DRAFT FOR REVIEW

HAWAII ETHANOL ALTERNATIVES

Study Conducted By

Stillwater Associates

For

Department of Business, Economic Development & Tourism

Strategic Industries Division

State of Hawaii

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SCOPE OF WORK

This study was commissioned by DBEDT to evaluate the potential impact of the 10% ethanol mandate in Chapter 486J, Hawaii Revised Statutes, amended by Act 77, Session Laws of Hawaii (SLH) 2002, on Hawaii's gasoline market in general and Act 77's price caps in particular.

Scope of Work: Stillwater Associates is to conduct an evaluation of Hawaii's 10% ethanol mandate, as described in Items 1 - 7 below, to determine and develop a report with findings, conclusions and recommended policy and/or other options the State of Hawaii and/or industry should consider addressing the following issues:

1. Impact of ethanol blending on overall fuel balances within the context of the Hawaii refinery production constraints, as well as costs for refiners and distributors, to include but not be limited to blending cost impacts, such as ethanol tankage addition, loading rack modifications, retail site preparation, and all other costs associated with the implementation and maintenance of a 10% ethanol mandate program.
2. Impact of implementation of the 10% ethanol mandate on the average cost of gasoline to the Hawaii consumer, in cents per gallon, both with and without the price caps in Act 77, SLH 2002.
3. Assess the impact of ethanol blending on implementation of the Act 77, SLH 2002 price caps.
4. Costs and benefits to the Hawaii economy in terms of the cost of State incentives and direct or indirect loss of tax revenues, versus gains from increased agricultural activity.
5. Alternative options to realize the gains of producing ethanol in Hawaii, but for exports to California rather than consumption in Hawaii.
6. Competitive positioning of Hawaii ethanol production for the California market versus producers in the Midwest, Brazil, and producers enjoying Caribbean Basin initiative benefits.
7. Identification of the logistic constraints and costs for all evaluated options.

During the course of the study, the scope has expanded to include an evaluation of the production potential and production cost of ethanol in Hawaii, without which a cost/benefit evaluation could not be undertaken.

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EXECUTIVE SUMMARY

The scope of this study was limited to assessing the impact of blending of ethanol into Hawaii's gasoline pool on the overall fuel balance, refinery economics, and gasoline distribution costs. Of particular interest were the likely consequences for Hawaii's gasoline consumers. As it turned out, a fair amount of time was spent in evaluating the supply economics for ethanol in Hawaii, because the cost of ethanol is a key element in the overall economical evaluation of market options.

The overall conclusion is that Hawaii has significant potential to economically produce ethanol from sugarcane. Large scale ethanol production could add as much as $300 million to the local economy in direct and indirect value. However, in the near to midterm future, it will be more beneficial for consumers, producers, the existing petroleum industry and the State of Hawaii's public finances if locally produced ethanol is not used in Hawaii but exported to California.

(i) **Hawaii's Ethanol Potential**. According to prior studies cited elsewhere in this report, Hawaii can produce up to 90 million gallons per year of ethanol for gasoline blending when sugarcane is used as energy crop.

a. Up to 85,500 acres of suitable land were identified in prior studies as available for sugarcane production yielding on average 18 ton of dry matter at a cost of $85 per ton of dry matter excluding land rents.

b. On Maui, Oahu and the Big Island, highly integrated processing plants can be built with sufficient economies of scale, combining ethanol production from crushed cane with efficient heat and power generation from bagasse and other biomass. Such power generation has the benefit of replacing diesel fuel as primary energy source.

c. Additional opportunities exist in generating ethanol from lignocellulosic biomass from waste if the developmental technologies to do so mature to a commercial stage. However, given Hawaii's high electricity prices, it is likely to be more economical to use this additional biomass for power generation through direct combustion rather than for ethanol production.

d. When produced at large scale in integrated processing plants that co-produce heat and power, the costs of producing ethanol from sugarcane in Hawaii are estimated to be competitive with production from corn in the Midwestern states, i.e., in the range of $1.25 to $1.30 per gallon. These costs include the effects of fiscal incentives for the producers but exclude the federal excise tax credit. With the excise tax credit, a blender of ethanol will enjoy a cost advantage over base gasoline blendstock at gasoline prices that correspond to world crude oil pricing as forecasted for the short to medium term.

(ii) **Considerations for Local Use**.

a. For each gallon of ethanol blended in Hawaii gasoline, the local refiners will have to downgrade two thirds of a gallon of gasoline to naphtha and export it at much lower margins or even at a loss. Moreover, to lower the vapor pressure of the remaining gasoline as required to meet industry specifications after ethanol blending, refiners may have to modify operations, and spend capital on distillation and storage facilities. Such cost increases however are offset by excise tax credits and octane value, and the net effect on the wholesale gasoline price at the truck loading rack is likely to be cost neutral.

b. Because of ethanol's affinity to water, the petroleum industry will have to segregate ethanol from gasoline until it is blended into the delivery truck. To provide a segregated distribution system for ethanol in the islands with blending facilities at the truck racks is estimated to cost up to $10 million, and strain already scarce port resources in terms of terminal space and dock use. Hawaii's small and fragmented gasoline market, which already suffers from high costs and diseconomies of scale, would be further strained by the cost of a separate ethanol distribution system.

c. It now seems unlikely that any significant ethanol production can be expected to start up until well into 2006. Since the Hawaii State retail excise tax exemption for gasoline containing 10% of ethanol is slated to disappear by the end of that year, this tax credit is unlikely to have an impact on local ethanol production and marketing.

d. Although the increases in the production cost of gasoline and the handling cost for the ethanol are offset by the effect of the Federal ethanol incentive, Hawaii consumers' expenditures for fuel would increase because of a 3% reduction in fuel efficiency due to the lower heat of combustion per unit of volume of ethanol versus gasoline. The increased usage is estimated to increase the cost to the Hawaii gasoline consumers by approximately $20 million per year.

e. The net effect of blending Hawaii-produced ethanol into most or all of Hawaii's gasoline is a reduction in combined State and County tax revenues of about $2 million per year (See Table 7.1).

(iii) **Benefits from Exporting Hawaii's Ethanol to California**. Hawaii's ethanol production can be exported to California, and to do so has significant benefits over local consumption:

a. California's requirements are in excess of 700 million gallons per year, and refiners in California are likely to welcome the opportunity to diversify supply from the Midwest by bringing in cargoes from Hawaii.

b. The size of the California market allows ethanol production in Hawaii at a scale not possible for the local market alone.

c. Hawaii would have all the economic benefits of ethanol production, such as a new lease on life for its sugarcane industry, the ethanol plant investments, and increased power generation from renewable fuels, without the burden to the State of losses in local excise taxes or even higher gasoline expenditures.

d. Hawaii's gasoline infrastructure, which is already a high cost operation, would be spared additional investments and costs which would have to be reclaimed from the consumers.

(iv) **Recommendations**. The key recommendation from this study is for Hawaii to pursue a public policy directed at promoting the production of ethanol from sugarcane and the use of energy crops for power generation, but not to mandate local use. Rather, Hawaii's policies should aim to promote exports of ethanol to California as a means to achieve the same benefits for the local economy. Specific recommendations are to:

a. Support private industry initiatives to produce and/or market ethanol, especially those directed at exports of ethanol to California.

b. Draft legislative proposals to repeal 486J §10 which currently requires the Petroleum Commissioner to enforce usage of ethanol once available.

c. Evaluate the potential of ethanol production in more detail in the context of an integrated energy policy for the State of Hawaii which includes potential distributed power generation from biomass, upgrades of refineries, and alternative fuels for power generation.

d. Evaluate the potential for production of Ethyl Tertiary Butyl Ether (ETBE) using locally produced ethanol and isobutylene from the local refineries as a means to avoid the difficulties of logistics and blending associated with blending of ethanol with gasoline.

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1 POTENTIAL FOR ETHANOL SUPPLY IN HAWAII

Several comprehensive studies have been completed over the last decade to evaluate the production potential of ethanol in Hawaii. In their aggregate, these studies considered a wide range of feedstocks and various production processes. In the limited scope of this study, it is not the intent to provide an independent reevaluation of the supply aspects. Rather, a summary is provided below of the previous work as the starting point for an analysis of the impact of ethanol on Hawaii fuel markets and the potential value of locally produced ethanol for exports.

1.1 Ethanol from Sugar and Molasses

Sugar and molasses have the advantage of being easily fermentable to ethanol using well proven commercial processes. Hawaii has more than 150 years of experience in growing sugarcane and an extensive commercial infrastructure exists in the islands for processing the cane into sugar. Moreover, the sugar cane industry in Hawaii has been in decline over the past decades, and there is unused acreage with idled facilities that could be brought into production again at costs well below new development. Sugarcane must therefore be considered the primary feedstock for development in the short term, i.e., within the next two to five years.

1.1.1 Supply Potential

In a detailed study completed in 1999 by the Department of Bioengineering of the University of Hawaii at Manoa under a grant from the National Renewable Energy Laboratory[1], Kinoshita and Zhou identified at total of 85,500 acres in Oahu, Hawaii, Maui and Kauai that are imminently suitable for growing energy crops. For this acreage, their study compared two grasses, sugarcane and banagrass, and two trees, eucalyptus and leucaena.

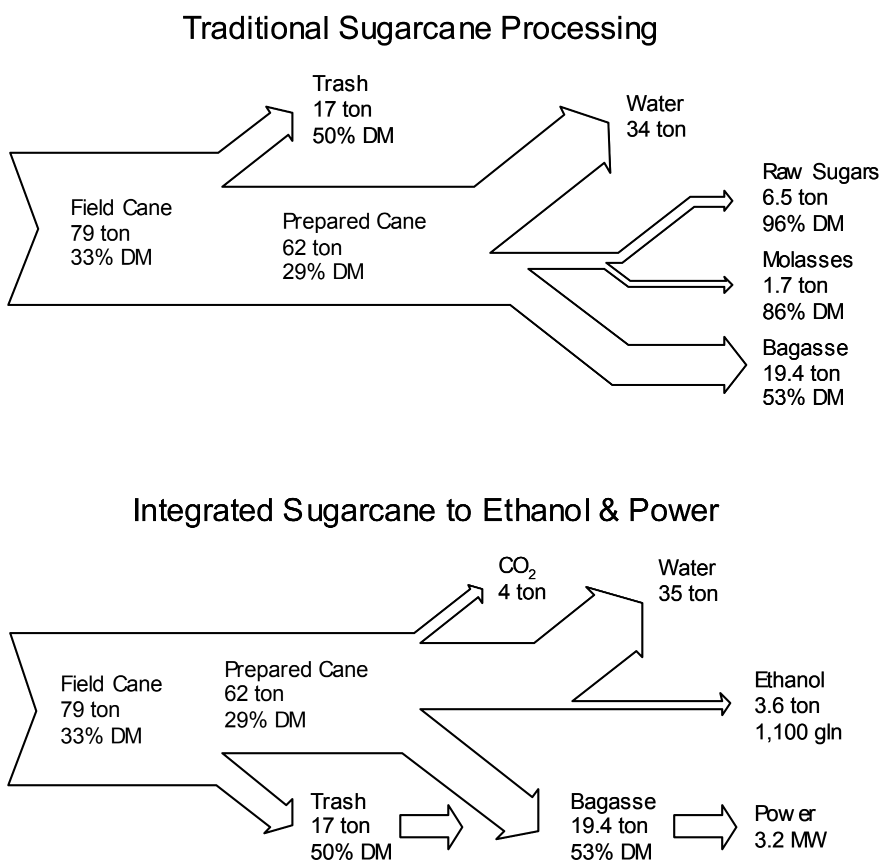
According to Kinoshita and Zhou, sugarcane crops in Hawaii yield approximately 18 tons of dry matter per acre per year at a cost of $85 per ton (excluding land rent). Using data from Dr Shleser's study of potential ethanol production in Hawaii[2], these 18 tons of dry matter yield on average 6.2 ton of raw sugars, 1.5 ton of molasses, and 10.3 ton of bagasse, all on a dry matter base (From Dr Shleser's report, Fig. III-9, *Prepared Cane to Ethanol Diagram*, by converting per crop numbers to acre-year with 18 tons total dry matter, see Figure 1.1 below). With conventional technology, it is assumed

1 Charles M. Kinoshita, Jiachun Zhou, *Siting Evaluation for Biomass Ethanol Production in Hawaii*, Bioengineering Department, University of Hawaii at Manoa, under NREL Grant XXE-8-17099-01

2 Dr Robert Shleser, *Ethanol in Hawaii*, Report Prepared for DBEDT 1994

that only the sugars and molasses can be converted to ethanol, yielding approximately 1,100 gallons of ethanol when still using Dr Shleser's numbers. Under this scenario, bagasse is burnt for steam and power at the mill, while the leafy trash is not used.

Figure 1.1 – Crop Yield Assumptions, Short Tons per Acre-Year[3]



If sugarcane were to be grown exclusively for the purpose of ethanol production, the crushed cane juice would be fermented directly, rather than refined into raw sugars and molasses first. In such a process, the leafy trash and the bagasse can be used as fuel for generation of process steam and power.

In a recent presentation, Yancey[4] uses ethanol yields of 150 gallons per ton of Dry Matter (DM) for raw sugars and 72 gallons per dry ton for molasses. With a per acre

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3 From Dr Shleser's report, Fig. III-9, *Prepared Cane to Ethanol Diagram*, by converting per crop numbers to acre-year with 18 tons total dry matter

4 Mark Yancey, *Economic Impact Assessment for Ethanol Production and Use in Hawaii: An Interim Report*, Presentation prepared by BBI International for the Hawaii Ethanol Workshop, November 14, 2002

yield of 6.2 ton of sugars and 1.5 ton (DM) of molasses this would result in a net ethanol production of 1,038 gallons per acre-year. Part of the difference between Yancey's numbers and those of Dr Shleser seem to be in the ethanol yield of molasses, which the latter pegs at 60% sugars, resulting in an ethanol yield of 92 gallons per dry ton versus Yancey's 72. These differences are well within the expected range of variations for crop related data.

With 85,500 acres of potential additional land to be cultivated for energy crops and a yield of 1,100 gallons of ethanol per acre-year, Hawaii in principle could produce over 90 million gallons per year of ethanol just based on sugarcane and conventional processing. A summary of the possibilities by island is provided in Table 1.1 below.

Table 1.1 – Ethanol Production Potential from Raw Sugar & Molasses

		Hawaii	Maui	Oahu	Kauai	Total
Available Land*	acres	27,000	26,000	25,500	7,000	**85,500**
Dry Biomass*	t/year	486,000	468,000	459,000	126,000	**1,539,000**
Raw Sugar	t/year	167,400	161,200	158,100	43,400	**531,100**
Molasses	t/year	40,500	39,000	38,250	10,500	**128,250**
Ethanol	**MM GPY**	**28.8**	**27.7**	**27.2**	**7.5**	**91.2**

* From Kinoshita and Zhou, Table 4.17 (ibid) using 300 crop delivery days per year to calculate annual totals. This does not include the acreage currently in sugar crop in Maui and Kauai (approximately 35,000 and 10,600 acres respectively).

In summary, using only raw sugars and molasses from idled lands while relying on proven commercial technologies, Hawaii has a short term supply potential of over 90 million gallon per year of ethanol.

1.1.2 Production Costs

The cost of producing ethanol will obviously depend on the process configuration and feedstock selection. One potential route, as proposed by Yancey in the study cited above and is also the basis for the small ethanol plant currently proposed for Maui, assumes that the ethanol plant is operated as a stand-alone facility which purchases raw sugar and molasses from a sugar mill. The feedstock costs used by Yancey assume the use of all molasses currently produced in Maui and Kauai, while purchasing raw sugars for the remainder of the feedstock requirements at prices below world market levels.

The potential problem with this configuration is that it assumes that the majority of the cost for growing and processing the sugarcane is born by the production of sugar as the main product, so that ethanol feedstock cost will benefit from by-product or incremental cost economics. However, there is uncertainty surrounding the continued economic viability of Hawaii's sugarcane industry in the face of more open competition when tariff protection is lifted. Therefore it seems more realistic to assume that future ethanol production will have to carry the full feedstock cost for the total harvest.

Typically, a dedicated sugarcane-to-ethanol plant would not separate and dewater the raw sugars and molasses, but ferment the crushed cane directly. In such an integrated operation, the unconverted biomass after fermentation would be used to generate heat and power. In a detailed engineering evaluation for ethanol production from lignocellulosic biomass, researchers and engineers from the National Renewable Energy Laboratory and the Harris Group provide cost data for a small state-of-the-art fluidized bed combustor for wet biomass waste[5].

In Table 1.2 below, capital and operating cost numbers for a stand-alone ethanol plant which purchases molasses and raw sugars are compared with a fully integrated operation for several plant sizes. The following assumptions were made when preparing Table 1.2.

- Capital costs are based on various estimates provided by industry sources[6]. A scaling exponent of 0.7 was used to calculate capital cost for larger scale plants.
- Capital cost for the biomass combustor was scaled in from the NREL study ($38 MM for a unit for 407,420 lb/hour of steam at 1,265 psia and 950 ^{0}F, generating 30.4 MW; cost included all auxiliaries including bag filters).
- Power consumption is estimated at 32.5 kWhr per ton of prepared cane (wet). Power consumption for the ethanol plant is estimated at 0.65 kWh per gallon of ethanol. Power is purchased at $0.12/kWh and sold at $0.06/kWh, numbers based on recent year averages on Maui and Kauai. A 30 MM GPY ethanol plant could generate as much as 68,000 MWh of export power, enough to replace approximately 10% of the power currently produced by diesel driven generators in Maui.

5 A. Aden, M. Ruth, K. Ibsen, J. Jechura, K. Neeves, J. Sheehan, and B. Wallace, *Lignocellulosic Biomass to Ethanol Process Design and Economics Utilizing Co-current Dilute Acid Prehydrolysis and Enzymatic Hydrolysis for Corn Stover*, National Renewable Energy Laboratory, June 2002, NREL/TP-510-32438

6 Amongst other sources, information was received from representatives of ED&F Man, the party currently contemplating an ethanol project at Maui.

- Feedstock costs are based on production costs of sugarcane biomass of $85 per ton of dry matter as calculated by Kinoshita and Zhou, with an adjustment for dry matter usage to reflect the 5% volume added by denaturants.

- For the stand-alone case, feedstock purchase prices are assumed at $40/ton for molasses (average historical, wet tons), and $200 for raw sugar, which is the expected level for world market sugar prices in a deregulated environment in 2005[7]. As such these prices represent the opportunity cost for the raw materials in the timeframe a new plant can be expected to come on-stream at the earliest.

- The payroll expenses are kept constant for the 10 and 20 million gallons per year cases. Within this range of operating capacities, staffing levels are the same. Adjustments are made however for operating a biomass cogeneration plant (one additional operator per shift) and for the very large unit.

- The required margin for debt service and capital recovery after taxes and depreciation is taken at 24% of capital costs. At 40% financing at 8% interest over 8 years, tax depreciation over 10 years, 34% federal tax and 6.44% State income tax, this would result in a return on equity of approximately 18 to 20%.

Table 1.2 below shows the breakdown of capital cost and operating expenses for a 10 MM GPY plant representative for a Kauai operation or a Maui based molasses only plant, and a medium and large facilities of 20 and 30 MM GPY respectively. The latter would be representative for the largest plant size sustainable by the sugarcane production potential of Oahu, Maui or Hawaii.

The resulting minimum price for ethanol from sugarcane ranges from $1.27 per gallon for a 20 MM GPY integrated plant to $1.53 per gallon for a large stand-alone facility using molasses and raw sugars at market prices. These prices include the effect of producer incentives which are valid for the first 8 to 10 years of operation. After taking into account the effect of the federal excise tax waiver of 52 cpg, the lower end of the production cost range will result in attractive economics for wholesale gasoline blenders.

7 Brent Borrel, David Pierce, *Sugar: The Taste of Liberalisation,* Centre for International Economics, October 1999

Table 1.2 – Production Costs of Ethanol from Sugarcane

Plantsize		Small 10 MM GPY		Medium 20 MM GPY		Large 30 MM GPY	
		Inte-grated	Stand Alone	Inte-grated	Stand Alone	Inte-grated	Stand Alone
Capital	**$ 000**	**19,000**	**14,000**	**32,000**	**24,000**	**42,500**	**31,900**
Operating Expense							
Feedstock							
Prepared Cane	ton (wet)	536,050	536,050	1,072,100	1,072,100	1,608,150	1,608,150
Total Dry Biomass	ton (dry)	155,455	155,455	310,909	310,909	466,364	466,364
	$/ton (dry)	85.00	-	85.00	-	85.00	-
	$ 000/yr	13,214	-	26,427	-	39,641	-
Raw sugars	ton (wet)	-	55,776	-	111,553	-	167,329
	ton (dry)	-	53,545	-	107,091	-	160,636
	$/ton (wet)	-	200.00	-	200.00	-	200.00
	$ 000/yr	-	11,155	-	22,311	-	33,466
Molasses	ton (wet)	-	15,063	-	30,127	-	45,190
	ton (dry)	-	12,955	-	25,909	-	38,864
	$/ton (wet)	-	40.00	-	40.00	-	40.00
	$ 000/yr	-	603	-	1,205	-	1,808
Bagasse	ton (wet)	293,310	-	586,621	-	879,931	-
	ton (dry)	155,455	-	310,909	-	466,364	-
	MM Btu/ton (dry)	-	-	-	-	-	-
	MM Btu/yr	-	-	-	-	-	-
Feedstock Cost	**$ 000/yr**	**13,214**	**11,758**	**26,427**	**23,516**	**39,641**	**35,273**
Ethanol Processing							
Other Chemicals							
Denaturant Price	$/bbl	36.00	36.00	36.00	36.00	36.00	36.00
Denaturant Usage	bbl/yr	12,143	12,143	24,286	24,286	36,429	36,429
Denaturant Costs	$ 000/yr	437	437	874	874	1,311	1,311
Chemicals	$ 000/yr	789	769	1,184	1,154	1,579	1,539
Total Chemicals	**$ 000/yr**	**1,226**	**1,206**	**2,058**	**2,028**	**2,890**	**2,850**
Utilities							
Fuel Oil Price	$/bbl	31.00	31.00	31.00	31.00	31.00	31.00
Fuel Oil Usage	bbl/yr	-	60,930	-	121,860	-	182,790
Fuel Oil Costs	$ 000/yr	-	1,889	-	3,778	-	5,666
Electricty Price	$/kWhr	0.06	0.12	0.06	0.12	0.06	0.12
Electricity Use (Production)	MWhr/yr	(22,667)	6,476	(45,333)	12,952	(68,000)	19,429
Electricity Cost (Revenue)	$ 000/yr	(1,451)	777	(2,901)	1,554	(4,352)	2,331
Utility Costs (Revenues)	**$ 000/yr**	**(1,451)**	**2,666**	**(2,901)**	**5,332**	**(4,352)**	**7,998**
Labor and Benefits	**$ 000/yr**	**828**	**753**	**828**	**753**	**828**	**753**
Other Ops Costs	**$ 000/yr**	**152**	**138**	**152**	**138**	**152**	**138**
SG & A	**$ 000/yr**	**1,911**	**1,911**	**2,796**	**2,796**	**3,493**	**3,493**
Total Ops Expense	**$ 000/yr**	**13,969**	**16,521**	**26,564**	**31,767**	**39,159**	**47,013**
	$/gln	**1.40**	**1.65**	**1.33**	**1.59**	**1.31**	**1.57**
Required Margin	**$ 000/yr**	**2,850**	**2,100**	**4,800**	**3,600**	**6,375**	**4,785**
	$/gln	**0.29**	**0.21**	**0.24**	**0.18**	**0.21**	**0.16**
Unsubsidized Price	**$/gln**	**1.68**	**1.86**	**1.57**	**1.77**	**1.52**	**1.73**
Federal Producer Incentive	**$/gln**	**0.10**	**0.10**	**0.08**	**0.08**	**0.05**	**0.05**
State Producer Incentive	**$/gln**	**0.30**	**0.30**	**0.23**	**0.23**	**0.15**	**0.15**
Required Plant Netback	**$/gln**	**1.28**	**1.46**	**1.27**	**1.47**	**1.32**	**1.53**

The optimal configuration seems to be a 20 to 30 MM GPY fully integrated plant which produces ethanol directly from crushed cane sugars and uses all other biomass to generate steam and electricity.

1.1.3 Molasses-Only Option

Alternative options exist for small scale production of ethanol based on the current production of molasses only. At the current rate of production of molasses, 14,000 ton in Kauai and 71,000 ton in Maui (both commercial, i.e. wet tonnage numbers), a single plant in Maui may produce up to 5 MM GPY of ethanol if not supplemented with raw sugars or molasses from other sources.

Such a plant would require a capital investment in the range of $12 to 18 million. Its feedstock cost of would be around $3.4 million per year, when molasses are priced at a world market alternative value of $40/ton. It could produce ethanol at a cash cost of around $1.00 per gallon.

Although attractive, the problem with this proposition is that such a plant could not survive on its own merits if the fundamental economics for sugarcane processing change, as may be the case when tariff protection for US sugar production is removed or reduced. It may be difficult under such circumstances to finance a project.

1.1.4 Proposed Projects

The only project for which an application has been received by DBEDT at this time is for a 7 MMGPY plant in Maui, with ED&F Man as the project developer. This plant would be designed to process the existing production of molasses and could serve either the local Maui market or could export its production to California.

The economics for this project would look very similar to the numbers provided above, which means that the project is viable, provided that the overall conditions in Hawaii's remaining sugar industry do not worsen to an extent where the availability of molasses is threatened.

Representatives of ED&F Man were very helpful in providing general background information for this study.

1.2 Ethanol from Biomass

If only the readily fermentable sugars are used for the production of ethanol, a large proportion of the total amount of biomass is left unused, or used only in part and at relatively low efficiencies for the generation of process heat and power, as is the case for bagasse in sugar cane crops.

Moreover, in addition to specially cultivated energy crops, processes that convert any type of biomass into ethanol can be used to produce high value transportation fuels from waste products, such as Municipal Solid Waste (MSW), waste products from the pulp and paper industry, and even manure. These products currently incur disposal cost and therefore have a negative value, which greatly assists the process economics.

Over the past two decades, significant research efforts have been directed at developing processes that allow conversion of the lignocellulosic biomass (present in the fibers and leafy parts of plant material, in paper, and organic waste) in addition to the starches and sugars. Today, several of these processes have been successfully tested at bench scale and in pilot plants, but as yet, none has been implemented at full commercial scale.

1.2.1 Supply Potential

Hawaii's supply potential of biomass from energy crops or organic waste has been extensively researched, notably by Shleser[8], and Kinoshita and Zhou[9]. Borrowing once more from their work, the biomass availability and potential ethanol yield is summarized below.

The theoretical ethanol production numbers shown in Table 1.3 are based on the chemical composition of each of the feedstock materials and estimated conversion yields to ethanol. They do not take into account the feedstock requirements for other process needs, such as steam and power generation.

Still, it is interesting to note that in principal, Hawaii has the potential to produce quantities of ethanol well in excess of its own consumption capacity, and that organic waste materials can be a significant source of additional biomass to supplement biomass from energy crops, or in stand-alone applications.

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8 Dr Robert Shleser, *Ethanol in Hawaii*, Report Prepared for DBEDT 1994

9 Charles M. Kinoshita, Jiachun Zhou, *Siting Evaluation for Biomass Ethanol Production in Hawaii*, Bioengineering Department, University of Hawaii at Manoa, under NREL Grant XXE-8-17099-01

Table 1.3 – Hawaii Dry Biomass* and Ethanol Potential by Island**

Energy Crops		Hawaii	Maui	Oahu	Kauai	Total
Available Land	acres	27,000	26,000	25,500	7,000	**85,500**
Sugarcane	t/year	486,000	468,000	459,000	126,000	**1,539,000**
	MMGPY	55.9	53.8	52.8	14.5	**177.0**
Irrigated grass	t/year	594,000	572,100	561,000	153,900	**1,881,000**
	MMGPY	41.6	40.0	39.3	10.8	**131.7**
Unirrigated grass	t/year	486,000	468,000	459,000	126,000	**1,539,000**
	MMGPY	34.0	32.8	32.1	8.8	**107.7**
Trees	t/year	270,000	260,100	255,000	69,900	**855,000**
	MMGPY	20.3	19.5	19.1	5.2	**64.1**
Organic Waste						
Newspaper	t/year	40,200	69,900	283,600	14,300	**408,000**
	MMGPY	4.4	7.7	31.2	1.6	**44.9**
Other MSW	t/year	50,000	111,900	444,900	29,800	**636,600**
	MMGPY	3.0	6.7	26.7	1.9	**38.2**
Max Ethanol	**MMGPY**	**63.6**	**68.2**	**110.7**	**18.0**	**260.1**

* From Kinoshita and Zhou, Table 4.17 using 300 crop delivery days per year to calculate annual totals.
**Theoretical Ethanol Yields from Shleser, Figure III-7.

1.2.2 Production Costs

Although there are currently no commercial plants in operation that convert lignocellulosic material into sugars and ethanol, costs estimates are available from detailed engineering studies based on pilot plant and laboratory data.

Regardless of the process route, feedstock costs will be a significant part of the total production costs, as shown in Table 1.4 below. It would seem that sugarcane, unirrigated banagrass, and tree crops result in similar feedstock cost per gallon of ethanol produced. However, since the tree and grass crops produce less dry biomass per acre-year at lower ethanol yields, sugarcane has the potential to offset the slight feedstock cost disadvantages by better economies of scale in the crop harvesting and production processes. Of course, the lowest feedstock costs are offered by biomass produced from Municipal Solid Waste and newspaper. It is important to take a look at the relative cost of these feedstocks on the basis of their energy content, in comparison to heating values of other feedstocks and final products.

Table 1.4 – Feedstock Cost per Gallon of Ethanol

	Cost $/ton DM	Yield ton/acre-year	Ethanol Yield gln/ton	Ethanol Yield gln/acre	Feedstock Cost $/gln
Sugarcane	85	18	115	**2,070**	**0.739**
Banagrass (irrigated)	66	22	67	**1,474**	**0.985**
Banagrass (unirrigated)	47	18	67	**1,206**	**0.701**
Trees	54	9	78	**702**	**0.692**
MSW	-	NA	60	**NA**	**0**
Paper	10	NA	110	**NA**	**0.091**

* From Kinoshita and Zhou, Table 4.17 using 300 crop delivery days per year to calculate annual totals.
**Theoretical Ethanol Yields from Shleser, Figure III-7.

In order to process the lignocellulosic material into fermentable sugars, an additional process step is required, for which several alternatives have been proposed. The primary routes are acid hydrolysis and enzymatic conversion. The NREL study of Aden et al[10] is probably one of the more detailed evaluations of the technology. The feedstock in their study was corn stover with a cost of $30/ton of dry biomass and an overall ethanol yield of 90 gallon per ton, a yield and cost similar to that of bagasse.

At a production capacity of 69 MMGPY of ethanol, the capital cost estimate for the project was $197 million, almost $90 million more than a simple fermentation plant for sugars and molasses for the same output would have cost (scaled up from Yancey's estimate). This capital number fits well with the low end of the range of capital estimates provided by Shleser for six different processes, which at a scale of 25 MM GPY varied from $81 to $127 million. Scaled up to 69 MM GPY and corrected for escalation since 1994, his numbers would have amounted to $193 to $302 million.

The minimum required gross margin over feedstock cost calculated by Aden et al is $0.735/gln ethanol (selling price of $1.07 minus feedstock cost of $0.335), a number

[10] Ibid, see footnote 5

which is well below the range of $0.94 to $1.66 predicted by Shleser [11] in 1994. The difference can be explained by the lower capital cost estimate, technological progress since 1994 resulting in higher ethanol yields, and the larger plant scale (Shleser assumed a 25 MMGPY plant).

While it is difficult to provide accurate cost data for a technology which is not yet practiced at a commercial scale, it is possible to look at the overall margins between the feedstock costs and product values on a heat content basis.

Table 1.5 – Heat Content Values of Feedstocks and Products

	Unit	Cost $/unit	MM Btu/unit	$/MM Btu
Feedstocks				
MSW	ton	-	9 - 10	**0**
Waste Paper	ton	10	15	**0.67**
Coal	ton	30 – 40	22	**1.36 – 1.81**
Crude Oil	bbl	25	5.8	**4.31**
Banagrass	ton	66	15	**4.40**
Sugarcane	ton	85	15	**5.67**
Market Value				
Gasoline (CA rack)	gln	0.82	0.1286	**6.38**
Gasoline (HI rack)	gln	0.95	0.1286	**7.38**
Ethanol (CA export)	gln	1.28	0.0839	**15.26**
Ethanol (HI rack)	gln	1.47	0.0839	**17.52**
Power (sale)	kWh	$0.06	0.003414	**17.57**
Power (purchase)	kWh	$0.12	0.003414	**35.15**

It will be clear from Table 1.5 that the biomass from energy crops such as banagrass and sugarcane in Hawaii is not exactly cheap. On a Btu basis, these feedstocks are more expensive than petroleum products at a crude oil price level of $25/bbl and in fact, the biomass fuel costs approach the wholesale price of gasoline. Based on the feedstock costs and product values, despite the fact that there are insufficient data to allow a detailed analysis of the cost structure for production of ethanol from lignocellulosic biomass, the following conclusions can be drawn:

[11] Ibid, “Summary of Results Table”, page ix.

- The capital requirements for a biomass-to-ethanol facility are likely to be in the order of $200 million for plants producing 60 MM GPY, the maximum size sustainable on Hawaii and Maui based on all available organic waste and idle acreage suitable for energy crops. For Oahu, a 100 MM GPY plant could cost close to $300 million.

- The minimum gross margin over feedstock cost needs to be at least in the order of $0.75 to $1.00 per gallon of ethanol produced.

- At an ethanol export netback value of $1.30 per gallon, corresponding to a crude oil price scenario of $25/bbl, the feedstock costs cannot exceed $65/ton of sugarcane, $38 per ton of banagrass and $44/ton of dry matter from tree harvests. These values are all below the estimated cost of producing and harvesting these energy crops, even when excluding the cost of land use.

- At an alternative value of $30 per ton and an ethanol yield of 86 gln/ton, bagasse could make an economical feedstock for ethanol production from lignocellulosic material.

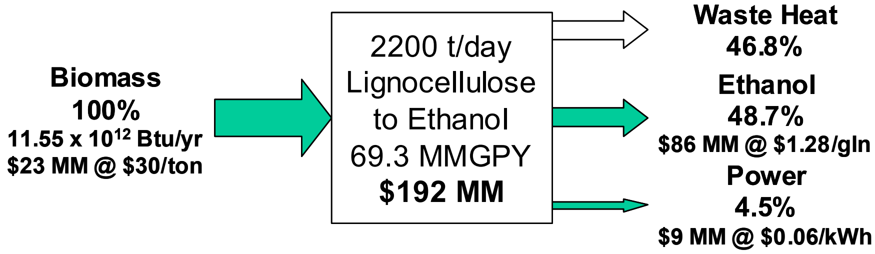
- Lignocellulosic materials from newspaper waste and organic content of Municipal Solid Waste can be economically converted into alcohols, provided that further work confirms the cost estimates contained in the current studies.

1.2.3 Comparison between Alcohol Production and Direct Combustion

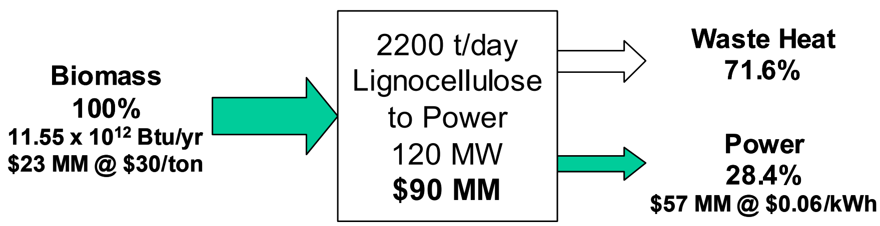
Although it appears that for lignocellulosic biomass with a cost of less than $30/ton, ethanol production is economically feasible, that does not automatically means that conversion to alcohol is the most attractive use of the biomass in terms of energy value. In particular in Hawaii, with its high electricity cost, it may be more attractive to use available biomass for power generation through direct combustion.

Figure 1.2 below takes the case of the 2000 metric ton per day example of the study of Aden et al, and compares it to an alternative whereby the combustor included in the design is scaled up to burn the total plant feed, rather than just the unconverted organic waste. In addition to scaling up the $38 million for the combustor, capital was added for receiving, storing, and shredding the feed, a control room and other offsites, estimated at $34 million. For the efficiency, a heat rate of 12,000 Btu/kWh is assumed.

Figure 1.2 – Lignocellulose Ethanol Conversion vs. Direct Combustion



Gross Margin $72 MM – $22 MM Fixed & Variable Operating = $50 MM
EBITDA/Capital = 0.26



Gross Margin $34 MM – $6 MM Fixed & Variable Operating = $28 MM
EBITDA/Capital = 0.31

Figure 1.2 shows that the Earnings Before Income Tax, Depreciation and Amortization (EBITDA) for each dollar of capital spent are almost 20% greater for a simple combustion plant generating power than for an ethanol production facility, even when no value is assigned to the waste heat of the power production, and a relatively low number for the value of the power is assumed (50% of market value). It is therefore more beneficial to burn the lignocellulosic biomass rather than to convert it at much higher capital costs to ethanol, given Hawaii's high cost of power production which in the Neighbor Islands is largely based on diesel driven generators.

This leads to the conclusion that the optimal scheme for sugarcane processing is a configuration whereby the raw sugars and molasses are processed into ethanol and all lignocellulosic biomass (bagasse and green waste) is burnt in a relatively efficient combustor, with sales of excess power to the grid. It would not be capital efficient to convert the bagasse and foliage into ethanol as compared to combustion for power generation.

2 ETHANOL MARKETS

The primary market choices for an ethanol producer in Hawaii are (i) the local market in the producing island, (ii) the total State of Hawaii, (iii) exports to California, or (iv) a combination of any of the above. Each of these options will be evaluated below.

2.1 Hawaii Ethanol Market

The total Hawaii gasoline market is between 26,000 and 27,000 BPD, with a breakdown by island as shown in Table 2.1 below.

Table 2.1 – Gasoline Market and Ethanol Potential by County

		Oahu	Big Island	Maui Molokai Lanai	Kauai	Total HI
Gasoline[12]	BPD	16,430	4,350	3,770	1,690	**26,240**
Ethanol Potential						
E10	MM Gln/Year	25.2	6.7	5.8	2.6	**40.2**

In principle, the total E10 market of Hawaii is well within the supply capabilities of conventional ethanol production from sugarcane, which was evaluated in Table 1.1 above at 90 million gallon per year (MM GPY). Larger scale ethanol production, as would be possible when conversion of lignocellulosic biomass were to become commercially feasible, would open up the possibility of limited use of E85 or ethanol as power fuel.

It is also noteworthy that at a 10% blending rate, the local demand in Maui is still below the production capacity of the proposed 7 MM GPY ethanol plant based on the local availability of molasses, especially since the demand of 5.8 MM GPY shown in Table 1.1 includes the potential consumption in Molokai and Lanai. If this plant were to be built and if the specified blend rate is kept at 10%, approximately 20% of its production would have to be exported.

2.2 Ethanol Supply/Demand USA

Ethanol supply and demand in the US is largely driven by farm support initiatives in the Midwest, which have resulted in a number of tax incentives for production and consumption of ethanol. Although the Renewable Fuel Standard (RFS) as part of the energy bill failed to pass in 2002, the expectation is that mandates for oxygenated fuels, construction subsidies for

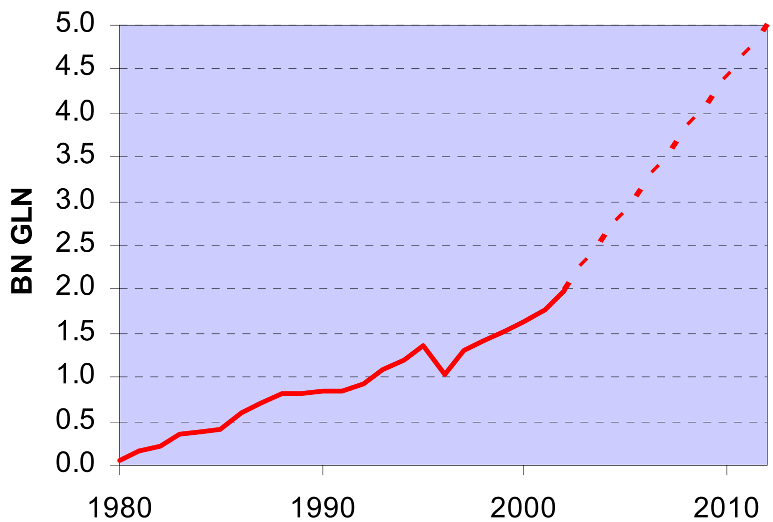
12 Source: Hawaii State Department of Taxation, "Liquid Fuel Tax Base and Tax Collections, Calendar Year 2000”

ethanol plants and the excise tax rebate will remain in place in the foreseeable future, i.e., at least until 2010.

2.2.1 US Ethanol Supply/Demand Balance

With the exception of the period 1996/1997, when corn prices were at record highs, the US ethanol production has seen spectacular growth over the past two decades, and production reached a level of almost 2 billion gallons in 2002.

Figure 2.1 – US Ethanol Demand[13]



The provisions of the RFS called for a total use of 5 BN GPY of ethanol by 2012. Other alternative fuels such as bio-diesel, will also play a role in meeting this target, but by the vast majority of the additional renewable fuel usage will be in the form of ethanol.

Most of the ethanol produced in the Midwest will also be consumed in the central parts of the US, but the coastal population centers will have to blend ethanol to meet mandated oxygenate levels. Given the power of the corn lobby, it is deemed unlikely that waivers would be granted for the oxygenate requirements, even when technical alternatives exist that would result in similar or lower emissions.

States in the central US are likely to blend ethanol in the 8 to 10% by volume range, while those areas that blend ethanol to meet the mandated 2% oxygen requirement will blend at 5.8%.

[13] Source: EIA (Year 2002 estimated)

So far, the ethanol industry has responded well and has been able to meet the phenomenal increase in demand, with new plants coming on stream in many locations. To meet the requirements of the RFS, the industry will have to bring new capacity on-stream at an average annual rate of increase of 300 MM GPY, likely to be in the form of 2 or 3 large facilities (> 50 MM GPY), and 5 to 10 smaller plants.

The outlook for supply and demand in the US can be summarized as follows:

- Despite the 2002 congressional setback in the approval of the RFS, the strength of the political support for a renewable energy bill is such that the goal to create a demand for 5 BN GPY of ethanol in the US by 2012 is likely to be realized.

- The required rate of increase of 300 MM GPY of new capacity every year between now and 2012 leaves sufficient room for ethanol production in Hawaii for export purposes.

2.2.2 Caribbean Basin Ethanol Production and Processing Capacity

Ethanol can be imported duty free from the Caribbean Basin countries under a waiver granted under the Caribbean Basin Economic Recovery Act (CBERA). Although the Caribbean countries that qualify for this duty exemption have approximately 300 MM GPY of indigenous ethanol production, the duty waiver can also be used for ethanol from other origins, as long as a treatment is performed in the Caribbean countries that qualifies for a change in origin.

Requirements for a change of origin for ethanol imported from Europe or Brazil and processed in a Caribbean Basin country are that a processing step is performed that adds at least 35% to the appraised value of the product at the time it is entered into the Caribbean Basin Country. This waiver is available for a quantity corresponding to 7% of the demand over the previous year as determined in November of each year based on WTO data, and is available on a first-come, first-served basis.

Under the CBERA duty waiver, imports of Brazilian ethanol potentially compete with eventual exports from Hawaii to California. It is therefore necessary to take a look at the cost of importing Brazilian ethanol to California. According to market information, the wet product can be made available FOB Santos for 72 – 88 cpg, for a landed cost in Costa Rica of 84 – 100 cpg. Adding the nominal 35% for the drying process and 8 cpg for the freight from Costa Rica to Long Beach, a landed cost of $1.05 – 1.27 per gallon is possible.

2.2.3 Cost of Corn Based Ethanol

The cost of production of ethyl alcohol will depend to a very large extend on factors such as feedstock costs, by-product credits, and utility cost, which are location specific and can vary significantly between plants. Other factors that are also location specific are construction cost, labor cost, cost of land, and permitting. Finally, there are cost differences that are inherent to the different process routes. For illustrative purposes, Table 2.2 shows an approximate comparison for a 100 MM GPY plant built in the US Midwest. For completeness, the production cost of synthetic ethanol through ethylene hydration is also shown.

Table 2.2 – Ethanol Production Cost

	Wet Milling	**Dry Milling**	**C2= Hydration**
Variable Costs			
Feedstocks[1]	88	88	85
Utilities	16	14	14
Other O & M	13	10	6
	117	**112**	**105**
By-Product Credit[2]	46	30	0
Net Variable Cost	**71**	**82**	**105**
Labor	**12**	**11**	**6**
Overheads[3]	**36**	**31**	**41**
Total Production Cost	**119**	**124**	**152**

1) Assumes corn at $2.30 per bushel with a yield of 2.6 gln/bushel, ethylene at 20 c/lbs with a yield of 0.234 gln/lbs (97%)

2) Wet milling: gluten feed at $70/short ton, gluten meal $280/short ton. Dry milling: dry grain solids $45/short ton

3) Capital (60 MM GPY): Wet Milling $172 MM, Dry Milling $136 MM, Ethylene Hydration $210 MM 40% debt financing @ 8%; 15% return on equity.

Most of the ethanol in the Midwest is produced in smaller plants than the 100 MM GPY scale used in the example of Table 2.2. For smaller scale production, costs can be higher by 5 to 10 cpg, and a good estimate for average production of corn based ethanol in the Midwest is $1.25/gln for wet milling and $1.30/gln for dry milling. In fact, ethanol production costs in the US have ranged between a low of $1.01 in December

1992 to a high of $1.54 in September 1996, based on historical data for corn cost and byproduct prices[14]. Prices for the byproducts in the wet milling process, gluten meal and especially those of gluten feed, have been on a steady decline since the early nineties, loosing 15% and 40% of their value respectively. This steady decline is likely to continue when ethanol production from corn doubles in the immediate future, and will act to keep upward pressure on the production costs of ethanol based on corn.

Other factors, such as market concentration and the need for new investments to meet growing demand, also will help to ensure that producers recover their full cost of production, including capital cost. The expectation is therefore that prices of fuel ethanol FOB Midwest will continue to be in their historic range of $1.00 to $1.50 per gallon, where the lower end of the range represents cash cost of the leading producers and operating cost recovery for the smaller producers, and the high end represents full economic rent for small standalone facilities.

2.3 Ethanol Supply/Demand California

The California gasoline market is approximately 1 MM BPD, growing on average 2% per year over the past decade. In addition, California refiners supply approximately 200 TBD of gasoline to neighboring states. Actual refinery production however is significantly lower and imports make up between 15 and 20% of the total. The California gasoline market represents a significant export opportunity for ethanol produced in Hawaii.

2.3.1 California Ethanol Demand

Ethanol is blended by California gasoline producers for any of the following reasons:

- **Mandated Usage**. In areas where a minimum of 2% oxygen is mandated, ethanol will need to be blended at a rate of 5.7%, which would require 760 MM GPY in 2004.

- **Octane Blending**. Even in areas where no minimum oxygenate content applies, refiners may want to blend ethanol because it represents the most economical means to achieve minimum octane requirements[15].

[14] Market Year Average Prices, US Department of Agriculture

[15] Source: "Potential Economic Benefits of the Feinstein – Bilbray Bill, An Analysis performed for Chevron Products Company and Tosco Corporation", Mathpro Inc., March 18, 1999

- **Other Reasons**. Some Midwest marketers, outside of government mandated areas, will blend with ethanol when the cost of gasoline gets high enough for ethanol to be economic as a substitute. California refiners, in RFG areas, are constrained to blending at 5.7%.

In total, the California market for ethanol in the near future is estimated at 760 to 990 MM GPY in 2004[16], growing proportionally to gasoline demand thereafter.

2.3.2 *Cost of Supply to California*

Most ethanol reaches California by railcar from the Midwest. Currently, terminals are being built capable of receiving unit trains, long trains of tank cars that are all interconnected so that the entire train can be loaded or emptied from a single point, significantly improving the handling costs. Similarly, the marine infrastructure is being developed to allow efficient receipt of cargoes of ethanol by vessel.

Table 2.3 – Delivered Cost of Ethanol to California ($/gln)

	Midwest Rail	**Brazil CBERA**	**Brazil Direct**	**Hawaii**
Production Cost	1.25 – 1.30	1.12	0.90	**1.27**
Transportation & Storage	0.12 – 0.15	0.22	0.20	**0.10 – 0.12**
Ex-Tank CA	1.37 – 1.45	1.34	1.10	**1.37 – 1.39**
Import Duty			0.53	
Excise duty waiver	0.52	0.52	0.52	**0.52**
Net cost	0.85 – 0.93	0.82	1.11	**0.85 – 0.87**
Octane Blending Value	0.02	0.02	0.02	**0.02**
Required Gasoline Price	0.83 – 0.91	0.80	1.09	**0.87 – 0.89**

Octane blending value represents the potential expense that the refineries can save by reducing the octane of their gasoline base stock and making that up with ethanol's high octane. The calculation above assumes that the local refiners' octane costs are 0.5 cents per octane gallon and that they can actually reduce their refining costs, to give an ethanol blending advantage of 1.5 cpg.

[16] Source: Pat Perez, Manager, Transportation Fuel Supply and Demand Office, Ethanol in California Workshop, Feb. 6, 2003.

The costs shown in Table 2.3 above assume average costs of production as outlined in Sections 1.2.2 and 2.2.3, and a fully developed import infrastructure. The conclusion of the above cost comparison is that Hawaii ethanol production is competitive with most other options available to California gasoline producers, presuming the Hawaii ethanol is produced in fully integrated plants at a scale of 20 to 30 MM GPY using the non-converted biomass for power generation.

2.4 Impact of Crude Oil Price and Gasoline Differentials

One of the single biggest factors impacting the economic viability of any alternative energy proposal is the cost of the competing fossil energy source. In the case of ethanol, which finds its application primarily as an automotive fuel, the key question is to predict the price of crude oil.

2.4.1 Crude Oil and Gasoline Price Forecast

The most recent crude oil forecast of the EIA[17] sees crude oil prices drop to $23/bbl in 2005, and recover to levels of $25 to $26/bbl, where they will stay well into the future in terms of constant dollars. In nominal dollars, this means that the EIA expects crude oil to be at $48/bbl by 2025. In the light of decreasing rates of reserve replacements, increasing finding costs of crude and ever increasing demand, this forecast seems fairly conservative.

Based on an evaluation of the crude oil slate of Hawaii and California refiners that was prepared by Stillwater Associates for the Hawaii Fuels study[18], and if a world oil price of $25/bbl is assumed, then the average landed cost of crude oil in Hawaii is likely to be around $1/bbl higher, while the California refiners who predominantly use heavy local crudes would have an average crude cost of $2/bbl below the marker price.

The price differentials for retail, rack and wholesale over crude oil and relative to each other as shown in Table 2.4 below are based on average differentials over the period 1998 – 2002, as per EIA and Lundberg data.

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17 EIA, *Annual Energy Outlook*, Report DOE/EIA #383 (2003), January 9, 2003.

18 Stillwater Associates, *Study of Fuel Prices and Legislative Initiatives for the State of Hawaii*, DBEDT Study, June 2003.

Table 2.4 – Typical Price Differentials at $25/bbl World Crude Oil Price

	Crude	Gasoline Wholesale	Rack	DTW	Retail Ex-Tax
Hawaii					
$/bbl	26.0	33.50	41.2	48.7	52.4
cpg	62	80	98	114	123
California					
$/bbl	23.0	31.0	36.1	39.5	42.9
cpg	55	74	86	94	102

2.4.2 Value of Ethanol Relative to Gasoline

Since ethanol is blended at the rack, the rack price will have to be used as the reference point for ethanol pricing. If the rack price is used as the basis and a 1.5 cpg octane blending value is added plus the 52 cpg excise tax credit, then the indifference price level for a gasoline blender would be $1.52 in Hawaii versus $1.44 in California for ethanol delivered at the rack blend point.

Of course, actual ethanol prices are likely to be different from the blending value. In a tight ethanol market, those gasoline blenders that have to meet minimum oxygen requirements will have to pay up, while in oversupplied markets where ethanol content is not mandated, ethanol will sell at prices determined by competitive forces. These are unlikely to be lower than the cost to produce ethanol, including the producer tax incentives.

With actual delivered ethanol prices at levels corresponding to production cost, i.e., in the range of $1.25 to $1.30 per gallon, the gasoline blenders will actually benefit substantially from the 52 cpg excise tax waiver, which reduces the net cost of ethanol to 73 to 78 cpg, well below the rack prices of gasoline that correspond to a world crude oil price level of $25/bbl.

3 TAX TREATMENT

Ethanol production enjoys preferential tax treatment at federal and state level, with incentives ranging from excise tax credits to production credits. Incentives are required because ethanol production costs are normally higher than gasoline production costs. An overview is provided below of the various incentives.

3.1 Federal Incentives

Blenders of ethanol and gasoline qualify for a reduction of the federal excise tax on gasoline. This reduction is current 52 cents per gallon of ethanol, which means that a 10% blend of ethanol into gasoline will reduce the excise tax from 18.4 cpg to 13.2 cpg[19]. The tax credit is claimed by the gasoline blender, and is used to offset the high cost of ethanol production.

The federal government offers a small ethanol producer credit of 10 cents per gallon. To qualify, an eligible small ethanol producer must have an annual productive capacity of less than thirty million gallons. The credit applies for up to fifteen million gallons or a maximum of $1.5 MM[20]. This program is intended to enable development of smaller resources and help overcome diseconomies of scale.

3.2 Hawaii State Incentives

The State of Hawaii has two incentives for the use of ethanol. The first incentive is a waiver of the General Excise Tax of 4%, which will reduce the tax on a gallon of gasoline by 4 to 5 cpg, depending on the wholesale price of gasoline. This excise tax waiver is scheduled to be phased out after December 31st, 2006.

The second is an ethanol investment tax credit that equates to a thirty cent per gallon production incentive. The Department of Business, Economic Development, and Tourism reports that Act 289 (2000) (Senate Bill 2221) contains the following:[21]

- An ethanol investment tax credit (30% of each $1 million per 1 million gallons per year capacity), roughly equal to thirty cents per gallon, subject to investment amount and facility size thresholds.

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[19] Publication 510 Excise Taxes for 2003 (Revised: 2/2003)

[20] Publication 378 Fuel Tax Credits and Refunds (Revised: 12/2002)

[21] http://www.state.hi.us/dbedt/ert/ethanol-incentive.html

- Maximum tax credit is $4.5 million per facility per year, for facilities over 15 million gallons per year; less for smaller facilities.
- The facility must produce at least 75% of its nameplate capacity in order to be eligible to receive the tax credit in that year.
- The tax credit may be taken for up to eight years, if the investment in the facility (exclusive of land costs) is less than $50 million; if the total investment in the facility is over $50 million, the credit may be taken for up to 10 years.
- If the credit exceeds the taxpayer's income tax liability, the excess shall be refunded to the taxpayer (i.e. the taxpayer shall receive a payment).
- The credit shall only be available to first 40 million gallons of capacity in the state, and the facility must be in production before January 1, 2012.
- The existing excise tax exemption for the sale of alcohol fuels (Section 237-27.1) is to be repealed on December 31, 2006.
- The Act applies to taxable years beginning January 1, 2002.

3.3 Combined incentives

For the ethanol producer, federal and state production incentives equal 40 cents per gallon for plants producing up to 15 million gallons per year. State support for a 7 million gallon per year plant would total about $2.1 MM and the federal incentive would be $0.7 MM.

For ethanol blended with gasoline, the State waives the General Excise Tax, worth about 4 cpg and the federal government reduces gasoline excise taxes by about 5 cpg. This roughly 9 cpg goes to the blender in the form of reduced taxes when the ethanol and gasoline is blended onto the delivery truck.

3.4 Tax Incentives and Market Impact

In Table 2.4 above a scenario was shown where world marker crude prices are around $25/bbl and gasoline prices are at historical differentials over crude oil resulting in a rack price of 98 cpg in Hawaii and 86 cpg in California. As pointed out in Section 2.4.1, under this scenario, the ethanol producers could in principle charge up to 154 cpg in Hawaii or 142 cpg in California for ethanol delivered at the rack, because for the gasoline marketer, the premium over gasoline price would be offset by the excise tax credit and the octane value.

What has been observed in the market however is that the ethanol producers have for the most part entered into agreements that reflect the cost of ethanol production rather than the market value. For instance, for the ethanol sold in California in 2003, prices remained in the order of 125 to 130 cpg, even when the gasoline prices at the rack rose to over $1/gln. It appears that at least for now, ethanol prices are determined on a cost-plus basis rather than on market value. A potential explanation for this phenomenon, which is common in markets for undifferentiated commodities, is that it is easier to obtain financing for new production capacity when cost-based contracts are secured rather than when a project is exposed to market risk.

When prices for ethanol are less than the gasoline rack price plus the excise tax credit of 52 cpg, then the gasoline marketer will benefit in part from the tax incentive. For instance, when ethanol is sold delivered at the rack for 130 cpg, then the gasoline marketer will benefit from the excise tax credit for any part of the gasoline rack price over 78 cpg.

4 ETHANOL CONTENT REQUIREMENT

From DBEDT's website, Section 486J(10) of Hawaii Revised Statutes (see www.capitol.hawaii.gov), as amended, states:

§486J-10 Ethanol content requirement.

(a) The commissioner shall adopt rules in accordance with chapter 91 to require that gasoline sold in the State for use in motor vehicles contain ten per cent ethanol by volume. The amounts of gasoline sold in the State containing ten per cent ethanol shall be in accordance with rules as the commissioner may deem appropriate. The commissioner may authorize the sale of gasoline that does not meet these requirements as provided in subsection (d).

(b) Gasoline blended with an ethanol-based product, such as ethyl tertiary butyl ether, shall be considered to be in conformance with this section if the quantity of ethanol used in the manufacture of the ethanol-based product represents ten per cent, by volume, of the finished motor fuel.

(c) Ethanol used in the manufacture of ethanol-based gasoline additives, such as ethyl tertiary butyl ether, may be considered to contribute to the distributor's conformance with this section; provided that the total quantity of ethanol used by the distributor is an amount equal to or greater than the amount of ethanol required under this section.

(d) The commissioner may authorize the sale of gasoline that does not meet the provisions of this section:

(1) To the extent that sufficient quantities of competitively-priced ethanol are not available to meet the minimum requirements of this section; or

(2) In the event of any other circumstances for which the commissioner determines compliance with this section would cause undue hardship.

(e) Each distributor, at such reporting dates as the commissioner may establish, shall file with the commissioner, on forms prescribed, prepared, and furnished by the commissioner, a certified statement showing:

(1) The price and amount of ethanol available;

(2) The amount of ethanol-blended fuel sold by the distributor;

(3) The amount of non-ethanol-blended gasoline sold by the distributor; and

(4) Any other information the commissioner shall require for the purposes of compliance with this section.

(f) Provisions with respect to confidentiality of information shall be the same as provided in section 486J-7.

(g) Any distributor or any other person violating the requirements of this section shall be subject to a fine of not less than $2 per gallon of nonconforming fuel, up to a maximum of $10,000 per infraction.

(h) The commissioner, in accordance with chapter 91, shall adopt rules for the administration and enforcement of this section.

§486J-1 Definitions. As used in this chapter:

"Petroleum commissioner" or "commissioner" means the administrator of the Strategic Industries Division of the department of business, economic development, and tourism.

"Competitively priced" means fuel-grade ethanol for which the wholesale price, minus the value of all applicable federal, state, and county tax credits and exemptions, is not more than the average posted rack price of unleaded gasoline of comparable grade published in the State.

"Distributor" means and includes:

(1) Every person who refines, manufactures, produces, or compounds fuel in the State, and sells it at wholesale or at retail, or who utilizes it directly in the manufacture of products or for the generation of power;

(2) Every person who imports or causes to be imported into the State or exports or causes to be exported from the State, any fuel; and

(3) Every person who acquires fuel through exchanges with another distributor.

5 LOGISTICS OF ETHANOL IN HAWAII

Most commercial storage and pipeline systems for gasoline, as well as gasoline barges and tankers, cannot be kept completely dry. Small amounts of water are introduced through atmospheric vents when volumes are displaced in tanks or cargo holds and will condense against tank walls to form an aqueous bottom layer. Small amounts of water are also entrained in the fuel as a result of the use of water and steam in refining processes.

Ethanol is soluble in water as well as in gasoline, but has a greater affinity for being in solution with water. Gasoline and water have very low solubility in each other, but the water solubility in gasoline is increased significantly in the presence of ethanol. These two effects can cause problems with ethanol in commercial gasoline storage and transportation systems, whereby depending on the quantities of water present, ethanol will leach out of the gasoline into the water layer, and/or water gets picked up by the gasoline.

For these reasons, ethanol is not blended at the refinery but is shipped separately to the final truck loading rack, where it is blended into the gasoline as the truck is loaded to make the final delivery to the retail station. The requirement to blend ethanol at the loading rack poses some significant challenges for distribution and marketing of ethanol in Hawaii.

5.1 Options for Inter-Island Usage and Distribution

5.1.1 Production for Local Consumption Only

In case of small scale production, as is the case of the project which is currently being contemplated for Maui, the easiest solution from a logistical point of view is to consume the entire production locally.

In Maui, given the lack of storage and the limited availability of land at the port, it may be necessary to maintain final product storage only at the production site. Trucks would then have to ferry the ethanol from the plant to the gasoline terminals at the port of Kahului, where splash blending or inline blending could be done using the ethanol truck as temporary storage.

From a point of view of operational reliability, this would not be the preferred solution, but it avoids the problem of having to add tankage. The costs are estimated at 3 to 4 cpg of ethanol.

5.1.2 Production for Total Hawaii Gasoline Pool

Current legislation requires blending of 10% by volume of ethanol in all gasoline sold in the Hawaii islands. To accomplish this with production concentrated in one or at the most two islands requires a logistic infrastructure with terminals and tankage for ethanol in each islands, and inter-island barging.

To achieve economies of scale in the production of ethanol, the preferred solution would be to produce all 40 MM GPY of ethanol in one location. In principle, Maui has sufficient potential to produce 40 MM GPY of ethanol, with current acreage in sugar crop of 35,400 acres[22] and potential additional lands of 26,000 acres as identified in Table 1.1. In total, this acreage could yield close to 68 MM GPY of ethanol. For an evaluation of the logistic cost, it will therefore be assumed that a single plant in Maui will supply all the islands.

An estimate for the required infrastructure is provided in Table 5.1 below.

Table 5.1 – Estimated Ethanol Infrastructure Requirements

	Prod MM GPY	Usage MM GPY	Tanks Req. # x bbl	Terminal $MM	Blending $MM	Distribution cpg
Maui	40	5.3	2 x 20,000	-	0.5	-
Oahu		25.2	2 x 20,000	2.0	5.0	10
Hawaii		6.7	2 x 5,000	0.5	1.0	10
Kauai		1.7	1 x 5,000	0.1	0.2	10
Lanai		0.3	1 x 150	0.1	0.2	11
Molokai		0.1	1 x 150	0.1	0.2	11
Total	**40**	**40**	**155,300**	**2.8**	**7.1**	**10**

The capital cost estimates for terminals and blending equipment are order of magnitude only, and are based on the following assumptions:

- The costs of two larger tanks at Maui are included in the plant cost, as are other infrastructure costs such as a pipeline from the plant to the port. In principle, the ethanol can be delivered from the plant to the port by truck (approximately 22 trips per working day), but a pipeline is likely to be a safer and more cost effective option.

22 Statistics of Hawaii Agriculture, http://www.nass.usda.gov/hi/stats/stat-19.html

- For Oahu, a new import terminal is assumed with two tanks of 20,000 bbl each at Barbers Point, which would result in total inventory capacity of approximately 22 days of consumption, with average expected net usable inventories of approximately 10 days. The cost estimate of $50/bbl of shell capacity is twice the US Gulf Coast average, reflecting the small scale of the project, high cost of land and the generally higher construction cost in Hawaii. Alternatively, the $2 MM shown may serve to acquire a share in the existing Aloha/USRP terminal at Barbers Point. In addition, smaller tankage, pumps and metering equipment will have to be provided to allow blending at the rack at each of the four major distribution terminals in Honolulu. Alternatively, the two tanks could be built in Honolulu and ethanol needed for the Aloha terminal would be trucked to Barbers Point.

- On Hawaii, it is assumed that Hilo would function as import terminal, with two new tanks capable of receiving a shipment equal to a typical barge compartment. Pipelines and metering equipment need to be installed to distribute the ethanol to all terminals in Hilo. A small ethanol tank and metering equipment might also have to be provided at Kawaihae, with ethanol supplied by truck from Hilo.

- The distribution cost assumes 5 cpg barging, 3 cpg terminal cost, 2 cpg local trucking. The local trucking applies to Oahu, and to part of the volumes in The Big Island and Kauai. In Lanai and Molokai there is no trucking of ethanol, but a freight penalty of 2 cpg is assumed for the barging cost because of the very small volumes involved while certain cost of barging are fixed.

- Marketers will have to pay close attention to the cleanliness of their service station tanks in this process. Each tank has to be thoroughly dewatered and cleaned in order to maintain the integrity of the ethanol/gasoline mixture. ConocoPhillips has significant experience in this area and they have found that the transition to ethanol blended gasolines has to be planned very carefully.[23]

All in all, total capital of $10 million and local distribution costs of 9 cpg are not unreasonable, and are in fact well below some estimates communicated by industry stakeholders which ranged from $10 to $20 million.

[23] ConocoPhillips, http://www.state.hi.us/dbedt/ert/ethanol-workshop/14-Duffin-color.pdf

5.1.3 ETBE Production

An alternative solution to the direct blending of ethanol in gasoline is to convert the ethanol first into ethyl tertiary butyl ether (ETBE) in a process whereby it is reacted with isobutylene. ETBE is a gasoline blendstock with several properties that make it a preferred blendstock for refiners in terms of its impact on octane, vapor pressure and boiling range properties. It can be blended at the refinery and no special adaptations in the distribution system are necessary.

It may be possible for the local refiners to produce isobutylene and ETBE at costs not much different from the costs of segregating and exporting more naphtha. In this case, the production of ETBE should be evaluated as an alternative to direct ethanol blending, provided sufficient safeguards can be provided to prevent leakage of gasoline into groundwater, where the presence of ETBE may cause odor and taste problems even at very low concentrations.

5.2 Production for Exports

In principle, production of ethanol for export to California could be of a much larger scale than production for Hawaii's internal consumption only. In section 2.3.1 it was shown that California ethanol demand is likely to be in the order of 700 to 900 MM GPY, a number that dwarfs even the highest quantities of ethanol Hawaii could theoretically produce. A reasonable assumption seems to be that a single plant in Maui with a capacity of 30 to 40 MM GPY would represent a good fit between economies of scale and the total production capacity of the island, taking into account existing sugarcane acreage as well as potential additional lands.

5.2.1 Shipping Options and Transportation Costs for Exports to California

Ethanol can be shipped in single hull tankers, including chemical parcel tankers as well as clean petroleum product carriers. However, for transports between Hawaii and the continental USA, it will be necessary to use Jones Act vessels, that is, vessels that are US built, US flagged and crewed by US citizens. Typically, freight rates for such vessels are approximately twice the costs of internationally flagged carriers. Options available for shipping of ethanol include:

- Barging of ethanol from Maui to Oahu for transshipment into tankers either in Honolulu or Barbers Point. Local infrastructure requirements in Maui would be essentially the same as for the local Hawaii market case outlined above. In Oahu however, at least 300,000 bbl of storage capacity will have to be provided in order to be able to load full cargoes. The costs for this option are estimated at 5 cpg for barging to Oahu, 2 cpg for terminalling, 8 cpg for shipment to California and 2 cpg for terminal plus truck delivery to the rack, for a total of 17 cpg. If US flagged vessels are not available or if costs prove to be prohibitive as Jones act vessels become more scarce, it may be worthwhile to try to obtain a congressional waiver to use non-US flagged vessels to transport the ethanol between Hawaii and the Mainland.

- Barging of ethanol directly from Kahului to California. Given the distance, integrated tug/barge combinations which can attain cruising speeds of up to 12 knots would probably be the most suitable form of barge transportation. The roundtrip costs for a 120,000 bbl tug/barge combination are estimated at $380,000, or 8 cpg, to which 2 cpg must be added for the receipt terminal and trucking to the rack, for a total of 10 cpg. Using a smaller towed barge may also be cost effective alternative, especially when an older single hull barge is used.

- Shipping ethanol in wing tanks of the vessel currently transporting raw sugars and molasses to California. According to market information, approximately 15,000 bbl of such capacity is available on the vessel which currently makes around 10 trips per year carrying raw sugars to California. Unfortunately, this would only cover 10% of the plant's output. Moreover, it appears that the commercial arrangements under which the sugars and molasses were shipped will end in the near future.

- Berth 1 in Kahului, with 35 feet draft and 1350 feet in length, is in principle capable of receiving product tankers. Although the draft restriction would probably prevent most tankers of taking on full cargoes, partial cargoes of up to 100,000 bbl or even 200,000 bbl are feasible. Freight rates are likely to be in the same order of magnitude as those outlined above for the integrated tug/barge, namely 8 cpg for total cost including California terminal and trucking fees of 10 cpg.

In summary, it would seem that at least two modes of transportation may result in similar overall delivery cost of around 10 cpg from FOB Kahului to a California truck rack terminal.

5.2.2 Local Infrastructure Requirements for Exports

In order to be able to load cargoes in the 100,000 to 200,000 bbl range, a Maui ethanol plant built primarily for exports to California would need to have more storage than a plant built for local Hawaii demand. A likely configuration may be to have two smaller production rundown tanks at the plant of each 10,000 bbl, with a delivery tank at the port of at least 150,000 bbl of capacity.

It may be difficult to obtain land and permits for building such large tankage in the port of Kahului. Alternatively, larger storage may be located at the site of production, approximately 3 miles inland with a larger pipeline (i.e., 16”) to obtain acceptable loading rates.

6 IMPACT OF ETHANOL BLENDING ON HAWAII'S REFINERIES

The mandate to blend ethanol into gasoline, whether as a local requirement or a under a federal Renewable Fuels Act, always has severe consequences for any local gasoline market, but because of Hawaii's isolation and unique fuel balance, the impact of an ethanol edict in Hawaii on the local refining infrastructure is likely to be more severe than elsewhere in the US.

6.1 Refining Issues

The two refineries on Oahu primarily produce jet fuel and residual fuel. The former supplies the airports and the latter is burned by the utilities to provide electricity. Gasoline production is an unusually small portion of the refineries' production slate. Table 6.1 shows typical supply and demand of Hawaii fuels.

Table 6.1 – Typical Product Slate for the Hawaii Refineries[24]

	Chevron bpd	Tesoro bpd	Supply bpd	Demand bpd	Exports bpd
Propane	1,500	1,500	3,000	3,000	-
Gasoline	14,000	14,000	28,000	28,000	-
Naphtha	6,000	7,000	13,000	7,000	6,000
Jet Fuel	13,000	26,000	39,000	45,000	(6,000)
Diesel	5,000	14,000	19,000	19,000	-
Fuel Oil*	14,000	23,000	37,000	37,000	-
Asphalt	500	500	>1,000	>1,000	-
	54,000	86,000	140,000	140,000	-

* Includes fuel oil consumed in the refinery: Chevron 1,000 bpd, Tesoro 2,000 bpd (estimated)

While short on jet fuel, which is imported on a regular basis, the refineries produce more material in the gasoline boiling range than the State of Hawaii consumes. Excess gasoline type material, generally naphtha, is exported by tankers to other markets, mostly to Japan as feedstock for the petrochemical industry.

6.1.1 Volume Impact of Ethanol Blending

Since the refiners are balanced on all other products and already try to minimize their non-profitable exports of naphtha, any further reduction in gasoline demand due to blending of ethanol will result in increased levels of naphtha exports. Alternatively, the

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24 Source: DBEDT statistics, information received from Chevron and Tesoro, and Stillwater's evaluation of typical refinery unit performance.

refiners could consider cutting production overall, but in general this is even less attractive.

When 10% by volume ethanol is blended into gasoline the volume loss is partially compensated because the lower heating value of ethanol will cause a drop in overall fuel efficiency. Ethanol has a Lower Heating Value (LHV, combustion of liquid fuel, with water as vapor in the exhaust gas) of 76,000 Btu/gln. The LHV for gasoline typically is in the range of 115,000 Btu/gln to 116,000 Btu/gln. The ethanol is likely to back out light naphtha components such as butane, pentane and hexanes, with an average LHV of around 110,000 Btu/gln. The remaining base gasoline blendstock when mixed with 10% ethanol will have an LHV of around 111,600 Btu/gln, or a loss of 3% versus conventional gasoline.

In older cars, the reduced heat content of the ethanol blend was partially offset by improvements in fuel efficiency due to the effect of the oxygenates, resulting in a net loss in mileage of about 2.5%. However, most cars produced since the early 1990s are equipped with oxygen sensors and other emission control systems. In these cars, which now constitute the vast majority of all cars on the road, the fuel efficiency improvement due to oxygenation of the fuel is negligible. Therefore, a 3% lower heating value for gasohol will result in a 3% increase in overall fuel consumption.

The net impact of increasing supply by 10% through blending of ethanol, coupled with a 3% increase in demand because of reduced fuel efficiency is therefore a net 7% reduction in the production of gasoline by the refiners. Thus, every gallon of ethanol blended into gasoline in Hawaii forces the Hawaii refiners to export 0.7 gallon of naphtha. At historical growth rates of 1% per year, it would take the Hawaii gasoline market up to 7 years to absorb this volume without the need for exports.

The difference in netback to the refiner between gasoline sold in the domestic market and exported naphtha is in the range of $10/bbl, or 24 cpg. Since the refiners use the relatively small volume of gasoline sales (19% of total refinery output) to compensate for their high cost of operations and low margins on other products, it is likely that they will attempt to exercise their market power in order to recover the lost margin on the increased naphtha exports. With an ethanol blending percentage of 10%, a 24 cpg loss on 7% of the sales might therefore lead to an increase of 1.7 cpg on the remaining gasoline volumes.

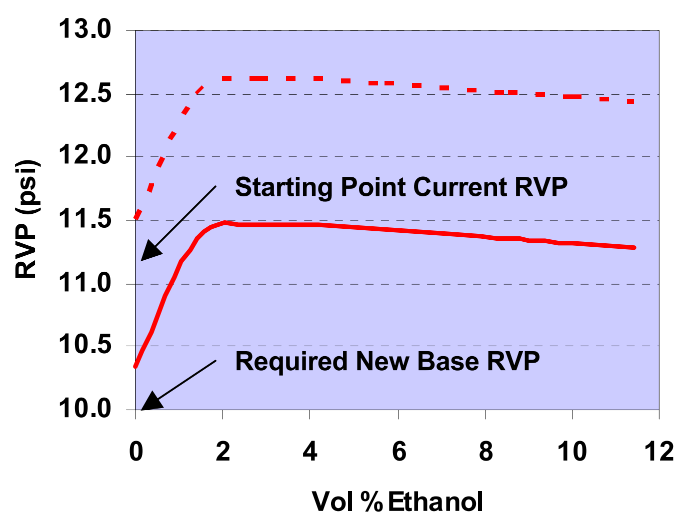
6.1.2 Vapor Pressure Issues

The refiners not only would have to reduce their overall production of gasoline in order to accommodate the blending of ethanol volumes, they will have to do so in a selective way with regard to certain components in order to maintain Reid Vapor Pressure (RVP), one of the specifications that gasoline refiners have to control in gasoline.

RVP is a measure of the volatility of a fuel and the level is set by industry standards. In Hawaii, RVP is set at a constant level of 11.5 psi, Volatility Class C, although in other areas of the country RVP can vary from 7 psi in the summer to 15 psi in the winter. Hawaii's retailers cannot sell gasoline with an RVP greater than 11.5 psi without violating the standards. Because the refiners have a number of specifications that they have to meet as well, they cannot even blend to 11.5 psi in some cases without exceeding other specification requirements such as distillation temperature distribution and true volatility.

While ethanol has many beneficial properties for blending with gasoline such as high octane and low sulfur, the most important negative characteristic is that blending ethanol with gasoline will raise the RVP of the mixture. Although the RVP of ethanol is low, blending ethanol at greater than 2% with gasoline will raise the RVP of the blend by about 1 psi. This steep initial RVP increase levels off with ethanol blends of greater than 20 to 25%.

Figure 6.1 – Vapor Pressure of Gasoline Ethanol Blends[25]



[25] Fredrick L. Potter, *21st Century Promise, Ethanol and ETBE as Key Tools for Public Policy and Fuel Quality Enhancement* , Hart/IRI Fuels Information Service, June 12, 2001, adjusted for Hawaii base gasoline RVP

As shown in Figure 6.1, blending 10% ethanol into Hawaii's current gasoline with a vapor pressure starting at 11.5 psi would result in vapor pressures of more than 12.5 psi for the blend. In Hawaii's temperate climate and mountainous terrain, this may well cause performance problems in automobile engines by creating vapor lock, leading to sudden loss of engine power. To stay in compliance with ASTM D4814 it will be necessary to lower the vapor pressure of the base blendstock gasoline to less than 10.5 psi to ensure that the vapor pressure of the blend is less than 11.5 psi.

When refiners have to reformulate their gasoline to reduce the vapor pressure, they generally can accomplish this by removing the high RVP components in their gasoline blending pool. The components to be removed first are butane and light straight run naphtha, which contains a high percentage of butanes and pentanes. A refiner may have to invest in additional distillation capacity to segregate these light streams from the rest of the gasoline to a higher degree than is currently the case. This will not be easy. For instance, Tesoro is constrained by Title V permits and would have to reformulate its gasoline to accommodate the RVP increase.[26]

Chevron is constrained by distillation and true volatility (T V/L) and cannot blend with another light component. They would have to dispose of their light fractions as well.[27] The refiners might be able to export the butane or light naphtha at a cost of $7 - $10 per barrel under gasoline value. In the worst case they would burn the material to fuel their refineries. Burning the material would reduce its value by roughly $12 to $15/bbl. Even then, in the case of Chevron, it may be necessary to import some heavy gasoline components such as toluene or reformate to maintain other specifications such as distillation curve and true volatility.

Gasoline samples were taken during the summer of 2003 that indicated that gasoline produced by the local refiners was not at maximum RVP. Tesoro explained that, from time to time, their RVP was not maximized when crude quality did not have normal levels of butanes. However, their RVP averaged near the maximum. On the other hand, ChevronTexaco determined that their premium gasoline could be blended with ethanol without causing volatility problems, but their regular gasoline could not because it is typically blended at the minimum T50 distillation point of 170 degrees F. Blending with ethanol would depress the T50 outside the ASTM specification.

[26] Conversation with Tesoro Hawaii personnel on March 16, 2003

[27] Conversation with ChevronTexaco personnel on March 20, 2003

Finally, an alternative way to produce the lower vapor pressure blendstock without modifications in Hawaii's local refineries is to back out even more standard Hawaii grade gasoline, up to a total of 22.5%. In addition to 10% ethanol, this would create room to blend in 12.5% of special (very expensive) California summer grade gasoline, CARBOB, which has a vapor pressure of only 5.8 psi. This of course would force the exports of even more naphtha, bringing the total cost per remaining gallon of Hawaii gasoline to 3 to 5 cpg, which is clearly not economical.

The additional operating cost and capital cost to segregate the light streams and produce a special low RVP blendstock are estimated at $2 million per year for each of the refineries, or 1 cpg. This brings the total cost impact of maintaining gasoline quality to 2.7 cpg, when including the effect of the product margin loss.

6.1.3 Impact of Partial Ethanol Blending

If Hawaii were to adopt a plan whereby only one island would start an ethanol blending program, i.e., Maui where a small local ethanol plant is planned, then the problems for the refiners would be compounded rather than lessened. In the case that ethanol blending was limited to Maui, rather than the whole state, it is likely that the refiners would determine that only one of the refineries would produce the low RVP material and sell the product to the other refiner as well as the other local marketers.

The problem now becomes one of segregation of the two separate gasoline specifications, the special low vapor pressure grade for ethanol blending in Maui and the normal grade for the other islands. The refinery modifications are still the same and investments in storage and handling facilities are largely determined by minimum production runs and size of barge shipments. It is estimated that the cost of separate production and segregation, if allocated to the barrels sold in Maui only, would amount to 4 to 5 cpg.

6.2 Impact of Ethanol Blending on Hawaii Gasoline Price

The net cost impact of blending of 10% ethanol in Hawaii's gasoline pool will be a combination of cost increases and tax credits.

6.2.1 *Impact of Federal Excise Tax Credit*

If world crude oil prices stay at average levels of $25/bbl, as is the current short to medium term outlook of the Energy Information Administration[28], and if ethanol continues to be priced at its cost level rather than its market value, then gasoline marketers will benefit in part from the effect of the federal excise tax credits.

With an average gasoline rack price of 98 cpg and ethanol delivered at the rack at a cost of 130 cpg, the advantage to the gasoline marketer after collecting the federal excise tax credit of 52 cpg is 20 cpg of ethanol, or 2 cpg of blended E10 gasoline.

6.2.2 *Impact of State and County Excise Tax Credit*

The Hawaii State and excise tax credit waiver of 4 cpg is slated to disappear after 2006. It is estimated that to build one or two large ethanol plants to produce 40 MM GPY will take at least one year to complete the design and permitting process, followed by a year of construction. Since currently no plans for large scale ethanol production in Hawaii exist, it also realistic to assume that prior to design and permitting work, at least 6 months to one year will be needed to conduct feasibility studies, finalize commercial agreements and arrange for financing.

Thus, the soonest one can expect to see large scale production of ethanol to come on-stream in Hawaii would be early to mid 2006, the year after which the State excise tax credit will disappear. Given current pressures on public finances, it is unlikely that an extension of the tax provision will be granted. The State excise tax credit is therefore unlikely to be a consideration in project decisions, nor will it have a significant impact on pricing.

[28] EIA, *Short Term Energy Outlook – July 2003*, http://www.eia.doe.gov/steo

6.2.3 Summary of Price Changes

The impact of various cost factors and tax provisions on gasoline pricing can now be summarized as follows:

	cpg	
Base gasoline price, rack price at $25/bbl crude	98.0	
Volume loss effect, net of effect reduced mileage	1.7	
RVP effect	1.0	
Lower octane requirement	-1.5	
	99.2	
At 90% blending rate		89.3
Ethanol price ex plant	127.0	
Average delivery cost to rack	10.2	
Excise tax credit	- 52.0	
	85.2	
At 10% blending rate		8.5
Rack price for E10 gasohol blend		97.8

The likely net effect, on average, of blending 10% ethanol in Hawaii's gasoline is therefore virtually cost neutral: the net cost of the base blendstock is likely to increase by approximately 1.2 cpg, but this increase is offset by the effect of the excise tax credit to the final blender. Given the uncertainties surrounding the cost of reducing the base blendstock RVP or the actual value to the refiners of reducing the octane requirements, both of which are highly dependent on operating conditions, crude slate and co-product values, it seems likely that the cost of gasoline at the wholesale level in Hawaii will not increase or decrease by more than 1 cpg due to ethanol blending.

Overall however, the impact of ethanol blending on consumer spending on gasoline will be negative because of the reduction in fuel efficiency by 3%. The impact of ethanol blending on Hawaii consumer spending on gasoline is: 3% x 400 MM GPY x $1.72 per gallon = $20.6 MM.

7 COST/BENEFIT ANALYSIS

An analysis of the cost and benefits of the various alternatives will have to consider the impact on the economic welfare of the State of Hawaii as a whole, as well as the impact on each of the constituent interest groups, such as the sugarcane industry, the refiners, gasoline consumers, etc.

7.1 Summary of Feasible Options

The feasible options for which the costs and benefits will be evaluated are:

- “Do-Nothing”, maintain the current status quo.
- Small scale production (6 MM GPY) in Maui for use in the local market.
- Small scale production (6 MM GPY) in Maui for exports.
- Production of 40 MM GPY in Maui for E10 blending in all of Hawaii.
- Production of 40 MM GPY for export to California.

Other scenarios exist, i.e., very large scale production of ethanol in several islands with both exports and local use of ethanol, but those are likely to be the result of a gradual evolution from more modest initial investments.

7.2 Cost and Benefits

For the cost benefit analysis, the following assumptions were made:

- Refiners and gasoline distributors will compensate for increased cost and loss of volume, net of the cost savings on ethanol as a result of the federal excise tax credit, by increasing the price of gasoline as outlined in Section 6.1 above.
- Total economic benefit from incremental activity 3 times local revenue.
- Tax incentives: State small producer credit $0.30/gln of ethanol (in the case of 40 MM gln of ethanol production, it is assumed to be produced in two plants of 20 MM gln/year each). State excise tax credit $0.04/gln of retail gasoline does not come into play: plants are assumed to start up in late 2006.
- Corporate income tax: State 6.44%, taxable income assumed to be 10% of revenues; tax receipts over direct and indirect revenues, with indirect revenues 3 x direct.
- Direct labor during construction phase: construction field work is 35% of total project cost, average cost $55,000/person-year, or 6.4 persons/$MM investment

- Direct labor during plant operations: ethanol 22 people for small plant 31 people for large plants. Indirect labor: equal to direct labor; average total payroll $70,000 per year.

Table 7.1 – Initial Costs & Benefits of Feasible Options

Scenario		Do Nothing 0 MM GPY	Maui Only 6 MM GPY	Maui Exports 6 MM GPY	All of Hawaii 40 MM GPY	CA Exports 40 MM GPY
Volumes						
HI Gasoline	MM GPY	400	397	400	372	400
HI Ethanol Production	MM GPY	-	5	5	40	40
HI E10 Blend Consumption	MM GPY	-	50	-	412	-
Naphtha Exports	MM GPY	92	95	92	120	92
Prices						
HI Gasoline Rack	$/gln	0.98	0.98	0.98	0.99	0.98
HI Gasoline Retail Ex-Tax	$/gln	1.23	1.23	1.23	-	1.23
HI Gasoline Retail	$/gln	1.72	1.72	1.72	-	1.72
Ethanol, Rack	$/gln	-	1.47	1.47	1.37	1.32
E10 Blend, Retail	$/gln	-	1.72	-	1.72	-
Naphtha Exports	$/gln	0.67	0.67	0.67	0.67	0.67
Direct Revenues						
Sugarcane	MM $/yr	-	6.0	6.0	52.8	52.8
Ethanol + Power	MM $/yr	-	7.3	7.3	60.1	58.2
Refiners & Distributors	MM $/yr	453.6	452.7	453.6	449.4	453.6
Total	**MM $**	**453.6**	**466.0**	**467.0**	**562.4**	**564.6**
Gain (Loss)	**MM $**	**-**	**12.4**	**13.3**	**108.7**	**111.0**
Total Direct & Indirect	**MM $**	**-**	**37.2**	**40.0**	**326.1**	**333.0**
Consumer Cost Impact						
Gasoline Purchases	MM $/yr	688.0	691.3	688.0	708.6	688.0
Gain (Loss) vs. current	MM $/yr	-	(3.3)	-	(20.6)	-
State & County Financial Impact						
S & C Excise Tax Receipts	MM $/yr	-	0.6	-	3.6	-
State Corp Income Tax	MM $/yr	-	0.2	0.3	2.1	2.1
State Personal Income Tax	MM $/yr	-	0.3	0.3	1.1	1.1
State Producer Incentive	MM $/yr	-	(1.5)	(1.5)	(9.0)	(9.0)
Net S & C vs. current	**MM $/yr**	**-**	**(0.4)**	**(1.0)**	**(2.2)**	**(5.8)**
Federal Excise Tax Effect						
Marketer Share (< gas price)	MM $	-	0.2	-	5.8	2.4
Producer Share (> gas price)	MM $	-	2.4	2.6	15.0	18.4
Capital						
Sugarcane	MM $	-	-	-	6.0	6.0
Ethanol	MM $	-	12.0	12.0	64.0	64.0
Refinery	MM $	-	2.0	-	4.0	-
Logistics	MM $	-	2.0	-	10.0	-
Total	**MM $**	**-**	**16.0**	**12.0**	**84.0**	**70.0**
Incremental Employment						
Construction Phase	#	-	206	154	1,076	896
Sugarcane Operations	#	-	-	-	62	62
Ethanol Plant(s)	#	-	22	22	31	31
Indirect Permanent Labor	#	-	44	44	186	186

Table 7.1 shows that in the case of 6 MM GPY production in Maui, ethanol blending is likely to cost Maui consumers about $3 million per year in increased gasoline costs. Statewide blending will cost consumers around $20 million per year. Combined State and County tax receipts go down about $0.4 million in the former case and $2.2 million in the latter. If plants

were to start up earlier in 2006 while the State retail excise tax exemption is still in effect, then the State could lose an additional million dollars per month in tax revenues for each month that a large plant would be in operation in 2006.

In case the ethanol is produced for exports, the cost for the Hawaii gasoline consumers obviously remains unchanged. In all cases the State would see an increase in corporate revenues in excess of $100 million per year. Economists often use multipliers of 3 when evaluating the impact of such incremental economic activity on a local economy, implying that for either case, the State of Hawaii's gross economic product would increase by well over $300 million.

The effect of the federal excise tax credit, which is included in the calculation of the blended cost for E10 gasoline, is that for the case where the ethanol is consumed locally, the State would see an influx of federal funds in excess of $20 million per year for the large scale production. This money however is used to offset higher cost in the production and use of the ethanol. Even after taking into account the effect of the excise tax credit, the cost of gasoline in Hawaii is expected to remain virtually unchanged as shown above in Section 6.

Although the federal excise tax credit is paid to the marketer of the gasoline, it is in fact a compensation for the higher cost of production and distribution of ethanol in gasoline. The line items in Table 7.1 under Federal Excise Tax Effect show the hypothetical split of the excise tax credit with that portion of the credit flowing to the marketer that corresponds to the differential of the gasoline rack price and the cost of the ethanol after the tax credit. The remainder of the tax credit is then in fact passed on to the ethanol producer in the form of a price premium for ethanol over the rack price of gasoline. In the California export cases, most of the federal excise tax credit would still flow to Hawaii in the form of the price premium paid by the gasoline marketers for the ethanol.

8 IMPACT OF ETHANOL BLENDING ON THE IMPLEMENTATION OF ACT 77 PRICE CAPS

A key consideration for this study was to investigate to potential interaction of price caps and ethanol blending. Below, the potential effect of price caps on ethanol production will be evaluated, as well as the reverse.

8.1 Impact of Act 77 Price Caps on Ethanol

The main thrust of Act 77 (SLH 2002) was to create a formula for limiting the price of regular self service gasoline. This formula is based on the spot price of conventional gasoline in various West Coast markets. In a recent study, Stillwater Associates calculated that the price caps would have had relatively little impact on overall price levels in Hawaii since retailers would price at the caps during periods when market conditions would have resulted otherwise in lower prices, to recover lost margins during periods when caps were in effect[29]. The price caps formula would also introduce the volatility and seasonality of the West Coast gasoline markets.

The price cap formula was designed to allow significant differentials over West Coast prices in order to allow survival of Hawaii's intrinsically high cost refining and distribution operations. The current study shows that with existing and proposed producer incentives, ethanol produced in Hawaii can in fact compete with other sources of ethanol for blending in West Coast gasoline markets. It therefore follows that there seems to be no danger that the effect of the price caps would be to render ethanol production in Hawaii economically unattractive.

Although the price caps are unlikely to materially affect the economic viability of local ethanol production, there are however other considerations. During industry stakeholder meetings conducted by Stillwater Associates as part of the price cap study, a clear message was received to the effect that few industry participants were considering new investments of any magnitude given the uncertainties surrounding the price cap legislation.

8.2 Impact of Ethanol Production on Act 77 Price Caps

Although market based, the current price cap formula does take into account some of the intrinsically higher cost of producing and distributing gasoline in Hawaii versus the West Coast reference markets. For instance, the 18 cpg distribution allowance recognizes the high cost associated with gasoline marketing overheads specific to Hawaii, such as the high cost of land for retail stations, which are only partially recovered through dealer leases.

[29] Stillwater Associates, *Study of Fuel Prices and Legislative Initiatives for the State of Hawaii*, DBEDT Study, June 2003.

If price caps are retained and ethanol production is indeed mandated in Hawaii, it would be fair to reevaluate the current formula and adjust basic production, distribution and location allowances for each island in the light of the cost structure that would emerge when ethanol is blended.

8.3 Ethanol Production and Alternatives Proposed to Price Caps

In Stillwater Associates' price cap study, several alternative solutions were proposed to price caps as a means to protect Hawaii's gasoline consumers. The primary alternative solution is to implement an effective system for monitoring volumes, prices and profitability in the different segments of the industry. If such a solution were to be adopted by the Legislation, it would have to include an eventual local ethanol industry in Hawaii as well.

Another alternative solution proposed in lieu of price caps by Stillwater Associates was to promote an integrated energy strategy for the State of Hawaii, combining refinery integration and optimization with exports of high quality gasoline blendstocks to California, introduction of Liquid Natural Gas as power fuel in Oahu, and creating opportunities for renewable energy. Ethanol production for exports to California and introduction of ethanol into Hawaii's gasoline pool would fit well into such an integrated strategy because exports of ethanol will benefit from economies of scale when gasoline blendstocks are shipped on a regular basis to California. Moreover, if the local Hawaii refineries are upgraded to maximize production of higher value components, any ethanol blended into gasoline in Hawaii would no longer result in forced exports of low value naphtha, but free up more gasoline for exports to the Mainland.

Under such scenario, the power generated from combustion of biomass would also gain in value because the shift in refinery production and fuel balance would result in an increase in distillate imports. Replacement of diesel as power fuel would thus reduce the need for diesel imports.

9 SUMMARY AND RECOMMENDATIONS

9.1 Conclusions

The main conclusions of this study are:

- The State of Hawaii has the potential to economically produce ethanol from sugarcane in quantities well in excess of what the local gasoline market could absorb. However, as is the case for ethanol production in the US in general, the economic viability of ethanol use as a gasoline blendstock depends on currently available tax incentives provided at Federal and State level.

- Hawaii's ethanol production potential is even larger if emerging technologies to produce ethanol from lignocellulosic biomass are confirmed as economically viable at commercial scale. However, given the high prices for electrical power in Hawaii, it is likely to be more advantageous to combust biomass directly for power generation rather than convert it to ethanol for use in transportation fuels.

- Opportunities exist for small scale production of ethanol from molasses available from currently operating sugar mills, notably in Maui for which such a project is currently contemplated. The difficulty with small scale production based on molasses only is that the long term viability depends on continued operation of the existing sugar industry, which in the light of upcoming removal of duty barriers is highly uncertain.

- A fully integrated plant in the range of 20 to 40 MM GPY, producing ethanol from direct fermentation of crushed cane and using all waste biomass (leafy trash, bagasse, and fibers) to produce heat and power, can produce ethanol at a price of $1.25 to $1.30 per gallon, when assuming a feedstock cost of $85 per ton of dry biomass. This price takes into account the available federal and State producer tax incentives.

- At this price level, Hawaii ethanol production can compete with small corn based producers in the Midwest for exports to California, based on shipping costs as currently incurred from either location.

- Production of approximately 40 MM GPY, enough to allow blending of up to 10% ethanol into Hawaii's entire gasoline pool, would generate in excess of $100 million per year in incremental revenues in the sugarcane, ethanol and petroleum industries. Taking into account a generally accepted multiplier factor of three, total impact on the Hawaii economy may be over $300 million per year and up to 200 new jobs.

- If locally produced ethanol is used in Hawaii, the local refineries will incur additional cost to segregate light components and export these at lower netbacks as naphtha. These costs are offset by the price differential of ethanol below gasoline rack prices after the federal excise tax credit. It is assumed that refiners and gasoline distributors will recover their additional cost of operations and required capital expenditures for logistic infrastructure, through small increases in the price of the base gasoline blendstock, estimated at 1 cpg.

- If the 40 MM GPY quoted as an example is consumed locally in Hawaii, it would result in increased spending for gasoline consumers by about $20 million per year, while net tax receipts for the State would be reduced by about $2 million per year.

- If the same 40 MM GPY of ethanol are exported to California, the State of Hawaii would see approximately the same overall economic benefits in terms of GDP contribution and additional employment (over $300 million per year and up to 200 new jobs) and reduced tax receipts, but at no cost to the Hawaii gasoline consumer.

9.2 Recommendations

The recommendations from this study for DBEDT are:

- Develop policy options and draft legislation with a focus on producing ethanol in Hawaii rather than mandating the usage in local gasoline blending. In particular, it will be necessary to repeal the current provision in §486J – 10 of the Hawaii Revised Statutes, which requires the Petroleum Commissioner to enforce blending of 10% ethanol in gasoline in Hawaii. Reference is also made to the recommendations made in Stillwater Associates' study into the effectiveness of price caps[30], to eliminate the position of a Petroleum Commissioner.

- Include ethanol in the list of products and classes of trade to be monitored under an eventual price transparency initiative to be considered as an alternative to price caps.

- Include ethanol production and production of power from biomass as part of an eventual integrated energy strategy for the State of Hawaii as proposed in Stillwater Associates' price cap study.

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30 Stillwater Associates, *Study of fuel prices and legislative initiatives for the State of Hawaii,* Study conducted for the Department of Business, Economic Development and Tourism, July 2003.

- Evaluate the possibility to produce ETBE as a means to introduce ethanol into the local gasoline pool, in order to avoid the need to maintain a segregate distribution system.
- Support the discretionary use of ethanol in fuels for applications like racing fuel or E85.
- Evaluate the possibility of obtaining an exemption for the use of Jones Act vessels to transport ethanol from Hawaii to Mainland US.