**
Capacity, Acres:
Capacity, Bioenergy: annually
Source: *Hawaii Directory of Sustainable Energy*
See at beginning of catalog for Framework functions
Governing body for the county of Maui (including the islands of Hawaii, Lanai, Molokai and Kahoolawe.

Diamond Head Renewable Sources

Website: www.diamondheadrr.com
Contact:
Phone:
Email: http://www.diamondheadrr.com/page1/page1.php
Location: State, HI
Island: Statewide
Product: Ethanol
Status: **Intend to perform**
Capacity, Acres:
Capacity, Bioenergy: 12M Gallons annually
Source: *Info from PBN: http://www.bizjournals.com/pacific/stories/2009/02/16/story12.html?b=1234760400%5E1778568*
See at beginning of catalog for Framework functions
New company plans to build a $200 million plant that would start off making 12 million gallons of ethanol annually, about 22 percent of the state's current use.
The company plans to start construction within a year and expand the plant over three years to eventually produce up to 40 million gallons annually. The company is trying to close a deal on a 30-acre lot at Kalaeloa. The plant would be fueled by garbage and nonfood feedstock and use a process that will turn garbage into fuel and also generate electricity.

The company worked out a deal to license the gasification technology for free from Syntec Biofuel, based in Vancouver, British Columbia.

Gay and Robinson Sugar Co.

Website:
Contact:
Phone:
Email: eak@gayandrobinson.com
Location: Kaumakani, HI
Island: Kauai
Product: Ethanol
Status: **Currently performing**
Capacity, Acres:
Capacity, Bioenergy: annually
Source: *http://archives.starbulletin.com/2008/09/11/news/story03.html*
See at beginning of catalog for Framework functions
Gay & Robinson plans to lease its sugar mill, terminal and other assets to Pacific West Energy LLC, which intends to expand sugar production to produce ethanol and energy in Kaumakani.

Grove Farm Company

Website: www.grovefarm.com
Contact:
Phone:
Email:
Location: Lihue, HI
Island: Kauai
Product: n/a
Status: **Currently performing**
Capacity, Acres:
Capacity, Bioenergy: annually
Source: *http://www.grovefarm.com/renewable-energy*
See at beginning of catalog for Framework functions
Grove Farm is committed to exploring sustainable ways to utilize its existing water and land resources to alleviate Kauai's dependence on expensive energy sources. Research is currently underway considering the feasibility of various alternative energy sources on Kaua`i.
In 2006, Grove Farm became a founding member of Hawaii BioEnergy (HBE), a corporation established by three of Hawai`i's largest landowners: Grove Farm Company, Kamehameha Schools, and Maui Land & Pineapple Company.

Hawaii Agribusiness Development Corp

Website: www.hawaii.gov/hdoa/adc/
Contact:
Phone:
Email: hiagribusiness@yahoo.com
Location: State, HI
Island: Statewide
Product: n/a
Status: **Currently performing**
Capacity, Acres:
Capacity, Bioenergy: annually
Source:
http://hawaii.gov/hdoa/adc/?searchterm=agribusiness%20development
See at beginning of catalog for Framework functions
The Agribusiness Development Corporation was established to facilitate and provide direction for the transition of Hawai`i's agriculture industry from a dominance of sugar and pineapple to one composed of a diversity of different crops.
The mission of the Agribusiness Development Corporation (ADC) is to acquire, and manage in partnership with farmers, ranchers, and aquaculture groups, selected high-value lands, water systems, and infrastructure for commercial agricultural use and to direct research into areas that will lead to the development of new crops, markets, and lower production costs.

Hawaii Agriculture Research Center

Website: www.harc-hspa.com
Contact: Mike Poteet
Phone: 292-9724
Email: Mpoteet@harc-hspa.com
Location: Kunia, HI
Island: Oahu
Product: Jatropha
Sugarcane
Sweet Sorghum
Status: **Currently performing**
Capacity, Acres: < 5
Capacity, Bioenergy: R&D/Demo Scale annually

Source: *Organization Provided*
See at beginning of catalog for Framework functions
HARC is a 501(c)(3) non-profit organization that functions as a support arm for Hawaii's agriculture industry. HARC has research programs in biotechnology, molecular biology, analytical biochemistry, sugarcane breeding and agronomy, coffee and cacao breeding, forestry, plant pathology, and biofuel feedstock development.

Hawai'i BioEnergy, LLC

Website: www.hawaiibioenergy.com
Contact:
Phone:
Email: paulzorner@msn.com
Location: Honolulu, HI
Island: Statewide
Product:
Status: **Intend to perform**
Capacity, Acres:
Capacity, Bioenergy: annually
Source: *www.hawaiibioenergy.com*
See at beginning of catalog for Framework functions
Hawai‘i BioEnergy (HBE) is a corporation established by three of Hawai‘i's largest landowners: Kamehameha Schools, Grove Farm Company Inc., and Maui Land & Pineapple Company, Inc.
Hawai‘i BioEnergy’s mission is to reduce Hawai‘i's energy costs, green house gas emissions, and dependence on imported fossil fuels through the research and development of local renewable bioenergy projects.
Hawai‘i BioEnergy is actively researching all technically, economically, and environmentally viable processing techniques and distribution channels for a variety of energy crops, including but not limited to sugarcane, woody biomass, and algae.

Hawaii Department of Agriculture

Website:
Contact:
Phone:
Email: earl.j.yamamoto@hawaii.gov
Location: State, HI
Island: Statewide
Product: n/a
Status: **Currently performing**
Capacity, Acres:
Capacity, Bioenergy: annually
Source:
See at beginning of catalog for Framework functions
State department created to support, enhance and promote Hawaii’s agriculture and aquaculture industries.

Hawaii Department of Business, Economic Development and Tourism

Website: www.dbedt.hawaii.gov
Contact:
Phone:
Email: tliu@dbedt.hawaii.gov
Location: State, HI
Island: Statewide
Product: n/a
Status: **Currently performing**
Capacity, Acres:
Capacity, Bioenergy: annually
Source: *Hawaii Directory of Sustainable Energy*
See at beginning of catalog for Framework functions
State agency whose core mission is to strengthen and diversify Hawai‘i’s economy, lead business development efforts, attract new businesses and investment, and document Hawai‘i’s economic development.

Hawaii Department of Land and Natural Resources

Website:
Contact:
Phone:
Email: ken.c.kawahara@hawaii.gov
Location: State, HI
Island: Statewide
Product: n/a
Status: **Currently performing**
Capacity, Acres:
Capacity, Bioenergy: annually
Source:
See at beginning of catalog for Framework functions

State agency whose core mission is to enhance, protect, conserve and manage Hawaii's unique and limited natural, cultural and historic resources held in public trust for current and future generations of visitors and the people of Hawaii nei in partnership with others from the public and private sectors

Hawaii Electric Light Company, Inc.

Website: www.helcohi.com
Contact:
Phone:
Email: jay.ignacio@helcohi.com
Location: ,
Island: Hawaii
Product: Electricity
Status: **Currently performing**
Capacity, Acres:
Capacity, Bioenergy: annually
Source: *Hawaii Directory of Sustainable Energy*
See at beginning of catalog for Framework functions
Hawai'i Electric Light Company provides electricity to nearly 80,000 customers on the Big Island.

Hawaii Farm Bureau Federation

Website: www.hfbf.org
Contact:
Phone:
Email: info@hfbf.org
Location: Honolulu, HI
Island: Statewide
Product: n/a
Status: **Currently performing**
Capacity, Acres:
Capacity, Bioenergy: annually
Source: *www.hfbf.org*
See at beginning of catalog for Framework functions
Association of farmers. The Hawaii Farm Bureau Federation (HFBF) is a non-profit organization of farming families united for the purpose of analyzing problems and formulating action to ensure the future of agriculture thereby promoting the well-being of farming and the State's economy.

Hawaiian Commercial and Sugar Company

Website: www.hcsugar.com
Contact:
Phone:
Email: ljakeway@hcsugar.com
Location: Puunene, HI
Island: Maui
Product: Electricity
Status: **Currently performing**
Capacity, Acres:
Capacity, Bioenergy: annually
Source: *http://www.hcsugar.com/*
See at beginning of catalog for Framework functions
HC&S grows sugar, owns land (or leases from related companies), generates electricity from combustion of bagasse and is positioned to do conversion to ethanol. East Maui Irrigation provides water. A&B owns these companies as well as the trucking, farm operation, and shipping (sugar). MECO buys electricity from HC&S and distributes to end users.

Hawaiian Electric Company, Inc.

Website: www.heco.com
Contact: Sam Pintz
Phone:
Email: s.pintz@heco.com
Location: Honolulu, HI
Island: Oahu
Product: Electricity
Status: **Currently performing**
Capacity, Acres:
Capacity, Bioenergy: annually
Source: *www.heco.com*
See at beginning of catalog for Framework functions
For more than 100 years, Hawaiian Electric Company has provided the energy that has fueled the islands' development from a Hawaiian kingdom to a modern state. Hawaiian Electric Company, Inc. (HECO), and its subsidiaries, Maui Electric Company, Ltd. (MECO), and Hawaii Electric Light Company, Inc. (HELCO), serves 95% of the state's 1.2 million residents on the islands of O`ahu, Maui, Hawai`i Island, Lana`i and Moloka`i.
Imports renewable crude fuel oil (various but mostly palm, need certification and testing with each differing type) and mixes it with traditional fuel oil to

fire boilers for turbine electricity generation. Mix experiments are from 5% BF on up to 100%.
Testing renewable fuel oil (not biodiesel) for use in diesel generators.
Contracts with HARC who has contracts with UHH and CTAHR to help select biofuel crop and growing methods for biostock production in Hawaii.

Hawaiian Islands Bioenergy

Website: www.bioenergyhawaii.com
Contact: Randall Lichner
Phone: 866-490-3665
808-561-5345
Email: RLICHNER@BIOENERGYHAWAII.COM
Location: Kapolei, HI
Island: Hawaii
Product: Biodiesel - B99, B50, B20, B5
Status: **Intend to perform**
Capacity, Acres:
Capacity, Bioenergy: Up to 20MM/GPY annually
Source: *Organization Provided*
See at beginning of catalog for Framework functions
Hawaiian Islands Bioenergy, Inc. owns and operates US-based biofuel processing and refinery operations with total production capacity in excess 1,000,000 gallons per month. HIB is registered as a refiner and blender of biofuel with the CCR, EPA, and IRS. Biofuel operations scheduled to begin in Hawaii late 2009.

Hawaiian Mahogany Inc.

Website: www.hawaiianmahogany.com
Contact:
Phone:
Email: treefarm@halekua.com
Location: Lawai, HI
Island: Kauai
Product: Eucalyptus

Status: **Currently performing**
Capacity, Acres:
Capacity, Bioenergy: annually
Source: *Hawaii Directory of Sustainable Energy*
See at beginning of catalog for Framework functions
Hawaiian Mahogany specializes in the research and development of renewable energy systems, sustainable timber and food systems, and the sustainable growth of biofuels.

HR Biopetroleum, Inc.

Website: www.hrbp.com
Contact:
Phone:
Email: esf@hawaii.rr.com
Location: ,
Island:
Product: Microalgae
Status: **Currently performing**
Capacity, Acres:
Capacity, Bioenergy: annually
Source: *Hawaii Directory of Sustainable Energy*
See at beginning of catalog for Framework functions
Technology company specializing in cultivation of algae to produce feedstock for biodiesel and to sequester CO2.

Hu Honua Bioenergy

Website: www.huhonua.com
Contact:
Phone:
Email: info@huhonua.com
Location: Honolulu, HI
Island: Oahu
Product: Electricity
Status: **Intend to perform**
Capacity, Acres:
Capacity, Bioenergy: annually
Source: *www.huhonua.com*
See at beginning of catalog for Framework functions
Hu Honua Bioenergy, LLC is a Hawaii-based company created to meet local electricity needs using renewable resources. It is co-owned by ERH, a local firm that has been pursuing renewable projects in Hawaii for the past five years, and MMA Renewable Ventures, LLC, a leading producer of energy from renewable sources.
North of Hilo, Hu Honua Bioenergy LLC is restoring the old Hilo Coast Processing Co. sugar mill at Pepeekeo. The company has been at work for

several months, retrofitting the facility to burn biofuel, clearing the 26-acre property of old coal and preparing the land to plant leucaena, a fast-growing tree used for fuel wood and cattle feed.
The Hu Honua plant would be a 24-megawatt operation and provide 7 percent to 10 percent of the island's energy demand. Hu Honua would be powered by a combination of eucalyptus, leucaena, green waste from the county and leftover material from land clearing.

Imperium Renewables

Website: www.imperiumrenewables.com
Contact:
Phone:
Email: david.leonard@
imperiumrenewables.com
Location: ,
Island:
Product: Biodiesel
Status: **Intend to perform**
Capacity, Acres:
Capacity, Bioenergy: annually
Source: *Hawaii Directory of Sustainable Energy*
See at beginning of catalog for Framework functions
Imperium Renewables Hawai‘i plans to produce biodiesel from palm oil imported from Malaysia, though the refinery would potentially encourage local farming of biofuel crops such as oil palm, soybean, flax, rapeseed, sunflower, peanut, kukui nut, avocado, coconut, neem and algae.

Kai Bioenergy Corp.

Website: www.kaibioenergy.com
Contact: Mario Larach
Phone: 858-945-5291
Email: larach.m@kaibioenergy.com
Location: Kailua Kona, HI
Island: Hawaii
Product: Fuel for Transportation or Power Gen
Status: **Currently performing**
Capacity, Acres:
Capacity, Bioenergy: 5MGY in 2 Years annually
Source: *Organization Provided*
See at beginning of catalog for Framework functions
Kai BioEnergy Corp (KAI) is a renewable energy company that has developed disruptive technology and processes that enable the first economically viable large scale commercial production of low-cost microalgae fossil-fuel-equivalent fuels for transportation or for zero-carbon electric power generation.

Kamehameha Schools

Website: www.ksbe.edu
Contact:
Phone:
Email: mamorton@ksbe.edu
Location: State, HI
Island: Statewide
Product: n/a
Status: **Currently performing**
Capacity, Acres:
Capacity, Bioenergy: annually
Source: *www.ksbe.edu*
www.hawaiibioenergy.com
See at beginning of catalog for Framework functions
Kamehameha Schools is the largest private landowner in the state of Hawai‘i. Income generated from its residential, commercial and resort leases, as well as diverse investments, fund the schools’ maintenance and operations.
The entity is also a Hawaii BioEnergy, LLC partner.

Kauai Island Utility Cooperative

Website: www.kiuc.coop
Contact:
Phone:
Email: srymsha@kiuc.coop
Location: Lihue, HI
Island: Kauai
Product: n/a
Status: **Currently performing**
Capacity, Acres:
Capacity, Bioenergy: annually
Source: *Hawaii Directory of Sustainable Energy*
See at beginning of catalog for Framework functions
In November of 2002, KIUC became the first electric cooperative in Hawai‘i. KIUC is a nonprofit organization owned by the 23,800 members it serves.

Increasing generation from renewable sources and diversifying our generation mix is a top priority of KIUC. By 2023 KIUC plans to achieve 1990 greenhouse gas emission levels, which will result in more than 50 percent of generation from renewable sources. Expansion of renewable generation sources will include biomass, wind, hydroelectric, solar and use of biofuels when economical.

Kuehnle Agrosystems

Website:
Contact:
Phone:
Email: gordon@kashawaii.com
Location: Honolulu, HI
Island: Oahu
Product: Microalgae
Status: **Currently performing**
Capacity, Acres:
Capacity, Bioenergy: annually
Source: *Pacific Business News*
See at beginning of catalog for Framework functions
Kuehnle AgroSystems works with algae growers to create customized strains using natural or genetic-modification techniques

Matson Navigation

Website: www.matson.com
Contact:
Phone:
Email:
Location: Honolulu, Hi
Island: Statewide
Product: n/a
Status: **Currently performing**
Capacity, Acres:
Capacity, Bioenergy: annually
Source: *www.matson.com*
See at beginning of catalog for Framework functions
Subsidiary of Alexander and Baldwin. Matson Navigation Company is one of the leading U.S.-flag carriers operating in the Pacific, with a longstanding reputation for quality service in the transportation industry. Founded in 1882 and incorporated in 1901, Matson is the principal carrier of containerized freight and automobiles between the West Coast and Hawaii, Guam and Mid-Pacific, and is the largest subsidiary of Honolulu-based Alexander & Baldwin, Inc.

Maui Economic Development Board

Website: www.medb.org
Contact:
Phone:
Email: tom@medb.org
Location: Kihei, HI
Island: Maui
Product: n/a
Status: **Currently performing**
Capacity, Acres:
Capacity, Bioenergy: annually
Source: *Hawaii Directory of Sustainable Energy*
See at beginning of catalog for Framework functions
A 501(c)(3) nonprofit corporation that has been serving the Maui County community since 1982. MEDB's mission is to provide leadership for the responsible design and development of a strong, sustainable and diversified economy. To achieve its goals, MEDB engages the community in economic development decision making, assists businesses in growth sectors, initiates education and work force preparation, and promotes economic literacy in partnership with business, government, academia and community stakeholders.

Maui Electric Company

Website: www.mauielectric.com
Contact:
Phone:
Email: edward.reinhardt@mauielectric.com
Location: ,
Island: Maui
Product: Electricity
Status: **Currently performing**
Capacity, Acres:
Capacity, Bioenergy: annually
Source: *Hawaii Directory of Sustainable Energy*
See at beginning of catalog for Framework functions

Maui Electric Company provides electricity to more than 65,000 customers on Maui, Molokaʻi and Lānaʻi.

Maui Land and Pineapple Company

Website: www.mauiland.com
Contact:
Phone:
Email: mlpcommunications@mlpmaui.com
Location: Kahului, HI
Island: Maui
Product: n/a
Status: **Currently performing**
Capacity, Acres:
Capacity, Bioenergy: annually
Source: *www.mauiland.com*
See at beginning of catalog for Framework functions
Maui Land & Pineapple Company, Inc. (ML&P) is a land holding and operating company dedicated to agriculture, resort operation and the creation and management of holistic communities. ML&P owns approximately 25,000 acres on the island of Maui, on which it operates the Kapalua Resort community and cultivates approximately 2,000 acres of pineapple. ML&P also owns and manages the 9,881 acre Pu`u Kukui Watershed Preserve, which is the largest private nature preserve in the state of Hawai`i.
The entity is also a Hawaii BioEnergy, LLC partner.

Maui Planning Commission

Website: www.co.maui.hi.us/index.asp?NID=191
Contact:
Phone:
Email: kalepa@maui.net
Location: ,
Island: Maui
Product: n/a
Status: **Currently performing**
Capacity, Acres:
Capacity, Bioenergy: annually
Source: *www.co.maui.hi.us/index.asp?NID=191*
See at beginning of catalog for Framework functions
Reviews other proposed land use ordinances and amendments prepared by the Planning Director or by the County Council, and after public hearings, transmits findings and recommendations to the County Council for consideration and action.

OmniGreen Renewables

Website:
Contact:
Phone:
Email: hoa.aina@yahoo.com
Location: ,
Island:
Product:
Status:
Capacity, Acres:
Capacity, Bioenergy: annually
Source:
See at beginning of catalog for Framework functions
Native Hawaiian firm. Waianae

Pacific Biodiesel, Inc.

Website: www.biodiesel.com
Contact: Robert King
Phone: (808) 877-3144
Email: info@biodiesel.com
Location: Kahului, HI
Island: Maui
Oahu
Product: Biodiesel
Status: **Currently performing**
Capacity, Acres:
Capacity, Bioenergy: 1,500,000 gal annually
Source: *www.biodiesel.com/index.php/company/about_pacific_biodiesel_inc*
See at beginning of catalog for Framework functions
Headquartered in Kahului, Hawaii, Pacific Biodiesel, Inc. was conceived in 1995 in response to serious environmental and health concerns surrounding unmanageable quantities of used cooking oil at the Central Maui Landfill. Robert King, then owner of King Diesel that maintains the landfill's generators, proposed converting the restaurant waste into biodiesel that would fuel the generators. Within a year, his proposal was a reality. The original small-scale plant — recognized as one of the first commercially viable biodiesel plants in the U.S. — marks the beginning of our company. Since

opening and operating the very first retail biodiesel pump in America, Pacific Biodiesel has built a solid reputation as a leading pioneer in the rapidly expanding biodiesel industry.
Pacific Biodiesel began offering its multi-feedstock process technology to other developing companies in 1997. That's when Japanese businessman Soichiro "Sol" Yoshida contracted Pacific Biodiesel to design and build a plant for his Kentucky Fried Chicken franchise in Nagano, Japan. Shortly after the completion of the Nagano plant, we began to attack an even larger problem for the Maui Landfill — grease trap waste. With the addition of a custom designed processor, the plant is able to supply its own boiler fuel while diverting 270 tons of trap grease from the landfill each month. In 2000, Pacific Biodiesel built a facility in Honolulu with a current capacity double that of the Maui plant.
Since its inception over a decade ago, Pacific Biodiesel has built 10 plants on the mainland U.S. and Japan, and completed expansions on several of those plants.

Pacific West Energy LLC

Website: www.pacificwestenergy.com
Contact:
Phone:
Email: wmaloney@aol.com
Location: Kaumakani, HI
Island: Kauai
Product: Ethanol
Electricity
Status: **Intend to perform**
Capacity, Acres:
Capacity, Bioenergy: annually
Source: *www.pacificwestenergy.com*
See at beginning of catalog for Framework functions
The company is currently actively developing an integrated energy bio-refinery producing ethanol and electricity on the island of Kaua'i. The Kaua'i project entails the operation of the 7,500-acre Gay & Robinson sugar plantation and mill, and the development, construction and operation of a fuel ethanol plant and electricity production facility integrated into the sugar mill. The company is also developing a biodiesel plant designed to produce biodiesel for use in green power production and for sale to third parties.

RealGreen Power LLC

Website: www.realgreenpower.com
Contact: Dennis Furukawa
Phone: 833-0181
Email: dennis@realgreenpower.com
Location: , Hawaii
California
Island: Maui
Product: n/a
Status:
Capacity, Acres:
Capacity, Bioenergy: 3200-12000MW annually
Source: *Organization Provided*
See at beginning of catalog for Framework functions
Renewable energy and purified water from wastewater. RGP's system produces zero air, water, or land pollution. Power outputs: 400kW to over 800kW per 1/2 million gallon facility, baseload and peak power, load-following capabilities. Computer-controlled automated operation. Designed for animal wastes, sugar mill and ethanol waste, biodiesel wastes, food processing wastes. Purified water volumes of 100,000 to 400,000 gal per day.

Society for Human Resource Management - Hawaii Chapter

Website: www.shrmhawaii.org
Contact: Melissa Pavlicek
Phone: 808-447-1840
Email: pavlicekm001@hawaii.rr.com
Location: State, HI
Island: Statewide
Product: n/a
Status: **Currently performing**
Capacity, Acres: n/a
Capacity, Bioenergy: n/a annually
Source: *Organization Provided*
See at beginning of catalog for Framework functions
SHRM is a non-profit trade organization relating to human resource management and engage in workforce development initiatives and workforce training.

Sunfuels Hawaii LLC

Website:
Contact: John Ray
Phone: 885-0441
Email: info@sunfuelshawaii.com
Location: Kamuela, HI
Island: Hawaii
Product: Biodiesel
Status: **Intend to perform**
Capacity, Acres:
Capacity, Bioenergy: annually
Source:
See at beginning of catalog for Framework functions
Sunfuels Hawaii, LLC is exploring the opportunity to establish a biomass-to-liquid plant to produce SunDiesel fuel on the Big Island.

Tesoro Hawaii

Website: www.tsocorp.com
Contact:
Phone:
Email: ltanaka@tsocorp.com
Location: ,
Island: Oahu
Maui
Hawaii
Product: Biodiesel
Status: **Currently performing**
Capacity, Acres:
Capacity, Bioenergy: annually
Source:
http://www.tsocorp.com/tsocorp/ProductsandServices/Refining/KapoleiHawaiiRefinery/KapoleiHawaiiRefinery
See at beginning of catalog for Framework functions
Tesoro Hawaii plays a key role in meeting the state's growing demand for energy, including its most pressing need: transportation fuels. Hawaii's isolated geographic location in the Pacific makes jet and marine fuels critical to powering the local economy, and Tesoro Hawaii rises to the challenge as the leading supplier of transportation fuels in the Islands.

Tesoro Hawaii, which operates the larger of the state's two refineries, efficiently converts crude oil into a full range of refined petroleum products that consumers and businesses need every day.

The Gas Company

Website: www.hawaiigas.com
Contact:
Phone:
Email: sackerman@hawaiigas.com
Location: State, HI
Island: Statewide
Product:
Status:
Capacity, Acres:
Capacity, Bioenergy: annually
Source: *www.hawaiigas.com*
See at beginning of catalog for Framework functions
The Gas Company provides gas energy to consumers, business and government throughout the state of Hawaii — Oahu, Maui, Hawaii, Kauai, Molokai and Lanai.

Tradewinds Forest Products

Website: www.tradewindsforestproducts.com
Contact:
Phone:
Email: don.b@tfp-hi.com
Location: Ookala, HI
Island: Hawaii
Product: Eucalyptus
Status: **Intend to perform**
Capacity, Acres:
Capacity, Bioenergy: annually
Source: *www.tradewindsforestproducts.com*
See at beginning of catalog for Framework functions
Tradewinds Forest Products was formed for the purpose of establishing a value-added forest products industry in Hawaii. Tradewinds will manufacture and market veneer made from eucalyptus logs. The company is located in the town of O'okala on the Big Island's Hamakua Coast.

Tradewinds' facility will include a wood-fired co-generation plant which will provide power and steam for the manufacturing process and sell surplus power to HELCO.

US Biodiesel Group

Website:
Contact:
Phone:
Email: kyledatta@yahoo.com
Location: ,
Island:
Product:
Status:
Capacity, Acres:
Capacity, Bioenergy: annually
Source:
See at beginning of catalog for Framework functions

U.S. Department of Energy

Website: www.energy.gov
Contact:
Phone:
Email:
Location: State, HI
Island: Statewide
Product: n/a
Status: **Currently performing**
Capacity, Acres:
Capacity, Bioenergy: annually
Source: *www.energy.gov*
See at beginning of catalog for Framework functions
The Department of Energy's overarching mission is to advance the national, economic, and energy security of the United States; to promote scientific and technological innovation in support of that mission; and to ensure the environmental cleanup of the national nuclear weapons complex. The Department's strategic goals to achieve the mission are designed to deliver results along five strategic themes including promoting America's energy security through reliable, clean, and affordable energy.

References

Subject Matter Experts

Kelly King, Vice President
Pacific Biodiesel Inc.

Robert King, President
Pacific Biodiesel Inc.

Dr. Charles Kinoshita, Associate Dean of Student Affairs
College of Tropical Agriculture and Human Resources, University of Hawaii

Mawae Morton, Strategic Resources Manager
Kamehameha Schools

Michael Saalfeld
SunFuels Hawaii, LLC

Arthur Seki, Director, Renewable Energy
Hawaiian Electric Company, Inc.

Dr. Robert Shleser, Chief Technology Officer
ClearFuels Technology, Inc.

Priscilla Thompson, Assistant Specialist
Hawaii Natural Energy Institute, University of Hawaii

Dr. Scott Turn, Associate Researcher
Hawaii Natural Energy Institute, University of Hawaii

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Pacific Business News

Sources as listed in "Source of Information" field in Bioenergy Partner Catalog.

Hawaii Bioenergy Master Plan

Economic Impacts

Prepared for

The Hawaii Natural Energy Institute

By

Makena Coffman
Department of Urban & Regional Planning
University of Hawaii at Manoa

December 2009

Executive Summary

The objective of this study is to identify and evaluate potential economic impacts from the production of biofuels at points along the value chain. The “value chain” is here defined as: feedstock production, feedstock logistics, conversion, distribution, and end use. To accomplish this task, a macroeconomic model of Hawaii’s economy, representing macro and sector-level inter-linkages, has been created. The model utilizes the 2005 State Input-Output Study for Hawaii, prepared by the Department of Business, Economic Development, and Tourism (DBEDT), as the primary data source. The 2005 Input-Output table is an excellent year in which to calibrate for this analysis because the recent price of world oil was similar: averaging $49/barrel.

Although there are several avenues by which a local bioenergy industry could develop, from biomass combustion for electricity to biomass for liquid fuel, this study focuses on sugarcane-to-ethanol. This scenario is chosen because 1) Hawaii has considerable experience with growing sugarcane as a feedstock and ethanol conversion is a currently commercially available technology, 2) a 10% ethanol-blending mandate for motor fuel was made effective and a 20% by 2020 Alternative Fuel Standard (AFS) was adopted in 2006, 3) ethanol blending facilities have been established within the state. Although the impetus of the 2006 mandate implementation, amongst other federal and state-level incentives, was to prompt a local bioenergy industry, the mandate has been met with imported ethanol sources.

To produce 93.7 million gallons of sugarcane derived ethanol in order to meet the AFS, 91,500 acres of irrigated agricultural land would need to be in sugarcane production. Assuming the industry is viable, it would be a $312 million sector and could produce ethanol at $3.33 per gallon – although costs may be brought down through the integration of byproducts with the electric sector. Roughly 1,200 jobs would be created with an average annual salary of $45,000. This results in an increase in gross state product of $272 million annually (+0.5%).

The creation of a local ethanol industry could serve to revitalize currently fallow agricultural lands as well as provide jobs in agriculturally oriented areas of Hawaii. On the other hand, it will take significant State support to make locally produced ethanol competitive with imported sources. The benefit stream must be assessed in relation to alternative agricultural activities, water consumption, community suitability and labor availability.

Ethanol is only one biofuel product that may be utilized within the state and findings about ethanol may not be applicable to other feedstock or conversion technologies. As bioenergy technologies become commercially available, both in Hawaii and elsewhere, there will be increasingly reliable information on their impacts and costs. Thus further study of biofuels for electricity generation and alternative liquid fuel products like biodiesel are needed to provide a more comprehensive view of the future of biofuels and their impacts to Hawaii’s economy.

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1. Introduction

The development of a local bioenergy sector is often seen as a means of "revitalizing" rural communities as well as a form of import-substitution development (De La Torre Ugarte et al., 2007; OECD, 2008). This study assesses the economic impacts to the State of Hawaii's economy of producing ethanol locally in order to meet the States' alternative liquid fuel targets.

There are many avenues by which a local bioenergy industry could develop. For example, sugarcane, banagrass, *Jatropha*, oil palm, or tree crops such as *Eucalyptus* or leucaena, could be used for either transportation or electricity fuels. This list is certainly not exhaustive, and there are also many technologies under development. For instance, considerable research is now being conducted on algae as a feedstock. Given the range of possibilities, this study starts with a currently commercially available technology and a fuel stock with which Hawaii has considerable knowledge: ethanol from sugarcane. Effective since 2006, the State has a 10% ethanol-blending requirement for motor fuel. More recently, an alternative fuel standard (AFS) of 20% by 2020 has been adopted. As such, this analysis focuses on increasing ethanol consumption within the State such that it accounts for 20% of vehicle fuel, approximately 93.7 million gallons per year, met through local production.

Although this report focuses on estimating the costs and economic impacts of ethanol in Hawaii, a discussion of biomass-to-electricity is also provided. Biomass-to-electricity is another likely scenario for Hawaii's bioenergy future, given technological viability of current feedstock production. A comprehensive assessment of cost estimates, however, is outside the scope of this study and merits further analysis.

Description of Work

The Task Objective is to identify and evaluate potential economic impacts from the production of biofuels at points along the value chain. The "value chain" is here defined as: feedstock production, feedstock logistics, conversion, distribution, and end use. To accomplish this task, the cost of ethanol is estimated and economy-wide impacts are assessed using a comprehensive model of Hawaii's economy.

The analysis of locally produced ethanol is taken in two steps. The first is to estimate the cost per gallon of local ethanol, including production costs along the value chain. This was accomplished using production data for sugarcane in Hawaii, including the cost of inputs such as labor, land, and equipment, and yield estimates for irrigated fields. Sugarcane is then assumed to be the feedstock for conversion to ethanol. A survey of other per gallon cost estimates for sugarcane to ethanol in Hawaii and the U.S. is also provided.

The second step is to assess the overall impacts to the state economy from producing ethanol locally. To do so, a model of economic activity in Hawaii is created, hereby called the Hawaii Bioenergy Model. The Hawaii Bioenergy Model utilizes the 2005 State Input-Output Study for Hawaii, prepared by the Department of Business, Economic Development, and Tourism (DBEDT), as the primary data source. The 2005 Input-Output table is an excellent year in which to calibrate for this analysis because the price of world oil was similar to today: averaging $49/barrel.[1] The 2005 Hawaii Input-Output Table outlines the production processes of 68 sectors in Hawaii's economy and 11 agents of final demand, including households, visitors, state and local government, federal military, and exports. For the purposes of this study, economic activity has been aggregated to 18 relevant sectors. Agricultural industries such as sugarcane production and petroleum manufacturing industries are detailed within this dataset.

The model is designed to help better understand the macro-economic impacts of a growing ethanol industry in Hawaii. The inputs and cost of production of ethanol in Hawaii are estimated, including inter-industry supply and demand. Ethanol, accounting for differences in energy content, is assumed to be substitutable with petroleum manufacturing output (i.e. gasoline) within the economy. Model results are estimated for the 1) impacts of meeting 20% of our vehicle fuel needs with locally produced ethanol and 2) with a 50% increase in the world price of oil.

Stakeholder Input

A stakeholder meeting was held on April 2, 2009 to gather perspectives on the potential economic impacts of local biofuel production. Issues of job creation, labor availability, financial incentives, production barriers, and community impacts were discussed. Various concerns and insights provided in that meeting are addressed throughout this report.

2. An Overview of Hawaii's Current Energy Economy

The State of Hawaii's economy produces $90 billion of economic goods and services annually and, accounting for the balance of trade, has a gross state product of $64 billion. The State imports over 50 million barrels of oil to the islands every year (DBEDT, 2007a). Roughly $1.7 billion dollars are spent on imports to the two petroleum refineries located on the island of Oahu: Tesoro and Chevron (DBEDT, 2008). The petroleum manufacturing industry accounts for roughly 2.7% of this economic output, a $2.4 billion industry. Although this seems like a relatively modest proportion of overall economic activity, strong evidence exists to show a compounding relationship between oil prices and macroeconomic indicators.[2] Primarily, there is a compounding economic effect of sudden, rising oil prices because petroleum products enter into the production of every

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[1] World crude oil prices averaged $49/barrel in 2005, based on the first week of every month. They ranged from a low of $35/barrel to a high of $60/barrel (EIA World Crude Oil Prices, http://tonto.eia.doe.gov/dnav/pet/hist/wtotworldw.htm).

[2] See Hamilton (1983), Burbidge and Harrison (1984), Keane and Prasad (1996), and Barsky and Killian (2004) for national and international examples; Coffman (2008) and Gopalakrishnan et al (1993) for a Hawaii-specific discussion.

sector of the economy. This relationship is particularly strong in Hawaii because the electric sector meets 78% of its energy needs through petroleum burning (Coffman, 2008).

There are an estimated 423 jobs in the petroleum manufacturing industry, paying an average wage and salary of $185,000 annually[3] (DBEDT, 2008). The primary consumers of petroleum manufacturing output are the electric sector (20.7% of the value of petroleum manufacturing output is consumed in the electric sector), air transportation sector (11.9%), and resident consumption of gasoline (17.2%). In addition, 25.1% of the value of petroleum manufacturing output is exported out of the State. Table 1 shows Sector-Level Petroleum Manufacturing Demand in the baseline economy. It provides a perspective of direct "petroleum-intensity" by sector. It shows the value of petroleum manufacturing as demanded by each sector as a proportion of total sector productivity, thus normalizing large and small sectors within Hawaii's economy.

[3] Calculated from the 2005 Input-Output Study: total Wages and Salaries paid in 2005 ($78.4 million) divided by the number of Wage and Salary Jobs (423).

Table 1. Sector-Level Petroleum Manufacturing Demand

	Value of Petroleum Manufacturing Input	Value of Total Sector Output	Proportion of Petroleum Manufacturing Input in Sector Output
	$ Million		%
Sugarcane	0.90	72.83	1.24%
Agriculture	11.82	653.95	1.81%
Mining & Construction	24.76	7,307.36	0.34%
Petroleum Manufacturing	112.04	2,425.54	4.62%
Other Manufacturing & Processing	21.47	2,739.10	0.78%
Air Transportation	**289.20**	**2,147.71**	**13.47%**
Water Transportation	73.76	1,677.32	4.40%
Other Transportation	31.33	1,411.87	2.22%
Electricity	**502.14**	**1,927.87**	**26.05%**
Gas Production & Distribution	**21.41**	**84.54**	**25.33%**
Wholesale & Retail Trade	28.39	9,030.68	0.31%
Finance & Insurance	1.53	4,399.57	0.03%
Real Estate	45.41	14,009.94	0.32%
Business & Professional Services	14.03	9,849.97	0.14%
Waste Management & Remediation Services	6.20	250.02	2.48%
Other Services	49.38	19,005.46	0.26%
Federal Government	1.80	7,608.43	0.02%
State & Local Government	20.33	5,693.40	0.36%

Source: Department of Business, Economic Development, and Tourism, State of Hawaii (2008). The 2005 State Input-Output Study for Hawaii. Aggregation by author.

The notably petroleum-intensive industries are air transportation (13.7% of the value of air transportation inputs are petroleum manufacturing), electricity (26.1%), and gas production & distribution (25.3%). This is a "direct" measure, i.e. sectors that directly purchase fuel products from the petroleum manufacturing industry. Many industries are substantial "indirect" consumers of petroleum manufacturing output, in the form of consumption of sector products like electricity. For example, industries like hotel and restaurant services tend to be indirectly petroleum-intensive through the substantial use of electricity.

Relevant State and Federal Policies

There are three policy mechanisms available to support a local biofuel industry: budgetary support measures, blending (or use) mandates, and trade restrictions (OECD, 2008). As a state without control over import tariffs, only the first two are relevant for Hawaii. Budgetary support measures include subsidies to biofuel producers, retailers or users; biomass producers; and infrastructure development. These measures are supported by the public budget in the form of forgone tax revenues or additional expenditures (OECD, 2008). Blending mandates require a minimum share of biofuels in transportation fuels. While generally neutral for public budgets, such mandates often lead to higher consumer prices (OECD, 2008). In addition, without complementary trade restrictions, there is no guarantee of local sourcing as a result of a blending mandate. The policies and incentives discussed below provide a brief overview of key legislation that has driven the use of ethanol in Hawaii and also provide a basis for modeling assumptions within this report.

In 1994, a mandate requiring blending of 10% ethanol in 85% of motor fuel sold within the State was introduced. Several studies on the economic potential for local ethanol production were commissioned by the State in 2003 that suggested promise for the industry (Stillwater Associates, 2003; BBI International, 2003). The mandate was implemented in April 2006. The same year, an Alternative Fuel Standard (AFS) was adopted requiring 20% of highway fuel demand be provided by alternate fuels by 2020. A number of ethanol processing facilities have been announced, though none have materialized. Consequently, the blending mandate has been met with imported ethanol. Roughly 55 million gallons of ethanol are imported annually (Hao, 2007; Kalani, 2009). In terms of physical volume, ethanol is equivalent to roughly 3% of the petroleum volume annually imported to the State.

In addition, there is a federal blending subsidy of 51 cents per gallon of ethanol. This means that the refineries receive $28 million per year from the federal government to support ethanol blending.[4] The blending subsidy is applicable to either imported or locally produced ethanol sources and thus there is no reason to assume that this provides support to develop local industry. Because of this, there is also no reason to assume that the ethanol producer (unless also the "blender") will capture this subsidy.

There are several State-level policies supporting the building of ethanol facilities. Most notably, the Ethanol Facility Tax Credit provides a 30% credit for qualifying ethanol facilities, not to exceed $12 million in the aggregate in any given year. While this tax credit has been described in previous reports and presentations as providing a subsidy of

[4] Although the federal government provides a subsidy for ethanol blending, it does not necessarily translate into profit. Specifically, stakeholder input suggested that the blending credit is passed on to ethanol producers.

30 cents on the dollar, a distinction between up-front and operating costs should be made. This incentive specifically targets up-front (sunk) costs.

In addition, the State of Hawaii has a very aggressive High Technology Business Investment Tax Credit. Until recently, this credit offered a 100% return to investors over a five-year period. This credit has been controversial and assessed to have cost the State over $747 million in forgone tax revenue since its inception in 1999 (Sample, 2009). In modest response, it has been scaled-back to 80%.

At the federal level, there is a ten-cents per gallon small producer credit. This credit is applicable to producers making less than 60 million gallons of ethanol annually, and only applies to the first 15 million gallons of ethanol produced in any tax year. This provision is scheduled to expire in 2010. This is one of the few incentives that target the operating (variable) cost of ethanol production.

For a more comprehensive overview of policies and incentives for biofuel production, refer to Vol II, Section 2.8 Financial Incentives.

3. Estimating the Cost of Ethanol Production in Hawaii

For the purposes of this study, ethanol is assumed to use sugarcane as a feedstock. Hawaii has over a 100-year history of growing sugarcane and thus a large body of knowledge exists on optimal growing conditions and techniques. Historically, sugarcane has been a primary export crop for Hawaii. In the peak years of sugarcane production, between 1950 and 1975, an average of one million tons of sugar was produced annually with over 200,000 acres of land committed to sugarcane production (HARC, 2009). Declines in sugarcane production began in the late 1970s and continue to the present day. For example, 55 plantations were in production in 1990 in comparison to just two in 2005.

Table 2 provides an overview of the inputs into sugarcane production. The largest input into production is labor costs, as 43.7% of the value of total output of sugarcane production is in compensation of employees (i.e. wages and salary payments). The second largest input is capital costs, 22.4%, in the form of harvesting equipment, facilities, and other machinery.

Table 2. Sugarcane Production in Hawaii

	2005 Sugarcane Production (2005 Million)	Proportion of Sugarcane Inputs (% of Total)
Sugarcane	$1.39	1.91%
Agriculture	$1.98	2.72%
Mining & Construction	$0.24	0.33%
Petroleum Manufacturing	$0.90	1.24%
Other Manufacturing & Processing	$0.88	1.21%
Air Transportation	$0.03	0.04%
Water Transportation	$0.03	0.04%
Other Transportation	$0.67	0.93%
Electricity	$1.27	1.74%
Gas Production & Distribution	$0.05	0.07%
Wholesale & Retail Trade	$2.52	3.47%
Finance & Insurance	$0.85	1.16%
Real Estate	$4.27	5.86%
Business & Professional Services	$0.42	0.57%
Waste Management & Remediation Services	$0.16	0.22%
Other Services	$0.40	0.55%
Federal Government	$0.00	0.00%
State & Local Government	$0.00	0.00%
Value-Added		
Imports	$8.23	11.29%
Compensation of employees	**$31.80**	**43.66%**
Proprietor's income	$0.41	0.57%
Indirect Business Taxes	$0.00	0.00%
Other capital costs	**$16.33**	**22.42%**
Total	$72.83	100.00%

*Source: Department of Business, Economic Development, and Tourism, State of Hawaii (2008). The 2005 State Input-Output Study for Hawaii. Aggregation by author.

In 2005, sugar was a $72.8 million dollar industry with 40,100 acres in production. Within the two sugarcane plantations on Kauai and Maui, with 7,100 and 33,000 acres, respectively, there were a total of 699 jobs paying an average wage and salary of $45,000[5][6] (DBEDT, 2006, 2008). There were also 542 proprietor jobs, representing considerable local ownership of the industry. At the April 2, 2009 stakeholder meeting, there was discussion whether the cost of labor was a barrier to production or a benefit from production. On the one hand, high labor costs are seen as prohibiting market viability. At the same time, it is in the public interest to provide living wage jobs.

It should be noted that a proportion of petroleum manufacturing output is used to produce sugarcane. At least initially, this would also then be true for the ethanol sector. The relative amount is small, however, at 1.24%. In addition, electricity and transportation services are petroleum-intensive sectors that go into producing sugarcane (1.74% and 1.1%, respectively). Although the energy-balance for ethanol from sugarcane is shown to be positive elsewhere, a Hawaii-specific analysis of total energy inputs versus energy output may be illustrative in order to better understand the full life-cycle costs of ethanol production in Hawaii.[7]

The development of a local bioenergy industry is an economic strategy based on import-substitution. In this case, an in-State ethanol industry would replace imported ethanol into the petroleum manufacturing sector as well as gasoline. Tables 3 and 4 present the production activity (i.e. proportion of necessary inputs) for a local ethanol industry. As a point of comparison, production of petroleum manufacturing is also shown.

[5] Calculated from the 2005 Input-Output Study: total Wages and Salaries paid in 2005 ($31.8 million) divided by the number of Wage and Salary Jobs (699).

[6] As an agricultural sector characterized by full-time employment, workers in the sugarcane industry made $45,000 on average in 2005. This is in contrast to the average wages of other agricultural workers, such as vegetable crops and macadamia nuts/coffee/other fruits who make $25,000 and $28,000 on average, respectively. The primary reason for this difference is the need for more full-time agricultural workers in sugarcane as a good serving an export market. Whether it would remain full-time employment as a bioenergy product is a question of interest.

[7] The question of net energy balance is crucial to understanding whether policy outcomes are achieving their stated goals. For example, a 2002 USDA report on the energy balance for corn ethanol estimates that corn ethanol produces 34% more energy than it takes to produce it (USDA, 2002). Sugarcane is thought to be quite a bit more energy positive, estimated to increase energy output by nearly 80%.

Table 3. Import Substitution Strategies: The Production of Petroleum Manufacturing and Ethanol

	Petroleum Manufacturing*	Ethanol Processing**
Sugarcane	0.00%	**52.39%**
Agriculture	0.01%	0.00%
Mining & Construction	0.09%	0.14%
Petroleum Manufacturing	4.62%	0.43%
Other Manufacturing & Processing	0.60%	2.72%
Air Transportation	0.21%	0.11%
Water Transportation	1.51%	0.59%
Other Transportation	0.27%	0.47%
Electricity	2.54%	0.57%
Gas Production & Distribution	0.11%	0.03%
Wholesale & Retail Trade	1.84%	0.00%
Finance & Insurance	1.05%	0.31%
Real Estate	1.33%	0.56%
Business & Professional Services	4.26%	3.08%
Waste Management & Remediation Services	0.69%	0.00%
Other Services	1.87%	1.05%
Federal Government	0.03%	0.15%
State & Local Government	0.34%	0.09%
Imports	**70.44%**	20.03%
Value-Added		
Compensation of employees	3.23%	**12.33%**
Proprietor's income	0.95%	4.37%
Indirect Business Taxes	0.12%	0.34%
Other capital costs	3.90%	0.28%
Total	100.00%	100.00%

*Source: Department of Business, Economic Development, and Tourism, State of Hawaii (2008). The 2005 State Input-Output Study for Hawaii.

**Estimated based on the production of sugarcane and the proportion of sugarcane in food processing and other manufacturing.

Sugarcane is the largest input into ethanol production, comprising 52% of total inputs. Other notable inputs include purchases from the petroleum manufacturing industry (i.e. gasoline), other manufacturing and processing inputs, travel in the form of water and ground transportation (inter- and intra-island), air transportation (a common operating expense, for example to attend industry-associated meetings), electricity purchases, wholesale and retail trade, finance and insurance, real estate and rentals, and business and professional services. Wages are a substantial portion of production inputs, accounting for 12% of the total value of production. The average wage of manufacturing and processing jobs in Hawaii is $41,000.

Table 4 provides an overview of jobs provided in the ethanol and petroleum manufacturing industries, normalized by $ million of output.

Table 4. Jobs per Million Dollars of Output: Petroleum Manufacturing and Ethanol (Sugarcane and Processing)

	Petroleum Manufacturing*	Ethanol**
Wage & Salary Jobs	0.17	8.09
Proprietor Jobs	0.00	4.59

*Source: Department of Business, Economic Development, and Tourism, State of Hawaii (2008). The 2005 State Input-Output Study for Hawaii. Value normalized by total sector output.
**Estimated based on the production of sugarcane and the proportion of sugarcane in food processing. Value normalized by total sector output.

The ethanol sector, including sugarcane growing and ethanol processing, provides substantially more employment per dollar of activity. The petroleum manufacturing sector provides 0.17 jobs for every million dollars of production while the ethanol sector is estimated to provide 8 jobs and 4.6 proprietors for every million dollars of production. For the ethanol sector, 64% of the jobs created are estimated to be in sugarcane growth and 36% in processing.

Ethanol Production Costs Per Gallon

The production function for ethanol was estimated using both a top-down and bottom-up process. It was assumed that sugarcane production is used entirely for ethanol production, where data for the production of sugarcane is taken from the Input-Output table. The other inputs into ethanol are estimated as the proportion of sugarcane into the sectors of processing and other manufacturing, excluding non-relevant inputs such as agriculture, wholesale and retail trade, and solid waste disposal.

To produce 93.7 million gallons of ethanol to meet 20% of Hawaii's vehicle fuel needs, the value of the ethanol industry is estimated to be $312 million.[8] Table 5 shows the per gallon cost of ethanol.

Table 5. Ethanol Cost Per Gallon[10]

Feedstock Cost Per Gallon	$1.75
Ethanol Processing Cost Per Gallon	$1.58
Total Cost Per Gallon (without subsidies)	$3.33
With Federal Small-Producer Incentive (if applicable)	$3.23

It is possible for costs to be brought down if offset by the realization of byproduct value, particularly with the electric sector. For example, Stillwater Associates (2003) estimates that a 10 million gallon per year operation could earn $1,451 annually from biomass sales to an electric utility. This equates, in their model, to a reduction of twenty cents from the per gallon cost of ethanol (i.e. $3.23 to $3.03).

To further substantiate the above estimates, these results were compared to previous work done by Stillwater Associates (2003) and BBI International (2003) on ethanol production in Hawaii. The Stillwater Associates and BBI International used bottom-up approaches to estimating the cost of ethanol production that were very specific to the ethanol plant, including the cost of capital, feedstock expenses, chemicals, fuel oil and electricity inputs, and labor costs. Combining the top-down and bottom-up vantage points allows for a more comprehensive view of the inputs into ethanol processing, including expenses such as on-island and between-island transportation of product. Many of the overall results are quite similar. For example, Stillwater Associates (2003) estimated that 40.5% of the value of inputs is from sugarcane feedstock while BBI International (2003) estimated 48%.[11] More recently, a 2006 U.S. Department of Agriculture study of the viability of ethanol from sugarcane in the United States estimated that feedstock costs comprise 62% of the cost of production.

For labor inputs, BBI International (2003) estimated roughly 11% of the total value of ethanol production will be accounted for in labor compensation. On the other hand, Stillwater Associates (2003) estimated less than 1% of the value of production will be accounted for in labor compensation, at $753,000 annually. This translates to an average annual salary of $24,000 including benefits. Given that the average salary of

[8] Sugarcane yield estimates and ethanol conversion factors follow from Keffer et al. 2008.
[10] This estimate is based on solely operations and maintenance and does not include up-front costs of capital. For this reason, the 30% State credit is not applicable. Given this credit targets facility production, it should not be applied to long-run economic viability analysis of the industry.
[11] Extrapolated from Stillwater (2003), Table 1.2 for the stand-alone 30 MM GPY plant, and BBI International (2003), Table 21 for Maui.

manufacturing workers in Hawaii is $41,000, this is a relatively low wage and unlikely to attract and retain a labor force. Thus the initial estimates, consistent with BBI International (2003), were used.

The per gallon cost estimate found in this study is substantially higher than those made by Stillwater Associates (2003) and BBI International (2003), at $1.73 and $1.38 per gallon, respectively.[12] For the U.S., a more recent report on the feasibility of sugarcane for ethanol production estimates costs to amount to $2.40 per gallon (USDA, 2006). For Hawaii, a very recent report estimates $3.08 per gallon (Yanagida et al., 2008). Although this analysis utilized a very different economic model, it resulted in very similar results. Recent data and analysis, including this report, suggest that locally produced ethanol from sugarcane will cost at least $3 per gallon.

4. Economy-Wide Impacts

To better understand the economy-wide impacts of pursuing a local ethanol industry, the Hawaii Bioenergy Model was created. It is a Computable General Equilibrium (CGE) model of Hawaii's economy calibrated to the economic conditions of the year 2005. The year 2005 is an appropriate year in which to calibrate the model because oil prices were similar to current prices, roughly $49/barrel.

CGE models are a tool used to capture economy-wide impacts of changing conditions within an economy. It is considered an improvement upon its theoretical predecessor, Input-Output modeling, because it also captures price effects. As such, it is a common critique that Input-Output models overestimate economic impacts because they apply multiplier techniques without accounting for adjusting price levels. CGE models have the ability to capture adjusting prices between sectors, direct, indirect and induced impacts.

The Hawaii Bioenergy Model assumes that players in the economy behave in ways consistent with micro-economic theory, meaning that households maximize their welfare and producers maximize profits. Given convexity of production and consumption functions, there is a set of market-clearing prices. The model takes a long-run view of the economy, and prices optimally adjust to respond to changing market conditions. In this case, the "shock" to the model is in the form of a burgeoning local ethanol industry. For full model details, see Appendix I.

Description of Scenario

In the baseline calibration of the model, bioenergy does not exist as a sector. Simulations are run such that ethanol meets 20% of Hawaii's motor fuel needs (i.e. supplying 93.7 million gallons of ethanol from local sources): 1) under current economic conditions, and 2) with a 50% increase in the world crude oil price (i.e. from $49 per barrel to $73 per

[12] Taken from: Stillwater Associates (2003), Table 1.2, Large, Stand-Alone plant, Unsubsidized price; BBI International, Table 21, Operating Cost Estimates for Maui ($20 million for 15 million gallons annual output)

barrel). [13] To make the local ethanol supply competitive with ethanol imports, it is assumed that the State (and, ultimately, residents) subsidize 30% of the operating expenses of ethanol production.

To meet 20% of Hawaii's motor fuel demand with locally produced ethanol, it is assumed that roughly 91,500 acres of land will be committed to sugarcane growth. From various conversations with potential ethanol producers, it seems there is a minimum scale of contiguous land of roughly 20,000 acres in order to make production feasible. Assuming the land is irrigated, this results in 93.7 million gallons of ethanol.[14] Scaling sugarcane production and ethanol output to this level determines the magnitude of the "shock" within the model.

The Economic Impacts of Local Ethanol Production

The following results provide insight into the economic impacts of making the switch to locally produced ethanol. From this baseline scenario, a discussion is then provided of what market forces will affect the outcome of that scenario including the price of crude oil and imported ethanol.

Substituting imported ethanol with locally produced product has a net positive economic outcome for the State. Table 6, Key Macroeconomic Indicators, shows impacts to real gross state product, real household expenditures, and labor demand.

Table 6. Key Macroeconomic Indicators

	Baseline Scenario	Ethanol Scenario	Difference
Gross State Product ($2005 million)	$55,072	$55,344	$272
Household Expenditures ($2005 million)	$36,386	$36,425	$39
Labor Force (# of Jobs)	838,588	839,371	1,221

Gross State Product is a measure of overall economic productivity, taking into account the balance of trade (exports less imports). The simulation shows that introducing the $312 million ethanol industry leads to a $272 million increase in overall State productivity, increasing productivity by 0.5%. Accounting for indirect and induced effects, the difference between ethanol sector productivity and total economic benefit is due to State support of the industry, assumed to be 30%. Nonetheless, this shows there is an overall net benefit to the State's economy.

[13] In 2005, world crude oil prices fluctuated between $35 and $60/barrel. In 2008, they skyrocketed to $125/barrel, in early 2009 went down to $34/barrel and in August 2009 went back up to $71/barrel (Source: EIA, http://tonto.eia.doe.gov/dnav/pet/hist/wtotworldw.htm). The volatility in oil prices has historically made it difficult for countries to foster bioenergy and renewable energy markets and thus a vital part of this analysis.
[14] Yield estimates and conversions of raw sugarcane to ethanol taken from Keffer et al. 2008.

Household Expenditures serves as a proxy for resident welfare. It represents the value of goods and services that households are able to purchase. A result of increased proprietor and employee compensation (i.e. income) due to the ethanol industry, residents are then able to spend that money within the economy (i.e. induced impacts). Employee compensation increases by $24.8 million and proprietor income increases by $15.6 million. Total household expenditures increase by $39 million.

In addition, 1,221 (net) jobs are created. Because demand for the ethanol sector draws activity away from other sectors, this new demand for labor also pulls workers away from other sectors. There are 1,689 full- and part-time jobs created in the ethanol industry. Of those, 1,081 are estimated to be in the sugarcane industry and 608 in ethanol processing. These estimates include both direct employment (i.e. field workers, machinery operators, agricultural specialists, and engineers) as well as indirect employment (i.e. truck drivers, lawyers, and marketing specialists).

While the Statewide economic impacts are relatively diffuse (+0.5% of total productivity), the impacts to communities with agricultural lands chosen as suitable for biofuel production may be quite pronounced. The benefits of ethanol production, from a purely financial vantage point, accrue to people participating in either the ethanol or complementary sectors, primarily sugarcane production. The financial costs, on the other hand, are borne by residents at large. Conversely, environmental benefits, though not quantified in this analysis, also accrue to residents at large. More specifically, job creation and increased wages will occur in relatively small geographic regions. Community suitability and assessment studies will be needed in order to determine region-specific impacts. In particular, analysis should determine whether the labor demand could be met within the community (i.e. assessing indicators such as local unemployment rates and available housing), address potential negative environmental and community effects, and alignment with regional plans including zoning and other infrastructure. Several community-level impacts identified in the April 2nd stakeholder meeting were increased road congestion, nearby environmental or health impacts of biorefineries, and potential adverse impacts to food agriculture.

Rising Crude Oil Prices

An increase in the world price of oil makes ethanol more attractive – particularly ethanol sources that have a high net energy output (i.e. relatively fewer fossil fuels are needed to make the ethanol product). To better understand the pressures on locally produced ethanol, a 50% increase in the world price of oil is simulated and global prices for ethanol are discussed.

Locally, if the world price of oil increases by 50% (i.e. from $49/barrel to $73/barrel), then there is a market shift away from petroleum-intensive goods (Coffman, 2008). For reference, the world crude price of oil was $71/barrel in August 2009[15]. Nonetheless, the demand for many petroleum-intensive goods is quite inelastic, particularly in the short-run. For example, the demand for electricity and transportation are not highly sensitive to

[15] EIA, http://tonto.eia.doe.gov/dnav/pet/hist/wtotworldw.htm.

changes in price (inelastic) in the short-run but are more sensitive (elastic) in the long-run as people are able to purchase energy-efficient appliances and more fuel-efficient vehicles. Ethanol (and other biofuels) provides a market substitute for crude oil products – both at the level of the refineries and other downstream industries such as the electric utilities. A 50% increase in the world price of oil would result in a 43% increase in the price of refined petroleum products. With gasoline prices hovering at $2.40 per gallon, this increases prices to $3.43 per gallon. Thus, locally produced ethanol becomes comparable to gasoline costs at roughly $70 per barrel. The volatility in world oil crude oil prices, however, is a barrier to creating a competitive market for ethanol.

Imported Ethanol

When local ethanol is made more attractive from an increase in the world price of oil, however, the same goes for imported ethanol. The competitiveness of imported ethanol sources is likely the most significant barrier to local production. For example, corn-based ethanol is selling on the U.S. mainland for an average of $1.72 per gallon (*Ethanol Market Weekly News*, 2009). For ethanol imported into the U.S., there is a 54-cent import tariff per gallon. The largest international producer of ethanol is Brazil, where the feedstock is primarily sugarcane. In terms of cost comparisons, the costs of sugarcane production in Brazil are 2.5 to 3 times less than the U.S. (USDA, 2007a). In 2006, Brazil produced 4 billion gallons of ethanol, representing nearly 38% of the world total (USDA, 2007a). In 2007, ethanol was produced in Brazil for roughly $1.10 per gallon (USDA, 2007b). Hawaii sources are likely to be more expensive than either the continental U.S. or imported sources.

Competition between ethanol sources means that imported sources will put additional pressure on the local market. When oil prices soared in 2008, over a 300% increase from today's price levels, it seemed possible for local ethanol to penetrate the market. But a comparison to oil alone is a limited view. The world supply of ethanol is developing and imported sources will be the primary competition for local ethanol production. This is particularly the case with a blending mandate without preference for local product.

Ethanol Facility Costs

There are substantial capital investments that need to be made in order to develop a local ethanol industry. There is, however, a large range in cost estimates. For example, BBI International (2003) estimates that construction of a 15 MMGY Molasses Plant on Maui would cost nearly $34 million. Stillwater Associates (2003) estimates that a 30 MMGY plant would cost nearly $32 million for a stand-alone plant and $43 million for a plant integrated with electricity production. For an out-of-state comparison, an estimate for a 32 MMGY sugarcane-to-ethanol plant in Louisiana is $41 million (USDA, 2006). There is large variation in capital expenditure projections because costs are often associated with unique region-specific circumstances (USDA, 2006, page 32).

Investment incentives such as the State's High Technology Tax Credit and the Ethanol Production Credit could help potential ethanol producers to create production facilities.

The cost of State-level facility production incentives, however, is ultimately borne by tax-paying residents. At the April 2nd stakeholder meeting, a theme of uncertainty and inconsistency arose. In particular, this pertained to inconsistent tax incentives, uncertainty about the longevity of tax incentives, and relatively cheap alternatives (i.e. fossil fuels and imported biofuels). Given the varying estimates of start-up construction costs and relatively high per gallon operating costs, there is likely to be difficulty in financing ethanol projects.

5. Impacts Along the Value Chain

Feedstock, Logistics, and Conversion Processes

From an economic perspective, feedstock production and logistics are captured in the activity of growing and transporting sugarcane, described in Table 2. Feedstock costs are estimated to comprise 52% of the cost of ethanol, or $1.75 per gallon of ethanol. Conversion of sugarcane to ethanol and elements of distribution of final ethanol product are described in Table 3. Ethanol processing costs are estimated to cost $1.58 per gallon of ethanol.

Labor is the largest input into sugarcane production, comprising nearly 44% of the value of total inputs. Although this was the case in the baseline dataset for sugarcane production, labor costs may be reduced due to increased mechanization in harvesting practices for ethanol production. Labor regardless remains a key input into production, however, primarily because sugarcane is harvested with frequent rotations, between 12 to 18 months. The question of tradeoffs between labor and capital nonetheless is an important consideration in assessing the benefits of local biofuels, particularly for crops with longer periods between harvests.

To build a local ethanol industry large enough to achieve the alternative fuel standard means both redirecting existing sugarcane production and committing additional lands into sugarcane. The cost of land (i.e. real estate) comprises nearly 6% of the value of inputs for sugarcane production. In 2005, with 40,100 acres of land in production, the total cost of land was $4.3 million. The opportunity cost of land, however, is not accounted for within this figure. The lack of commitment from large landowners is one of the primary impediments to local biofuel production identified in the April 2nd stakeholder meeting. A participant stated, “Issues about biofuels are issues about having a healthy agricultural industry,” suggesting that agriculture in general is suffering. The pressure on agricultural lands to be rezoned for urban use or made into “gentleman estates” is sizeable and merits further analysis.

Refinery Operations

In terms of distribution to end-use, ethanol would likely continue to be blended with petroleum-based motor fuel. The federal blending credit would remain relevant, regardless of whether the ethanol is imported or produced locally. Thus the refineries would continue to receive support of the federal government, an estimated $28 million annually.[16]

There are two refineries operating on the island of Oahu. Chevron processes 54,000 barrels a day while Tesoro can process 94,000 barrels a day. It is uncertain whether Chevron, the smaller of the two refineries, will remain in operation. It is possible that that it will cease refinery operations and become a terminal (Clark and Campbell, 2009). Amongst the reasons for this potential change is pressure on the refinery due to its relatively outdated technology.

The simple distillation of crude oil (i.e. earlier refinery technologies) leads to end products in virtually fixed proportions (Manne 1951, 400). The lighter products are recovered at the lowest temperatures, including liquid petroleum gases and certain gasoline types. Middle distillates include jet fuel, kerosene, and distillates (such as diesel oil). The heaviest products are recovered at higher temperatures, including residual fuel oil.[17] Although residual fuel oil is currently used in Hawaii to generate electricity, State efforts to move away from fossil fuel based electricity sources may decrease on-island demand for this product.

The importation of ethanol reduced the demand for gasoline and thus there was an increase in the naphtha byproduct as a result of the blending mandate,[18] which is then exported out of the State (Stillwater Associates, 2003). In 2005, for example, refined petroleum products were the State's highest valued export (State of Hawaii, 2008). In addition, there was an up-front cost to upgrade refinery operations to meet the blending requirement. The estimated $10 million cost in upgrades to refinery operations to both separate and blend ethanol with gasoline (Stillwater Associates, 2003) have presumably been paid for, as the refineries have been blending ethanol since 2006.

Petroleum refineries are not only dependent on the technologies employed to achieve an optimal output mix, but also the type of crude oil affects the ability to achieve that mix. Hawaii's refineries were built in a time when light crude oil was plentiful on the world market. At the time, it was more profitable to use light crude oil imports without employing cracking technology (Manes, 1964). In an era of rising costs for light crude, however, refineries worldwide are faced with changing economic circumstances. The shift in the world market for oil has likely put additional strains on Hawaii's refineries.

There are considerable capital costs to developing and building more modern refinery capabilities to adjust to changing crude oil supplies and possible changes in product mix. Although this analysis is out of the scope of this study, estimating the costs of this upgrade would be helpful to understand and predict the future of Hawaii's refineries. In

[16] Although the federal government provides a subsidy for ethanol blending, it does not necessarily translate into profit. Specifically, stakeholder input suggested that the blending credit is passed on to ethanol producers.
[17] EIA, *Simple Distillation*.
[18] Each gallon of ethanol blended in the State, with current refinery operations, means that two thirds of a gallon of gasoline will be downgraded to naptha and exported out of the State (Stillwater Associates, 2003).

particular, whether the companies view upgrades to the Hawaii refineries as worthwhile investments in comparison to investments in other refineries worldwide. In general, the impacts to the refineries of rising world oil prices and increasing local production of energy are not well understood and merit further analysis.

Considerations for End-Use

At the State and national levels, alternative fuel vehicles are largely flex-fuel vehicles, accepting 85% ethanol (E85). Of the 5,907 alternative fuel vehicles in Hawaii in 2007, 4,943 of them were E85 vehicles (EIA, 2007). There is an enormous gap in the market, as there were over 1.1 million vehicles registered in the State that same year (DBEDT, 2007b). Thus, the vast majority of existing resident vehicles only support E10, consistent with the 10% ethanol blending mandate. In addition, there are currently no E85 fueling stations in Hawaii. To go beyond E10 would require considerable increase in demand amongst E85 vehicles and supporting infrastructure. In addition, there is competition amongst alternative fueled vehicles, particularly with the potential of electric vehicles. A recent study suggests that, from a greenhouse gas emissions perspective, biomass-to-electricity is far more efficient than ethanol, on an order of 80%. This is primarily due to the inefficient nature of the internal combustion engine (Campbell et al., 2009). Biomass generation from tree plantations is an imminent possibility, particularly on the Hamakua coast of Hawaii Island.

6. Other Bioenergy Scenarios

This study has narrowly focused on sugarcane as a feedstock for ethanol production. It has focused on this scenario for several reasons: 1) the blending requirement is a current law, 2) ethanol facilities are established at the level of the refineries and there is current distribution infrastructure for E10 vehicle fuel, 3) sugarcane production infrastructure is, in many cases, still in place including roads, irrigation systems, and portions of processing facilities, and 4) there is publicly available data on sugarcane operations. It is, however, a limited view of the potential for bioenergy in the state.

Energy from tree plantations is a scenario that has gotten considerable attention on the Hamakua coast of Hawaii Island. After the closure of the Hamakua Sugar Company in 1993, Kamehameha Schools purchased the land. Kamehameha Schools and its lessees converted 60% of it into *Eucalyptus* tree farms, 22% into conservation, and 18% into cattle operations. Today there are nearly 14,000 acres of *Eucalyptus* trees, ranging from nine to twelve years in age (Stormont, 2009). The trees are currently being leased to Grantham, Mayo, Van Otterloo & Co. (GMO) and managed by American Forest Management (AFM). While there are no current commitments to use the trees for energy purposes, discussions are ongoing (Motto, 2009). Additional *Eucalyptus* tree plantations exist on Parker Ranch lands and Kamehameha Schools lands in Kau. Forest Solutions International is currently managing these trees. There are a total of 25,000 acres of mature *Eucalyptus* trees on Hawaii Island. Of the potential buyers for *Eucalyptus* trees, a possible idea is to pursue biomass-to-energy for electricity production and another to use

Eucalyptus as a feedstock for biomass-to-liquid fuel. At present, a bioenergy power plant located on the Hamakua coast could provide 24 MW to the Hawaii Electric Light Co.'s system (Hu Honua, 2009). A more distant possibility, Sunfuels Hawaii LLC intends to make a synthetic diesel fuel. The scale of biomass-to-liquid fuel production has yet to be determined.

Some have described *Eucalytpus* plantations as: "the plantations without the jobs." Unlike sugar, which is harvested in 12 to 18 month rotations, tree crops are harvested much less frequently, potentially every 7 to 10 years. For example, in a public meeting, AFM projected that the trees would be managed and harvested by roughly 3-4 work crews with 5-6 operators per crew (Stormont, 2009). The jobs are likely to be highly mechanized and thus characterized by skilled labor. Because the jobs will require skill-sets more similar to construction industry jobs than traditional agricultural jobs, wages are likely to be around $66,000 annually.[19]

Cost estimates for tree and grass crops for biodiesel and ethanol are assessed in Yanagida et al. (2008). Between *Eucalyptus*, leucaena, banagrass, sugarcane, oil palm, and *Jatropha*, banagrass is found to be the only feedstock with positive net returns. This was based on assumptions about the availability and cost of cellulosic feedstock conversion, which is still in experimental phases.

The costs of production for other feedstock for electricity are not addressed in this report. For tree crops, costs can vary widely depending on management practices such as coppicing versus replanting and is an area of future inquiry.

7. Greenhouse Gas Emissions Legislation

In the absence of federal legislation, states have pioneered climate change mitigation policies and over half of all U.S. states have committed to meeting greenhouse gas reduction targets and many more are participating as observers. In Act 234, SLH 2007, the State of Hawaii committed to reducing its greenhouse gas emissions footprint to 1990 levels by the year 2020. In addition, the Obama Administration campaigned on the platform of a national cap-and-trade system that would achieve 1990 levels by the year 2020 and 80% below 1990 levels by the year 2050 (Zeleny, 2007). House Energy and Commerce Chairman Henry Waxman and Representative Edward Markey introduced the most recent proposal for greenhouse gas legislation at the federal level in March 2009. The goal of the legislation would be to reduce the nation's greenhouse gas emissions by 20% from 2005 levels by the year 2020 and by 80% from 2005 levels by the year 2050 (Eilperin, 2009).

The form of future national legislation will greatly affect the status of State greenhouse gas emissions mitigation strategies. In general, however, greenhouse gas emissions policy aims to reduce the use of fossil fuels and promote renewable and alternative energy technologies. Most policies, including the Hawaii-based law, emphasize the use of market-based mechanisms to achieve these goals. This means the implementation of

[19] Average wage and salary for the mining and construction industry, 2005 Input-Output Study.

(or participation in) either a carbon tax or cap-and trade system. Carbon tax and cap-and-trade mechanisms create markets for environmental pollution and implicitly set a price for pollution that emitters and final consumers must pay. This cost provides a financial incentive to reduce emissions and improve environmental outcomes. Both mechanisms are designed to establish a cost for polluting and provide emitters with greater flexibility in how they respond to environmental targets.

It remains unclear how biofuels will be treated within a State or Federal greenhouse gas emissions reduction system. There is early evidence, however, that the combustion of bioenergy products will be treated differently than other emissions sources and in some instances omitted from regulation. For example, within the final rule of the Environmental Protection Agency's guidelines on mandatory greenhouse gas emissions report, ethanol production is excluded (EPA, 2009). This means that the gases emitted from ethanol production will not be subject to mandatory reporting. The logic of excluding biofuels from greenhouse gas regulation is that the feedstock itself is carbon neutral. This general assumption, however, is argued by some to be flawed depending on the scope of carbon accounting (Johnson, 2009). As such, the EPA is also currently developing guidelines on lifecycle greenhouse gas emissions analysis for renewable fuel sources (EPA, RFS2) and possible threshold standards.

8. Conclusions

In 1994, a 10% ethanol-blending requirement for motor fuel was introduced. In 2006, the blending mandate was implemented and an Alternative Fuel Standard (AFS) of 20% by 2020 for vehicle fuel was adopted. Although plans for a number of local ethanol production facilities have been introduced, none have materialized. This study uses production data from the 2005 State of Hawaii Input-Output Table to estimate the costs and inputs into local production of ethanol. In addition, a general equilibrium model of the State's economy is created to understand the economy-wide impacts of substituting imported ethanol with in-State production. This study assesses ethanol industry-level operation, including production costs, labor demand, and compensation to employees. Macroeconomic impacts are estimated including impact to gross state product, aggregate resident welfare, and shifts in sector-level demand.

Key Findings

To produce 93.7 million gallons of ethanol locally, in order to meet the AFS, over 91,500 acres of agricultural land would have to be committed to sugarcane production. Key findings of this report include:

1) Ethanol from sugarcane can be produced locally at $3.33 per gallon – although costs may be brought down with integration of byproducts, particularly with the electric sector.

2) Assuming the industry is viable, it would be, including all points of the value chain, a $312 million industry.

3) Assuming that the State offsets at least 30% of the cost of locally produced ethanol to make the industry viable, there would be an increase in Gross State Product of $272 million annually.

4) The introduction of the ethanol sector would create roughly 1,200 new jobs in agricultural production, processing, and various support industries.

The switch from imported to locally produced ethanol within the State has positive economic implications – 0.5% of real gross state product. Yet while overall costs and benefits are diffuse, the region-specific impacts may be sizeable. The benefits to employees in terms of job creation and compensation will be concentrated amongst those working within the industry and indirect impacts are likely to be felt within those specific communities. The industry is not viable without State support, however, and costs of subsidies will be borne by residents at large.

Regional Impacts

Moreover, region-specific studies should be conducted to better understand the availability of labor. While the State unemployment rate is currently high, over 7%, Hawaii's unemployment rate was close to 3% just a year ago (BLS, 2009). For more labor-intensive crops like sugarcane, it is unclear whether the demand of labor can be met within specific communities. In the case of sugarcane, production is most likely to occur on the island of Maui because of the active sugarcane operations or on other islands where infrastructure and facilities remain relatively intact.

The non-monetized impacts to communities may also be persuasive – particularly in increasing demand for agricultural lands with zoning-consistent use, maintaining open space and promoting rural lifestyles. On the other hand, stakeholder input also voiced that locating ethanol-processing facilities may be difficult and it is important to involve specific communities through all steps of the process. The Hamakua community's outcry in November 2008 in response to the possibility of *Eucalyptus* plantation expansion without community input serves as testament to the importance of regional planning in the process of pursuing statewide energy goals.

Policy Discussion

There are two primary policy mechanisms at the disposal of the State to pursue local biofuel production: budgetary support measures, and blending (or use) mandates (OECD, 2008). A blending mandate is already in place and has resulted in the consumption of imported ethanol. Determining whether ethanol imports are positive or pejorative is outside the scope of this analysis. Rather, the important point is that the blending mandate did not foster local production. Budgetary support measures have also been provided, but primarily target the up-front costs of ethanol processing and not overall operations. This analysis, however, shows that operating costs alone are not competitive with imported sources. A participant in the April 2nd stakeholder meeting aptly said: "[We] need to remember the driving motivations: the Environment and Geopolitics. It's why we're willing to support certain local biofuels." The question of whether it is appropriate to use budgetary support measures rests on the accrued benefit stream in terms of improved outcomes for increased energy resiliency; reduced greenhouse gas emissions; and benefits to rural communities in Hawaii.

Among the reasons for supporting a local biofuel industry in comparison to global sources, several are environmental in nature. In particular, deforestation practices, net energy inputs, and transportation emissions are all considerations in choosing to support a local ethanol industry over imported sources. In the face of potential national and international greenhouse gas emissions commitments, environmental consequences may eventually have financial impacts as well. As such, the potential benefits of biofuels should be assessed in comparison to other renewable energy technologies. Biofuels have been particularly attractive because they are a firm energy source that, in comparison to intermittent sources like solar and wind, can be readily integrated into current energy infrastructure. A stakeholder pointed out, however, that improved battery technology or grid resiliency resulting from inter-island connectivity could be "game-changers" for the demand for biofuels.

The creation of a local ethanol industry could serve to revitalize currently fallow agricultural lands as well as provide jobs in agriculturally oriented areas of Hawaii. On the other hand, it will take significant State-level support to make locally produced ethanol competitive with imported sources. The benefits of local biofuels must be assessed in relation to alternative agricultural activities, water consumption, community acceptance and labor availability.

Information needs identified during this study:

Thus further study of biofuels for electricity generation and alternative liquid fuel products like biodiesel are needed to provide a more comprehensive view of the future of biofuels and their impacts to Hawaii's economy.

Biomass-to-electricity is another likely scenario for Hawaii's bioenergy future, given technological viability of current feedstock production. A comprehensive assessment of cost estimates, however, is outside the scope of this study and merits further analysis.

Although the energy-balance for ethanol from sugarcane is shown to be positive elsewhere, a Hawaii-specific analysis of total energy inputs versus energy output may be illustrative in order to better understand the full life-cycle costs of ethanol production in Hawaii.[20] This would also serve to inform compliance with the proposed EPA

[20] The question of net energy balance is crucial to understanding whether policy outcomes are achieving their stated goals. For example, a 2002 USDA report on the energy balance for corn ethanol estimates that corn ethanol produces 34% more energy than it takes to produce it (USDA, 2002). Sugarcane is thought to be quite a bit more energy positive, estimated to increase energy output by nearly 80%.

[22] Refer to the EPA Renewable Fuel Standard Program (RFS2): Notice of Proposed Rulemaking published May 26, 2009.

Renewable Fuel Standard guidelines for lifecycle analysis of greenhouse gas emissions (which was being simultaneously developed at the time of this report).[22]

Community suitability and assessment studies will be needed in order to determine region-specific impacts, including impacts to food production (including crops and livestock).

The question of tradeoffs between labor and capital nonetheless is an important consideration in assessing the benefits of local biofuels, particularly for crops with longer periods between harvests.

The pressure on agricultural lands to be rezoned for urban use or made into "gentleman estates" is sizeable and merits further analysis.

In general, the impacts to the refineries of rising world oil prices and increasing local production of energy are not well understood and merit further analysis.

The costs of production for other feedstock for electricity are not addressed in this report. For tree crops, costs can vary widely depending on management practices such as coppicing versus replanting and is an area of future inquiry.

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Appendix I: Detailed Model Overview

Hawai‘i is an excellent case study for CGE modeling because it truly is a small, open economy. Hawai‘i producers are modeled as world price takers, including the world price of oil. Representing a classic Walrasian system, goods are produced under perfect competition and constant returns to scale using intermediate commodities, imports, labor, and capital. Households supply labor, and final demand is generated by households, visitors, various government entities, and exports (Shoven & Whalley, 1984, 1992). The model is estimated using GAMS (General Algebraic Modeling Systems) and MPSGE (Mathematical Programming System for General Equilibrium Analysis). For more information on these modeling platforms, refer to Brooke et al., 1988, and Rutherford, 1987 and 1999, respectively.

The model is calibrated to the economic activity of Hawaii in the year 2005. Table I shows an overview of data used to calibrate the Hawaii Bioenergy Model.

Table I. Overview of Hawaii's Economy

	Total Output	Inter-Industry Demand	Imports	Labor Income	Proprietor Income	Other Value-Added	Jobs
			$ 2005 Billion				#
Total	**$90.3**	**$23.5**	**$11.8**	**$32.5**	**$3.0**	**$19.6**	**838,588**
Sugarcane	0.08%	0.31%	0.07%	0.10%	0.01%	0.08%	0.15%
Agriculture	0.72%	1.06%	0.83%	0.70%	0.39%	0.56%	1.72%
Mining & Construction	8.09%	4.16%	15.31%	7.12%	12.87%	2.94%	5.35%
Petroleum Manufacturing	2.69%	5.35%	14.53%	0.24%	0.78%	0.50%	0.05%
Other Manufacturing & Processing	3.03%	5.35%	8.61%	1.91%	7.42%	0.16%	2.16%
Air Transportation	2.38%	0.62%	3.98%	1.73%	0.14%	0.73%	1.22%
Water Transportation	1.86%	1.47%	4.46%	0.53%	0.01%	0.47%	0.42%
Other Transportation	1.56%	2.35%	0.83%	1.90%	4.14%	1.41%	2.13%
Electricity	2.14%	4.48%	2.01%	0.88%	0.08%	2.95%	0.34%
Gas Production & Distribution	0.09%	0.24%	0.08%	0.04%	0.00%	0.13%	0.02%
Wholesale & Retail Trade	10.00%	9.25%	9.27%	9.40%	9.45%	12.91%	13.19%
Finance & Insurance	4.87%	8.28%	4.07%	3.56%	3.26%	5.88%	3.01%
Real Estate	15.52%	17.64%	4.45%	1.86%	15.36%	43.39%	5.05%
Business & Professional Services	10.91%	27.86%	8.81%	12.69%	22.79%	7.20%	13.88%
Waste Management & Remediation Services	0.28%	1.00%	0.13%	0.25%	0.19%	0.34%	0.20%
Other Services	21.05%	7.75%	19.59%	22.58%	23.10%	14.16%	30.53%
Federal Government	8.43%	1.12%	0.63%	20.92%	0.00%	3.08%	10.06%
State & Local Government	6.31%	1.72%	2.34%	13.60%	0.00%	3.10%	10.51%

Source: Department of Business, Economic Development, and Tourism, State of Hawaii (2008). The 2005 State Input-Output Study for Hawaii.

Hawaii produces over $90 billion of output annually. There are 838,588 jobs, with the largest employment in the service sector, including wholesale and retail trade (13% of jobs), and other services (30%). The state and local government is also a large employer, with 11% of jobs and 14% of wages paid. Sugarcane production accounts for less than 0.01% of Hawaii's overall economic activity, and agriculture as a whole is less than

0.1%. Petroleum manufacturing accounts for nearly 3% of economic output and other energy-intensive sectors like air transportation, electricity production, water transportation and other transportation account for nearly 8% of economic activity.

Production

Production in the economy is represented through a nested-Leontief function. This means that commodities are a set of complementary inputs into each sector's output, both intermediate inputs and value added activities. The nested structure comes into play through allowing substitution within factors of production (i.e. capital and labor are flexible in producing a specified level of value added).

At the first level, a Leontief production function represents final output (Y_j) in sector j = 1,.., n as made up of intermediate inputs (Z_{ij}) of commodity i, and value-added (V_j):

$$Y_j = \min[Z_{1j} / a_{1j}, ...Z_{nj} / a_{nj}, V_j / a_{vj}] \tag{1}$$

where a_{ij}, a_{vj} are unit input coefficients for intermediates and value-added respectively.

At the second level, intermediate inputs consist of flexible domestically-produced and importable commodities represented through an Armington[23] constant elasticity of substitution (CES) production nest:

$$Z_{ij} = [\theta_{Dij} D_{ij}^{(\varepsilon_{ijm}-1)/\varepsilon_{ijm}} + \theta_{Mi} M_i^{(\varepsilon_{ijm}-1)/\varepsilon_{ijm}}]^{\varepsilon_{ijm}/(\varepsilon_{ijm}-1)} \tag{2}$$

where ε_{ijm} is the CES substitution between domestically-produced good i and imports by producer j. D_{ij} is sector i demands by producer j for domestically-produced goods and M_i is the composite import good demand in sector i. The parameter shares are represented by θ_{Dij} and θ_{Mi}, respectively.

Value-added (V_j) consists of capital (K_j), wage labor (L_j), and proprietor income (R_j):

$$V_j = [\alpha_{Lj} L_j^{(\sigma_j-1)/\sigma_j} + \alpha_{Kj} K_j^{(\sigma_j-1)/\sigma_j} + \alpha_{Rj} R_j^{(\sigma_j-1)/\sigma_j}]^{\sigma_j/(\sigma_j-1)} \tag{3}$$

where σ_j is the CES among value-added variables and α_{Lj}, α_{Kj} are the respective parameter shares.

The initial endowment of wage labor, proprietor income, and capital ($\bar{L}_0, \bar{R}_0, \bar{K}_0$) are given within the baseline dataset. In calibration, the value of the initial endowment of

[23] The "Armington assumption" states that goods are differentiated by country of origin and is often used in regional CGE models to account for cross-hauling in trade data and to preclude unrealistic extreme specialization within countries. See Armington, 1969.

wage labor, proprietor income and other value-added must equal the sum of each factor over all j=1,..,n industries (a baseline full employment assumption).

$$L \equiv \overline{L}_0 = \sum_j L_j \tag{4}$$

$$R \equiv \overline{R}_0 = \sum_j R_j \tag{5}$$

$$K \equiv \overline{K}_0 = \sum_j K_j \tag{6}$$

Output commodity Y_j can either be consumed domestically or exported and, under the Armington assumption, is differentiated for those markets using a constant elasticity of transformation (CET) function between domestic (D_j) sales and exports (X_j):

$$Y_j = [\beta_{Dj} D_j^{(\varepsilon_j - 1)/\varepsilon_j} + \beta_{Xj} X_j^{(\varepsilon_j - 1)/\varepsilon_j}]^{\varepsilon_j/(\varepsilon_j - 1)} \tag{7}$$

where ε_j is the elasticity of transformation and β_{Dj}, β_{Xj} are parameter shares.

Ethanol Production

In the baseline calibration, because the production of ethanol costs more than the production of other refined petroleum products, no ethanol is produced (Bohringer, 1998). In the scenario, the production of ethanol (as outlined in Table 3), is introduced into the economy to a level that it can offset 10% of motor fuel consumption.

Consumption

On the demand side, the model reflects the behavior of Hawai‘i residents (r) and visitors (v). Although both agents follow a utility-maximizing behavior, the structure of visitor utility differs because visitors must purchase air transportation before all other commodities.

Consumption demand is represented through a CES utility function:

$$U_r = [\sum_i \rho_{ri} C_{ri}^{\sigma_{ri}-1/\sigma_{ri}}]^{\sigma_{ri}/\sigma_{ri}-1} \tag{8}$$

where U is a utility level, C_{ri} is consumption and ρ_{ri} is the resident income expenditure share of i= 1,..,n,m (where n are the number of domestically-produced commodities and m is the imported composite good). σ_{rN} is the CES between all goods.

Consumers flexibly demand both domestically-produced goods (i=1,…,n) and an imported composite good (m):

$$C_{ri} = [\theta_{Dri} D_{ri}^{(\varepsilon_{rim} - 1)/\varepsilon_{rim}} + \theta_{Mr} M_r^{(\varepsilon_{rim} - 1)/\varepsilon_{rim}}]^{\varepsilon_{rim}/(\varepsilon_{rim} - 1)} \tag{9}$$

where ε_{rim} is the Armington CES for residents between domestically-produced good *i* and imports *m*, taking a Cobb-Douglas form. D_{ri} is sector *i* demands for domestically-produced goods and M_r is imported demand. The parameter shares are represented by θ_{Dri} and θ_{Mr}, respectively.

A representative consumer's expenditure constraint can be written as:

$$\sum_i p_i C_{ri} = p_L L + P_R R + P_K K + \overline{p}_{fx} BP - T_r \qquad (10)$$

where prices p_i represent the market prices for imports and commodities $i = 1,..n, m$. The resident derives income from factors of production including labor (L), proprietor income (R), and capital (K), where p_L, p_R, p_K are the market price of the respective factors. The resident pays a lump-sum tax (T_r), net of transfer payments, to the State and Local Government. The resident also receives foreign exchange ($\overline{p}_{fx} BP$) from a balance of payment deficit, described below in equation (18).

Government

Government activity is represented through three branches – the State and Local Government (*SL*), the Federal Military Government (*FM*), and the Federal Civilian Government (*FC*). Each government type purchases domestic commodities (G_{gi}) and imports (G_{gm}) according to a Leontief utility function to assure a constant level of public provision:

$$U_g = \min[G_{g1},..,G_{gn},G_{gm}] \qquad (11)$$

where $g = SL, FM, FC$.[24]

The State and Local Government depends entirely on the economy for the tax base:

$$\sum_i p_i G_{SLi} + p_m G_{SLm} = \sum_i p_i Y_i \tau_i + T_r \qquad (12)$$

where p_i and p_m are the price of commodities i=1,..,*n* and imports, respectively. Thus the left-hand side represents the cost of public expenditures. These expenditures are funded primarily through the State's general excise tax (τ_i) on producer output (Y_i) of commodity *i*.[25] The State and Local Government also impose a variety of taxes (T_r), such as property and income taxes on residents.[26]

[24] The specification for government utility follows Kim and Konan (2005).
[25] Shown in the 2005 I-O table as "indirect taxes" for each commodity.
[26] Shown in the 2005 I-O table as "indirect taxes" for final demand.

The market clearing conditions must hold such that the cost of public expenditures balances government income.

$$\sum_i p_i G_{gi} + p_m G_{gm} = I_{g0} \equiv I_g \tag{13}$$

Balance of Payments

A balance of external payments (*BP*) is maintained under the assumption of a fixed exchange rate ($\bar{p}_{fx}$), where $\bar{p}_{fx}$ is the exchange rate with the "rest of the world." This assumption is made because Hawai'i uses the U.S. dollar as a means of exchange and, as a small economy, has no effect on the exchange rate. The quantity of imports (*M*) are constrained by the inflow of dollars obtained from visitor expenditures (I_v), Federal Government expenditures (I_{FM}, I_{FC}), and Hawai'i exports (X_j). Because Hawai'i is a price taker, import and export prices are perfectly inelastic.

$$\bar{p}_{fx} BP = \bar{p}_m M - I_v - I_{FM} - I_{FC} - \sum_j \bar{p}_{xj} X_j \tag{14}$$

Market Clearing

Constant returns to scale and perfect competition ensure that the producer price (p_j) equals the marginal cost of output in each sector *j*. In addition, the State and Local Government collects a general excise tax (τ_j) on sales. This implies that the value of total output (supply) equals producer costs, where p_L, p_K, p_R, equal the market price of labor, capital, and proprietor income respectively.

$$p_j Y_j (1 + \tau_j) = \sum_{l=1,..,n} p_l Z_{lj} + P_L L_j + p_k K_j + p_R R_j + p_m M_{Yj} \tag{15}$$

In addition, sector *j* output, which supplied to the domestic market (D_j), is demanded by consumers $a \in \{r,v\}$, government agencies $g \in \{SL,FC,FM\}$, and industries Z_i $i = 1,..,n$.

$$D_j = \sum_a C_{aj} + \sum_g G_{gj} + \sum_i Z_i \tag{16}$$

In equilibrium, the value of output balances the value of inter-industry, consumer, and government agencies demand.

Appendix II: Stakeholder Input

In a stakeholder summit held on April 2, 2009, participants were asked to provide their input on five questions regarding economic impacts and financial barriers/incentives. Because of the similar topics, the tasks of assessing economic impacts and financial barriers/incentives were combined for the purpose of this exercise.

The four questions were:

1) What are the primary financial barriers that inhibit the economic feasibility and competitiveness of locally grown biofuels?

2) In the next 2-3 years, what financial incentives will create economic feasibility and encourage the competitiveness of locally grown biofuels?

3) In the next 2-3 years, what policy changes will create economic feasibility and encourage the competitiveness of locally grown biofuels?

4) The Biofuel industry is often seen as a way to revitalize rural communities. Please share examples you know of that demonstrate the impact of the biofuel industry on rural communities.

5) What best practices would you recommend to assure a win/win experience for biofuel industries and rural/agricultural regions of Hawaii? (How can we minimize negative impacts and optimize positive impacts?)

In response to each question, participants were asked to brainstorm ideas. Present was both a third-part facilitator and note-taker. The following presents the "group memory" from the brainstorm session and have not been altered by the author.

What are the primary financial barriers that inhibit the economic feasibility and competitiveness of locally grown biofuels?

Costs

- Price of oil;
- High cost of capital structure for bio-refineries;
- High cost of land, labor, energy, feedstock;
- Price at the pump is affected by taxes or the lack thereof;
- Cost of labor – is it a barrier or benefit? For example, agriculture wages are lower on the chart. The whole process of end-product might be a challenge against the Third World Market;
- Some operations have unionized labor and they do have living wages;
- There is an assumption about the work ethic of Hawaii is that that we don't work very hard. People may presume they have to double labor costs;

- Cost to get the product to the end-user where it will be used. Cost of distribution;
- Cost of resources: politically, water, fertilizer;
- Critical mass – it's hard to make a large economic plant for a small population.

Tax Credits/Incentives

- Tax incentives – inconsistent funding. It is difficult to get funders to invest without an assurance of incentives, future, etc.;
- There aren't consistent tax credits across all types of biofuel crops. That is a Federal and State issue;
- Some rules have changed on tax credits;
- We should look at the breakdowns project by project to figure out maximum tax breaks. What works elsewhere won't necessarily work in Hawaii;
- Tax structure – pyramiding, off-set by tax incentives for biofuel growth.

Large Landowners

- The availability of land to grow crops is limited to some large landowners. If they want to make money, they'll diversify to other investments;
- Lack of commitment by large landowners;
- Looking for "silver bullet" vs. smaller scale production here that would fully benefit the state. "Large" doesn't have to be "economically viable."

Getting Buy-In/Investment

- Is this a risk people are willing to put money into?;
- Size – large money is easier to get than small money;
- There's an extremely widely held perception by institutions that it's difficult to do business in Hawaii, from a regulatory standpoint. They don't want to invest here.

Inexpensive Alternatives

- Cheap alternatives;
- Cheap imports – competition (e.g., ethanol – already has existing infrastructure).

Recession

- The recession affects ability to raise funds;
- The recession caused competition to get large amount of funds out there. People are more willing to invest in different areas at this time because of the market.

Determining Which Crops to Invest In

- Some crops involve more labor than others. We need to examine this to determine which crops to invest in;

- We lack a sense of direction regarding which crops we're going to be growing – it's hard to get investment if we don't know.

Other Comments

- Fragmented distribution of available land;
- Time is money – permitting process is time consuming;
- Three-fifths of all biofuels went to Europe – totally changed dynamic in U.S.

1. **In the next 2-3 years, what financial incentives will create economic feasibility and encourage the competitiveness of locally grown biofuels?**

Tax Incentives

- Monetize tax incentives; direct check at completion of project vs. tax credit;
- Create tax credit incentives for growers and large landowners;
- Need tax support for biofuels – but mandating is problematic.

Other State Incentives

- Hope Hawaii projects attract Stimulus Funding – deadline is May 29. Grants.gov is a resource. It is helpful if the State commits funding – matching funds are needed for the Federal funds;
- Look at requiring vehicles that come here be able to use these fuels; educate consumers to make these changes;
- Mechanism for fast-tracking permitting and new facilities might create better financial environment.

Incentives for Co-Use/Co-Products

- Incentives across co-products need parity to make whole operation financially feasible;
- There is a bill in the Legislature now looking at food and biofuels at same time and creating incentives for both rather than as competitors against each other.

Financing Options/Incentives

- It is a 15-20 year financial commitment. If the State could guarantee a bridge (2 years) between balloon and re-financing and support corrections that needed to be made in operations over balloon time. This will allow for better chance of refinancing;
- Hawaii Clean Energy Initiative restructures debt on the balance sheet.

Investor Incentives

- The State bundles projects into a size appealing to investors;

- We need a clear definition on how the State handles these things, i.e., what will PUC do? Pay attention to everything the investment community is looking for – we need to shore up the process.

Preference for Locally-Grown Biofuels

- A clearly stated and quantified preference for locally-grown biofuels – especially the State of Hawaii using them in vehicles and facilities. This helps to calculate price advantage;
- Look at State procurement code for preference for buying local.

Wheeling

- Bio-energy side, not just for biofuels. Also transportation. Feed-in tariff/wheeling;
- Wheeling for biofuel-produced electricity instead of selling power to HECO for 50% of what they sell it for, can sell at 80%.

Other Comments

- Some kind of incentive to landowners to put land in biofuel production vs. other kinds of development;
- Act 221 – keep it alive and meaningful. 100% payback over 5 years.

2. In the next 2-3 years, what policy changes will create economic feasibility and encourage the competitiveness of locally grown biofuels?

Hybrid Model

- The Hybrid Model is not totally tied to the price of oil, but somewhat tied; that could decrease over time. Using liquid fuels and electricity;
- Integrated refineries producing both liquid and electricity. What role can public State and County play? What contribution can State make (lands, subsidies) to decrease the footprint required?

Tax Issues

- Carbon content of different biofuels. Local biofuels might have an advantage. Create premium for carbon advantaged biofuel. Create a carbon tax at State and national levels;
- Policy changes towards taxation of local fuels e.g., road tax. Price matters. State can shift their priorities by taxation policies (That's how we can fund the bridge).

Create Effective Storage System

- State should go after stimulus money to enable a decent battery (could be thermal, etc.) or environmentally sound storage system (e.g., Maui system is not able to store energy for use at another time). Need energy storage system for electricity especially;

- On storage – non-storability hasn't been resolved internationally. Value of biofuel: can offset the intermittent nature of solar and wind.

Education/Shifting Perspectives

- Shift idea of change – change is good, should not be resisted. Doing things, not just talking;
- Separate bad from good biofuels, attributes would go a long way towards community acceptance.

Other Comments

- Structuring stand-by Purchase of Power Agreements to accommodate night or low-end times, when solar or wind are not being used. Create the ability to bring power online or offline as needed. May help to incentivize;
- Mandate use of biofuel for State vehicle fleets – would stimulate demand
- Note: electric vehicles are good, but if they plug into grid the it is a problem because the grid is powered by fossil fuels;
- Bioenergy Master Plan is a great first step. Let's look at what the appropriate role of biofuels is in our energy future. Develop a roadmap where technology developments are expected. This helps at the policy level and decreases infighting;
- Transparency at all levels of Road Map/Plan;
- There is a bill in the Legislature now – looking at food and biofuels at same time – incentives for both rather than as competitors against each other;
- Everyone is looking at their portfolio needs. If investors are assured they'll realize their investment, it'll increase investment. Shows State and County commitment to create loaning scenario without worry;
- Policy changes within the university – Research and Development areas to enhance economic viability.

3. *Original Question:* **The Biofuel industry is often seen as a way to revitalize rural communities. Please share examples you know of that demonstrate the impact of the biofuel industry on rural communities.** *Participants asked the Task Leader for clarification on this question.*

- There are positives and negatives: Community support, opposition. This question targets change in the sense of "revitalizing" communities. This doesn't always happen. Is it more useful to ask about *any* impact?

As a result, the Task Leader and group agreed to an amended question:

Revised Question: **The Biofuel industry is often seen as a way to change communities dependent on agricultural land or that have some connection to the land. Please share examples you know of that demonstrate the impact of the biofuel industry on these communities.**

- If not for Kamehameha Schools buying Hamakua Sugar, that land would have been gentrified;
- Growing back to large scale agriculture, tens of thousands of acres. Need major placeholder for agricultural lands;
- Many rural communities – plantation model – huge community camps. The centralization happened when ag opportunities decreased. The job opportunities that were once there when they were plantation communities diminished. Biofuel is one way to incorporate the ag industry back into communities;
- Impact on food security, i.e., if local biofuels are available, they can fuel equipment that can produce food locally (create available power);
- Create more employment, increase local jobs, but trying to site a facility is not easy – it can be controversial;
- Level out income – more diversity of income, spread out over year, increase stability;
- Ability to keep family together in farming and related enterprises. Looking to train talent here – mechanical, fabricators, operators, increase opportunities for job skills learning. Not just jobs, but what they represent;
- Spin off industries from a large core ag operation, e.g, rum – trash goes to cattle farmers;
- Tourism associated with biofuel start to finish. People interested in ag tours and there is not much of that here now. Could be adjunct to biofuels;
- If we have a healthy ag industry tied together with biofuels it can contribute to critical mass. Irrigation systems, knowledge, training, fertilizers made from biofuels. Reframe Food vs. Fuel to Plants vs. Pavement;
- Absent of viable ag enterprises, we can't preserve ag nature of any plant – turns into payment;
- Compatible land use that supports energy and agriculture;
- This would create an increase in the use of roads, particularly by large vehicles. An advantage is that we could convert half of traffic to transportation of non-explosive ag products and we'd be better off. In other words, increase vehicles, decrease "bombs";
- Energy independence for communities – possibility? Depends on economies of scale;
- Amount of pesticides/herbicides being used on biofuel crops could be high or low, depending on what used.

4. **What best practices would you recommend to assure a win/win experience for biofuel industries and rural/agricultural regions of Hawaii? (How can we minimize negative impacts and optimize positive impacts?)**

   <u>Water Management</u>

   - Water delivery infrastructure – purchase water to support community, e.g., Kula;

- The issue about water tables is that our state doesn't have a sophisticated water table system throughout all islands;
- Cleaning of water with nutrients – if irrigating to clean water, can possibly grow something ("Phytoremediation," e.g., plant in Pearl Harbor), ways to re-use water;
- Hawaiian Electric is re-using water through "RO" – reverse osmosis;
- We need to work more aggressively to stop water runoff, minimizing runoff to ocean, and reefs, replenish water tables in aquifers, perhaps produce power, use dams to capture water and minimize loss and runoff;
- Hamakua Coast – is there a way to use runoff water (stop it?). This is a policy issue;
- Plant biofuel crops in areas that could contain or border some of water runoff. Manage plantings to minimize runoff;

Co-Use

- Look at Food and Biofuels at the same time – incentives for both rather than compete (Bill in Legislature now);
- Food/Fuel working together. Specific example – 2 industries come together and share irrigation costs and integrate operations. Ecosystem benefits;
- There may be increased opportunity for biomass to solve some problems on ag land and produce a product, e.g., like salvaging bush (the devil's in the details on this).

Community Engagement

- Engage the community – first and foremost. Crucial, especially if public lands. Must have the support, endorsement and desire of community;
- A model that includes all pieces would allow decision analysis capabilities within State to see how pieces fit together. Take system to community to increase understanding and get input, help them see where important connection points are, and how it can benefit or interfere. Allows for increased discussion;
- Development of leadership and communities – rely on transparency.

Other Comments

- Educate legislators and policy makers – make sure they understand details we're discussing today. Can't assume policy-makers understand;
- Land stewardship policies – what the impact of different planting will be – harvest methodologies. Major potential negative impact;
- Fully integrated system – feed, fuel, lumber products – everything put together – social aspect, keep community viable, e.g., byproducts from one becomes feedstock for another;
- Ensure this industry can generate enough revenue to support a critical mass. Otherwise, we will lose young people who move away from the State. Real jobs for people. Must support other economies in State. Can't just benefit a small group of people or large landowners;

- Align selves with State's initiative toward sustainability, degrees in sustainability at college level;
- Biofuels from feedstock to production – resources for Best Practices:
  - International: Roundtable on Sustainable Biofuels
  - National: Sustainable Biodiesel Alliance;
- A philosophical question – what else can we bring here? Issue of diverse solutions;
- Can stabilize the price fluctuations of electricity;
- Can stop money from flying out the door to BP and Shell (related to transportation).

Hawaii Bioenergy Master Plan

Potential Environmental Impacts of Bioenergy Development in Hawaii

Pacific Consulting Services, Inc.
Andrew Tomlinson

December 2009

Executive Summary

An evaluation of the potential environmental impacts associated with bioenergy development in Hawaii was conducted as part of the Hawaii Bioenergy Master Plan mandated by Act 253 of the Hawaii State Legislature in 2007. This effort included the characterization of the general environmental impacts and issues associated with bioenergy development, the identification of potential environmental impacts in Hawaii for each portion of the biofuels value chain, and recommendations for State action.

Despite the obvious potential benefits of reduced greenhouse gas (GHG) emissions and energy self-sufficiency offered to Hawaii by bioenergy development, there are many potential environmental impacts that need to be considered when developing bioenergy policy and projects in Hawaii. The following is a summary list of the potential environmental impacts and issues associated with bioenergy development in Hawaii.

- Reduction in greenhouse gas emissions and use of fossil fuels
- Invasive species management
- Agricultural land use conflicts
- Water use and water rights
- Water pollution/quality
- Soil quality
- Air quality
- Residue management
- Socio-economic community impacts
- Cultural impacts
- Transnational environmental issues

The following list of recommendations has been developed based on stakeholder input and information collected in the preparation of this study.

1. Environmental Impact Assessment – As specific proposals are put forward for development of aspects of the bioenergy value chain, environmental assessments or environmental impact statements should be completed pursuant to the State of Hawaii environmental review law (Chapter 343, HRS) and the Department of Health Title 11-200 administrative rules governing the review process. It should be noted that not all bioenergy projects may trigger Chapter 343, HRS due to their proposed locations, land ownership, and/or funding.

   Environmental assessments and impact statements should include evaluations of the potential social, economic, and cultural impacts associated with the proposed projects, as required in the Title 11-200 administrative rules for the environmental review process. Assessments should strive to include analysis of how specific proposed projects for bioenergy development in Hawaii will effect and be affected by international market conditions. This analysis will give transparency to the potential indirect and direct environmental impacts of biofuels development in Hawaii.

2. Life-Cycle Analysis (LCA) – Life-Cycle Analysis (LCA) is the cradle to grave systems approach for examining technology and systems. LCA should be used to examine the specific technical aspects of any proposed biofuels value chain, the crops, energy requirements, emissions, land use changes, water use requirements, wastes, logistics, conversion technology, distribution, and end use to determine the net energy and greenhouse gas balances of the biofuel. This process is being used nationally and internationally to evaluate bioenergy development and could be employed for analysis of local conditions and permitting.

   The State should establish requirements for LCA based on Hawaii's specific environmental conditions, goals and needs. The State should establish guidelines for LCA, including certification of LCA methodologies, and the minimum attainment of positive net energy and greenhouse gas balances. LCA should be used as an integral component in a biofuels certification process.

3. Conservation Agriculture – Since most environmental impacts from bioenergy development are found in the feedstock production phase, the State should require appropriate conservation agriculture practices for biofuels feedstock production. This would help reduce water consumption, use of pesticides and fertilizers, and pollution.

4. Weed Risk Assessment (WRA) – Weed Risk Assessment (WRA) should be required for all candidate crops for biofuel production. Since Hawaii has sensitive natural resources that are susceptible to invasive species, the State should establish criteria for restricting certain candidate crops that may have the greatest potential for harm. It may also want to limit introduction of certain crops from areas near sensitive habitats depending on the individual characteristics of the candidate crop.

5. Examine the Issue of Agricultural Land Use and Biofuels – The State should commission a study to examine the potential issues related to agricultural land use and biofuels. The potential impacts to local agriculture from an introduction of large-scale biofuel development may be significant. Of particular importance is the potential loss of local food-crop production as prime agricultural lands are shifted to biofuels and other non-agricultural uses.

   The study should examine how existing agricultural practices and uses of land, including small farming and ranching, may be impacted by the introduction of incentives and subsidies for biofuels. This should include an analysis of food security and fuel security issues in Hawaii. The study should also examine how the conversion of prime agricultural lands to non-agricultural uses may affect biofuels development and long-term viability.

6. Encourage Use of Existing Infrastructure – To minimize the potential environmental impacts from the development of new infrastructure needed to support bioenergy, the State should encourage the use of existing conversion facilities, pipelines, and other infrastructure where applicable.

7. Community-Based Bioenergy Working Group – Many stakeholders expressed concern about the lack of information regarding environmental issues and the State's plan for bioenergy development. Many requested a forum to exchange information. The State should establish a community-based working group with representatives from various stakeholders including, but not limited to, representatives from State of Hawaii Departments of Agriculture; Business, Economic Development and Tourism; Land and Natural Resources; Attorney General; bioenergy entrepreneurs; large landowners; small farmers; environmentalists; Native Hawaiian groups; the power industry; etc.

   This forum would be useful for creating community dialogue and understanding about bioenergy development and environmental issues in Hawaii. It could also be used as a tool for gathering information for social and cultural impact assessment.

8. Biofuel Certification Program – To safeguard Hawaii's unique native eco-systems and culture, and support sustainable biofuels development, the State should explore the possible development of a certification program for biofuels. Many countries are proposing that biofuels meet certain mandated targets or minimum goals to receive subsidies and government recognition. A certification program in Hawaii could include various sustainability requirements related to net energy and greenhouse gas balances, invasive species protection, water and land conservation, protection of local food supplies and farming, and other social and cultural issues.

   It should be noted that certification programs are difficult to employ and may, if too unwieldy or burdensome, constrain the development of the local biofuel industry in Hawaii. If employed, certification should be targeted at specific local problems and tailored to meet specific sustainability goals established by the Legislature.

   Due to the complexity of the issues, the State should commission a separate study to examine biofuels certification for Hawaii. The study should include analysis and recommendations for sustainability requirements, implementation and timing guidelines, and the specification of departmental permitting responsibilities. A central component of the study also should be the analysis of the various certifying methods including government run certification programs, preliminary certification for "First-Movers", voluntary certification, and third-party certification. Optimally, certification of any sort should not add to the duration of the overall permitting process. Efforts should be made to coordinate existing permitting and disclosure processes and reduce or eliminate redundancies.

   Optimally, a certification program should be established prior to the development of new subsidies for biofuels in Hawaii. However, due to the State's desire to encourage rapid development of bioenergy there may need to be some discussion about creating initial screening processes and preliminary certification to help first movers with "shovel-ready" projects or demonstration projects. If a "First-Movers Program" for preliminary certification was established, any participating programs should be required to complete a full and timely certification and LCA as part of their final permitting/compliance. Strict precautions would need to be taken in a preliminary certification process to safe-guard against invasive species and any other irreversible commitment of resources that may be proposed by a project under a “First-Movers Program”.

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1. Introduction

Increased petroleum costs and the threat of global warming and climate change are pushing governments and industry to explore the transition to renewable and more ecologically friendly energy sources. Bioenergy[1] is identified as one of the potentially viable sources of renewable and environmentally friendly energy for Hawaii. Bioenergy crops can reduce or offset greenhouse gas emissions by directly removing carbon dioxide from the air as they grow and may increase stores of soil organic carbon over time. Resources can also be grown or produced domestically from a wide array of plants or wastes including corn, sugar cane, oil palm, waste cooking oil, switchgrass, and eucalyptus to name few. Biomass resources can be used for both liquid or solid biofuels for transportation and electrical power generation.

In recognition of the potential for bioenergy to help meet the need for renewable and environmentally friendly energy in Hawaii, the 2007 Hawaii State Legislature passed legislation mandating the development of a Bioenergy Master Plan, subsequently enacted as Act 253, Part III. The primary objective of the Master Plan is to develop a Hawaii renewable biofuels program to manage the State's transition to energy self-sufficiency. For this study, the presumed goal is displacement of 20% of 2007 transportation (gasoline and diesel) and power generation (diesel and fuel oil) fuel use with bioenergy resources by 2020. The Master Plan is intended to address 1) Strategic partnerships for the research, development, testing, and deployment of renewable biofuels technologies and production of biomass crops; 2) Evaluation of Hawaii's potential to rely on biofuels as a significant renewable energy resource; 3) Biofuels demonstration projects, including infrastructure for production, storage, and transportation of biofuels; 4) Promotion of Hawaii's renewable biofuels resources to potential partners and investors for development in Hawaii as well as for export purposes; and 5) A plan or roadmap to implement commercially viable biofuels development.

The Bioenergy Master Plan is constructed around implementation of the biofuel value chain including feedstock production, feedstock logistics, conversion, distribution, and end use of biofuels. The plan addresses various issues for implementing the value chain including water and land resources, distribution infrastructure for both marine and land, labor resources, technological production of feedstocks, permitting, financial incentives and barriers, business partnering, and policy requirements. Act 253 also directs that the Bioenergy Master Plan identify and analyze the environmental impacts of transitioning to a bioenergy economy.

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[1] Bioenergy technologies use renewable biomass resources to produce an array of energy-related products, including electricity, liquid (biodiesel and ethanol), solid, and gaseous fuels, heat, chemicals, and other materials. Biomass is any organic matter that can be used for energy production, including trees, agricultural food and feed crops, crop and wood wastes, aquatic plants (algae), animal and municipal wastes, and dedicated energy crops.

2. Consideration for Bioenergy Development in Hawaii

Passage of Act 253 and development of this Master Plan followed the preparation of various studies in support of bioenergy development and the convening of the Governor's Biofuels Summit and the Ag Bioenergy Workshop in 2006. These initiatives indicate that the focus of bioenergy development efforts in Hawaii has been on biodiesel and ethanol-based biofuel to reduce Hawaii dependence on imported petroleum for both transportation and electrical energy generation.

Poteet (2006) evaluated the potential for biodiesel development in Hawaii based on the development of a wide-range of biodiesel crops including soybean, flax, rapeseed, sunflower, peanut, African oil palm, kukui nut, avocado, coconut, *Jatropha curas*, Neem tree, and algae. Poteet found that, over time and under specified conditions, Hawaii has the potential to produce 150 million gallons of biodiesel per year or more than 55% of the total diesel usage of roughly 263 million gallons for the State of Hawaii in 2004. Poteet also highlights the co-products that would be available for use in Hawaii as part of biodiesel development - glycerin, seedcake, residual biomass, food products, and other chemical compounds. Poteet noted, however, there is a general lack of knowledge about co-products in Hawaii and that the markets for their use will need to be developed as biodiesel production is expanded.

Keffer *et al.*(2006) analyzed the ethanol production potential for the State of Hawaii based on four crop scenarios; 1) sugar cane grown on all soils suitable for sugar, 2) *Leucaena* and *Eucalyptus* grown on all soils suitable for trees, 3) sugar cane given first priority, grown on all soils suitable for sugar, and *Leucaena* and *Eucalyptus* given second priority, grown on remaining soils suitable for wood, and 4) banagrass grown on all soils suitable for sugar. The authors concluded that a renewable fuels goal of 20% of motor gasoline, 134 million gallons of ethanol equivalent, could be achieved under all these crop scenarios. The limiting factor for production was the amount and type of lands used in production.

In addition to identifying potential crops for production, various authors examined the land and water requirements for bioenergy development in Hawaii. The Rocky Mountain Institute's (RMI) *Hawaii Biofuels Summit Briefing Book*, which outlined the State of Hawaii's biofuels goals and issues prior to the Governor's Biofuels Summit, highlighted the market and resource requirements needed to reach a 20% alternative fuel standard by 2020. RMI assumed that all future sugarcane production in the state, which amounts to approximately 36,700 acres on Maui and 11,000 acres on Kauai, would convert to biofuel production and that an additional 83,000 acres of prime farm land would be needed to produce enough biofuels to meet the 20% alternative fuel standard by 2020 (RMI, 2006).

Availability of water for biofuels production in Hawaii is regarded as an ill-defined variable at this point. The cultivation of irrigated crops will require substantial quantities of agricultural water and it is unclear whether there are sufficient water resources to meet the demand for the 20% alternative fuel standard (RMI, 2006). Certain technological advances including development of cellulosic ethanol and algae for biofuels do show promise and their use may lessen land and water inputs in comparison to conventional crops and conversion technologies.

Lastly, biofuels development in Hawaii suffers in some regard from the "chicken or the egg" dilemma. Without an established end market for biofuels produced from locally grown feedstocks, there are few economic incentives to put agricultural lands into biofuel production. Conversely, potential purchasers of biofuels, like electrical generating companies, may not invest in biofuel compatible generating plants unless there is a viable and economic supply of feedstock or finished biofuels. One proposed solution is the importation of finished biofuels for use in newly developed generating plants, thus supporting creation of an end-market for local biofuels. The development of biofuels in Hawaii is ultimately based on international market forces, and locally grown biofuels will only be economically viable if they can be produced at or below import parity prices for both feedstock and finished fuel (RMI, 2006).

3. Need for Environmental Analysis of Bioenergy Development

Despite the obvious potential benefits of reduced greenhouse gas (GHG) emissions and energy self-sufficiency offered by biofuels, some studies have called into question the environmental sustainability of biofuels (Sharlemann and Laurance, 2008, Zah *et al.*, 2007, Muller, 2008). This is mainly based on the overall environmental costs and negative greenhouse gas balances of some biofuels and their production cycles when compared to fossil fuels (Zah *et al.*, 2007). Zah *et al.* (2007) (as cited in Sharlemann and Laurance, 2008) found that most first generation biofuels[2] (21 of 26) reduce GHG emissions by more than 30% in comparison to gasoline, but that 12 of 26 have greater aggregate environmental costs than fossil fuels.

Beyond the effects on greenhouse gas emissions, the increased production of biofuels has direct and indirect environmental consequences. Water, land, and soil are all potentially affected by intensive biomass production. For example, the increased economic demand for biofuel feedstocks contributes to tropical deforestation by increasing demand for conversion of forest areas to biomass crop production. (WWF, 2006). Increased competition for land and water resources between biofuel crops and food crops also creates food security and other social issues for local communities (Muller, 2008).

Despite the potential environmental impacts associated with development of the bioenergy value chain, many authors (Zah *et al.*, 2007, Muller, 2008, and WWF, 2006) note that biofuels can be developed sustainably and become important sources of energy for local communities while reducing greenhouse gas emissions. In general, the desirability and sustainability of bioenergy as an alternative to petroleum depends largely on how it is developed. It is imperative that some form of comprehensive Life-Cycle Analysis (LCA) and environmental impact assessment be conducted for the bioenergy value chain to determine the appropriate technologies and direction for bioenergy development (Sharlemann and Laurance, 2008, Zah *et al.*,2007, Muller, 2008).

[2] Second generation biofuels include those made from the breakdown of plant cellulose or lignin

This chapter of the Bioenergy Master Plan identifies and evaluates the potential environmental impacts that could occur from the production of biofuels along the value chain, including feedstock production, feedstock logistics, conversion, biofuel distribution, and end use in Hawaii. The first section is a discussion of the Objectives and scope of work of the study. The second section on Findings is divided between an overview discussion of the general environmental issues associated with the development of bioenergy and an analysis of the potential environmental impacts associated with the bioenergy value chain in Hawaii. The last section of the chapter includes recommendations for the Bioenergy Master Plan on managing environmental issues of bioenergy in Hawaii.

4. Objectives

Since the technologies, crops, methods, locations, and timing for development of the bioenergy value chain in Hawaii are not specifically identified and may change over time as technologies emerge, the objective of this chapter of the Master Plan is to provide a general assessment of the broad environmental impacts[3] and issues related to bioenergy development in Hawaii and to establish a framework for assessing specific impacts as technologies and projects are proposed and implemented. Future Life-Cycle Analysis of biofuels processes and environmental impact assessment[4] of individual projects will be necessary in order to create an environmentally sustainable bioenergy industry that meets the State's goals of reducing greenhouse emissions and increasing energy security.

5. Scope of Work

The scope of work of this chapter includes:

1. Identify appropriate stakeholders, technical experts, and information sources throughout the state.
2. Conduct meetings and surveys with stakeholders, and research and analysis to:
    a. Document the range of potential environmental impacts that are applicable to transitioning Hawaii to a bioenergy economy;
    b. Identify parameters that will serve as indicators of the potential impacts identified in 2 a and how they can be monitored;
    c. Other considerations relevant to the topic.
3. Based on work conducted per item 2 above:
    a. Conduct analysis of environmental impacts, related to development of a bioenergy industry;

[3] The term "environmental impacts" was interpreted by the authors to include socio-economic and cultural impacts. The inclusion of these associated impacts in environmental impact analysis is standard practice under the National Environmental Policy Act (NEPA) and Chapter 343, Hawaii Revised Statues.

[4] Not all bioenergy projects may be required to complete federal and state Environmental Assessments (EA) or Environmental Impact Statements (EIS). The National Environmental Policy Act (NEPA) and Chapter 343, Hawaii Revised Statues have specific triggering requirements for preparation and processing of EAs and EISs for proposed actions. The authors do not imply that the legal processes included in those statues are, or are not required, for all bioenergy development projects in Hawaii.

b. Provide analysis of ways to reduce the likelihood of negative environmental impacts and increase the likelihood of positive environmental impacts;
c. Identify methods to facilitate development of a bioenergy industry using an approach that is sensitive to impacts; and
d. Conduct other related work to further support the objectives of this Task.

The majority of activities completed for the scope of work were related to research and analysis. Broad research and analysis was completed on the environmental aspects of bioenergy development throughout the world and the United States.

To complete the scope of work for this chapter, various activities were completed in 2009. A stakeholder meeting with two break-out sessions was completed on April 2, 2009. During this meeting stakeholders were asked to give their impressions and views on the potential environmental impacts of bioenergy development in Hawaii. Individual meetings were also held with selected stakeholders from the environmental and business communities to clarify some specific issues. Stakeholder input was used in the development of recommendations. The environmental impacts breakout section notes are included as Appendix 1. Highlights of the responses are provided below.

<u>Question 1</u>. What do you think are the most critical environmental issues related to bioenergy development in Hawaii?

Responses to Question 1. included discussions on (1) the environmental impact assessment process and the uncertainty it may present to the bioenergy development process, (2) land use change and competition for scare agricultural land between biofuels feedstock crops and small farmers, (3) risks of biofuels feedstock crops being invasive species, (4) impacts to water quality and water use from biofuels, (5) general regulatory issues, (6) crop abandonment, and (7) environmental justice regarding locating of bioenergy facilities.

Question 2. What would be the best way to continue the community discussion on the environmental issues as the Master Plan is developed in the next 6 months? And in the next 2 -3 years should this planning effort continue?

In responses to Question 2. stakeholders identified a desire to (1) develop a Hawaii energy forum for discussing bioenergy, (2) use existing websites, (3) develop a public education outreach and extension effort, (4) conduct comprehensive review of permitting issues related to bioenergy.

6. Environmental Issues

The evaluation of the environmental impacts of bioenergy and biofuel development has principally focused on the potential benefits to climate change from the reduction in greenhouse gases offered by a reduction in the use of fossil fuels. This approach is too narrow because of the array of direct and indirect environmental impacts associated with the various components of the bioenergy value chain. The following section describes the factors involved in assessing the potential environmental impacts of bioenergy development and discusses how they may be manifested in Hawaii.

6.1 Net Energy Balance

The reduction in use of fossil fuels for energy is regularly sited as one of the reasons for developing bioenergy technologies. Biofuels can replace fossil fuels in a wide array of electrical generation and transportation fuel uses. Despite bioenergy being a “renewable” energy source, it does require the consumption of fossil fuels in the various phases of the value chain. This includes energy for growing seeds, powering farm machinery and buildings, producing fertilizers and pesticides, processing and conversion of biomass to fuels, transporting feedstocks and biofuels, storage of biofuels, and end use distribution. To be a viable alternative to fossil fuel from a net energy perspective, a biofuel should provide a net energy gain.

The analysis and debate regarding the benefit of biofuels in the displacement of fossil fuel is focused on the net energy balance of the various biomass crops and the amount of nonrenewable energy required in the production value chain of the biofuel. There is, however, considerable variability in the methods used to determine the net energy balance of biofuels and a general lack of consensus among proponents and detractors on how to evaluate each bioenergy technology.

Since, one of the goals of State is to reduce Hawaii’s reliance on imported petroleum then the individual proposed bioenergy technologies in Hawaii should be evaluated for their net energy balance.

6.2 Greenhouse Gas Reduction

A major promise of bioenergy development is the potential reduction in greenhouse gas emissions provided by the reduction in use of fossil fuels. Biofuels can provide energy that displaces fossil fuels for both electrical generation and transportation uses. Bioenergy crops also can reduce or offset greenhouse gas emissions by directly removing carbon dioxide from air as they grow and storing it in crop biomass and soil. In addition to biofuels, many biomass crops generate co-products, such as protein for animal feed or corn oil that further reduce the need for fossil fuels.

Recent scientific studies have revealed that different biofuels vary widely in their greenhouse gas balances when compared to petroleum products (Farrell *et al*., 2006, Scharlemann and Laurance, 2008, Farigone *et al*., 2008). Depending on the methods or inputs used to produce the feedstock and process the biofuel, some technologies can even generate more greenhouse gases than do fossil fuels. For example, nitrous oxide, a greenhouse gas with global-warming potential around 300 times greater than that of carbon dioxide, is released from nitrogen fertilizers that are used in producing some biofuels. Greenhouse gases also are emitted at other stages in the value chain and in the production of fertilizers, pesticides and fuel used in farming and during chemical processing, transport and distribution, and final use. The effective use of co-products from bioenergy conversion and processing is critical to establishing a positive net greenhouse gas balance. However, marginal markets for some co-products may reduce the overall greenhouse gas benefit of some biofuels.

Another contributing factor to the greenhouse gas balances of biofuels is the land use changes brought on by their development. As a result of increased demand for biofuels such as corn, palm oil, and soy, more lands are being placed in biofuel crop production. This increased demand for land displaces traditional food crops and increases the conversion of marginal lands to agricultural production for both biofuels and food crops (Searchinger *et al*., 2008, Fargione *et al.*, 2008). Because existing land uses already provide carbon benefits in storage and sequestration, dedicating new lands to biofuels can potentially reduce greenhouse gases only if doing so increases the carbon benefit of using land for biofuels. Fargione *et al.* (2008) found that the conversion of native rainforests, peatlands, and grasslands to biofuels production creates a "biofuel carbon debt" by releasing 17 to 420 times more carbon dioxide than the annual greenhouse gas reductions that biofuels would provide by displacing fossil fuels. Searchinger *et al.* (2008) also find that by including land use change in their greenhouse gas balance model, corn-based ethanol nearly doubles greenhouse gas emissions over 30 years, while switchgrass, grown on converted corn lands, increases emissions by 50%. The substantial increase in greenhouse gas emissions for biofuels produced on converted crop lands highlights the value of biofuels made from waste products such as cellulosic ethanol (Searchinger *et al.*, 2008).

It is important to establish accounting methods that evaluate the greenhouse gas balances for individual biofuel value chains in Hawaii to understand if they will provide a net positive greenhouse gas balance. This evaluation should include analysis of the possible conversion to biofuels production of existing sugarcane lands, fallow prime agricultural lands, forested lands, lands currently in diversified agriculture, or those lands in cattle production.

6.3 Land Use

Bioenergy development generally requires significant tracts of agricultural land to produce the quantities of feedstock needed for biofuel production. Consequently, there are various potential impacts to land use in Hawaii from the proposed development of bioenergy to meet the 20% alternative fuel standard. The Bioenergy Master Plan focuses on availability and potential development of prime agricultural lands. El-Kadi and Ogoshi (2009) find that approximately 53,246 acres may be devoted to bioenergy production by 2030 based on an optimistic projection. This does not include the possible development of former plantation lands held by private landowners.

Economic incentives or subsidies for biofuels on state and private lands may shift current uses of agricultural lands toward the bioenergy market and displace current agricultural patterns. Existing large-scale sugarcane production on Maui and Kauai may be shifted to other biofuel crops. Prime agricultural lands also may be taken out of small-scale farming, cattle production, or other agricultural operations as demand for prime agricultural land increases and the market for biofuels expands. This could result in a reduction in the number of acres of diversified agriculture in the state, reversing an expansion that began with the reduction in plantation agriculture statewide in the early 1990s. A reduction in local diversified agriculture and food crop production may result in increased petroleum use in order to import replacement food to the state. Furthermore, the state's ability to produce local food and decrease its reliance on food imports may be diminished.

The shift to a bioenergy market also may cause land use conflicts centered around the development of biofuels on fallow agricultural lands that border newly developed residential areas. Recent urbanization on all islands has resulted in the residential development of more and more former agricultural lands. The reintroduction of intensive agriculture may cause conflicts between residents and agricultural activities. In addition, development of biofuels conversion plants and other supporting infrastructure in close proximity to newly developed residential areas also may cause conflicts between residents and these industrial operations.

Biofuels development also may be affected by the conversion of prime agricultural lands to non-agricultural uses. Since biofuel feedstocks are proposed to be grown on prime agricultural lands to attain maximum productivity and economic viability, the loss of prime lands could reduce the amount and diversity of available agricultural lands for their development.

6.4 Water Resources

Bioenergy development may adversely impact water resources in Hawaii because of the quantities of water required for some feedstock crops and the biofuel conversion process. Crops like sugar and banagrass would most likely require some form of annual irrigation, while other crops, including *Leucaena* and *Eucalyptus*, would be grown without applied irrigation (Keffer *et al*., 2006). Because different crops and production processes require varying amounts of water, it is difficult to quantify the potential water resource requirements. However, according to RMI (2006) in its evaluation of bioenergy development in Hawaii, it is unclear whether there are sufficient water resources to meet the potential future demand of a 20% alternative fuels standard. Currently, there is competing demand for scare water resources in Hawaii between residential developers, small farmers, industrial agriculture, and others, making water a sought after commodity. Various high profile water rights cases have been decided in the courts recently because of the high demand for scarce water resources. The use of less water-intensive technologies or crops, such as those for cellulosic biofuels production, may help reduce the overall impact to water resources.

6.5 Water Pollution

Bioenergy development also has the potential to adversely affect both marine and fresh water quality. Intensive agricultural development for biofuels feedstock may increase erosion and sedimentation of streams and near-shore waters. The increased use of agricultural chemicals, fertilizers and pesticides on currently fallow land also may affect water quality from the runoff of these chemicals to streams, near-shore waters and infiltration to groundwater. Furthermore, wastewater from the feedstock production, logistics, and conversion phases will need to be managed and processed before being released to the environment. Depending on the biofuel crops and processes used, wastewater can be minimized through its use in the development of co-products.

6.6 Invasive Species

Invasive species are introduced species that spread in a new geographic region, resulting in undesirable ecological, economic or human health consequences. Most invasive species are introduced deliberately or accidentally by people. Invasive species are recognized as a major ecological and economic issue worldwide, but they are of special concern in Hawaii.

Hawaii's natural flora and fauna are composed of unique species, most of which are found nowhere else in the world. For example, more than 85% of Hawaii's native plants are found only in Hawaiʻi. Many of these native species are now rare or at risk of extinction. Hawaiʻi has more Endangered and Threatened plants than any other state. Invasive species can compete with native species or cause disturbances that promote habitat degradation. Furthermore, invasive diseases, parasites and predators also harm native species. In addition to their ecological impacts, invasive species threaten Hawaii's agriculture and forestry industries, and they potentially have negative consequences for tourism.

Although most introduced species do not become invasive, the introduction and promotion of non-native species for biofuel poses some risks. All plant species currently under consideration as biofuels are introduced species. Biofuels may pose particularly high risks of becoming invasive because many of the same traits that are desirable for biofuels, such as rapid growth and wide environmental tolerance, are also associated with invasiveness. Hawaiʻi has a history of quickly importing and promoting plants that prove to be economically non-viable in cultivation; some of these have had enormous economic costs. A classic example was the importation and promotion of indigo, which never developed into a viable dye industry in Hawaiʻi, but the plants quickly spread across Hawaiʻi in the late 1800's, becoming one of the worst weeds in agriculture at that time. Careful screening of plants for weediness or invasiveness can help minimize problems like this.

A weed risk assessment(WRA) system has been developed for Hawaiʻi to evaluate risk of invasiveness in introduced plants. The WRA consists of a series of 49 questions addressing aspects of an introduced plant's ecology, reproduction, growth, dispersal, harm to livestock and humans, and behavior as a weed in other parts of the world. Answers to these questions are used to generate a numeric WRA score. A high score (> 6) corresponds to a high risk that a plant will become a problematic weed.

Retrospective testing has demonstrated that Hawaii's WRA system has an overall accuracy rate of around 80% in correctly identifying real invaders as high risk and non-invasive plants as low risk. The WRA for a candidate biofuel can be completed in one day at low cost (about 6 hours of research); therefore, using WRA to evaluate all biofuels is a sensible first step to screen out invasive plants. Many candidate biofuels have already been evaluated using the WRA system.

Current candidate biofuel crops

Sugarcane (*Saccharum officinarum* and hybrids with *S. spontaneum* or *S. robustum*)
Weed Risk Assessment Score – 2 (low risk)

Sugarcane was an early Polynesian introduction to Hawaiʻi, and it has been grown in large plantations for more than a century. Sugarcane is a perennial grass that is rarely found outside of cultivation. It rarely if ever, reproduces by seed in nature. Plants are persistent within abandoned plantations, but over time the abandoned plantations become increasingly dominated by other grasses such as Guinea grass (*Panicum maximum*) or woody species such as Leuceana. Sugarcane has a low WRA score, in part due to its low potential to spread and its lack of behavior as a weed around the world. All lines of evidence suggest that sugarcane poses little risk of becoming invasive in Hawaiʻi.

Domesticated food crops (corn, soybeans, peanut, sweet sorghum, cassava)
Weed Risk Assessment Score for *Manihot esculenta* (cassava) -- 3 (low risk)

Although most of these domesticated crops have not yet been formally screened by WRA, the fact that they are highly domesticated greatly reduces the WRA score. Furthermore, all of these species have a history of more than 100 years of cultivation in Hawaiʻi, during which time they have not become invasive. These species pose little risk of becoming invasive.

Banagrass (*Pennisetum purpureum*, possibly a hybrid with *P. glaucum*)
Weed Risk Assessment Score for *Pennisetum purpureum* – 16 (high risk)

Banagrass, is an extremely tall (4-7 meters) and densely-growing grass originally from Africa. Banagrass is often referred to as *Pennisetum purpureum* in agronomic literature, but it may also refer to a hybrid between *P. purpureum* and *P. glaucum*. In order to properly assess the potential invasiveness of banagrass in Hawaiʻi, the genetic constituency of the plants being proposed for biofuel use needs to be clearly determined, and the proper scientific name should always accompany the name "banagrass". In the absence of information to the contrary, it is assumed that banagrass is ecologically the same as Napier grass (*Pennisetum purpureum*). Napier grass was first documented from Lanai in 1922, where it was planted at the Agricultural Experiment Station. Field trials with banagrass/Napier grass have continued on several islands, but at a small (experimental) scale and at relatively few sites. Banagrass/Napier grass has become naturalized in Hawaiʻi, where it is prominently seen along roadsides and around pastures, mainly at wet sites. A major concern is that this massive grass could become established along streamsides, clogging waterways, promoting flash floods, and affecting water delivery. The weed risk assessment recognizes banagrass/Napier grass as a serious weed in other parts of the world, including Florida, which shares many invasive species with Hawaiʻi. Although banagrass/Napier grass is already present in Hawaiʻi, large scale plantings can be expected to substantially increase sites of invasion in Hawaiʻi.

Eucalyptus (*Eucalyptus grandis*, *Eucalyptus urophylla*, hybrids, and other Eucalyptus species)
Weed Risk Assessment Scores, *Eucalyptus grandis* – 11 (high risk)
Eucalyptus urophylla – 4 (low risk)

More than 400 species of Eucalyptus are known. Almost all of them are native to Australia, and 100 or more species have been widely planted for forestry around the world. They are rarely invasive. In Hawaiʻi, Eucalypts have been popular trees for forestry since the early 1900s, with 30 or more species now found in plantations. It is not uncommon to find seedlings in the vicinity of plantings, but as yet none of the Eucalypts in Hawaiʻi can be classified as important invasive species. Nevertheless, *Eucalyptus grandis*, which is one of the popular biofuel species, received a WRA rating of 'high risk'. This species has a high WRA score primarily based on its invasive behavior in South Africa. In South Africa, *E. grandis* invades along river courses. This is a particular concern in drought-prone regions of South Africa because Eucalypts have been shown to use more water than native vegetation, reducing the water available for human needs. Large plantations of *E. grandis* are already established in Hawaiʻi, but most of these are recent plantings, so there has been little time to judge invasiveness within Hawaiʻi. For the most part, Hawaiʻi lacks riverine habitats like those susceptible to *E. grandis* invasion in South Africa, and this may decrease the risk in Hawaiʻi, but this species should be monitored.

Leucaena (*Leucaena leucocephala*)
Weed Risk Assessment Score – 15 (high risk)

Leucaena is a fast-growing small tree that harbors nitrogen-fixing bacteria in its roots. This adaptation allows Leucaena to thrive in poor soils. Leucaena is also drought tolerant, making plantings feasible at many leeward sites, even without irrigation. Leucaena has been present in Hawaiʻi for more than 150 years, and it has been widely planted. It is found growing wild in dry habitats on all the main Hawaiian Islands, and it is often considered a problematic weed of natural areas, capable of forming dense stands. Leucaena also invades pastures, but it is generally considered palatable to livestock. The weed risk assessment identifies Leucaena as serious weed in various places around the world, including Hawaiʻi, where it can form dense thickets. Leucaena also produces long-lived seeds, which promote the plant's persistence in the wild. In Hawaiʻi, Leucaena has probably already reached its full range of invasion. Its abundance seems to be regulated by fire-return intervals in dry habitats. Because of its extensive spread in Hawaiʻi, additional plantings for biofuel may have limited impacts. However, if new Leucaena cultivars are considered, then the risk should be carefully re-considered, as new cultivars may differ ecologically, potentially resulting in greater invasiveness and new unintended impacts.

Jatropha (*Jatropha curcas*)
Weed Risk Assessment Score – 17 (high risk)

Jatropha is a small, drought tolerant tree grown for its oil-rich seeds. It is a relative of *kukui* (*Aleurites moluccanus*), a much larger tree common in Hawaiʻi that also produces oil-rich nuts. Jatropha has been present in Hawaiʻi, probably since the early 1900's; however, plantings have been very small in scale, providing little opportunity for these plants to spread. Nevertheless, Jatropha is now found in wild populations on the south slope of Haleakala, Maui, as well as escaped from small-scale plantings on the island of Hawaiʻi, and to a lesser extent on Oʻahu. The WRA recognizes Jatropha's status as a noxious weed in Australia, where it is banned from cultivation. In South Africa, Jatropha can be planted only with a research permit, due to concerns about its environmental and economic impacts. This plant forms dense stands in natural habitats, and it has toxic seeds. Accidental poisonings have been reported in various parts of the world; the fruits are reportedly attractive to children. Planting of Jatropha as a biofuel is likely to increase the rate and extent of Jatropha invasion in Hawaiʻi, and this risk should be carefully considered prior to adopting Jatropha for biofuel production.

African Oil Palm (*Elaeis guineensis*)
Weed Risk Assessment Score – 10 (high risk)

African oil palm is one of the most common sources of palm seed oil, which is used in various types of food products. Therefore, plantations of African oil palm already exist in tropical zones on all continents, as well as on many tropical islands. In Hawaiʻi, African oil palm occurs primarily in botanical gardens, although small-scale research plantings have also been undertaken. The weed risk assessment indicates a high risk of invasiveness, partly due to its production of large numbers of bird-dispersed fruits, which are liable to be carried into natural habitats. African oil palm has also been reported as naturalized at a few sites around the world. This is not surprising, considering the scale of plantings that have occurred; rather, what is striking from the WRA is that there is no documented evidence of negative impacts of African oil palm despite it having been distributed around the world for at least a century and planted in very large quantities. Considering the global history of African oil palm, naturalization may be expected in Hawaiʻi if it is grown at a large scale, but impacts of naturalization may be difficult to document.

Algae
Much of the biofuel research today targets microalgae growing in artificial tanks or closed system cultures. The weed risk assessment developed for land plants is not adaptable to single-celled algae because traits or features of single-celled organisms are different from those of large terrestrial plants. Nevertheless, risks posed by these algae should be assessed by examining at least two general issues, 1) likelihood that alga will escape into nature; this may depend on the circumstances of culture or harvesting, and 2)

the potential impacts on aquatic habitats if the alga escapes; this could be judged partly from impacts observed in other parts of the world. If the micro-alga is already naturally occurring in Hawaiʻi, then its cultivation as a biofuel an artificial or closed system would probably pose little risk.

Other invasive species risks

While most species currently under consideration as biofuels are already present in Hawaiʻi, there will likely to be a need to import new plant material. Importations may include new plant species or new genetic stock of species already present in Hawaiʻi. In either case, importation of new plant material involves risks of unintentionally importing diseases and other plant pests. In Hawaiʻi, strict quarantine procedures are already developed for importation of grasses. Establishing similar quarantine procedures for all imported biofuel materials would help protect the industry while also reducing risks to agriculture and native ecosystems.

6.7 Soil Quality

Intensive feedstock cultivation may also adversely impact soil quality. Biomass crops pose a challenge to good soil management because the plant material is often completely harvested leaving little organic matter or plant nutrients for recycling back to the soil. Intensive use of fertilizers and pesticides also may negatively impact soil quality. However, conversion of crop lands from annual crops to fast-growing woody crops or perennial herbaceous crops progressively increases the soils' organic matter content (Cook and Beyea, 2008). Also, a transition to perennial crops from annual crops may reduce the use of fertilizers and pesticides, depending on the crops and what uses they displace (Cook and Beyea, 2008).

6.8 Air Quality

Bioenergy development may have both positive and adverse affects on air quality through the value chain. During feedstock production air quality may be adversely affected as areas come under cultivation and soil erosion is increased, affecting neighboring communities. Increased vehicular traffic during the logistics phase of the value chain, emissions during conversion processing of biofuels, and traffic during distribution of end product may contribute to increased air emissions. In particular, the processing of biofuel feed stocks can affect local air quality with carbon monoxide, particulates, nitrogen oxide, sulphates and volatile organic compounds released by industrial processes.

Analysis of the potential impacts of bioenergy technologies on air quality and health by Hill *et al.* (2009) show that a shift from gasoline and the current generation of food-based ethanol biofuels to cellulosic ethanol will have health benefits to society of comparable importance to the climate change benefits of a reduction in greenhouse gas emissions. The advantages to air quality in the form of a reduction in $PM_{2.5}$ from a shift to cellulosic ethanol are directly tied to the source of land used to produce the biomass crops and the potential indirect impacts from land use changes (Hill *et al.*, 2009)

6.9 Residue Management

Feedstock production, feedstock logistics, and the biofuel conversion phases of the bioenergy value chain generate residues that must be managed. Some residues can be used and marketed as co-products or by-products, including distillers grains and glycerin. Distillers grains are routinely used in animal feed. The market for biofuel co-products in Hawaii is not clear. Residue products from the various processes that are not used or shipped out of state will need to be disposed of locally. This may cause adverse impacts to already taxed local landfills.

Some forms of biodiesel are derived from waste vegetable oil collected from various restaurants and other sources. Waste oil is processed into biodiesel and marketed for use in transportation and electrical energy production. Currently, Pacific Biodiesel has the capacity to produce approximately 1,500,000 gallons of biodiesel annually at its plants in Honolulu and Kahului for use in local transportation (National Biodiesel Board, 2009).

6.10 Socio-economic and Cultural

Social and cultural issues are routinely included in environmental impact assessment of proposed actions to assist in understanding the broader implications of those actions for Hawaii and its local communities. Of particular importance is evaluating how potential environmental impacts and use of resources may affect Native Hawaiian cultural issues and rights.

Full-scale development of bioenergy to the 20% alternative fuel standard may have significant social, economic, and cultural implications for Hawaii. The reemergence of intensive agricultural activities for feedstock production will produce new jobs and training requirements for a portion of Hawaii's labor market. With the virtual demise of plantation agriculture, there may no longer be a reliable supply of agricultural workers for feedstock production on the various islands. Bioenergy may spur employment and renewed community development in certain areas.

Introduction of bioenergy production also may displace existing agricultural activities like small farming or cattle-raising on which some communities are based. This may cause social conflicts between the proponents of bioenergy and these existing activities. Displacement of existing small farms and ranches may cause a reduction in locally grown truck crops or meat, causing an increase in prices for local produce. However, the potential for development of various co-products may support other local agricultural enterprises.

Development of bioenergy projects will require the construction and operation of conversion facilities and related infrastructure. Facilities may be proposed for development in communities that are averse to having agricultural and industrial biofuels production in their areas. Increased traffic, noise, and air pollution from all phases of development of the value chain may cause adverse impacts to local communities. These adverse impacts may cause varying degrees of social conflicts.

Lastly, the potential demand for water and land from bioenergy development may cause significant impacts to existing communities that rely on these resources or border potential biofuels production crops or facilities. In particular, impacts to Native Hawaiian cultural practices from the development of the bioenergy value chain need to be evaluated as projects are proposed. Water rights as well as ceded lands issues will most certainly be affected by the potential use of large quantities of water and State lands.

It is difficult to evaluate the potential social and cultural issues related to bioenergy development without concrete development plans. In general, it will be important for proponents of bioenergy to establish a continuous dialogue with community stakeholders to minimize potential conflicts.

6.11 Transnational Environmental Issues

Despite Hawaii being one of the most isolated areas in the world, any development of bioenergy in Hawaii will be effected by, and potentially may affect, international biofuel and agricultural markets and local environmental conditions. The introduction of biofuels crops and production in the United States has affected land use in other parts of the world. This is exemplified by the case of increased corn-ethanol production in the United States whereby farmers were incentivized to shift from soybeans, wheat, and other crops to meet the demand for corn. The subsequent rise in prices for soy beans and other agricultural commodities induced an indirect increase in soy bean production in Brazil and conversion of marginal lands and rainforest to agricultural production (FAO, 2008).

The possible importation to Hawaii of finished biofuels or feedstock for use by end users also may cause direct environmental impacts and land use changes in those countries that supply the finished biofuels or feedstock. Currently, Hawaiian Electric Company (HECO) proposes to import Malaysian palm oil from a provider that certifies the environmental sustainability of the production process in Malaysia. The use of the finished biofuel by HECO or others may help create the end market for biofuels in Hawaii and thus should help to induce local production of suitable biofuels to replace imported products. While the certification of the imported finished biofuels helps reduce environmental impacts in Malaysia where these fuels are produced, the increase in the international market demand for finished palm oil may induce farmers to convert sensitive habitat or marginal lands to biofuels production in other areas.

There are direct and indirect land use changes resulting from biofuels development that must be accounted for in the overall analysis of environmental impacts. Development of a bioenergy economy in Hawaii, that relies at least in part on imported biofuels, may create further market demand internationally and require that local producers be able to produce biofuels competitive with international market prices.

7. Value Chain Impact Analysis

The following section includes brief descriptions of possible actions and activities to be undertaken under each phase of the bioenergy value chain in Hawaii and a summary of the possible environmental impacts.

7.1 Feedstock Production

Types of Actions and Activities: Feedstock production includes the growing of biomass crops. There are a diversity of crops and techniques for growing feedstocks, and these generally require land, water, some external energy source, fertilizers, pesticides, and labor.

Types of Environmental Impacts: Agricultural production of feedstocks has many potential environmental impacts. The potential impacts of feedstock production include greenhouse gas sequestration, land use changes, water use, water pollution, waste management, soil erosion and degradation, invasive plant introduction, air quality degradation, and socio-economic and cultural impacts. There may be conflicts over land and water use. Feedstock production, to the extent it may rely on imported oils as a transitional strategy, also may cause direct and indirect environmental impacts to other areas on the mainland or internationally that are affected by the international markets for bioenergy.

7.2 Feedstock Logistics

Types of Actions and Activities: Feedstock Logistics involves the harvesting, transportation, and storage of biofuel feedstocks. This generally requires land for storage of feedstock and vehicles. External energy sources are required for development and operations.

Types of Environmental Impacts: The potential environmental impacts may include land use changes for storage of feedstock and baseyarding of vehicles, soil erosion and air quality degradation during harvesting, and the socio-economic and cultural impacts.

7.3 Conversion

Types of Actions and Activities: Conversion involves the processing of feedstocks into biofuels. It represents a wide range of processes for production of biodiesel, ethanol, or other biofuels. Generally, conversion is the more industrial phase of the value chain and requires the greatest input of external energy sources. Water and chemicals also are required in this phase for processing of feedstocks to biofuels.

Types of Environmental Impacts: Since the conversion process phase is the most industrial, many of the potential environmental impacts are related to waste management and pollution. Air quality degradation is a potential impact from the processing of biofuels. There may be socio-economic and cultural impacts to local communities from the development of industrial facilities in some areas. While some jobs and economic activity will be created, there may be conflict over development and operations of these facilities.

7.4 Distribution

Types of Actions and Activities: The Distribution phase of the value chain includes the transportation of finished biofuels to end users. This phase will involve development and use of some transportation infrastructure including ports, pipelines, tanker trucks, and storage facilities. Land and external energy resources will be required for the development and operation of this infrastructure.

Types of Environmental Impacts: The potential environmental impacts from the Distribution phase will be similar to other transportation actions and activities. There may be construction of improved port facilities, pipelines, baseyards, and storage facilities to accommodate the movement and storage of biofuels. Employment opportunities will be created. There may be some additional socio-economic and cultural impacts from the development of new facilities in ports and on other lands. This may result in some conflicts over land use.

7.5 End Use

Types of Actions and Activities: The End Use phase of the value chain involves the use of biofuels for transportation uses and electrical energy generation.

Types of Environmental Impacts: The environmental impacts of the End Use phase include the reduction in use of fossil fuels and greenhouse emissions through the use of biofuels.

8. Recommendations

As various authors have found (Zah *et al*., 2008, Scharlemann and Laurance, 2008, Hill *et al*., 2009), not all biofuels are beneficial when the full extent of their environmental impacts are assessed. There is a clear need to evaluate the costs and benefits of reducing the use of imported fossil fuels and greenhouse gas emissions, as well as the other environmental aspects of the process. The environmental, social, and cultural impacts of bioenergy development need to be evaluated at the local level in Hawaii as aspects of the value chain are defined for proposed projects and technologies. Particular attention should be focused on the feedstock portion of the value chain since most of the potential environmental and social impacts from bioenergy development occur during this phase. In particular, the potential risks to Hawaii from invasive species are critical. It should be noted that many of the potential environmental impacts from bioenergy are the same as those of traditional agriculture. The State of Hawaii needs to be selective in the crops and technologies that may be supported with subsidies and tax benefits, keeping in mind that second generation biofuels, including cellulosic ethanol and algae, show great potential to reduce many of the adverse environmental impacts.

The potential impacts to agricultural land use practices from biofuels development also need to be examined further. Introduction of biofuels subsidies and incentives will increase competition for use of prime agricultural lands between biofuels proponents, small farmers, ranchers, and non-agricultural developers. The State needs to examine the balance between food security, fuel security, and development in Hawaii and reassert its priorities for prime agricultural lands.

The socio-economic and cultural impacts from bioenergy also need to be evaluated along with the biophysical. The potential impacts to local communities should be evaluated using a community-based approach where a long-term dialogue is initiated with local communities and stakeholders to help define potential impacts and mitigation measures for affected areas.

Through a rigorous environmental assessment and life-cycle analysis process, and the establishment of sound policies and incentives, a more sustainable bioenergy industry may be developed. The State of Hawaii should evaluate all the potential environmental issues, including net energy and greenhouse gas balances, potential shifts in agricultural uses, air quality impacts, water use issues, risks from invasive species, and possible social and cultural impacts, prior to commencing with bioenergy development in the Hawaii. The following are specific recommendations for evaluating and mitigating potential environmental impacts from bioenergy development in Hawaii.

1. <u>Environmental Impact Assessment</u> – As specific proposals are put forward for development of aspects of the bioenergy value chain, environmental assessments or environmental impact statements should be completed pursuant to the State of Hawaii environmental review law (Chapter 343, HRS) and the Department of Health Title 11-200 administrative rules governing the review process. It should be noted that not all bioenergy projects may trigger Chapter 343, HRS due to their proposed locations, land ownership, and/or funding.

   Environmental assessments and impact statements should include evaluations of the potential social, economic, and cultural impacts associated with the proposed projects, as required in the Title 11-200 administrative rules for the environmental review process. Assessments should strive to include analysis of how specific proposed projects for bioenergy development in Hawaii will effect and be affected by international market conditions. This analysis will give transparency to the potential indirect and direct environmental impacts of biofuels development in Hawaii.

2. <u>Life-Cycle Analysis (LCA)</u> – Life-Cycle Analysis (LCA) is the cradle to grave systems approach for examining technology and systems. LCA should be used to examine the specific technical aspects of any proposed biofuels value chain, the crops, energy requirements, emissions, direct and indirect land use changes, water

use requirements, wastes, logistics, conversion technology, distribution, and end use to determine the net energy and greenhouse gas balances of the biofuel. This process is being used nationally and internationally to evaluate bioenergy development and could be employed for analysis of local conditions and permitting.

The State should establish requirements for LCA based on Hawaii's specific environmental conditions, goals and needs. The State also should establish guidelines for conducting LCA including certification of LCA methodologies. LCA should be used as an integral component in a biofuels certification process.

3. Conservation Agriculture – Since most environmental impacts from bioenergy development are found in the feedstock production phase, the State should require appropriate conservation agriculture practices for biofuels feedstock production. This would help reduce water consumption, use of pesticides and fertilizers, and pollution.

4. Weed Risk Assessment (WRA) – Weed Risk Assessment (WRA) should be required for all candidate crops for biofuel production. Since Hawaii has sensitive natural resources that are susceptible to invasive species, the State should establish criteria for restricting certain candidate crops that may have the greatest potential for harm. It may also want to limit introduction of certain crops from areas near sensitive habitats depending on the individual characteristics of the candidate crop.

5. Examine the Issue of Agricultural Land Use and Biofuels – The State should commission a study to examine the potential issues related to agricultural land use and biofuels. The potential impacts to local agriculture from an introduction of large-scale biofuel development may be significant. Of particular importance is the potential loss of local food-crop production as prime agricultural lands are shifted to biofuels and other non-agricultural uses.

   The study should examine how existing agricultural practices and uses of land, including small farming and ranching, may be impacted by the introduction of incentives and subsidies for biofuels. This should include an analysis of food security and fuel security issues in Hawaii. The study should also examine how the conversion of prime agricultural lands to non-agricultural uses may affect biofuels development and long-term viability.

6. Encourage Use of Existing Infrastructure – To minimize the potential environmental impacts from the development of new infrastructure needed to support bioenergy, the State should encourage the use of existing conversion facilities, pipelines, and other infrastructure where applicable.

7. Community-Based Bioenergy Working Group – Many stakeholders expressed concern about the lack of information regarding environmental issues and the

State's plan for bioenergy development. Many requested a forum to exchange information. The State should establish a community-based working group with representatives from various stakeholders including, but not limited to, representatives from State of Hawaii Departments of Agriculture; Business, Economic Development and Tourism; Land and Natural Resources; Attorney General; bioenergy entrepreneurs; large landowners; small farmers; environmentalists; Native Hawaiian groups; the power industry; etc.

This forum would be useful for creating community dialogue and understanding about bioenergy development and environmental issues in Hawaii. It could also be used as a tool for gathering information for social and cultural impact assessment.

8. Biofuel Certification Program – To safeguard Hawaii's unique native eco-systems and culture, and support sustainable biofuels development, the State should explore the possible development of a certification program for biofuels. Many localities are proposing that biofuels meet certain mandated targets or minimum goals to receive subsidies, permits, and government recognition. A certification program in Hawaii should include various sustainability requirements related to attaining specific net energy and greenhouse gas balance goals, ensuring protection against invasive species, establishing water, soil, and land conservation, protection of local food supplies and farming, protection against transnational environmental issues and indirect impacts to land use, and other social and cultural issues.

   It should be noted that certification programs are difficult to employ and may, if too unwieldy or burdensome, constrain the development of the local biofuel industry in Hawaii. If employed, certification should be targeted at specific local problems and tailored to meet specific sustainability goals established by the Legislature.

   Due to the complexity of the issues, the State should commission a separate study to examine biofuels certification for Hawaii. The study should include analysis and recommendations for sustainability requirements, implementation and timing guidelines, requirements for LCA and methodologies, and the specification of departmental permitting responsibilities. A central component of the study also should be the analysis of the various certifying methods including government run certification programs, preliminary certification for "First-Movers", voluntary certification, and third-party certification. Optimally, certification of any sort should not add to the duration of the overall permitting process. Efforts should be made to coordinate existing permitting and disclosure processes and reduce or eliminate redundancies.

   Optimally, a certification program should be established prior to the development of new subsidies for biofuels in Hawaii. However, due to the State's desire to encourage rapid development of bioenergy there may need to be some discussion about creating initial screening processes and preliminary certification to help first movers with “shovel-ready” projects or demonstration projects. If a “First-Movers Program” for preliminary certification was established, any participating programs should be required to complete a full and timely certification and LCA as part of their final permitting/compliance. Strict precautions would need to be taken in a preliminary certification process to safe-guard against invasive species and any other irreversible commitment of resources that may be proposed by a project under a “First-Movers Program”.

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Appendix 1

Summary Notes from Environmental Impacts Session at April 2, 2009
Stakeholder Meeting

Environmental Impacts Breakout Session Notes
Hawaii Bioenergy Master Plan Stakeholder Meeting

Session 1

1. What do you think are the most critical environmental issues related to bioenergy development in Hawaii? *Participants were asked to brainstorm their ideas. The participants then grouped similar ideas. They were asked to identify the 3 most critical issues.*

EIS and Environmental Regulations

- Passage of more stringent legislation relative to environmental issues potentially stalls the process for bioenergy development.
- Our group is interested in business aspects of bioenergy development. How would environmental issues be reconciled with beneficial economic issues? EIS in place to protect interests. It's a paradox.
- EIS can balance out the process
- Are the guidelines clear for EIS?
- There is uncertainty in the time necessary to do all the environmental assessments and it is difficult to make all stakeholders comfortable. It means greater potential investment risk for bioenergy ventures.
- The uncertainty discourages investment.
- issues related to EIS statements

Land Use Priorities

- There is competition between bionergy versus food production. Bioenergy is highly subsidized.
- How can we address the EIS without it becoming an obstacle?
- Is there a concern regarding who gets priority for things like subsidies?
- Priorities over land use – e.g., public lands; property for planting
- This falls under competing land uses specific to public lands
- How do we ensure this is a continuing process?
- Should there be a higher priority for bioenergy? Industry vs. small farmers?
- Land and water use are competing priorities for all lands.

Invasive Species

- The State has a weed risk assessment. It should be part of the evaluation. In a recent study, "Assessing Biofuel Crop Invasiveness," a case study by Christoper Buddenhagan, Charles Chimera, and Patti Clifford, more than half are more likely to become invasive.
- Do you know if the top 5 on the bioenergy list (from handout in packet) are invasive?
- Any review/recommendations go through State assessment.
- Invasive species - Weed Risk Assessment is part of the Environmental Impact process**2. What would be the best way to continue the community discussion on the environmental issues as the Master Plan is developed in the next 6 months? And in the next 2 -3 years should this planning effort continue?** *Participants were asked to brainstorm their ideas. The participants then grouped similar ideas.*

Use Existing Forums

- Use existing technology like the Hawaii Natural Energy website (a web based resource for the community)
- Environmental-focused groups and forums
- Create links to agencies (the Hawaii Invasive Species Council has links) and facilitate access to information

Communication Plan Should include:

- In Hawaii people like community meetings
- Someone needs to organize a communication strategy
- Site link, social chat rooms, and community meetings
- Business Roundtable – you need a strategic communication plan
- Allow for balance in communication; public, clear decision making opportunity
- Centrally organized – names, email, list serve
- Include Q and A, talking points, FAQs
- General public audience
- Complicated issues made easily understood
- Balance is important. It needs to be very organized, but keep it diverse. Everyone wants information. It is human nature to seek an edge.
- Need to rely on the corporate sector to get the message out
- I can't imagine balance in 6 months, but you can distribute good information
- Small farmers need their information in their language. High speed internet is not always accessible for them.
- CTAHR (College of Tropical Agriculture and Human Resources) Cooperative Extension SVC can help bring small farmers in (field workers)
- Write up a draft to react to and gather feedback

Permitting Concerns

- We need to conduct a comprehensive review of the permitting process. Are the lags at the county level or state level?
- Currently, all agencies – how to create more certainty about permitting

- Independent review could give us idea of what's short and long term realities tied to environmental issues

<u>Other</u>

Funding issues?

Session 2

1. **What do you think are the most critical environmental issues related to bioenergy development in Hawaii?** *Participants were asked to brainstorm their ideas. The participants then grouped similar ideas. They then voted to identify which group was the most critical Environmental issue.*

<u>Invasive Species (5 votes)</u>

- Introduction of invasive species
- 2 to 5 biofuels are more likely to be invasive
- We say we are helping solve the invasive species problem, but the reality is many areas are inaccessible and are not an economic option

<u>Water and Land impacts; secondary environmental impacts (5 votes)</u>

- Hawaii uses billions of gallons of gasoline – for every gallon of ethanol, you need 5 – 6 gallons of water
- We have competing land and water use, such as growing crops for food versus fuel
- If chemicals are used it can impact our water quality
- International studies on biofuels report that the high expectations aren't necessarily being met
- There is a good return, but waste products impact the environment
- What about harvesting? What are the negatives? It adds jobs. What is the environmental impact?
- Reef impacts with erosion through intensive agriculture

<u>Regulatory Issues – water (1 vote)</u>

- In the case of micro algae – what happens if regulation on emissions, ground level, permitting, technical sides?

<u>Production of jobs (1 vote)</u>

- Biofuels could provide new jobs

<u>Crop abandonment (0 votes)</u>

- From the landowner perspective, what happens after a crop is planted? What if it doesn't pan out? What's the consequence?
- If biofuels become invasive, then crop abandonment occurs
- Who is responsible for crops that don't stay put?
- Costs are passed on to the community

<u>Environmental Justice (0 votes)</u>

- Environmental justice has to be considered in the location of processing plants

2. **What would be the best way to continue the community discussion on the environmental issues as the Master Plan is developed in the next 6 months? And in the next 2 -3 years should this planning effort continue?** *Participants were asked to brainstorm their ideas. The participants then grouped similar ideas.*

Community Dialog

- Have a community dialog on each island
- Reach out to the average public and communicate how it will impact them
- Actively seek interested people as opposed to "passively" interested – "proactive" outreach
- Have a Hawaii Energy policy forum
- Publicize via a website – increase public awareness (e.g., DBEDT website)

Public Education

- Education – go to schools and educate kids and they will educate their parents
- A landowner can plant whatever s/he wants. They are not regulated. Large landowners and farmers need education and training.
- Put together an educational symposium for public awareness and training.

Hawaii Bioenergy Master Plan

State, County, and Federal
Plans, Policies, Statutes, and Regulations

Richelle Thomson
Denise Antolini

April 2009

This compilation of State, County, and Federal Plans, Policies, Statutes, and Regulations was prepared as part of the Hawaii Bioenergy Master Plan project based on information available as of April 28, 2009.

Hawaii Bioenergy Master Plan

State, County and Federal
Plans, Policies, Statutes, and Regulations

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Hawaii Bioenergy Master Plan

State, County and Federal
Plans, Policies, Statutes, and Regulations

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1.0 STATE OF HAWAII

1.1 State Energy Policy Context

1970s Oil Crisis and Resulting Hawaii Laws:
1974 – Act 235 established the University of Hawaii's Hawaii Natural Energy Institute to develop local natural energy research; HNEI coordinates governmental and private efforts and federal funding and is to serve as the central repository of information on natural energy policies and programs.
1974 – Act 236 established the Natural Energy Laboratory of Hawaii in North Kona, a support facility for electrical energy research programs, including biomass conversion.
1976 – Act 189 established tax incentives for use of alternate energy devises (solar primarily) to increase efficiency[i]

Current Statutes and Programs

HRS § 226-7: Objectives and Policies for the Economy – Agriculture

HRS § 196: Energy Resources
Findings: The global demand for petroleum and its derivatives has caused severe economic hardships throughout the State and threatens to impair the public health, safety and welfare. The State of Hawaii, with its total dependence on imported fossil fuel, is particularly vulnerable to dislocations in the global energy market. This is an anomalous situation, as there are few places in the world so generously endowed with natural energy: geothermal, solar radiation, ocean temperature differential, wind, waves, and currents--all potential non-polluting power sources; there is a real need for strategic comprehensive planning in the effort towards achieving full utilization of Hawaii's energy resource programs and the most effective allocation of energy resources throughout the State. Planning is necessary and desirable in order that the State may recognize and declare the major problems and opportunities in the field of energy resources.

Act 234, Session Laws of Hawaii 2007

Established the State's policy framework and requirements to address Hawaii's greenhouse gas emissions, recognizing the potential adverse effects of the recent climate change and global warming to Hawaii's economy, public health, natural resources, and environment. The general purpose of Act 234 is to establish and cost-effectively achieve State policy of greenhouse gas (GHG) emissions reductions and limits at or below the best estimates and updates of the inventory of Hawaii's greenhouse gas emissions estimates of 1990 emissions levels by January 1, 2020.[ii]

Hawaii Clean Energy Initiative

The state of Hawaii has signed a Memorandum of Understanding (MOU) with the U.S. Department of Energy (DOE) Assistant Secretary for Energy Efficiency and Renewable Energy (EERE) to establish the Hawaii Clean Energy Initiative. DOE and the state pledge to collaborate to produce 70% of the state's energy needs from clean energy sources by 2030. The goals of the partnership include defining the structural transformation required to transition the state to a clean energy-dominated economy; demonstrate and foster innovation in the use of clean energy, including alternative fuels; create opportunities for the widespread distribution of clean energy benefits; establish an open learning model for other states and entities to adopt; and build a workforce with cross-cutting skills to support a clean energy economy in the state. For more information about Hawaii Clean Energy Initiative, see the full text of the MOU.[iii]

The goals of the Hawaii Clean Energy Initiative are:

- Achieve a 70% clean energy economy for Hawaii within a generation
- Increase Hawaii's security
- Capture economic benefits of clean energy for all levels of society
- Foster and demonstrate innovation
- Build the workforce of the future
- Serve as a model for the US and the world[iv]

Honolulu Clean Cities Coalition

The Honolulu Clean Cities Coalition is part of a national network of approximately 90 volunteer coalitions that develop public/private partnerships to promote alternative fuels and advanced vehicles, fuel blends, fuel economy, hybrid vehicles, and idle reduction. Clean Cities strives to advance the nation's economic, environmental, and energy security by supporting local decisions to adopt practices that contribute to the reduction of petroleum consumption.[v]

Hawaii-based public and private companies and organizations participate at whatever level they feel comfortable. For example, agreements between several fleets to use a single alternative-fuel refueling site, instead of installing several alternative-fuel sites, results in savings for everyone.[vi]

Bioenergy Master Plan: Act 253 of 2007, Part III

DBEDT shall develop and prepare a bioenergy master plan in consultation with representatives of the relevant stakeholders. The primary objective of the bioenergy master plan shall develop a Hawaii renewable biofuels program to manage the State's transition to energy self-sufficiency based in part on biofuels for power generation and transportation.[vii] As required by law, DBEDT made its report to the legislature in 2008.[viii]

Act 240
A 2006 law that provided funding to DBEDT to "conduct a statewide multi-fuel biofuels production assessment of potential feedstocks and technologies, the economics of the various renewable fuels pathways, and the potential for ethanol, biodiesel, and renewable hydrogen production to contribute to Hawaii's near-, mid-, and long-term energy needs." The project is under contract with Black & Veatch Corporation, with expected completion mid-2009.[ix]

HRS 226-18: Objectives and policies for facility systems
Planning for the State's facility systems with regard to energy shall be directed toward the achievement of the following objectives, giving due consideration to all:
1) Dependable, efficient, and economical statewide energy systems capable of supporting the needs of the people;
2) Increased energy self-sufficiency where the ratio of indigenous to imported energy use is increased;
3) Greater energy security in the face of threats to Hawaii's energy supplies and systems; and
4) Reduction, avoidance, or sequestration of greenhouse gas emissions from energy supply and use.[x]

HRS § 196-1.5: **Priority permitting process for renewable energy projects**
All agencies shall provide priority handling and processing for all state permits required for renewable energy projects.

HRS 196-41: State support for achieving renewable portfolio standards (RPS)

Section 196-41, which was signed into law in 2004, established the renewable portfolio standards (RPS) within HRS 269.

(a) The department of land and natural resources and department of business, economic development, and tourism shall facilitate the private sector's development of renewable energy projects by supporting the private sector's attainment of the renewable portfolio standards in section 269-92. Both departments shall provide meaningful support in areas relevant to the mission and functions of each department as provided in this section, as well as in other areas the directors of each department may deem appropriate.

(c) The department of business, economic development, and tourism shall:
1) Develop a program to maximize the use of renewable energy and cost-effective conservation measures by state government agencies;
2) Work with federal agencies to develop as much research, development and demonstration funding, and technical assistance as possible to support Hawaii in its efforts to achieve its renewable portfolio standards; and

3) Biennially, beginning in January 2006, issue a progress report to the governor and legislature.

1.2 Alternate and Renewable Energy Standards and Incentives

The objectives in the area of Alternate and Renewable Energy statutes are to promote commercialization of Hawaii's sustainable energy resources and technologies to reduce the state's high dependence on imported oil, increase local economic development, and reduce the potential negative economic impacts of oil price fluctuations. Hawaii's Renewable Portfolio Standards are described in HRS 269-91 through 269-95 "Renewable portfolio standards."[xi]

Activities include providing resource data; technical and economic analyses; support for research, demonstration, development, and application of renewable energy technologies; partnerships and technology transfer; and public outreach.

The State of Hawaii encourages development of renewable sources of energy, including biomass, and offers a number of tax and policy incentives to advance the use of renewable energy. Tax incentives for alternative transportation fuels include a corporate income tax credit for ethanol production, an exemption from the 4% excise tax on retail sales of gasohol (HRS § 237-027), and reduced tax rates for alternative fuels.

The state also provides business investment and research and development incentives for qualified high technology businesses in the area of "nonfossil fuel energy-related technology." Additional benefits are available for qualifying businesses located in Enterprise Zones.[xii]

HRS 196-3: Energy Resources Coordinator

Established the State Energy Resources Coordinator (ERC) role, the State's cabinet-level energy advisor to the Governor, Legislature, and people of Hawaii. The law assigns the role of State ERC to the Director of the Department of Business, Economic Development, and Tourism (DBEDT).[xiii]

HRS 201-12.5: Renewable Energy Facilitator
Established a full-time, temporary renewable energy facilitator position within DBEDT with the following responsibilities:

- Facilitate the efficient permitting of renewable energy projects
- Improve the efficiency of the permitting process in order to implement key renewable energy projects
- Coordinate projects on behalf of DBEDT, including the HRS 201N renewable energy facility siting process[xiv]

HRS 201N: Renewable Energy Facility Siting Process
Chapter 201N authorizes the State Energy Resources Coordinator (HRS Section 196-3) to develop a "permit plan," and on a fee-for-service basis, assists applicants by coordinating permitting processes. The coordinator is also charged with developing administrative rules (based in part on existing rules in Washington and Oregon).[xv]

1.3 Incentives Related to Biomass/Agricultural Production

Energy Feedstock Program, HRS § 141-9
The Energy Feedstock Program was established within the Department of Agriculture to promote and support the production of energy feedstock in Hawaii and establish milestones and objectives for energy feedstock to be grown in the state to meet its energy requirements. Energy feedstock includes feedstock used to produce biofuels.[xvi]

HRS 209E: Enterprise Zone Program
HAR 15-6, authority for designating areas for the purposes of stimulating business and industrial growth. Enterprise Zones are entitled to certain state incentives, including exemptions from General Excise Tax, income tax abatements, and other incentives.

Government Incentives for Tree Planting or Forestry Management on Private Lands[xvii]

Forest Stewardship Program (FSP)

Forest Legacy

Natural Areas Partnership (NAP)

Wetlands Reserve Program

Farm and Ranchland Protection Program

Partners for Fish & Wildlife

Safe Harbor Agreements (SHA)

Watershed Partnership Program

Environmental Quality Incentives Program (EQIP)

Wildlife Habitat Incentives Program (WHIP)

Army Compatible Use Buffers Program

Urban & Community Forestry ~ Kaulunani

HRS 186 Tree Farm Designation

Federal Income Taxes

Property Tax Treatment (Honolulu C&C)

Agricultural Property Tax Reduction (Kauai County)

Agricultural Property Tax Exemption (Kauai County)

Agricultural Tax Rates (Hawaii County)

Native Forest Dedication (Hawaii County)

Property Tax Treatment (Maui County)

A comparison chart of the above-listed federal, state, and county incentives was compiled by: Katie Friday, United States Department of Agriculture, Forest Service (USDA FS); Sheri Mann, Hawaii Dept. Lands & Natural Resources, Division of Forestry and Wildlife (DOFAW); and Steve Smith, Forestry Management Consultants – Hawaii. The authors note:

- Most cost-share programs reimburse landowners for a portion of their costs; payments are limited by (a) percentages or ratio of payment to match, (b) standard rates (caps) for eligible practices, and (c) annual or project total maximums.
- Most programs have guidelines for what can qualify as the "match" for the cost-share; for example, funding from one program usually cannot match funding from another.
- Federal and state cost-share payments must be reported in tax returns and may be taxable.

Business Investment Tax Credit: HRS § 235-7.3 and §235-110.9
Through December 31, 2010, taxpayers making a high technology business investment are eligible for a tax credit the year in which the investment is made and for the proceeding four years. A "qualified high technology business" is one in which more than 50% of the activities are qualified research (75% of which is conducted in Hawaii) and in which more than 75% of the income (i.e. income from products sold from, manufactured, or produced in Hawaii or from

services performed in Hawaii) is derived from qualified research. "Qualified research" includes research that is related to non-fossil fuel energy-related technology. The tax credit is equal to a percentage of the investment made, up to the following maximums:

Year	Tax Credit (percent of investment made)	Maximum Value of Credit
Year of Investment	35%	$700,000
1st Year Following Investment	25%	$500,000
2nd Year Following Investment	20%	$400,000
3rd Year Following Investment	10%	$200,000
4th Year Following Investment	10%	$200,000

If the tax credit exceeds the taxpayer's income tax liability for any of the five years that the credit is taken, the excess of the tax credit may be used as a credit in subsequent years until exhausted. A taxpayer may continue to claim the credits if the five-year period to claim the credits commences in taxable years beginning before January 1, 2010.[xviii]

Ethanol Production Incentive: HRS § 235-110.3
An income tax credit is available for qualifying ethanol production facilities equal to 30% of nameplate capacity between 500,000 and 15 million gallons per year. The facility must produce at least 75% of its nameplate capacity to be eligible to receive the tax credit in that year, and the tax credit may be taken for up to eight years. The credit is only available to the first 40 million gallons of ethanol produced per year. Qualifying ethanol production facilities must be in operation prior to January 1, 2017.[xix]

Alcohol Fuel Tax Exemption, HRS § 237-27.1
Alcohol fuel sold for consumption or use by the purchaser is exempt from state excise tax. For the purpose of this exemption, alcohol fuel is defined as neat biomass-derived alcohol liquid fuel or a mixture of petroleum-derived fuel and alcohol fuel consisting of at least 10% denatured biomass-derived alcohol that is used to fuel a motor vehicle. A producer, wholesaler, or retailer of alcohol fuels must pass any savings from this exemption on to the consumer. This exemption expires June 30, 2009.[xx]

Biofuels Procurement Preference, HRS § 103D-1012
State agency contracts for the purchase of diesel fuel are to be awarded with preference given to bids for biofuels or blends of biofuel and petroleum fuel. When purchasing fuel for use in diesel engines, the preference price is $0.05 per gallon of B100; for blends containing both biodiesel and petroleum-based diesel, the preference is applied only to the biodiesel portion of the blend. Biodiesel is defined as a vegetable oil-based fuel that meets ASTM specification D6751. Biofuel

is defined as fuel from non-petroleum plant or animal based sources that can be used for the generation of heat or power.[xxi]

Alternative Fuel Development Support, HRS § 196-42

The state is responsible for facilitating the development of alternative fuels and supporting the attainment of a statewide alternative fuels standard. The alternative fuels standard will be as follows: 10% of highway fuel use to be provided by alternative fuels by 2010, 15% by 2015, and 20% by 2020. For the purposes of the alternative fuels standard, ethanol produced from cellulosic materials is to be considered the equivalent of 2.5 gallons of non-cellulosic ethanol.[xxii]

Renewable Fuel Standard: HRS § 486J-10 and HAR Title 15, Department of Business, Economic Development and Tourism, Chapter 35

At least 85% of Hawaii's unleaded gasoline must be fuel blends containing at least 10% ethanol (E10). Gasoline blended with an ethanol-based product, such as ethyl tertiary butyl ether, will be considered to be in conformance with this requirement. Retail fuel distributors must meet this requirement and report to the state Petroleum Commissioner (the Administrator of the Energy, Resources, and Technology Division of the Department of Business, Economic Development, and Tourism) on a monthly basis.[xxiii]

Alternative Fuel Tax Rate, Hawaii Revised Statutes Section 243-4

A distributor of any alternative fuel for operation in an internal combustion engine is required to pay a license tax of $0.025 for each gallon of alternative fuel sold or used by the distributor. In addition, a distributor is required to pay a license tax for each gallon of fuel sold or used by the distributor for operating a motor vehicle(s) on state public highways according to the following rates:

Fuel Type	Tax
Ethanol	0.145 times the rate for diesel
Methanol	0.11 times the rate for diesel
Biodiesel	0.25 times the rate for diesel
Liquefied Petroleum Gas	0.33 times the rate for diesel

For other alternative fuels, the rate is based on the energy content of the fuels as compared to diesel fuel, using a lower heating value of 130,000 British thermal units per gallon as a standard for diesel, so that the tax rate, on an energy content basis, is equal to one-quarter the rate for diesel fuel.[xxiv]

Current Issues within the Policy/Regulatory Framework

- Utilities compensated for increased electricity sales; pass-through of fuel price increase is renewable disincentive
- IPPs need transparent "rules of the road," certainty and predictability
- No clear policy support or incentives for significant new investment and technology upgrades in renewable generation, advanced transmission and distribution
- Need policy on net metering, interconnection, wheeling, and utility protocols for integrating variable generation which will impact transmission and distribution systems[xxv]

1.4 Environmental Laws Relating to Land Use

Hawaii Environmental Policy Act (HEPA)
The state version of the National Environmental Policy Act, HEPA, is a system of environmental review that ensures environmental concerns are given appropriate consideration in decision making along with economic and technical considerations. HRS § 343-1. HEPA will potentially apply whenever an agency or applicant initiates an action that requires a discretionary consent or approval. HRS § 343-2. An applicant must comply with HEPA if its proposed action is one of the triggers enumerated under HRS §343-5. A common trigger is the proposed "use of state or county lands."[xxvi]

If a state or county agency determines that an action "triggers" HRS § 343 and HAR § 11-200, EIS law and rules (being zoned in the Conservation District is a trigger in itself), it must then decide whether the action is:

1. Exempt from preparing an EA or EIS. Contact the State Office of Environmental Quality Control if a proposed land use will have minimal or no significant effect on the environment and might be declared exempt.[xxvii] Exemptions mean that a project will have minimal or no significant impact, and exemptions are listed under HAR § 11-200-8:
    a. Operation, repairs, or maintenance of existing facilities or topographical features.
    b. Replacement or reconstruction of existing structures and facilities.
    c. Construction and location of single, new, small facilities or structures.
    d. Minor alterations in the conditions of land, water, or vegetation.
    e. Basic data collection, research, and experimental management.
    f. Construction or placement of minor structures accessory to existing facilities.
    g. Interior alterations.
    h. Demolition of structures except historic structures.
    i. Zoning variances except shoreline setback variances.
    j. Continuing administrative activities such as purchasing supplies.
    k. There are exclusions from these exemptions for actions in particularly sensitive environments or in areas where a cumulative impact necessitates an EA or EIS. Particularly sensitive areas include floodplains, wetlands, beaches and coastal areas, erosion-prone areas, geologically hazardous land, habitat, and estuaries.[xxviii]
2. Requires an Environmental Assessment (EA)

3. Requires a full EIS

Resources for Environmental Compliance

Hawaii Office of Environmental Quality Control implements HRS § 343 (Environmental Impact Statements) by reviewing hundreds of environmental disclosure documents each year. OEQC's Environmental Assessment Preparation Toolkit[xxix] is an invaluable resource in understanding the EA process.

HRS § 343: Environmental Impact Statements under the purview of the State Department of Health[xxx] – Environmental Assessment (EA) or Environmental Impact Statement (EIS)
HAR § 11-200: Environmental Impact Statement Rules[xxxi]; exemptions from rule found at HAR § 11-200-8
Environmental Law Program, University of Hawaii, William S. Richardson School of Law, OHELO: database of law and policy relating to environmental issues[xxxii]

The official statutes may be reviewed at the Hawaii State Libraries and the Legislative Reference Bureau Library, or accessed at **http://www.capitol.hawaii.gov/hrscurrent/**

Unofficial H.R.S. Chapter 205 Land Use Commission

Unofficial Hawaii Revised Statutes, Chapter §26-35, Administrative Supervision of Boards and Commissions

Unofficial Hawaii Revised Statutes, Chapter 91, Administrative Procedure

Unofficial Hawaii Revised Statutes, Chapter 92, Public Agency Meetings and Records

Unofficial Hawaii Revised Statutes, Chapter 183C, Conservation District

Unofficial Hawaii Revised Statutes, Chapter 343, Environmental Impact Statements

Unofficial Hawaii Administrative Rules, Chapter 15-15, Land Use Commission Rules
Unofficial Hawaii Administrative Rules, Chapter 11-200, Department of Health
Unofficial Hawaii Administrative Rules, Chapter 13-5, Department of Land and Natural Resources

1.5 Other Hawaii Laws Related to Bioenergy Production

HRS 342B – Clean Air and Air Pollution Control[xxxiii]

See also, Air Quality State Implementation Plan[xxxiv]
HRS § 128D – Environmental Response Law[xxxv]

HRS §§ 141-168 – Farming
HRS § 195D – Endangered Species Act, Conservation of Aquatic Life, Wildlife, and Land Plants[xxxvi]
HRS §§ 342J, 128D, 128E – Hazardous Waste, Oil, Toxic Substances
HRS § 149A – Pesticides
HRS § 150A – Importing Plants, Animals, and Microorganisms[xxxvii].
HRS § 194 – Invasive Species Council. There is established the invasive species council for the special purpose of providing policy level direction, coordination, and planning among state departments, federal agencies, and international and local initiatives for the control and eradication of harmful invasive species infestations throughout the State and for preventing the introduction of other invasive species that may be potentially harmful.[xxxviii]
HRS § 520A – Landowners liable to control invasive species[xxxix]
HRS § 152 – Noxious weed control[xl]
HRS § 195 – Natural Area Reserve Systems. The legislature finds and declares that (1) the State of Hawaii possesses unique natural resources, such as geological and volcanological features and distinctive marine and terrestrial plants and animals, many of which occur nowhere else in the world, that are highly vulnerable to loss by the growth of population and technology; (2) these unique natural assets should be protected and preserved, both for the enjoyment of future generations, and to provide base lines against which changes which are being made in the environments of Hawaii can be measured; (3) in order to accomplish these purposes the present system of preserves, sanctuaries and refuges must be strengthened, and additional areas of land and shoreline suitable for preservation should be set aside and administered solely and specifically for the aforesaid purposes; and (4) that a statewide natural area reserves system should be established to preserve in perpetuity specific land and water areas which support communities, as relatively unmodified as possible, of the natural flora and fauna, as well as geological sites, of Hawaii. [xli]
HRS § 186 – Tree Farms. Included within the Agricultural District under HRS 205-2 or within the Conservation District and zoned for commercial forest use.
HRS § 58 – Exceptional Trees: It is the policy of the State to safeguard exceptional trees from destruction due to improper land development, and the legislature finds that enactment of protective regulations by the counties to accomplish this is a valid and important public purpose.[xlii]

1.6 Land Use Laws, Regulations, and Permitting

Hawaii Constitution[xliii]
Hawaii Revised Statutes (HRS)[xliv]
Hawaii Administrative Rules (HAR)[xlv]

Overview of Hawaii's Land Use Regulatory System
See, a report prepared by the Hawaii County Planning Director in 2006.[xlvi]

Bioenergy Crops: Where Can They Be Grown?

- Land zoned for agriculture (1,928,034 acres)

- HRS § 205-2, 205-4.5, 205.4.6: uses and restrictions on use on agricultural zoned land. Permitted uses include growing of crops for bioenergy and biofuel processing facilities.
- Land owned by the State of Hawaii (430,000 acres)
- Land owned by large land owners
- Important Agricultural Lands (IAL) (977,043 acres)[xlvii]
    - HRS § 205-41, et seq. govern the more restrictive uses allowed on IAL. See also Article XI, Section 3 of the Hawaii Constitution, which provides as follows: The State shall conserve and protect agricultural lands, promote diversified agriculture, increase agricultural self-sufficiency and assure the availability of agriculturally suitable lands. Pursuant to HRS § 205-47, each county must develop maps of potential lands.
    - HRS § 205-44: Reclassification of IAL must meet strict criteria.
    - HRS § 205-46: Incentives for important Ag lands: grants, tax incentives, and other benefits.
    - Article XI, Sec 3. (1978) - Constitutional Mandate for IAL: The State shall conserve and protect agricultural lands, promote diversified agriculture, increase agricultural self-sufficiency and assure the availability of agriculturally suitable lands. The legislature shall provide standards and criteria to accomplish the foregoing. Lands identified by the State as important agricultural lands needed to fulfill the purposes above shall not be reclassified by the State or rezoned by its political subdivisions without meeting the standards and criteria established by the legislature and approved by a two-thirds vote of the body responsible for the reclassification or rezoning action.
    - Act 183 (2005) – Fact sheet on IAL
    - SB 2646 (2008) - Incentives which trigger IAL process
    - March 9, 2009: The Land Use Commission granted the first IAL designation to Alexander & Baldwin, concerning 3,773.1 acres of land on Kauai.

Acreage Available for Biofuel Production[xlviii]

Max potential estimated acres available for biofuels crop production (exclusive of non-sugar Ag land). Total: 139,400 acres:

- Maui County: 53,400
- Kauai: 43,300
- Oahu: 19,500
- Hawaii: 23,200

Renewable Energy Permitting (Biomass, Geothermal, Wave, Wind, Solar)[xlix]

	Environmental Review	Environmental Impact	Construction/Op	Land Use/Zoning	Total
Federal	3	15	3	2	23
State	2	19	16	17	54
County	1	3	10	18	32
Total	6	37	29	37	109

Possible Permits Required for Biomass Burning[l]

Federal	14
State	43
County	31
Total	88

Who's Involved in Permitting?

- 25 Federal, State, and County Agencies
  - Agencies with the most impact: State Department of Health, DLNR, Office of Planning; U.S. EPA; County planning offices
- Energy projects are also dependent on the Public Utilities Commission (PUC)
  - Power Purchase Agreements (PPA)
  - Transmission[li]

1.7 State Land Use Districts

Hawaii State Planning Act, HRS § 226

No amendment to any land use district boundary nor any other action by the land use commission shall be adopted unless such amendment or other action conforms to the Hawaii state plan. HRS § 205-16.

Land Use Districts

- HRS § 205 defines state law and outlines areas subject to county-level regulation.
- Each county has a different set of ordinances HRS § 46.1.5(13) grants authority to the counties to enact ordinances.

Land Use District boundaries were originally set by the State Land Use Commission (HRS § 205-2, HAR § 15-5). Each zone has a list of uses that are permitted by statute. There are four land use zones:

1. Conservation
2. Agricultural
3. Rural
4. Urban

Conservation District
Under exclusive State control (except for land in the Special Management Area, which is under dual state and county control; discussed below). The Board of Land and Natural Resources administers the district, and resources and uses are subject to rules promulgated by the Department of Land and Natural Resources.[lii]

DLNR's Office of Conservation and Coastal Lands oversees the approximately 2 million acres of private and public lands that lie within the State Land Use Conservation District.[liii]

Conservation Subzones, from most strict to least restrictive (in terms of permitted uses):
1. Protective
2. Limited
3. Resource
4. General
5. Special: for unique projects

Conservation District land is primarily forest and water reserve areas, necessary to protect watersheds and water resources, scenic and historic areas, parks, wilderness, open space, recreational areas, habitat, and all submerged lands seaward of the shoreline. The Conservation District includes lands that are subject to flooding and erosion.[liv]

Permitted uses: very restricted, under HRS § 183C[lv] and HAR § 13 (DLNR).

Most uses require a Conservation District Use Permit (CDUP), which is issued by the Board of Land and Natural Resources. CDUPs are issued at the discretion of either the Chair or the Board of Land and Natural Resources (BLNR). A CDUP application, along with the DLNR's Office of Conservation and Coastal Lands staff's recommendation on the application, will be presented to the chair or the Board within 180 days of the CDUP's acceptance for processing.[lvi]

Land uses in the Conservation District trigger HRS § 343, and require an Environmental Assessment (EA) or Environmental Impact Statement (EIS) unless they are declared "exempt." Contact the State Office of Environmental Quality Control if a proposed land use will have minimal or no significant effect on the environment and might be declared exempt.[lvii] See below for further information on environmental laws relating to land use.

Agricultural
LUC subdivides Ag zoned land into categories from most productive land to lowest: A and B, to C, D, E, and U.[lviii] Uses in A and B categories are governed by HRS § 205-4.5.[lix] Counties administer Ag zoned land within the state land use law and LUC rules.

Permissible uses on Ag land in the A and B categories include: cultivating crops, aquaculture, livestock, wind energy, timber, agriculture-support activities (mills, employee housing). Permissible uses are further described in HRS 205-4.5 (agricultural processing and biofuels processing are specifically listed). See also HAR § 15-15-25.

Permissible agricultural uses in the C, D, E, and U categories include all uses permissible on A and B lands, plus those uses listed in HRS § 205-2d

Agricultural Lands of Importance (ALISH)
The State Department of Agriculture developed a rating system for agricultural land based on analyses of soil productivity, water retention, erosion, chemical make-up, and other factors affecting root growth. The department classifies agricultural land in the following subcategories:

1. Prime: the best possibilities for agricultural production
2. Unique: land suited for special needs and high-value crops such as watercress, coffee, and taro
3. Other: not prime, but important due to factors such as proximity to water or location.[lx]

Biofuels Production Land Use Allowance: Senate Bill 2849, 2008. Became Act 145, signed into law on June 5, 2008
In order to reduce dependence on petroleum, achieve environmental sustainability, and create jobs, the state of Hawaii permits the use of lands originally zoned as agricultural land use districts to be used for renewable energy production, storage, and distribution, including the production of biofuels. Biofuels production facilities must be integrated with an agricultural activity and may not adversely impact agricultural land and other agricultural uses in the vicinity. Biofuels production facilities include facilities that produce liquid or gaseous fuels from organic sources such as biomass crops, agricultural residues, food wastes, and oil crops including palm, canola, soybean, and waste cooking oils.[lxi]

Special Use Permits (SUP), authorized by HRS § 205-6, are obtained from the counties' Planning Commissions, allow "certain unusual and reasonable" uses in the agricultural and rural districts; these uses must comply with the Hawaii Land Use Law and meet the LUC guidelines. Permit applications are submitted to the county planning commission. For projects of 15 acres or more, the SUP must be approved by both the County Planning Commission and the State LUC (by a 5-4 vote).[lxii]

HAR § 15-15-95(b) provides guidelines as to what is an "unusual and reasonable" use of agricultural land. Zoning References and links to county specific permitting information for SUPs are available online.[lxiii]

Rural
Small farms and low-density residential uses, with a minimum ½-acre lot size. Jurisdiction is shared by the counties and the State LUC. Variances obtained by way of Special Use Permit process.[lxiv] County jurisdiction, although State LUC acts on Special Use Permits for projects of 15 acres or more within this district.[lxv]

Urban
Primarily county jurisdiction, although State LUC acts on Special Use Permits.[lxvi]

Coastal Zone Management Area and Special Management Area
The coastal area receives additional scrutiny in permitting land uses, primarily through Special Management Area (SMA permit)[lxvii] (HAR § 15-1-150). SMA maps are enacted by the counties' planning commissions. The SMA is an area from the shoreline inland to the "SMA line," which can be inland by one mile or more.

Land near the coast also is subject to the provisions of the Coastal Zone Management statute, HRS 205A[lxviii]. The "Coastal Zone Management Area" (CZMA) includes all lands of the State and an area extending seaward from the shoreline to the limit of the State's jurisdictional boundary (3 nautical miles from shore). The State Office of Planning is the lead agency. Other important agencies include the Hawaii State Coastal Zone Management Program and NOAA-Office of Ocean &Coastal Resource Management.

Also pursuant to HRS § 205A, the Special Management Area (SMA) is an area banding the islands near the shoreline. The boundaries are set by the counties by way of ordinance, and the administrative authority rests with the counties' planning commissions, with permitting authority primarily resting with the counties' planning departments (or the Department of Land Use of the City and County of Honolulu).

Uses within the SMA require an SMA permit, and if located within the Conservation zone, will require a Conservation District Use Permit (CDUP) (see section on Conservation Zoned land, above). Projects in the SMA can also need approval from the Hawaii Community Development Authority[lxix] if they are located within the "Community Development Districts" (designations of urban areas for revitalization, primarily the Kaka'ako area on Oahu) and the Hawaii Historic Preservation Division if historical sites may be located within the project area, pursuant to HRS § 6E. SMA use approvals require compliance with HRS § 343-5(3), and will require an Environmental Assessment or Environmental Impact Statement unless exempt.

Projects in the SMA that will require an SMA permit include the following "development": grading, change in intensity of water use, and construction of any structure. "Development" does not include "use of land for the purpose of cultivating, planting, growing, and harvesting plants, crops, trees, and other agricultural, horticultural, or forestry products or animal husbandry, or aquaculture or mariculture of plants or animals, or other agricultural purposes."[lxx]

Historic Sites
State Historic Preservation Division Review of Permits: HRS § 6E-42 requires that the DLNR-SHPD be given notice from a permitting agency when the agency has reason to believe that a

project “may affect historic property.” Grading and grubbing projects that disturb 1 acre or more of land require grading or grubbing permits, and those permits are subject to review when required by HRS § 6E-42. While the review appears “noticelike” in statute (an applicant is required to submit notice to SHPD, and if SHPD does not act within 30 days, the requirement is met). However, in practice permitting departments have held permits pending SHPD review, and the backlog at SHPD has caused significant delays in permitting.

Land Use Boundary Amendments

- Initiated primarily by petition from landowners, developers, the state, or county to change land from one zoning classification to another
- 15 acres or less: By way of ordinance passed by the County Council
- 15 acres or more: Land Use Commission also must approve by a 6-3 vote
- Conservation land: Only the LUC can take land out of the Conservation District (regardless of the size of the parcel). On petitions to reclassify Conservation land, requirements of the EIS law (HRS § 343) must be met.[lxxi]
- Land Use Commission Process Flow Chart for Boundary Amendments: Regular (1-Year) Petition Process
- Decision-making criteria include the counties’ General Plans and the State Coastal Zone Management Law (HRS § 205A)[lxxii]

Land Use Boards and Commissions

Land Use Commission[lxxiii] (LUC). Nine-members appointed by the governor. In 1961, the Hawaii State Legislature determined that a lack of adequate controls had caused the development of Hawaii’s limited and valuable land for short-term gain for the few while resulting in long-term loss to the income and growth potential of our State’s economy. Development of scattered subdivisions, creating problems of expensive yet reduced public services, and the conversion of prime agricultural land to residential use, were key reasons for establishing the state-wide zoning system. To administer this state-wide zoning law, the Legislature established the Land Use Commission.[lxxiv]

Board of Land and Natural Resources[lxxv]

The Board of Land and Natural Resources (BLNR), is composed of seven members, one from land district and two at large, and the Chairperson, the executive head of the Department. Members are nominated and, with the consent of the Senate, appointed by the Governor for a 4-year term. No more than three members of the board may be from the same political party. Any member having any interest, direct or indirect, in any matter before the board must disqualify him/herself from voting on or participating in the discussion of the matter. The BLNR convenes twice monthly to review and take action on department submittals, including land leases and Conservation District Use Applications (CDUAs). Proposed land uses within the Conservation District must be reviewed by BLNR, pursuant to Title 13, Chapter 5 of the Hawaii Administrative Rules. See, HRS § 171-4. Land uses may require Site Plan Approval, HAR § 13-5-38 or Subzone Boundary Determination, § 13-5-17.

DLNR Land Division

HAR § 183-185, 190, 219-223

The Land Division is responsible for managing State-owned lands in ways that will promote the social, environmental and economic well-being of Hawaii's people and for ensuring that these lands are used in accordance with the goals, policies and plans of the State. Lands that are not set aside for use by other government agencies come within the direct purview of the division. These lands are made available to the public through fee sales, leases, licenses, grants of easement, rights-of-entry, month-to-month tenancies or kept as open space area.[lxxvi]
2 million acres of land zoned Conservation
1.2 million acres of state-owned land[lxxvii]

1.8 Water: Laws and Regulations

The Hawaii Constitution provides that the State has an obligation to protect, control, and regulate the waters of the state. There are 23,000 acres of inland surface water, 3 million acres of state ocean water, and 410,000 acres of coral reef around the Main Hawaiian Islands.

Marine Waters
DLNR's Office of Conservation and Coastal Lands oversees beach and marine lands out to the seaward extent of the State's jurisdiction (3 nautical miles from shore).[lxxviii] HRS § 183C (governing lands located within the Conservation District) and marine activities within State marine waters typically require a Conservation District Use Permit (CDUP). Uses that require a CDUP include mariculture and other energy or water, research, scientific, and educational activities in, on, or under state marine waters or submerged lands. Mariculture includes the production for research, development, and demonstration purposes of plants and animals within the State's marine environment.[lxxix]

HRS § 190D-21[lxxx] details the leasing of state waters and submerged lands for private uses that have been approved via the requirements of a marine-related CDUP. As with land-based permits, CDUPs require compliance with HRS § 343 (Environmental Impact Statement law, see section in Land Use above) and HAR § 11-200 and compliance with the applicable county Special Management Area (SMA) regulations.[lxxxi]

Ground and Surface Water
Hawaii's Commission on Water Resource Management has jurisdiction over ground and surface waters, including any and all water on or beneath the surface of the ground, including natural or artificial watercourses, lakes, ponds, or diffused surface water and water percolating, standing, or flowing beneath the surface of the ground. State Water Code, HRS § 174C of the Hawaii Revised Statutes; Hawaii Administrative Rules §§ 13-167 to 13-171

The State Water Code, Chapter 174C, Hawaii Revised Statutes, authorizes the Commission to designate water management areas for surface water use regulation where the Commission, after research and investigations, and consultation with the appropriate county mayor, county council, and county water agency, and after public hearing and published notice, finds that serious disputes respecting the use of surface water resources are occurring.

National Pollutant Discharge Elimination System (NPDES) Permits
Since 1974, the U.S. Environmental Protection Agency delegated permitting authority for NPDES permits to the State of Hawaii, Department of Health, Clean Water Branch. NPDES permitting requirements apply to both "point source" (generally, pipes or manmade ditches) or "non-point sources," such as stormwater runoff.

NPDES State Statutes and Rules
Nonpoint Source Pollution Management and Control, HRS § 342E
Water Pollution, HRS 342D
Water Pollution Control, HAR 11-55
Water Quality Standards, Chapter 11-54, Water Quality Standards
"What's New in the NPDES," Dept. of Health, Clean Water Branch presentation

NPDES Stormwater: Polluted Runoff Control Program[lxxxii]

Nonpoint Source Pollution caused by rainfall moving over and through the ground, carrying pollutants that are eventually deposited into streams, wetlands, coastal waters, and aquifers.
Hawaii 2006 Water Quality Monitoring and Assessment Report
Hawaii's Coastal Nonpoint Pollution Control Management Plan - June 1996
Hawaii's Implementation Plan for Polluted Runoff Control - July 2000
Hawaii's Local Action Strategy to Address Land-Based Pollution Threats to Coral Reefs - March 22, 2004

Two types of NPDES Permits: General and Individual
General Permit: HAR § 11-55 covers 11 types of General Permits for projects of a "similar nature of discharge," minor and non-controversial, discharge enters Class 2 (inland water) or Class A (marine water). Process begins with filing a "Notice of Intent" and the permit is good for 5 years.

General Permits apply to: construction projects (disturbing 1 acre or more, cumulative scope of project considered), operation of industrial facilities, discharge of stormwater and certain non-storm water into municipal sewer systems, and other. A "Notice of Intent" must include the classification of the "receiving state waters," which is available at the Water Quality Standards Maps used in conjunction with HAR, Chapter 11-54, Water Quality Standards or by contacting the Clean Water Branch. Currently, the DLNR State Historic Preservation Division must be notified; however, a proposal to delete that required notice is currently being considered.

Apply for NPDES General Permit coverage with the Notice of Intent (NOI) forms and guidelines.[lxxxiii] Standard General Permit Conditions for NPDES General Permits

Individual Permit: Discharge does not qualify for a general permit. Discharge initially enters Class 1 (inland water) or Class AA (marine water), custom (site specific), takes 6 months or more to process, and good for 5 years. Process begins with submitting an NPDES Application.
Standard NPDES Permit Conditions for NPDES Individual Permits

Compliance: Stormwater Pollution Prevention Plans for Construction Activities
Developing Your Stormwater Pollution Prevention Plan: A Guide for Construction Sites

[SWPPP Templates](#)
[Sample Inspection Form](#)
[Example SWPPPs](#)
[Key Resources](#)
[Selected State BMP/Guidance Manuals](#)

Issues with Water-Based Biofuels Production and Conversion to Energy

- Many newer biofuels production technologies are water-intensive
- Transition to biofuels requires significantly more water than fossil fuels
- Power plants require cooling, scrubbing, and CO2 removal (indicating siting issues)
- Biorefineries impact water supply
- Biofuels production (on land and in water) compete with other water uses[lxxxiv]

Water Availability and Limitations on Use of Water for Biofuels Production
Is the land located within a State Water Management Areas or a Non-Designated Water Management Areas? Water Use Permits are issued for “Reasonable-Beneficial” use, and must include an analysis of alternatives[lxxxv]

The CWRM, Stream Protection and Management Branch, issues permits for new and existing uses of surface and ground water.[lxxxvi] Surface Water Management Areas are special areas designated by CWRM requiring users of surface water sources (such as streams, diversions, and ditches) to obtain surface water use permits to withdraw and use water for various purposes. Individual surface water management areas coincide with individual hydrologic units (watersheds).

Users of ground water (aquifer, wells) in a Ground Water Management Area require a Ground Water Use Permit, issued by the commission. Both surface and ground water users are required to file monthly and annual water use reports. Existing permits may be transferred to new users upon application. The State Office of Environmental Quality Control has published guidelines for water well development projects[lxxxvii] that assist applicants for permits with the environmental review process.

Permit applications must address environmental considerations (requiring an EA under HRS § 343) and include: A discussion of how waters will be used, and an analysis of how the proposed water use may affect land and water uses on the island and in the region. The analysis should include a discussion of the following:

- Hawaii State Water Plan and its component parts
- County General, Development, and/or Community Plans
- Plans for future water development within the aquifer
- Any related water, wastewater, drainage or erosion control plans
- Historical water supply and demand figures for the region
- How the water use may affect existing water sources
- Any secondary or cumulative impacts caused by promoting land uses that alter the hydrology of the source and/or end-use area
- An assessment of the proposed water use's impact on the land owners, water users including farmers and kuleana residents in the region and a declaration if ceded lands are involved. [lxxxviii]

Sources of Information for Water Use
Hydrologic information may be obtained from the Commission on Water Resource Management[lxxxix]:

- location of existing wells;
- CWRM aquifer boundary;
- information on nearby streams;
- sustainable yield for aquifer;
- authorized water use by CWRM (for water management areas only);
- current water use within aquifer;
- current installed capacity within aquifer;
- pending installed capacity and water use within aquifer;
- Hawaii State Water Plan and its component parts;
- water levels of nearby wells; and
- salinity levels of nearby wells.

Contamination information may be obtained from the Department of Health[xc]. Department of Health Rules are governed by HAR § 11. The DOH Environmental Health Administration assists the public with complying with environmental regulations.

Information available from the DOH Environmental Division branches[xci] includes: Safe Drinking Water Branch

- results of water quality tests of nearby wells;
- records of contamination problems in the aquifer; and
- locations of drywells and injection wells.

Wastewater Branch: locations of individual wastewater systems.

Solid and Hazardous Waste Branch

- location of hazardous waste sites; and
- location of landfills.

Preliminary information about the well head protection area may be obtained from the Safe Drinking Water Branch, Department of Health.

Information about wetlands may be obtained from the U.S. Army Corps of Engineers.

County general, development and community plans may be obtained from the respective planning departments.

Algae: Biofuel of the Future?

Microalgae are single-cell, photosynthetic organisms known for their rapid growth and high energy content. Some algal strains are capable of doubling their mass several times per day. In some cases, more than half of that mass consists of lipids or triacylglycerides—the same material found in vegetable oils. These bio-oils can be used to produce such advanced biofuels as biodiesel, green diesel, green gasoline, and green jet fuel. Significant research and development efforts have been revived; however algal biofuels remain cost-ineffective at this point in time. Based on conservative estimates, algal biofuels produced in large volumes with current technology would cost more than $8 per gallon (in contrast to $4 per gallon for soybean oil today).[xcii]

The benefits of algae as a biofuels feedstock:

- High yield of feedstock for fuel production
  - 50% lipids by dry weight
  - Good FAMES profiles (mole weight distribution) for biodiesel
- Sustainable
  - Does not divert prime food crops away from human and animal consumption
  - Marine algae do not need or divert freshwater from other uses
  - Does not need prime farmland
- Sunlight as energy source: Converts solar energy into carbohydrates and oils
- Potential for carbon sequestration when carbon dioxide utilized as carbon source[xciii]
- Fact Sheet: Algal Biofuels, September 2008 (PDF 582 KB) U.S. DOE Biomass Program

Algae Research Activities in Hawaii

• HRbio - industrial collaboration on marine algae
• Jaw-Kai Wang Corp. - patented commercial open production system
• Hawaii Natural Energy Institute - pending partnerships with mainland companies (two phototrophic, one heterotrophic) focused on extraction technology
• National Renewable Energy Laboratory biofuels collection at UH
• UH partnering in development of Southwest Center for Sustainable algal biofuels
• U.S. Defense Advanced Research Projects Agency (DARPA) has expressed interest in Hawaii programs[xciv]

1.9 Resources

NAME/EMAIL[xcv]	AGENCY	TITLE	PHONE/FAX
Robert Primiano rprimiano@honolulu.gov	Honolulu Clean Cities Coalition	Clean Cities Coordinator	Phone: (808) 768-3500 Fax: (808) 768-3506
Mike Bednarz michael.bednarz@netl.doe.gov	U.S. Department of Energy, National Energy Technology Laboratory	Project Manager	Phone: (412) 386-4862 Fax:
Maria Tome mtome@dbedt.hawaii.gov	Hawaii Department of Business, Economic Development, and Tourism, Strategic Industries Division	Alternate Energy Engineer	Phone: (808) 587-3809 Fax: (808) 587-3820
	Hawaii Department of Business, Economic Development, and Tourism		Phone: (808) 587-3814 Fax:
Hoku Keolanui tkeolanui@hawaiigas.com	The Gas Company, LLC	Account Executive	Phone: (808) 594-5585 Fax: (808) 594-5528
	Hawaii State Department of Taxation		Phone: (800) 222-3229 Fax:
Collette Craig collette.craig@gsa.gov	U.S. General Services Administration	AFV Contact, Region 9	Phone: (928) 524-3975 Fax: (928) 524-2324

Presentations at the kickoff meeting for the development of the Hawaii Bioenergy Master Plan.[xcvi]

The *Bioenergy Master Plan - Progress Report to the Legislature* provides a status report as of December, 2008, and an outline of the approach to be taken in 2009 in developing the final report for transmission to the Legislature by December 2009.[xcvii]

University of Hawaii at Hilo, College of Agriculture, Forestry & Natural Resource Management[xcviii]

University of Hawaii at Manoa, College of Tropical Agriculture & Human Resources[xcix]

DBEDT – Natural Energy Lab of Hawaii[c]

Hawaii Agricultural Research Center (HARC), www.harc-hspa.com: HARC specializes in horticultural crop research including agronomy and plant nutrition, plant physiology, breeding, genetic engineering and tissue culture, and control of diseases and pests through integrated pest management. HARC also performs pesticide registration work; training in areas such as pesticide application and environmental compliance; ground water monitoring; and technical literature searches.

Survey of State Policies Related to Biomass

Ethanol Production Incentives: A number of states have designed financial incentives for the production of ethanol. Several provide partial exemptions from state gasoline excise taxes (separate from federal excise tax and exemption). The trend is toward producer credits to keep business promotion within the state.

Renewable Portfolio Standard: As of early 2004, thirteen states required electric power generators to use a certain percentage of renewable energy.

Public Benefits Funds or Systems Benefit Charges (SBC): 23 states and the District of Columbia have implemented state-level programs developed through the electric utility restructuring process as a measure to assure continued support for renewable energy resources, energy efficiency initiatives, and low-income support programs. More than half of these specifically include funding for biomass projects, according to the Database of State Incentives for Renewable Energy (DSIRE).

Information on state programs for:

- Grant/Loan Programs
- Production Incentives for Renewable Power Generation and Fuels
- Tax Incentives
- Industrial Recruitment Incentives
- Rebate Programs
- Green Power Purchasing/Aggregation Policies
- Utility Green Pricing Programs, etc.
- Outreach Programs

Can be found at:

- EERE/National Council of State Legislature's State Energy Alternatives
- Database of State Incentives for Renewable Energy (DSIRE)
- American Council for an Energy-Efficient Economy
- Ethanol Fuel Incentives Applied in the U.S.: Reviewed from California's Perspective (PDF 770 KB)[ci]

2.0 FEDERAL GOVERNMENT

2.1 International Bioenergy Policy Context

U.N. Energy, Sustainable Bioenergy: A Framework for Decision Makers, "[G]lobal interest in bioenergy has grown rapidly in recent years. From being merely an interest of marginal innovators, it has become a multibillion dollar business – transforming economies – thanks to rising attention and support from government and the public. What could be more appealing than home-grown energy, essentially created by sun-and-water-fuelled photosynthesis, with new jobs and development opportunities to be tapped?"[cii] Yet, the report quickly points out that the concerns over biofuels – adverse net environmental impacts, pushing out food crops in favor of energy crops, raising food prices, and exacerbating food security – affects policymaking on a global level.[ciii]

United Nations: An Overview of UN-Energy Activities This UN-Energy report compiles United Nations agency member profiles to highlight their activities across the energy spectrum. It provides information on UN-Energy, joint activities among members, and member energy programs.

2.2 Federal Bioenergy Policy Context

National Energy Policy Report

- Forward (325KB)
  Overview (125KB)
- Energy Challenges facing the US (1000KB)
- Impacts of High Energy Prices (990KB)
- Protecting America's Environment (1000KB)
- Using Energy Wisely (740KB)
- Energy for a New Century (1000KB)
- Nature's Power (880KB)
- America's Energy Infrastructure (1500KB)
- Enhancing National Energy Security (980KB)
- Summaries (49KB)
  Glossary (121KB)
  Errata (65KB)
- Complete Report of the National Energy Policy Development Group (2500KB)

U.S. Department of Energy: Biomass Benefits

Biomass and the U.S. Economy: Cheap oil fuels America's economy — most of which is imported. Small changes in crude oil prices or supplies can have an enormous impact on our economy - increasing trade deficits, decreasing in industrial investment, and lowering employment levels. Developing a strong industry for biomass fuels, power, and products in the United States will have tremendous economic benefits including trade deficit reduction, job creation, and the strengthening of agricultural markets.

Biomass and U.S. Energy Security: According to the EIA, in 2002 the United States consumed 19.3M barrels of petroleum (crude oil and petroleum products) per day, or about one-quarter of total world oil production. More than half of that oil is imported and is mostly used in the transportation sector. One way to diversity our energy supply and to build economic security is to increase our consumption of renewable energy sources, such as biomass-derived transportation fuels.[civ]

Biomass and the Environment: Biomass is a renewable energy and its usage has several environmental benefits. Growing biomass, (e.g. energy crops like switchgrass), has important land, habitat, and soil conservation benefits. Producing energy from residues in forests, mills, and landfills avoids the release of methane into the atmosphere from decomposition of unused wood and agricultural wastes. Depending upon how much fossil energy is used to grow and process biomass feedstock, the result is a substantial reduction of net greenhouse gas emissions. Most important, biomass is the only renewable energy that can be directly substituted for petroleum based transportation fuels, which account for one-third of US's CO_2 emissions - one of the principal greenhouse gases. Much of this CO_2 and other harmful emissions can be alleviated by substituting biofuels for fossil fuels or by using them as fuel additives — such as ethanol. Click for detailed information on Biomass Benefits and answers to frequently asked questions.[cv]

U.S. Department of Energy: Biomass Resources for Policymakers

Existing Federal and State biomass-related policies, along with other legislation that drives biomass R&D has facilitated the adoption of biomass technologies that decrease U.S. dependence on foreign oil and reap other benefits. Pending policies and legislation, if enacted into law, could increase the adoption rate for biomass technologies.

Examples of existing biomass incentives are:

- Excise Tax Exemption for Ethanol Blended Gasoline
- Excise Tax Exemption for Biodiesel
- Credit for Biodiesel under Alternative Fuel Fleet Requirements
- Commodity Credit Corporation Bioenergy Program
- Clean Air Act Oxygenated Fuel Requirements

Information on proposed incentives/programs for biomass use:

- Legislative information in a searchable database can be found at the Library of Congress' THOMAS web site. For instance, type "biomass" in the "word/phrase" box to find a comprehensive list of biomass related bills.

- The Biomass Initiative maintains a list of current biomass related bills on the hill.
- Governor's Ethanol Coalition Ethanol Legislation
- National Corn Growers Association Legislative Action Center
- Renewable Fuels Association Public Policy
- Environmental and Energy Study Institute details current biomass issues, technologies, policies, and programs. Provides relevant policy briefings, events, publications.

2.3 Federal Policy and Law

EPA: Federal Biomass Policy Overview: A summary of significant bioenergy-related policy and laws.

Energy Independence and Security Act (EISA) 2007
The EISA raises standards for vehicle fuel economy and mandate that U.S. transportation fuel include 21 billion gallons of advanced biofuels by 2022 and 2 billion gallons as soon as 2012. The legislation further requires that these advanced biofuels must achieve at least a 50% reduction in life-cycle greenhouse gas emissions.

Currently, corn is the predominant base-product of ethanol produced and used in the United States.[cvi] The priority crop – on both scientific and legislative levels – is production of cellulosic ethanol.[cvii] The EISA contains four specific sections that incorporate cellulosic ethanol as part of the solution to meeting the Act's biofuel requirements.[cviii] Beginning in 2016, all mandatory increases in the yearly Renewable Fuel Standard (RFS) amounts must consist of advanced biofuels, which are defined as cellulosic ethanol and fuels derived from products other than corn starch.[cix]

Funding for cellulosic ethanol development is provided in section 230 of the EISA, entitled "Cellulosic Ethanol and Biofuels Research."[cx] That section authorizes the Department of Energy to make grants of $50 million for cellulosic ethanol and biofuels research and development to 10 eligible entities."[cxi] Section 230 adds $385 million in DOE funding designated for cellulosic ethanol efforts through FY 2010.[cxii]

EISA 2007, Section 202: New Renewable Fuel Standard:
- Expand use of renewable fuels to 36 billion gallons annually by 2022
- Cellulosic biofuels component: 0.5 billion gallons by 2012, 3 billion gallons by 2015, 16 billion gallons by 2022
- "30x30": Displace 30% of US gasoline consumption by 2030 with biofuels (60 billion gallons)[cxiii]

Biomass Research & Development Act of 2000 Public Law 106-224; 7 U.S.C. 8101 note) formed the Biomass Initiative, a multi-agency effort to coordinate and accelerate federal biobased products, biofuels, and bioenergy research and development. The act was revised by Energy Policy Act of 2005, Section 941,(Pub.L. 109-58) (EPAct) in part by providing tax incentives and loan guarantees for energy production. See: Links to Biomass Initiative major milestones and agency actions.[cxiv]

Biomass Initiative -- Objectives (Energy Policy Act of 2005, Section 941):
The objectives of the Initiative are to develop:

1. technologies and processes necessary for abundant commercial production of biobased fuels at prices competitive with fossil fuels;
2. high-value biobased products to enhance the economic viability of biobased fuels and power; and as substitutes for petroleum-based feedstocks and products; and
3. a diversity of sustainable domestic sources of biomass for conversion to biobased fuels and biobased products.[cxv]

The Department of Energy's Renewable Energy Biomass Program, run by the Office of Energy Efficiency and Renewable Energy includes major programs for developing and improving technology for biomass power; for making biofuels such as ethanol (from biomass residues as well as grain) and renewable diesel; and for making plastics and chemicals from renewable, biobased materials. [cxvi] The Biomass Program works with industry, academia, and national laboratory partners on a balanced portfolio of research in biomass feedstocks and conversion technologies.[cxvii]

Biomass Research and Development Initiative
The U.S. Department of Agriculture Office of Rural Development, in conjunction with U.S. Department of Energy, provides grant funding for projects addressing research and development of biomass-based products, bioenergy, biofuels, and related processes under the Section 9008 Biomass Research and Development Initiative. Eligible recipients may receive up to $1 million for projects that involve feedstock production for biobased fuels and products, converting cellulosic biomass into biobased fuels, technologies for co-producing biobased products in biofuel production facilities, and strategic guidance for improving overall sustainability and environmental quality of biomass technologies. For more information, visit the Section 9008 Program Web site and contact the appropriate State Rural Development Office.

2008 National Biofuels Action Plan
The DOE's Action Plan was created in response to President Bush's "Twenty in Ten" goal and later to meet the Renewable Fuel Standard (RFS) as outlined in the Energy Independence and Security Act of 2007. The Action Plan is organized around five action areas based on feedstocks-to-biofuels supply chain: feedstock production, feedstock logistics, conversion science and technology, distribution infrastructure, and blending. The plan also identifies two cross-cutting action areas: sustainability and environment, health and safety.[cxviii]

Environmental Policy Act (EPAct) 2005

- Section 932 required the Secretary of Energy to solicit proposals for cellulosic biorefinery demonstration projects that produce biofuels, in addition to chemicals power; ensured geographical distribution of projects; were able to be replicated; and did not require Federal funding after construction reached completion. The recipients of these awards were announced on February 28, 2007. More information about these projects can be found on the Deployment page.
- Section 1501 establishes a Renewable Fuel Standard (RFS) that mandates that all gasoline sold in the United States contain 7.5 billion gallons of renewable fuels by 2012.

In 2013, the renewable fuels used should contain 250 million gallons of fuel derived from cellulosic biomass.

- Title XVII calls for the Secretary of Energy to establish a program that provides guaranteed loans for energy projects which “employ new or significantly improved technologies as compared to commercial technologies", including renewable energy technologies. Click here for more information on Department of Energy loan guarantees. EPAct 2005 provides a variety of incentives for biofuels. See, Energy Policy Act.

Farm Bill: Food, Conservation, and Energy Act of 2008
In May 2008, Congress overrode a presidential veto to pass the Food, Conservation, and Energy Act of 2008 (House Resolution 2419), which provides funding for commodity, rural development, conservation, and energy programs. The bill included language that authorizes $1 billion in funds for renewable energy programs and new feedstock production, and reauthorizes many 2002 Farm Bill programs, including the Biomass Research and Development Initiative, the Biobased Products and Bioenergy Program, and a biodiesel education program. The bill also allows for a cellulosic biofuel production credit.

Other Federal Environmental and Alternative Energy Laws, Programs, and Incentives[cxix]

National Environmental Policy Act, 42 U.S.C. §4321 et seq. (1969)
The underlying policy of the National Environmental Policy Act (NEPA) is to assure that all branches of government give proper consideration to the environment prior to undertaking any major federal action that significantly affects the environment. Environmental Impact Assessments (EA) and Statements (EIS)[cxx] are assessments of the likelihood of impacts from alternative courses of action, are required from all federal agencies and are the most visible NEPA requirements.[cxxi]

NEPA Resources
PDF of NEPA, from U.S. Senate
EPA's NEPA Home Page
Considering Ecological Processes in Environmental Impact Assessments (July, 1999) (PDF) -- Guidance on how to incorporate ecological considerations into the preparation and review of environmental impact assessments
Environmental Impact Statement (EIS) Filing System Guidance (March, 1989) -- Information for Federal agencies regarding the administrative aspects of the EIS filing process
Habitat Evaluation: Guidance for the Review of Environmental Impact Assessment Documents (January, 1993) (PDF) -- Information to assist EPA NEPA reviewers in evaluating the ecological risks associated with federal actions and writing NEPA comments related to habitat loss and degradation issues.
NEPAnet, a website maintained by the President's Council on Environmental Quality, for additional policies and guidance regarding the National Environmental Policy Act.[cxxii]

The Department of Transportation Act (DOT Act) of 1966 included a special provision - Section 4(f) - which stipulated that the Federal Highway Administration (FHWA) and other DOT agencies cannot approve the use of land from publicly owned parks, recreational areas, wildlife and waterfowl refuges, or public and private historical sites unless the following conditions apply:

- There is no feasible and prudent alternative to the use of land.
- The action includes all possible planning to minimize harm to the property resulting from use.[cxxiii]

Clean Air Act[cxxiv]

The Clean Air Act is the law that defines EPA's responsibilities for protecting and improving the nation's air quality and the stratospheric ozone layer. The last major change in the law, the Clean Air Act Amendments of 1990, was enacted by Congress in 1990. Legislation passed since then has made several minor changes.
Clean Air Act as of February 2004 (PDF) - This version of the Clean Air Act, provided by the U.S. Senate Committee on Environment and Public Works, includes amendments through the 108th Congress. See also, Plain English Guide to the Clean Air Act

Clean Air Act, New Source Review Permits
In the context of biofuels production this Act applies primarily to emissions from factories or power plants. Congress established the New Source Review (NSR) permitting program as part of the 1977 Clean Air Act Amendments. NSR is a preconstruction permitting program that serves two purposes:

- First, it ensures that air quality is not significantly degraded from the addition of new and modified factories, industrial boilers and power plants. In areas with unhealthy air, NSR assures that new emissions do not slow progress toward cleaner air. In areas with clean air, especially pristine areas like national parks, NSR assures that new emissions do not significantly worsen air quality.
- Second, the NSR program assures people that any large new or modified industrial source in their neighborhoods will be as clean as possible, and that advances in pollution control occur concurrently with industrial expansion.

NSR permits are legal documents that the facility owners/operators must abide by. The permit specifies what construction is allowed, what emission limits must be met, and often how the emissions source must be operated.[cxxv]

NSR Resources
Basic Information - Learn the basics about NSR and the terms associated with NSR. What are permits and who issues them?
Hawaii permitting information.[cxxvi]
Regulations & Standards - Regulations under development or recently issued as well as regulations currently in effect.
Publications - Publications related to NSR.
Related Links - Other sources of information about permits and air pollution.
Laws & Statutes - What parts of the Clean Air Act apply to NSR?
Policy & Guidance - A full-document-searchable compendium of NSR policy and guidance.[cxxvii]

Air Pollution Control Program
The Clean Air Act provides legal authority for the EPA's Air Pollution Control Program, which assists state, local, and tribal agencies in planning, developing, establishing, improving, and maintaining adequate programs for prevention and control of air pollution or implementation of national air quality standards. Plans may emphasize alternative fuels, vehicle maintenance, and transportation choices to reduce vehicle miles traveled. Eligible applicants may receive federal funding for up to 60% of project costs to implement their plans.[cxxviii]

2.4 Coastal Zones and Water Use

Protection of the Environment, Title 40, Code of Federal Regulations[cxxix]

Coastal Zone Management Act (CZMA) & Coastal Zone Management Act Reauthorization Amendments (CZARA) Section 6217
The objective of the Coastal Zone Management Act is to control nonpoint pollution sources that affect coastal water quality.
Surface and Groundwater
Coastal Nonpoint Source Pollution Control Program
Protecting Coastal Waters from Nonpoint Source Pollution

CZMA and CZARA compliance and enforcement
Water Enforcement Division
Water Enforcement Bulletin
Multimedia Enforcement Division
Final Administrative Changes to the Coastal Nonpoint Pollution Control Program Guidance for Section 6217 of CZARA (PDF) (8 pp, 138K)
Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters

DOE's Energy-Water Nexus Investigations
The continued security and economic health of the United States depends on a sustainable supply of both energy and water. These two critical resources are inextricably and reciprocally linked; the production of energy requires large volumes of water while the treatment and distribution of water is equally dependent upon readily available, low-cost energy. The nation's ability to continue providing both clean, affordable energy and water is being seriously challenged by a number of emerging issues.

"Energy Demands on Water Resources," U.S. Dept. of Energy report to Congress (2006)[cxxx]

"Water Implications of Biofuels Production in the United States," National Academies, National Research Council Division on Earth and Life Sciences, Water Science and Technology Board (2005-2007)[cxxxi]

Clean Water Act[cxxxii]
The Clean Water Act (CWA) establishes the basic structure for regulating discharges of pollutants into the waters of the United States and regulating quality standards for surface waters.

See, PDF of CWA, from U.S. Senate, CWA History, and the EPA Watershed Academy's Introduction to the Clean Water Act

The CWA made it unlawful to discharge any pollutant from a point source into navigable waters, unless a permit was obtained. EPA's National Pollutant Discharge Elimination System (NPDES) permit program controls discharges by regulating point sources that discharge pollutants into waters of the United States. Point sources are discrete conveyances such as pipes or manmade ditches. Industrial, municipal, and other facilities must obtain permits if their discharges go directly to surface waters. The State of Hawaii, Department of Health, Clean Water Branch administers the NPDES permit program.

NPDES regulations exclude irrigated agriculture and agricultural stormwater runoff from the universe of entities requiring permit coverage. Discharges from concentrated animal feeding operations, concentrated aquatic animal production facilities, and silviculture, as well as discharges to aquaculture projects are not excluded from permitting requirements.[cxxxiii]

Stormwater Runoff
40 C.F.R. § 122.26
Stormwater runoff is generated when precipitation from rain and snowmelt events flows over land or impervious surfaces and does not percolate into the ground. As the runoff flows over the land or impervious surfaces (paved streets, parking lots, and building rooftops), it accumulates debris, chemicals, sediment, or other pollutants that could adversely affect water quality if the runoff is discharged untreated. The primary method to control stormwater discharges is the use of best management practices (BMPs). For more information about the Stormwater program, visit the Stormwater Basic Information page.

Hawaii is authorized to implement the Stormwater NPDES permitting program. The NPDES Stormwater Program regulates stormwater discharges from three potential sources: municipal separate storm sewer systems (MS4s), construction activities (construction sites that are one acre or larger (including smaller sites that are part of a larger common plan of development) may be required to obtain authorization to discharge stormwater under an NPDES construction stormwater permit), and industrial activities.

Best Management Practices

States assist and encourage agricultural producers through a variety of programs to use best management practices (BMPs) designed to reduce or prevent pollution from point and non-point sources migrating into waters. States manage non-point-source programs on a watershed-by-watershed basis whenever possible.

BMP Authority and References:
Clean Water Act Section 319
Clean Water Act Section 402
Agricultural Management Practices for Water Quality Protection
Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters
Forestry Best Management Practices in Watersheds

National Menu of Stormwater Best Management Practices

Nonpoint Source References, compiled by EPA:

Core4 Conservation Practices: the common sense approach to natural resource conservation. U.S. Department of Agriculture, Natural Resources Conservation Service (1999). This reference manual is intended to help USDA-NRCS personnel and other conservation and nonpoint source management professionals implement effective programs on the land using four core conservation practices: conservation tillage, nutrient management, pest management, and conservation buffers. The Core4 concept was established by the Conservation Technology Information System and is supported by USDA, EPA, and agribusiness.[cxxxiv]

Farming for Clean Water in South Carolina: a handbook of conservation practices. South Carolina Department of Natural Resources (1997). Compiled by Dennis DeFrancesco of USDA-NRCS for the South Carolina DNR, this 135-page manual covers all the farming basics: calibration, stripcropping, water diversions, composting, IPM, recordkeeping, pesticides, nutrients...and the list goes on. Based in large part on the Field Office Technical Guide and Clemson University publications, this document was produced using Section 319 funding. While not in-depth, the document has great pictures and an easy to follow, consistent format. Contact SCDNR for more information: (803) 737-0800.

50 Ways Farmers Can Protect Their Groundwater. University of Illinois, College of Agriculture, Cooperative Extension Service (1993). The title says it all. While focusing on the management of fertilizers and pesticides, this 190-page book covers livestock waste, wells, hazardous chemicals, and water testing briefly. Contact Information Services, 217-333-2007 for information.

Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters. U.S. Environmental Protection Agency, Office of Water (1993). Developed for use by State Coastal Nonpoint Pollution Control Programs, Chapter 2 of this document covers erosion control, animal feeding operation management, grazing practices, and management of nutrients, pesticides, and irrigation water. This document has become a must-have for nonpoint source control professionals.[cxxxv]

National Handbook of Conservation Practices. U.S. Department of Agriculture, Natural Resources Conservation Service. This resource contains all conservation practice standards issued by the Natural Resources Conservation Service. All conservation topics are covered: nutrient management, conservation tillage, erosion control, irrigation, grazing, etc.[cxxxvi]

60 Ways Farmers Can Protect Surface Water and 60 ways Farmers Can Protect Groundwater. University of Illinois, College of Agriculture, Cooperative Extension Service (1993). Topics include residue management, water flow control, nutrient management, livestock waste handling, and pesticide management.[cxxxvii]

Soybean Management and the Land: A Best Management Practices Handbook for Growers. American Soybean Association (2000). This manual is a two-for-one bonus. The "Resource Book" presents information on BMPs for the farmstead, cropland, pastureland, and other areas. All types of BMPs are covered: erosion, pest management, nutrients, well protection, buffers, etc. The BMP discussion includes real world examples of how these practices work through testimonials from real farmers. The "Workbook" allows soybean growers to assess the conditions on their farm and determine their environmental risk level. The "Workbook" also guides the producer to make a plan for improvement.[cxxxviii]

Best Management Practices for Agrichemical Handling and Farm Equipment Maintenance. Florida Department of Agriculture and Consumer Services and Florida Department of Environmental Protection (May 1998). This 51-page booklet covers pesticides, fertilizers, and solvents and degreasers. Emphasis is placed on storage, mixing, loading, spill management, and disposal. Emergency reporting is also stressed.[cxxxix]

Irrigation Guide: USDA-NRCS National Engineering Handbook: Part 652. U.S. Department of Agriculture, Natural Resources Conservation Service (1997). This manual describes the NRCS-recommended processes for planning, designing, evaluating, and managing irrigation systems.[cxl]

Irrigation Management Practices to Protect Ground Water and Surface Water Quality, State of Washington. Washington State Department of Ecology and Washington State University Cooperative Extension (1995). The handbook emphasizes a systems approach to irrigation management and water quality protection. Introductory material covers water quality issues and the basics of soil-water-plant relationships and irrigation processes.[cxli]

Floodplain Management and Wetlands

Statement of Procedures on Floodplain Management and Wetlands Protection (January, 1979) (PDF) -- The purpose of this Statement of Procedures is to set forth Agency policy and guidance for carrying out the provisions of Executive Orders 11988 ("Floodplain Management") and 11990 ("Wetlands Protection").

Wetlands Regulatory Authority Fact Sheet (PDF)
Clean Water Act 404 -- Text
40 CFR Parts 230-233 (PDF)

Clean Water Act Section 404 Regulations
Policy and Technical Guidance Documents
Executive Orders
Wetlands
Wetlands Fact Sheets
National Management Measures To Protect and Restore Wetlands and Riparian Areas for the Abatement of Nonpoint Source Pollution
Section 404 and Swampbuster: Wetlands on Agricultural Lands
USDA NRCS - Wetland Conservation Provisions (Swampbuster)

Wetlands Compensatory Mitigation

Final Compensatory Mitigation Rule - Issued March 31, 2008
Compensatory Mitigation - updates and background information regarding Clean Water Act Section 404 Compensatory Mitigation Requirements.
National Wetlands Mitigation Action Plan - a list of 17 tasks that the partner agencies will complete by the end of 2005 to improve the ecological performance and results of compensatory mitigation. As of February 2006, nine of the 17 tasks are complete. Four of the remaining eight tasks are drafted and are currently under review.

2.5 Other Federal Laws Implicated in Bioenergy Crop Production

Comprehensive Environmental Response, Compensation and Liability Act (CERCLA, or Superfund)
Emergency Planning and Community Right-to-Know Act (EPCRA)
Endangered Species Act (ESA)
EO 13211: Actions Concerning Regulations That Significantly Affect Energy Supply, Distribution, or Use
Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)
Marine Protection, Research, and Sanctuaries Act (MPRSA, also known as the Ocean

Dumping Act)
National Technology Transfer and Advancement Act (NTTAA)
Occupational Safety and Health (OSHA)
Ocean Dumping Act - See Marine Protection, Research, and Sanctuaries Act
Pollution Prevention Act (PPA)
Resource Conservation and Recovery Act (RCRA) Safe Drinking Water Act (SDWA)
Superfund - See Comprehensive Environmental Response, Compensation and Liability Act
Superfund Amendments and Reauthorization Act (SARA) - See Comprehensive Environmental Response, Compensation and Liability Act
Toxic Substances Control Act (TSCA)
Historic Preservation laws; information at Advisory Council on Historic Preservation, Section 106[cxlii]

2.6 Incentives and Programs

The American Recovery and Reinvestment Act of 2009 (Recovery Act)
The Recovery Act presents opportunities for the advancement of biomass technologies. Signed into law by President Obama on February 17, 2009, the Recovery Act is an unprecedented effort to jumpstart our economy, create or save millions of jobs, and focus on addressing long-neglected challenges so our country can thrive in the twenty-first century. See Recovery Act funding for biomass projects.

State Energy Program (SEP) Funding
SEP provides grants to states to assist in designing, developing, and implementing renewable energy and energy efficiency programs. Funding from the SEP is directed to state energy offices, and each state's energy office manages all SEP-funded projects. States may also receive project funding from technology programs in the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) for SEP Special Projects. EERE distributes the funding through an annual competitive solicitation to state energy offices. For more information about the SEP, including SEP project descriptions, visit the Web site.[cxliii]

Clean Cities
The mission of Clean Cities is to advance the energy, economic, and environmental security of the United States by supporting local initiatives to adopt practices that reduce the use of petroleum in the transportation sector. Clean Cities carries out this mission through a network of more than 80 volunteer coalitions, which develop public/private partnerships to promote alternative fuels and advanced vehicles, fuel blends, fuel economy, hybrid vehicles, and idle reduction. Clean Cities provides information about financial opportunities, coordinates technical assistance projects; updates and maintains databases and Web sites, and publishes fact sheets, newsletters, and related technical and informational materials.[cxliv] See, Honolulu Clean Cities.

Emergency Economic Stabilization Act/Energy Improvement and Extension Act of 2008
The Emergency Economic Stabilization Act (House Resolution 1424) was signed by President Bush, enacting the Energy Improvement and Extension Act of 2008. The bill amends and extends existing biodiesel blending and production tax credits, extends existing alternative fuel excise tax credit, and extends the alternative fueling infrastructure tax credit.

Renewable Energy Systems and Energy Efficiency Improvements Grant
Competitive grant funding and guaranteed loans are available from the U.S. Department of Agriculture Office of Rural Development's Section 9006 Energy Program for the purchase of renewable energy systems and energy improvements for agricultural producers and small rural businesses. Qualified projects must occur in a rural area and implement technology that is pre-commercial or commercially available and replicable. Research and development does not qualify. Applicants must provide at least 75% of eligible project costs, and grant assistance to a single individual or entity may not exceed $750,000. Eligible projects include biofuels, hydrogen, and energy efficiency improvements, as well as solar, geothermal, and wind. The Section 9006 Energy Program has not been funded for Fiscal Year 2008. For more information, visit the Section 9006 Program Web site, and contact the appropriate State Rural Development Office.[cxlv]

Alternative Fuel Infrastructure Tax Credit
A tax credit is available for the cost of installing alternative fueling equipment placed into service after December 31, 2005. Qualified alternative fuels are natural gas, liquefied petroleum gas, hydrogen, electricity, E85, or diesel fuel blends containing a minimum of 20% biodiesel. The credit amount is up to 30% of the cost, not to exceed $30,000, for equipment placed into service before January 1, 2009. The credit amount is up to 50% not to exceed $50,000, for equipment placed into service on or after January 1, 2009. Fueling station owners who install qualified equipment at multiple sites are allowed to use the credit towards each location. Consumers who purchase residential fueling equipment may receive a tax credit of up to $1,000, which increases to $2,000 for equipment placed into service after December 31, 2008. The maximum credit amount for hydrogen fueling equipment placed into service after December 31, 2008, and before January 1, 2015, is $200,000. The credit expires December 31, 2010, for all other eligible fuel types. Form 8911 (PDF 247 KB) provides additional information and must be used in order to claim the tax credit.[cxlvi]

Biobased Products and Bioenergy Program
The goal of the Biobased Products and Bioenergy Program is to help finance technologies that are needed to convert biomass into biobased products and bioenergy in a cost-competitive manner in national and international markets. Loans for biomass conversions are eligible for financing under the Business and Industry Guaranteed Loan Program. For the purpose of this program, biomass is defined as any organic matter that is available on a renewable or recurring basis, excluding timber, and including dedicated energy crops and trees, agricultural food and feed crop residues, aquatic plants, wood and wood residues, animal wastes, and other waste materials. A biobased product is considered any commercial or industrial product that utilizes biological products or renewable domestic agricultural or forestry materials, including biofuels. For more information, visit Biobased Products and Bioenergy Program and contact the appropriate State Rural Development Office.[cxlvii]

Value-Added Producer Grants (VAPG)
The U.S. Department of Agriculture Office of Rural Development awards Value-Added Producer Grants for planning activities and working capital for marketing value-added agricultural products and farm-based renewable energy. Eligible applicants include independent

producers, farmer and rancher cooperatives, agricultural producer groups, and majority-controlled producer-based business ventures. Eligible participants may apply for either a planning grant or a working capital grant, but not both. In addition, no more than 10% of program funds may be awarded to majority-controlled producer-based business ventures. Grants will only be awarded if projects are determined to be economically viable and sustainable. For more information about grant eligibility, visit the VAPG Web site and contact the appropriate State Rural Development Office.[cxlviii]

Improved Energy Technology Loans

The U.S. Department of Energy (DOE) provides loan guarantees through the Loan Guarantee Program to eligible projects that reduce air pollution and greenhouse gases, and support early commercial use of advanced technologies, including biofuels and alternative fuel vehicles. The Program is not intended for research and development projects. DOE may issue loan guarantees for up to 100% of the amount of the loan for an eligible project. For loan guarantees of over 80%, the loan must be issued and funded by the Treasury Department's Federal Financing Bank. For additional Program guidelines and solicitation announcements, visit the Loan Guarantee Program Web site.[cxlix]

Biodiesel Income Tax Credit

A taxpayer that delivers pure, unblended biodiesel (B100) into the tank of a vehicle or uses B100 as an on-road fuel in their trade or business may be eligible for an incentive in the amount of $1.00 per gallon of biodiesel, agri-biodiesel, or renewable diesel. If the biodiesel was sold at retail, only the person that sold the fuel and placed it into the tank of the vehicle is eligible for the tax credit. The incentive is allowed as a credit against the taxpayer’s income tax liability. Under current law, this incentive expires December 31, 2009. For more information, see IRS Publication 510 and IRS Forms 637 and 8864, which are available via the IRS Web site.[cl]

Biorefinery Assistance Program Funds Availability and Proposed Rulemaking Announced

The U.S. Department of Agriculture’s (USDA) Rural Business-Cooperative Service has announced an Advanced Notice of Proposed Rule Making (PDF 94KB) and seeks comments for the development of a proposed rule to implement a Biorefinery Assistance guaranteed loan program. In addition, USDA published a separate notice announcing a Notice of Funds Availability (PDF 130KB) for the Biorefinery Assistance Program, which will provide guaranteed loans for the development and construction of commercial-scale biorefineries or for the retrofitting of existing facilities using eligible technology for the development of advanced biofuels. Created in the Food, Conservation, and Energy Act of 2008 (2008 Farm Bill), the purpose of the Biorefinery Assistance Program is to assist in the development of new and emerging technologies for the development of advanced biofuels.

Cellulosic Biofuel Producer Tax Credit

A cellulosic biofuel producer that is registered with the Internal Revenue Service (IRS) may be eligible for a tax incentive in the amount of up to $1.01 per gallon of cellulosic biofuel that is: sold and used by the purchaser in the purchaser’s trade or business to produce a cellulosic biofuel mixture; sold and used by the purchaser as a fuel in a trade or business; sold at retail for use as a motor vehicle fuel; used by the producer in a trade or business to produce a cellulosic biofuel mixture; or used by the producer as a fuel in a trade or business. If the cellulosic biofuel also qualifies for alcohol fuel tax credits, the credit amount is reduced to $0.46 per gallon for biofuel that is ethanol and $0.41 per gallon if the biofuel is not ethanol. Cellulosic biofuel is defined as liquid fuel produced from any lignocellulosic or hemicellulosic matter that is available on a renewable basis, and meets U.S. Environmental Protection Agency fuel and fuel additive registration requirements. Alcohol with a proof of less than 150 is not considered cellulosic biofuel. The incentive is allowed as a credit against the producer's income tax liability. Under current law, only qualified fuel produced in the U.S. between January 1, 2009, and December 31, 2012, for use in the U.S. may be eligible. For more information, see IRS Publication 510 and IRS Forms 637 and 6478, which are available via the IRS Web site.[cli]

Small Agri-Biodiesel Producer Tax Credit

A small agri-biodiesel producer that is registered with the Internal Revenue Service may be eligible for a tax incentive in the amount of $0.10 per gallon of agri-biodiesel that is: sold and used by the purchaser in the purchaser's trade or business to produce an agri-biodiesel and diesel fuel mixture; sold and used by the purchaser as a fuel in a trade or business; sold at retail for use as a motor vehicle fuel; used by the producer in a trade or business to produce an agri-biodiesel and diesel fuel mixture; or used by the producer as a fuel in a trade or business. A small producer is one that has, at all times during the tax year, not more than 60 million gallons of productive capacity of any type of agri-biodiesel. Agri-biodiesel is defined as diesel fuel derived solely from virgin oils, including esters derived from corn, soybeans, sunflower seeds, cottonseeds, canola, crambe, rapeseeds, safflowers, flaxseeds, rice bran, mustard seeds, and camelina, and from animal fats; renewable diesel does not qualify for the credit. The incentive applies only to the first 15 million gallons of agri-biodiesel produced in a tax year is allowed as a credit against the producer's income tax liability. Under current law, this incentive expires December 31, 2009. For more information, see IRS Publication 510 and IRS Forms 637 and 8864, which are available via the IRS Web site.[clii]

Biodiesel Mixture Excise Tax Credit

A biodiesel blender that is registered with the Internal Revenue Service (IRS) may be eligible for a tax incentive in the amount of $1.00 per gallon of pure biodiesel, agri-biodiesel, or renewable diesel blended with petroleum diesel to produce a mixture containing at least 0.1% diesel fuel. Only blenders that have produced and sold or used the qualified biodiesel mixture as a fuel in their trade or business are eligible for the tax credit. The incentive must first be taken as a credit against the blender's fuel tax liability; any excess over this tax liability may be claimed as a direct payment from the IRS. Claims must include a copy of the certificate from the registered biodiesel producer or importer that: identifies the product; specifies the product's biodiesel, agri-biodiesel, and/or renewable diesel content; confirms that the product is properly registered as a fuel with the U.S. Environmental Protection Agency; and confirms that the product meets the requirements of ASTM specification D6751. Renewable diesel is defined as liquid fuel derived from biomass that meets EPA's fuel registration requirements and ASTM specifications D975 or D396; the definition of renewable diesel does not include any fuel derived from co-processing biomass with a feedstock that is not biomass. Under current law, this incentive expires December 31, 2009. For more information, see IRS Publication 510 and IRS Forms 637, 720, 4136, 8849, and 8864, which are available via the IRS Web site.[cliii]

U.S. Department of Energy's Energy Efficiency and Renewable Energy department manages the 10 EERE programs.

U.S. Department of Energy's Pacific Regional Biomass Energy Program
Hawaii, Alaska, Idaho, Montana, Oregon, and Washington. The program's mission is to use its unique state, local, and other networks to provide information, technical, and other assistance to mitigate barriers and to develop and deploy bioenergy technologies for the improvement of regional environments and economies.[cliv] Also see, Hawaii Biomass Energy Program.

U.S. Department of Agriculture Commodity Credit Corporation (CCC) Bioenergy Program
Under the program, the CCC makes payments to eligible bioenergy producers to encourage increased purchases of agricultural commodities for the purpose of expanding production of bioenergy (ethanol and biodiesel) and to encourage the construction of new production capacity.clv The USDA Farm Service Agency and Commodity Credit Corporation operate under the Farm Security and Rural Investment Act of 2002 (2002 Farm Bill; 107-171 - (PDF), the Consolidated Farm and Rural Development Act (CONACT) - (PDF), the Commodity Credit Corporation Charter Act (CCC Charter Act as amended through P.L. 108-358 - (PDF), Food Security Act of 1985 (1985 Farm Bill); Conservation Programs - (PDF), the United States Warehouse Act (USWA) - (PDF), and numerous other laws.[clvi]

2.7 Resources

2.7.1 U.S. Department of Energy:

Biofuels Information Center
Energy Efficiency and Renewable Energy Network (EREN)
Federal laws
Federal regulations, reports, and other links
National Clean Cities Home Page

2.7.2 National Renewable Energy Laboratory

Advanced Vehicles and Fuels Research
National Biodiesel Board
Institute for Local Self-Reliance (ILSR)
Union of Concerned Scientists
Canadian Renewable Fuels Association

2.7.3 Council for Sustainable Biomass Production: Feedstock Production Standards Development

The Council on Sustainable Biomass Production (CSBP) is a multi-stakeholder group developing voluntary biomass to biofuel sustainability principles and standards for the production of feedstocks for second generation refineries (feedstocks for cellulosic refineries). CSBP's focus includes dedicated fuel crops, crop residues, purpose-grown wood, and forestry residues in North America. The principles and standards being developed are intended to reach the broadest land base possible by embracing the concept of continuous improvement. Fundamentally, the principles and standards will be economically practical and environmentally sound. The Council expects to develop a program over time that will provide for third party audit/certification.[clvii]

2.7.4 U.S. Department of Energy: Biomass Publications[clviii]

- The Biomass Document Database is a comprehensive collection of technical and outreach documents produced by the Biomass Program and predecessor Biofuels Program.
- BIOBIB is a bibliography of documents for biomass feedstock research and analysis work at Oak Ridge National Laboratory and is an excellent resource for bioenergy crop research.
- National Biofuels Action Plan, October 2008 (PDF 4.8 MB) Biomass Research and Development Board
- 2007 Biomass Program Overview (PDF 1.9 MB)
- Biomass 2008: Fueling Our Future Conference, April 2008
- 2007 Biomass Program Peer Review **Full Report** With Program Platform Summary Reports (PDF 11.1 MB)
- U.S. Department of Energy Office of the Biomass Program Peer Review Report - **Program Summary Section** (PDF 291 KB)
- 2007 Biomass Program Accomplishments Report Introduction (PDF 84 KB) Program Report (PDF 2.1 MB)
- 2007 Biomass Program Peer Review website
- Biomass Program Brochure (PDF 844 KB)
- Bioenergy Knowledge Discovery Framework (KDF) Fact Sheet (PDF 4.4 MB)
- Ethanol Myths Fact Sheet (PDF 2.6 MB)
- Biomass Program Partnerships Fact Sheet (PDF 653 KB)
- EERE Office of the Biomass Program Multi-Year Program Plan 2007–2017 (PDF 20.0 MB)
- Vision for Bioenergy and Biobased Products in the United States (2006) (PDF 1.4 MB)
- Roadmap for Biomass Technologies in the United States (2007) (PDF 2.3 MB)
- Plant/Crop-Based Renewable Resources 2020: A Vision to Enhance U.S. Economic Security through Renewable Plant/Crop-Based Resource Use (PDF 593 KB)
- The Technology Roadmap for Plant/Crop-Based Renewable Resources 2020: Research Priorities for Fulfilling a Vision to Enhance U.S. Economic Security through Renewable Plant/Crop-Based Resource Use (PDF 797 KB)
- Fostering the Bioeconomic Revolution in Biobased Products and Bioenergy: An Environmental Approach (PDF 887 KB)

2.7.5 Feedstocks

- Bioenergy Feedstock Information Network (an Oak Ridge National Laboratory Web site)

- Increasing Feedstock Production for Biofuels: Economic Drivers, Environmental Implications, and the Role of Research, November 2008 (PDF 7 MB) Biomass R&D Board - Interagency Feedstock Working Group
- 2007 Biomass Program Peer Review Feedstock Platform Summary of Results (PDF 706 KB)
- 2007 Biomass Program Feedstock Platform Accomplishments Report (PDF 423 KB)
- Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply, April 2005 (PDF 8.5 MB)
- Historical Perspective on How and Why Switchgrass was Selected as a "Model" High-Potential Energy Crop, July 2007 (PDF 1.7 MB)
- Roadmap for Agriculture Biomass Feedstock Supply in the United States (PDF 18.9 MB)
- Biomass Feedstock Availability in the United States: 1999 State Level Analysis
- Innovative Methods for Corn Stover Collecting, Handling, Storing, and Transporting (PDF 2.3 MB)
- Corn Stover for Bioethanol—Your New Cash Crop (PDF 256 KB)
- Biofuels and Agriculture: A Factsheet for Farmers (PDF 593 KB)
- Biofuels from Trees: Renewable Energy Research Branches Out (PDF 907 KB)
- Energy from Biofuels: The Greening of America (PDF 428 KB)
- Biofuels from Switchgrass: Greener Energy Pastures (PDF 197 KB)

2.7.6 *Biochemical Conversion Platform Technology*

- Biochemical Production of Ethanol from Corn Stover: 2007 State of Technology Model (PDF 518 KB)
- 2007 Biomass Program Peer Review Biochemical and Products Platform Summary of Results (PDF 1.2 MB)
- 2007 Biomass Program Biochemical Conversion Platform Accomplishments Report (PDF 538 KB)
- Biofuels for Your State: Helping the Economy and the Environment (PDF 322 KB)
- Bioethanol: Fueling Sustainable Transportation (PDF 322 KB)
- Bioethanol: Moving into the Marketplace (PDF 373 KB)
- 1999 Process Design Report for Wood Feedstock: Lignocellulosic Biomass to Ethanol Process Design and Economics Utilizing Co-Current Dilute Acid Prehydrolysis and Enzymatic Hydrolysis Current and Futuristic Scenarios (PDF 1.9 MB)
- 2002 Process Design Report for Stover Feedstock: Lignocellulosic Biomass to Ethanol Process Design and Economics Utilizing Co-Current Dilute Acid Prehydrolysis and Enzymatic Hydrolysis for Corn Stover (PDF 4.9 MB)
- Determining the Cost of Producing Ethanol From Corn Starch and Lignocellulosic Feedstocks (PDF 525 KB)
- Feasibility Study for Co-Locating and Integrating Ethanol Production Plants from Corn Starch and Lignocellulosic Feedstocks (PDF 1.2 MB)
- Washing Away Bioprocessing Cost (Pressurized Hot Wash fact sheet) (PDF 739 KB)

2.7.7 *Thermochemical Conversion Platform Technology*

- Production of Gasoline and Diesel from Biomass via Fast Pyrolysis, Hydrotreating and Hydrocracking: A Design Case (PDF 4 MB)
- 2007 Biomass Peer Review Thermochemical Conversion Platform Summary of Results (PDF 798 KB)
- 2007 Biomass Program Thermochemical Conversion Platform Accomplishments Report (PDF 278 KB)
- Thermochemical Design Report: Thermochemical Ethanol via Indirect Gasification and Mixed Alcohol Synthesis of Lignocellulosic Biomass, April 2007 (PDF 3.2 MB)
- Today's Biopower (PDF 329 KB)
- Biomass Power for Rural Development (PDF 297 KB)
- Project Update: The Vermont Gasifier (PDF 294 KB)
- Small Modular Biomass Systems (PDF 325 KB)
- Preliminary Screening—Technical and Economic Assessment of Synthesis Gas to Fuels and Chemicals with Emphasis on the Potential for Biomass-Derived Syngas (PDF 1.6 MB)
- Breaking the Chemical and Engineering Barriers to Lignocellulosic Biofuels: Next Generation Hydrocarbon Biorefineries, A Research Roadmap for Making Lignocellulosic Biofuels A Practical Reality (PDF 8.9 MB)

2.7.8 *Biobased Products*

- 2007 Biomass Program Peer Review Biochemical and Products Platform Summary of Results (PDF 1.2 MB)
- New Biocatalysts: Essential Tools for a Sustainable 21st Century Chemical Industry (PDF 612 KB)
- Top Value Added Chemicals from Biomass, Volume I—Results of Screening for Potential Candidates from Sugars and Synthesis Gas (PDF 1.4 MB)
- Top Value-Added Chemicals from Biomass, Volume II - Results of Screening for Potential Candidates from Biorefinery Lignin (PDF 1.0 MB)

2.7.9 *Integrated Biorefineries*

- Information on Integrated Biorefinery Solicitations can be found on the Financial Opportunities page.
- Integrated Biorefinery Project Fact Sheets
- Map of DOE Cellulosic Biorefinery Deployment Projects (PDF 104 KB)
- 2007 Biomass Program Peer Review Integrated Biorefinery Platform Summary of Results (PDF 397 KB)
- 2007 Biomass Program Integrated Biorefineries Platform Accomplishments Report (PDF 333 KB)
- The Biomass Economy, Excerpt from National Renewable Energy Laboratory 2002 Research Review, 1st Edition (PDF 664 KB)

2.7.10 Infrastructure

- Effects of Intermediate Ethanol Blends on Legacy Vehicles and Small Non-Road Engines, Report 1 - Updated (originally released October 2008, updated February 2009) (PDF 5.0 MB)
- 2007 Biomass Program Infrastructure Technology Area Accomplishments Report (PDF 33 KB)
- "Fuel Economy and Emissions of the Ethanol-Optimized Saab 9-5 BioPower", Brian West et. al., SAE 2007 Transactions Journal of Engines, 2007-01-3994 (PDF 220 KB)

2.7.11 Bioethanol and the Ethanol Industry Today

- Biofuels Market Data - updated weekly
- 2007 Year in Review - U.S. Ethanol Industry: The Next Inflection Point, May 2008 (PDF 2.7 MB)
- Handbook for Handling, Storing, and Dispensing E85—Office of Energy Efficiency and Renewable Energy (EERE) Brochure (PDF 1.7 MB)
- The U.S. Dry-Mill Ethanol Industry: Biobased Products and Bioenergy Initiative Success Stories - 2001 (PDF 186 KB)
- Ethanol Fuel Incentives Applied in the U.S. Reviewed from California's Perspective (PDF 770 KB)
- U.S. Ethanol Industry Production Capacity Outlook: Update of 2001 Survey Results (PDF 126 KB)
- Fuel Specifications and Fuel Property Issues and Their Potential Impact on the Use of Ethanol as a Transportation Fuel (PDF 1.2 MB)
- Transportation and Infrastructure Requirements for a Renewable Fuels Standard (PDF 483 KB)
- Infrastructure Requirements for an Expanded Fuel Ethanol Industry (PDF 2.1 MB)

2.7.12 Biodiesel and the Biodiesel Industry Today

- Biofuels Market Data - updated weekly
- 2007 Biomass Program Peer Review Biodiesel and Other Technologies Summary of Results (PDF 713 KB)
- 2007 Biomass Program Other Technologies Accomplishments Report (PDF 168 KB)
- 2008 Biodiesel Handling and Use Guidelines (PDF 2.0 MB)
- Business Management for Biodiesel Producers (PDF 2.1 MB)
- Biomass Oil Analysis: Research Needs and Recommendations (PDF 1.4 MB)

2.7.13 Sustainability & Environmental Impacts

- Fact Sheet: Our Commitment to Sustainability, October 2008 (PDF 1.4 MB) Biomass Program

- Biofuels and Sustainable Development (May 2008), Sustainability Science Program, Harvard Kennedy School of Government (PDF 163 KB)
- Fact Sheet: Leading the Fight Against Hunger (May 2008), White House Web site
- The Effects of Ethanol on Agricultural Food and Feed (April 2008), Texas A&M University Agricultural Food and Policy Center (PDF 2.3 MB)
- The Impact of Ethanol Production on U.S. and Regional Gasoline Prices and on the Profitability of the U.S. Oil Refinery Industry (April 2008), Iowa State University Center for Agricultural and Rural Development (PDF 349 KB)
- Analysis of the Efficiency of the U.S. Ethanol Industry 2007 (March 2008), Argonne National Laboratory (PDF 137 KB)
- Ethanol Facts: Food vs. Fuel (October 2007), National Farmers Union (PDF 329 KB)
- Energy and Environmental Aspects of Using Corn Stover for Fuel Ethanol (2004) National Renewable Energy Laboratory/MIT/Yale University (PDF 1.7 MB)
- Quantifying Cradle-to-Farm Gate Life Cycle Impacts Associated with Fertilizer Used for Corn, Soybean, and Stover Production (PDF 1.3 MB)
- Fuel Cycle Evaluations of Biomass-Ethanol and Reformulated Gasoline (PDF 7.5 MB)
- Fuel-Cycle Fossil Energy Use and Greenhouse Gas Emissions of Fuel Ethanol Produced from U.S. Midwest Corn (PDF 2.6 MB)
- An Overview of Biodiesel and Petroleum Diesel Life Cycles - 5/98 (PDF 463 KB)
- Life Cycle Inventory of Biodiesel and Petroleum Diesel for Use in an Urban Bus - 5/98 (PDF 1.5 MB)

2.7.14 National Bioenergy Center Facilities

- BSCL Use Plan: Solving Biomass Recalcitrance (PDF 1.2 MB)
- The National Bioenergy Center: Laying the Foundation for Biorefineries (PDF 544 KB)
- The DOE Bioethanol Pilot Plant: A Tool for Commercialization (PDF 211 KB)
- NREL Bioprocessing Pilot Plant: Available for Industrial Use (PDF 404 KB)
- DOE Thermochemical Users Facility: A Proving Ground for Biomass Technology (PDF 924 KB)
- Biomass Rapid Analysis Network (PDF 1.7 MB)
- Bioprocessing Research User Facility (PDF 888 KB)

2.7.15 Archival Documents

- 2004 Biomass Program Multi-Year Technical Plan (PDF 6.8 MB)
- Office of the Biomass Program Technical Plan Summary (synopsis of Biomass Program Multi-Year Technical Plan) (PDF 228 KB)
- DOE Biomass Power Program: Strategic Plan, 1996-2015 (PDF 597 KB)
- Biofuels Program Plan: FY 1992 - FY 1996 (PDF 23.8 MB)
- Biopower Program, Activities Overview (PDF 389 KB)
- Agriculture — Industry of the Future: Accelerating the growth of the emerging biobased products industry (PDF 407 KB)

- A Look Back at the U.S. Department of Energy's Aquatic Species Program: Biodiesel from Algae Close-Out Report (PDF 3.7 MB)
- Biodiesel Research Progress 1992-1997 (PDF 838 KB)

Alternative Fuels Data Center
Argonne National Laboratory
Bioenergy Feedstock Information Network - http://bioenergy.ornl.gov/
Biomass R&D Initiative – www.biomass.govtools.us
Department of the Interior
Department of Transportation
Department of Energy (DOE)
DOE Biomass Program
DOE Energy Efficiency and Renewable Energy (EERE), (202) 586-9220, http://eere.energy.gov
DOE EERE Green Power Network
DOE EERE Renewable Electric Plant Information System (REPiS)
DOE Office of Science Bioenergy Research Center
DOE Office of Science Energy Biosciences Program
DOE-USDA Plant Feedstock Geonomics for Bioenergy Program
Economic Research Services (ERS)
EPA AgSTAR Program
EPA Clean Energy Program
Grant Solicitations - www.grants.gov
Idaho National Engineering and Environmental Laboratory
National Bioenergy Center
Office of Science and Technology Policy
Office of the Federal Environmental Executive
The National Science Foundation
United States Department of Agriculture
United States Department of Agriculture—Agricultural Research Service
USDA Biofuels Research Program
USDA Farm Bill proposals – www.usda.gov
USDA Federal Biobased Preferred Products Procurement Program
USDA Federal Biotechnology Resources
USDA Forest Service
USDA Pacific Basin Agriculture Resource Center
USDA Rural Development

3.0 COUNTY OF HAWAII

3.1 Policy

Hawaii County General Plan

Overall guide to county land-use decisions. As a policy document, the General Plan provides the legal basis for all subdivision, zoning, and related ordinances. It also provides the legal basis for the initiation and authorization for all public improvements and projects.[clix] The General Plan is an ordinance, the most recent version was enacted in 2005. The General Plan includes goals, policies, standards, courses of action, and Land Use Pattern Allocation Guide Maps (LUPAG), designating the general location of land uses (including roadways) in the county.[clx]

The General Plan is considered when the Planning Commission is determining a change in zoning, SMA permit, or a Special Use Permit. The application also should comply with the LUPAG map.[clxi]

The Hawaii General Plan states that the island relies on petroleum for 75 percent of its energy needs and that the county "must decrease economic vulnerability and energy costs," in part by way of development of natural renewable energy alternatives.[clxii]

General Plan Policies Related to Alternative Energy

- Encourage development of alternative energy resources.
- Encourage the development and se of agricultural products and bi-products as sources of alternative energy fuel.
- Encourage the expansion of energy research industry.
- Strive to diversify the energy supply and minimize the environmental impacts associated with energy usage.
- New power plants should minimize pollution and comply with HAR 11-46, 59, 60 (noise and air pollution)[clxiii]

Hawaii County Community Development Plans

Layered below the county general plan, community development plans are district policy documents that can offer advance insight to public opinion for and against certain land uses. These plans are also considered with requests for special permits or variances. After being inactive for several years, the community development plans are in the process of being updated.[clxiv]

County Charter

In 1963 the legislature of the State of Hawaiʻi enacted Act 73 enabling the counties of the State of Hawaiʻi to establish charter commissions to study their existing governments and to recommend and draft charters upon determination that a charter form of government was fit and desirable. The County Charter is the "constitution" of the government of the County of Hawaiʻi, and provided the basic framework for its organization and operation.

3.2 Issues Affecting Bioenergy Policy

Biomass Conversion

Biomass has been the Big Island's largest renewable energy resource. From 1994, approximately 13 percent of the island's electricity production was provided by two sugar mills that burned biomass, coal, and fuel oil. The mills have ceased biomass conversion. Biomass conversion is being considered by the Natural Energy Laboratory of Hawaii (NELHA) program at North Kona.[clxv]

1980 Report: Energy Self-Sufficiency for the Big Island of Hawaii
Recommended that county government provide a favorable climate for new energy production and establish an Office of Energy Coordinator who would assist businesses in obtaining information and financial support for energy-related development and recommend changes to the county's energy program, among other duties.[clxvi]

Additional Public/Private Objectives
• Small scale to match the diversified land holdings and communities' desire for smaller-sized businesses
• On-island use of the bioenergy production vs. for export
• Non-extractive utilization of the natural resources
• Regenerative approach – cellulosic processing of crops and by-products
• Locally grown and produced energy can also afford the island's communities the opportunity to assure that environmentally sound practices are adhered to and energy security is enhanced[clxvii]

Opportunities and Challenges for Development of Biofuels Production
• Landholdings extensive and available at reasonable prices
• Zoning infrastructure in place to support both production and processing
• No set systems for the industry; allows for innovation[clxviii]
• Environmental Constraints
  - Land use & competition with food crops
  - Water use constraints
  - Possible invasive species
  - Pesticides & herbicides
• Physical Constraints
  - Limited port storage
  - No refining capacity
  - Impact on local infrastructure[clxix]

Procurement & The Market
- HELCO, a subsidiary of Hawaiian Electric Company, will transition its diesel powered plants from petroleum to biodiesel
- This is significant market encouragement for locally grown biocrops and biodiesel
- Not clear if the utility's commitment to purchase certified, sustainable biofuels is a requirement or simply a purchasing preference[clxx]

County Incentives & Issues
- Success of new crops and industries are often contingent upon adequate subsidies
- Agricultural or Ranch Land Dedication Program requires long term commitment to active agricultural production with lower assessed value
- Biomass crops property tax rate: $500 (dedicated lands)
- Potential for the creation of energy zones

- Facilitate energy crop growth
- Facilitate bio-fuel processing
- Streamlined permitting process at the County level including zoning and building permits[clxxi]

Potential for Biofuels Production
Hawaii Agriculture Research Center (HARC, formerly Hawaii Sugar Planters' Association) 2006 study, "Biodiesel Crop Implementation in Hawaii" indicated
Potential yields in Hawaii County at over 100 million gallons of biodiesel
Resulting in meeting the needs of all the island's demand for highway, non-highway, and utility use three times over[clxxii]

Possible Biofuels Crops
- Algae may have the largest potential with low inputs and high output of energy
- Agroforestry
- Kukui Nut (Aleurites moluccana)
- Macadamia Nut
- Avocado
- Coconut[clxxiii]

Current County Efforts
- Procure funding for experimental production studies to assess the feasibility of cellulosic and biodiesel crop growth and harvesting on Hawaii Island.
- Supplemental funds to support research into production and fuel potential
- Access provided to County lands at Paauilo for UH-H's College of Agriculture, Forestry & Natural Resource Management

3.3 County Ordinances & Zoning

Hawaii Island Zoning:
Conservation: 51 percent
Agricultural: 46 percent
Rural: less than 1%
Urban: 2.5 percent[clxxiv]

Hawaii County Code[clxxv]
The Hawaii County Code is a compilation of all ordinances of a general and permanent nature, with some exceptions. Ordinances relating to the County budget, appropriations, the issuance of bonds, State land use boundary amendments, improvement districts, salary ordinances, and emergency ordinances are not included in this Code. Likewise, the Hawai'i County general plan is also not included.[clxxvi]

Hawaii County Code, Chapter 25: Zoning Code
Hawaii Island has only had island-wide zoning since 1967, when a set of zoning maps were adopted by ordinance. Zoning changes are reviewed by the Planning Commission and are

approved by the County Council through ordinance. There have been more than 1,000 zoning changes in the past 35 years.[clxxvii]

Hawaii County Code, Chapter 28: State Land Use Boundary Amendment Procedures
The County Council, by ordinance, may amend the boundaries of parcels of land that are 15 acres or less in the urban, rural, and agricultural districts. The State Land Use Commission must approve boundary amendments of 15 acres or more, and any boundary amendments affecting land zoned Conservation.[clxxviii] The applicant must fulfill the requirements of the permit for State Land Use Boundary Amendment. See, Hawaii County Planning Commission Rules, Rule 13

Hawaii County Code, Chapter 29: Hawaii County Water Code
As mandated by HRS 174C, the state water code, the Hawaii County Water Code sets out the policy governing water use in the county and coordinates with the county's general plan.

3.4 Permits

Steps (simplified):

1. What are the uses allowed under the Zoning Code?
2. Review the Land Use Pattern Allocation Guide Maps. See, other county maps, including GIS Data Links.
3. Does the project require a zoning boundary amendment?
4. Is the project within the Special Management Area? Does it require a major or minor permit, or is it exempt?
5. Does the project require a Special Permit, Use Permit, or Variance?
6. What are the general administrative/ministerial permit requirements for the particular project or zone? See the Hawaii County Permissible Uses Table, which sets out the uses permitted under the Zoning Code, Chapter 25 of the County Code

Land Use Approval Process
Depending on the uses allowed under the applicable portion of the Zoning Code, some uses are allowed without any further approval. With minor exceptions, permits for construction of structures requires the Planning Department's approval.

Administrative (discretionary) permits: Most common permitting is done administratively through the Planning Department; the Department of Public Works (DPW) and the Department of Water Supply play major roles as well. For example, Grading and Grubbing permits are issued by the DPW. The Planning Department reviews the permit application to determine whether it complies with the applicable zoning code section. The Department of Public Works maintains a building permits page.

Hawaii County Planning Commission Rules
The Planning Commission maintains a website listing most of the common permit forms that require action by the Planning Commission, including applications for:

- Variance – a request to accommodate unusual property circumstances.
- Special Permits – for "unusual and reasonable" uses of land not allowed under the Hawaii County Code. See, Hawaii County Planning Commission Rules, Rule 6

- Use Permits -- Hawaii County Code. See, Hawaii County Planning Commission Rules, Rule 7
- Shoreline Setback Rules -- Hawaii County Code. See, Hawaii County Planning Commission Rules, Rule 8
- Hawaii County Special Management Area (SMA), Hawaii County Planning Commission Rule 9: The SMA, a band around the island from the shoreline up to a mile or more inland, is designated on the zoning maps. Permit applications for projects within the SMA require a determination of whether the "development" (as specified in the rule at 9-4(10) requires a SMA major or SMA minor permit, or is exempt. Projects requiring SMA major permits include those valued over $125,000, or if the Planning Director determines that the development may have a significant environmental or ecological effect within the SMA. The Planning Commission must consider both the objectives and policies of the state coastal zone management program (HRS § 205A-2) and the state Special Management Area guidelines (HRS 205A-26).

3.5 Resources

Hawaii County Energy Offices

Ms. Andrea T. Gill
Hawaii Energy Extension Service
Hawaii Business Center
99 Aupuni Street, Room 214
Hilo, Hawaii 96720
Phone: (808) 933-0312
Fax: (808) 933-0313
Email: agill@dbedt.hawaii.gov

County of Hawaii
Department of Research and Development
25 Aupuni St.
Hilo, HI 96720
Phone: (808) 961-8366
Fax: (808) 935-1205
Email: dley@co.hawaii.hi.us

4.0 COUNTY OF MAUI: MAUI, MOLOKAI, AND LANAI

4.1 Policy

Maui County General Plan

Overall guide to county land-use decisions. As a policy document, the General Plan provides the legal basis for all subdivision, zoning, and related ordinances. It also provides the legal basis for the initiation and authorization for public improvements and projects. The 1990 version of the Maui County General Plan is in effect now; the 2030 General Plan is pending release.[clxxix] The January 2008 draft plan is available online for reference purposes.

Maui County Geographic Information Systems Mapping (GIS) Section

The GIS section provides services to the Planning Department, as well as providing limited assistance to other departments and the public. The GIS team develops and maintains a number of spatial databases and GIS layers. Team members perform spatial data analysis; and develop models, reports, and maps to summarize and illustrate a variety of information important in the planning process. **Reference maps** depict development project resources analysis in support of long range land use planning. **Policy maps** illustrate the draft growth policy of the 2030 General Plan.

Maui County Community Development Plans[clxxx]

The community plans include the goals, objectives, policies, and implementing actions for each district.

Kihei - Makena (1998)
Paia - Haiku (1995)
Wailuku - Kahului (2002)
Makawao - Pukalani - Kula (1996)
Hana (1994)
West Maui (1996)
Lanai (1998)
Molokai; informative also is the USDA's Molokai Enterprise Community project progress reports
Kahoolawe (1995)

4.2 Issues Affecting Bioenergy Policy

2030 Draft General Plan Policies Related to Alternative Energy

While the 2030 Maui County General Plan has not yet been adopted by ordinance, the themes and information in the draft plan are relevant for information purposes.

Self-Sufficiency and Strengthening the Local Economy

The county's economic climate would improve through self-sufficient agriculture, aquaculture, manufacturing, and energy production. Diversification provides opportunities for employment. A key strategy in implementing the General Plan is supporting "clean" industries that meet the county's energy needs.[clxxxi]

Water Use: Issues with Past Privatization

From the late 1800s, privately owned and constructed ditches, flumes, and wells diverted water from streams and aquifers to the sugarcane fields. Some of the aquifers have been damaged from over-use or contamination and water use is a limiting factor on development in the county. Land-use decisionmaking is closely tied to water availability.[clxxxii]

Zoning and Important Agricultural Lands
Of Maui County's 750,900 combined total acreage, 168,500 acres have been identified as potential "Important Agricultural Lands" pursuant to the mandate set by HRS § 205-41, et seq. Food and energy production required for the county could take place entirely within the county.[clxxxiii]

Land Use: 53.8 percent of the land in Maui County is Ag zoned:
Maui: 52.8 percent
Molokai: 67.3 percent
Lanai: 51.5 percent
(Kahoolawe is 100% Conservation zoned.)[clxxxiv]

Maui Economic Development Board
The MEDB was formed to assist the mayor in diversifying the county's high-tech potential. Projects include the Maui Research and Technology Park in Kihei.[clxxxv] The Research and Technology Park is a separately zoned sub-district governed by Maui County Code § 19.33.

4.3 Land Use

Maui County Code[clxxxvi]
Maui County Code, Title 16: Buildings and Construction
Maui County Code, Title 19: Zoning Code
Agricultural District Zoning, § 19.30A
Permitted uses include agriculture and agricultural parks,
Maui County Code, Title 20: Environmental Protection
Includes ordinances relating to air pollution and soil erosion and sedimentation control.
Maui County Code, Title 22: Agricultural Parks

Land Use Approval Process
Administrative (discretionary) permits: Most common permitting is done administratively through the Planning Department; the Department of Public Works (DPW) and the Department of Water Supply play major roles as well. For example, Grading and Grubbing permits are issued by the DPW. The Planning Department reviews the permit application to determine whether it complies with the applicable zoning code section. The Department of Public Works maintains a building permits information page.

Construction Permits & Applications

Development Permits, Applications, Reviews, and Variances
Alphabetical listing of Development Applications
Amendment to Planning Permit Terms
Arborist Committee Plans Review
Community Plan Amendment (CPA)

Conditional Permit**:** The intent of the conditional permit, under Maui County Code § 19.40 is to provide the opportunity to consider establishing uses not specifically permitted within a given use zone where the proposed use is similar, related or compatible to those permitted uses and which has some special impact or uniqueness such that its effect on the surrounding environment cannot be determined in advance of the use being proposed for a particular location.
Environmental Assessment Determination (EA, EIS, EAE)
Farm Plan Application
Lanai
Molokai
Project Master Plan Approval(PMP)
Review: This link includes applications for review of a variety of permits and environmental review.
Special Management Area: These include a variety of applications necessary for development (large and small) or increase in intensity or change of use within the SMA, which is that area of land in proximity to Maui's shoreline.
Special Use Permit, Maui County Code § 19.510.070, Special Permit, HRS 205A-29 (State Land Use Commission action required for parcels 15 acres or larger.) SUPs are required for "unusual and reasonable" uses within the Agricultural and Rural districts. "Special use" means a use which meets the intent and purpose of the zoning district but which requires the review and approval of the appropriate planning commission in order to ensure that any adverse impacts on adjacent uses, structures, or public services and facilities which may be generated by the use can be, and are, mitigated. "Major utility facilities," pursuant to Maui County Code § 19.04.040 require a special permit.
Variance and Appeals: These applications are used to request a variance to a zoning standard or requirement or to appeal a decision rendered by a county department or commission.
Zoning and Land Use: land use entitlements and zoning changes, such as Change in Zoning Permit; Community Plan Amendment; State Land Use Commission District Boundary Amendment; and Zoning and Flood Confirmation Form

4.4 Land Use Departments, Agencies, Commissions, other links

- Water use: Maui County rules and regulations
- Maui County Department of Planning
- The Department of Planning offers technical advice to the mayor, Maui County Council, and commissions, proposes zoning legislation, drafts long range plans, reviews development proposals, and enforces zoning regulations. Other planning responsibilities include general and community planning, cultural resources management, data collection, census information, mapping and geographic information, special projects, and miscellaneous permits. The Department's **Zoning Administration and Enforcement Division (ZAED)** responds to zoning questions, reviews the zoning requirements for building permit and subdivision applications and handles enforcement of the zoning codes.
- Public Works, Development Services Administration (DSA)
- Department of Water Supply
- Hawaii State Department of Health
- Maui Fire Prevention Bureau
- Management Information Systems

- Department of Environmental Management
- State Department of Land & Natural Resources (DLNR)
- Department of Housing & Human Concerns
- Maui County Planning Commission advises the Mayor, County Council, and Planning Director in matters concerning planning programs.
- Reviews the general plan and revisions thereof prepared by the Planning Director or at the request of the County Council, and after public hearings, transmits findings and recommendations to the County Council for consideration and action. Reviews other proposed land use ordinances and amendments prepared by the Planning Director or by the County Council, and after public hearings, transmits findings and recommendations to the County Council for consideration and action. Acts as the authority in all matters relating to the Coastal Zone Management Law. Adopts rules pursuant to land use ordinances or law.[clxxxvii]
- Maui County Board of Variances and Appeals hears and determines applications for variances from the strict application of any general plan, zoning, subdivision or building ordinances. Holds public hearing prior to ruling on a variance application and issues findings of fact and conclusions of law on decisions granting or denying variance applications.

4.5 Resources

Maui County Energy Offices

Victor Reyes
Energy Commissioner
Office of Economic Development
Maui County
2200 Main Street, Rm. 305
Wailuku, HI 96790
Phone: (808) 270-7203
Fax: (808) 270-7995
Email: Victor.Reyes @mauicounty.gov

Kalvin Kobayashi
Energy Coordinator
County of Maui
Managing Director's Office
200 South High Street, Room 604
Wailuku, Maui, Hawaii 96793
Phone: (808) 270-7832
Fax: (808) 270-7141
Email: energy.office@mauicounty.gov
Website: www.co.maui.hi.us/departments/Management/energy.htm

5.0 CITY & COUNTY OF HONOLULU

5.1 Policy

Oahu General Plan's Energy section includes the following policies:

- Develop and maintain a comprehensive plan to guide and coordinate energy conservation and alternative energy development and utilization programs on Oahu.
- Establish economic incentives and regulatory measures which will reduce Oahu's dependence on petroleum as its primary source of energy.
- Support programs and projects which contribute to the attainment of energy self-sufficiency on Oahu.
- Give adequate consideration to environmental, public health, and safety concerns, to resource limitations, and to relative costs when making decisions concerning alternatives for conserving energy and developing natural energy resources.
- Support the increased use of operational solid waste energy recovery and other biomass energy conversion systems.
- Support and participate in research, development, demonstration, and commercialization programs aimed at producing new, economical, and environmentally sound energy supplies from: solar insulation; biomass energy conversion; wind energy conversion; geothermal energy; and ocean thermal energy conversion.
- Secure State and Federal support of City and County efforts to develop new sources of energy.

The Department of Planning and Permitting, Planning Division, helps establish, promote, and implement long-range planning programs for Honolulu. The Planning Division is responsible for maintaining and updating the Oahu General Plan, regional Development/Sustainable Communities Plans, Development Plan Land Use Annual Reports, Special Area and Neighborhood Master Plans. The Planning Division also provides research and statistical information related to Oahu's population, land use, and employment. The Planning Division, participates in various planning initiatives for the island of Oahu. These initiatives include:

- Board of Water Supply Watershed Management Plans
- Oahu Metropolitan Planning Organization
- Hawaii 2050 Sustainability Summit

Honolulu City and County Neighborhood Boards

There are 36 neighborhood boards on the island of Oahu. The Neighborhood Board system is an island-wide network of elected neighborhood boards as communication channels, expanding and facilitating opportunities for community and government interaction.[clxxxviii]

Interactive GIS Maps and Data

The Honolulu Land Information System (HoLIS) is a Geographic Information System (GIS) with land use, permit, tax, infrastructure, and environmental data.

5.2 Permitting and Land Use

Department of Planning and Permitting provides information concerning land use planning-related approvals, including development plan and public infrastructure map amendments, State

Special Use Permits (involving less than 15 acres), and zoning map changes. Also, information about State Land Use Boundary amendments for sites involving less than 15 acres.

Land Use Permits Division

The Department of Permits and Planning, Land Use Permits Division (LUPD), administers the City's zoning ordinance, the Land Use Ordinance (LUO) (the zoning code for the City and County of Honolulu), and other land use regulations mandated by the City, State and Federal governments.

LUPD processes "discretionary" permits, which will usually include conditions to prevent negative impacts on other uses within a zoning district. Almost all permits are classified as either Major or Minor, depending on the anticipated impacts within each zoning districts. List and Description of Permits

- Dept. of Planning & Permitting Rules, Part 1, Rules of Practice and Procedure
- Dept. of Planning & Permitting Rules, Part 2, Rules Relating to Shoreline Setbacks and the Special Management Area
- Master Application Form
- Planning Permits include State Land Use District Boundary Amendment, State Special Use Permits, Zone Change Applications
- Zoning and Land Use Permits include Special Management Area Use, Conditional Use, Zoning Variance, and Zoning Adjustment
- Engineering and Subdivision Permits
- Land Use Permits Division Contact List

Building Permit Information

Information concerning the building permit process and approvals, including plan review information and permit forms. Also available is the building report for daily, monthly and yearly permit activities.

- Building Code
- Building Permit Fees Summary Table
- Construction and Building Permits
- Checklist for Submitting Permit Plans

5.3 Resources

Official website of the City & County of Honolulu
Economic Development Data Center
Economic Development Resources

6.0 KAUAI COUNTY

6.1 Policy

Kauai Economic Development Plan (2005-2015) and Kauai General Plan

- Minimize imports and promote import substitution
- Diversify economy
- Industries with export potential preferred
- Biomass and ethanol provide opportunities for cross-industry benefits between alternative energy producers and agricultural producers.
- Goal: Develop a renewable energy park to showcase new renewable energy technologies, and commercial and residential installation/use.
- Plan, construct, and maintain an ethanol plant and biomass facility

Kauai Geographic Information Systems Mapping

- Links to Land Use Maps and Heritage Resource Maps
- **KOHA** - Kauai Online Hazard Assessment Tool is now online. This site was developed (and is currently being hosted) by the National Oceanic & Atmospheric Administration (NOAA).

Kauai's Agricultural Lands

Total Land Area: 353,900 acres
Agricultural District 140,800 acres

Agricultural Lands of Importance to the State of Hawaii (ALISH study):

- Prime, Unique, and Other Important lands: 83,040
- Prime: 54,920

University of Hawaii Land Study Bureau (LSB) Lands:

- Lands Rated "A", "B", and "C": 68,980
- Lands Rated "A" and "B": 40,440
- Lands in Crop Production: 38,100

6.2 Water & Irrigation

Department of Water - forms and permit applications
Board of Water Supply: Kauai County Charter – Article XVII, rules and regulations
Wastewater Management
Kauai Fire Department - permits for temporary structures and above ground / under ground tank installation and removal

Many reservoirs and ditches are poorly maintained, and some – primarily on the north and east sides of the island – have been taken out of use or abandoned. Some systems have been interrupted by land subdivisions, so that the reservoir may be owned by one entity while the ditches are divided among multiple owners.[clxxxix]

On the North Shore, some former Kilauea Plantation systems no longer function due to ownership or operational problems. On the east side, former systems are falling into disrepair in areas such as Kapaa and Kealia where Lihue Plantation has abandoned cultivation and is selling off lands. In contrast, on the south and west sides of the island, large sugar, seed corn, and coffee plantations continue to use and maintain their irrigation systems. Without irrigation, the potential for intensive agriculture is severely diminished, if not lost.

The State Department of Agriculture, Agribusiness Development Corporation's mission is to acquire, and manage in partnership with farmers, ranchers, and aquaculture groups, selected high-value lands, water systems, and infrastructure for commercial agricultural use and to direct research into areas that will lead to the development of new crops, markets, and lower production costs.

6.3 Land Use Authority and Process

Kauai County Charter

Governing document for county governance and procedure.

Comprehensive Zoning Ordinance

The purpose of the Comprehensive Zoning Ordinance (CZO) is to provide regulations and standards for land development and the construction of buildings and other structures. The regulations and standards prescribed in the CZO are intended to regulate development to ensure its compatibility with the overall character of the island. Copies of individual ordinances are available from the County Clerk's Office, phone (808) 241-6371.

Planning Department

The Planning Department advises the mayor, Planning Commission, and County Council on planning and land use matters for the County of Kauai. The Department is also responsible for the administration and enforcement of the Zoning and Subdivision Ordinances as well as the County's planning program, which consists of long range and regulatory policy documents like the General Plan and Comprehensive Zoning Ordinance.

The Planning Commission consists of seven members from the public that are appointed by the Mayor and confirmed by the Council. The Planning Commission meets twice a month to hold public hearings on zoning and land use permits and applications, as well as render decisions on these matters.

Department of Public Works Building Division

The Building Code Enforcement Section is responsible for the review of projects to ensure compliance and enforcement, of the all applicable building trade codes and ordinances, related to building construction. As the central coordination agency in the building permitting process, the program is responsible for the circulation and consolidation of comments from County, State, and Federal agencies, prior to permit approval. The program is also responsible for building, electrical, plumbing, and sign code enforcement inspection, as part of the permitting process.
Building Permit Guide - guide to obtaining building permits, including forms and frequently asked questions.

Building Permit Status – application status, plan tracking, and inspections
Engineering Division - Provides general engineering and surveying services for the department

of Public Works. The division administers grading, grubbing, stockpiling, flood plain ordinance, speed hump ordinance, and driveway approach ordinance. There are three subdivisions: **Construction Management & Inspection**, **Design & Permitting**, and **Survey & Mapping**.

6.4 Resources

Kauai County Energy Office
Glenn Sato
Energy Coordinator
County of Kauai
Office of Economic Development
4444 Rice Street, Suite 200
Lihue, HI 96766
Phone: (808) 241-4951
Fax: (808) 241-6399
Email: GSato@kauai.gov
Website: http://www.kauai.gov/

Hawaii Department of Health - permits and licenses, including burn permits
Kauai Office of Economic Development
Kaua'i Economic Development Board
Kaua'i Chamber of Commerce
Kaua'i Community College
Garden Island Resource Conservation and Development, Inc.,
West Kaua'i Community Development Corporation
Kapaa Business Association
North Shore Business Association
Open Space Commission: Public Access, Open Space, and Natural Resources Preservation for the island of Kauai.
Kauai Historic Preservation Commission: The Kauai Historic Preservation Review Commission, which consists of nine members, meets on a monthly basis and is staffed by the Planning Department. Meetings usually entail project reviews at which time the KHPRC provides recommendations on various aspects of archaeological and building design review of historic resources and in-fill development. Other issues relating to the promotion of historic preservation on Kauai are also discussed.

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