Stable Final Data – All Scenarios

Available on the Tableau Dashboard

Purpose of Analysis and Overall Approach

The analysis associated with this report builds upon the work presented in Chapters 3-4 of HSEO's Hawai'i Pathways to Decarbonization Report Decarbonization Report, specifically the electric sector analysis. The scope of the analysis includes many of the same assumptions discussed in depth on pages 155-169 of the Decarbonization Report .[1] The electric sector modeling effort, completed in Engage,[2] identified the most cost-effective portfolios of generation and storage. As a new analysis component, the models were used to determine the least-cost resource portfolio when liquified natural gas is included as an option for electrical generation. Engage analysis determines the most cost-effective generation resource portfolio to meet energy demands based on assumptions about future electricity demand (e.g. load shapes), fuel prices, technology availability, technology costs and performance, and user-defined constraints such as those determined by policy and regulation.

HSEO worked closely with NREL staff to ensure conservative cost assumptions were applied widely for natural gas technologies given the need to eventually retire all natural gas resources and avoid abandoned and costly assets. The analysis is not intended to prescribe capacities, but rather the capacity expansion analysis is intended to inform decision-making on the cost-effectiveness of various resource portfolio options. The next steps of the analysis include adjustment of capacities based on interconnection feasibility and technical constraints, full production cost models, input cost refinement based on the selected preferred pathway, and capital costs refinement as determined by more detailed engineering and lifecycle cost analysis.

Scenario Assumptions

Underlying.Electrical.Demand

To determine the impact of electrical load on resource selection, a total of three (3) different underlying electricity demands were applied to two (2) different price scenarios (high-cost / low-cost NG), across three (3) separate island grids – O'ahu, Hawai'i Island, and Maui. The various scenarios and model adjustments demonstrated substantial resource selection sensitivity. In other words, the resources chosen by the model and the amount of build-out of certain new resources were highly dependent upon and sensitive to the built-in technology assumptions.

Table 1 below shows the underlying demands applied across scenarios. While Maui and Hawai'i were initially evaluated, HSEO did not proceed with further analysis for these islands.

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[1] https://energy.hawaii.gov/wp-content/uploads/2022/10/Act-238_HSEO_Decarbonization_FinalReport_2023.pdf

[2] Engage is a free, publicly available modeling tool built around Calliope (2023) an open-source modeling framework for cross-sectoral energy system modeling and planning. Engage is a least-cost optimization model, meaning the model assesses the most cost-effective way to meet demand in each year.

Table 1: Underlying Demands Cases Applied Across Scenarios				
Model	**Scenario**	**Total Modeled Demand in 2045**	**Source / Justification for Underlying Demand Assumptions***	**Total Cumulative Demand (2021-2050)**
Oʻahu	Reference	~ 10.2 TWh	Hawaiian Electric Pathways	247,009.8 GWh
Oʻahu	Conservative	~ 12.3 TWh	Hawaiian Electric Pathways	274,521.2 GWh
Oʻahu	Aggressive	~ 14.7 TWh	Hawaiian Electric Pathways	313,852.4 GWh
Hawaiʻi	Reference	~ 1.6TWh	Hawaiian Electric Pathways	38,140.6 GWh
Hawaiʻi	Conservative	~ 2.3 TWh	Hawaiian Electric Pathways	48,174.7 GWh
Hawaiʻi	Aggressive	~ 2.9 TWh	Hawaiian Electric Pathways	56,666.9 GWh
Maui	Reference	~3 TWh	Hawaiian Electric Pathways	40,834.31 GWh
Maui	Conservative	~2.1 TWh	Hawaiian Electric Pathways	45,460.42 GWh
Maui	Aggressive	~ 1.8 TWh	Hawaiian Electric Pathways	55,167.55 GWh

*Raw.data.courtesy.of.Hawaiian.Electric¡.The.same.processing.described.in.the.Hawai›i.Decarbonization. Report.was.applied.to.all.underlying.demand.scenarios¡.Hawai›i.and.Maui.were.not.pursued.beyond.the. bookend.analysis¡

Note: A low natural gas and high natural gas cost was applied to all of the scenarios above. The "NG High Cost" runs assume the FSRU is less utilized resulting in higher costs for natural gas. The "NG Low Cost" runs assume the FSRU is more utilized resulting in lower costs for natural gas. In addition, all scenarios were modeled with and without the inclusion of offshore wind.

Infrastructure & capital costs assumed

Hawai›i.Cost.Premium

A Hawaiʻi cost multiplier of 2.154 was calculated by comparing recently completed PV projects in Hawaiʻi to continental US prices for utility-scale PV. It was applied to all capacity expansion technologies besides the FSRU itself. The decision to include the premium on the NG technologies was to explore the most conservative scenario for the economic viability of natural gas. A higher multiplier does not necessarily result in a less immediate transition in favor of the status quo; however, one thing that could change with a reduced multiplier would be the speed at which the new generation is built instead of using older legacy generators. The rollout of renewable energy in all model runs is primarily driven by the RPS, so the effect of a lower multiplier is limited.

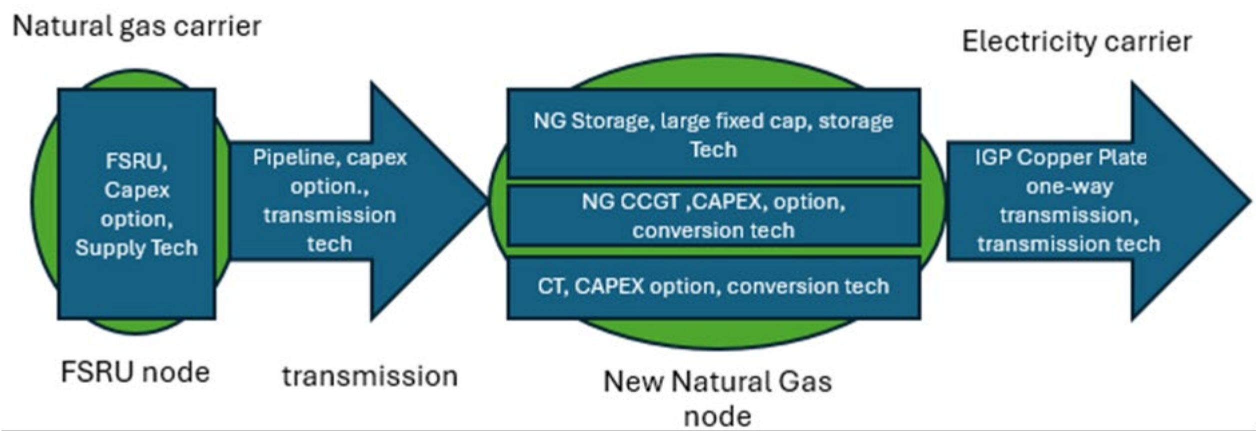
Interest.Rates.™.Amortization.Assumptions

As a part of the analysis, costs were largely driven by the assumed amortization, or payback period for the installed infrastructure. For fossil fuel infrastructure, a shorter amortization period was assumed to ensure actions would not economically prolong the utilization of natural gas. All PPAs were priced with an assumed ROA of 7%. The default lifetime for most technologies was 20 years. Shorter lifetimes were assumed for natural gas and other fossil fuel infrastructure that could not be used, or retrofitted, for renewable hydrogen operations beyond the required RPS retirement dates.

Assumptions.by.Generation.Resource

Natural Gas

Engage.natural.gas.system.representation.- .costs.were.estimated.for.each.part.of.the.resource.supply. chain¡



Two iterations of this analysis were completed. The first iteration utilized assumptions and price configurations for natural gas, and the second iteration used more conservative independently derived figures (i.e., higher storage costs), described in detail below. The second iteration included model runs with hydrogen technology available in the later years, and two (2) different resource availability scenarios one with offshore wind and the second with no offshore wind. Floating storage regasification unit (FSRU) costs were independently verified by HDR and FGE (under contract with HSEO). The FSRU costs were assumed to include the infrastructure needed to transport natural gas from the FSRU and onto the island. On-island natural gas storage, the pipeline, and the turbines were all individually priced and expanded separately in the models. Each island had separate on-island natural gas infrastructure sized to meet the needs of that island. The non-Oahu models had increased FSRU costs to represent the transport of natural gas from Oʻahu.

<u>1st Iteration "Alternative Fuels Study 2024 (first draft)"</u>

The first iteration represents the baseline, lowest-capital-cost scenario. This uses the capital and operational costs (CAPEX and OPEX, respectively) from the preliminary analysis and assumes H2-capable gas turbines (both CCGT as well as CT). The amortization period for the FSRU and pipeline ends in 2045 (i.e., a length of 2045 – build year), which assumes that the plant is no longer needed once the State's decarbonization is achieved.

Fuels Costs – The LNG fuel costs are costs from the JKM PLATTS East Asia Spot. These costs are converted to kWh and real 2018$ (assuming the nominal values were calculated with a 2.5% inflation rate from 2024 onward, the PPI index used to convert values from 2018-2023). These costs are incurred as the 'carrier production cost' ($/kWh) constraint in the FSRU technology.

FSRU – The report assumes a capital cost of $200 million for the FSRU (regasification/storage component construction or conversion) + $200 million for the terminal – total costs of $400,000 million, with different utilization resulting in different costs to build and use the FSRU. These costs were then put through the PPA process to obtain annual costs for leasing the FSRU. The FSRU costs were spot-checked with other estimates and it was decided that the 2.154 premium (see Hawaiʻi Cost Premium, above) was not applicable for the FSRU.[3] Finally, the fixed O&M is calculated as 2% of the total costs and accounts for a yearly production of 2,000,000 tons per year.

Pipeline and Transmission – The preliminary analysis assumed a unit cost of $20 million per mile of pipeline. To connect a pipeline from the Honolulu port to the Waiau generation plant is approximately 9.6 miles via HI-99. The upper bound for pipelines similar to the volume needed on Oʻahu (150 mmcfd) is equivalent to an energy throughput of 1,901,299 kW, resulting in a "cost of production capacity" (i.e., transportation cost) of approximately 101 $/kW. The amortization period, interest rate, and ROA are assumed to be the same as the other fossil technologies (up to 2045, 4%, and 7%, respectively).

Onshore Storage - Natural gas storage works differently than water or diesel storage because natural gas (after regasification) can be compressed within a storage unit or a pipeline. The physical natural gas storage is modeled at the same node as an infinite Engage storage technology. An infinite storage capacity was applied, which assumes that storage capacity would not be a limiting factor on the system. The storage unit can only store the natural gas carrier and then supply it to the CCGT or CT turbines if built into the model. Note: All FSRU storage costs are included in the FSRU facility costs.

Powerplants – Natural gas capacity expansion technology options modeled consisted of Combined Cycle Gas Turbines (CCGTs) and Combustion Turbines (CTs), also called Gas Turbines (GTs). While these units are capable of running on diesel, biodiesel, renewable natural gas, or other future renewable fuels, in the current model, they are assumed to run off natural gas.

The CCGT technology has a higher efficiency and higher capital cost, while the CT technology has a lower technology cost and lower efficiency. The technology heat rates (called conversion efficiencies in Engage) are sourced from the NREL 2023 ATB[4], and adjusted by the heat rate multipliers used in the ReEDS model. The multipliers are applied to the ideal technology heat rates reported by the ATB to account for the model not running always running the generator at the optimal heat rate.

Table 8. Multipliers Applied to Full-Load Heat Rates to Approximate Heat Rates for Part-Load Operation

Technology	Adjustment Factor
Coal (all)	1.0674
Gas-CC	1.0545
Gas-CT	1.1502
OGS	1.1704

[3] The FSRU costs were spot-checked against other industry estimates, including recent project data and market benchmarks, to ensure consistency and accuracy. The 2.154 multiplier was not applied because the specific capital costs for FSRU construction and terminal development were considered directly comparable to global estimates without requiring an adjustment for Hawaiʻi-specific cost premiums.
[4] https://atb.nrel.gov/electricity/2023/fossil_energy_technologies

Table 8 reproduced from Regional.Energy.Deployment.System.(ReEDS).Model.Documentation¿Version. 8686, Jonathan Ho et al., https://www.nrel.gov/docs/fy21osti/78195.pdf.

Engage operates on an hourly time series, and these technologies can ramp up to 100% of capacity within an hour, so no ramp rates are configured. Additionally, no minimum operating parameters or min up/down times are enforced to reduce model complexity. No minimum or maximum capacity constraints are enforced, meaning the model can optimize the desired CT/CCGT capacity. The carrier production costs for both CCGT and CT technologies are from RESOLVE input workbooks from Hawaiian Electric's IGP.[5]

2nd Iteration "Alternative Fuels Study 2024"

The second iteration included adjusted assumptions for high storage costs and other infrastructure cost adjustments beyond the 1st iteration.

FSRU – Same capital cost as 1st iteration, except that the fixed O&M cost and cost of production capacity are derated for a 600MW output, thus raising their respective costs. The fixed O&M cost and cost of production capacity rise from 3.22 $/kW and 161 $/kW in the 1st iteration to 13.33 $/kW and 666 $/kW in the 2nd iteration, respectively.

Pipeline and Transmission – The amortization period, interest rate, and ROA are the same as the 1st iteration. As with the FSRU, the cost of production capacity is derated for a 600MW output, raising it from ~101 $/kW to 320 $/kW.

Storage, Fuel Costs, Powerplant(s) – Same as 1st iteration.

Biofuels

Biomass – The capital costs reflect the ATB/EIA cost projections for biopower, which represents costs for a dedicated biomass plant. Both CAPEX and OPEX are scaled using the 2.154 Hawaii cost multiplier, with the current biomass fuel/variable cost at 60.9 $/MWh of production.

Biodiesel – Similar to biomass, the capital cost assumptions reflect the ATB/EIA cost projections for biopower, with additional diesel turbine costs applied.

Fossil

Planned retirement dates from the IGP are assumed. No economic retirements are included in the analysis.

Hydrogen Combustion Turbine (CT)

The H2 infrastructure (CAPEX/OPEX) costs are derived from the ATB and scaled for Hawaii using the 2.154 cost multiplier. Costs for appropriate turbine technologies from the ATB are applied, escalated to account for hydrogen-capable turbines, and adjusted prior to the PPA process. Costs were generated for electrolyzers, CTs, and H2 storage across all years, but hydrogen is only included in 2045. Import costs

[5] Hawaiian Electric IGP Workbooks. Available at https://www.hawaiianelectric.com/a/10684

include transportation to the islands and delivery to storage or turbine locations. Hydrogen pricing incorporates all IRA incentives.

Distributed Generation PV

Assumptions for distributed generation PV remain the same as in the Decarbonization.Report.

Utility-Scale PV

Third-party PPA costs are updated using the 2023 ATB with the NREL PPA model. Technology assumptions remain consistent with the Decarbonization.Report.

Onshore Wind

PPA costs are updated with the 2023 ATB, scaled using the 2.154 Hawaii cost multiplier, and supplemented with independent power producer unit costs. Technology assumptions align with the Decarbonization.Report.

Offshore Wind

PPA costs are updated with the 2023 ATB, following assumptions from the Decarbonization.Report. In this analysis, technical potential (maximum resource capacity) is capped at 400 MW.

Waste-to-Energy

The existing H-Power waste-to-energy plant is modeled as-is for this analysis. No additional capacity is included.

\.In.the.Decarbonization.Report?.for.Oʻahu?.Hawaiʻi.Island?.and.Maui.solar.and.land_based.wind.resource. technical.potential.are.sourced.from.8689.Hawaiian.Electric.IGP.Base.scenario.assumptions¡.The.8689. Hawaiian.Electric.IGP.Base.scenario.uses.the.Alt_7.land.exclusions.outlined.in.the.8687.update.of.the. NREL.technical.potential.report¡[6].The.capacity.expansion.analysis.used.representative.weather.year. technical.potential.profiles.published.in.the.Hawaiian.Electric.IGP.workbooks¡[7].Cost.assumptions.are. discussed.in.detail.on.pages.7❷❷_7❷❺¡[8].

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[6] Grue, N., Waechter, K., Williams, T., & Lockshin, J. (2021). Assessment of Wind and Photovoltaic Technical Potential for the Hawaiian Electric Company. National Renewable Energy Laboratory.

[7] The solar and wind technical potential profiles used in this study are provided in Excel workbooks at this website: https://www.hawaiianelectric.com/clean-energy-hawaii/integrated-grid-planning/power-supply-improvement-plan. For Oʻahu, Hawaiʻi Island, Maui, Molokaʻi, and Lānaʻi, Hawaiian Electric published four workbooks with inputs to their IRP processes under the heading "March 31, 2022 – Hawaiian Electric Response to Order No. 38253 Approving Inputs and Assumptions with Modifications (PDF)." The solar and wind technical potential profiles are sourced from the workbooks associated with each island entitled "Workbook 2."

[8] https://energy.hawaii.gov/wp-content/uploads/2022/10/Act-238_HSEO_Decarbonization_FinalReport_2023.pdf

Model constraints and resource selection drivers

A key constraint within the model was the attainment of the Renewable Portfolio Standard (RPS). To ensure the selected technologies did not backslide on current laws, the following RPS constraints were included in the model. The selected generation resources were required to meet these renewable targets:

- 39% by 2029
- 40% by 2030
- 55% by 2035
- 70% by 2040
- 100% by 2045

RPS constraints were unchanged from the decarbonization study and compliant with Hawai‘i Revised Statutes §269-91(definitions) and §269-92 (generation requirements). The RPS is a major driver of buildout as expected and was one of the most heavily-binding constraints in the model. The incremental capacity increases throughout the years are primarily driven by the need to increase the amount of RE generation.

Power.Plant.Retirements

Power plant retirements were preprogrammed into the model based on the published retirement dates in Hawaiian Electric’s IGP. Economic retirements were not considered in this analysis.

Other.Major.Assumptions?.Constraints?.and.Resource.Selection.Influences

Demand scenarios were pulled from the Hawaiian Electric Pathways report because the Decarbonization Report had extremely aggressive energy efficiency (EE) assumptions, sourced from the 2020 State of Hawai‘i Market Potential Study.[9] incorporated into the scenarios. While energy efficiency is a critical component of Hawai‘i’s energy plan, the adoption of the EE measures to the scale described in the Decarbonization Report will be challenging and may not be practical without substantial resources. Therefore, for more conservative estimates with less aggressive demand reductions, forecasts from Hawaiian Electric were applied.

The different prices due to FSRU utilization play a major role in whether natural gas is built across the islands, especially on O‘ahu. This can be seen by comparing the modeled natural gas capacities between high and low-pricing scenarios in the Appendices, where no natural gas capacity is added in the high-pricing scenarios across all islands.

The model preferred offshore wind over other resources and imposed offshore wind constraints (400 MW or 0MW) have a noticeable impact on results. Without offshore wind, the additional capacity of natural gas is most substantial in 2035, when offshore wind was assumed to become available.

[9] https://puc.hawaii.gov/wp-content/uploads/2021/02/Hawaii-2020-Market-Potential-Study-Final-Report.pdf

Appendix 1 – O‘ahu Results Tables (with and without offshore wind)

Appendix 1.1 – O‘ahu Aggressive Electrification High Costs Scenarios

Oahu Alternative Fuels Study - Scenario Results

Scenario	Category	Resource	Capacity (MW)				Generation (GWh)				Cost (million USD)			
			2030	2035	2040	2045	2030	2035	2040	2045	2030	2035	2040	2045
Aggressive High Costs with Offshore Wind	Generation	Biofuels	8	8	314	492	0	4	1,926	2,217	0	2	460	492
		Hydrogen CT	0	0	0	559	0	0	0	2,295	0	0	0	166
		Hydrogen Electrolyzer	0	0	0	0	0	0	0	0	0	0	0	0
		Natural Gas	0	0	0	0	0	0	0	0	0	0	0	0
		Offshore Wind	0	400	400	400	0	2,061	2,112	2,109	0	203	204	203
		Onshore Wind	286	286	286	286	1,073	993	976	995	142	121	64	64
		Petroleum	1,095	722	550	0	2,698	2,204	1,134	0	440	483	246	0
		Solar DGPV	1,467	1,729	2,550	2,605	2,755	3,162	4,683	4,879	125	154	249	251
		Solar PV	943	943	915	915	1,919	1,862	1,853	1,862	135	123	103	93
		Waste-to-Energy	68	68	68	68	402	348	392	436	15	13	12	11
	Non-Generation	Battery (2hr/4hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (6hr/8hr)	0	0	324	324	0	0	631	540	0	0	126	125
		Battery (10hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (DER)	206	225	270	306	188	299	318	288	8	11	13	14
		Battery (Existing/Planned)	868	868	868	868	1,260	1,454	1,380	1,180	51	45	40	36
		Hydrogen Storage	-	-	-	-	-	-	-	-	0	0	0	0
		Hydrogen Supply	-	-	-	-	-	-	-	-	0	0	0	204
		Natural Gas Distribution	-	-	-	-	-	-	-	-	0	0	0	0
		Natural Gas Supply	-	-	-	-	-	-	-	-	0	0	0	0
		Transmission/Distribution	-	-	-	-	-	-	-	-	14	21	21	21
Aggressive High Costs without Offshore Wind	Generation	Biofuels	8	91	365	543	0	571	2,452	2,724	0	135	570	596
		Hydrogen CT	0	0	0	591	0	0	0	2,631	0	0	0	175
		Hydrogen Electrolyzer	0	0	0	0	0	0	0	0	0	0	0	0
		Natural Gas	0	0	0	0	0	0	0	0	0	0	0	0
		Offshore Wind	0	0	0	0	0	0	0	0	0	0	0	0
		Onshore Wind	286	286	286	286	1,070	1,008	983	994	142	121	64	64
		Petroleum	1,095	722	550	0	2,698	2,539	1,603	0	440	558	343	0
		Solar DGPV	1,467	2,325	3,130	3,312	2,715	4,318	5,833	6,193	125	230	324	340
		Solar PV	943	943	915	915	1,934	1,873	1,842	1,871	135	123	103	93
		Waste-to-Energy	68	68	68	68	402	375	407	442	15	14	12	11
	Non-Generation	Battery (2hr/4hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (6hr/8hr)	0	213	506	506	0	410	1,020	920	0	77	191	191
		Battery (10hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (DER)	206	225	270	302	151	267	284	277	8	11	13	14
		Battery (Existing/Planned)	868	868	868	868	1,085	1,350	1,277	1,179	51	45	40	36
		Hydrogen Storage	-	-	-	-	-	-	-	-	0	0	0	0
		Hydrogen Supply	-	-	-	-	-	-	-	-	0	0	0	234
		Natural Gas Distribution	-	-	-	-	-	-	-	-	0	0	0	0
		Natural Gas Supply	-	-	-	-	-	-	-	-	0	0	0	0
		Transmission/Distribution	-	-	-	-	-	-	-	-	14	14	14	14

Appendix 1.2 – Oʻahu Aggressive Electrification Low Costs Scenarios

Oahu Alternative Fuels Study - Scenario Results

			Capacity (MW)				Generation (GWh)				Cost (million USD)			
			2030	2035	2040	2045	2030	2035	2040	2045	2030	2035	2040	2045
Aggressive Low Costs with Offshore Wind	Generation	Biofuels	8	8	8	186	0	0	3	30	0	0	1	21
		Hydrogen CT	0	0	0	970	0	0	0	4,847	0	0	0	315
		Hydrogen Electrolyzer	0	0	0	0	0	0	0	0	0	0	0	0
		Natural Gas	130	195	449	0	941	1,131	2,379	0	54	78	172	0
		Offshore Wind	0	400	400	400	0	2,062	2,073	2,095	0	203	204	203
		Onshore Wind	286	256	286	286	1,075	970	925	969	142	112	63	63
		Petroleum	1,095	722	550	0	1,875	1,160	1,149	0	306	252	247	0
		Solar DGPV	1,366	1,663	2,382	2,424	2,586	2,978	4,327	4,515	107	140	224	224
		Solar PV	943	943	915	915	1,932	1,903	1,774	1,834	135	123	103	93
		Waste-to-Energy	68	68	68	68	431	364	350	404	15	13	12	11
	Non-Generation	Battery (2hr/4hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (6hr/8hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (10hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (DER)	206	225	270	306	172	181	368	301	8	11	13	14
		Battery (Existing/Planned)	868	868	868	868	1,216	1,073	1,395	1,083	51	45	40	36
		Hydrogen Storage	-	-	-	-	-	-	-	-	0	0	0	11
		Hydrogen Supply	-	-	-	-	-	-	-	-	0	0	0	431
		Natural Gas Distribution	-	-	-	-	-	-	-	-	23	27	93	93
		Natural Gas Supply	-	-	-	-	-	-	-	-	76	95	236	38
		Transmission/Distribution	-	-	-	-	-	-	-	-	14	21	21	21
Aggressive Low Costs without Offshore Wind	Generation	Biofuels	8	8	139	317	0	0	893	1,034	0	0	208	228
		Hydrogen CT	0	0	0	989	0	0	0	5,101	0	0	0	314
		Hydrogen Electrolyzer	0	0	0	0	0	0	0	0	0	0	0	0
		Natural Gas	130	432	457	0	941	2,503	2,563	0	54	170	179	0
		Offshore Wind	0	0	0	0	0	0	0	0	0	0	0	0
		Onshore Wind	286	256	286	286	1,076	975	990	992	142	112	63	63
		Petroleum	1,095	722	550	0	1,875	1,107	1,349	0	306	239	285	0
		Solar DGPV	1,366	2,027	2,741	2,827	2,562	3,765	4,951	5,286	107	187	270	275
		Solar PV	943	943	915	915	1,939	1,874	1,881	1,863	135	123	103	93
		Waste-to-Energy	68	68	68	68	431	378	383	428	15	14	12	11
	Non-Generation	Battery (2hr/4hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (6hr/8hr)	0	0	63	63	0	0	118	75	0	0	24	24
		Battery (10hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (DER)	206	225	270	302	153	248	381	267	8	11	13	14
		Battery (Existing/Planned)	868	868	868	868	1,111	1,246	1,443	1,092	51	45	40	36
		Hydrogen Storage	-	-	-	-	-	-	-	-	0	0	0	7
		Hydrogen Supply	-	-	-	-	-	-	-	-	0	0	0	453
		Natural Gas Distribution	-	-	-	-	-	-	-	-	23	67	67	67
		Natural Gas Supply	-	-	-	-	-	-	-	-	76	233	238	28
		Transmission/Distribution	-	-	-	-	-	-	-	-	14	14	14	14

Appendix 1.3 – Oʻahu Conservative Electrification High Costs Scenarios

Oahu Alternative Fuels Study - Scenario Results

			Capacity (MW)				Generation (GWh)				Cost (million USD)			
			2030	2035	2040	2045	2030	2035	2040	2045	2030	2035	2040	2045
Conservative High Costs with Offshore Wind	Generation	Biofuels	8	8	192	370	0	0	1,216	1,408	0	0	289	317
		Hydrogen CT	0	0	0	509	0	0	0	2,051	0	0	0	151
		Hydrogen Electrolyzer	0	0	0	0	0	0	0	0	0	0	0	0
		Natural Gas	0	0	0	0	0	0	0	0	0	0	0	0
		Offshore Wind	0	400	400	400	0	1,984	2,088	2,100	0	203	204	203
		Onshore Wind	286	256	286	286	1,073	977	960	990	142	112	63	63
		Petroleum	1,095	722	550	0	2,096	1,437	1,166	0	339	310	252	0
		Solar DGPV	1,201	1,364	1,835	1,876	2,274	2,503	3,431	3,541	83	99	152	152
		Solar PV	943	943	915	915	1,929	1,915	1,834	1,863	135	123	103	93
		Waste-to-Energy	68	68	68	68	406	342	384	424	15	13	12	11
	Non-Generation	Battery (2hr/4hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (6hr/8hr)	0	0	96	96	0	0	168	131	0	0	36	36
		Battery (10hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (DER)	206	225	270	306	181	253	323	291	8	11	13	14
		Battery (Existing/Planned)	868	868	868	868	1,259	1,319	1,388	1,166	51	45	40	36
		Hydrogen Storage	-	-	-	-	-	-	-	-	0	0	0	0
		Hydrogen Supply	-	-	-	-	-	-	-	-	0	0	0	182
		Natural Gas Distribution	-	-	-	-	-	-	-	-	0	0	0	0
		Natural Gas Supply	-	-	-	-	-	-	-	-	0	0	0	0
		Transmission/Distribution	-	-	-	-	-	-	-	-	14	21	21	21
Conservative High Costs without Offshore Wind	Generation	Biofuels	8	19	256	434	0	78	1,692	1,911	0	19	395	418
		Hydrogen CT	0	0	0	549	0	0	0	2,531	0	0	0	163
		Hydrogen Electrolyzer	0	0	0	0	0	0	0	0	0	0	0	0
		Natural Gas	0	0	0	0	0	0	0	0	0	0	0	0
		Offshore Wind	0	0	0	0	0	0	0	0	0	0	0	0
		Onshore Wind	286	286	286	286	1,071	1,046	986	1,001	142	121	64	64
		Petroleum	1,095	722	550	0	2,096	2,562	1,726	0	339	562	370	0
		Solar DGPV	1,201	1,766	2,389	2,481	2,248	3,248	4,439	4,655	83	150	222	228
		Solar PV	943	943	915	915	1,929	1,874	1,868	1,875	135	123	103	93
		Waste-to-Energy	68	68	68	68	406	359	398	441	15	13	12	11
	Non-Generation	Battery (2hr/4hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (6hr/8hr)	0	19	240	240	0	35	463	384	0	7	90	90
		Battery (10hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (DER)	206	225	270	302	151	274	287	272	8	11	13	14
		Battery (Existing/Planned)	868	868	868	868	1,080	1,324	1,274	1,162	51	45	40	36
		Hydrogen Storage	-	-	-	-	-	-	-	-	0	0	0	0
		Hydrogen Supply	-	-	-	-	-	-	-	-	0	0	0	225
		Natural Gas Distribution	-	-	-	-	-	-	-	-	0	0	0	0
		Natural Gas Supply	-	-	-	-	-	-	-	-	0	0	0	0
		Transmission/Distribution	-	-	-	-	-	-	-	-	14	14	14	14

Appendix 1.4 – Oʻahu Conservative Electrification Low Costs Scenarios

Oahu Alternative Fuels Study - Scenario Results

Scenario	Category	Item	Capacity (MW)				Generation (GWh)				Cost (million USD)			
			2030	2035	2040	2045	2030	2035	2040	2045	2030	2035	2040	2045
Conservative Low Costs with Offshore Wind	Generation	Biofuels	8	8	8	186	0	0	3	28	0	0	1	19
		Hydrogen CT	0	0	0	723	0	0	0	3,381	0	0	0	229
		Hydrogen Electrolyzer	0	0	0	0	0	0	0	0	0	0	0	0
		Natural Gas	57	72	225	0	418	415	1,187	0	24	29	86	0
		Offshore Wind	0	400	400	400	0	2,058	2,096	2,106	0	203	204	203
		Onshore Wind	286	256	286	286	1,075	973	946	962	142	112	63	63
		Petroleum	1,095	722	550	0	1,734	1,050	1,229	0	281	229	264	0
		Solar DGPV	1,151	1,324	1,918	1,960	2,169	2,456	3,427	3,672	74	91	160	160
		Solar PV	943	943	915	915	1,933	1,878	1,834	1,815	135	123	103	93
		Waste-to-Energy	68	68	68	68	423	351	345	396	15	13	12	11
	Non-Generation	Battery (2hr/4hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (6hr/8hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (10hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (DER)	206	225	270	306	151	287	365	327	8	11	13	14
		Battery (Existing/Planned)	868	868	868	868	1,094	1,462	1,464	1,155	51	45	40	36
		Hydrogen Storage	-	-	-	-	-	-	-	-	0	0	0	6
		Hydrogen Supply	-	-	-	-	-	-	-	-	0	0	0	300
		Natural Gas Distribution	-	-	-	-	-	-	-	-	10	10	51	51
		Natural Gas Supply	-	-	-	-	-	-	-	-	34	35	121	20
		Transmission/Distribution	-	-	-	-	-	-	-	-	14	21	21	21
Conservative Low Costs without Offshore Wind	Generation	Biofuels	8	8	75	253	0	0	458	531	0	0	108	123
		Hydrogen CT	0	0	0	838	0	0	0	4,293	0	0	0	263
		Hydrogen Electrolyzer	0	0	0	0	0	0	0	0	0	0	0	0
		Natural Gas	57	290	312	0	418	1,668	1,738	0	24	113	122	0
		Offshore Wind	0	0	0	0	0	0	0	0	0	0	0	0
		Onshore Wind	286	256	286	286	1,074	1,002	973	992	142	112	63	63
		Petroleum	1,095	722	550	0	1,734	1,076	1,596	0	281	232	335	0
		Solar DGPV	1,151	1,699	2,225	2,267	2,168	3,072	4,082	4,229	74	140	200	200
		Solar PV	943	943	915	915	1,934	1,937	1,853	1,870	135	123	103	93
		Waste-to-Energy	68	68	68	68	423	373	381	419	15	14	12	11
	Non-Generation	Battery (2hr/4hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (6hr/8hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (10hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (DER)	206	225	270	306	151	207	402	272	8	11	13	14
		Battery (Existing/Planned)	868	868	868	868	1,094	1,148	1,526	1,018	51	45	40	36
		Hydrogen Storage	-	-	-	-	-	-	-	-	0	0	0	6
		Hydrogen Supply	-	-	-	-	-	-	-	-	0	0	0	381
		Natural Gas Distribution	-	-	-	-	-	-	-	-	10	47	47	47
		Natural Gas Supply	-	-	-	-	-	-	-	-	34	160	167	20
		Transmission/Distribution	-	-	-	-	-	-	-	-	14	14	14	14

Appendix 1.5 – O‘ahu Reference High Costs Scenarios

Oahu Alternative Fuels Study - Scenario Results

			Capacity (MW)				Generation (GWh)				Cost (million USD)			
			2030	2035	2040	2045	2030	2035	2040	2045	2030	2035	2040	2045
Reference High Costs with Offshore Wind	Generation	Biofuels	8	8	24	202	0	0	103	138	0	0	26	43
		Hydrogen CT	0	0	0	486	0	0	0	1,971	0	0	0	144
		Hydrogen Electrolyzer	0	0	0	0	0	0	0	0	0	0	0	0
		Natural Gas	0	0	0	0	0	0	0	0	0	0	0	0
		Offshore Wind	0	364	400	400	0	1,884	2,041	2,085	0	185	205	204
		Onshore Wind	286	256	286	286	1,078	958	947	970	142	112	63	63
		Petroleum	1,095	722	550	0	2,126	1,040	1,307	0	344	227	281	0
		Solar DGPV	1,212	1,290	1,465	1,507	2,292	2,392	2,700	2,820	85	90	107	108
		Solar PV	943	943	915	915	1,926	1,805	1,828	1,843	135	123	103	93
		Waste-to-Energy	68	68	68	68	406	313	334	387	15	13	12	11
	Non-Generation	Battery (2hr/4hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (6hr/8hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (10hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (DER)	206	225	270	306	182	330	370	341	8	11	13	14
		Battery (Existing/Planned)	868	868	868	868	1,247	1,615	1,503	1,226	51	45	40	36
		Hydrogen Storage	-	-	-	-	-	-	-	-	0	0	0	0
		Hydrogen Supply	-	-	-	-	-	-	-	-	0	0	0	175
		Natural Gas Distribution	-	-	-	-	-	-	-	-	0	0	0	0
		Natural Gas Supply	-	-	-	-	-	-	-	-	0	0	0	0
		Transmission/Distribution	-	-	-	-	-	-	-	-	14	21	21	21
Reference High Costs without Offshore Wind	Generation	Biofuels	8	8	152	330	0	0	988	1,113	0	0	231	248
		Hydrogen CT	0	0	0	512	0	0	0	2,422	0	0	0	152
		Hydrogen Electrolyzer	0	0	0	0	0	0	0	0	0	0	0	0
		Natural Gas	0	0	0	0	0	0	0	0	0	0	0	0
		Offshore Wind	0	0	0	0	0	0	0	0	0	0	0	0
		Onshore Wind	286	286	286	286	1,070	1,025	994	1,004	142	121	64	64
		Petroleum	1,095	722	550	0	2,126	2,207	1,752	0	344	478	372	0
		Solar DGPV	1,212	1,547	1,732	1,774	2,269	2,801	3,221	3,344	85	123	142	142
		Solar PV	943	943	915	915	1,930	1,915	1,877	1,879	135	123	103	93
		Waste-to-Energy	68	68	68	68	406	356	392	434	15	13	12	11
	Non-Generation	Battery (2hr/4hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (6hr/8hr)	0	0	36	36	0	0	64	49	0	0	14	14
		Battery (10hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (DER)	206	225	270	306	151	183	282	271	8	11	13	14
		Battery (Existing/Planned)	868	868	868	868	1,079	1,089	1,256	1,097	51	45	40	36
		Hydrogen Storage	-	-	-	-	-	-	-	-	0	0	0	0
		Hydrogen Supply	-	-	-	-	-	-	-	-	0	0	0	215
		Natural Gas Distribution	-	-	-	-	-	-	-	-	0	0	0	0
		Natural Gas Supply	-	-	-	-	-	-	-	-	0	0	0	0
		Transmission/Distribution	-	-	-	-	-	-	-	-	14	14	14	14

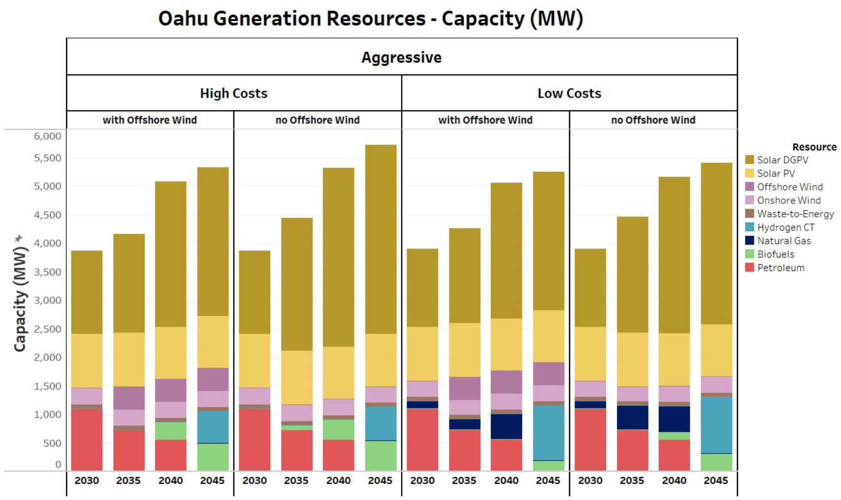
Appendix 1.6 – O‘ahu Reference Low Costs Scenarios

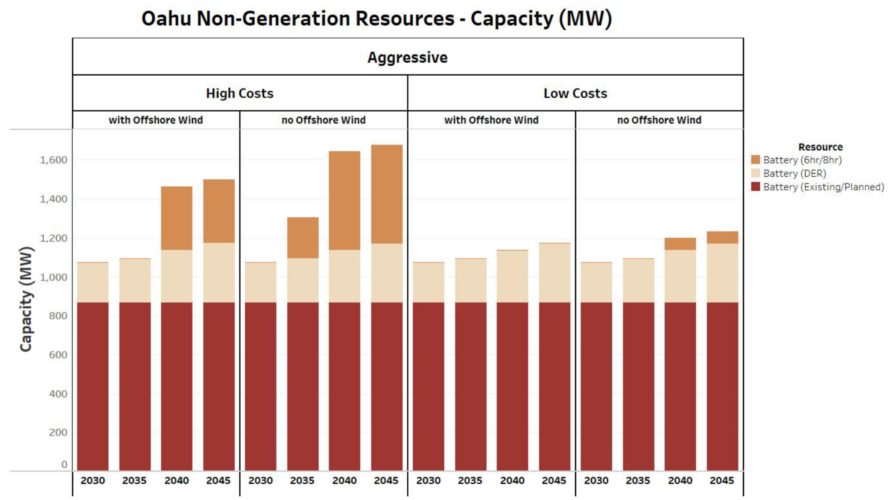
Oahu Alternative Fuels Study - Scenario Results

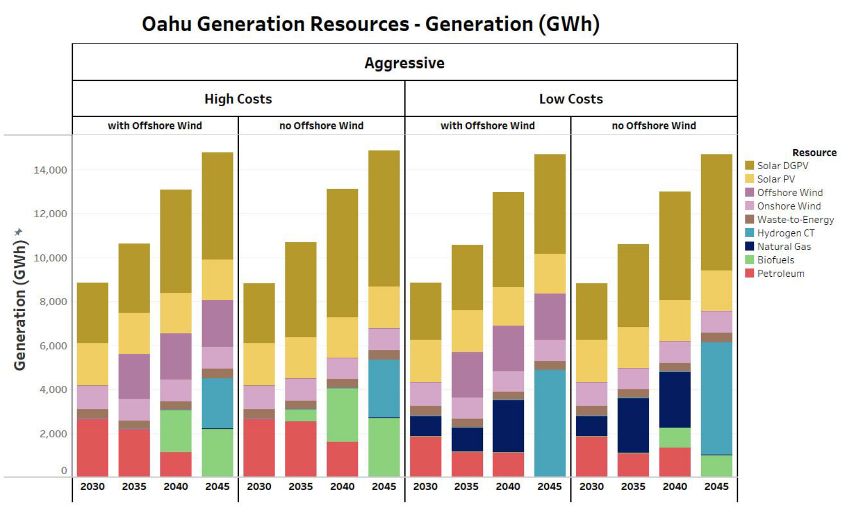
Scenario	Category	Resource	Capacity (MW)				Generation (GWh)				Cost (million USD)			
			2030	2035	2040	2045	2030	2035	2040	2045	2030	2035	2040	2045
Reference Low Costs with Offshore Wind	Generation	Biofuels	8	8	8	186	0	0	1	27	0	0	1	19
		Hydrogen CT	0	0	0	520	0	0	0	2,242	0	0	0	158
		Hydrogen Electrolyzer	0	0	0	0	0	0	0	0	0	0	0	0
		Natural Gas	65	82	94	0	481	457	510	0	27	33	37	0
		Offshore Wind	0	321	400	400	0	1,670	2,067	2,081	0	163	207	206
		Onshore Wind	286	256	163	163	1,075	952	770	784	142	112	31	31
		Petroleum	1,095	722	550	0	1,704	740	1,037	0	277	166	222	0
		Solar DGPV	1,161	1,239	1,472	1,514	2,207	2,278	2,717	2,852	76	81	105	106
		Solar PV	943	943	915	915	1,933	1,865	1,807	1,829	135	123	103	93
		Waste-to-Energy	68	68	68	68	424	340	345	394	15	13	12	11
	Non-Generation	Battery (2hr/4hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (6hr/8hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (10hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (DER)	206	225	270	306	174	182	356	323	8	11	13	14
		Battery (Existing/Planned)	868	868	868	868	1,220	1,078	1,477	1,195	51	45	40	36
		Hydrogen Storage	-	-	-	-	-	-	-	-	0	0	0	2
		Hydrogen Supply	-	-	-	-	-	-	-	-	0	0	0	199
		Natural Gas Distribution	-	-	-	-	-	-	-	-	12	12	12	12
		Natural Gas Supply	-	-	-	-	-	-	-	-	39	39	42	5
		Transmission/Distribution	-	-	-	-	-	-	-	-	14	20	21	21
Reference Low Costs without Offshore Wind	Generation	Biofuels	8	8	8	186	0	0	3	23	0	0	1	14
		Hydrogen CT	0	0	0	667	0	0	0	3,468	0	0	0	207
		Hydrogen Electrolyzer	0	0	0	0	0	0	0	0	0	0	0	0
		Natural Gas	65	206	218	0	481	1,187	1,231	0	27	81	86	0
		Offshore Wind	0	0	0	0	0	0	0	0	0	0	0	0
		Onshore Wind	286	256	201	201	1,075	1,001	831	839	142	112	41	41
		Petroleum	1,095	722	550	0	1,704	1,082	1,556	0	277	233	325	0
		Solar DGPV	1,161	1,510	1,860	1,902	2,187	2,763	3,433	3,588	76	116	154	155
		Solar PV	943	943	915	915	1,934	1,930	1,849	1,860	135	123	103	93
		Waste-to-Energy	68	68	68	68	424	370	356	413	15	14	12	11
	Non-Generation	Battery (2hr/4hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (6hr/8hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (10hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (DER)	206	225	270	302	151	245	375	286	8	11	13	14
		Battery (Existing/Planned)	868	868	868	868	1,096	1,251	1,497	1,105	51	45	40	36
		Hydrogen Storage	-	-	-	-	-	-	-	-	0	0	0	4
		Hydrogen Supply	-	-	-	-	-	-	-	-	0	0	0	308
		Natural Gas Distribution	-	-	-	-	-	-	-	-	12	32	32	32
		Natural Gas Supply	-	-	-	-	-	-	-	-	39	110	114	13
		Transmission/Distribution	-	-	-	-	-	-	-	-	14	14	14	14

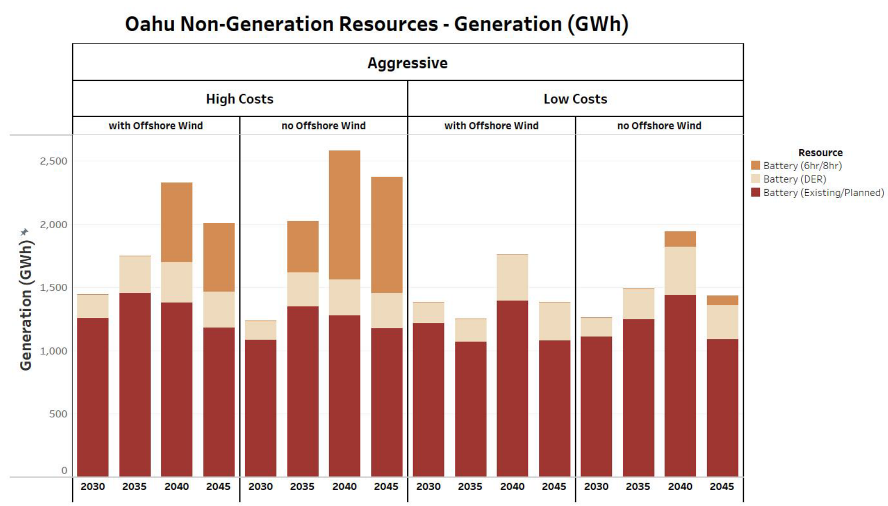
Appendix 2 - O‘ahu Results Charts

Appendix 2.1 - O‘ahu Aggressive Electrification Scenarios



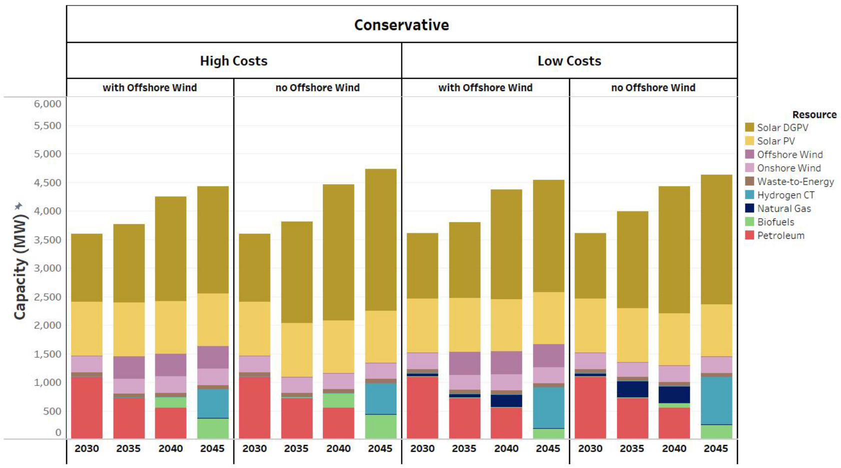




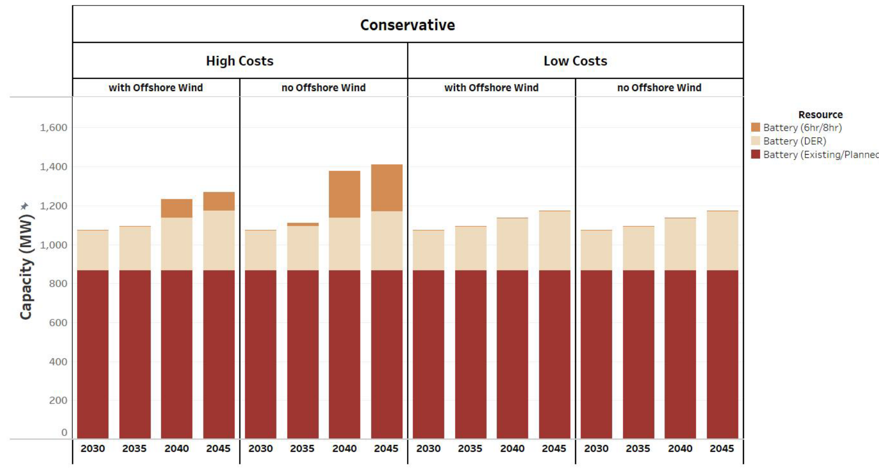


Appendix 2.2 - Oʻahu Conservative Electrification Scenarios

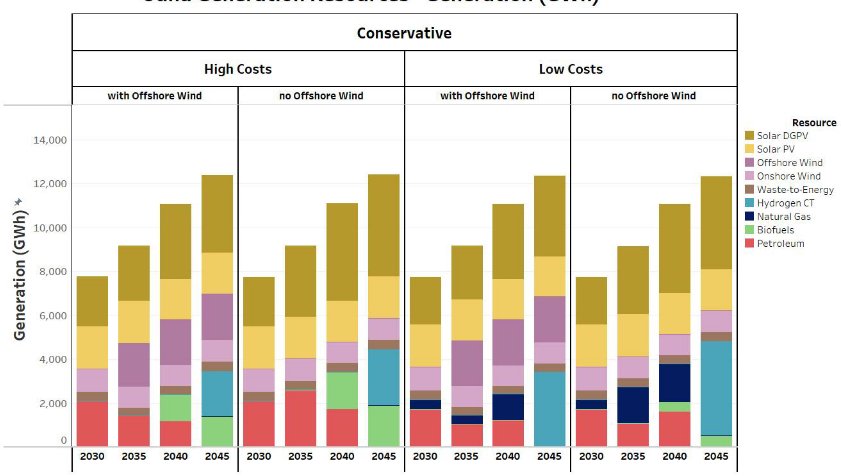
Oahu Generation Resources - Capacity (MW)



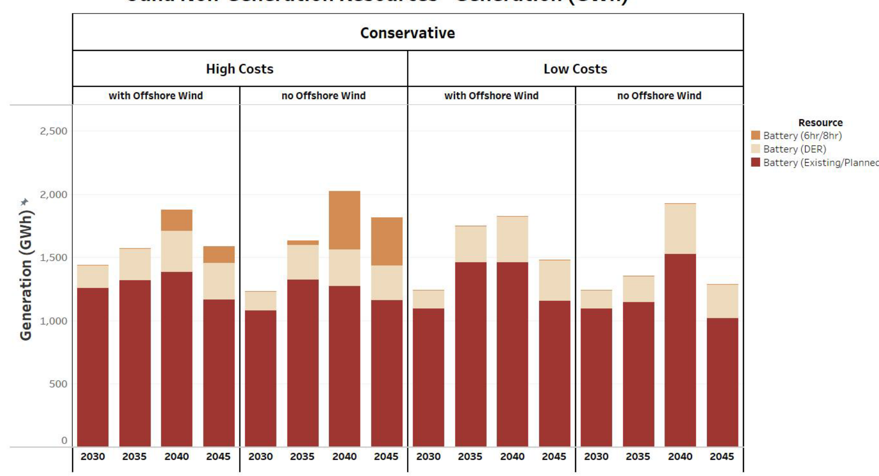
Oahu Non-Generation Resources - Capacity (MW)



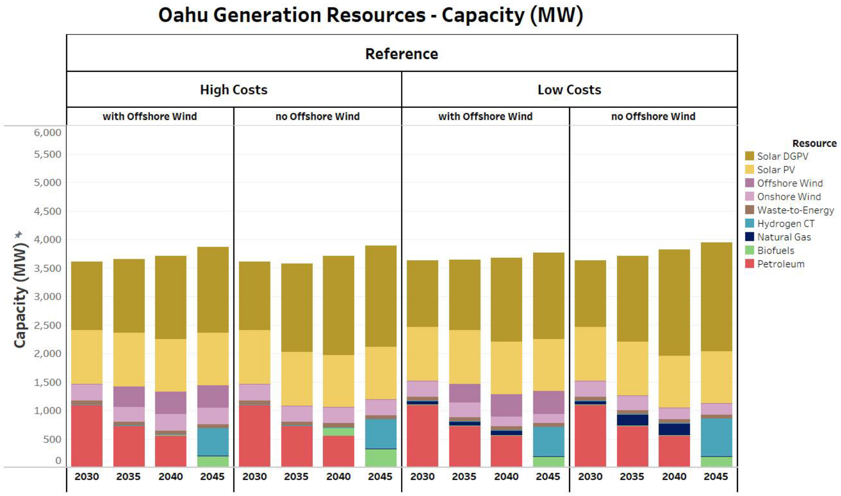
Oahu Generation Resources - Generation (GWh)

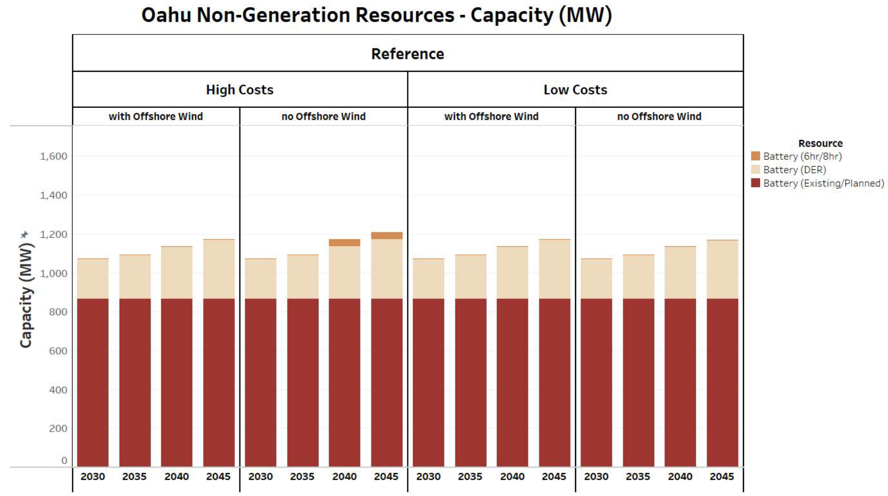


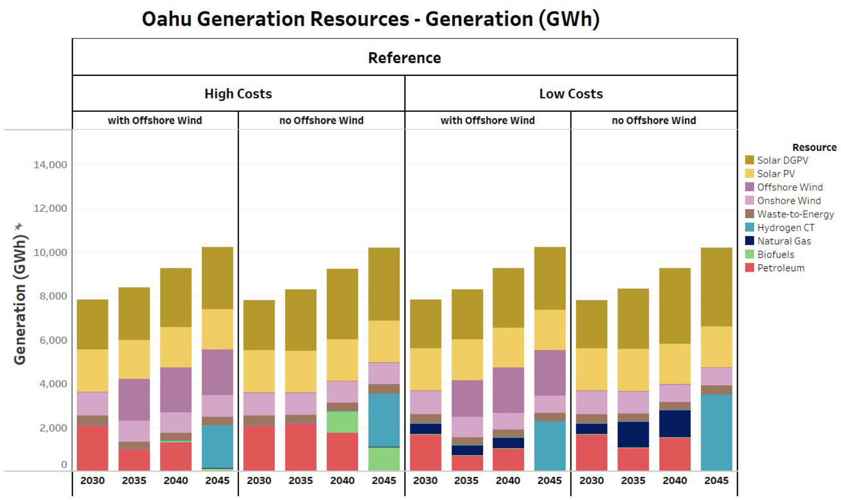
Oahu Non-Generation Resources - Generation (GWh)

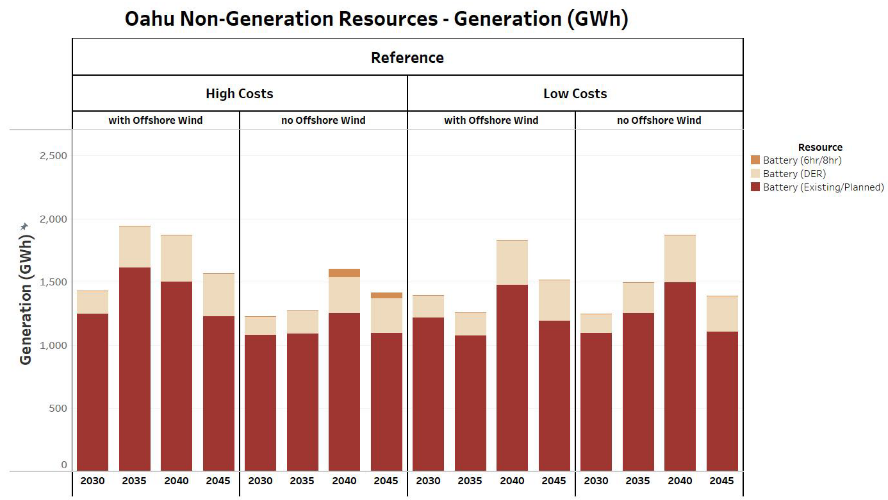


Appendix 2.3 - O'ahu Reference Electrification Scenarios









Appendix 3 – Maui Results Tables

Appendix B.1 – Maui Aggressive Electrification Scenarios

Maui Alternative Fuels Study - Scenario Results

Scenario	Category	Technology	Capacity (MW)				Generation (GWh)				Cost (million USD)			
			2030	2035	2040	2045	2030	2035	2040	2045	2030	2035	2040	2045
Aggressive High Costs with Offshore Wind	Generation	Biofuels	0	0	0	309	0	0	0	359	0	0	0	131
		Hydrogen CT	0	0	0	0	0	0	0	0	0	0	0	0
		Hydrogen Electrolyzer	0	0	0	0	0	0	0	0	0	0	0	0
		Natural Gas	0	0	0	0	0	0	0	0	0	0	0	0
		Onshore Wind	72	96	171	270	297	399	708	1,049	50	21	41	66
		Petroleum	155	155	155	0	89	201	354	0	22	37	61	0
		Solar DGPV	181	202	355	556	343	390	621	895	0	0	17	38
		Solar PV	352	352	346	346	664	749	725	704	58	54	49	45
	Non-Generation	Battery (2hr/4hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (6hr/8hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (DER)	57	72	85	96	45	91	100	166	0	0	0	0
		Battery (Existing/Planned)	371	371	371	371	356	473	482	715	58	57	56	60
		Hydrogen Storage	-	-	-	-	-	-	-	-	0	0	0	46,816
		Hydrogen Supply	-	-	-	-	-	-	-	-	0	0	0	0
		Natural Gas Distribution	-	-	-	-	-	-	-	-	0	0	0	0
		Natural Gas Supply	-	-	-	-	-	-	-	-	0	0	0	0
		Transmission/Distribution	-	-	-	-	-	-	-	-	3	9	15	24
Aggressive Low Costs with Offshore Wind	Generation	Biofuels	0	0	0	309	0	0	0	359	0	0	0	131
		Hydrogen CT	0	0	0	0	0	0	0	0	0	0	0	0
		Hydrogen Electrolyzer	0	0	0	0	0	0	0	0	0	0	0	0
		Natural Gas	0	0	0	0	0	0	0	0	0	0	0	0
		Onshore Wind	72	96	171	270	296	398	713	1,025	50	21	41	66
		Petroleum	155	155	155	0	89	201	354	0	22	37	61	0
		Solar DGPV	181	202	355	556	344	390	626	850	0	0	17	38
		Solar PV	352	352	346	346	666	749	724	728	58	54	49	45
	Non-Generation	Battery (2hr/4hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (6hr/8hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (DER)	57	72	85	96	45	91	112	101	0	0	0	0
		Battery (Existing/Planned)	371	371	371	371	358	465	533	491	58	57	56	60
		Hydrogen Storage	-	-	-	-	-	-	-	-	0	0	0	46,816
		Hydrogen Supply	-	-	-	-	-	-	-	-	0	0	0	0
		Natural Gas Distribution	-	-	-	-	-	-	-	-	0	0	0	0
		Natural Gas Supply	-	-	-	-	-	-	-	-	0	0	0	0
		Transmission/Distribution	-	-	-	-	-	-	-	-	3	9	15	24

Appendix B.2 – Maui Conservative Electrification Scenarios

Maui Alternative Fuels Study - Scenario Results

Scenario	Category	Technology	Capacity (MW)				Generation (GWh)				Cost (million USD)			
			2030	2035	2040	2045	2030	2035	2040	2045	2030	2035	2040	2045
Conservative High Costs with Offshore Wind	Generation	Biofuels	0	0	0	224	0	0	0	190	0	0	0	72
		Hydrogen CT	0	0	0	0	0	0	0	0	0	0	0	0
		Hydrogen Electrolyzer	0	0	0	0	0	0	0	0	0	0	0	0
		Natural Gas	0	0	0	0	0	0	0	0	0	0	0	0
		Onshore Wind	53	71	106	147	221	289	427	563	46	16	25	36
		Petroleum	155	155	155	0	83	165	235	0	21	32	43	0
		Solar DGPV	181	202	259	416	343	390	475	686	0	0	5	22
		Solar PV	352	352	346	346	664	746	721	722	58	54	49	45
	Non-Generation	Battery (2hr/4hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (6hr/8hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (DER)	57	72	85	96	45	87	71	159	0	0	0	0
		Battery (Existing/Planned)	371	371	371	371	368	476	342	715	58	57	56	60
		Hydrogen Storage	-	-	-	-	-	-	-	-	0	0	0	46,816
		Hydrogen Supply	-	-	-	-	-	-	-	-	0	0	0	0
		Natural Gas Distribution	-	-	-	-	-	-	-	-	0	0	0	0
		Natural Gas Supply	-	-	-	-	-	-	-	-	0	0	0	0
		Transmission/Distribution	-	-	-	-	-	-	-	-	1	6	10	13
Conservative Low Costs with Offshore Wind	Generation	Biofuels	0	0	0	224	0	0	0	190	0	0	0	72
		Hydrogen CT	0	0	0	0	0	0	0	0	0	0	0	0
		Hydrogen Electrolyzer	0	0	0	0	0	0	0	0	0	0	0	0
		Natural Gas	0	0	0	0	0	0	0	0	0	0	0	0
		Onshore Wind	53	71	106	147	221	274	426	557	46	16	25	36
		Petroleum	155	155	155	0	83	165	235	0	21	32	43	0
		Solar DGPV	181	202	259	416	342	386	475	683	0	0	5	22
		Solar PV	352	352	346	346	666	741	721	724	58	54	49	45
	Non-Generation	Battery (2hr/4hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (6hr/8hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (DER)	57	72	85	96	45	60	72	152	0	0	0	0
		Battery (Existing/Planned)	371	371	371	371	368	353	342	681	58	57	56	60
		Hydrogen Storage	-	-	-	-	-	-	-	-	0	0	0	46,816
		Hydrogen Supply	-	-	-	-	-	-	-	-	0	0	0	0
		Natural Gas Distribution	-	-	-	-	-	-	-	-	0	0	0	0
		Natural Gas Supply	-	-	-	-	-	-	-	-	0	0	0	0
		Transmission/Distribution	-	-	-	-	-	-	-	-	1	6	10	13

Appendix B.3 – Maui Reference Scenarios

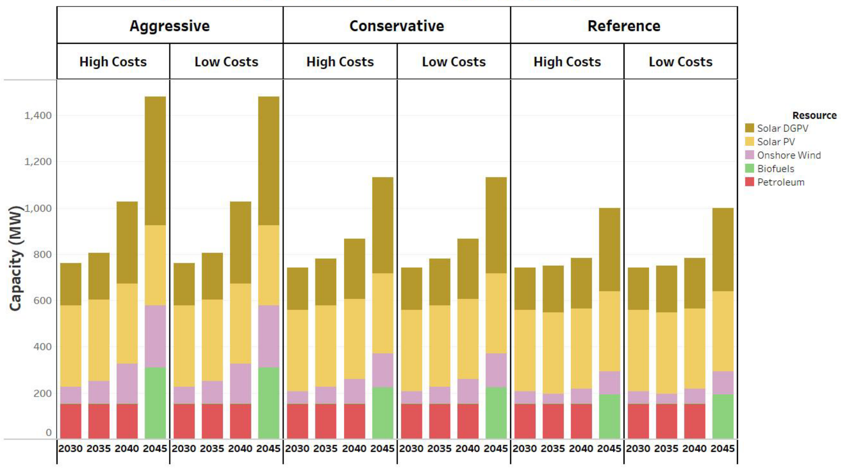
Maui Alternative Fuels Study - Scenario Results

			Capacity (MW)				Generation (GWh)				Cost (million USD)			
			2030	2035	2040	2045	2030	2035	2040	2045	2030	2035	2040	2045
Reference High Costs with Offshore Wind	Generation	Biofuels	0	0	0	194	0	0	0	119	0	0	0	48
		Hydrogen CT	0	0	0	0	0	0	0	0	0	0	0	0
		Hydrogen Electrolyzer	0	0	0	0	0	0	0	0	0	0	0	0
		Natural Gas	0	0	0	0	0	0	0	0	0	0	0	0
		Onshore Wind	53	42	63	100	223	163	255	361	46	9	15	24
		Petroleum	155	155	155	0	84	130	176	0	21	27	34	0
		Solar DGPV	181	202	218	358	344	384	417	594	0	0	0	15
		Solar PV	352	352	346	346	663	732	715	705	58	54	49	45
	Non-Generation	Battery (2hr/4hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (6hr/8hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (DER)	57	72	85	96	45	60	71	113	0	0	0	0
		Battery (Existing/Planned)	371	371	371	371	367	375	352	567	58	57	56	60
		Hydrogen Storage	-	-	-	-	-	-	-	-	0	0	0	46,816
		Hydrogen Supply	-	-	-	-	-	-	-	-	0	0	0	0
		Natural Gas Distribution	-	-	-	-	-	-	-	-	0	0	0	0
		Natural Gas Supply	-	-	-	-	-	-	-	-	0	0	0	0
		Transmission/Distribution	-	-	-	-	-	-	-	-	1	4	6	9
Reference Low Costs with Offshore Wind	Generation	Biofuels	0	0	0	194	0	0	0	119	0	0	0	48
		Hydrogen CT	0	0	0	0	0	0	0	0	0	0	0	0
		Hydrogen Electrolyzer	0	0	0	0	0	0	0	0	0	0	0	0
		Natural Gas	0	0	0	0	0	0	0	0	0	0	0	0
		Onshore Wind	53	42	63	100	219	164	255	362	46	9	15	24
		Petroleum	155	155	155	0	84	130	176	0	21	27	34	0
		Solar DGPV	181	202	218	358	340	384	417	597	0	0	0	15
		Solar PV	352	352	346	346	672	731	716	725	58	54	49	45
	Non-Generation	Battery (2hr/4hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (6hr/8hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (DER)	57	72	85	96	45	60	71	154	0	0	0	0
		Battery (Existing/Planned)	371	371	371	371	368	375	352	676	58	57	56	60
		Hydrogen Storage	-	-	-	-	-	-	-	-	0	0	0	46,816
		Hydrogen Supply	-	-	-	-	-	-	-	-	0	0	0	0
		Natural Gas Distribution	-	-	-	-	-	-	-	-	0	0	0	0
		Natural Gas Supply	-	-	-	-	-	-	-	-	0	0	0	0
		Transmission/Distribution	-	-	-	-	-	-	-	-	1	4	6	9

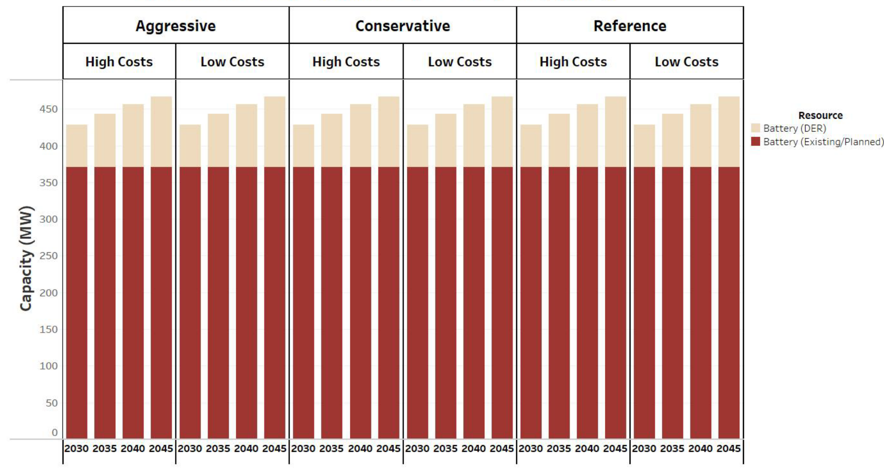
Appendix 4 – Maui Results Charts

Appendix 4.1 - Maui All Scenarios

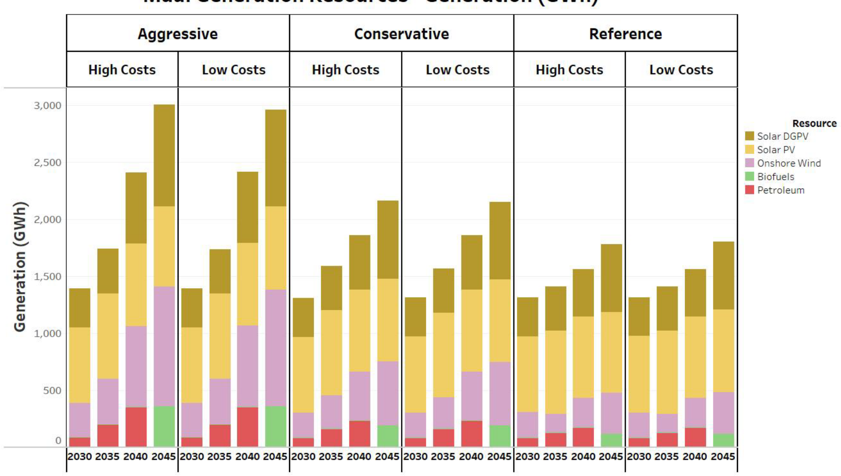
Maui Generation Resources - Capacity (MW)



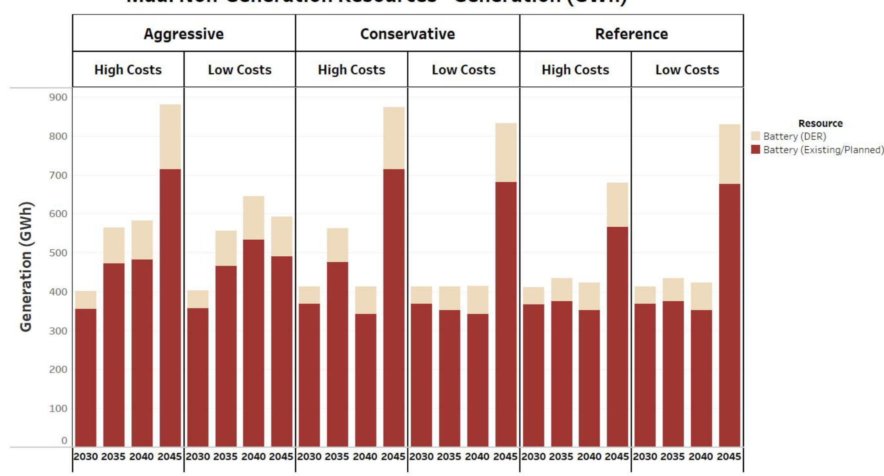
Maui Non-Generation Resources - Capacity (MW)



Maui Generation Resources - Generation (GWh)



Maui Non-Generation Resources - Generation (GWh)



Appendix 5 – Hawai‘i Island Results Tables

Appendix 5.1 – Hawai‘i Island Aggressive Electrification Scenarios

Hawaii Island Alternative Fuels Study - Scenario Results

Scenario	Category	Resource	Capacity (MW)				Generation (GWh)				Cost (million USD)			
			2030	2035	2040	2045	2030	2035	2040	2045	2030	2035	2040	2045
Aggressive High Costs with Offshore Wind	Generation	Biofuels	0	0	0	124	0	0	0	79	0	0	0	37
		Geothermal	46	46	81	146	258	259	575	1,053	81	76	122	199
		Hydrogen CT	0	0	0	0	0	0	0	0	0	0	0	0
		Hydrogen Electrolyzer	0	0	0	0	0	0	0	0	0	0	0	0
		Hydropower	18	18	18	18	47	47	47	47	3	3	3	3
		Natural Gas	0	0	0	0	0	0	0	0	0	0	0	0
		Onshore Wind	49	115	145	145	208	504	617	594	11	26	33	33
		Petroleum	182	124	124	0	31	124	176	0	31	39	54	0
		Solar DGPV	162	184	212	227	296	336	388	410	0	0	2	2
		Solar PV	243	244	284	346	578	582	660	741	47	42	53	60
	Non-Generation	Battery (2hr/4hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (6hr/8hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (DER)	38	53	65	74	30	43	55	64	0	0	0	0
		Battery (Existing/Planned)	225	225	225	225	259	228	226	256	52	56	59	54
		Hydrogen Storage	-	-	-	-	-	-	-	-	0	0	0	0
		Hydrogen Supply	-	-	-	-	-	-	-	-	0	0	0	0
		Natural Gas Distribution	-	-	-	-	-	-	-	-	0	0	0	0
		Natural Gas Supply	-	-	-	-	-	-	-	-	0	0	0	0
		Transmission/Distribution	-	-	-	-	-	-	-	-	5	14	18	18
Aggressive Low Costs with Offshore Wind	Generation	Biofuels	0	0	0	124	0	0	0	86	0	0	0	40
		Geothermal	46	46	81	151	258	259	576	1,078	81	76	122	205
		Hydrogen CT	0	0	0	0	0	0	0	0	0	0	0	0
		Hydrogen Electrolyzer	0	0	0	0	0	0	0	0	0	0	0	0
		Hydropower	18	18	18	18	47	47	47	47	3	3	3	3
		Natural Gas	0	0	0	0	0	0	0	0	0	0	0	0
		Onshore Wind	49	115	145	145	209	506	616	618	11	26	33	33
		Petroleum	182	124	124	0	31	124	176	0	31	39	54	0
		Solar DGPV	162	184	212	227	296	336	387	411	0	0	2	2
		Solar PV	243	244	284	316	577	580	660	681	47	42	53	55
	Non-Generation	Battery (2hr/4hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (6hr/8hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (DER)	38	53	65	76	30	43	55	67	0	0	0	0
		Battery (Existing/Planned)	225	225	225	225	259	227	226	242	52	56	59	54
		Hydrogen Storage	-	-	-	-	-	-	-	-	0	0	0	46,816
		Hydrogen Supply	-	-	-	-	-	-	-	-	0	0	0	0
		Natural Gas Distribution	-	-	-	-	-	-	-	-	0	0	0	0
		Natural Gas Supply	-	-	-	-	-	-	-	-	0	0	0	0
		Transmission/Distribution	-	-	-	-	-	-	-	-	5	14	18	18

Appendix 5.2 – Hawai‘i Island Conservative Electrification Scenarios

Hawaii Island Alternative Fuels Study - Scenario Results

Scenario	Category	Resource	Capacity (MW)				Generation (GWh)				Cost (million USD)			
			2030	2035	2040	2045	2030	2035	2040	2045	2030	2035	2040	2045
Conservative High Costs with Offshore Wind	Generation	Biofuels	0	0	0	124	0	0	0	81	0	0	0	37
		Geothermal	46	46	46	90	248	267	275	561	80	77	76	127
		Hydrogen CT	0	0	0	0	0	0	0	0	0	0	0	0
		Hydrogen Electrolyzer	0	0	0	0	0	0	0	0	0	0	0	0
		Hydropower	18	18	18	18	47	47	47	47	3	3	3	3
		Natural Gas	0	0	0	0	0	0	0	0	0	0	0	0
		Onshore Wind	26	81	127	127	107	351	551	555	6	18	31	30
		Petroleum	182	124	124	0	15	74	158	0	27	28	48	0
		Solar DGPV	162	184	202	217	296	336	371	397	0	0	0	0
		Solar PV	243	243	259	292	576	579	614	647	47	42	48	50
	Non-Generation	Battery (2hr/4hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (6hr/8hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (DER)	38	53	65	76	32	43	55	76	0	0	0	0
		Battery (Existing/Planned)	225	225	225	225	278	247	231	285	52	56	59	54
		Hydrogen Storage	-	-	-	-	-	-	-	-	0	0	0	46,816
		Hydrogen Supply	-	-	-	-	-	-	-	-	0	0	0	0
		Natural Gas Distribution	-	-	-	-	-	-	-	-	0	0	0	0
		Natural Gas Supply	-	-	-	-	-	-	-	-	0	0	0	0
		Transmission/Distribution	-	-	-	-	-	-	-	-	2	9	15	15
Conservative Low Costs with Offshore Wind	Generation	Biofuels	0	0	0	124	0	0	0	81	0	0	0	37
		Geothermal	46	46	46	90	248	267	275	566	80	77	76	127
		Hydrogen CT	0	0	0	0	0	0	0	0	0	0	0	0
		Hydrogen Electrolyzer	0	0	0	0	0	0	0	0	0	0	0	0
		Hydropower	18	18	18	18	47	47	47	47	3	3	3	3
		Natural Gas	0	0	0	0	0	0	0	0	0	0	0	0
		Onshore Wind	26	81	127	127	106	351	552	542	6	18	31	30
		Petroleum	182	124	124	0	15	74	158	0	27	28	48	0
		Solar DGPV	162	184	202	217	295	336	371	397	0	0	0	0
		Solar PV	243	243	259	292	576	579	614	659	47	42	48	50
	Non-Generation	Battery (2hr/4hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (6hr/8hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (DER)	38	53	65	76	30	43	55	78	0	0	0	0
		Battery (Existing/Planned)	225	225	225	225	268	247	231	307	52	56	59	54
		Hydrogen Storage	-	-	-	-	-	-	-	-	0	0	0	46,816
		Hydrogen Supply	-	-	-	-	-	-	-	-	0	0	0	0
		Natural Gas Distribution	-	-	-	-	-	-	-	-	0	0	0	0
		Natural Gas Supply	-	-	-	-	-	-	-	-	0	0	0	0
		Transmission/Distribution	-	-	-	-	-	-	-	-	2	9	15	15

Appendix 5.3 – Hawai‘i Island Reference Scenarios

Hawaii Island Alternative Fuels Study - Scenario Results

Scenario	Category	Resource	Capacity (MW)				Generation (GWh)				Cost (million USD)			
			2030	2035	2040	2045	2030	2035	2040	2045	2030	2035	2040	2045
Reference High Costs with Offshore Wind	Generation	Biofuels	0	0	0	124	0	0	0	45	0	0	0	23
		Geothermal	46	46	46	46	242	252	274	237	80	76	76	73
		Hydrogen CT	0	0	0	0	0	0	0	0	0	0	0	0
		Hydrogen Electrolyzer	0	0	0	0	0	0	0	0	0	0	0	0
		Hydropower	18	18	18	18	47	47	47	47	3	3	3	3
		Natural Gas	0	0	0	0	0	0	0	0	0	0	0	0
		Onshore Wind	13	15	31	70	51	60	130	297	4	4	8	17
		Petroleum	182	124	124	0	10	15	31	0	26	15	18	0
		Solar DGPV	162	184	202	217	295	336	370	397	0	0	0	0
		Solar PV	243	243	243	243	573	576	578	577	47	42	45	41
	Non-Generation	Battery (2hr/4hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (6hr/8hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (DER)	38	53	65	76	33	54	55	68	0	0	0	0
		Battery (Existing/Planned)	225	225	225	225	291	304	273	272	52	56	59	54
		Hydrogen Storage	-	-	-	-	-	-	-	-	0	0	0	0
		Hydrogen Supply	-	-	-	-	-	-	-	-	0	0	0	0
		Natural Gas Distribution	-	-	-	-	-	-	-	-	0	0	0	0
		Natural Gas Supply	-	-	-	-	-	-	-	-	0	0	0	0
		Transmission/Distribution	-	-	-	-	-	-	-	-	0	1	3	8
Reference Low Costs with Offshore Wind	Generation	Biofuels	0	0	0	124	0	0	0	45	0	0	0	23
		Geothermal	46	46	46	46	242	252	274	237	80	76	76	73
		Hydrogen CT	0	0	0	0	0	0	0	0	0	0	0	0
		Hydrogen Electrolyzer	0	0	0	0	0	0	0	0	0	0	0	0
		Hydropower	18	18	18	18	47	47	47	47	3	3	3	3
		Natural Gas	0	0	0	0	0	0	0	0	0	0	0	0
		Onshore Wind	13	15	31	70	51	60	130	298	4	4	8	17
		Petroleum	182	124	124	0	10	15	31	0	26	15	18	0
		Solar DGPV	162	184	202	217	294	334	370	397	0	0	0	0
		Solar PV	243	243	243	243	571	572	578	576	47	42	45	41
	Non-Generation	Battery (2hr/4hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (6hr/8hr)	0	0	0	0	0	0	0	0	0	0	0	0
		Battery (DER)	38	53	65	76	30	43	55	69	0	0	0	0
		Battery (Existing/Planned)	225	225	225	225	272	275	273	270	52	56	59	54
		Hydrogen Storage	-	-	-	-	-	-	-	-	0	0	0	46,816
		Hydrogen Supply	-	-	-	-	-	-	-	-	0	0	0	0
		Natural Gas Distribution	-	-	-	-	-	-	-	-	0	0	0	0
		Natural Gas Supply	-	-	-	-	-	-	-	-	0	0	0	0
		Transmission/Distribution	-	-	-	-	-	-	-	-	0	1	3	8

Appendix 6 – Hawai‘i Island Results Charts

Appendix 6.1 - Hawai‘i Island All Scenarios