Hawaiian Electric

2020 Integrated Grid Planning Inputs and Assumptions

March 2021 Update

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1. INTRODUCTION

This document describes the key inputs and assumptions for Hawaiian Electric's 2020 Integrated Grid Planning process modeling and provides an overview of how the inputs and assumptions are used by the RESOLVE and PLEXOS models to develop a reference portfolio.

The assumptions described herein include:

- Sales forecast by forecast layer for the underlying load, distributed energy resource, energy efficiency, and electrification of transportation layers
- Fuel price forecast
- Resource cost forecast
- Additional assumptions used to characterize the existing and planned resource portfolio

This March 2021 update of the Inputs and Assumptions reflects feedback received from stakeholders throughout the IGP process to date. The feedback incorporated herein is summarized in *IGP Stakeholder Feedback Summary, March 2021*. Key updates since the September 2020 Inputs and Assumptions report, include:

Increased Transparency

The Companies provided a workbook containing inputs and assumptions ("I&A Workbook") used in the RESOLVE model, including the annual hourly ("8760 hourly" or "8760s") profiles that define the load forecast and its layers for the underlying forecast, distributed energy resources, electric vehicles, and energy efficiency, the available generation from variable renewable resources and reserve requirements for FFR, inertia, and regulating reserves. Inputs workbooks for Oʻahu, Hawaiʻi Island, Maui, Molokaʻi, and Lānaʻi can be found on the IGP website.[1]

Resource Costs and New Resource Options

The resource costs assumed for the various candidate options were updated for several changes in 2020.

- The Federal ITC schedule for grid-scale PV, distributed PV, onshore wind, and offshore wind was updated in December 2020.
- Updated forecasts were provided by IHS Markit in December 2020 for grid-scale and distributed PV, onshore wind, and in January 2021 for utility and distributed storage.

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[1] Inputs workbooks for Oʻahu, Hawaiʻi Island, Maui, Molokaʻi, and Lānaʻi, available under the September 25, 2020 materials at https://www.hawaiianelectric.com/clean-energy-hawaii/integrated-grid-planning/stakeholder-engagement/working-groups/forecast-assumptions-documents

- The latest 2020 Annual Technology Baseline ("ATB") was used to update the source data for geothermal, biomass, offshore wind, and concentrated solar power as well as the future trendlines for combustion turbines, internal combustion engines, municipal solid waste, and synchronous condensers.

NREL is working with the Bureau of Ocean Energy Management and Hawaii State Energy Office to conduct a Hawaiʻi specific offshore wind cost modeling study. The study was introduced through a kickoff meeting in the SEOWG and stakeholders were supportive of using the specific costs established by the study in IGP.

For distributed energy resources, a paired residential PV+BESS resource was also made available as a resource option within the RESOLVE modeling with a developable potential defined as the difference between the technical potential provided by NREL and the capacity assumed in the market forecast. This incremental DER above the forecast would be able to export and participate in grid services.

Renewable Resource Potential

NREL will be re-engaged to model an additional scenario to modify the assumptions made on slope, land exclusions, minimum wind speed, and minimum parcel size and array density for grid-scale solar potential, as suggested by a stakeholder.

High and Low Bookend Sensitivities

Bookends will be evaluated as a sensitivity around the reference forecast, to establish a plausible set of assumptions for each of the layers within the load forecast to define a cumulative high forecast and cumulative low forecast. These high and low bookends could include the evaluation of higher and lower adoption of distributed energy resources, electric vehicles, energy efficiency, and time-of-use ("TOU") rates adoption. The bookends can also incorporate high and low assumptions on variable renewable generation. While the market forecast and renewable profiles provided in the inputs workbooks represent the best estimate of those assumptions, the results of the bookends will be useful to directionally inform how the resource plan and system costs will change as load and the need for renewable generation increases or decreases.

- For electric vehicles, a factor can be applied to the unmanaged charging to account different levels of adoption.
- A wider range of energy efficiency measures will be incorporated; however, modeling more detailed energy efficiency sensitivities will require additional guidance and information to do so.
- For time-of-use rates, initial "best guess" assumptions for TOU adoption and load shapes will be developed as a placeholder until proposals can be finalized in the ARDS track of the DER docket.

An initial proposal for the bookends is provided below. In sum, the low and high bookends, labeled as Slower Customer Technology Adoption and Faster Customer Technology Adoption respectively, represent a deceleration and acceleration of customer adoption of distributed energy resources, electric vehicles, energy efficiency, and time-of-use rates which are all key drivers of the load forecast.

Table 1: Proposal for Bookends Sensitivity

Assumption	Slower Customer Technology Adoption	Base	Faster Customer Technology Adoption
DER	• Market Forecast • DER aggregator as a resource option	• Market Forecast • DER aggregator as a resource option	• Increase DER layer in market forecast by 30%, capped at the technical potential established by NREL • DER aggregator as a resource option
Electric Vehicles	• Reduce electric vehicle layer in market forecast by 30%	• Market Forecast	• Increase electric vehicle layer in the market forecast by 30%, capped at the same market saturation levels in the Market Forecast
Energy Efficiency	• Reduce energy efficiency layer in market forecast by 30%	• Market Forecast	• Increase energy efficiency layer in market forecast by 30%
TOU	• Market Forecast (no assumed TOU)	• Managed EV TOU • Managed DER TOU	• Higher Managed EV TOU adoption • Higher Managed DER TOU adoption

Generating Unit Removal from Service

A fossil generation removal from service plan will be provided for O‘ahu, with considerations for units on Hawai‘i Island and Maui, to mitigate the risk of an aging generation fleet and to assess the impact of accelerating renewable resource development as generating unit utilization declines. Section 6 provides an initial schedule that will be assumed in the planning analyses.

2. OVERVIEW OF THE RESOLVE AND PLEXOS MODELS

Hawaiian Electric will use the RESOLVE model to produce a reference optimized resource plan that is then verified in PLEXOS through an hourly production simulation to capture total system costs as part of the Grid Needs Assessment.

2.1. RESOLVE CAPACITY EXPANSION MODEL

RESOLVE is a mixed-integer linear optimization model that is explicitly tailored to the study of electricity systems with high renewable and clean energy policy goals. The optimization performed in RESOLVE balances the fixed costs of new investments with variable costs of system operations, identifying a least-cost portfolio of resources to meet planning needs across a long-term horizon.

RESOLVE can solve for:

- Optimal investments in renewable resources, energy storage, thermal generating units as well as retention of existing thermal resources.

Subject to the following constraints:

- An annual renewable energy constraint that reflects the State of Hawaiʻi's Renewable Portfolio Standards policy;
- An Energy Reserve Margin constraint to maintain adequacy of supply for reliability;
- Constraints on operational reserves for regulating reserve, fast frequency response, and minimum system inertia;
- Operational restrictions and performance characteristics for generators and resources;
- Hourly load requirements; and
- Constraints on the ability to develop specific new resources (timing and amount).

RESOLVE uses statistical sampling to downscale annual data to 30 representative days per year. These representative days are weighted based on historical data to capture operational costs under most conditions. In addition to the day sampling, resources with similar operating characteristics are aggregated to facilitate efficient solving for the optimized portfolio.

The day sampling algorithm is based on a mixed-integer linear program that allows selection of a sampled number of days using historical or synthetic timeseries data to find a subset of days that are representative of the long-run distributions for system load, wind, solar, and hydro conditions. The optimization model minimizes the absolute error between the overall distribution of data and the sampled distribution for the selected days.

For example, a common implementation of the day sampling algorithm is to have 30 sampled days and select one representative day for summer peak, winter peak, and each month-weekday/weekend combination. This results in 26 represented day types that will be included in the final sample. Once the day sampling processing has selected an initial set of 26 day types, the overall sampling algorithm is rerun to find an additional 4 days to reduce the overall absolute error and calculate weights for each of the selected days.

Historical data to be used for sampling includes:

- Gross Load
- Aggregate Solar
- Aggregate Wind
- Net Load

The representative days developed for the RESOLVE modeling, including their day weights and distributions, are provided below.

O'ahu

Table 2: O'ahu Day Weights

Model Day	Weight	Historical Day
1	26.327	11/16/2016
2	20.132	8/8/2016
3	19.134	6/12/2016
4	18.757	5/30/2015
5	18.040	2/25/2016
6	17.242	3/4/2017
7	16.360	9/7/2015
8	16.312	1/31/2016
9	15.927	12/1/2016
10	15.806	4/27/2015
11	15.737	7/6/2017
12	15.243	7/31/2016
13	14.913	12/3/2018
14	14.668	1/26/2017
15	13.738	3/28/2016

16	13.407	10/11/2018
17	12.282	10/26/2018
18	12.222	5/9/2017
19	10.192	2/25/2018
20	9.801	6/8/2018
21	9.394	8/17/2017
22	8.126	4/6/2018
23	7.679	9/4/2016
24	6.049	4/26/2015
25	5.941	9/10/2018
26	5.291	10/21/2017
27	2.654	11/23/2018
28	1.453	8/11/2018
29	1.175	12/10/2017
30	1.000	11/13/2016

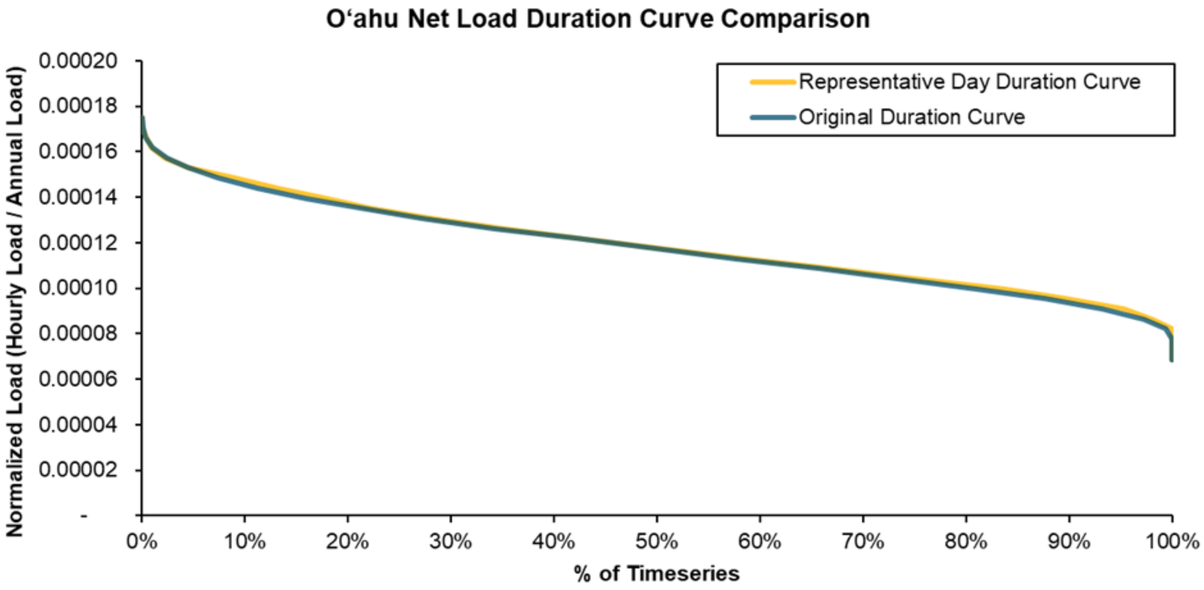

Figure 1: O‘ahu Net Load Duration Curve Comparison

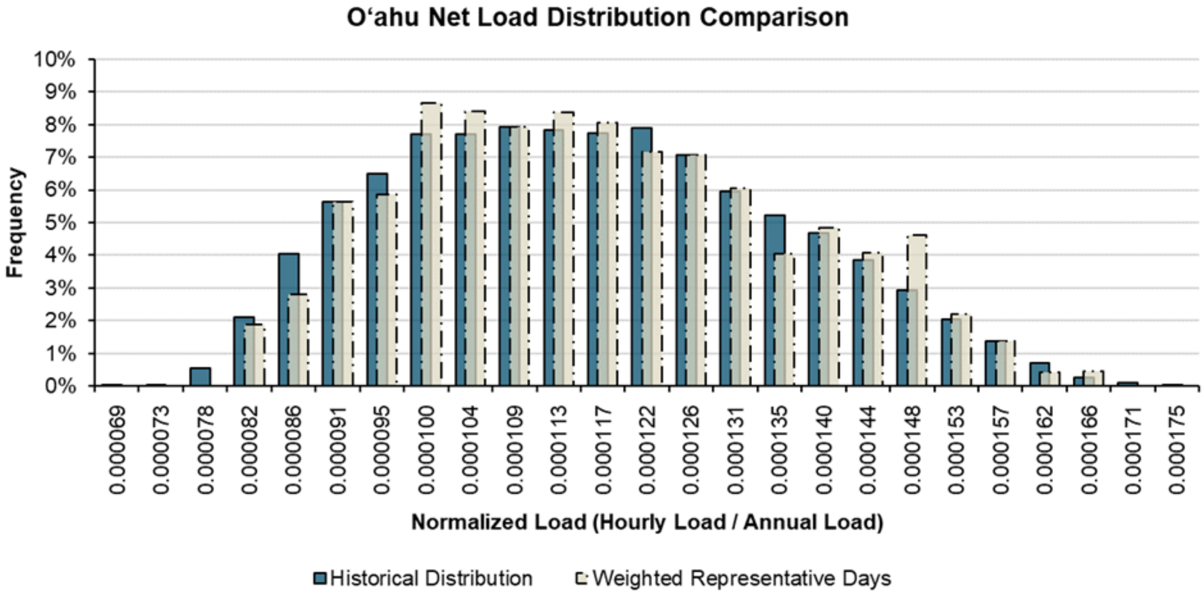

Figure 2: O‘ahu Net Load Distribution Comparison

Hawai‘i Island

Table 3: Hawai‘i Island Day Weights

Model Day	Weight	Historical Day
1	29.984	8/3/2017
2	26.625	4/5/2016
3	26.040	2/3/2017
4	25.358	6/9/2016
5	21.690	1/24/2017
6	21.568	5/8/2015
7	19.093	10/10/2016
8	18.935	3/11/2015
9	16.383	11/26/2015
10	16.315	12/5/2017
11	15.444	7/8/2017
12	15.337	9/10/2017

13	14.647	9/3/2018
14	13.647	7/6/2017
15	11.958	12/17/2016
16	11.891	10/22/2017
17	11.049	3/3/2018
18	9.294	1/3/2016
19	8.416	5/7/2017
20	8.101	11/3/2016
21	5.500	11/11/2017
22	4.626	6/25/2017
23	3.359	4/21/2018
24	2.703	12/21/2018
25	1.893	7/20/2016
26	1.144	2/14/2016
27	1.001	2/16/2017
28	1.000	3/19/2015
29	1.000	8/20/2017
30	1.000	5/11/2018

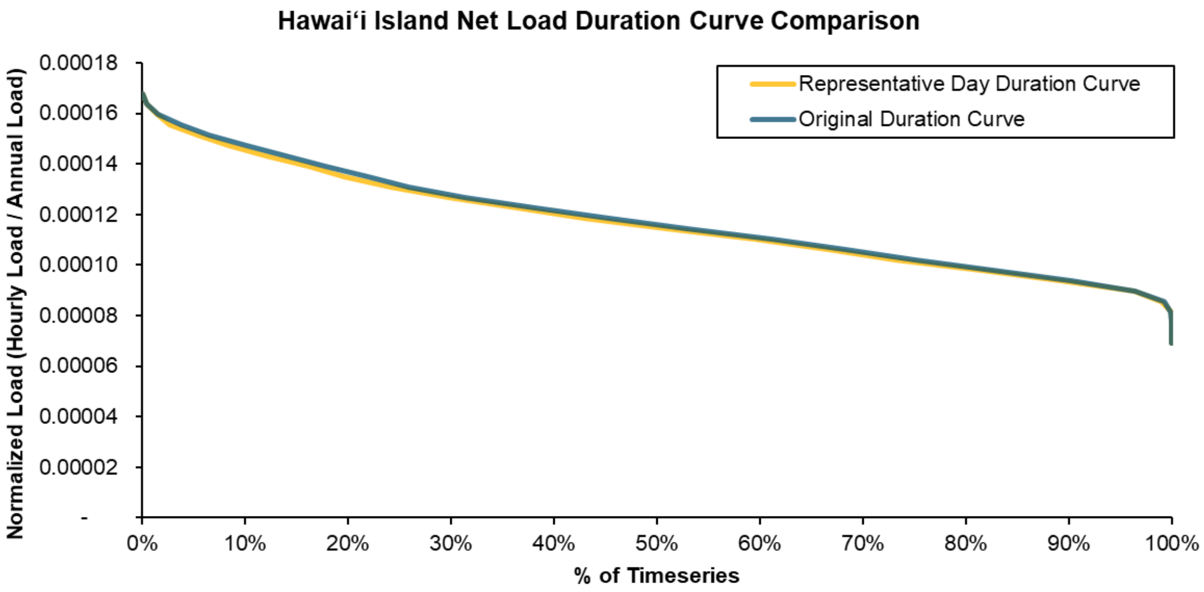

Figure 3: Hawaiʻi Island Net Load Duration Curve Comparison

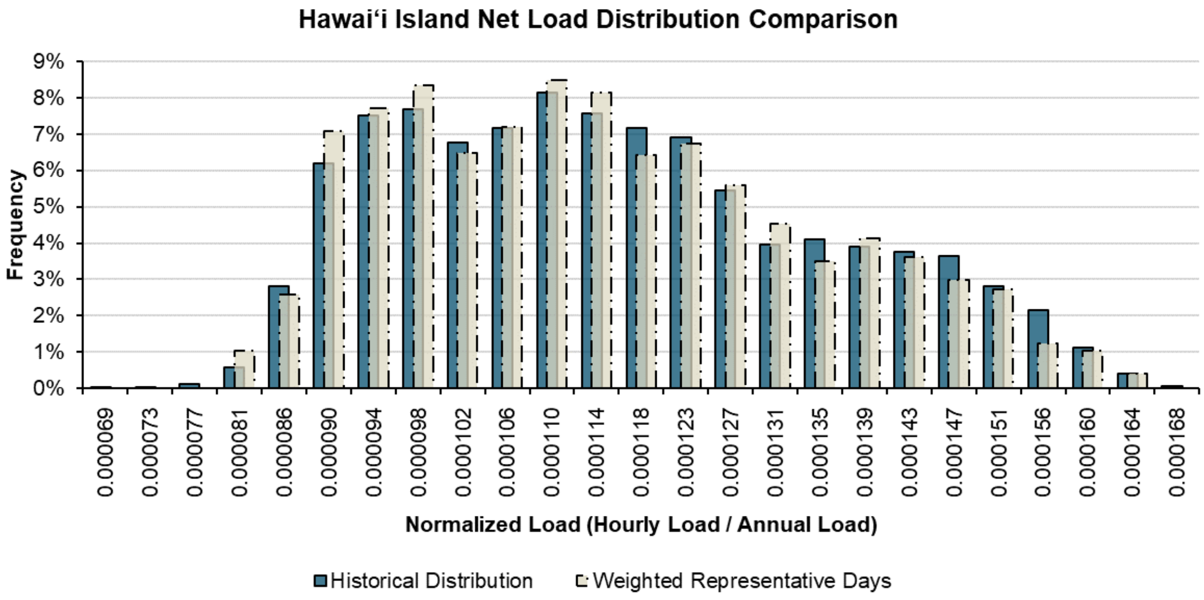

Figure 4: Hawaiʻi Island Net Load Distribution Comparison

Maui

Table 4: Maui Day Weights

Model Day	Weight	Historical Day
1	20.599	2/6/2018
2	20.506	5/16/2016
3	18.987	8/18/2018
4	18.818	4/18/2017
5	18.208	1/31/2016
6	18.081	6/15/2017
7	17.924	7/22/2016
8	17.295	9/11/2016
9	16.926	11/24/2017
10	16.855	3/25/2015

11	14.129	3/29/2015
12	14.038	10/20/2016
13	12.776	1/17/2017
14	12.689	9/28/2018
15	12.282	12/26/2016
16	12.214	12/22/2018
17	11.996	8/6/2015
18	11.903	6/12/2016
19	11.167	4/10/2016
20	11.166	10/17/2015
21	10.124	11/8/2016
22	8.674	7/26/2018
23	6.810	5/31/2015
24	6.586	2/14/2016
25	6.479	12/23/2015
26	5.780	10/3/2016
27	4.386	7/8/2017
28	3.667	5/4/2018
29	2.934	11/21/2015
30	1.000	2/19/2016

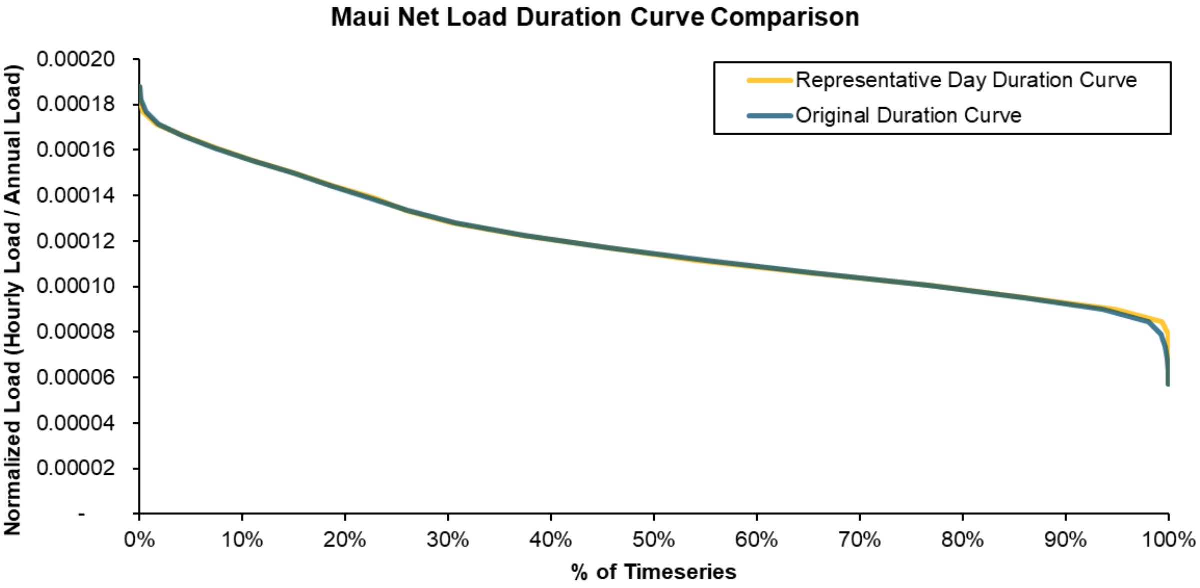

Figure 5: Maui Net Load Duration Curve Comparison

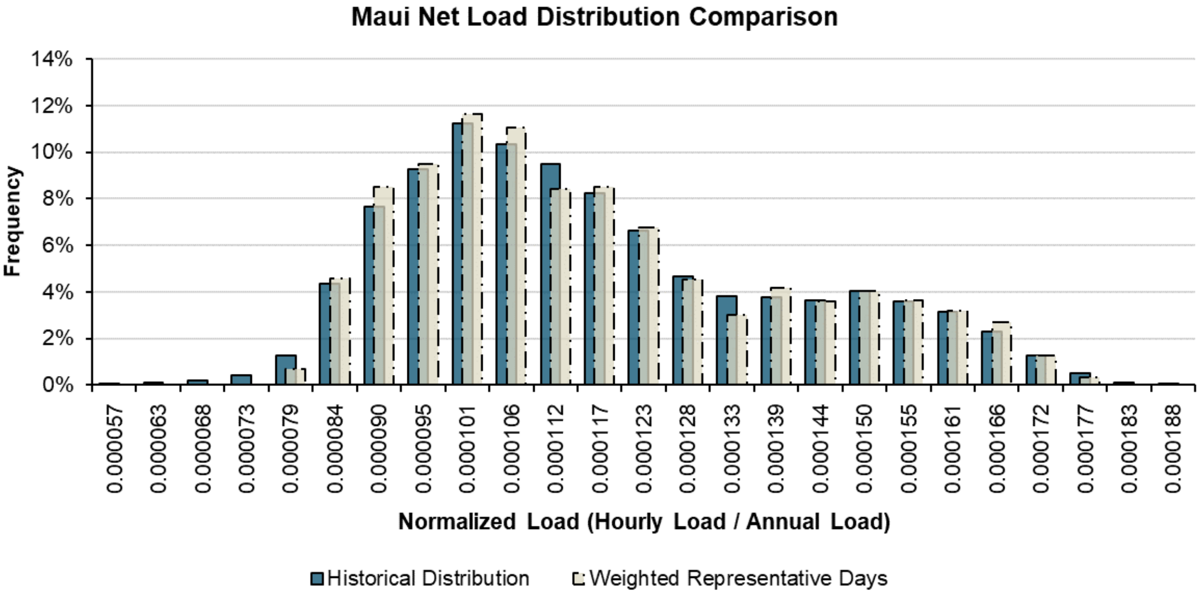

Figure 6: Maui Net Load Distribution Comparison

Molokaʻi

Table 5: Molokaʻi Day Weights

Model Day	Weight	Historical Day
1	26.64	7/23/2017
2	23.83	8/23/2017
3	21.21	9/1/2018
4	19.75	1/21/2017
5	16.96	3/22/2017
6	16.42	2/27/2017
7	15.78	11/2/2018
8	15.74	5/4/2018
9	15.63	6/9/2018
10	15.53	12/25/2017
11	15.45	12/22/2018
12	15.43	10/31/2018
13	15.24	5/20/2017
14	15.07	4/16/2018
15	14.03	3/25/2017
16	13.35	6/8/2018
17	13.20	11/22/2017
18	12.09	10/14/2018
19	11.80	4/7/2017
20	11.76	2/18/2018
21	11.23	1/17/2017
22	8.77	9/28/2018
23	6.16	8/18/2018
24	3.47	10/30/2018
25	3.35	7/14/2018
26	3.12	4/22/2017
27	1.00	6/15/2017

28	1.00	7/13/2017
29	1.00	8/2/2017
30	1.00	11/11/2017

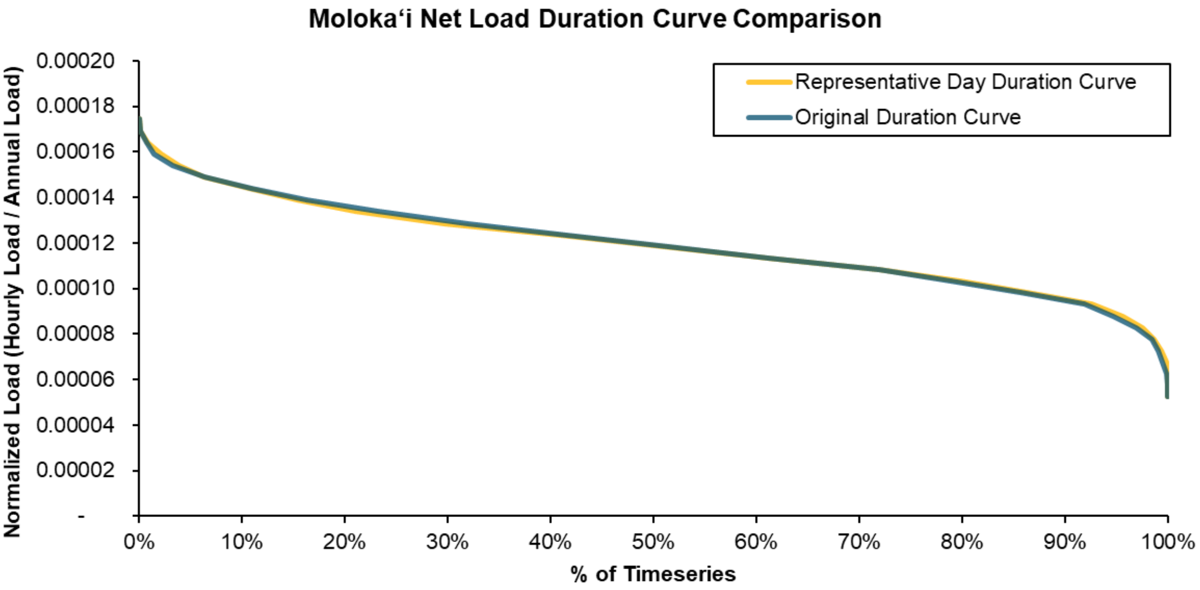

Figure 7: Moloka‘i Net Load Duration Curve Comparison

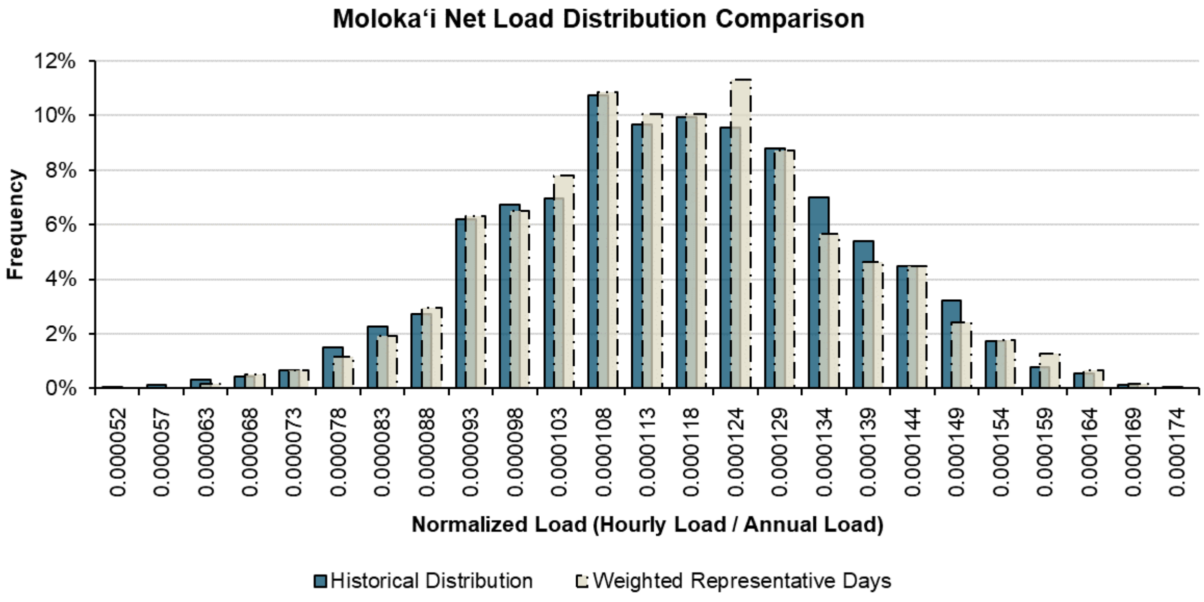

Figure 8: Moloka‘i Net Load Distribution Comparison

Lāna‘i

Table 6: Lāna‘i Day Weights

Model Day	Weight	Historical Day
1	26.803	1/17/2017
2	26.214	7/18/2017
3	23.755	10/13/2017
4	19.847	8/11/2017
5	19.206	9/3/2018
6	18.965	6/15/2017
7	18.125	5/11/2017
8	17.128	2/18/2018
9	16.906	3/9/2018
10	16.280	12/22/2018
11	15.442	4/15/2018
12	14.708	12/6/2017
13	14.559	4/18/2018
14	14.104	11/12/2018
15	13.095	3/3/2018
16	11.876	5/10/2018
17	11.036	6/24/2017
18	10.873	2/14/2018
19	10.795	9/22/2018
20	10.155	8/30/2017
21	8.079	11/15/2018
22	7.818	11/11/2017
23	6.247	10/8/2018
24	4.198	1/20/2018
25	3.787	7/14/2018

26	1.000	5/6/2017
27	1.000	7/13/2017
28	1.000	3/21/2018
29	1.000	8/18/2018
30	1.000	10/6/2018

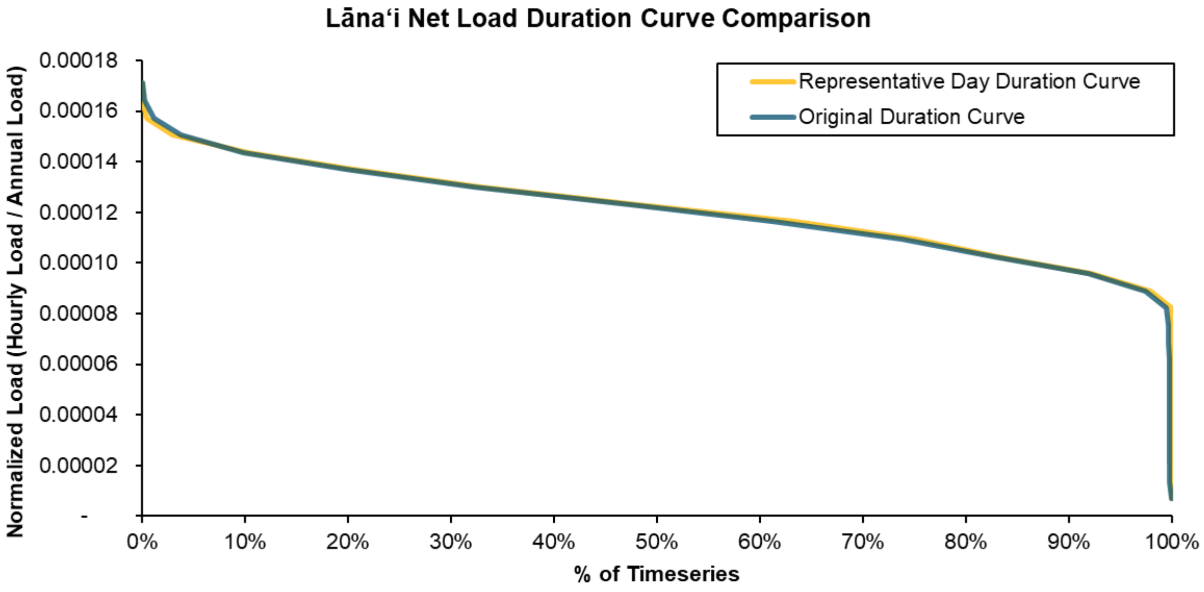

Figure 9: Lānaʻi Net Load Duration Curve Comparison

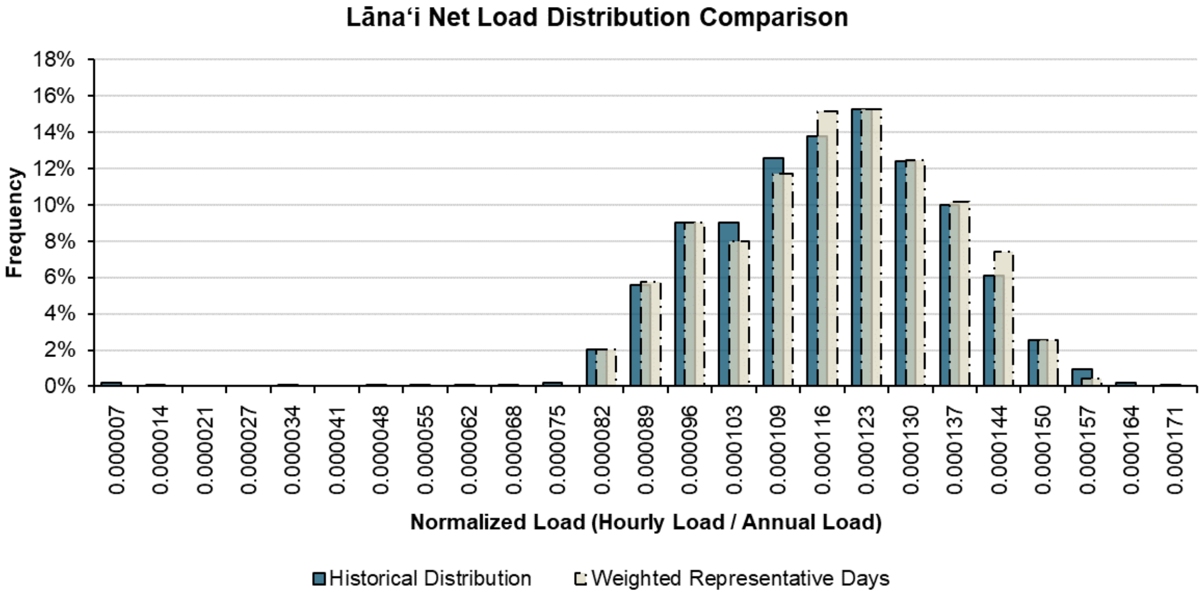

Figure 10: Lānaʻi Net Load Distribution Comparison

2.2. PLEXOS PRODUCTION SIMULATION MODEL

PLEXOS is a production simulation model that analyzes the chronological, hour-by-hour operation of a utility's generation system. PLEXOS dispatches (mathematically allocates) the forecasted hourly net megawatt (MW) load among the dispatchable generating units in operation. Unit commitment (starting and stopping of units) and dispatch levels of generation are generally based on fuel cost and unit efficiency.

The net load – that is, the load remaining after partly being served by non-dispatchable energy – is allocated to the dispatchable resources such that overall fuel expense of the system is minimized (*i.e.*, economically dispatched) within the constraints of the system. The model calculates the fuel consumed using the generating unit dispatch described above. The total fuel consumed is the summation of hourly fuel consumption from all the generating units.

The PLEXOS modeling software provides the flexibility to model a wide range of current and future technologies, such as energy storage, demand response, variable generation renewable resources, firm renewable resources and fast starting resources.

The key inputs to the PLEXOS production simulation model, as applied to the Hawaiian Electric system, are as follows:

- Hourly load to be served by all units (dispatchable and non-dispatchable);
- Operating characteristics of each Hawaiian Electric and IPP generating unit;
- Operating constraints such as system inertia, fast frequency response, and regulating reserve requirements;
- Contractual terms for IPP generating units;
- Planned maintenance schedules for the generating units;
- Estimated forced outage rates for Hawaiian Electric and thermal IPP generating units;
- Prices for fuels used by the dispatchable generating units; and
- Hourly MW profiles for non-dispatchable, variable renewable generation sources.

Inputs workbooks for Oʻahu, Hawaiʻi Island, Maui, Molokaʻi, and Lānaʻi are available online and provide additional information on the modeling inputs used by the RESOLVE and PLEXOS models.[2]

3. FORECAST ASSUMPTIONS

The modeling process for the Grid Needs Assessment relies on a set of forecast assumptions to define what the future system could look like. Many of these assumptions have been developed by the Forecast Assumptions Working Group (FAWG) and the Solution Evaluation & Optimization Working Group (SEOWG).

3.1. LOAD FORECAST

The load forecast is a key assumption for the planning models that provides the energy requirements and peak demands that must be served by Hawaiian Electric through the planning horizon. The forecasts will be used to start the planning process along with sensitivities discussed with the FAWG and SEOWG. The load forecast is just one of the many assumptions that the resource planners use in their models to stress test the various plans under varying conditions. Sensitivities[3] were developed to help address uncertainty in providing a range of forecasts to plan around given the uncertainties surrounding adoption of behind the meter technologies. Additional sensitivities will also be identified in the resource planning stage.

The forecasts were developed for each of the five islands and began with the development of the energy forecast ("sales forecast") by rate class (residential, small, medium and large

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[2] Inputs workbooks for Oʻahu, Hawaiʻi Island, Maui, Molokaʻi, and Lānaʻi, available under the September 25, 2020 materials at https://www.hawaiianelectric.com/clean-energy-hawaii/integrated-grid-planning/stakeholder-engagement/working-groups/forecast-assumptions-documents

[3] The modeling sensitivities are provided as Appendix E of the Grid Needs Assessment.

commercial and street lighting) and by layer (underlying load forecast and adjusting layers – energy efficiency, distributed energy resources, and electrification of transportation).

The underlying load forecast is driven primarily by the economy, weather, electricity price, and known adjustments to large customer loads and is informed by historical data, structural changes[4], and historical and future disruptions. The impacts of energy efficiency (EE), distributed energy resources (DER), primarily photovoltaic systems with and without storage (*i.e.*, batteries), and electrification of transportation (light duty electric vehicles (EV) and electric buses (eBus)) (collectively "EoT") were layered onto the underlying sales outlook to develop the sales forecast at the customer level.

Multiple methods and models were analyzed to develop the underlying forecast as presented in the July 17, 2019 FAWG meeting.[5] The forecasts and assumptions presented in the FAWG meetings held from March 2019 through March 2020 and described in the response to PUC-HECO-IR-1[6] were developed prior to the unprecedented global and local events of the COVID-19 pandemic and therefore do not include impacts of the virus on the forecasts. The Company updated its forecasts to account for the impacts of COVID-19 as presented in the August 31, 2020 FAWG meeting and described further in Appendix C: Forecast Methodologies.[7] Feedback from stakeholders on the assumptions used to develop the forecasts and the resulting forecast were an important part of the process and are summarized in *IGP Stakeholder Feedback Summary, March 2021*.

The residential and commercial sectors are forecasted separately as each sector's electricity usage has been found to be related to a different set of drivers as described in Appendix C: Forecast Methodologies. Historical recorded sales used in econometric models are adjusted to remove sales impact of DER, EE and EoT, which are treated as separate layers. Input data sources for developing the underlying sales forecast include economic drivers, weather variables, electricity price and historical data from the Company's own assumptions, as shown in the table below.

Table 7: Input Data Sources for Underlying Forecast

University of Hawaii Economic Research Organization	Real personal income Resident population

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[4] Structural changes include the addition of new resort loads or new air conditioning loads that have a persistent impact on the forecast.

[5] *See* https://www.hawaiianelectric.com/documents/clean_energy_hawaii/integrated_grid_planning/stakeholder_engagement/working_groups/forecast_assumptions/20190717_wg_fa_meeting_presentation_materials.pdf, slides 10-12.

[6] *See* https://www.hawaiianelectric.com/documents/clean_energy_hawaii/integrated_grid_planning/stakeholder_engagement/working_groups/forecast_assumptions/dkt_20180165_20200702_HECO_response_to_PUC_IRs_1-2.pdf

[7] *See* https://www.hawaiianelectric.com/documents/clean_energy_hawaii/integrated_grid_planning/stakeholder_engagement/working_groups/forecast_assumptions/20200831_wg_fa_meeting_presentation_materials_HECO.pdf, slides 6, 9, 11, 13 and 16 for O‘ahu, Maui, Moloka‘i, Lāna‘i and Hawai‘i islands respectively.

	Non-farm jobs Visitor arrivals
NOAA - Honolulu, Kahului, Hilo and Kona Airports	Cooling degree days Dewpoint Temperature Rainfall
Itron, Inc.	Commercial energy intensity trend for Pacific Region for non-heating/cooling end uses.
Hawaiian Electric	Recorded kWh sales Recorded customer counts Large load adjustments Real electricity price

3.1.1. DISTRIBUTED ENERGY RESOURCE FORECASTS

The DER layer includes impacts of behind the meter PV and battery energy storage systems as well as known projects for other technologies (*e.g.,* wind). This forecast adjustment estimated new additions of DER capacity in each month by island, rate class and program, and projected the resulting monthly sales impact from these additions. Future DER capacity modeling considered two time horizons:

- Near term (2020 through 2022) reflects the current pace of incoming applications and executed agreements, existing program (NEM, NEM+, SIA, CGS, GSP, CSS and ISE)[8] subscription level and caps, feedback from the Companies' program administrators and installers, customer input and any studies or upgrades being done to address short-term hurdles (e.g. circuit study, equipment upgrades) that affect the installation pace; and

- Longer term are model based as the detailed application information is not available. To extend the DER forecast from the short-term through the full planning period an economic choice model using simple payback considers a set of assumptions such as the installed cost of PV and battery, installation incentives, electricity price, program structure that affect the economic benefit to the customer which is the primary driver of their decision to adopt the system. The addressable market, or the number of utility customers that have the potential to install a DER behind the meter is also considered.

Another important assumption to consider was the structure of programs. There is an array of program choices today, some of which are subject to capacity caps. Assumptions were

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[8] Existing programs include Net Energy Metering, Net Energy Metering Plus, Standard Interconnection Agreement, Customer Grid Supply, Customer Grid Supply Plus, Customer Self Supply, and Interim Smart Export.

made as to the structure of future programs for the long term after obtaining input and perspectives from program administrators/designers, industry and policy/consultancies. The future new tariff is assumed to have compensation for export[9] that is aligned with system needs and allows for controllability during system emergencies. The export compensation and exact tariff structure was not available at the time the forecasts were developed however, insight from the DER panel members on the Panel of Experts meeting held on March 22, 2019 as well as already interconnected systems, applications and permit data show that customers are choosing to use battery storage to shift their generation to offset their own load rather than exporting to the grid during the daytime. Since storage is expected to continue to decline in cost and it seems likely that compensation for daytime export will continue to be relatively low compared to retail rates, the assumption was made that most future systems under the future tariff will be paired with storage. Furthermore, the likely rollout of a broad opt-out time-of-use (TOU) rate would increase the incentive to pair future systems with storage, adding additional credence to this assumption. Hawaiian Electric will also include high and low scenarios, to test different rates of technologies by customers. Since advanced rate designs and long-term distributed energy resource programs are in the process of being finalized and implemented, the Companies will take a "best guess" approach to assume high and low levels of TOU adoption within the high and low scenarios.

The assumptions developed around the future new tariff are still consistent with the discussions in the DER workshops, filings, and advance rate design working groups. As work progresses on advanced rate design, forecast assumptions may be revisited as information becomes available.[10]Though, potential impacts from adjustments made to these assumptions may not necessarily require restating the forecast if impacts are within the bounds of the forecasted sensitivities.

The current rate of DER applications and remaining capacities to reach set caps of interim programs, coupled with recent system configuration trends in DER applications were used to set the pace, capacities and amount of PV systems paired storage in the near term. The increasing trends in PV systems paired with batteries was observed among recent DER applications. The forecasted ramping up of paired storage systems was also supported from feedback received during the Panel of Experts meeting held on March 22, 2019 from industry leaders.[11] For residential systems in the near-term, the number of systems paired with storage increased from roughly 60% to as high as 95% for some islands in 2022.

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[9] *See* Order No. 37066 issued on April 9, 2020 in Docket No. 2019-0323, Instituting a Proceeding to Investigate Distributed Energy Resource Policies pertaining to the Hawaiian Electric Companies.

[10] In the November Commission Guidance, the Commission stated, "[t]he Companies' IGP forecasting team should also coordinate with the Companies' staff working on developing the Advanced Rate Design Strategy in the DER docket." at pp. 9-10.

[11] *See* https://www.hawaiianelectric.com/documents/clean_energy_hawaii/integrated_grid_planning/stakeholder_engagement/working_groups/forecast_assumptions/20190522_wg_fa_meeting_presentation_materials.pdf

Similarly, the small and medium commercial classes had a ramping up of paired storage systems through the course of the near term to meet with the assumptions of the model that picks up after 2022.

The model assumptions were that all small and medium commercial and all residential systems will be paired with storage after 2022. Storage size assumptions for each island and rate class were optimized based on return on investment for an average customer. By modeling average customer's optimal pairing size, the amount of forecasted storage was appropriately captured for the overall rate class as customers with larger storage requirements offset those with smaller or no storage requirements. PV installs for large commercial customers were modeled without battery storage.

There is not enough information to include grid services revenues yet however, knowing that there will likely be a program in the future that supports the assumption that PV systems paired with storage are the preferred future. Standard Interconnection Agreements were assumed to be utilized by large commercial customers with loads exceeding potential on-site PV generation. Grid service programs, such as "bring your own device", are expected to be implemented in the near future. These programs will be new to Hawai'i but as more information becomes available, such grid services oriented programs will be incorporated into the long-term planning and forecasting.

Monthly DER capacity factors for each island were used to convert installed capacity to customer energy reductions. The monthly capacity factors recognize the variations in solar irradiance throughout the year rather than using a single average annual capacity factor to more accurately reflect monthly variations in the energy production of DER systems. A degradation factor of 0.5% a year[12] was applied to the sales impacts to recognize that the DER system's performance degrades over time.

For incentives, the following was assumed for Federal and State investment tax credits.

Table 8: Federal Tax Incentive Rate Schedule

Class	2019	2020	2021	2022+
Residential	30%	26%	22%	0%
Commercial	30%	26%	22%	10%

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[12] Median degradation rate from NREL "Photovoltaic Degradation Rates - An Analytical Review", D.C. Jordan and S.R. Kurz, 2012, http://www.nrel.gov/docs/fy12osti/51664.pdf

Table 9: State Tax Incentive Rate Schedule

2019	2020	2021	2022	2023	2024	2025	2026	2027+
35%	35%	25%	25%	25%	20%	20%	20%	15%

- Cap on residential PV-only systems: $5,000 in all years
- Cap on residential PV+storage systems: $5,000 in 2019-2020, $10,000 in 2021-forward

The addressable market for residential customers included single family and multi-family homes with a maximum of four units that were owner occupied and with a high enough energy consumption to utilize at least a 3 kW PV system. Historically, only 15-20% of residential PV installations have been below 3 kW. From a practical perspective, customers with low consumption are less likely to make an investment in rooftop PV. Smaller systems are also less cost-effective due to fixed portions of the installation and material costs being spread out over smaller total capacity and savings potential.

Table 10: Addressable Market for Residential Customers

Island	Percent of Schedule R Customers	Average PV System Size (KW)	Average Storage Size (KWH)
Oʻahu	37%	7.0	15.5
Hawaiʻi Island	40%	6.0	11.0
Maui	43%	7.0	15.0
Lānaʻi	24%	4.0	9.0
Molokaʻi	30%	4.0	12.0

For commercial customers, public and private building ownership was considered. Structures greater than six stories were excluded. Similar to residential customers, small and medium commercial consumption needed to be above a set threshold. Commercial thresholds were established using rate class customers' previous 12-months usage, historical PV installation data, and business types. PV and non-PV customers were segmented by business type and distributions for total usage[13] were created for PV customers. Usage at the lower 1/8th quantile was used as the threshold for business types that had five or more customers who already installed PV. The default thresholds of 500kWh for Schedule G and 5,000 kWh for Schedule J are used for business types with less than five existing customers with PV already installed.

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[13] Total usage is the sum of the previous 12-months sales plus the sum of the previous 12-months estimated PV generation.

Table 11: Addressable Market for Commercial Customers

Island	Percent of Schedule G Customers	Percent of Schedule J Customers	Percent of Schedule P Customers
Oʻahu	37%	53%	78%
Hawaiʻi	35%	68%	44%
Maui	41%	63%	68%

Table 12: Addressable Market, Average PV System Size, and Average Storage Size for Schedule G Customers

Island	Percent of Schedule G Customers	Average PV System Size (KW)	Average Storage Size (KWH)
Oʻahu	37%	7.0	12.5
Hawaiʻi	35%	5.5	9.5
Maui	41%	7.0	14.5

Table 13: Addressable Market, Average PV System Size, and Average Storage Size for Schedule J Customers

Island	Percent of Schedule J Customers	Average PV System Size (KW)	Average Storage Size (KWH)
Oʻahu	53%	76.0	40.0
Hawaiʻi	68%	64.0	15.0
Maui	63%	59.0	45.0

Table 14: Addressable Market, Average PV System Size, and Average Storage Size for Schedule P Customers

Island	Percent of Schedule P Customers	Average PV System Size (KW)	Average Storage Size (KWH)
Oʻahu	78%	330.0	0.0
Hawaiʻi	44%	64.0	0.0
Maui	68%	330.0	0.0

Table 15: Cumulative Distributed PV Capacity (kW)

Year	O'ahu	Hawai'i Island	Maui	Moloka'i	Lāna'i	Consolidated
kW	A	B	C	D	E	F =A + B + C + D +E
2025	655,712	135,631	145,757	3,112	1,006	941,218
2030	757,845	156,486	168,105	3,440	1,187	1,087,064
2040	936,374	197,218	207,486	4,088	1,545	1,346,711
2045	1,011,101	220,219	223,980	4,400	1,739	1,461,440
2050	1,073,105	241,791	238,385	4,668	1,912	1,559,861

Table 16: Cumulative Distributed BESS Capacity (kWh)

Year	O'ahu	Hawai'i Island	Maui	Moloka'i	Lāna'i	Consolidated
kWh	A	B	C	D	E	F =A + B + C + D +E
2025	133,409	69,805	82,955	796	362	287,326
2030	276,352	94,799	118,891	1,480	605	492,127
2040	553,654	145,443	184,317	2,824	1,082	887,319
2045	671,661	176,872	214,197	3,460	1,325	1,067,515
2050	768,058	206,292	240,143	4,000	1,550	1,220,042

3.1.2. ENERGY EFFICIENCY

The energy efficiency layer is based on projections from the Statewide Market Potential Study prepared by Applied Energy Group (AEG) and sponsored by the Hawai'i Public Utilities Commission.[14] The preliminary results from the study were presented to the FAWG on January 29, 2020.[15] The market potential study considered customer segmentation, technologies and measures, building codes and appliance standards as well

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[14] *See* https://622c4de9-1fe4-418c-ac8a-695cbe1a8f60.filesusr.com/ugd/0c9650_647db07744d248fab7a9f563cf5b416d.pdf

[15] *See* https://www.hawaiianelectric.com/documents/clean_energy_hawaii/integrated_grid_planning/stakeholder_engagement/working_groups/forecast_assumptions/20200129_wg_fa_hawaii_market_potential_study_draft_results.pdf

as the progress towards achieving the Energy Efficiency Portfolio Standards. The study included technical, economic and achievable energy efficiency potentials.

An achievable Business As Usual (BAU) energy efficiency potential forecast by island and sector covering the years 2020 through 2045 was provided to the Company in February 2020 to use for the Company's forecasts. The BAU potential forecast represented savings from realistic customer adoption of energy efficiency measures through future interventions that were similar in nature to existing interventions. In addition to the BAU forecast, a codes and standards (C&S) forecast was also provided.

The forecasts provided to the Company reclassified certain market segments to different customer classes to align with how the Company forecasts sales. Since a thirty-year forecast was needed, the Company extended the forecast out to 2050 using trends in AEG's forecast. AEG's forecast for Lānaʻi and Molokaʻi was adjusted to be consistent with Hawaii Energy's historical island allocation. A five year average net-to-gross ratio from Hawaii Energy's program years 2014 through 2018 for each island was applied to the forecasts in order to exclude free riders[16] from the energy savings estimates as impacts from free riders were assumed to be embedded in the underlying forecasts described above. The impacts from AEG were derived at an annualized level and included free riders which reflected savings for all measures as if they were all installed in January and provided savings for the whole year. The annualized impacts were ramped throughout the year to arrive at energy efficiency impacts by month for each forecasted year. For simplicity, the installations were assumed to be evenly distributed throughout the year.

3.1.3. ELECTRIFICATION OF TRANSPORTATION

The electrification of transportation layer consists of impacts from the charging of light duty electric vehicles and electric buses.

<u>Light Duty Electric Vehicles</u>

The light duty electric vehicle forecast was based on an adoption model developed by Integral Analytics, Inc. as described in Appendix E of the EoT Roadmap[17] to arrive at EV saturations of total light duty vehicles (LDV) by year for each island. Historical data for LDV registrations were provided by the Department of Business, Economic Development, and Tourism (DBEDT) and reported at the county level. In order to get to the island level for Maui County, an allocation factor supplied by DBEDT and based on vehicle registration for the three islands was used. The total LDV forecast for each county was estimated using a

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[16] A free rider is someone who would install an energy efficient measure without program incentives.

[17] *See* https://www.hawaiianelectric.com/documents/clean_energy_hawaii/electrification_of_transportation/201803_eot_roadmap.pdf

regression model driven by population and jobs based on UHERO's October 2019 economic forecast. The development of the EV forecast utilized the EV saturation by island as shown on tab "EV Stauration" in Attachment 8 of PUC-HECO-IR-1 and applied the saturation to the LDV forecast for each island to arrive at the number of light duty EVs.[18] Although EV saturations were not specifically consistent with carbon neutrality in Hawaii by 2045, they are consistent with County goals for 2035.

To estimate the sales impact from EV charging for each island, the annual kWh used per vehicle was calculated based on the following equation:

$$Annual\ kWh\ per\ vehicle\ = \frac{\left(Annual\ VMT * (kWh\ per\ mile)\right) * 10^6}{Total\ LDV\ Forecast}$$

where

- *Annual VMT* is the annual vehicle miles travelled
- *kWh per mile* is a weighted average of fuel economies of electric vehicles registered

Annual VMT is forecasted by applying the baseline economic growth rate developed by the Federal Highway Administration for light duty vehicles to DBEDT's reported vehicle miles travelled for each county.[19] For Lāna‘i and Moloka‘i, vehicle miles travelled were developed based on information from DBEDT and on-island sources.

Historical *kWh per mile* was obtained using the weighted average fuel economy of registered electric vehicles by island. For Lāna‘i and Moloka‘i, the fuel economy from the Nissan Leaf represented each island's average. Fuel economy and vehicle registration by type data were obtained from the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy and Electric Power Research Institute (EPRI), respectively[20]. *Annual kWh per vehicle* was forecasted by applying a reference growth rate developed using the U.S. Energy Information Administration's (EIA) Annual Energy Outlook to the historical weighted average fuel economies.[21] The reference fuel economy growth rate was developed based on the expectation that battery technology will improve and larger vehicles will be produced.

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[18] *See* https://www.hawaiianelectric.com/documents/clean_energy_hawaii/integrated_grid_planning/stakeholder_engagement/working_groups/forecast_assumptions/PUC-HECO-IR-1_att_8_electric_vehicles.xlsx

[19] *See* https://www.fhwa.dot.gov/policyinformation/tables/vmt/vmt_forecast_sum.pdf

[20] *See* http://www.fueleconomy.gov

[21] *See* https://www.eia.gov/outlooks/aeo/data/browser/#/?id=113-AEO2019&cases=ref2019&sourcekey=0

Car registration data at the ownership level was not available to determine whether a car was a personally or commercially owned vehicle. Therefore, the Company used a ratio between residential and commercial PV installations in historical years to allocate the number of EVs between residential and commercial customers for each island. EVs were a relatively new technology and the number of PV installations were found to be correlated to EV adoption. Within the commercial EVs, a percentage based on PV capacity installed by commercial rate Schedules G, J, and P was applied to the total commercial EV count to arrive at the number of EVs at the commercial rate schedule level. The sales impact by rate schedule was calculated by multiplying the number of EVs by sales impact per vehicle for each island.

Electric Buses

The electric bus forecast was based on information provided by the Company's Electrification of Transportation team following discussions with several bus operators throughout Honolulu, Hawai'i and Maui counties. Route information and schedules for weekdays, weekends and holidays were used to estimate the miles traveled for each bus operator. Since specific information on the buses were not available for most operators, the Company used the average bus efficiency (kWh per mile) for two different Proterra models. For each island, the total sales impact for each bus operator was applied to the rate schedule on which each bus operator was serviced.

Once all the layers are developed for each island, they are added together to arrive at the sales forecast at the customer level by island as shown in the following tables.

Table 17: O'ahu Sales Forecast

Year	Underlying	Distributed Energy Resources (PV and BESS)	Energy Efficiency	Electric Vehicles	Customer Level Sales Forecast
GWH	A	B	C	D	E =A + B + C + D
2025	9,456	(1,141)	(1,887)	92	6,521
2030	10,133	(1,293)	(2,307)	221	6,753
2040	11,110	(1,551)	(2,917)	789	7,432
2045	11,499	(1,643)	(3,142)	1,366	8,079
2050	11,905	(1,714)	(3,332)	1,964	8,822

Table 18: Hawai‘i Island Sales Forecast

Year	Underlying	Distributed Energy Resources (PV and BESS)	Energy Efficiency	Electric Vehicles	Customer Level Sales Forecast
GWH	A	B	C	D	E =A + B + C + D
2025	1,471	(223)	(268)	10	990
2030	1,535	(252)	(345)	39	977
2040	1,634	(307)	(461)	172	1,038
2045	1,670	(337)	(501)	288	1,120
2050	1,708	(364)	(535)	435	1,244

Table 19: Maui Sales Forecast

Year	Underlying	Distributed Energy Resources (PV and BESS)	Energy Efficiency	Electric Vehicles	Customer Level Sales Forecast
GWH	A	B	C	D	E =A + B + C + D
2025	1,474	(251)	(300)	14	937
2030	1,572	(285)	(371)	56	973
2040	1,726	(341)	(473)	255	1,166
2045	1,787	(362)	(505)	357	1,277
2050	1,852	(379)	(529)	443	1,388

Table 20: Moloka‘i Sales Forecast

Year	Underlying	Distributed Energy Resources (PV and BESS)	Energy Efficiency	Electric Vehicles	Customer Level Sales Forecast
GWH	A	B	C	D	E =A + B + C + D
2025	36.0	(5.6)	(3.1)	0.1	27.4
2030	36.4	(6.1)	(3.6)	0.3	27.0
2040	37.8	(7.0)	(4.2)	1.1	27.7
2045	38.3	(7.4)	(4.5)	2.1	28.5

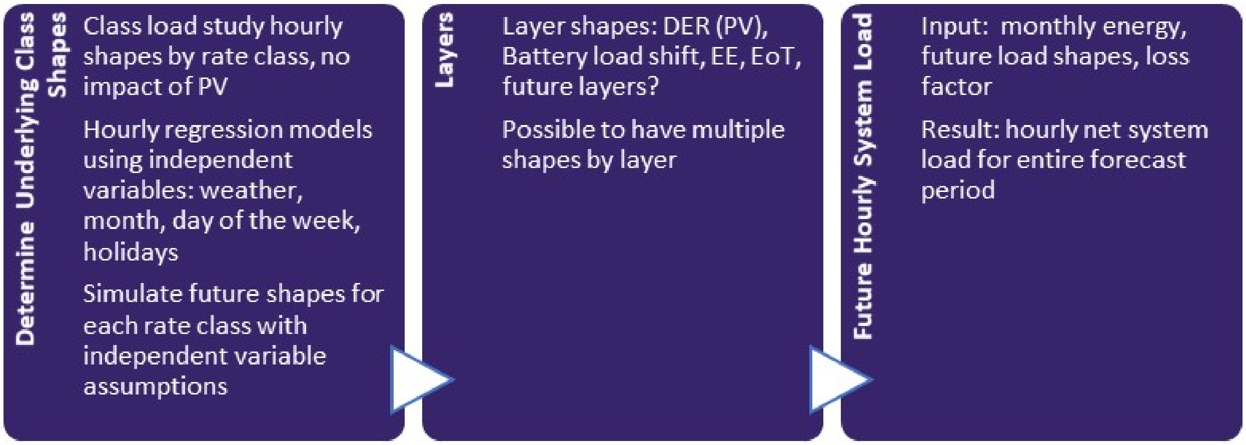
2050	38.9	(7.7)	(4.7)	3.2	29.7

Table 21: Lānaʻi Sales Forecast

Year	Underlying	Distributed Energy Resources (PV and BESS)	Energy Efficiency	Electric Vehicles	Customer Level Sales Forecast
GWH	A	B	C	D	E =A + B + C + D
2025	40.8	(1.6)	(1.6)	0.1	37.7
2030	42.2	(1.9)	(2.0)	0.2	38.5
2040	44.1	(2.4)	(2.8)	0.7	39.7
2045	44.7	(2.6)	(3.0)	1.3	40.4
2050	45.6	(2.9)	(3.3)	1.9	41.3

3.2. PEAK FORECASTS

Once the sales forecast is developed by layer (underlying, DER, EE and EoT) for each island, it is converted from a monthly sales forecast into a load forecast at the system level for each hour over the entire forecast horizon. The method to do the conversion from sales to an hourly load forecast is shown in the figure below. Hourly shapes from class load studies ("CLS") for each rate class or the total system load excluding the impact from PV are used to derive the underlying system load forecast shape. Hourly regression models are evaluated to look for relationships with explanatory variables (weather, month, day of the week, holidays) in order to accommodate change in the underlying shapes over time for each rate class or total system load. The hourly regression models are used to simulate shapes for the underlying forecast based on the forecast assumptions over the entire horizon. The forecasted energy for the underlying and each adjusting layer (DER PV, battery load shift, energy efficiency and EoT) is placed under its respective future load shape then converted from the customer level to system level using a loss factor[22] as presented in the July 17, 2019[23] and March 9, 2020[24] FAWG meetings .



Determine Underlying Class Shapes

- Class load study hourly shapes by rate class, no impact of PV
- Hourly regression models using independent variables: weather, month, day of the week, holidays
- Simulate future shapes for each rate class with independent variable assumptions

Layers

- Layer shapes: DER (PV), Battery load shift, EE, EoT, future layers?
- Possible to have multiple shapes by layer

Future Hourly System Load

- Input: monthly energy, future load shapes, loss factor
- Result: hourly net system load for entire forecast period

The result is an hourly net system load for the entire forecast period.

Once all the forecasted layers are developed by hour for each island, they are combined to arrive at an aggregated hourly load forecast. The annual peak forecast is the highest value in each year. The peaks presented in the August 31, 2020 FAWG meeting include the impacts of COVID-19.[25] This forecast assumes EVs will be charged at each owner's convenience which may occur during the daytime on-peak period. This initial forecast will inform downstream processes in the development of programs and incentives related to shifting EV charging to off-peak periods. These programs and incentives will then be integrated into the forecast through an iterative process in the Grid Needs Assessment. As a result of this initial forecast which utilizes "unmanaged" charging, the peak contribution from EVs increases over time as EVs become more widely owned.

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[22] The net-to-system factor used to convert customer sales to system level load is calculated as equal to 1/(1-loss factor) and include company use. The loss factors are included below: - Oahu: 4.43% - Hawaii: 6.76% - Maui: 5.17% - Lanai: 4.39% - Molokai: 9.07%

[23] *See* https://www.hawaiianelectric.com/documents/clean_energy_hawaii/integrated_grid_planning/stakeholder_engagement/working_groups/forecast_assumptions/20190717_wg_fa_meeting_presentation_materials.pdf

[24] *See* https://www.hawaiianelectric.com/documents/clean_energy_hawaii/integrated_grid_planning/stakeholder_engagement/working_groups/forecast_assumptions/20200309_wg_fa_meeting_presentation_materials.pdf

[25] *See* https://www.hawaiianelectric.com/documents/clean_energy_hawaii/integrated_grid_planning/stakeholder_engagement/working_groups/forecast_assumptions/20200831_wg_fa_meeting_presentation_materials_HECO.pdf and https://www.hawaiianelectric.com/documents/clean_energy_hawaii/integrated_grid_planning/stakeholder_engagement/working_groups/forecast_assumptions/20200831_wg_fa_meeting_presentation_materials_HECO.pdf. See slides 7, 10, 12, 14 and 17 for O‘ahu, Maui, Moloka‘i, Lāna‘i and Hawai‘i islands respectively.

Table 22: Oʻahu Peak Forecast (MW)

Year	Underlying	Distributed Energy Resources (PV and BESS)	Energy Efficiency	Electric Vehicles	Peak Forecast
MW	A	B	C	D	E =A + B + C + D
2025	1574	(14)	(340)	31	1251
2030	1637	(30)	(403)	68	1272
2040	1791	(58)	(488)	245	1489
2045	1868	(68)	(528)	432	1703
2050	1947	(78)	(556)	621	1935

Table 23: Hawaiʻi Island Peak Forecast (MW)

Year	Underlying	Distributed Energy Resources (PV and BESS)	Energy Efficiency	Electric Vehicles	Peak Forecast
MW	A	B	C	D	E =A + B + C + D
2025	228.2	(4.9)	(44.7)	3.0	181.6
2030	236.8	(8.5)	(55.5)	11.9	184.7
2040	241.2	(12.4)	(76.3)	63.0	215.5
2045	247.2	(3.5)	(85.3)	103.7	262.1
2050	253.3	(3.7)	(90.5)	156.7	315.8

Table 24: Maui Peak Forecast (MW)

Year	Underlying	Distributed Energy Resources (PV and BESS)	Energy Efficiency	Electric Vehicles	Peak Forecast
MW	A	B	C	D	E =A + B + C + D
2025	247.0	(5.4)	(47.6)	3.8	197.8
2030	261.5	(8.8)	(58.5)	18.4	212.6
2040	287.0	(14.1)	(74.5)	85.8	284.2
2045	297.0	(16.8)	(80.9)	121.1	320.4

2050	304.1	(22.6)	(87.4)	160.2	354.3

Table 25: Moloka‘i Peak Forecast (MW)

Year	Underlying	Distributed Energy Resources (PV and BESS)	Energy Efficiency	Electric Vehicles	Peak Forecast
MW	A	B	C	D	E =A + B + C + D
2025	6.0	(0.1)	(0.2)	0.1	5.8
2030	6.0	(0.1)	(0.3)	0.1	5.7
2040	6.3	(0.4)	(0.3)	0.3	5.9
2045	6.4	(0.4)	(0.4)	0.5	6.1
2050	6.5	(0.5)	(0.4)	0.9	6.5

Table 26: Lāna‘i Peak Forecast (MW)

Year	Underlying	Distributed Energy Resources (PV and BESS)	Energy Efficiency	Electric Vehicles	Peak Forecast
MW	A	B	C	D	E =A + B + C + D
2025	6.8	-	(0.1)	-	6.7
2030	7.1	-	(0.2)	-	6.9
2040	7.5	(0.1)	(0.3)	0.2	7.3
2045	7.6	(0.1)	(0.4)	0.4	7.5
2050	7.8	(0.1)	(0.4)	0.5	7.8

3.3. FUEL PRICE FORECASTS

The cost of producing electricity is dependent upon, in part, the cost of fuels utilized to generate power. Hawaiian Electric uses the following fuel types:

- Low Sulfur Fuel Oil (LSFO): A residual fuel oil similar to No. 6 fuel oil that contains less than 5,000 parts per million of sulfur; about 0.5% sulfur content
- No. 2 Diesel Oil
- Ultra-Low Sulfur Diesel (ULSD)

- Naphtha
- High Sulfur Fuel Oil (HSFO): Also called Industrial Fuel Oil (IFO), HSFO contains less than 2% sulfur

The fuel price forecast was developed using a correlation between historical, actual fuel prices and the Brent North Sea Crude Oil Benchmark (Brent) from 1983-2019.[26] The R^2 value for petroleum fuels was greater than 0.93. Hawaiian Electric's 2020 forecast was based on the Brent forecast provided by Facts Global Energy (FGE) with near-term prices reflecting the current oil situation.

Table 27: O'ahu Fuel Price Forecast

Year $/MMBTU	LSFO	Diesel	ULSD - CIP	ULSD - SGS	Biodiesel
2020	7.38	10.11	10.52	11.31	26.84
2021	9.40	12.20	12.67	13.47	28.66
2022	11.45	14.33	14.84	15.66	30.50
2023	11.35	14.27	14.79	15.62	30.77
2024	10.38	13.32	13.82	14.66	30.38
2025	10.72	13.71	14.22	15.08	30.97
2026	11.84	14.89	15.43	16.30	32.14
2027	13.06	16.18	16.76	17.64	33.40
2028	13.43	16.60	17.19	18.08	34.03
2029	14.39	17.63	18.24	19.15	35.11
2030	13.68	16.94	17.54	18.46	34.94
2031	12.39	15.67	16.24	17.18	34.36
2032	13.39	16.73	17.33	18.28	35.48
2033	14.02	17.43	18.05	19.01	36.33
2034	14.18	17.64	18.27	19.24	36.84
2035	13.31	16.79	17.41	18.40	36.58
2036	13.41	16.95	17.57	18.58	37.06
2037	13.87	17.46	18.10	19.12	37.81
2038	14.37	18.02	18.67	19.71	38.59

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[26] Hawaiian Electrric chose to use a Brent forecast provided by Facts Global Energy because it provides a more accurate reflection of Brent compared to EIA data.

2039	15.05	18.77	19.44	20.50	39.52
2040	15.81	19.60	20.29	21.36	40.51
2041	16.45	20.30	21.01	22.09	41.41
2042	17.15	21.06	21.80	22.90	42.37
2043	17.87	21.85	22.61	23.72	43.35
2044	18.60	22.66	23.44	24.57	44.34
2045	19.36	23.48	24.28	25.43	45.36
2046	20.13	24.33	25.15	26.32	46.40
2047	20.92	25.19	26.04	27.22	47.46
2048	21.73	26.08	26.95	28.15	48.54
2049	22.56	26.98	27.88	29.10	49.64
2050	23.42	27.91	28.83	30.07	50.77

Table 28: Hawai‘i Island Fuel Price Forecast

Year	IFO	Diesel	ULSD	Naphtha	Biodiesel
$/MMBTU					
2020	6.27	10.72	11.21	12.41	26.84
2021	8.02	12.97	13.52	14.56	28.66
2022	9.80	15.27	15.87	16.74	30.50
2023	9.72	15.21	15.82	16.72	30.77
2024	8.87	14.18	14.76	15.79	30.38
2025	9.16	14.60	15.19	16.22	30.97
2026	10.13	15.86	16.50	17.44	32.14
2027	11.19	17.26	17.93	18.79	33.40
2028	11.51	17.71	18.39	19.25	34.03
2029	12.34	18.81	19.52	20.32	35.11
2030	11.72	18.07	18.77	19.67	34.94
2031	10.59	16.69	17.36	18.42	34.36
2032	11.46	17.84	18.54	19.53	35.48
2033	12.01	18.59	19.31	20.28	36.33

2034	12.15	18.81	19.54	20.53	36.84
2035	11.38	17.89	18.61	19.71	36.58
2036	11.47	18.06	18.78	19.91	37.06
2037	11.87	18.61	19.35	20.47	37.81
2038	12.30	19.21	19.97	21.08	38.59
2039	12.89	20.01	20.80	21.88	39.52
2040	13.55	20.90	21.71	22.76	40.51
2041	14.09	21.65	22.48	23.51	41.41
2042	14.70	22.48	23.33	24.33	42.37
2043	15.32	23.32	24.20	25.17	43.35
2044	15.96	24.19	25.09	26.03	44.34
2045	16.61	25.08	26.01	26.91	45.36
2046	17.28	25.98	26.94	27.81	46.40
2047	17.96	26.91	27.90	28.74	47.46
2048	18.66	27.87	28.88	29.68	48.54
2049	19.38	28.84	29.88	30.65	49.64
2050	20.12	29.84	30.90	31.63	50.77

Table 29: Maui County Fuel Price Forecast

Year	Maui				Moloka‘i	Lāna‘i
$/MMBTU	IFO	Diesel	ULSD	Biodiesel	ULSD	ULSD
2020	5.93	10.23	10.56	26.84	11.39	14.53
2021	7.66	12.56	12.95	28.66	13.75	16.91
2022	9.41	14.94	15.38	30.50	16.15	19.32
2023	9.33	14.86	15.30	30.77	16.09	19.31
2024	8.49	13.77	14.19	30.38	15.01	18.31
2025	8.77	14.19	14.62	30.97	15.45	18.79
2026	9.72	15.50	15.96	32.14	16.78	20.15
2027	10.77	16.93	17.43	33.40	18.24	21.64
2028	11.08	17.38	17.89	34.03	18.71	22.16

2029	11.90	18.52	19.05	35.11	19.87	23.35
2030	11.28	17.73	18.24	34.94	19.09	22.65
2031	10.16	16.28	16.76	34.36	17.66	21.30
2032	11.01	17.45	17.97	35.48	18.86	22.53
2033	11.55	18.22	18.75	36.33	19.64	23.37
2034	11.68	18.43	18.97	36.84	19.88	23.66
2035	10.92	17.46	17.98	36.58	18.93	22.78
2036	11.01	17.62	18.14	37.06	19.10	23.02
2037	11.39	18.17	18.71	37.81	19.68	23.65
2038	11.81	18.78	19.33	38.59	20.31	24.34
2039	12.39	19.60	20.17	39.52	21.16	25.23
2040	13.04	20.50	21.10	40.51	22.09	26.22
2041	13.57	21.26	21.88	41.41	22.88	27.06
2042	14.17	22.10	22.74	42.37	23.74	27.98
2043	14.78	22.96	23.62	43.35	24.63	28.92
2044	15.40	23.85	24.53	44.34	25.54	29.88
2045	16.04	24.75	25.45	45.36	26.47	30.87
2046	16.70	25.67	26.40	46.40	27.42	31.88
2047	17.37	26.62	27.37	47.46	28.39	32.91
2048	18.06	27.59	28.36	48.54	29.39	33.97
2049	18.76	28.58	29.38	49.64	30.41	35.05
2050	19.48	29.60	30.42	50.77	31.46	36.15

3.4. RESOURCE COST FORECASTS

Resource cost assumptions were based on a combination of publicly available datasets as well as the Company's own assumptions, as shown in Table 30.

Table 30: Resource Cost Data Sources

U.S. Department of Energy (DOE)	• Distributed wind[27,28]
National Renewable Energy Laboratory (NREL)	• Geothermal[29] • Biomass[30] • Offshore wind[31,32]
US Energy Information Administration (EIA)	• Waste-to-energy[33]
IHS Markit[34]	• Grid-scale PV[35] • Distributed PV[36] • Onshore wind[37] • Grid-scale storage[38] • Distributed storage[39]
Hawaiian Electric	• ICE[40] • Pumped storage hydro[41]

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[27] U.S. Department of Energy, 2017 Distributed Wind Market Report, https://www.energy.gov/eere/wind/downloads/2017-distributed-wind-market-report

[28] U.S. Department of Energy, 2018 Distributed Wind Market Report, https://www.energy.gov/eere/wind/downloads/2018-distributed-wind-market-report

[29] National Renewable Energy Laboratory 2020 Annual Technology Baseline, 2020 ATB Data, https://atb.nrel.gov/electricity/2020/data.php

[30] Ibid.

[31] Ibid.

[32] National Renewable Energy Laboratory, Cost of Floating Offshore Wind Energy Using New England Aqua Ventus Concrete Semisubmersible Technology, https://www.nrel.gov/docs/fy20osti/75618.pdf

[33] U.S. Energy Information Administration, Cost and Performance Characteristics of New Generating Technologies, Annual Energy Outlook 2019

[34] IHS Markit was used because they provide frequent market research data for PV, wind, and BESS resources which inform their resource cost forecasts.

[35] IHS Markit: North America Solar PV Capital Cost and LCOE Outlook, December 2020, https://connect.ihsmarkit.com/master-viewer/show/phoenix/3855821

[36] Ibid.

[37] IHS Markit: North America Wind Capital Cost and LCOE Outlook, December 2020, https://connect.ihsmarkit.com/master-viewer/show/phoenix/3855784

[38] IHS Markit: US Battery Storage Capital and Levelized Cost Outlook, January 2021, https://connect.ihsmarkit.com/master-viewer/show/phoenix/2654698

[39] Ibid.

[40] ICE costs are based on the Schofield Generating Station provided in Docket No. 2017-0213, in response to the Consumer Advocate’s information request number 19.

[41] Pumped storage hydro costs are based on the Companies’ assumption from the 2016 Power Supply Improvement Plan.

General Electric	• LM2500 and LM6000 CT and Combined Cycle[42]
Siemens	• Synchronous Condenser[43]

Resource cost assumptions began with a base technology capital cost that was adjusted for:

1. Future technology trends through the planning period;
2. Location-specific capital and O&M cost adjustments for Hawai'i; and
3. Applicable Federal & State tax incentives.

Figure 11 is a summary of the resource forecasts in nominal dollars. The resource cost forecasts from 2020-2050 can be found in Appendix A: Resource Cost Forecasts (2020 – 2050). In the near-term, there are price declines after accounting for the investment tax credit schedules for the Federal and State investment tax credits. Over the longer term, after the tax credit schedules ramp down and are held constant, the resources costs generally increase over time.

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[42] Combustion Turbine and Combined Cycle unit costs are based on estimates provided by GE and include additional costs for installing similar sized thermal generators at Maalaea.

[43] Synchronous condenser costs based on estimates provided by Siemens.

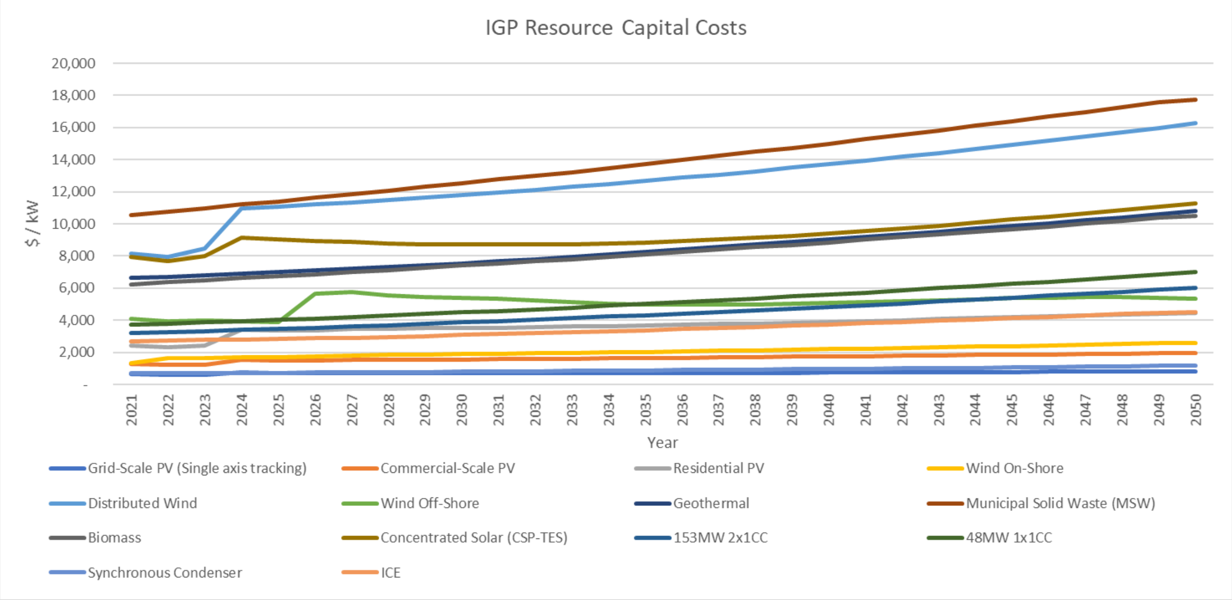
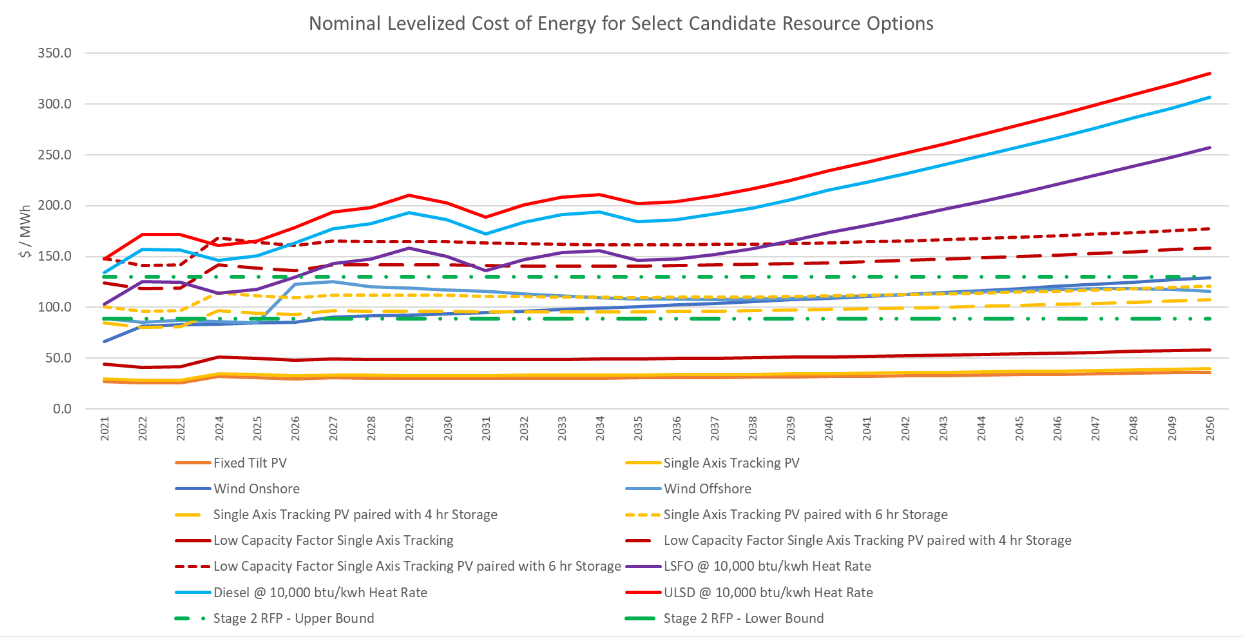


Figure 11: Capital Costs for IGP Candidate Resources

A comparison of the levelized cost of energy for select resources to the recently procured solar paired with storage PPAs[44] is shown below in Figure 12.



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[44] *See* https://www.hawaiianelectric.com/new-renewable-projects-submitted-to-regulators-will-produce-lower-cost-electricity-advance-clean-energy

Figure 12: Levelized Cost of Energy for Select IGP Candidate Resources

Photovoltaics (PV)

For PV, three different classes were forecasted: Grid-Scale PV, Commercial PV, and Residential PV. Each class used a similar process to develop the cost forecast.

Data Source

The source data for capital and fixed operations and maintenance (O&M) costs was provided by the IHS Markit North America Solar PV Capital Cost and LCOE Outlook. The capital costs were provided in nominal dollars $\$/\text{kW}_{dc}$. The fixed O&M costs were in nominal $/kW-year. The capital costs were adjusted to remove embedded interconnection and land cost components from the estimate. The future trend for the capital cost was derived from the IHS Markit projections. The future cost for O&M was derived by applying a future escalation factor.

Location Adjustment

A location adjustment factor was applied to convert both capital costs ($/kW) and O&M costs ($/kW-year) to Hawai‘i costs. A 62% location adjustment factor for capital[45] was provided by the U.S. Energy Information Administration (EIA)[46] and an 18.5% location adjustment factor for fixed O&M costs was provided by the RSMeans City Cost Index.[47]

DC to AC Conversion

Capital costs for PV were converted from $\$/\text{kW}_{dc}$ to $\$/\text{kW}_{ac}$. For commercial and residential PV, a DC to AC conversion factor of 1.15 was used. For grid-scale PV, a conversion factor of 1.3 was used. These conversion factors were based on assumptions provided by IHS Markit.

Investment Tax Credit Adjustment

The Federal[48] and State ITC[49] schedules assumed for PV are summarized in Table 31 below. In December 2020, the Federal ITC for PV was given a two-year extension.[50] Also in

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[45] A location cost variation percentage from the EIA Capital Cost Estimates for Utility Scale Electricity Generating Plants.

[46] *See* https://www.eia.gov/analysis/studies/powerplants/capitalcost/pdf/capcost_assumption.pdf

[47] RSMeans Building Construction Cost Data (BCCD) is a reference book for estimating construction costs in the U.S. and Canada.

[48] *See* https://www.greentechmedia.com/articles/read/solar-and-wind-tax-credit-extensions-energy-rd-package-in-spending-bill-before-congress

[49] See https://tax.hawaii.gov/geninfo/renewable

[50] *See* https://www.greentechmedia.com/articles/read/solar-and-wind-tax-credit-extensions-energy-rd-package-in-spending-bill-before-congress

December 2020, the capital cost projection from IHS was updated. As a result, the capital cost for Grid-Scale PV, Commercial PV, and Residential PV were adjusted accordingly.

Table 31: Federal and State ITC Schedule for PV

Year	2020	2021	2022	2023	2024	2025	2026	2027	Future
Federal ITC for Grid-Scale and Commercial-Scale PV	26%	26%	26%	22%	10%	10%	10%	10%	10%
Federal ITC for Residential PV	26%	26%	26%	22%	0%	0%	0%	0%	0%
State ITC for Grid-Scale, Commercial and Residential PV	35%	25%	25%	25%	20%	20%	20%	15%	15%

Onshore Wind

Data Source

The source data for capital and fixed O&M costs for on-shore wind was provided by the IHS Markit North America Wind Capital Cost and LCOE Outlook. The capital costs were in nominal dollars $/kW. The fixed O&M costs were in nominal $/kW-year. The future trend for the capital costs was derived from the IHS Markit projections. The future cost for O&M was derived by applying a future escalation factor.

Location Adjustment

The capital costs were converted to Hawai‘i costs using a 35% factor from EIA for wind technology. The O&M costs were converted to Hawai‘i costs using an 18.5% RSMeans factor. Location-specific interconnection costs were not included in the estimate.

Investment Tax Credit Adjustment

The Federal[51, 52] and State ITC[53] schedules assumed for Onshore Wind are summarized in Table 32 below. Initially, the Federal ITC for Onshore Wind was to expire at the end of

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[51] https://www.energy.gov/sites/prod/files/2020/02/f71/weto-funding-factsheet-2020.pdf and https://www.greentechmedia.com/articles/read/solar-and-wind-tax-credit-extensions-energy-rd-package-in-spending-bill-before-congress

[52] https://www.greentechmedia.com/articles/read/solar-and-wind-tax-credit-extensions-energy-rd-package-in-spending-bill-before-congress

[53] https://tax.hawaii.gov/geninfo/renewable

2020.[54] In December 2020, however, the expiration date was extended a year.[55] Also in December 2020, the capital cost projection from IHS was also updated. As a result, the capital cost was for Onshore Wind was adjusted accordingly.

Table 32: Federal and State ITC Schedule for Onshore Wind

Year	2020	2021	2022	2023	2024	2025	2026	2027	Future
Federal ITC	18%	18%	0%	0%	0%	0%	0%	0%	0%
State ITC	20%	20%	20%	20%	20%	20%	20%	15%	15%

Offshore Wind

Data Source

The source data for the offshore wind estimate was developed in collaboration with stakeholders, who directed the Companies to review the NREL study, *Cost of Floating Offshore Wind Energy Using New England Aqua Ventus Concrete Semisubmersible Technology*.[56] The NREL study was used to determine the underlying costs for both capital and O&M .Cost trends provided in the study for capital and O&M were used as initial data points for capital and O&M costs from 2020-2032. Initially, cost in the report were interpreted to be nominal. Upon further review, the costs provided in the report were stated in real 2018 dollars. Resource costs for offshore wind stated in this document were revised appropriately. Capital and O&M costs for years 2033-2050 were not available in the study so the cost forecast for the remaining years was estimated based on the NREL ATB for offshore wind technology. In July 2020, the capital cost projection from ATB was updated. The percent change in capital and O&M cost from NREL was used to approximate the cost trend for 2033-2050 for offshore wind.

Location Adjustment

The capital costs were converted to Hawaiʻi costs using a 35% EIA factor for wind technology. The O&M costs were converted to Hawaiʻi using an 18.5% RSMeans factor. The location-specific interconnection costs were not included in the estimate, however, 1 kilometer of interconnection on dry land was included in the cost estimate as provided in the offshore wind study.

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[54] https://www.energy.gov/sites/prod/files/2020/02/f71/weto-funding-factsheet-2020.pdf and https://www.greentechmedia.com/articles/read/solar-and-wind-tax-credit-extensions-energy-rd-package-in-spending-bill-before-congress

[55] https://www.greentechmedia.com/articles/read/solar-and-wind-tax-credit-extensions-energy-rd-package-in-spending-bill-before-congress

[56] https://www.nrel.gov/docs/fy20osti/75618.pdf

Investment Tax Credit Adjustment

The Federal[57] and State ITC[58] schedules assumed for Offshore Wind are summarized in Table 33 below. Initially, Offshore Wind followed the same schedule as Onshore Wind. In December 2020, the Federal ITC for Offshore Wind was developed.[59] As a result, the capital cost for Offshore Wind was adjusted accordingly.

Table 33: Federal and State ITC Schedule for Offshore Wind

Year	2020	2021	2022	2023	2024	2025	2026	2027	Future
Federal ITC	30%	30%	30%	30%	30%	30%	0%	0%	0%
State ITC	20%	20%	20%	20%	20%	20%	20%	15%	15%

Distributed Wind

Data Source

The capital and fixed O&M source data for distributed wind was provided by the Department of Energy's Distributed Wind Market Reports. The capital cost was provided in the Department of Energy's 2017 Distributed Wind Market Report.[60] Initially, capital costs in the report were interpreted to be in 2017 dollars. Upon further review, the costs provided in the report were stated in 2016 dollars. Resource costs for distributed wind stated in this document were then adjusted accordingly. The O&M cost were provided in the Department of Energy's 2018 Distributed Wind Market Report. Initially, O&M cost in the report were from the Department of Energy's 2017 Wind Technologies Market Report, but were updated based on the 2018 Distributed Wind Market Report. The average installed small wind costs were used from these reports. These costs were converted to 2019 dollars using a fixed escalation rate of 2.3%. The future cost trend was estimated using the future cost projections from the NREL ATB for land-based wind.

Location Adjustment

The U.S. benchmark cost was converted to Hawai'i costs for capital and O&M cost estimates. A 35% EIA factor for wind technology was applied for the capital cost conversion to Hawai'i. An 18.5% RSMeans factor was used to convert fixed O&M costs to Hawai'i costs. Location-specific interconnection costs were not included in the estimate.

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[57] https://www.greentechmedia.com/articles/read/solar-and-wind-tax-credit-extensions-energy-rd-package-in-spending-bill-before-congress

[58] https://tax.hawaii.gov/geninfo/renewable

[59] https://www.greentechmedia.com/articles/read/solar-and-wind-tax-credit-extensions-energy-rd-package-in-spending-bill-before-congress

[60] As stated in the 2018 report, because of the extremely low number of small wind project records with installed cost data, a 2018 average cost analysis was not presented in the 2018 report.

Investment Tax Credit Adjustment

The Federal[61,62] and State ITC[63] schedules assumed for Distributed Wind are summarized in Table 34 below. In December 2020, the Federal ITC was given a two-year extension.[64]

Table 34: Federal and State ITC for Distributed Wind

Year	2020	2021	2022	2023	2024	2025	2026	2027	Future
Federal ITC	26%	26%	26%	22%	0%	0%	0%	0%	0%
State ITC	20%	20%	20%	20%	20%	20%	20%	15%	15%

Biomass

Data Source

The source data for biomass capital, fixed O&M, and variable O&M costs as well as biomass fuel sources were provided by the NREL ATB for dedicated biomass technology. In July 2020, the capital cost projection provided by the NREL ATB was updated. The capital costs, O&M costs, and fuel costs were given in real dollars. The real 2019 costs were converted to nominal 2019 dollars by applying an escalation factor of 2.3%. The future cost trend was converted from real dollars to nominal by applying an escalation factor.

Location Adjustment

Nominal capital, O&M and fuel costs for biomass were converted to Hawai‘i costs. The capital costs were converted using a 46% EIA factor. The O&M and fuel costs were converted to Hawaii using an 18.5% RSMeans factor. Location-specific interconnection costs were not included in the estimate.

Pumped Storage Hydro

Data Source

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[61] https://www.law.cornell.edu/uscode/text/26/48

[62] https://rules.house.gov/sites/democrats.rules.house.gov/files/BILLS-116HR133SA-RCP-116-68.pdf

[63] https://tax.hawaii.gov/geninfo/renewable

[64] See https://www.greentechmedia.com/articles/read/solar-and-wind-tax-credit-extensions-energy-rd-package-in-spending-bill-before-congress

Costs for pumped storage hydro were sourced from Hawaiian Electric's 2016 Power Supply Improvement Plan. The 2016 capital and O&M cost estimates were escalated to 2019 dollars by applying an escalation factor of 2.3%.

Combustion Turbine with Synchronous Condenser Function

Data Source

The source data for high level capital costs for a combustion turbine that can function as a synchronous condenser were provided by General Electric and were based on the LM2500 and LM6000 technology. The O&M costs were estimated from NREL ATB. The O&M costs were given in real dollars and converted to nominal 2019 dollars by applying an escalation factor of 2.3%. The future capital cost trend was based on the NREL ATB. Hawaiian Electric estimates for additional plant infrastructure, outside engineering, and construction costs were added to the equipment cost estimates provided by General Electric to further supplement the forecasted capital cost. In July 2020, the cost projection provided by the NREL ATB was updated.

Location Adjustment

A 45% EIA factor for CT technology was used to convert the capital costs to Hawaiʻi costs and an 18.5% RSMeans factor was used to convert the fixed O&M and variable O&M costs to Hawaiʻi costs. Location-specific interconnection costs were not included in the estimate.

Concentrated Solar Power (CSP)

Data Source

The source data for concentrated solar power (CSP) capital, fixed O&M and variable O&M costs was provided by the NREL ATB. In July 2020, the cost projection provided by the NREL ATB was updated. Capital costs, O&M costs and fuel costs were given in real dollars and converted to nominal 2019 dollars by applying an escalation factor of 2.3%. The future cost trend was converted from real dollars to nominal by applying an escalation factor.

Location Adjustment

A 62% EIA factor for PV was used as an approximation to convert capital costs to Hawaiʻi costs. The federal and state investment tax credit schedule was assumed to be the same as grid scale PV. Fixed and variable O&M costs were converted to Hawaiʻi costs using an 18.5% RSMeans factor. Location-specific interconnection costs were not included in the estimate.

Investment Tax Credit Adjustment

The Federal[65] and State ITC[66] schedules assumed for CSP are summarized in Table 35 below. Initially, there were no Federal or State ITC assumed for CSP. After additional consideration, it was determined that a CSP system should be considered as a system that uses solar energy to generate electricity. As a result, CSP should receive the Federal and State ITC. The latest Federal and State ITC were applied and the capital cost was adjusted.

Table 35: Federal and State ITC Schedule for CSP

Year	2020	2021	2022	2023	2024	2025	2026	2027	Future
Federal ITC	26%	26%	26%	22%	10%	10%	10%	10%	10%
State ITC	35%	25%	25%	25%	20%	20%	20%	15%	15%

Geothermal

Data Source

The source data for the geothermal capital, fixed and variable O&M were provided by the NREL ATB for geothermal geo-hydro binary technology. In July 2020, the cost projection provided by the NREL ATB was updated. The capital costs, O&M costs and fuel costs in ATB were given in real dollars and converted to nominal 2019 dollars by applying an escalation factor of 2.3%. The future cost trend was converted from real dollars to nominal by applying an escalation factor.

Location Adjustment

A 20% EIA factor for geothermal technology was used to convert capital costs to Hawaiʻi costs. Fixed O&M and variable O&M costs used an 18.5% RSMeans factor. Location-specific interconnection costs were not included in the estimate.

Investment Tax Credit Adjustment

The following federal tax credit schedule[67] was assumed for geothermal technology.

Table 36: Federal and State ITC for Geothermal

Year	2020	2021	2022	2023	2024	2025	2026	2027	Future
Federal ITC	10%	10%	10%	10%	10%	10%	10%	10%	10%

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[65] *See* https://www.greentechmedia.com/articles/read/solar-and-wind-tax-credit-extensions-energy-rd-package-in-spending-bill-before-congress

[66] *See* https://tax.hawaii.gov/geninfo/renewable

[67] https://programs.dsireusa.org/system/program/detail/658

State ITC	0%	0%	0%	0%	0%	0%	0%	0%	0%

Internal Combustion Engine (ICE)

Data Source

The source data to estimate internal combustion engine (ICE) technology was informed by actual costs for the Schofield Generating Station project constructed on O‘ahu. The cost estimates were escalated from 2017 dollars by applying an escalation factor of 2.3%. The future cost trend was estimated using the cost trend for gas CT technology discussed above due to limited information on a future ICE capital cost trend.

Municipal Solid Waste (MSW)

Data Source

The MSW source data was based on the U.S. Energy Information Administration Cost and Performance Characteristics of New Generating Technologies Annual Energy Outlook for 2019. The costs were adjusted from 2018 dollars to 2019 dollars by applying an escalation factor of 2.3%. The future cost projections were estimated using future cost trend from biomass technology discussed above due to limited information on future MSW capital cost trend.

Location Adjustment

A 20% EIA factor for biomass technology was used as an approximation to convert capital costs. Fixed O&M and variable O&M costs were converted to Hawai‘i costs using an 18.5% RSMeans factor.

Battery Energy Storage

The battery energy storage system (BESS) costs were estimated for grid-scale, commercial-scale and residential storage. Capital costs for various storage durations were based on balance of system costs plus the storage duration multiplied by the storage module component price provided by IHS. Data provided by IHS Markit assumed 5 MW and 50 MW grid-scale storage for one hour through eight hour durations, 150 kW commercial storage for two hour duration, and 5 kW residential storage for 2.4 hour duration.

Data Source

The source data for grid-scale, commercial and residential storage was provided in the IHS Markit US Battery Storage Capital and Levelized Cost Outlook . Capital costs were given in nominal dollars, $/kW for the balance of system costs and $/kWh for the storage module costs. Embedded interconnection cost was removed from the estimate. In January 2021, the capital and O&M cost projection from IHS was updated. As a result, the costs for the Battery Energy Storage systems were adjusted accordingly.

Location Adjustment

The capital costs for balance of system and modules were converted to Hawaiʽi costs using a 32% EIA factor. Fixed O&M and variable O&M costs were converted to Hawaiʽi costs using an 18.5% RSMeans factor.

Pairing Adjustment

The battery costs for paired systems assumed a 7% co-location savings on capital and 20% co-location savings on fixed O&M. Paired storage capital costs were adjusted based on the PV tax credit schedule. Because the State tax credit has a dollar cap, the State tax credit applied to paired storage is the difference between the cap and the amount already applied to the PV system.

Synchronous Condenser

Data Source

The cost estimate for synchronous condensers was based on estimates from Siemens. The future capital cost trend was estimated using the NREL ATB for combustion turbines. In July 2020, the cost projection provided by NREL ATB was updated. Cost for conversion of existing generators to synchronous condensers will be considered on a case by case basis.

Location Adjustment

A 45% EIA factor for combustion turbines was used as an approximation to convert capital costs.

4. RESOURCE POTENTIAL AND RENEWABLE ENERGY ZONES

The first year available for each of the candidate resources that can be selected in RESOLVE reflects typical development timelines to bring the resource online. The first year available varies by resource and is summarized in the table below. Planned resources will be built according to their commercial operations date before 2025.

Table 37: First Year Available for Candidate Resources

Resource Type	First Year Available
Grid-Scale PV	2025
Onshore Wind	2025

Battery Energy Storage	2025
Synchronous Condenser	2025
Offshore Wind	2028-2030
ICE	2028-2030
Combustion Turbine	2028-2030
Combined Cycle	2028-2030
Biomass	2028-2030
Geothermal	2028-2030

4.1 NREL SOLAR AND WIND RESOURCE POTENTIAL STUDY UPDATE

NREL will use their Renewable Energy Potential Model (reV) to assess the potential for solar and wind energy deployment. The solar and wind resource data sets will be sourced from the National Solar Radiation Database and the Hawaii WIND toolkit. The NSRDB has a temporal interval of 30-minutes and nominal spatial resolution of 4 km. The WIND toolkit has an hourly temporal interval with a nominal spatial resolution of 2 km. The model will consider land exclusions such as slope, man-made structures, protected areas, and land cover. System configurations can also be considered in the model such as axis tracking, losses, tilt, panel type, inverter efficiency, and DC/AC ratio.

The NREL Resource Potential Study will also include PV rooftop potential analysis, which will rely upon Light Detection and Ranging (LiDAR) data. The model will consider LiDAR point clouds, buildings, solar resource from the NSRDB, parcels, and tree canopy. The system configurations can also be considered such as, fixed roof, losses, tilt, azimuth, panel type, module efficiency, inverter efficiency, and DC/AC ratio.

The latest draft of the NREL Resource Potential Study update can be found online[68] as part of the August 18, 2020 Stakeholder Council meeting materials.

5. THERMAL GENERATING UNIT PORTFOLIOS

Hawaiian Electric's thermal generating unit capacity is provided by a mix of utility-owned generation and independent power producers (IPPs). Key inputs to characterize the operation of the utility-owned generation include the minimum and maximum capacity,

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[68] See https://www.hawaiianelectric.com/documents/clean_energy_hawaii/integrated_grid_planning/stakeholder_engagement/stakeholder_council/20200818_sc_heco_tech_potential_final_report.pdf

heat rate coefficients, planned maintenance outages, forced outage rates, and maintenance outage rates.

Minimum and Maximum Capacity

The minimum and maximum capacity of a generating unit define its dispatchable range.

Heat Rate Coefficients

The heat rate coefficients define the heat input function $y = cx^2 + bx + a$ where y is the amount of fuel consumed to produce at the megawatt level x for one hour.

Maintenance Outages

Maintenance outages can be defined as discrete occurrences with a start date and duration or can be defined as a percentage of the year that the unit will be out of service on maintenance. Maintenance outages can remove an entire unit from service or reduce the generating unit's capacity that is available for service.

Forced Outages

Forced outages are unexpected and unplanned generating unit outages and are defined as a percentage of the year that the unit may experience an outage based on historical data.

O'ahu

Table 38: O'ahu Minimum and Maximum Capacity for Thermal Resources

Unit	Operating Minimum (Net MW)	Normal Top Load (Net MW)	Fuel Type
Kahe 1	23.2	82.6	LSFO
Kahe 2	23.3	82.4	LSFO
Kahe 3	23.1	86.1	LSFO
Kahe 4	23.1	85.4	LSFO
Kahe 5	50.4	134.9	LSFO
Kahe 6	50.4	134.7	LSFO
Waiau 3	23.5	47.1	LSFO
Waiau 4	23.5	46.5	LSFO
Waiau 5	23.4	54.4	LSFO
Waiau 6	23.5	53.7	LSFO
Waiau 7	23.1	82.9	LSFO

Waiau 8	23.1	86.3	LSFO
Waiau 9	5.9	52.9	Diesel
Waiau 10	5.9	49.9	Diesel
Campbell Industrial Park	41.2	129.0	Diesel
H-Power	35.0	68.5	Refuse
AES	63.0	180.0	Coal
Kalaeloa Energy Partners	65.0	208.0	LSFO
Airport DSG	4.0	8.0	Biodiesel
Schofield 1	4.0	8.1	ULSD / Biodiesel
Schofield 2	4.0	8.1	ULSD / Biodiesel
Schofield 3	4.0	8.1	ULSD / Biodiesel
Schofield 4	4.0	8.1	ULSD / Biodiesel
Schofield 5	4.0	8.1	ULSD / Biodiesel
Schofield 6	4.0	8.1	ULSD / Biodiesel

Table 39: Oʻahu Heat Rate Coefficients for Thermal Resources

Unit	A Coefficient (MMBTU/hr)	B Coefficient (MMBTU/hr-MW)	C Coefficient (MMBTU/hr-MW^2)
Kahe 1	72.1042	9.1921	0.0022
Kahe 2	72.0121	8.3600	0.0118
Kahe 3	73.2636	8.1711	0.0167
Kahe 4	116.5162	6.5015	0.0264
Kahe 5	113.3406	7.9454	0.0106
Kahe 6	59.8050	9.4934	0.0031
Waiau 3	60.8508	8.5429	0.0309
Waiau 4	25.8219	10.3352	0.0272
Waiau 5	37.8539	10.2088	0.0019
Waiau 6	33.4800	10.0324	0.0143
Waiau 7	101.1916	7.4411	0.0174
Waiau 8	78.0588	8.2162	0.0117
Waiau 9	206.3054	7.0804	0.0249

Waiau 10	190.6694	8.0059	0.0184
Campbell Industrial Park	271.1301	8.6971	0.0050
H-Power	1	1	1
AES	258.7479	14.9713	0.0051
Kalaeloa Energy Partners	299.0258	4.4067	0.0093
Airport DSG	0.0000	10.2090	0.0000
Schofield 1	8.5503	6.8097	0.0602
Schofield 2	8.4677	6.7967	0.0614
Schofield 3	8.5584	6.7376	0.0684
Schofield 4	8.5071	6.6227	0.0814
Schofield 5	8.4171	6.8237	0.0550
Schofield 6	7.6438	7.0152	0.0513

Table 40: O‘ahu Forced Outage Rates for Thermal Resources (1 of 4)

Year	Waiau 3	Waiau 4	Waiau 5	Waiau 6	Waiau 7	Waiau 8	Waiau 9	Waiau 10
%								
2021	7	7	4.5	4.5	4.5	4.5	4	4
2022	7	7	4.5	4.5	4.5	4.5	4	4
2023	7	7	4.5	4.5	4.5	4.5	4	4
2024	7	7	4.5	4.5	4.5	4.5	4	4
2025	9	9	5	5	4.5	4.5	4	4
2026	9	9	5	5	4.5	4.5	4	4
2027	9	9	5	5	4.5	4.5	4	4
2028	9	9	5	5	4.5	4.5	4	4
2029	9	9	5	5	4.5	4.5	4	4
2030	9	9	6	6	5.5	5.5	4	4
2031	9	9	6	6	5.5	5.5	4	4
2032	9	9	6	6	5.5	5.5	4	4
2033	9	9	6	6	5.5	5.5	4	4
2034	9	9	6	6	5.5	5.5	4	4
2035	9	9	6	6	5.5	5.5	4	4

2036	9	9	6	6	5.5	5.5	4	4
2037	9	9	6	6	5.5	5.5	4	4
2038	9	9	6	6	5.5	5.5	4	4
2039	9	9	6	6	5.5	5.5	4	4
2040	9	9	6	6	5.5	5.5	4	4
2041	9	9	6	6	5.5	5.5	4	4
2042	9	9	6	6	5.5	5.5	4	4
2043	9	9	6	6	5.5	5.5	4	4
2044	9	9	6	6	5.5	5.5	4	4
2045	9	9	6	6	5.5	5.5	4	4
2046	9	9	6	6	5.5	5.5	4	4
2047	9	9	6	6	5.5	5.5	4	4
2048	9	9	6	6	5.5	5.5	4	4
2049	9	9	6	6	5.5	5.5	4	4
2050	9	9	6	6	5.5	5.5	4	4

Table 41: O‘ahu Forced Outage Rates for Thermal Resources (2 of 4)

Year	Kahe 1	Kahe 2	Kahe 3	Kahe 4	Kahe 5	Kahe 6	CIP CT-1
%							
2021	4.5	4.5	4.5	4.5	5	5	3
2022	4.5	4.5	4.5	4.5	5	5	3
2023	4.5	4.5	4.5	4.5	5	5	3
2024	4.5	4.5	4.5	4.5	5	5	3
2025	4.5	4.5	4.5	4.5	5	5	3
2026	4.5	4.5	4.5	4.5	5	5	3
2027	4.5	4.5	4.5	4.5	5	5	3
2028	4.5	4.5	4.5	4.5	5	5	3
2029	4.5	4.5	4.5	4.5	5	5	3
2030	5.5	5.5	5	5	5	5	3
2031	5.5	5.5	5	5	5	5	3
2032	5.5	5.5	5	5	5	5	3

2033	5.5	5.5	5	5	5	5	3
2034	5.5	5.5	5	5	5	5	3
2035	5.5	5.5	5	5	5	5	3
2036	5.5	5.5	5	5	5	5	3
2037	5.5	5.5	5	5	5	5	3
2038	5.5	5.5	5	5	5	5	3
2039	5.5	5.5	5	5	5	5	3
2040	5.5	5.5	5	5	5	5	3
2041	5.5	5.5	5	5	5	5	3
2042	5.5	5.5	5	5	5	5	3
2043	5.5	5.5	5	5	5	5	3
2044	5.5	5.5	5	5	5	5	3
2045	5.5	5.5	5	5	5	5	3
2046	5.5	5.5	5	5	5	5	3
2047	5.5	5.5	5	5	5	5	3
2048	5.5	5.5	5	5	5	5	3
2049	5.5	5.5	5	5	5	5	3
2050	5.5	5.5	5	5	5	5	3

Table 42: O‘ahu Forced Outage Rates for Thermal Resources (3 of 4)

Year	Airport DSG	Schofield 1	Schofield 2	Schofield 3	Schofield 4	Schofield 5	Schofield 6
%							
2021	5	2	2	2	2	2	2
2022	5	2	2	2	2	2	2
2023	5	2	2	2	2	2	2
2024	5	2	2	2	2	2	2
2025	5	2	2	2	2	2	2
2026	5	2	2	2	2	2	2
2027	5	2	2	2	2	2	2
2028	5	2	2	2	2	2	2
2029	5	2	2	2	2	2	2

2030	5	2	2	2	2	2	2
2031	5	2	2	2	2	2	2
2032	5	2	2	2	2	2	2
2033	5	2	2	2	2	2	2
2034	5	2	2	2	2	2	2
2035	5	2	2	2	2	2	2
2036	5	2	2	2	2	2	2
2037	5	2	2	2	2	2	2
2038	5	2	2	2	2	2	2
2039	5	2	2	2	2	2	2
2040	5	2	2	2	2	2	2
2041	5	2	2	2	2	2	2
2042	5	2	2	2	2	2	2
2043	5	2	2	2	2	2	2
2044	5	2	2	2	2	2	2
2045	5	2	2	2	2	2	2
2046	5	2	2	2	2	2	2
2047	5	2	2	2	2	2	2
2048	5	2	2	2	2	2	2
2049	5	2	2	2	2	2	2
2050	5	2	2	2	2	2	2

Table 43: O‘ahu Forced Outage Rates for Thermal Resources (4 of 4)

Year	H-POWER	Kalaeloa	AES
%			
2021	3	1.5	1.5
2022	3	1.5	1.5
2023	3	1.5	
2024	3	1.5	
2025	3	1.5	
2026	3	1.5	

2027	3	1.5	
2028	3	1.5	
2029	3	1.5	
2030	3	1.5	
2031	3	1.5	
2032	3	1.5	
2033	3	1.5	
2034	3	1.5	
2035	3	1.5	
2036	3	1.5	
2037	3	1.5	
2038	3	1.5	
2039	3	1.5	
2040	3	1.5	
2041	3	1.5	
2042	3	1.5	
2043	3	1.5	
2044	3	1.5	
2045	3	1.5	
2046	3	1.5	
2047	3	1.5	
2048	3	1.5	
2049	3	1.5	
2050	3	1.5	

Table 44: O‘ahu Maintenance Outage Rates for Thermal Resources (1 of 3)

Year	Waiau 3	Waiau 4	Waiau 5	Waiau 6	Waiau 7	Waiau 8	Waiau 9	Waiau 10
%								
2021	1.92	1.92	5.75	5.75	7.67	7.67	3.84	15.34
2022	13.42	1.92	21.10	13.42	3.84	3.84	3.84	3.84

2023	1.92	13.42	3.84	3.84	13.42	13.42	3.84	3.84
2024	3.84	3.84	5.75	5.75	7.67	7.67	3.84	3.84
2025	13.42	1.92	13.42	13.42	1.92	1.92	3.84	3.84
2026	0.00	13.42	0.00	0.00	17.26	13.42	26.85	3.84
2027	3.84	3.84	5.75	5.75	5.75	5.75	3.84	26.85
2028	13.42	1.92	13.42	21.10	3.84	3.84	3.84	3.84
2029	1.92	13.42	1.92	1.92	13.42	21.10	3.84	3.84
2030	1.92	1.92	3.84	3.84	5.75	5.75	3.84	3.84
2031	13.42	1.92	21.10	13.42	1.92	1.92	3.84	3.84
2032	1.92	13.42	1.92	1.92	13.42	13.42	15.34	3.84
2033	1.92	1.92	5.75	5.75	5.75	5.75	3.84	15.34
2034	13.42	1.92	13.42	13.42	5.75	5.75	3.84	3.84
2035	0.00	13.42	0.00	0.00	17.26	13.42	3.84	3.84
2036	1.92	1.92	5.75	5.75	5.75	5.75	3.84	3.84
2037	13.42	0.00	13.42	21.10	1.92	1.92	3.84	3.84
2038	0.00	13.42	1.92	1.92	13.42	21.10	26.85	3.84
2039	1.92	1.92	5.75	5.75	3.84	3.84	3.84	26.85
2040	13.42	1.92	13.42	13.42	3.84	3.84	3.84	3.84
2041	1.92	13.42	5.75	5.75	13.42	13.42	3.84	3.84
2042	1.92	1.92	5.75	5.75	5.75	5.75	5.75	5.75
2043	1.92	1.92	5.75	5.75	5.75	5.75	5.75	5.75
2044	1.92	1.92	5.75	5.75	5.75	5.75	5.75	5.75
2045	1.92	1.92	5.75	5.75	5.75	5.75	5.75	5.75
2046	1.92	1.92	5.75	5.75	5.75	5.75	5.75	5.75
2047	1.92	1.92	5.75	5.75	5.75	5.75	5.75	5.75
2048	1.92	1.92	5.75	5.75	5.75	5.75	5.75	5.75
2049	1.92	1.92	5.75	5.75	5.75	5.75	5.75	5.75
2050	1.92	1.92	5.75	5.75	5.75	5.75	5.75	5.75

Table 45: Oʻahu Maintenance Outage Rates for Thermal Resources (2 of 3)

Year	Kahe 1	Kahe 2	Kahe 3	Kahe 4	Kahe 5	Kahe 6	CIP CT-1

%							
2021	21.10	5.75	5.75	5.75	5.75	5.75	3.84
2022	3.84	17.26	3.84	13.42	13.42	3.84	3.84
2023	3.84	5.75	13.42	5.75	3.84	13.42	3.84
2024	13.42	7.67	7.67	7.67	5.75	5.75	15.34
2025	1.92	13.42	3.84	13.42	19.18	1.92	3.84
2026	0.00	0.00	17.26	0.00	0.00	23.01	3.84
2027	13.42	7.67	7.67	7.67	5.75	5.75	3.84
2028	1.92	13.42	1.92	21.10	13.42	3.84	3.84
2029	3.84	3.84	13.42	3.84	1.92	13.42	3.84
2030	21.10	5.75	5.75	5.75	5.75	5.75	19.18
2031	3.84	17.26	1.92	13.42	13.42	1.92	3.84
2032	3.84	3.84	21.10	3.84	3.84	13.42	3.84
2033	13.42	7.67	7.67	7.67	7.67	7.67	3.84
2034	5.75	13.42	5.75	13.42	13.42	3.84	3.84
2035	0.00	0.00	13.42	1.92	1.92	23.01	3.84
2036	13.42	7.67	7.67	7.67	7.67	5.75	15.34
2037	1.92	13.42	1.92	21.10	13.42	1.92	3.84
2038	3.84	3.84	13.42	1.92	1.92	13.42	3.84
2039	21.10	5.75	5.75	5.75	5.75	5.75	3.84
2040	5.75	17.26	5.75	13.42	13.42	3.84	3.84
2041	3.84	3.84	13.42	3.84	3.84	13.42	3.84
2042	7.67	7.67	7.67	7.67	7.67	7.67	5.75
2043	7.67	7.67	7.67	7.67	7.67	7.67	5.75
2044	7.67	7.67	7.67	7.67	7.67	7.67	5.75
2045	7.67	7.67	7.67	7.67	7.67	7.67	5.75
2046	7.67	7.67	7.67	7.67	7.67	7.67	5.75
2047	7.67	7.67	7.67	7.67	7.67	7.67	5.75
2048	7.67	7.67	7.67	7.67	7.67	7.67	5.75
2049	7.67	7.67	7.67	7.67	7.67	7.67	5.75
2050	7.67	7.67	7.67	7.67	7.67	7.67	5.75

Table 46: O‘ahu Maintenance Outage Rates for Thermal Resources (3 of 3)

Year	Airport DSG	Schofield 1	Schofield 2	Schofield 3	Schofield 4	Schofield 5	Schofield 6
%							
2021	1.92	1.90	1.90	1.90	1.90	1.90	1.90
2022	1.92	1.90	1.90	1.90	1.90	1.90	1.90
2023	1.92	1.90	1.90	1.90	1.90	1.90	1.90
2024	1.92	1.90	1.90	1.90	1.90	1.90	1.90
2025	1.92	1.90	1.90	1.90	1.90	1.90	1.90
2026	1.92	1.90	1.90	1.90	1.90	1.90	1.90
2027	1.92	1.90	1.90	1.90	1.90	1.90	1.90
2028	1.92	1.90	1.90	1.90	1.90	1.90	1.90
2029	1.92	1.90	1.90	1.90	1.90	1.90	1.90
2030	1.92	1.90	1.90	1.90	1.90	1.90	1.90
2031	1.92	1.90	1.90	1.90	1.90	1.90	1.90
2032	1.92	1.90	1.90	1.90	1.90	1.90	1.90
2033	1.92	1.90	1.90	1.90	1.90	1.90	1.90
2034	1.92	1.90	1.90	1.90	1.90	1.90	1.90
2035	1.92	1.90	1.90	1.90	1.90	1.90	1.90
2036	1.92	1.90	1.90	1.90	1.90	1.90	1.90
2037	1.92	1.90	1.90	1.90	1.90	1.90	1.90
2038	1.92	1.90	1.90	1.90	1.90	1.90	1.90
2039	1.92	1.90	1.90	1.90	1.90	1.90	1.90
2040	1.92	1.90	1.90	1.90	1.90	1.90	1.90
2041	1.92	1.90	1.90	1.90	1.90	1.90	1.90
2042	1.92	1.90	1.90	1.90	1.90	1.90	1.90
2043	1.92	1.90	1.90	1.90	1.90	1.90	1.90
2044	1.92	1.90	1.90	1.90	1.90	1.90	1.90
2045	1.92	1.90	1.90	1.90	1.90	1.90	1.90
2046	1.92	1.90	1.90	1.90	1.90	1.90	1.90
2047	1.92	1.90	1.90	1.90	1.90	1.90	1.90

2048	1.92	1.90	1.90	1.90	1.90	1.90	1.90
2049	1.92	1.90	1.90	1.90	1.90	1.90	1.90
2050	1.92	1.90	1.90	1.90	1.90	1.90	1.90

Hawai‘i Island

Table 47: Hawai‘i Island Minimum and Maximum Capacity for Thermal Resources

Unit	Operating Minimum (Net MW)	Normal Top Load (Net MW)	Fuel Type
PGV (2022)	20	46	Geothermal
PGV (2021, off-peak)	22.0	38.0	Geothermal
PGV (2021, on-peak)	33.9	38.0	Geothermal
Hill 5	4.0	14.2	IFO
Hill 6	8.0	20.2	IFO
Kanoelehua CT1	0.5	10.5	Diesel
Kanoelehua D11	2.0	2.0	ULSD
Kanoelehua D15	0.8	2.5	ULSD
Kanoelehua D16	0.8	2.5	ULSD
Kanoelehua D17	0.8	2.5	ULSD
Kapua D27	1.3	1.3	ULSD
Keahole CT2	5.0	13.8	Diesel
Keahole D21	0.8	2.5	ULSD
Keahole D22	0.8	2.5	ULSD
Keahole D23	0.8	2.5	ULSD
Ouli D25	1.3	1.3	ULSD
Panaewa D24	1.3	1.3	ULSD
Puna	6.0	15.7	IFO
Puna CT3	7.0	20.0	Diesel
Punaluu D26	1.3	1.3	ULSD
Waimea D12	0.8	2.5	ULSD
Waimea D13	0.8	2.5	ULSD

Waimea D14	0.8	2.5	ULSD
Keahole CT4	7.0	20.0	Diesel
Keahole CT5	7.0	20.0	Diesel
Keahole ST7	1.5	13.5	-
HEP CT1	5.0	20.8	Naphtha
HEP CT2	5.0	20.8	Naphtha
HEP ST	3.3	19.0	-

Table 48: Hawai‘i Island Heat Rate Coefficients for Thermal Resources

Unit	A Coefficient (MMBTU/hr)	B Coefficient (MMBTU/hr-MW)	C Coefficient (MMBTU/hr-MW^2)
Hill 5	24.6229	8699.0000	0.2033
Hill 6	64.0000	4000.0000	0.2550
Kanoelehua CT1	74.0422	9150.1300	0.1272
Kanoelehua D11	6.1493	4323.1400	1.5805
Kanoelehua D15	7.6830	4326.1600	1.2637
Kanoelehua D16	7.6830	4326.1700	1.2637
Kanoelehua D17	7.6830	4326.1800	1.2637
Kapua D27	2.8000	3200.0300	3.2800
Keahole CT2	56.9838	8864.6600	0.0040
Keahole D21	7.6834	4326.1500	1.2637
Keahole D22	7.6834	4326.1400	1.2637
Keahole D23	7.6834	4326.1300	1.2637
Ouli D25	2.8000	3200.0400	3.2800
Panaewa D24	2.8000	3200.0100	3.2800
Puna	41.8152	7738.1000	0.2001
Puna CT3	49.3842	7680.7600	0.0310
Punaluu D26	2.8000	3200.0200	3.2800
Waimea D12	7.6830	4326.1600	1.2637
Waimea D13	7.6830	4326.1700	1.2637
Waimea D14	7.6830	4326.1500	1.2637

Keahole CT4	49.3842	7680.7600	0.0310
Keahole CT5	53.1791	6858.6800	0.0689
Keahole ST7	59.8609	20348.8000	0.0000
HEP CT1	56.5930	7544.0000	0.0504
HEP CT2	56.5930	7544.0000	0.0504
HEP ST	49.1130	14653.0000	0.0000

Table 49: Hawai'i Island Forced Outage Rates for Thermal Resources (1 of 4)

Year	Hill 5	Hill 6	Puna Steam	Kanoelehua D11	Waimea D12	Waimea D13	Waimea D14	Kanoelehua D15
%								
2021	1.78	1.38	1.58	17.31	19.44	12.04	14.85	0.50
2022	1.78	1.38	1.58	17.31	19.44	12.04	14.85	0.50
2023	1.78	1.38	1.58	17.31	19.44	12.04	14.85	0.50
2024	1.78	1.38	1.58	17.31	19.44	12.04	14.85	0.50
2025	1.78	1.38	1.58	17.31	19.44	12.04	14.85	0.50
2026	1.78	1.38	1.58	17.31	19.44	12.04	14.85	0.50
2027	1.78	1.38	1.58	17.31	19.44	12.04	14.85	0.50
2028	1.78	1.38	1.58	17.31	19.44	12.04	14.85	0.50
2029	1.78	1.38	1.58	17.31	19.44	12.04	14.85	0.50
2030	1.78	1.38	1.58	17.31	19.44	12.04	14.85	0.50
2031	1.78	1.38	1.58	17.31	19.44	12.04	14.85	0.50
2032	1.78	1.38	1.58	17.31	19.44	12.04	14.85	0.50
2033	1.78	1.38	1.58	17.31	19.44	12.04	14.85	0.50
2034	1.78	1.38	1.58	17.31	19.44	12.04	14.85	0.50
2035	1.78	1.38	1.58	17.31	19.44	12.04	14.85	0.50
2036	1.78	1.38	1.58	17.31	19.44	12.04	14.85	0.50
2037	1.78	1.38	1.58	17.31	19.44	12.04	14.85	0.50
2038	1.78	1.38	1.58	17.31	19.44	12.04	14.85	0.50
2039	1.78	1.38	1.58	17.31	19.44	12.04	14.85	0.50
2040	1.78	1.38	1.58	17.31	19.44	12.04	14.85	0.50
2041	1.78	1.38	1.58	17.31	19.44	12.04	14.85	0.50

2042	1.78	1.38	1.58	17.31	19.44	12.04	14.85	0.50
2043	1.78	1.38	1.58	17.31	19.44	12.04	14.85	0.50
2044	1.78	1.38	1.58	17.31	19.44	12.04	14.85	0.50
2045	1.78	1.38	1.58	17.31	19.44	12.04	14.85	0.50
2046	1.78	1.38	1.58	17.31	19.44	12.04	14.85	0.50
2047	1.78	1.38	1.58	17.31	19.44	12.04	14.85	0.50
2048	1.78	1.38	1.58	17.31	19.44	12.04	14.85	0.50
2049	1.78	1.38	1.58	17.31	19.44	12.04	14.85	0.50
2050	1.78	1.38	1.58	17.31	19.44	12.04	14.85	0.50

Table 50: Hawai‘i Island Forced Outage Rates for Thermal Resources (2 of 4)

Year	Kanoelehua D16	Kanoelehua D17	Keahole D21	Keahole D22	Keahole D23	Panaewa D24	Ouli D25	Punaluu D26
%								
2021	17.65	7.09	6.73	8.33	7.99	4.14	1.65	6.40
2022	17.65	7.09	6.73	8.33	7.99	4.14	1.65	6.40
2023	17.65	7.09	6.73	8.33	7.99	4.14	1.65	6.40
2024	17.65	7.09	6.73	8.33	7.99	4.14	1.65	6.40
2025	17.65	7.09	6.73	8.33	7.99	4.14	1.65	6.40
2026	17.65	7.09	6.73	8.33	7.99	4.14	1.65	6.40
2027	17.65	7.09	6.73	8.33	7.99	4.14	1.65	6.40
2028	17.65	7.09	6.73	8.33	7.99	4.14	1.65	6.40
2029	17.65	7.09	6.73	8.33	7.99	4.14	1.65	6.40
2030	17.65	7.09	6.73	8.33	7.99	4.14	1.65	6.40
2031	17.65	7.09	6.73	8.33	7.99	4.14	1.65	6.40
2032	17.65	7.09	6.73	8.33	7.99	4.14	1.65	6.40
2033	17.65	7.09	6.73	8.33	7.99	4.14	1.65	6.40
2034	17.65	7.09	6.73	8.33	7.99	4.14	1.65	6.40
2035	17.65	7.09	6.73	8.33	7.99	4.14	1.65	6.40
2036	17.65	7.09	6.73	8.33	7.99	4.14	1.65	6.40
2037	17.65	7.09	6.73	8.33	7.99	4.14	1.65	6.40
2038	17.65	7.09	6.73	8.33	7.99	4.14	1.65	6.40

2039	17.65	7.09	6.73	8.33	7.99	4.14	1.65	6.40
2040	17.65	7.09	6.73	8.33	7.99	4.14	1.65	6.40
2041	17.65	7.09	6.73	8.33	7.99	4.14	1.65	6.40
2042	17.65	7.09	6.73	8.33	7.99	4.14	1.65	6.40
2043	17.65	7.09	6.73	8.33	7.99	4.14	1.65	6.40
2044	17.65	7.09	6.73	8.33	7.99	4.14	1.65	6.40
2045	17.65	7.09	6.73	8.33	7.99	4.14	1.65	6.40
2046	17.65	7.09	6.73	8.33	7.99	4.14	1.65	6.40
2047	17.65	7.09	6.73	8.33	7.99	4.14	1.65	6.40
2048	17.65	7.09	6.73	8.33	7.99	4.14	1.65	6.40
2049	17.65	7.09	6.73	8.33	7.99	4.14	1.65	6.40
2050	17.65	7.09	6.73	8.33	7.99	4.14	1.65	6.40

Table 51: Hawai‘i Island Forced Outage Rates for Thermal Resources (3 of 4)

Year	Kapua D27	Kanoelehua CT1	Keahole CT2	Puna CT3	Keahole CT4	Keahole CT5	Keahole ST	HEP CT1
%								
2021	0.61	0.94	4.18	1.81	4.68	6.30	2.93	2.05
2022	0.61	0.94	4.18	1.81	4.68	6.30	2.93	2.05
2023	0.61	0.94	4.18	1.81	4.68	6.30	2.93	2.05
2024	0.61	0.94	4.18	1.81	4.68	6.30	2.93	2.05
2025	0.61	0.94	4.18	1.81	4.68	6.30	2.93	2.05
2026	0.61	0.94	4.18	1.81	4.68	6.30	2.93	2.05
2027	0.61	0.94	4.18	1.81	4.68	6.30	2.93	2.05
2028	0.61	0.94	4.18	1.81	4.68	6.30	2.93	2.05
2029	0.61	0.94	4.18	1.81	4.68	6.30	2.93	2.05
2030	0.61	0.94	4.18	1.81	4.68	6.30	2.93	2.05
2031	0.61	0.94	4.18	1.81	4.68	6.30	2.93	2.05
2032	0.61	0.94	4.18	1.81	4.68	6.30	2.93	2.05
2033	0.61	0.94	4.18	1.81	4.68	6.30	2.93	2.05
2034	0.61	0.94	4.18	1.81	4.68	6.30	2.93	2.05
2035	0.61	0.94	4.18	1.81	4.68	6.30	2.93	2.05

2036	0.61	0.94	4.18	1.81	4.68	6.30	2.93	2.05
2037	0.61	0.94	4.18	1.81	4.68	6.30	2.93	2.05
2038	0.61	0.94	4.18	1.81	4.68	6.30	2.93	2.05
2039	0.61	0.94	4.18	1.81	4.68	6.30	2.93	2.05
2040	0.61	0.94	4.18	1.81	4.68	6.30	2.93	2.05
2041	0.61	0.94	4.18	1.81	4.68	6.30	2.93	2.05
2042	0.61	0.94	4.18	1.81	4.68	6.30	2.93	2.05
2043	0.61	0.94	4.18	1.81	4.68	6.30	2.93	2.05
2044	0.61	0.94	4.18	1.81	4.68	6.30	2.93	2.05
2045	0.61	0.94	4.18	1.81	4.68	6.30	2.93	2.05
2046	0.61	0.94	4.18	1.81	4.68	6.30	2.93	2.05
2047	0.61	0.94	4.18	1.81	4.68	6.30	2.93	2.05
2048	0.61	0.94	4.18	1.81	4.68	6.30	2.93	2.05
2049	0.61	0.94	4.18	1.81	4.68	6.30	2.93	2.05
2050	0.61	0.94	4.18	1.81	4.68	6.30	2.93	2.05

Table 52: Hawaiʻi Island Forced Outage Rates for Thermal Resources (4 of 4)

Year	HEP CT2	HEP ST	PGV
%			
2021	4.22	2.52	9.22
2022	4.22	2.52	9.22
2023	4.22	2.52	9.22
2024	4.22	2.52	9.22
2025	4.22	2.52	9.22
2026	4.22	2.52	9.22
2027	4.22	2.52	9.22
2028	4.22	2.52	9.22
2029	4.22	2.52	9.22
2030	4.22	2.52	9.22
2031	4.22	2.52	9.22
2032	4.22	2.52	9.22

2033	4.22	2.52	9.22
2034	4.22	2.52	9.22
2035	4.22	2.52	9.22
2036	4.22	2.52	9.22
2037	4.22	2.52	9.22
2038	4.22	2.52	9.22
2039	4.22	2.52	9.22
2040	4.22	2.52	9.22
2041	4.22	2.52	9.22
2042	4.22	2.52	9.22
2043	4.22	2.52	9.22
2044	4.22	2.52	9.22
2045	4.22	2.52	9.22
2046	4.22	2.52	9.22
2047	4.22	2.52	9.22
2048	4.22	2.52	9.22
2049	4.22	2.52	9.22
2050	4.22	2.52	9.22

Table 53: Hawai‘i Island Maintenance Outage Rates for Thermal Resources (1 of 4)

Year %	Hill 5	Hill 6	Puna Steam	Kanoelehua D11	Waimea D12	Waimea D13	Waimea D14	Kanoelehua D15
2021	8.75	9.44	4.78	4.18	3.62	3.08	3.20	3.29
2022	8.75	9.44	4.78	4.18	3.62	3.08	3.20	3.29
2023	8.75	9.44	4.78	4.18	3.62	3.08	3.20	3.29
2024	8.75	9.44	4.78	4.18	3.62	3.08	3.20	3.29
2025	8.75	9.44	4.78	4.18	3.62	3.08	3.20	3.29
2026	8.75	9.44	4.78	4.18	3.62	3.08	3.20	3.29
2027	8.75	9.44	4.78	4.18	3.62	3.08	3.20	3.29
2028	8.75	9.44	4.78	4.18	3.62	3.08	3.20	3.29
2029	8.75	9.44	4.78	4.18	3.62	3.08	3.20	3.29

2030	8.75	9.44	4.78	4.18	3.62	3.08	3.20	3.29
2031	8.75	9.44	4.78	4.18	3.62	3.08	3.20	3.29
2032	8.75	9.44	4.78	4.18	3.62	3.08	3.20	3.29
2033	8.75	9.44	4.78	4.18	3.62	3.08	3.20	3.29
2034	8.75	9.44	4.78	4.18	3.62	3.08	3.20	3.29
2035	8.75	9.44	4.78	4.18	3.62	3.08	3.20	3.29
2036	8.75	9.44	4.78	4.18	3.62	3.08	3.20	3.29
2037	8.75	9.44	4.78	4.18	3.62	3.08	3.20	3.29
2038	8.75	9.44	4.78	4.18	3.62	3.08	3.20	3.29
2039	8.75	9.44	4.78	4.18	3.62	3.08	3.20	3.29
2040	8.75	9.44	4.78	4.18	3.62	3.08	3.20	3.29
2041	8.75	9.44	4.78	4.18	3.62	3.08	3.20	3.29
2042	8.75	9.44	4.78	4.18	3.62	3.08	3.20	3.29
2043	8.75	9.44	4.78	4.18	3.62	3.08	3.20	3.29
2044	8.75	9.44	4.78	4.18	3.62	3.08	3.20	3.29
2045	8.75	9.44	4.78	4.18	3.62	3.08	3.20	3.29
2046	8.75	9.44	4.78	4.18	3.62	3.08	3.20	3.29
2047	8.75	9.44	4.78	4.18	3.62	3.08	3.20	3.29
2048	8.75	9.44	4.78	4.18	3.62	3.08	3.20	3.29
2049	8.75	9.44	4.78	4.18	3.62	3.08	3.20	3.29
2050	8.75	9.44	4.78	4.18	3.62	3.08	3.20	3.29

Table 54: Hawai‘i Island Maintenance Outage Rates for Thermal Resources (2 of 4)

Year	Kanoelehua D16	Kanoelehua D17	Keahole D21	Keahole D22	Keahole D23	Panaewa D24	Ouli D25	Punaluu D26
%								
2021	3.64	3.23	1.86	2.46	3.69	0.41	0.19	0.39
2022	3.64	3.23	1.86	2.46	3.69	0.41	0.19	0.39
2023	3.64	3.23	1.86	2.46	3.69	0.41	0.19	0.39
2024	3.64	3.23	1.86	2.46	3.69	0.41	0.19	0.39
2025	3.64	3.23	1.86	2.46	3.69	0.41	0.19	0.39
2026	3.64	3.23	1.86	2.46	3.69	0.41	0.19	0.39

2027	3.64	3.23	1.86	2.46	3.69	0.41	0.19	0.39
2028	3.64	3.23	1.86	2.46	3.69	0.41	0.19	0.39
2029	3.64	3.23	1.86	2.46	3.69	0.41	0.19	0.39
2030	3.64	3.23	1.86	2.46	3.69	0.41	0.19	0.39
2031	3.64	3.23	1.86	2.46	3.69	0.41	0.19	0.39
2032	3.64	3.23	1.86	2.46	3.69	0.41	0.19	0.39
2033	3.64	3.23	1.86	2.46	3.69	0.41	0.19	0.39
2034	3.64	3.23	1.86	2.46	3.69	0.41	0.19	0.39
2035	3.64	3.23	1.86	2.46	3.69	0.41	0.19	0.39
2036	3.64	3.23	1.86	2.46	3.69	0.41	0.19	0.39
2037	3.64	3.23	1.86	2.46	3.69	0.41	0.19	0.39
2038	3.64	3.23	1.86	2.46	3.69	0.41	0.19	0.39
2039	3.64	3.23	1.86	2.46	3.69	0.41	0.19	0.39
2040	3.64	3.23	1.86	2.46	3.69	0.41	0.19	0.39
2041	3.64	3.23	1.86	2.46	3.69	0.41	0.19	0.39
2042	3.64	3.23	1.86	2.46	3.69	0.41	0.19	0.39
2043	3.64	3.23	1.86	2.46	3.69	0.41	0.19	0.39
2044	3.64	3.23	1.86	2.46	3.69	0.41	0.19	0.39
2045	3.64	3.23	1.86	2.46	3.69	0.41	0.19	0.39
2046	3.64	3.23	1.86	2.46	3.69	0.41	0.19	0.39
2047	3.64	3.23	1.86	2.46	3.69	0.41	0.19	0.39
2048	3.64	3.23	1.86	2.46	3.69	0.41	0.19	0.39
2049	3.64	3.23	1.86	2.46	3.69	0.41	0.19	0.39
2050	3.64	3.23	1.86	2.46	3.69	0.41	0.19	0.39

Table 55: Hawai‘i Island Maintenance Outage Rates for Thermal Resources (3 of 4)

Year	Kapua D27	Kanoelehua CT1	Keahole CT2	Puna CT3	Keahole CT4	Keahole CT5	Keahole ST	HEP CT1
%								
2021	0.14	3.05	3.56	6.95	3.17	5.30	7.95	3.09
2022	0.14	3.05	3.56	6.95	3.17	5.30	7.95	3.09
2023	0.14	3.05	3.56	6.95	3.17	5.30	7.95	3.09

2024	0.14	3.05	3.56	6.95	3.17	5.30	7.95	3.09
2025	0.14	3.05	3.56	6.95	3.17	5.30	7.95	3.09
2026	0.14	3.05	3.56	6.95	3.17	5.30	7.95	3.09
2027	0.14	3.05	3.56	6.95	3.17	5.30	7.95	3.09
2028	0.14	3.05	3.56	6.95	3.17	5.30	7.95	3.09
2029	0.14	3.05	3.56	6.95	3.17	5.30	7.95	3.09
2030	0.14	3.05	3.56	6.95	3.17	5.30	7.95	3.09
2031	0.14	3.05	3.56	6.95	3.17	5.30	7.95	3.09
2032	0.14	3.05	3.56	6.95	3.17	5.30	7.95	3.09
2033	0.14	3.05	3.56	6.95	3.17	5.30	7.95	3.09
2034	0.14	3.05	3.56	6.95	3.17	5.30	7.95	3.09
2035	0.14	3.05	3.56	6.95	3.17	5.30	7.95	3.09
2036	0.14	3.05	3.56	6.95	3.17	5.30	7.95	3.09
2037	0.14	3.05	3.56	6.95	3.17	5.30	7.95	3.09
2038	0.14	3.05	3.56	6.95	3.17	5.30	7.95	3.09
2039	0.14	3.05	3.56	6.95	3.17	5.30	7.95	3.09
2040	0.14	3.05	3.56	6.95	3.17	5.30	7.95	3.09
2041	0.14	3.05	3.56	6.95	3.17	5.30	7.95	3.09
2042	0.14	3.05	3.56	6.95	3.17	5.30	7.95	3.09
2043	0.14	3.05	3.56	6.95	3.17	5.30	7.95	3.09
2044	0.14	3.05	3.56	6.95	3.17	5.30	7.95	3.09
2045	0.14	3.05	3.56	6.95	3.17	5.30	7.95	3.09
2046	0.14	3.05	3.56	6.95	3.17	5.30	7.95	3.09
2047	0.14	3.05	3.56	6.95	3.17	5.30	7.95	3.09
2048	0.14	3.05	3.56	6.95	3.17	5.30	7.95	3.09
2049	0.14	3.05	3.56	6.95	3.17	5.30	7.95	3.09
2050	0.14	3.05	3.56	6.95	3.17	5.30	7.95	3.09

Table 56: Hawai‘i Island Maintenance Outage Rates for Thermal Resources (4 of 4)

Year	HEP CT2	HEP ST	PGV
%			

2021	3.47	3.62	3.94
2022	3.47	3.62	3.94
2023	3.47	3.62	3.94
2024	3.47	3.62	3.94
2025	3.47	3.62	3.94
2026	3.47	3.62	3.94
2027	3.47	3.62	3.94
2028	3.47	3.62	3.94
2029	3.47	3.62	3.94
2030	3.47	3.62	3.94
2031	3.47	3.62	3.94
2032	3.47	3.62	3.94
2033	3.47	3.62	3.94
2034	3.47	3.62	3.94
2035	3.47	3.62	3.94
2036	3.47	3.62	3.94
2037	3.47	3.62	3.94
2038	3.47	3.62	3.94
2039	3.47	3.62	3.94
2040	3.47	3.62	3.94
2041	3.47	3.62	3.94
2042	3.47	3.62	3.94
2043	3.47	3.62	3.94
2044	3.47	3.62	3.94
2045	3.47	3.62	3.94
2046	3.47	3.62	3.94
2047	3.47	3.62	3.94
2048	3.47	3.62	3.94
2049	3.47	3.62	3.94
2050	3.47	3.62	3.94

Maui

Table 57: Maui Minimum and Maximum Capacity for Thermal Resources

Unit[69]	Operating Minimum (Net MW)	Normal Top Load (Net MW)	Fuel Type
Kahului 1	2.26	4.71	IFO
Kahului 2	2.28	4.76	IFO
Kahului 3	3.00	11.50	IFO
Kahului 4	3.00	11.50	IFO
Maalaea 1	2.50	2.50	ULSD
Maalaea 2	2.50	2.50	ULSD
Maalaea 3	2.50	2.50	ULSD
Maalaea 4	1.86	5.51	Diesel
Maalaea 5	1.86	5.51	Diesel
Maalaea 6	1.86	5.51	Diesel
Maalaea 7	1.86	5.51	Diesel
Maalaea 8	1.86	5.48	Diesel
Maalaea 9	1.86	5.48	Diesel
Maalaea 10	7.87	12.34	Diesel
Maalaea 11	7.87	12.34	Diesel
Maalaea 12	7.87	12.34	Diesel
Maalaea 13	7.87	12.34	Diesel
Maalaea X1	2.50	2.50	ULSD
Maalaea X2	2.50	2.50	ULSD
Maalaea 14	5.88	21.13	Diesel
Maalaea 15	3.73	13.38	–
Maalaea 16	5.88	21.13	Diesel
Maalaea 17	5.93	21.47	Diesel
Maalaea 18	2.96	12.99	–
Maalaea 19	5.93	21.47	Diesel

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[69] Kahului 1-4 units retire in 2023-24.

Hana 1	0.00	0.97	ULSD
Hana 2	0.00	0.97	ULSD

Table 58: Maui Heat Rate Coefficients for Thermal Resources

Unit	A Coefficient (MMBTU/hr)	B Coefficient (MMBTU/hr-MW)	C Coefficient (MMBTU/hr-MW^2)	Average Heat Rate (BTU/KWH) [70]
Kahului 1	10.5570	12.0740	0.2260	
Kahului 2	8.1530	12.7150	0.2130	
Kahului 3	20.6320	11.1090	0.0270	
Kahului 4	30.2160	8.4170	0.2860	
Maalaea 1	0.0000	10.2878	0.0000	
Maalaea 2	0.0000	10.2878	0.0000	
Maalaea 3	0.0000	10.2878	0.0000	
Maalaea 4	12.4800	4.1590	0.7290	
Maalaea 5	12.4800	4.1590	0.7290	
Maalaea 6	12.4800	4.1590	0.7290	
Maalaea 7	12.4800	4.1590	0.7290	
Maalaea 8	10.8880	4.7170	0.5900	
Maalaea 9	10.8880	4.7170	0.5900	
Maalaea 10	11.6310	6.7910	0.1320	
Maalaea 11	11.6310	6.7910	0.1320	
Maalaea 12	11.6310	6.7910	0.1320	
Maalaea 13	11.6310	6.7910	0.1320	
Maalaea X1	0.0000	10.2878	0.0000	
Maalaea X2	0.0000	10.2878	0.0000	
Maalaea 14	80.4330	4692.0000	0.1360	
Maalaea 15	28.5852	20758.1000	0.1072	
Maalaea 16	80.4330	4692.0000	0.1360	

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[70] Hana 1 and 2 are primarily used as backup generation only for line maintenance and repair work in Hana. Therefore, they are modeled using an average heat rate, which is based on the maximum monthly usage over a 5-year historical period.

Maalaea 17	48.5120	8439.0000	0.0120	
Maalaea 18	66.9740	14784.0000	0.3347	
Maalaea 19	48.5120	8439.0000	0.0120	
Hana 1	–	–	–	11532.0000
Hana 2	–	–	–	11532.0000

Table 59: Maui Forced Outage Rates for Thermal Resources (1 of 3)

Year	Kahului 1	Kahului 2	Kahului 3	Kahului 4	Maalaea 1	Maalaea 2	Maalaea 3	Maalaea 4
%								
2021			0.08	0.34	3.93	3.93	3.93	1.45
2022			0.08	0.34	3.93	3.93	3.93	1.45
2023					3.93	3.93	3.93	1.45
2024					3.93	3.93	3.93	1.45
2025					3.93	3.93	3.93	1.45
2026					3.93	3.93	3.93	1.45
2027					3.93	3.93	3.93	1.45
2028					3.93	3.93	3.93	1.45
2029					3.93	3.93	3.93	1.45
2030					3.93	3.93	3.93	1.45
2031					3.93	3.93	3.93	1.45
2032					3.93	3.93	3.93	1.45
2033					3.93	3.93	3.93	1.45
2034					3.93	3.93	3.93	1.45
2035					3.93	3.93	3.93	1.45
2036					3.93	3.93	3.93	1.45
2037					3.93	3.93	3.93	1.45
2038					3.93	3.93	3.93	1.45
2039					3.93	3.93	3.93	1.45
2040					3.93	3.93	3.93	1.45
2041					3.93	3.93	3.93	1.45
2042					3.93	3.93	3.93	1.45

2043					3.93	3.93	3.93	1.45
2044					3.93	3.93	3.93	1.45
2045					3.93	3.93	3.93	1.45
2046					3.93	3.93	3.93	1.45
2047					3.93	3.93	3.93	1.45
2048					3.93	3.93	3.93	1.45
2049					3.93	3.93	3.93	1.45
2050					3.93	3.93	3.93	1.45

Table 60: Maui Forced Outage Rates for Thermal Resources (2 of 3)

Year	Maalaea 5	Maalaea 6	Maalaea 7	Maalaea 8	Maalaea 9	Maalaea 10	Maalaea 11	Maalaea 12
%								
2021	1.45	1.45	1.45	2.36	2.36	0.63	0.63	0.63
2022	1.45	1.45	1.45	2.36	2.36	0.63	0.63	0.63
2023	1.45	1.45	1.45	2.36	2.36	0.63	0.63	0.63
2024	1.45	1.45	1.45	2.36	2.36	0.63	0.63	0.63
2025	1.45	1.45	1.45	2.36	2.36	0.63	0.63	0.63
2026	1.45	1.45	1.45	2.36	2.36	0.63	0.63	0.63
2027	1.45	1.45	1.45	2.36	2.36	0.63	0.63	0.63
2028	1.45	1.45	1.45	2.36	2.36	0.63	0.63	0.63
2029	1.45	1.45	1.45	2.36	2.36	0.63	0.63	0.63
2030	1.45	1.45	1.45	2.36	2.36	0.63	0.63	0.63
2031	1.45	1.45	1.45	2.36	2.36	0.63	0.63	0.63
2032	1.45	1.45	1.45	2.36	2.36	0.63	0.63	0.63
2033	1.45	1.45	1.45	2.36	2.36	0.63	0.63	0.63
2034	1.45	1.45	1.45	2.36	2.36	0.63	0.63	0.63
2035	1.45	1.45	1.45	2.36	2.36	0.63	0.63	0.63
2036	1.45	1.45	1.45	2.36	2.36	0.63	0.63	0.63
2037	1.45	1.45	1.45	2.36	2.36	0.63	0.63	0.63
2038	1.45	1.45	1.45	2.36	2.36	0.63	0.63	0.63
2039	1.45	1.45	1.45	2.36	2.36	0.63	0.63	0.63

2040	1.45	1.45	1.45	2.36	2.36	0.63	0.63	0.63
2041	1.45	1.45	1.45	2.36	2.36	0.63	0.63	0.63
2042	1.45	1.45	1.45	2.36	2.36	0.63	0.63	0.63
2043	1.45	1.45	1.45	2.36	2.36	0.63	0.63	0.63
2044	1.45	1.45	1.45	2.36	2.36	0.63	0.63	0.63
2045	1.45	1.45	1.45	2.36	2.36	0.63	0.63	0.63
2046	1.45	1.45	1.45	2.36	2.36	0.63	0.63	0.63
2047	1.45	1.45	1.45	2.36	2.36	0.63	0.63	0.63
2048	1.45	1.45	1.45	2.36	2.36	0.63	0.63	0.63
2049	1.45	1.45	1.45	2.36	2.36	0.63	0.63	0.63
2050	1.45	1.45	1.45	2.36	2.36	0.63	0.63	0.63

Table 61: Maui Forced Outage Rates for Thermal Resources (3 of 3)

Year	Maalaea 13	Maalaea X1	Maalaea X2	Maalaea 14	Maalaea 15	Maalaea 16	Maalaea 17	Maalaea 18	Maalaea 19
%									
2021	0.63	3.93	3.93	0.16	0.41	0.16	0.49	0.30	0.49
2022	0.63	3.93	3.93	0.16	0.41	0.16	0.49	0.30	0.49
2023	0.63	3.93	3.93	0.16	0.41	0.16	0.49	0.30	0.49
2024	0.63	3.93	3.93	0.16	0.41	0.16	0.49	0.30	0.49
2025	0.63	3.93	3.93	0.16	0.41	0.16	0.49	0.30	0.49
2026	0.63	3.93	3.93	0.16	0.41	0.16	0.49	0.30	0.49
2027	0.63	3.93	3.93	0.16	0.41	0.16	0.49	0.30	0.49
2028	0.63	3.93	3.93	0.16	0.41	0.16	0.49	0.30	0.49
2029	0.63	3.93	3.93	0.16	0.41	0.16	0.49	0.30	0.49
2030	0.63	3.93	3.93	0.16	0.41	0.16	0.49	0.30	0.49
2031	0.63	3.93	3.93	0.16	0.41	0.16	0.49	0.30	0.49
2032	0.63	3.93	3.93	0.16	0.41	0.16	0.49	0.30	0.49
2033	0.63	3.93	3.93	0.16	0.41	0.16	0.49	0.30	0.49
2034	0.63	3.93	3.93	0.16	0.41	0.16	0.49	0.30	0.49
2035	0.63	3.93	3.93	0.16	0.41	0.16	0.49	0.30	0.49
2036	0.63	3.93	3.93	0.16	0.41	0.16	0.49	0.30	0.49

2037	0.63	3.93	3.93	0.16	0.41	0.16	0.49	0.30	0.49
2038	0.63	3.93	3.93	0.16	0.41	0.16	0.49	0.30	0.49
2039	0.63	3.93	3.93	0.16	0.41	0.16	0.49	0.30	0.49
2040	0.63	3.93	3.93	0.16	0.41	0.16	0.49	0.30	0.49
2041	0.63	3.93	3.93	0.16	0.41	0.16	0.49	0.30	0.49
2042	0.63	3.93	3.93	0.16	0.41	0.16	0.49	0.30	0.49
2043	0.63	3.93	3.93	0.16	0.41	0.16	0.49	0.30	0.49
2044	0.63	3.93	3.93	0.16	0.41	0.16	0.49	0.30	0.49
2045	0.63	3.93	3.93	0.16	0.41	0.16	0.49	0.30	0.49
2046	0.63	3.93	3.93	0.16	0.41	0.16	0.49	0.30	0.49
2047	0.63	3.93	3.93	0.16	0.41	0.16	0.49	0.30	0.49
2048	0.63	3.93	3.93	0.16	0.41	0.16	0.49	0.30	0.49
2049	0.63	3.93	3.93	0.16	0.41	0.16	0.49	0.30	0.49
2050	0.63	3.93	3.93	0.16	0.41	0.16	0.49	0.30	0.49

Table 62: Maui Maintenance Outage Rates for Thermal Resources (1 of 3)

Year	Kahului 1	Kahului 2	Kahului 3	Kahului 4	Maalaea 1	Maalaea 2	Maalaea 3	Maalaea 4
%								
2021			0.49	1.34	1.29	1.29	1.29	1.17
2022			0.49	1.34	1.29	1.29	1.29	1.17
2023					1.29	1.29	1.29	1.17
2024					1.29	1.29	1.29	1.17
2025					1.29	1.29	1.29	1.17
2026					1.29	1.29	1.29	1.17
2027					1.29	1.29	1.29	1.17
2028					1.29	1.29	1.29	1.17
2029					1.29	1.29	1.29	1.17
2030					1.29	1.29	1.29	1.17
2031					1.29	1.29	1.29	1.17
2032					1.29	1.29	1.29	1.17
2033					1.29	1.29	1.29	1.17

2034					1.29	1.29	1.29	1.17
2035					1.29	1.29	1.29	1.17
2036					1.29	1.29	1.29	1.17
2037					1.29	1.29	1.29	1.17
2038					1.29	1.29	1.29	1.17
2039					1.29	1.29	1.29	1.17
2040					1.29	1.29	1.29	1.17
2041					1.29	1.29	1.29	1.17
2042					1.29	1.29	1.29	1.17
2043					1.29	1.29	1.29	1.17
2044					1.29	1.29	1.29	1.17
2045					1.29	1.29	1.29	1.17
2046					1.29	1.29	1.29	1.17
2047					1.29	1.29	1.29	1.17
2048					1.29	1.29	1.29	1.17
2049					1.29	1.29	1.29	1.17
2050					1.29	1.29	1.29	1.17

Table 63: Maui Maintenance Outage Rates for Thermal Resources (2 of 3)

Year	Maalaea 5	Maalaea 6	Maalaea 7	Maalaea 8	Maalaea 9	Maalaea 10	Maalaea 11	Maalaea 12
%								
2021	1.17	1.17	1.17	1.39	1.39	2.17	2.17	2.17
2022	1.17	1.17	1.17	1.39	1.39	2.17	2.17	2.17
2023	1.17	1.17	1.17	1.39	1.39	2.17	2.17	2.17
2024	1.17	1.17	1.17	1.39	1.39	2.17	2.17	2.17
2025	1.17	1.17	1.17	1.39	1.39	2.17	2.17	2.17
2026	1.17	1.17	1.17	1.39	1.39	2.17	2.17	2.17
2027	1.17	1.17	1.17	1.39	1.39	2.17	2.17	2.17
2028	1.17	1.17	1.17	1.39	1.39	2.17	2.17	2.17
2029	1.17	1.17	1.17	1.39	1.39	2.17	2.17	2.17
2030	1.17	1.17	1.17	1.39	1.39	2.17	2.17	2.17

2031	1.17	1.17	1.17	1.39	1.39	2.17	2.17	2.17
2032	1.17	1.17	1.17	1.39	1.39	2.17	2.17	2.17
2033	1.17	1.17	1.17	1.39	1.39	2.17	2.17	2.17
2034	1.17	1.17	1.17	1.39	1.39	2.17	2.17	2.17
2035	1.17	1.17	1.17	1.39	1.39	2.17	2.17	2.17
2036	1.17	1.17	1.17	1.39	1.39	2.17	2.17	2.17
2037	1.17	1.17	1.17	1.39	1.39	2.17	2.17	2.17
2038	1.17	1.17	1.17	1.39	1.39	2.17	2.17	2.17
2039	1.17	1.17	1.17	1.39	1.39	2.17	2.17	2.17
2040	1.17	1.17	1.17	1.39	1.39	2.17	2.17	2.17
2041	1.17	1.17	1.17	1.39	1.39	2.17	2.17	2.17
2042	1.17	1.17	1.17	1.39	1.39	2.17	2.17	2.17
2043	1.17	1.17	1.17	1.39	1.39	2.17	2.17	2.17
2044	1.17	1.17	1.17	1.39	1.39	2.17	2.17	2.17
2045	1.17	1.17	1.17	1.39	1.39	2.17	2.17	2.17
2046	1.17	1.17	1.17	1.39	1.39	2.17	2.17	2.17
2047	1.17	1.17	1.17	1.39	1.39	2.17	2.17	2.17
2048	1.17	1.17	1.17	1.39	1.39	2.17	2.17	2.17
2049	1.17	1.17	1.17	1.39	1.39	2.17	2.17	2.17
2050	1.17	1.17	1.17	1.39	1.39	2.17	2.17	2.17

Table 64: Maui Maintenance Outage Rates for Thermal Resources (3 of 3)

Year	Maalaea 13	Maalaea X1	Maalaea X2	Maalaea 14	Maalaea 15	Maalaea 16	Maalaea 17	Maalaea 18	Maalaea 19
%									
2021	2.17	1.29	1.29	1.69	0.48	1.69	1.32	0.92	1.32
2022	2.17	1.29	1.29	1.69	0.48	1.69	1.32	0.92	1.32
2023	2.17	1.29	1.29	1.69	0.48	1.69	1.32	0.92	1.32
2024	2.17	1.29	1.29	1.69	0.48	1.69	1.32	0.92	1.32
2025	2.17	1.29	1.29	1.69	0.48	1.69	1.32	0.92	1.32
2026	2.17	1.29	1.29	1.69	0.48	1.69	1.32	0.92	1.32
2027	2.17	1.29	1.29	1.69	0.48	1.69	1.32	0.92	1.32

2028	2.17	1.29	1.29	1.69	0.48	1.69	1.32	0.92	1.32
2029	2.17	1.29	1.29	1.69	0.48	1.69	1.32	0.92	1.32
2030	2.17	1.29	1.29	1.69	0.48	1.69	1.32	0.92	1.32
2031	2.17	1.29	1.29	1.69	0.48	1.69	1.32	0.92	1.32
2032	2.17	1.29	1.29	1.69	0.48	1.69	1.32	0.92	1.32
2033	2.17	1.29	1.29	1.69	0.48	1.69	1.32	0.92	1.32
2034	2.17	1.29	1.29	1.69	0.48	1.69	1.32	0.92	1.32
2035	2.17	1.29	1.29	1.69	0.48	1.69	1.32	0.92	1.32
2036	2.17	1.29	1.29	1.69	0.48	1.69	1.32	0.92	1.32
2037	2.17	1.29	1.29	1.69	0.48	1.69	1.32	0.92	1.32
2038	2.17	1.29	1.29	1.69	0.48	1.69	1.32	0.92	1.32
2039	2.17	1.29	1.29	1.69	0.48	1.69	1.32	0.92	1.32
2040	2.17	1.29	1.29	1.69	0.48	1.69	1.32	0.92	1.32
2041	2.17	1.29	1.29	1.69	0.48	1.69	1.32	0.92	1.32
2042	2.17	1.29	1.29	1.69	0.48	1.69	1.32	0.92	1.32
2043	2.17	1.29	1.29	1.69	0.48	1.69	1.32	0.92	1.32
2044	2.17	1.29	1.29	1.69	0.48	1.69	1.32	0.92	1.32
2045	2.17	1.29	1.29	1.69	0.48	1.69	1.32	0.92	1.32
2046	2.17	1.29	1.29	1.69	0.48	1.69	1.32	0.92	1.32
2047	2.17	1.29	1.29	1.69	0.48	1.69	1.32	0.92	1.32
2048	2.17	1.29	1.29	1.69	0.48	1.69	1.32	0.92	1.32
2049	2.17	1.29	1.29	1.69	0.48	1.69	1.32	0.92	1.32
2050	2.17	1.29	1.29	1.69	0.48	1.69	1.32	0.92	1.32

Molokaʻi

Table 65: Molokaʻi Minimum and Maximum Capacity for Thermal Resources

Unit	Operating Minimum (Net MW)	Normal Top Load (Net MW)	Fuel Type
Palaau 01	0.31	1.25	ULSD
Palaau 02	0.31	1.25	ULSD

Palaau 03	0.25	0.97	ULSD
Palaau 04	0.25	0.97	ULSD
Palaau 05	0.25	0.97	ULSD
Palaau 06	0.25	0.97	ULSD
Palaau 07	0.66	2.20	ULSD
Palaau 08	0.66	2.20	ULSD
Palaau 09	0.66	2.20	ULSD
Palaau GT1	1.1	2.20	ULSD

Table 66: Molokaʻi Heat Rate Coefficients for Thermal Resources

Unit	A Coefficient (MMBTU/hr)	B Coefficient (MMBTU/hr-MW)	C Coefficient (MMBTU/hr-MW^2)
Palaau 01	1.3894	9.6947	-0.8835
Palaau 02	0.8831	10.4922	-1.7433
Palaau 03	5.4111	-4.6487	10.2493
Palaau 04	4.5017	1.8072	5.8410
Palaau 05	1.3975	9.3826	-0.3959
Palaau 06	1.5392	8.5616	0.1192
Palaau 07	3.1052	6.6925	0.8483
Palaau 08	2.0900	8.2860	0.2125
Palaau 09	2.1250	8.0170	0.3328
Palaau GT1	0.0000	18.8310	0.0000

Table 67: Molokaʻi Forced Outage Rates for Thermal Resources

Year	Palaau 01	Palaau 02	Palaau 03	Palaau 04	Palaau 05	Palaau 06	Palaau 07	Palaau 08	Palaau 09	Palaau GT1
%										
2021	2.69	2.69	0.45	0.45	0.45	0.45	0.36	0.36	0.36	0
2022	2.69	2.69	0.45	0.45	0.45	0.45	0.36	0.36	0.36	0
2023	2.69	2.69	0.45	0.45	0.45	0.45	0.36	0.36	0.36	0
2024	2.69	2.69	0.45	0.45	0.45	0.45	0.36	0.36	0.36	0

2025	2.69	2.69	0.45	0.45	0.45	0.45	0.36	0.36	0.36	0
2026	2.69	2.69	0.45	0.45	0.45	0.45	0.36	0.36	0.36	0
2027	2.69	2.69	0.45	0.45	0.45	0.45	0.36	0.36	0.36	0
2028	2.69	2.69	0.45	0.45	0.45	0.45	0.36	0.36	0.36	0
2029	2.69	2.69	0.45	0.45	0.45	0.45	0.36	0.36	0.36	0
2030	2.69	2.69	0.45	0.45	0.45	0.45	0.36	0.36	0.36	0
2031	2.69	2.69	0.45	0.45	0.45	0.45	0.36	0.36	0.36	0
2032	2.69	2.69	0.45	0.45	0.45	0.45	0.36	0.36	0.36	0
2033	2.69	2.69	0.45	0.45	0.45	0.45	0.36	0.36	0.36	0
2034	2.69	2.69	0.45	0.45	0.45	0.45	0.36	0.36	0.36	0
2035	2.69	2.69	0.45	0.45	0.45	0.45	0.36	0.36	0.36	0
2036	2.69	2.69	0.45	0.45	0.45	0.45	0.36	0.36	0.36	0
2037	2.69	2.69	0.45	0.45	0.45	0.45	0.36	0.36	0.36	0
2038	2.69	2.69	0.45	0.45	0.45	0.45	0.36	0.36	0.36	0
2039	2.69	2.69	0.45	0.45	0.45	0.45	0.36	0.36	0.36	0
2040	2.69	2.69	0.45	0.45	0.45	0.45	0.36	0.36	0.36	0
2041	2.69	2.69	0.45	0.45	0.45	0.45	0.36	0.36	0.36	0
2042	2.69	2.69	0.45	0.45	0.45	0.45	0.36	0.36	0.36	0
2043	2.69	2.69	0.45	0.45	0.45	0.45	0.36	0.36	0.36	0
2044	2.69	2.69	0.45	0.45	0.45	0.45	0.36	0.36	0.36	0
2045	2.69	2.69	0.45	0.45	0.45	0.45	0.36	0.36	0.36	0
2046	2.69	2.69	0.45	0.45	0.45	0.45	0.36	0.36	0.36	0
2047	2.69	2.69	0.45	0.45	0.45	0.45	0.36	0.36	0.36	0
2048	2.69	2.69	0.45	0.45	0.45	0.45	0.36	0.36	0.36	0
2049	2.69	2.69	0.45	0.45	0.45	0.45	0.36	0.36	0.36	0
2050	2.69	2.69	0.45	0.45	0.45	0.45	0.36	0.36	0.36	0

Table 68: Moloka‘i Maintenance Outage Rates for Thermal Resources

Year	Palaau 01	Palaau 02	Palaau 03	Palaau 04	Palaau 05	Palaau 06	Palaau 07	Palaau 08	Palaau 09	Palaau GT1
%										

2021	6.1	2.54	5.06	5.06	5.06	5.06	2.04	2.04	2.04	0
2022	2.54	13.77	8.62	10.54	5.06	5.06	2.04	2.04	17.1	1.64
2023	2.54	2.54	5.06	8.62	16.29	8.62	16.56	16.56	2.04	0
2024	8.02	2.54	10.54	5.06	5.06	10.54	2.04	2.04	2.04	0
2025	2.54	2.54	5.06	5.06	10.54	5.06	2.04	5.6	5.6	1.37
2026	2.54	8.02	5.06	8.62	5.06	5.06	5.6	2.04	2.04	0
2027	6.1	2.54	8.62	5.06	5.06	8.62	2.04	2.04	2.04	0
2028	2.54	2.54	5.06	5.06	8.62	5.06	2.04	5.6	5.6	0
2029	2.54	6.1	5.06	14.38	5.06	5.06	5.6	2.04	2.04	0
2030	8.02	2.54	10.54	5.06	5.06	10.54	2.04	2.04	2.04	1.37
2031	2.54	2.54	5.06	5.06	10.54	5.06	2.04	5.6	5.6	0
2032	2.54	8.02	5.06	8.62	5.06	5.06	5.6	2.04	2.04	0
2033	6.1	2.54	8.62	5.06	5.06	8.62	2.04	2.04	2.04	0
2034	2.54	2.54	5.06	5.06	8.62	5.06	2.04	5.6	5.6	0
2035	2.54	6.1	5.06	14.38	5.06	5.06	5.6	2.04	2.04	1.37
2036	8.02	2.54	10.54	5.06	5.06	10.54	2.04	2.04	2.04	0
2037	2.54	2.54	5.06	5.06	10.54	5.06	2.04	5.6	5.6	0
2038	2.54	8.02	5.06	8.62	5.06	5.06	5.6	2.04	2.04	0
2039	6.1	2.54	8.62	5.06	5.06	8.62	2.04	2.04	2.04	0
2040	2.54	2.54	5.06	5.06	8.62	5.06	2.04	5.6	5.6	1.37
2041	2.54	6.1	5.06	8.62	5.06	5.06	5.6	2.04	2.04	0
2042	9.93	2.54	10.54	5.06	5.06	10.54	2.04	2.04	2.04	0
2043	2.54	2.54	5.06	5.06	10.54	5.06	2.04	5.6	5.6	0
2044	2.54	8.02	5.06	8.62	5.06	5.06	5.6	2.04	2.04	0
2045	6.1	2.54	8.62	5.06	5.06	8.62	2.04	2.04	2.04	1.37
2046	2.54	2.54	5.06	5.06	5.06	5.06	2.04	2.04	2.04	0
2047	2.54	2.54	5.06	5.06	5.06	5.06	2.04	2.04	2.04	0
2048	2.54	2.54	5.06	5.06	5.06	5.06	2.04	2.04	2.04	0
2049	2.54	2.54	5.06	5.06	5.06	5.06	2.04	2.04	2.04	0
2050	2.54	2.54	5.06	5.06	5.06	5.06	2.04	2.04	2.04	0

Lānaʻi

Table 69: Lānaʻi Minimum and Maximum Capacity for Thermal Resources

Unit	Operating Minimum (Net MW)	Normal Top Load (Net MW)	Fuel Type
LL 1	0.5	1.0	ULSD
LL 2	0.5	1.0	ULSD
LL 3	0.5	1.0	ULSD
LL 4	0.5	1.0	ULSD
LL 5	0.5	1.0	ULSD
LL 6	0.5	1.0	ULSD
LL 7	0.3	2.2	ULSD
LL 8	0.3	2.2	ULSD
CHP	0.83	0.83	ULSD

Table 70: Lānaʻi Heat Rate Coefficients for Thermal Resources

Unit	A Coefficient (MMBTU/hr)	B Coefficient (MMBTU/hr-MW)	C Coefficient (MMBTU/hr-MW^2)
LL 1	1.9016	6.6910	1.9235
LL 2	1.9054	6.9548	2.1515
LL 3	0.9656	10.5671	-0.8720
LL 4	0.6577	11.5526	-1.6507
LL 5	1.2913	9.0183	0.3364
LL 6	0.9302	10.1353	-0.6496
LL 7	3.4169	6.6148	0.6626
LL 8	3.1015	7.1223	0.3705
CHP	0	11.380	0

Table 71: Lānaʻi Forced Outage Rates for Thermal Resources

Year %	LL 1	LL 2	LL 3	LL 4	LL 5	LL 6	LL 7	LL 8	CHP

2021	4.93	4.93	4.93	4.93	4.93	4.93	4.30	4.30	16.35
2022	4.93	4.93	4.93	4.93	4.93	4.93	4.30	4.30	16.35
2023	4.93	4.93	4.93	4.93	4.93	4.93	4.30	4.30	16.35
2024	4.93	4.93	4.93	4.93	4.93	4.93	4.30	4.30	16.35
2025	4.93	4.93	4.93	4.93	4.93	4.93	4.30	4.30	16.35
2026	4.93	4.93	4.93	4.93	4.93	4.93	4.30	4.30	16.35
2027	4.93	4.93	4.93	4.93	4.93	4.93	4.30	4.30	16.35
2028	4.93	4.93	4.93	4.93	4.93	4.93	4.30	4.30	16.35
2029	4.93	4.93	4.93	4.93	4.93	4.93	4.30	4.30	16.35
2030	4.93	4.93	4.93	4.93	4.93	4.93	4.30	4.30	16.35
2031	4.93	4.93	4.93	4.93	4.93	4.93	4.30	4.30	16.35
2032	4.93	4.93	4.93	4.93	4.93	4.93	4.30	4.30	16.35
2033	4.93	4.93	4.93	4.93	4.93	4.93	4.30	4.30	16.35
2034	4.93	4.93	4.93	4.93	4.93	4.93	4.30	4.30	16.35
2035	4.93	4.93	4.93	4.93	4.93	4.93	4.30	4.30	16.35
2036	4.93	4.93	4.93	4.93	4.93	4.93	4.30	4.30	16.35
2037	4.93	4.93	4.93	4.93	4.93	4.93	4.30	4.30	16.35
2038	4.93	4.93	4.93	4.93	4.93	4.93	4.30	4.30	16.35
2039	4.93	4.93	4.93	4.93	4.93	4.93	4.30	4.30	16.35
2040	4.93	4.93	4.93	4.93	4.93	4.93	4.30	4.30	16.35
2041	4.93	4.93	4.93	4.93	4.93	4.93	4.30	4.30	16.35
2042	4.93	4.93	4.93	4.93	4.93	4.93	4.30	4.30	16.35
2043	4.93	4.93	4.93	4.93	4.93	4.93	4.30	4.30	16.35
2044	4.93	4.93	4.93	4.93	4.93	4.93	4.30	4.30	16.35
2045	4.93	4.93	4.93	4.93	4.93	4.93	4.30	4.30	16.35
2046	4.93	4.93	4.93	4.93	4.93	4.93	4.30	4.30	16.35
2047	4.93	4.93	4.93	4.93	4.93	4.93	4.30	4.30	16.35
2048	4.93	4.93	4.93	4.93	4.93	4.93	4.30	4.30	16.35
2049	4.93	4.93	4.93	4.93	4.93	4.93	4.30	4.30	16.35
2050	4.93	4.93	4.93	4.93	4.93	4.93	4.30	4.30	16.35

Table 72: Lānaʻi Maintenance Outage Rates for Thermal Resources

Year	LL 1	LL 2	LL 3	LL 4	LL 5	LL 6	LL 7	LL 8	CHP
%									
2021	1.57	1.57	1.57	1.57	1.57	1.57	3.04	3.04	8.12
2022	1.57	1.57	1.57	1.57	1.57	1.57	3.04	3.04	8.12
2023	1.57	1.57	1.57	1.57	1.57	1.57	3.04	3.04	8.12
2024	1.57	1.57	1.57	1.57	1.57	1.57	3.04	3.04	8.12
2025	1.57	1.57	1.57	1.57	1.57	1.57	3.04	3.04	8.12
2026	1.57	1.57	1.57	1.57	1.57	1.57	3.04	3.04	8.12
2027	1.57	1.57	1.57	1.57	1.57	1.57	3.04%	3.04	8.12
2028	1.57	1.57	1.57	1.57	1.57	1.57	3.04	3.04	8.12
2029	1.57	1.57	1.57	1.57	1.57	1.57	3.04	3.04	8.12
2030	1.57	1.57	1.57	1.57	1.57	1.57	3.04	3.04	8.12
2031	1.57	1.57	1.57	1.57	1.57	1.57	3.04	3.04	8.12
2032	1.57	1.57	1.57	1.57	1.57	1.57	3.04	3.04	8.12
2033	1.57	1.57	1.57	1.57	1.57	1.57	3.04	3.04	8.12
2034	1.57	1.57	1.57	1.57	1.57	1.57	3.04	3.04	8.12
2035	1.57	1.57	1.57	1.57	1.57	1.57	3.04	3.04	8.12
2036	1.57	1.57	1.57	1.57	1.57	1.57	3.04	3.04	8.12
2037	1.57	1.57	1.57	1.57	1.57	1.57	3.04	3.04	8.12
2038	1.57	1.57	1.57	1.57	1.57	1.57	3.04	3.04	8.12
2039	1.57	1.57	1.57	1.57	1.57	1.57	3.04	3.04	8.12
2040	1.57	1.57	1.57	1.57	1.57	1.57	3.04	3.04	8.12
2041	1.57	1.57	1.57	1.57	1.57	1.57	3.04	3.04	8.12
2042	1.57	1.57	1.57	1.57	1.57	1.57	3.04	3.04	8.12
2043	1.57	1.57	1.57	1.57	1.57	1.57	3.04	3.04	8.12
2044	1.57	1.57	1.57	1.57	1.57	1.57	3.04	3.04	8.12
2045	1.57	1.57	1.57	1.57	1.57	1.57	3.04	3.04	8.12
2046	1.57	1.57	1.57	1.57	1.57	1.57	3.04	3.04	8.12
2047	1.57	1.57	1.57	1.57	1.57	1.57	3.04	3.04	8.12
2048	1.57	1.57	1.57	1.57	1.57	1.57	3.04	3.04	8.12

2049	1.57	1.57	1.57	1.57	1.57	1.57	3.04	3.04	8.12
2050	1.57	1.57	1.57	1.57	1.57	1.57	3.04	3.04	8.12

6. THERMAL GENERATING UNIT REMOVAL FROM SERVICE SCHEDULES

The planned removal from service schedules for O‘ahu, Hawai‘i Island, and Maui are provided below. These schedules represent initial assumptions made on the timing for the removal of utility-owned, thermal generating units.

The removal from service schedules assume that adequate replacement resources can be installed in a timely manner to facilitate the generating units’ removal. However, the planning analyses in the Grid Needs Assessment may deem it prudent to delay certain units’ removal to address shortfalls in grid services, including Energy Reserve Margin. The order in which units are removed may be further adjusted to account for flexibility needs and unit age.

Table 73: Planned Removal from Service Assumptions for O‘ahu, Hawai‘i Island, and Maui

Island	O‘ahu	Hawai‘i Island	Maui
2023	Waiau 3-4 Removed from Service		
2025		Puna Steam Removed from Service	
2026	Waiau 5-6 Removed from Service		
2027		Hill 5-6 Removed from Service	
2029	Kahe 1-2 Removed from Service		
2030			Maalaea 4-9 Removed from Service
2033	Waiau 7-8 Removed from Service		

2037	Kahe 3-4 Removed from Service		
2046	Kahe 5-6 Removed from Service		

7. VARIABLE RENEWABLE, STORAGE, AND GRID SERVICE RESOURCE PORTFOLIOS

In addition to the thermal generating units, Hawaiian Electric has a diverse range of variable renewable resources including wind, solar, and hydro in its portfolio. Several upcoming projects will also add storage to the resource mix, paired with solar or as a standalone resource. The following resources are assumed to be online in the RESOLVE and PLEXOS models and are either existing resources that are currently online or have had an application submitted for approval. More information on the status of these new renewable energy projects can be found on the Renewable Project Status Board.[71] The year in service shown for the Stage 1 and Stage 2 RFP projects have been rounded to the nearest beginning of year. The planned resource portfolio will be updated for the projects resulting from the Community-Based Renewable Energy (CBRE) Phase 2 once they are known. Grid Services RFP projects noted below are assumed to be online at partial capacity in 2021 and ramp to their full capacity by 2023.

O'ahu

Table 74: O'ahu Variable Renewable, Storage, and Grid Service Resources

Unit	Year in Service	Capacity (MW)	Storage Capacity (MWh)	Capacity Factor (%)
Kapolei Sustainable Energy Park	2012	1.0	-	21.9%
Kalaeloa Solar Two	2013	5.0	-	25.7%
Kalaeloa Renewable Energy Park	2014	5.0	-	20.5%
Kahuku Wind	2011	30.0	-	27.2%
Kawailoa Wind	2013	69.0	-	19.7%
West Loch	2019	20.0	-	25.1%
Lanikuhana Solar	2019	14.7	-	27.1%

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[71] *See* https://www.hawaiianelectric.com/clean-energy-hawaii/our-clean-energy-portfolio/renewable-project-status-board

Waipio PV	2019	45.9	-	27.1%
Kawailoa Solar	2019	49.0	-	27.1%
Na Pua Makani	2020	24.0	-	42.5%
Waianae Solar	2017	27.6	-	27.1%
Feed-In-Tariff Tier 1 and 2		24.8	-	19.3%
Feed-In-Tariff Tier 3		20.0	-	
Aloha Solar Energy Fund 1 & 2	2020	10.0	-	19.3%
Mauka FIT 1	2020	3.5	-	19.3%
Waihonu Solar	2016	6.5	-	19.3%
CBRE Phase 1	2021	5.0	-	24.5%
Stage 1				
Hoohana Solar 1	2024	52.0	208.0	25.1%
AES West Oahu Solar	2023	12.5	50.0	25.2%
Mililani 1 Solar	2023	39.0	156.0	27.2%
Waiawa Solar Power	2023	36.0	144.0	27.9%
Stage 2				
Kupehau Solar	2022	60.0	240.0	21.2%
Waiawa Phase 2 Solar	2024	30.0	240.0	20.5%
Mountain View Solar	2023	7.0	35.0	17.3%
Barber's Point Solar	2024	15.0	60.0	22.2%
Mahi Solar	2024	120.0	480.0	25.8%
Kapolei Energy Storage	2022	185.0	565.0	-
Grid Services RFP				
Load Build	2023	14.8	-	-
Load Reduce	2023	19.4	-	-
FFR	2023	37.3	-	-

Hawai'i Island

Table 75: Hawai'i Island Variable Renewable, Storage, and Grid Service Resources

Unit	Year in Service	Capacity (MW)	Storage Capacity (MWh)	Capacity Factor (%)
Small Hydros		0.2	-	85.7%
Wailuku Hydro	1993	12.1	-	18.9%
HRD Wind	2006	10.5	-	42.4%
Tawhiri	2007	20.5		63.6%
SIA Wind		3.5	-	30.3%
Feed-In-Tariff		9.1		18.1%
Puueo Hydro	2005	3.3	-	54.8%
Waiau Hydro	1920	2.0	-	53.2%
CBRE Phase 1	2022	1.0	-	16.9%
Stage 1 RFP				
Hale Kuawehi Solar	2023	30.0	120.0	33.2%
Waikoloa Solar	2023	30.0	120.0	30.9%
Stage 2 RFP				
Puako Solar	2024	60.0	240.0	32.2%
Keahole Battery Energy Storage	2023	12.0	12.0	-
Grid Services RFP				
FFR	2023	5.9	-	-
Load Reduce	2023	4.3	-	-
Load Build	2023	3.2	-	-

Maui

Table 76: Maui Variable Renewable, Storage, and Grid Service Resources

Unit	Year in Service	Capacity (MW)	Storage Capacity (MWh)	Capacity Factor (%)

Feed-In-Tariff		6.75	-	17%
Kaheawa Wind Farm I	2006	30.0	-	43%
Kaheawa Wind Farm II	2012	21.0	-	47%
Auwahi Wind Farm	2012	21.0	-	51%
South Maui Renewable Resources	2018	2.9	-	29%
Kuia Solar	2018	2.9	-	29%
CBRE Phase 1	2021	0.025	-	28%
Stage 1 RFP				
Kuihelani	2024	60.0	240.0	31%
Paeahu Solar	2023	15.0	60.0	31%
Stage 2 RFP				
Kahana Solar	2024	20.0	80.0	43%
Pulehu Solar	2023	40.0	160.0	31%
Waena BESS	2023	40.0	160.0	-
Grid Services RFP				
Load Build	2023	2.0	-	-
Load Reduce	2023	7.2	-	-
FFR1	2023	6.1	-	-

Molokaʻi

Table 77: Molokaʻi Variable Renewable, Storage, and Grid Service Resources

Unit	Year in Service	Capacity (MW)	Storage Capacity (MWh)	Capacity Factor (%)
CBRE Phase 1	2021	0.25	-	27.60%

Lānaʻi

Table 78: Lānaʻi Variable Renewable, Storage, and Grid Service Resources

Unit	Year in Service	Capacity (MW)	Storage Capacity (MWh)	Capacity Factor (%)
Lanai Sustainability Research	2009	1.2	-	26.15%

Appendix A:Resource Cost Forecasts (2020 – 2050)

Table 79: Capital and O&M Costs for Resource Options (Grid-Scale PV, Commercial-Scale PV)

Year	Grid-Scale PV (Fixed tilt)		Grid-Scale PV (Single axis tracking)		Commercial-Scale PV	
	Capital ($/kW)	O&M ($/kW-year)	Capital ($/kW)	O&M ($/kW-year)	Capital ($/kW)	O&M ($/kW-year)
2020	558	13	606	14	1,366	19
2021	574	12	626	14	1,260	18
2022	538	12	588	13	1,198	17
2023	539	11	589	13	1,221	17
2024	668	11	730	13	1,522	16
2025	645	11	707	12	1,497	16
2026	624	11	685	12	1,476	16
2027	642	10	704	12	1,541	16
2028	637	10	697	12	1,543	16
2029	634	10	693	12	1,551	15
2030	632	10	691	12	1,558	15
2031	632	10	692	12	1,571	15
2032	634	10	694	12	1,586	15
2033	638	10	696	12	1,606	15
2034	640	10	698	12	1,622	15
2035	644	10	703	12	1,640	15
2036	647	10	707	12	1,660	16
2037	653	10	713	12	1,680	16
2038	658	11	719	12	1,700	16
2039	664	11	726	12	1,720	16
2040	670	11	733	12	1,742	16
2041	677	11	740	12	1,759	16

Year	Grid-Scale PV (Fixed tilt)		Grid-Scale PV (Single axis tracking)		Commercial-Scale PV	
	Capital ($/kW)	O&M ($/kW-year)	Capital ($/kW)	O&M ($/kW-year)	Capital ($/kW)	O&M ($/kW-year)
2042	684	11	749	13	1,781	17
2043	693	11	758	13	1,803	17
2044	700	11	767	13	1,823	17
2045	709	11	777	13	1,845	17
2046	718	12	786	13	1,868	18
2047	728	12	796	14	1,890	18
2048	739	12	807	14	1,909	18
2049	748	12	820	14	1,934	18
2050	759	12	831	14	1,959	19

Table 80: Capital and O&M Costs for Resource Options (Residential PV, Onshore Wind, Distributed Wind)

Year	Residential PV		Onshore Wind		Distributed Wind	
	Capital ($/kW)	O&M ($/kW-year)	Capital ($/kW)	O&M ($/kW-year)	Capital ($/kW)	O&M ($/kW-year)
2020	2,443	19	1,356	40	8,271	49
2021	2,423	18	1,337	40	8,151	49
2022	2,344	17	1,646	40	7,927	49
2023	2,417	17	1,663	40	8,441	49
2024	3,418	16	1,682	40	10,948	49
2025	3,382	16	1,701	40	11,075	50
2026	3,351	16	1,723	41	11,215	50
2027	3,482	16	1,817	41	11,350	50
2028	3,487	16	1,840	41	11,494	51
2029	3,501	15	1,863	42	11,637	51
2030	3,518	15	1,887	43	11,789	52
2031	3,540	15	1,912	43	11,944	53
2032	3,570	15	1,940	44	12,119	54

Year	Residential PV		Onshore Wind		Distributed Wind	
	Capital ($/kW)	O&M ($/kW-year)	Capital ($/kW)	O&M ($/kW-year)	Capital ($/kW)	O&M ($/kW-year)
2033	3,602	15	1,969	45	12,301	55
2034	3,633	15	1,999	46	12,490	56
2035	3,671	15	2,030	46	12,682	57
2036	3,709	16	2,060	47	12,873	58
2037	3,751	16	2,092	48	13,073	59
2038	3,796	16	2,126	49	13,284	60
2039	3,841	16	2,160	50	13,498	62
2040	3,888	16	2,195	51	13,715	63
2041	3,933	16	2,231	53	13,938	64
2042	4,011	17	2,268	54	14,173	66
2043	4,073	17	2,307	55	14,414	67
2044	4,133	17	2,346	56	14,659	69
2045	4,191	17	2,386	57	14,911	70
2046	4,247	18	2,428	59	15,170	72
2047	4,296	18	2,470	60	15,434	74
2048	4,349	18	2,513	61	15,706	75
2049	4,408	18	2,557	63	15,982	77
2050	4,461	19	2,602	64	16,262	79

Table 81: Capital and O&M Costs for Resource Options (Offshore Wind, Residential Storage, Commercial Storage)

Year	Offshore Wind		Residential Storage (2 hours)		Commercial Scale Storage (2 hours)	
	Capital ($/kW)	O&M ($/kW-year)	Capital ($/kW)	O&M ($/kW-year)	Capital ($/kW)	O&M ($/kW-year)
2020	4,158	95	3,869	21	2,612	21
2021	4,107	91	3,610	20	2,409	20
2022	3,918	81	3,472	20	2,327	20

Year	Offshore Wind		Residential Storage (2 hours)		Commercial Scale Storage (2 hours)	
	Capital ($/kW)	O&M ($/kW-year)	Capital ($/kW)	O&M ($/kW-year)	Capital ($/kW)	O&M ($/kW-year)
2023	4,006	84	3,302	19	2,229	19
2024	3,955	80	3,238	19	2,195	19
2025	3,906	77	3,175	19	2,161	19
2026	5,664	74	3,138	19	2,144	19
2027	5,761	77	3,105	19	2,131	19
2028	5,529	69	3,075	19	2,118	19
2029	5,464	68	3,049	19	2,109	19
2030	5,401	66	3,025	20	2,125	20
2031	5,341	65	3,007	20	2,139	20
2032	5,226	62	2,995	20	2,158	20
2033	5,120	62	2,988	20	2,179	20
2034	5,042	62	2,986	21	2,202	21
2035	4,992	62	2,987	21	2,228	21
2036	4,965	62	2,992	21	2,256	21
2037	4,962	62	2,996	21	2,283	21
2038	4,978	63	3,005	22	2,313	22
2039	5,011	63	3,017	22	2,345	22
2040	5,059	64	3,032	22	2,378	22
2041	5,117	64	3,062	23	2,413	23
2042	5,182	65	3,094	23	2,450	23
2043	5,249	66	3,127	23	2,487	23
2044	5,313	67	3,163	24	2,527	24
2045	5,371	67	3,199	24	2,567	24
2046	5,415	68	3,238	25	2,608	25
2047	5,440	69	3,279	25	2,652	25
2048	5,440	70	3,321	25	2,697	25
2049	5,406	71	3,365	26	2,743	26

Year	Offshore Wind		Residential Storage (2 hours)		Commercial Scale Storage (2 hours)	
	Capital ($/kW)	O&M ($/kW-year)	Capital ($/kW)	O&M ($/kW-year)	Capital ($/kW)	O&M ($/kW-year)
2050	5,332	72	3,411	26	2,791	26

Table 82: Capital and O&M Costs for Resource Options (5 MW Grid-Scale Storage, 50 MW Grid-Scale Storage)

Year	5 MW Grid-Scale Storage			50 MW Grid-Scale Storage		
	Balance of System ($/kW)	Modules ($/kWh)	O&M ($/kW-year)	Balance of System ($/kW)	Modules ($/kWh)	O&M ($/kW-year)
2020	1,195	221	21	874	210	19
2021	1,164	195	20	839	184	18
2022	1,150	189	20	823	178	18
2023	1,127	180	19	799	169	18
2024	1,117	187	19	786	170	17
2025	1,097	183	19	771	171	17
2026	1,102	180	19	774	170	17
2027	1,109	179	19	779	169	17
2028	1,117	178	19	783	169	18
2029	1,125	178	19	789	168	18
2030	1,134	178	20	794	167	18
2031	1,145	173	20	801	163	18
2032	1,157	169	20	809	159	18
2033	1,171	166	20	818	156	18
2034	1,185	163	21	828	154	19
2035	1,201	161	21	839	151	19
2036	1,218	158	21	850	149	19
2037	1,234	156	21	861	147	19
2038	1,252	154	22	873	146	20

Year	5 MW Grid-Scale Storage			50 MW Grid-Scale Storage		
	Balance of System ($/kW)	Modules ($/kWh)	O&M ($/kW-year)	Balance of System ($/kW)	Modules ($/kWh)	O&M ($/kW-year)
2039	1,271	153	22	885	144	20
2040	1,290	151	22	898	143	20
2041	1,310	150	23	912	142	21
2042	1,331	149	23	926	140	21
2043	1,352	148	23	941	140	21
2044	1,375	147	24	956	139	22
2045	1,397	146	24	971	138	22
2046	1,420	146	25	987	138	22
2047	1,445	146	25	1,004	137	23
2048	1,469	145	25	1,020	137	23
2049	1,495	145	26	1,038	137	23
2050	1,521	146	26	1,056	137	24

Table 83: Capital and O&M Costs for Resource Options (5 MW Paired Grid-Scale Storage (4hrs), 50 MW Paired Grid-Scale Storage (4hrs))

Year	5 MW Paired Grid-Scale Storage (4hr)		50 MW Paired Grid-Scale Storage (4hr)	
	Capital ($/kW)	O&M ($/kW-year)	Capital ($/kW)	O&M ($/kW-year)
2020	1,384	17	1,133	15
2021	1,179	16	924	15
2022	1,142	16	885	14
2023	1,157	16	886	14
2024	1,339	15	1,032	14
2025	1,306	15	1,023	14
2026	1,293	15	1,022	14
2027	1,342	15	1,070	14

Year	5 MW Paired Grid-Scale Storage (4hr)		50 MW Paired Grid-Scale Storage (4hr)	
	Capital ($/kW)	O&M ($/kW-year)	Capital ($/kW)	O&M ($/kW-year)
2028	1,344	15	1,070	14
2029	1,348	16	1,071	14
2030	1,353	16	1,073	14
2031	1,347	16	1,064	14
2032	1,344	16	1,059	15
2033	1,344	16	1,056	15
2034	1,345	16	1,055	15
2035	1,349	17	1,055	15
2036	1,354	17	1,056	15
2037	1,360	17	1,058	16
2038	1,367	17	1,061	16
2039	1,375	18	1,065	16
2040	1,383	18	1,069	16
2041	1,393	18	1,074	16
2042	1,404	18	1,080	17
2043	1,415	19	1,087	17
2044	1,428	19	1,094	17
2045	1,441	19	1,102	18
2046	1,455	20	1,111	18
2047	1,471	20	1,121	18
2048	1,487	20	1,132	18
2049	1,505	21	1,143	19
2050	1,523	21	1,155	19

Table 84: Capital and O&M Costs for Resource Options (5 MW Paired Grid-Scale Storage (6hrs), 50 MW Paired Grid-Scale Storage (6hrs), DER Aggregator)

Year	5 MW Paired Grid-Scale Storage (6hr)		50 MW Paired Grid-Scale Storage (6hr)		DER Aggregator - PV+Storage	
	Capital ($/kW)	O&M ($/kW-year)	Capital ($/kW)	O&M ($/kW-year)	Capital ($/kW)	O&M ($/kW-year)
2020	1,881	17	1,584	15	5,219	36
2021	1,630	16	1,328	15	4,877	34
2022	1,581	16	1,277	14	4,689	33
2023	1,600	16	1,278	14	4,766	32
2024	1,858	15	1,461	14	6,400	32
2025	1,814	15	1,444	14	6,303	31
2026	1,796	15	1,438	14	6,234	31
2027	1,784	15	1,466	14	6,307	31
2028	1,786	15	1,465	14	6,289	31
2029	1,791	16	1,466	14	6,283	31
2030	1,796	16	1,468	14	6,283	31
2031	1,785	16	1,454	14	6,293	31
2032	1,778	16	1,445	15	6,317	31
2033	1,775	16	1,439	15	6,346	32
2034	1,774	16	1,435	15	6,378	32
2035	1,776	17	1,433	15	6,421	32
2036	1,781	17	1,434	15	6,466	32
2037	1,786	17	1,435	16	6,516	33
2038	1,793	17	1,437	16	6,575	33
2039	1,801	18	1,441	16	6,638	34
2040	1,810	18	1,445	16	6,707	34
2041	1,821	18	1,450	16	6,786	34
2042	1,832	18	1,457	17	6,905	35
2043	1,845	19	1,465	17	7,008	36
2044	1,860	19	1,473	17	7,110	36

Year	5 MW Paired Grid-Scale Storage (6hr)		50 MW Paired Grid-Scale Storage (6hr)		DER Aggregator - PV+Storage	
	Capital ($/kW)	O&M ($/kW-year)	Capital ($/kW)	O&M ($/kW-year)	Capital ($/kW)	O&M ($/kW-year)
2045	1,876	19	1,483	18	7,210	37
2046	1,897	20	1,493	18	7,308	37
2047	1,919	20	1,506	18	7,402	38
2048	1,943	20	1,519	18	7,500	38
2049	1,969	21	1,533	19	7,608	39
2050	1,996	21	1,548	19	7,710	40

Table 85: Capital and O&M Costs for Resource Options (Synchronous Condenser, Geothermal, Municipal Solid Waste)

Year	Synchronous Condenser	Geothermal		Municipal Solid Waste (MSW)		
	Capital ($/kVar)	Capital ($/kW)	O&M ($/kW-year)	Capital ($/kW)	O&M ($/kW-year)	Var O&M ($/MWH)
2020	682	6,520	223	10,349	528	12
2021	694	6,617	228	10,558	540	12
2022	707	6,715	232	10,772	553	12
2023	715	6,814	237	10,989	566	13
2024	718	6,914	241	11,211	579	13
2025	726	7,015	246	11,408	592	13
2026	738	7,116	250	11,632	606	13
2027	749	7,219	255	11,853	620	14
2028	762	7,323	260	12,084	635	14
2029	777	7,427	265	12,315	649	14
2030	791	7,533	270	12,538	664	15
2031	806	7,670	277	12,769	680	15
2032	821	7,809	283	12,998	696	15
2033	836	7,951	290	13,230	712	16

Year	Synchronous Condenser	Geothermal		Municipal Solid Waste (MSW)		
	Capital ($/kVar)	Capital ($/kW)	O&M ($/kW-year)	Capital ($/kW)	O&M ($/kW-year)	Var O&M ($/MWH)
2034	852	8,095	296	13,480	728	16
2035	869	8,242	303	13,730	745	17
2036	886	8,392	310	13,965	763	17
2037	905	8,545	318	14,224	781	17
2038	923	8,700	325	14,483	799	18
2039	942	8,858	333	14,734	817	18
2040	960	9,019	340	14,986	836	19
2041	980	9,183	348	15,269	856	19
2042	1,000	9,349	356	15,535	876	19
2043	1,020	9,519	365	15,817	896	20
2044	1,041	9,692	373	16,102	917	20
2045	1,063	9,868	382	16,401	938	21
2046	1,084	10,048	391	16,675	960	21
2047	1,106	10,230	400	16,975	983	22
2048	1,128	10,416	409	17,280	1,005	22
2049	1,152	10,605	419	17,589	1,029	23
2050	1,165	10,798	428	17,748	1,053	23

Table 86: Capital and O&M Costs for Resource Options (Biomass, Pumped Storage Hydro)

Year	Biomass				Pumped Storage Hydro	
	Capital ($/kW)	O&M ($/kW-year)	Var O&M ($/MWH)	Fuel Cost ($/MWH)	Capital ($/kW)	O&M ($/kW-year)
2020	6,110	153	6	53	3,838	39
2021	6,234	156	6	54	3,927	40
2022	6,360	160	6	55	4,018	41
2023	6,488	163	6	56	4,112	42
2024	6,619	167	6	58	4,208	43

Year	Biomass				Pumped Storage Hydro	
	Capital ($/kW)	O&M ($/kW-year)	Var O&M ($/MWH)	Fuel Cost ($/MWH)	Capital ($/kW)	O&M ($/kW-year)
2025	6,735	171	7	59	4,306	44
2026	6,868	175	7	60	4,406	45
2027	6,998	179	7	62	4,508	46
2028	7,134	183	7	63	4,613	47
2029	7,271	188	7	65	4,721	48
2030	7,403	192	7	66	4,831	49
2031	7,538	197	8	68	4,943	50
2032	7,674	201	8	69	5,058	51
2033	7,811	206	8	71	5,176	53
2034	7,958	211	8	72	5,296	54
2035	8,106	216	8	74	5,420	55
2036	8,245	221	8	76	5,546	56
2037	8,398	226	9	78	5,675	58
2038	8,550	231	9	79	5,807	59
2039	8,699	236	9	81	5,942	60
2040	8,848	242	9	83	6,081	62
2041	9,015	247	10	85	6,222	63
2042	9,172	253	10	87	6,367	65
2043	9,338	259	10	89	6,515	66
2044	9,506	265	10	91	6,667	68
2045	9,683	271	10	93	6,822	69
2046	9,845	278	11	96	6,981	71
2047	10,022	284	11	98	7,144	73
2048	10,202	291	11	100	7,310	74
2049	10,384	297	11	102	7,480	76
2050	10,478	304	12	105	7,654	78

Table 87: Capital and O&M Costs for Resource Options (Concentrated Solar, 2x1 Combined Cycle)

Year	Concentrated Solar			153 MW 2x1 Combined Cycle		
	Capital ($/kW)	O&M ($/kW-year)	Var O&M ($/MWH)	Capital ($/kW)	O&M ($/kW-year)	Var O&M ($/MWH)
2020	8,204	84	5	3,117	16	3
2021	7,957	86	5	3,183	16	3
2022	7,702	86	5	3,250	17	3
2023	8,017	85	5	3,318	17	3
2024	9,167	85	5	3,387	18	3
2025	9,048	85	5	3,459	18	3
2026	8,945	84	5	3,535	18	3
2027	8,861	84	5	3,613	19	3
2028	8,797	83	5	3,694	19	3
2029	8,747	83	5	3,778	20	3
2030	8,718	82	6	3,862	20	3
2031	8,708	84	6	3,949	21	3
2032	8,716	86	6	4,038	21	4
2033	8,744	88	6	4,128	22	4
2034	8,785	90	6	4,221	22	4
2035	8,849	92	6	4,317	23	4
2036	8,926	94	6	4,415	23	4
2037	9,020	96	7	4,515	24	4
2038	9,132	98	7	4,618	24	4
2039	9,258	101	7	4,723	25	4
2040	9,398	103	7	4,829	25	4
2041	9,550	106	7	4,940	26	4
2042	9,714	108	7	5,051	26	4
2043	9,892	110	8	5,166	27	5
2044	10,076	113	8	5,284	28	5
2045	10,267	116	8	5,405	28	5
2046	10,468	118	8	5,526	29	5

Year	Concentrated Solar			153 MW 2x1 Combined Cycle		
	Capital ($/kW)	O&M ($/kW-year)	Var O&M ($/MWH)	Capital ($/kW)	O&M ($/kW-year)	Var O&M ($/MWH)
2047	10,668	121	8	5,652	30	5
2048	10,873	124	8	5,781	30	5
2049	11,078	127	9	5,912	31	5
2050	11,276	130	9	6,037	32	5

Table 88: Capital and O&M Costs for Resource Options (1x1 Combined Cycle, Simple Cycle CT)

Year	48 MW 1x1 Combined Cycle			34 MW Simple Cycle CT		
	Capital ($/kW)	O&M ($/kW-year)	Var O&M ($/MWH)	Capital ($/kW)	O&M ($/kW-year)	Var O&M ($/MWH)
2020	3,623	16	3	2,484	14	6
2021	3,699	16	3	2,540	14	6
2022	3,776	17	3	2,596	15	6
2023	3,855	17	3	2,650	15	6
2024	3,933	18	3	2,702	16	6
2025	4,016	18	3	2,758	16	6
2026	4,104	18	3	2,818	16	6
2027	4,194	19	3	2,878	17	7
2028	4,288	19	3	2,942	17	7
2029	4,385	20	3	3,009	17	7
2030	4,482	20	3	3,076	18	7
2031	4,583	21	3	3,145	18	7
2032	4,685	21	4	3,215	19	7
2033	4,790	22	4	3,286	19	8
2034	4,898	22	4	3,360	20	8
2035	5,009	23	4	3,437	20	8
2036	5,121	23	4	3,514	20	8
2037	5,238	24	4	3,594	21	8
2038	5,357	24	4	3,676	21	8

Year	48 MW 1x1 Combined Cycle			34 MW Simple Cycle CT		
	Capital ($/kW)	O&M ($/kW-year)	Var O&M ($/MWH)	Capital ($/kW)	O&M ($/kW-year)	Var O&M ($/MWH)
2039	5,478	25	4	3,759	22	9
2040	5,601	25	4	3,844	22	9
2041	5,729	26	4	3,932	23	9
2042	5,858	26	4	4,021	23	9
2043	5,991	27	5	4,112	24	9
2044	6,127	28	5	4,206	25	10
2045	6,267	28	5	4,302	25	10
2046	6,407	29	5	4,399	26	10
2047	6,553	30	5	4,499	26	10
2048	6,702	30	5	4,601	27	11
2049	6,854	31	5	4,706	28	11
2050	6,997	32	5	4,805	28	11

Table 89: Capital and O&M Costs for Resource Options (Simple Cycle CT, Internal Combustion Engine)

Year	55 MW Simple Cycle CT			Internal Combustion Engine		
	Capital ($/kW)	O&M ($/kW-year)	Var O&M ($/MWH)	Capital ($/kW)	O&M ($/kW-year)	Var O&M ($/MWH)
2020	2,485	14	6	2,648	37	28
2021	2,540	14	6	2,697	38	29
2022	2,597	15	6	2,746	39	29
2023	2,651	15	6	2,778	40	30
2024	2,702	16	6	2,791	41	31
2025	2,758	16	6	2,822	42	31
2026	2,818	16	6	2,866	43	32
2027	2,879	17	7	2,909	44	33
2028	2,943	17	7	2,961	45	34
2029	3,010	17	7	3,020	46	34
2030	3,077	18	7	3,074	47	35

Year	55 MW Simple Cycle CT			Internal Combustion Engine		
	Capital ($/kW)	O&M ($/kW-year)	Var O&M ($/MWH)	Capital ($/kW)	O&M ($/kW-year)	Var O&M ($/MWH)
2031	3,146	18	7	3,133	48	36
2032	3,216	19	7	3,191	49	37
2033	3,287	19	8	3,248	50	38
2034	3,361	20	8	3,311	51	39
2035	3,438	20	8	3,378	53	40
2036	3,515	20	8	3,444	54	40
2037	3,595	21	8	3,516	55	41
2038	3,677	21	8	3,588	56	42
2039	3,760	22	9	3,659	58	43
2040	3,845	22	9	3,730	59	44
2041	3,933	23	9	3,809	60	45
2042	4,022	23	9	3,885	62	46
2043	4,113	24	9	3,965	63	48
2044	4,207	25	10	4,046	65	49
2045	4,303	25	10	4,131	66	50
2046	4,400	26	10	4,210	68	51
2047	4,500	26	10	4,297	69	52
2048	4,602	27	11	4,385	71	53
2049	4,707	28	11	4,475	73	55
2050	4,806	28	11	4,527	74	56

Appendix B: Distributed Energy Resource Forecasts (2020 – 2050)

Table 90: Cumulative Distributed PV Capacity (kW)

Year	O‘ahu	Hawai‘i Island	Maui	Moloka‘i	Lāna‘i	Consolidated
MW	A	B	C	D	E	F =A + B + C + D +E
2020	534,704	110,108	119,232	2,678	833	767,555
2021	565,107	118,283	128,567	2,824	870	815,651
2022	601,702	122,997	131,907	2,896	877	860,379
2023	618,835	127,691	136,773	2,952	897	887,147
2024	636,514	131,481	141,221	3,068	926	913,210
2025	655,712	135,631	145,757	3,112	1,006	941,218
2026	675,603	140,212	150,356	3,168	1,026	970,365
2027	695,495	144,658	154,651	3,208	1,046	999,058
2028	716,340	148,650	159,069	3,264	1,066	1,028,389
2029	737,067	152,672	163,613	3,392	1,103	1,057,848
2030	757,845	156,486	168,105	3,440	1,187	1,087,064
2031	778,022	160,105	172,688	3,500	1,211	1,115,526
2032	797,664	163,684	177,069	3,552	1,248	1,143,218
2033	816,292	167,474	181,111	3,608	1,268	1,169,753
2034	834,767	171,437	185,115	3,728	1,288	1,196,335
2035	852,922	175,586	189,077	3,768	1,368	1,222,721
2036	870,329	179,801	192,966	3,824	1,388	1,248,308
2037	887,436	184,047	196,883	3,868	1,421	1,273,656
2038	904,167	188,540	200,786	3,924	1,441	1,298,858
2039	920,312	193,032	204,136	4,044	1,461	1,322,985
2040	936,374	197,218	207,486	4,088	1,545	1,346,711

Year	Oʻahu	Hawaiʻi Island	Maui	Molokaʻi	Lānaʻi	Consolidated
MW	A	B	C	D	E	F =A + B + C + D +E
2041	952,402	201,997	211,111	4,144	1,582	1,371,237
2042	968,095	206,471	214,395	4,188	1,606	1,394,755
2043	983,174	211,196	217,814	4,244	1,626	1,418,055
2044	997,406	215,876	220,958	4,348	1,646	1,440,234
2045	1,011,101	220,219	223,980	4,400	1,739	1,461,440
2046	1,024,363	224,815	226,932	4,440	1,759	1,482,309
2047	1,037,199	229,056	230,054	4,488	1,779	1,502,576
2048	1,049,547	233,467	232,821	4,524	1,799	1,522,158
2049	1,061,511	237,512	235,751	4,636	1,819	1,541,229
2050	1,073,105	241,791	238,385	4,668	1,912	1,559,861

Table 91: Cumulative Distributed BESS Capacity (kWH)

Year	O‘ahu	Hawai‘i Island	Maui	Moloka‘i	Lāna‘i	Consolidated
MW	A	B	C	D	E	F =A + B + C + D +E
2020	54,034	37,313	41,409	173	114	133,043
2021	65,031	50,121	55,946	299	215	171,613
2022	72,813	56,282	61,629	412	236	191,372
2023	90,228	60,872	68,863	544	281	220,787
2024	109,710	65,008	75,778	664	317	251,477
2025	133,409	69,805	82,955	796	362	287,326
2026	159,502	75,392	90,268	928	407	326,497
2027	186,584	80,833	97,019	1,048	452	365,936
2028	215,901	85,545	104,122	1,180	497	407,244
2029	245,942	90,311	111,485	1,336	551	449,624
2030	276,352	94,799	118,891	1,480	605	492,127
2031	306,418	99,031	126,452	1,624	659	534,183
2032	336,513	103,084	133,559	1,780	713	575,649
2033	365,350	107,523	140,023	1,912	758	615,566
2034	393,977	112,279	146,501	2,044	803	655,603
2035	422,151	117,376	152,886	2,164	848	695,425
2036	449,654	122,594	159,195	2,296	893	734,631
2037	476,620	127,971	165,535	2,428	938	773,492
2038	503,011	133,800	171,872	2,560	983	812,225
2039	528,360	139,627	178,102	2,692	1,028	849,809
2040	553,654	145,443	184,317	2,824	1,082	887,319
2041	579,001	151,796	190,621	2,956	1,136	925,510
2042	603,735	158,139	196,772	3,088	1,190	962,923
2043	627,365	164,393	202,709	3,220	1,235	998,922
2044	649,979	170,666	208,538	3,340	1,280	1,033,802
2045	671,661	176,872	214,197	3,460	1,325	1,067,515
2046	692,512	182,991	219,702	3,580	1,370	1,100,154

Year	O‘ahu	Hawai‘i Island	Maui	Moloka‘i	Lāna‘i	Consolidated
MW	A	B	C	D	E	F =A + B + C + D +E
2047	712,548	189,009	225,054	3,688	1,415	1,131,713
2048	731,763	194,891	230,222	3,796	1,460	1,162,131
2049	750,256	200,652	235,251	3,904	1,505	1,191,567
2050	768,058	206,292	240,143	4,000	1,550	1,220,042

Appendix C: Forecast Methodologies

1. UNDERLYING FORECAST METHODOLOGIES

The sales forecasts were developed for each of the five islands and began with the development of the sales forecast by rate class (residential, commercial and street lighting) and by layer (underlying load forecast and adjusting layers – energy efficiency, distributed energy resources, and electrification of transportation). Key factors that affect sales in the future are identified such as the economic outlook, analysis of existing and proposed large customer loads, and impacts of customer-sited technologies such as energy efficiency measures, distributed energy resources and emerging technologies such as electric vehicles. This section focuses on the development of the underlying sales forecast which excludes impacts from previously installed and future DER, EE and EVs.

Multiple methods and models were analyzed to develop the underlying forecast as one model does not fit all. The methods are described below and were presented in the July 17, 2019 FAWG meeting, slides 10-12[72]. More than one model or method may be used to blend together a short term forecast with a long term forecast. Methods for the underlying layer include:

- Market analysis - a ground up forecast evaluating individual customers, particularly large commercial customers, forecasting individual projects or awareness of events that may merit a specific carve out if significant, i.e. new large projects or loss of large loads.
- Customer service - analysis of recent trends in customer counts, sales and use per customer and applies knowledge of local conditions such as construction activity, state of the visitor industry, trends in weather including impacts of storms and volcanic eruptions.
- Trending models – uses historical data series to project future sales or customer counts. Works well when historical data series has identifiable patterns and future trends aren't expected to vary from the past.
- Econometric models – relates sales or customers' use of electricity to macroeconomic variables such as personal income, jobs, population and visitor arrivals as well as other variables such as temperature, humidity or electricity price.

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[72] Available at, https://www.hawaiianelectric.com/documents/clean_energy_hawaii/integrated_grid_planning/stakeholder_engagement/working_groups/forecast_assumptions/20190717_wg_fa_meeting_presentation_materials.pdf

> Econometric models may also incorporate time series parameters such as lagged dependent variables or an autoregressive term. The quantification of the impact of changes in the economic and other variables on use is the strength of these models. The econometric model is specified in the following form:
>
> $$Y = \beta 0 + \sum_{i=1}^{n} (\beta i \ x \ Xi)$$
>
> where the dependent variable, Y, is kWh sales or use per customer and is related to the independent (explanatory) variables, X*i*, which represent economic or other variables. Variables β*i* represent the regression model coefficients. The constant variable β_o represents the Y-intercept.

Various models are evaluated for best fit and explanatory power however, it is important to assess if the models make sense. Is it reasonable to believe that electricity sales are related to the external variables in the model? Is the direction of the relationship plausible?

A description of the assumptions and models used to develop the underlying forecasts presented at the March 3, 2020 FAWG meeting and described in the response to PUC-HECO-IR-1[73] by rate class for Oʻahu, Hawaiʻi, Maui, Molokaʻi and Lānaʻi are provided below under each island's section.

Leading up to the March 3rd FAWG meeting, local economists were describing Hawaiʻi's economy as being on an expected slowing trend for the past several years even prior to the spread of the coronavirus ("COVID-19"). Immediately following the March 3rd meeting economic scenarios about the impact of COVID-19 were being developed with very limited information. The COVID-19 pandemic resulted in unprecedented disruptions to global travel, local resident behavior, economic activity and as a result, electricity consumption. State and county emergency orders beginning with stay-at-home orders and mandatory post-arrival travel quarantines in March 2020 basically shutdown the Hawaiʻi economy, especially the tourism industry. Electricity usage was severely impacted, although in different ways depending on the sector. Several economic updates were issued in the following months by the University of Hawaiʻi Economic Research Organization ("UHERO"), with the outlook rapidly changing as new emergency orders went into effect.

The Company's updated forecast was informed by multiple types of data to provide numerous sources of insight into this unprecedented time. Customer information was analyzed including available customer-level consumption data from before and after the governments' emergency orders went into effect, customers' public announcements regarding closures and reopening plans, feedback from customers to their Hawaiian Electric account managers,

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[73] Available at, https://www.hawaiianelectric.com/documents/clean_energy_hawaii/integrated_grid_planning/stakeholder_engagement/working_groups/forecast_assumptions/dkt_20180165_20200702_HECO_response_to_PUC_IRs_1-2.pdf

distribution circuit data from before and after emergency orders went into effect, and customer billing data. Local economists, organizations and businesses in Hawai'i discussed impacts to the local economy and their perspectives on recovery in multiple public forums. Information from other utilities on Covid-19 related impacts to electricity consumption and methods for projecting recovery was also considered. The Company updated its underlying forecasts to account for the impacts of COVID-19 and anticipated recovery as presented in the August 31, 2020 FAWG meeting[74] and are also described for each island below.

O'ahu Underlying Forecast

Econometric methods were used for deriving the underlying sales for both the residential and commercial sectors. Historical recorded sales used in econometric models were adjusted to remove sales impact of DER, EE and EoT, which are treated as separate layers.

Residential Sales

The residential econometric equation was specified using a monthly use per residential customer in kilowatt-hours ("kWh"). The monthly econometric model describes residential electricity use per customer as a function of temperature, humidity, electricity price and real personal income per capita as these variables were all found to have relationships with residential use per customer. In addition, a simple trend variable and a monthly dummy variable were included in the models. The trend variable which increases by 1 was used as a proxy for growth and the binary dummy variable representing January or August (1 if January or August; 0 otherwise) improves the model statistics. Additional details on each variable, dependent and independent, used in deriving the monthly use per residential customer including the name of the variable and the source of the information are shown below. The values of the variables fed into the econometric modeling tool and the output from the model are contained in the Excel file "Appendix C Att 1 HE Underlying Inputs and Predicted.xlsx" which accompanies this report.

The specification and evaluation of the hypothetical relationships was performed using a proprietary software package, MetrixND from Itron, Inc. MetrixND is a statistical analysis package which allows Hawaiian Electric to conduct analyses and statistical testing of econometric models. Many hypothetical relationships were considered, tested, and rejected until econometric equations for residential use per customer and commercial kWh sales were identified for use in Hawaiian Electric's sales projections.

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[74] Available at, https://www.hawaiianelectric.com/documents/clean_energy_hawaii/integrated_grid_planning/stakeholder_engagement/working_groups/forecast_assumptions/20200831_wg_fa_meeting_presentation_materials_HECO.pdf

Table 92: O‘ahu Residential Customer Econometric Sales Model Variables

Variables	Description	Source	Variable Labels
Dependent Variable:			
Monthly Residential Use Per Customer	Monthly residential recorded kWh sales divided by Monthly residential recorded customers	Hawaiian Electric's monthly reports filed with the Commission	Res_rcd_adj divided by Res_Cust_rcd
Weather Variables:			
Cooling Degree Days	1999 – 2018 average + warming trend	Historical HNL airport data from NOAA, see FAWG presentation on August 27, 2019.	cdd_99_18add
Dewpoint Temperature	1999 – 2018 average	Historical HNL airport data from NOAA	dewpt_99_18
Economic Variables:			
Real Residential electricity price	Real Residential $ (1982-84=100) per kWh	See FAWG presentation on August 27, 2019	Res_rprc_rcd
Real personal income per capita	Real personal income (1982-84=100) ÷ Resident population	UHERO updated forecast dated October 2019	ypc_r_hon = y_r_hon ÷ respop_hon
Trend & Dummy Variables:			
Trend variable	Growth proxy	Trend variable that increases by 1 per month	mo_yr_time
Monthly dummy variables	January and August	Improves model statistics	m_1 and m_8

To arrive at sales per month, the monthly use per residential customer derived in MetrixND was multiplied by the number of residential customers. The number of customers per month was derived using a linear trend time series model based on historical residential customer data from January 1980 through December 2018. The trending model used the maximum data points available to incorporate historical trends since residential customer growth is relatively stable.

The resulting residential GWh underlying sales forecast is residential kWh use per customer ÷ 10^6 x number of customers (Res_rcd_adj ÷ 10^6 x Res_Cust_rcd). An adjustment was made to include an extra day for leap year.

Commercial Sales

The econometric model used for underlying commercial sales was run for the combined rate schedules applied to small, medium and large commercial customers excluding street lighting rather than for individual rate schedules (Schedules G, J, P, DS and U) as it had stronger explanatory relationships since O‘ahu commercial customers historically tend to transfer between commercial rate schedules on a regular basis (based on tariff requirements). The underlying commercial sales econometric equation was specified using monthly sales in kilowatt-hours. The monthly econometric model describes electricity sales as a function of temperature, humidity, electricity price and non-agricultural jobs as these variables were all found to have relationships with commercial sales. In addition, monthly binary dummy variables representing February, August or October (1 if February, August or October; 0 otherwise) and another dummy variable for months starting from January 2015 and onwards which reflect a change in the relationship between non-agricultural jobs and sales improve the model statistics. Additional details on each variable, dependent and independent, used in deriving the monthly sales including the name of the variable and the source of the information are shown below. The values of the variables fed into the econometric modeling tool (independent variables) and the output from the model are contained in the Excel file “Appendix C Att 1 HE Underlying Inputs and Predicted.xlsx”.

Table 93: O‘ahu Commercial Customer Econometric Sales Model Variables

Variable	Description	Source	Variable Labels
Dependent Variable:			
Commercial Sales	Commercial recorded kWh sales (1984 - 2018)	Hawaiian Electric’s monthly reports filed with the Commission	Com_rcd_adj
Weather Variables:			
Cooling Degree Days	1999 – 2018 average + warming trend	Historical HNL airport data from NOAA see FAWG presentation on August 27, 2019	cdd_99_18add
Dewpoint Temperature	1999 – 2018 average	Historical HNL airport data from NOAA	dewpt_99_18
Economic Variables:			

Real commercial electricity price	Real commercial $ (1982-84=100) per kWh	See FAWG presentation on August 27, 2019	Com_rprc_rcd
Non-Ag Jobs	Non-agricultural job counts	UHERO, October 2019	E_NF_Hon
Trend Variable:			
Trend variable	Growth proxy	Trend variable that increases by 1 per month	mo_yr_time
Monthly dummy variables	February, August, and October	Improves model statistics	m_2, m_8, m_10
Dummy variable	For all months starting in January 2015 and continuing through December 2050	Relationship between non-ag jobs and commercial kWh appeared to change beginning in 2015, addition of this variable improved model statistics.	d_15on

The resulting commercial GWh sales forecast is commercial kWh underlying sales forecast ÷ 10^6. (Com_rcd_adj ÷ 10^6). Adjustments were made to include an extra day for leap year and for known large projects.

Street Lighting Sales

Sales for street lighting are less sensitive to changes in economic and weather drivers than sales in other rate schedules and represent less than 0.5% of Hawaiian Electric's sales. Consequently, an econometric or modeled approach to forecasting Schedule F sales was not developed. The average 2013 – 2018 growth rate in the underlying Schedule F kWh sales (excluding EE impacts) was applied as year-over-year growth for the forecast horizon. Additional growth was included for new unmetered pole attachments (e.g., third party telecom and network devices) based on market projections for number of attachments and existing attachments' kWh use.

The resulting street lighting GWh sales forecast is the underlying street lighting commercial kWh underlying sales forecast ÷ 10^6 (f_rcd_adj ÷ 10^6). An adjustment was made to include an extra day for leap year.

The values of the underlying street lighting in kWh are contained in the Excel file "Appendix C Att 1 HE Underlying Inputs and Predicted.xlsx" [4].

COVID-19 Update to the Underlying Sales for Oʻahu

Oʻahu's stay-at-home orders went into effect on March 23, 2020. Under Mayor Caldwell's Emergency Order No. 2020-02, "All persons may leave their residences only for Essential Activities, Essential Governmental Functions, or to operate Essential Businesses,..." This order basically shutdown the Oʻahu economy, especially the tourism industry. This unprecedented shutdown was a shock to Hawaiʻi's economy that has never been experienced before. Electricity usage was severely impacted, although in different ways depending on the sector. The economic impact and uncertainty about the length of the shutdown added to the confusion. Several economic updates were issued in the following month or two by UHERO, rapidly changing as new emergency orders went into effect.

Hawaiian Electric's econometric models were unable to incorporate the changes in the economic outlook because there had never been a period in history that could establish what the relationship between the economic shock and electricity use might be. Stay-at home orders basically shutdown hotels, office buildings, schools, retail and other building types where occupants could work from home or were not providing an essential service (including restaurants, bars, movie theaters, and most small businesses). On the other hand, residential usage increased as people were forced to stay home 24 hours a day.

The economic information and updates were rapidly changing and did not have as much detail as would normally be used in the sales forecast, in addition, customer behavior changed immediately and drastically in response to emergency orders and fears of the new unknown virus. As a result, a sales forecast update for the very near-term (2020 – 2021) was developed using more judgmental techniques to update the very near-term forecast, then blended with more traditional econometric models using updated economic outlooks (covering 2 – 5 years) as they became available.

For the very near-term forecast, current to 18 months ahead, the Oʻahu forecast was developed by analyzing very limited data for specific customers in Itron Inc.'s MV-Web billing system. Using available customer data for before and after the shutdown orders went into effect (only 3 – 4 weeks of post COVID data was available when the analysis was done), an estimate of the immediate impact (percentage change) was developed to use as a proxy for the commercial sectors by business types (e.g., hotel, office, retail, education, etc.). UHERO updates were used to estimate the length of time the lowest economic activity would continue and the how long it would take to see some recovery.

The residential sector was even more difficult to estimate because meter reads were stopped due to safety concerns for customers and meter readers. Residential customers' bills were estimated from late March until mid-May 2020 using previous consumption patterns which were low relative to stay-at-home COVID usage. There was no billing data beyond anecdotal stories about how residential usage was affected by the stay-at-home orders. The Distribution Planning Department assisted in obtaining real time circuit level energy data from the

Company’s PI system for specific residential areas. This data was used to derive a high-level impact factor to apply to total residential sales.

Information on data and trends in other jurisdictions were obtained from webinars, meetings, blogs, email blasts, and publications, primarily from EEI and other utilities. This information was used to help validate the projections the Company was developing for Oʻahu. Of particular interest were the trends from other utilities that had more granular data from widely deployed AMI meters. UHERO, DBEDT, and other economists discussed the local economy in multiple meetings with the State Legislature, business groups, and in the news which provided rapidly changing outlooks that influenced forecast assumptions.

In the longer run (2 – 5) years, UHERO provided an April 2020 economic outlook that was used to develop econometric models for the commercial sectors. The econometric relationship for the residential sector remained undeterminable, so a year-over-year percentage growth from the IGP forecast was used. After 5 years, the impact of the COVID pandemic had dissipated (assuming a vaccine was developed) and the more normal economic trends resumed. As a result, the IGP forecast was used for the long-term.

Hawaiʻi Underlying Forecast

For Hawaiʽi Island the underlying forecast is developed by rate class - residential, small and medium commercial, large power and street lighting. Similar to Oʻahu, historical recorded sales used in the models were adjusted to remove sales impact of DER, EE and EoT.

Residential Sales

The residential underlying sales forecast is developed using a combination of two forecast methods, the customer service method in the near term (2019-2020) and then an econometric model for the remainder of the forecast period. The customer service method allows for factors including knowledge of local economic conditions such as construction activity, the state of the visitor industry and a review of weather conditions as well as other island specific circumstances such as the volcano eruption on Hawaiʽi Island in 2018 to be considered in the analysis. At the time the underlying forecast was developed, actual Schedule R data was available through October 2019, which was used to inform the forecasts for 2019 and 2020.

The customer service method for residential sales examines historical and recent trends in customer count growth and underlying average use (kWh sales) per customer. In forecasting 2019 and 2020, this analysis also needed to take into consideration the residential customer losses that occurred in 2018 when homes were destroyed by the volcano eruption. October 2019 year-to-date year-over-year growth in customer count excluding eruption losses was used as the basis for projecting 2019 and 2020 residential customers. Similarly, careful analysis of underlying average use through October 2019 looking at both year-to-date and recent monthly trends in year-over-year changes was undertaken. This analysis included factoring in unusual circumstances from 2018 such as eruption losses, impacts of transfers from Schedule G to Schedule R and poor air quality in the summer as a result of the eruption as well as weather impacts in 2019. Forecasted 2019 and 2020 underlying average use was forecasted taking these factors into consideration. The forecasted number of customers multiplied by the forecasted average use per customer results in the forecasted residential underlying sales for 2019 and 2020.

The residential econometric equation is specified using adjusted residential class sales per month in megawatt-hours (MWh). The adjusted sales are the monthly residential MWh sales excluding the historical estimated impacts from each of the layers (DER, EE and EV) to result in underlying residential sales. This also includes impacts from significant transfers between rate classes, to reflect the accounts currently in the rate class.

The monthly econometric model describes residential electricity sales as a function of resident population, real personal income per capita, monthly visitor arrivals to the County, electricity price and weather variables (temperature humidity index and precipitation). In recognition of the climate differences between the Hilo and Kona sides of the island, the Hilo and Kona weather data is weighted based on historical sales by region and weighted weather variables are utilized in the model. For the forecast years, the weighting is a five-year historical average (2014-2018). These variables were all found to have relationships with residential sales. In addition, three sets of binary dummy variables were created – 1) monthly dummy variables representing individual months of the year, excluding February, used to account for seasonal variations, 2) a dummy variable to account for the significant amount of air conditioner installs starting in June 2015 and 3) a monthly dummy variable from October 2017 onwards in recognition of the policy change in the timing of transferring customers from a temporary service under commercial rate Schedule G to the residential rate Schedule R.

The specification and evaluation of the hypothetical relationships was performed using a proprietary software package, MetrixND from Itron, Inc. Many hypothetical relationships were considered, tested, and rejected until econometric equations for residential use per customer and commercial kWh sales were identified for use in Hawaiian Electric's sales projections.

Additional details on each variable, dependent and independent, used in deriving the monthly residential customer sales including the name of the variable and the source of the information are shown below. The values of the variables fed into the econometric modeling tool and the output from the model are contained in the Excel file "Appendix C Att 2 HL Underlying Inputs and Predicted.xlsx" which accompanies this report.

Table 94: Hawai'i Residential Econometric Sales Model Variables

Variable	Description	Source	Variable Labels
Dependent Variable:			

Residential Sales	Adjusted Schedule R Sales (MWh)	Hawaiian Electric's monthly reports filed with the Commission	Adjusted R Sales (MWh)
Economic Variables:			
Monthly Resident Population	Resident Population, Hawai'i County. Allocated to monthly values using straight-line approach with annual values assumed to be in July of each year	UHERO, October 2019	Monthly Resident Population
Real Annual Income Per Capita	Real Personal Income (1982-84 = 100) ÷ Resident Population (Hawai'i County)	UHERO, October 2019	Annual Income Per Capita ($82-84)
Monthly Visitor Arrivals	Visitor Arrivals (Hawai'i County), allocated to monthly values using historical patterns	UHERO, October 2019	Monthly Visitor Arrivals
Real Monthly Residential Electricity Price, one-month lag	Real residential dollars per kwh (1982-84=100) (Hawai'i Island)	see FAWG presentation on August 27, 2019	R Electricity Price ($82-84) (1-month lag)
Weather Variables:			
Monthly Weighted THI (temperature humidity index)	Composite weather variable to incorporate both temperature and humidity. Wtd THI = 17.5 + (0.55 * Wtd	Historical airport weather data (Hilo and Kona) from NOAA	Weighted THI

	Avg Temperature) + (0.20 * Wtd Dewpoint) Forecast uses 20-year average (1999-2018) of weighted average temperature and weighted dewpoint to calculate THI. Warming trend included in forecasted average temperatures.		
Monthly Weighted Precipitation	Rainfall in inches	Historical airport weather data (Hilo and Kona) from NOAA	Weighted Precipitation
Dummy Variables:			
Monthly dummy variables	Dummy variable for each individual month to account for seasonal variation, excluding February	Improves model statistics	Dmy Jan, Dmy Mar…Dmy Dec
Dummy variable starting in June 2015	Proxy for impacts of increased a/c installs	Improves model statistics	Dmy 615-on
Dummy variable for Schedule G to Schedule R transfers	October 2017-on, proxy for policy change for transfer of temporary Schedule G (construction	The historical sales data series was adjusted for known transfers, but the dummy variable reflects the change in the	Dmy GtoR TFR

	accounts) to Schedule R	transfer process and picks up additional effects	

The resulting monthly sales from the econometric model are then summed to annual sales forecast values. The year-over-year growth rates from the annual sales are then applied to the 2020 customer service forecast to extend the forecast out to the full 30-year range. Adjustments are made to include an extra day in leap years.

Small and Medium Commercial Sales (Rate Schedules G and J)

The small/medium commercial underlying sales forecast is developed using a combination of two forecast methods, the customer service method in the near term (2019-2020) and then applying year over year growth rates from an econometric model for the remainder of the forecast period. The customer service method allows for factors including knowledge of local economic conditions such as construction activity, the state of the visitor industry and a review of weather conditions as well as other island specific circumstances such as the volcano eruption on Hawai‘i Island in 2018 to be considered in the analysis. At the time the underlying forecast was developed, actual Schedule G/J data was available through October 2019, which was used to inform the forecasts for 2019 and 2020.

The customer service method for small/medium commercial sales examines historical and recent trends in customer count growth and underlying average use (kWh sales) per customer similar to the approach for residential sales. In forecasting 2019 and 2020, this analysis also needed to take into consideration the small commercial customer account losses that occurred in 2018 as a result of the volcano eruption and account transfers from Schedule G to Schedule R. Careful analysis of both customer counts underlying average use through October 2019 examining both year-to-date and recent monthly trends in year-over-year changes was undertaken. Forecasted 2019 and 2020 underlying average use was forecasted taking these factors into consideration. The forecasted number of customers multiplied by the forecasted average use per customer results in the forecasted small/medium commercial underlying sales for 2019 and 2020.

The Schedule G/J econometric equation is specified using adjusted small/medium commercial class sales per month in megawatt-hours (MWh). The adjusted sales are the monthly Schedule G/J MWh sales excluding the historical estimated impacts from each of the layers (DER, EE and EV) to result in underlying Schedule G/J sales. This also includes impacts from significant transfers between rate classes, to reflect the accounts currently in the rate class.

The monthly econometric model describes Schedule G/J electricity sales as a function of resident population, real personal income per capita, monthly visitor arrivals to the County and weather variables (cooling degree days and precipitation). In recognition of the climate differences between the Hilo and Kona sides of the island, the Hilo and Kona weather data is weighted based on historical sales by region and weighted weather variables are utilized in the model. For the forecast years, the weighting is a five-year historical average (2014-2018). These variables were all found to have relationships with Schedule G/J sales. In addition, three sets of binary dummy variables were created – 1) monthly dummy variables representing individual months of the year, excluding February, used to account for seasonal variations, 2) a monthly dummy variable from September 2001 to September 2002 as a proxy for 9/11 impacts and 3) a dummy variable in February of leap years to account for leap day.

Additional details on each variable, dependent and independent, used in deriving the monthly small/medium commercial sales including the name of the variable and the source of the information are shown below. The values of the variables fed into the econometric modeling tool and the output from the model are contained in the Excel file "Appendix C Att 2 HL Underlying Inputs and Forecast.xlsx " which accompanies this report.

Table 95: Hawai'i Small and Medium Commercial Customer Econometric Sales Model Variables

Variable	Description	Source	Variable Labels
Dependent Variable:			
Small/Medium Commercial Sales	Adjusted Schedule G/J Sales (MWh)	Hawaiian Electric's monthly reports filed with the Commission	Adjusted GJ Sales (MWh)
Economic Variables:			
Monthly Resident Population	Resident Population, Hawai'i County. Allocated to monthly values using straight-line approach with annual values assumed to be in July of each year	UHERO, October 2019	Monthly Resident Population
Real Annual Income Per Capita	Real Personal Income (1982-84 = 100) ÷ Resident Population (Hawai'i County)	UHERO, October 2019	Annual Income Per Capita ($82-84)
Monthly Visitor Arrivals	Visitor Arrivals (Hawai'i	UHERO, October 2019	Monthly Visitor Arrivals

	County), allocated to monthly values using historical patterns		
Weather Variables:			
Monthly Weighted CDD (cooling degree days)	Cooling degree days (CDD) are the difference between the daily mean temperature (F) and 65 degrees, which are summed over the month. Forecast uses 20-year average (1999-2018) of cooling degree days. Warming trend included in forecasted CDD.	Historical airport weather data (Hilo and Kona) from NOAA	Weighted CDD
Monthly Weighted Precipitation, one-month lag	Rainfall in inches lagged by one month	Historical airport weather data (Hilo and Kona) from NOAA	Weighted Precipitation
Dummy Variables:			
Monthly dummy variables	Dummy variable for each individual month to account for seasonal variation, excluding February	Improves model statistics	Dmy Jan, Dmy Mar…Dmy Dec
Dummy variable September 2001 through September 2002	Proxy for 9/11 impacts	Improves model statistics	Dmy 911
Dummy variable for leap day	Dummy variable for February in	Improves model statistics	Dmy leap day

	leap years (historical only)		

The resulting monthly sales from the econometric model are then summed to annual sales forecast values. The year-over-year growth rates from the annual sales are then applied to the 2020 customer service forecast to extend the forecast out to the full 30-year range. Adjustments are made to include new projects and an extra day in leap years.

Large Power Sales (Rate Schedule P)

The large power (Schedule P) sales forecast is developed using a combination of two forecast methods, the market analysis method in the near term (2019-2021) and an econometric model for the remainder of the forecast (2022-2050). The market analysis method is based on an analysis of the market conditions influencing different rate schedules with special emphasis on customer-by-customer accounting of loads in Large Power Schedule P services. Market analysis is the primary accepted near-term forecasting method for Schedule P services for Hawaiʻi Island, because the small number of large power customers (less than 100) allows for in-depth customer-by-customer analysis by the Company's Commercial Account Managers. The expected addition or loss of specific Schedule P customers is also accounted for.

The large power econometric equation is specified using adjusted annual large power class sales in megawatt-hours (MWh). The adjusted sales are the annual large power MWh sales excluding the historical estimated impacts from each of the layers (DER, EE and EV) to result in underlying large power sales. This also includes impacts from significant transfers between rate classes, to reflect the accounts currently in the rate class.

The annual econometric model describes large power electricity sales as a function of large power electricity sales lagged by one year, non-farm jobs and two sets of binary dummy variables – 1) a dummy variable in 2001 and 2002 to account for impacts to large power sales from 9/11 and the lingering economic impacts and 2) a dummy variable for years with a U.S. recession in at least six months of the year. These variables were all found to have relationships with large power sales.

Additional details on each variable, dependent and independent, used in deriving the annual large power sales including the name of the variable and the source of the information are shown below. The values of the variables fed into the econometric modeling tool and the output from the model are contained in the Excel file "Appendix C Att 2 HL Underlying Inputs and Forecast.xlsx " which accompanies this report.

Table 96: Hawaiʻi Large Power Customer Econometric Sales Model Variables

Variable	Description	Source	Variable Labels
Dependent Variable:			

Large Power Sales	Adjusted P Sales (MWh)	Hawaiian Electric's monthly reports filed with the Commission	Adjusted P Sales (MWh)
Lagged Dependent Variable:			
Lagged Dependent Variable	Adjusted Schedule P Sales with one-year lag		Lagged Dependant - Adjusted P Sales (MWh) (1-year lag)
Economic Variables:			
Annual Non-Farm Jobs	Non-Farm Jobs, Hawai'i County	UHERO, October 2019	Annual Non-Farm Jobs
Dummy Variables:			
Dummy variable 2001-2002	Proxy for 9/11 impacts	Improves model statistics	Dmy 911
Dummy variable for recessions	Dummy variable for years with a U.S. recession in at least 6 months	Improves model statistics	Dmy Recession

The resulting year-over-year growth rates from the annual sales econometric model are then applied to the 2020 customer service forecast to extend the forecast out to the full 30 year range . Adjustments are made to include large new projects and an extra day in leap years.

Street Lighting Sales (Schedule F)

The Schedule F forecast is developed using the customer service method for the duration of the forecast. Schedule F makes up a small portion (0.2-0.3%) of total Hawai'i Island sales and is less sensitive to economic drivers than the other rate schedules.

The trend in average annual kWh sales for new Schedule F customers in recent history (2016-2019) and the average number of new customers was analyzed, and those averages were applied to determine annual incremental kWh sales. The annual incremental kWh sales are then applied as year-over-year growth for the forecast horizon.

COVID-19 Update to the Underlying Sales for Hawai'i Island

Hawai'i Island stay-at-home orders went into effect on March 25, 2020 in conjunction with Governor Ige's initial statewide stay at home orders effective through April 30, 2020. Similar to Oah'u this order shutdown the visitor industry, schools and all but essential businesses.

A sales forecast update for the very near-term (2020 – 2021) was developed within the first month of the stay at home orders. This forecast used more judgmental techniques to update the very near-term forecast. More traditional econometric models using updated economic outlooks were developed for the years 2022-2025 assuming that more traditional economic relationships would resume even though the economy was expected to remain below pre-pandemic levels. UHERO's forecast update as of May 8, 2020 was utilized in developing the forecast update.

The 2020 update for Hawai'i Island was developed within less than two weeks of the shutdown. To develop the update, an analysis was done of daily system load after the shutdown compared to the same day in the prior year as well as in the weeks prior to the shutdown. This provided an estimate of total sales reductions on a percentage basis that were occurring under the stay-at-home orders and served as the lower bound of the monthly forecast. Based on the fast and furious changes in economic outlooks and information that could be gathered from various news sources, a corporate assumption of visitor arrivals beginning to resume in August became another bound of the forecast in that some recovery in electric sales would begin in August. The assumptions by customer class as describe below were assumed to be in place from April to July, with incremental recovery in August through October and an additional increment of recovery in November through December.

To assist in forecasting the different customer classes, hourly circuit data was obtained for selected circuits on Hawai'i Island that would be representative of heavily impacted sectors such as hotels, airports, retail and residential. The year-over-year changes as well as comparisons to before the shutdown from selected circuits helped to inform assumptions for residential and commercial sales reductions.

For residential sales, Hawai'i Island is unique compared to other islands in having a higher percentage of visitors reporting accommodations as rental homes or staying with family and friends. Also, there is a higher portion of service jobs and fewer traditional office jobs, where working from home may not be an option. The analysis of selected circuits serving predominantly residential customers across the island showed a mix of increased and decreased electricity usage. This supported the assumption that no changes would be made to the residential sales forecast in 2020.

For both large power and small/medium commercial sales, circuit analysis provided some guidance to potential sales losses in certain business sectors. In addition, estimated sales reductions by business sector were informed by judgmental analysis of sectors most likely to be impacted by the shutdown, the degree to which they would be impacted and recognizing that large power customers would be impacted differently than medium and small commercial customers in the same sector. These estimated reductions by sector were applied to the Schedule P customer by customer forecast to estimate the overall Schedule P sales reductions by month. Small commercial (Schedule G) and medium commercial (Schedule J) sales were analyzed separately with estimated percentage reductions applied to 2019 sales for the impacted sectors to determine estimated total year-over-year percentage reductions. These reductions were used as a guideline for the "all-in" forecast reductions for Schedule G and Schedule J. No forecast changes were made to Street Lighting (Schedule F). The total resulting reduction in the "all-in" forecast for April through July was compared to the average overall daily year-over-year system load reductions that were seen in the first few weeks after the shutdown to assess the reasonableness of the reductions. These reductions were then scaled back in three month increments over the remainder of the year. No changes were assumed to the layers, so underlying sales was derived by taking the revised "all-in" sales by

The 2021 forecast was developed by incorporating an analysis of the losses in underlying sales by rate class during the Great Recession (2009 vs 2007) while also looking at the corresponding forecasted economic impacts compared to the Great Recession economic impacts. This was used to inform the forecast reductions by rate class.

From 2022-2025, the economic forecast data from the May 8, 2020 UHERO forecast update was used to rerun the econometric models for all rate classes. The resulting growth rates in underlying sales from these updated forecasts were applied to the 2021 forecast update underlying sales in order to derive the 2022-2025 forecasts. For all rate schedules except Schedule P, the forecast rejoined the original IGP forecast in 2026. For Schedule P the forecast update included an assumption that several new projects would each be delayed by a year, so the return to the IGP forecast did not occur until 2028.

Maui Island Underlying Forecast

For Maui Island, the underlying forecast is developed by rate class - residential, small and medium commercial, large power and street lighting. Maui Island also used historical recorded sales in the models adjusted to remove sales impact of DER, EE and EoT.

Residential Sales

The residential underlying sales forecast is developed using the customer service method in 2019 and an econometric model for the remainder of the forecast period. The customer service method allows for factors including 2019 year to date sales, knowledge of local economic conditions such as construction activity, the state of the visitor industry and a review of short-term weather trends and conditions. The residential sales forecast for 2019 included actual Schedule R sales through September 2019 and a use per customer model for October through December.

The residential econometric equation specified using a residential class use per customer per month in kilowatt-hours. The monthly econometric model describes residential electricity use per customer as a function of real personal income per capita, electricity price, visitor arrivals and average billed days along with temperature humidity index interaction terms, dummy variables and moving average error terms. The model includes two interaction terms, one between real personal income per capita and temperature humidity index and the another between electricity price and temperature humidity index. There are also six monthly dummy variables included in the model used to account for seasonal variations in residential use per customer. In addition, there is a dummy variable that is used to calibrate 1995 with the other years in the historical data There are also three moving average error terms that are used to improve the fit of the model.

The specification and evaluation of the hypothetical relationships was performed using a proprietary software package, MetrixND from Itron, Inc. Many hypothetical relationships were considered, tested, and rejected until econometric equations for residential use per customer and commercial kWh sales were identified for use in Hawaiian Electric's sales projections.

Additional details on each variable, dependent and independent, used in deriving the monthly use per residential customer including the name of the variable and the source of the information are shown below. The values of the variables fed into the econometric modeling tool and the output from the model are contained in the Excel file "Appendix C Att 3 Maui Underlying Inputs and Predicted.xlsx" which accompanies this report.

Table 97: Maui Residential Customer Econometric Sales Model Variables

Variable	Description	Source	Variable Labels
Dependent Variable:			
Use per Customer	Adjusted Underlying Residential Sales ÷ Monthly Total Residential Customer Count	Hawaiian Electric's monthly reports filed with the Commission	Adjusted Billed R Use Per Customer kWh
Economic Variables:			
12-Month Moving Average Real Personal Income Per Capita	Real Personal Income (1982-84 = 100) ÷ Resident Population (Maui County)	UHERO, October 2019	Adjusted Billed R Use Per Customer kWh
6-Month Moving Average Real Residential Electricity Price	Real residential dollars per kwh (1982-	Internal Records, see FAWG presentation	Maui Island R Electricity Price 82-84$/kWh, 6 Month Moving Average

	84=100) (Maui Island)	on August 27, 2019	
Monthly Visitor Arrivals	Visitor Arrivals (Maui Island), allocated to monthly values using historical patterns	UHERO, October 2019	Maui County Visitor Arrivals
Average Billed Days	Monthly Average Number of Billed Days	Internal Records	Days
Weather Interaction Variables:*			
12-Month Moving Average Real Personal Income Per Capita × Monthly THI	See Variable Descriptions	UHERO and NOAA	Real Income Per Capita - THI Degree Days Interaction
6-Month Moving Average Real Residential Electricity Price × Monthly THI	See Variable Descriptions	Internal Records and NOAA	Maui Island R Electricity Price 82-84$/kWh - THI Degree Day Interaction
Dummy Variables:			
Monthly Dummy Variables	Dummy variable for six months found to seasonally differ from the base case, excluding Apr, Jul, Sep - Dec	Improves model statistics	Jan…Mar, May, June, Aug
Dummy Variable for All of 1995	Calibration factor for 1995	Improves model statistics	1995

To arrive at sales per month, the monthly use per residential customer derived in MetrixND was multiplied by the number of residential customers. The resulting residential GWh underlying sales forecast is residential kWh use per customer ÷ 10^6 x number of customers (Res_rcd_adj ÷ 10^6 x Res_Cust_rcd). An adjustment was made to include an extra day for leap year.

Growth rates from the econometric model are applied to the 2019 forecast to extend the forecast out to the full 30 year range.

Small and Medium Commercial Sales

The Maui Island the small and medium commercial underlying sales forecast is developed using the customer service method in 2019 and an econometric model for the remainder of the forecast period. Similarly, the small and medium commercial sales forecast for 2019 included actual Schedule G and Schedule J sales through September 2019 and a monthly customer service model for October through December.

The econometric model used for underlying small and medium commercial sales was modeled together since there are a significant number of rate transfers between the two commercial rate schedules on a regular basis (based on tariff requirements). The underlying small and medium commercial sales econometric equation was specified using monthly sales in kilowatt-hours. The monthly econometric model describes electricity sales as a function of real personal income, temperature humidity index, precipitation, Itron's Statistically Adjusted End-Use ("SAE") model's monthly energy intensity index, and average billed days along with several monthly dummy variables and moving average error terms. There are seven consecutive monthly dummy variables included in the model used to account for seasonal variations in monthly underlying sales. There are also six moving average error terms that are used to improve the fit of the model.

Additional details on each variable, dependent and independent, used in deriving the monthly small and medium commercial customer sales including the name of the variable and the source of the information are shown below. The values of the variables fed into the econometric modeling tool and the output from the model are also contained in the Excel file "Appendix C Att 3 Maui Underlying Inputs and Predicted.xlsx" which accompanies this report.

Table 98: Maui Small and Medium Commercial Customer Econometric Sales Model Variables

Variable	Description	Source	Variable Labels
Dependent Variable:			
Underlying Small and Medium Commercial Sales	Monthly Adjusted Underlying Small and Medium Commercial Sales	Hawaiian Electric's monthly reports filed with the Commission	Adjusted Billed GJ Sales MWh

Economic Variables:			
12-Month Moving Average Real Personal Income	Real Personal Income (1982-84 = 100)	UHERO, October 2019	Maui Island Personal Income Mil 82-84$, 12 Month Moving Average
Itron SAE Monthly Commercial Energy Intensity	Energy Intensity Index to Calibrate Historical Energy Usage	Itron, 2019 SAE Pacific Region	Monthly Commercial Energy Intensity
Average Billed Days	Monthly Average Number of Billed Days	Internal Records	Days
Weather Variables:*			
Monthly THI (temperature humidity index)	Composite weather variable to incorporate both temperature and humidity. Wtd THI = 17.5 + (0.55 * Wtd Avg Temperature) + (0.20 * Wtd Dewpoint) Forecast uses 20-year average (1999-2018) of weighted average temperature and weighted dewpoint to calculate THI. Warming trend included in forecasted	Historical Kahului airport weather data from NOAA	THI Degree Days

	average temperatures.		
Monthly Precipitation	Current month's rainfall in inches	Historical Kahului airport weather data from NOAA	Precipitation
1-Month Lagged Monthly Precipitation	Previous month's rainfall in inches	Historical Kahului airport weather data from NOAA	Precipitation Lag 1 Month
Interaction Variables:*			
Itron SAE Monthly Energy Intensity multiplied by Dummy variable for October 2017 forward	Energy Intensity Index to Calibrate Historical Energy Usage × Dummy for the months of October 2017 forward	Itron, 2019 SAE Pacific Region	Monthly Commercial Energy Intensity - October 2017 Forward Interaction
Dummy Variables:			
Monthly Dummy Variables	Dummy variable for seven consecutive months found to seasonally differ from the base case, excluding Jan-Apr, Dec	Improves model statistics	May - Nov

Growth rates from the econometric model are applied to the 2019 forecast to extend the forecast out to the full 30 year range.

Large Commercial Sales

The large commercial sales forecast is developed using market analysis techniques for the first three years and an econometric model for the forecast period after 2021. The market analysis is developed through ground up forecasting of each customer in the rate class. Commercial Account Managers ("CAMs") work with customers in the rate class to forecast customer usage; accounting for individual projects, renovations, expansions, and changes in customer equipment. Within the market analysis, CAMs forecast customers' underlying load, additional

DER equipment, and energy efficiencies independently. Engineering requests for service, news articles, and county permitting information is also used to help forecast potential additions of new large loads or loss of large loads. Rate transfers between large commercial rate schedules and small and medium rate schedules along with impending future transfers are also factored into the market analysis forecast.

In 2022, growth rates from the econometric model for underlying large commercial sales is used to forecast the remainder of the forecast period. This model is specified using monthly adjusted sales as a factor of real personal income, average billed days, and Itron's SAE commercial energy intensity index, temperature humidity index, and precipitation along with one structural break interaction term and several dummy variables and moving average error terms. The model includes one interaction terms, between a structural break dummy from October 2017 forward and Itron's SAE commercial energy intensity index. There are also six monthly dummy variables included in the model used to account for seasonal variations in large commercial sales. There are six moving average error terms that are used to improve the fit of the model.

Additional details on each variable, dependent and independent, used in deriving the monthly large commercial sales including the name of the variable and the source of the information are shown below. The values of the variables fed into the econometric modeling tool and the output from the model are also contained in the Excel file "Appendix C Att 3 Maui Underlying Inputs and Predicted.xlsx" which accompanies this report.

Table 99: Maui Large Power Customer Econometric Sales Model Variables

Variable	Description	Source	Variable Labels
Dependent Variable:			
Underlying Large Commercial Sales	Monthly Adjusted Underlying Large Commercial Sales	Hawaiian Electric's monthly reports filed with the Commission	Adjusted Billed P Sales MWh
Economic Variables:			
12-Month Moving Average Real Personal Income	12-Month Moving Average Real Personal Income (1982-84 = 100) (Maui County)	UHERO, October 2019	Maui Island Personal Income Mil 82-84$, 12 Month Moving Average

Itron SAE Monthly Commercial Energy Intensity	Energy Intensity Index to Calibrate Historical Energy Usage	Itron, 2019 SAE Pacific Region	Monthly Commercial Energy Intensity
Average Billed Days	Monthly Average Number of Billed Days	Hawaiian Electric's monthly reports filed with the Commission	Days
Weather Variables:*			
Maui Temperature-Humidity Cooling Degree Days	Annual sum of daily temperature-humidity index in excess of 85	Historical Kahului airport weather data from NOAA	THI Degree Days
Monthly Precipitation	Current month's rainfall in inches	Historical Kahului airport weather data from NOAA	Precipitation
Structural Break Interaction Variables:*			
Itron SAE Monthly Energy Intensity multiplied by Dummy variable for October 2017 forward	Energy Intensity Index to Calibrate Historical Energy Usage × Dummy for the months of October 2017 forward	Itron, 2019 SAE Pacific Region	Monthly Commercial Energy Intensity - October 2017 Forward Interaction
Dummy Variables:			
Monthly Dummy Variables	Dummy variable for six months found to seasonally differ from the base case, excluding Jan, Mar-May, Sep, Dec	Improves model statistics	Feb, Jun… Aug, Oct, Nov

Street Lighting Sales (Schedule F)

The Schedule F forecast is developed using the customer service method for 2019 to 2023 and a trending model for the remaining duration of the forecast period. Schedule F makes up a small portion (0.4-0.6%) of total Maui Island sales and is less sensitive to economic drivers than the other rate schedules. While historical schedule F sales have been relatively flat, the customer service portion of the forecast reflects a significant decline in sales, as the planned replacement of existing streetlight fixtures with LED fixtures are executed. The customer service approach takes into consideration the information and replacement schedule provided by the engineering department tasked with the conversion. Schedule F sales are expected to decrease to less than half of the historical level during the years of the customer service portion of the forecast. Thereafter, growth rates from the linear trend model that accounts for monthly seasonality are applied to forecast the remaining years of the forecast period.

COVID-19 Update to the Underlying Sales

Stay-at-home orders went into effect on March 25, 2020 in conjunction with Governor Ige's initial statewide stay at home orders effective through April 30, 2020. Similar to the other islands this order shutdown the visitor industry, schools and all but essential businesses.

For the very near term, 2020-2021, the commercial forecast was developed using several sources of information. Where available, customer data from before and after the shutdown orders went into effect, customer announcements regarding closures, and feedback from customers to their Hawaiian Electric account managers were analyzed to produce an estimate of the immediate impact (percent change). The impacts were used as a proxy for the commercial sectors by business types (e.g. hotel, office, retail, education, etc.). UHERO updates were used to estimate the length of time the lowest economic activity would continue and how long it would take to see recovery.

The residential sector was initially difficult to estimate because meter reads were halted due to safety concerns for customers and meter readers. Residential customers' bills were estimated from late March until mid-May 2020 using prior consumption, which was low relative to residential usage under the stay-at-home order. Real time circuit level energy data for a sample of residential areas was used to help derive a high-level impact factor to apply to total residential sales. As billing data became available, the initial forecast was refined and updated.

In the longer run (2022-2025), the economic outlook from UHERO was used to update econometric models. For 2022, results from the econometric models were averaged with the 2021 forecast in order to smooth the transition from the near-term forecast and the econometric models. Following 2025, the forecast transitions to the previously developed IGP forecast. Smoothing of the transition was performed by applying adjustment factors of 0.985-0.995 to the underlying sales from 2026-2028.

Lānaʻi Island Underlying Forecast

The Lānaʻi underlying forecast is developed by rate class - residential, small and medium commercial, large power and street lighting. Lānaʻi also used historical recorded sales in the models adjusted to remove sales impact of DER, EE and EoT.

Residential Sales

The residential underlying sales forecast is developed using the customer service method for 2019 to 2022 and an econometric model for the remainder of the forecast period. The customer service method allows for factors including 2019 year to date sales, knowledge of local economic conditions such as construction activity, the state of the visitor industry and a review of short-term weather trends and conditions. The residential sales forecast for 2019 included actual Schedule R sales through September 2019 and a use per customer model for October through December. This portion of the forecast was primarily derived from an analysis on forecasted customer count and average use per customer trends.

The residential econometric equation is specified using a residential class annual sales model in megawatt-hours. The annual econometric model describes adjusted underlying residential electricity sales as a function of customer counts, previous year's real electricity price, a dummy variable for 2007, and a 1-year lagged dependent variable.

> Additional details on each variable, dependent and independent, used in deriving the monthly use per residential customer including the name of the variable and the source of the information are shown below. The values of the variables fed into the econometric modeling tool and the output from the model are contained in the Excel file "Appendix C Att 4 Lanai Underlying Inputs and Predicted.xlsx" which accompanies this report.

Table 100: Lānaʻi Residential Customer Econometric Sales Model Variables

Variable	Description	Source	Variable Labels
Dependent Variable:			
Annual Adjusted Underlying Sales	Adjusted underlying residential sales	Internal Records	Adjusted Billed R Sales MWh
Economic Variables:			
Annual Residential	Number of customers in the	Hawaiian Electric's	Residential class customer count

Customer Counts	residential rate class by year	monthly reports filed with the Commission	
1-Year Lagged Real Residential Electricity Price	Average annual real residential dollars per kwh from previous year (1982-84=100) (Lānaʻi)	Internal Records, see FAWG presentation on August 27, 2019	Real residential electricity price lag one year
1-Year Lagged Dependent	Adjusted underlying residential sales from previous year (MWH)	Internal Records	Lagged Dependent
Dummy Variables:			
2007 Calibration Dummy Variable	Binary variable coded as 1 for year 2007 and 0 for all other years	Calibrates 2007 and improves model statistics	Dummy 2007

Growth rates from the econometric model are applied to the 2022 forecast to extend the forecast out to the full 30 year range.

Small and Medium Commercial Sales

The Lānaʻi small and medium commercial underlying sales forecast is developed using the customer service method in 2019 through 2021 and a trending model for the remainder of the forecast period. Similarly, the small and medium commercial sales forecast for 2019 included actual Schedule G and Schedule J sales through September 2019 and a monthly customer service model for October through December. The opening of The Lodge at Koele has stimulated and supported growth in small and medium commercial sales in 2019 and expected to continue for a portion of 2020. The customer service model assumed a leveling-off in growth for 202l sales to the 5-Year (2014-2018) historical average growth rate for the small and medium commercial sectors.

After 2021, the trending model used growth rates from a damped exponential smoothing function to forecast the small and medium commercial sales to 2050.

Large Commercial Sales

The large commercial sales forecast is developed using market analysis techniques for the first three years and the customer service method for the forecast period after 2021. The market analysis is developed through ground up forecasting of each customer in the rate class. CAMs develop sales forecast with customers in the rate class to forecast underlying usage and sales to account for individual projects, renovations, expansions, and changes in customer equipment. Like the market analysis for Maui Island, CAMs forecast Lānaʻi customers' underlying load, additional DER equipment, and energy efficiencies independent and alongside the underlying sales. Engineering request, news articles, and county permitting information is also used to help forecast potential additions or loss of large loads. Rate transfers between large commercial rate schedules and small and medium rate schedules along with impending future transfers are also factored into the market analysis forecast. With the launch of Sensei Lānaʻi, A Four Seasons Resort (formerly The Lodge at Koele), sales for the large commercial sector on Lānaʻi are expected to increase substantially in the near term. This expected growth is captured in the market analysis portion of the forecast.

For 2022 forward, the customer service method is used to forecast underlying sales in the large commercial sector for Lānaʻi. In 2022 with Sensei Lānaʻi fully operational, growth in the sector is expected to level off. A growth rate of 0.2% annual increase in underlying sales was applied to carry the market analysis forecast out to 2050.

Street Lighting Sales (Schedule F)

The Schedule F forecast is developed using the customer service method for 2019 to 2023 and a trending model for the remaining duration of the forecast period. Schedule F makes up a small portion (0.4-0.6%) of total Lānaʻi. The customer service portion of the forecast reflects a significant decline in sales, as the planned replacement of existing streetlight fixtures with LED fixtures are executed. The customer service approach takes into consideration the information and replacement schedule provided by the engineering department tasked with the conversion. Schedule F sales are expected to decrease to less than half of the historical level (114-137 MWh annually) during the years of the customer service portion of the forecast. Thereafter, sales are expected to remain flat at 42 MWh annually for the remained of the forecast.

Molokaʻi Island Underlying Forecast

The Molokaʻi underlying forecast is developed by rate class - residential, small and medium commercial, large power and street lighting. Molokaʻi also used historical recorded sales in the models adjusted to remove sales impact of DER, EE and EoT.

Residential Sales

The residential underlying sales forecast is developed using the customer service method for 2019 to 2023 and an econometric model for the remainder of the forecast period. The customer service method allows for factors including 2019 year to date sales, knowledge of local economic conditions such as construction activity, the state of the visitor industry and a review of short-term weather trends and conditions. The residential sales forecast for 2019 included actual Schedule R sales through September 2019 and a use per customer derived forecast for October through December. The customer service portion of the forecast was primarily derived from an analysis on forecasted customer count and use per customer trends.

The residential econometric equation is specified using a residential class annual sales model in megawatt-hours. The annual econometric model describes adjusted underlying residential electricity sales as a function of real personal income, real electricity price, the annual sum of cooling degree days from Maui's temperature-humidity index, and a 1-year lagged dependent variable.

Additional details on each variable, dependent and independent, used in deriving the monthly use per residential customer including the name of the variable and the source of the information are shown below. The values of the variables fed into the econometric modeling tool and the output from the model are contained in the Excel file "Appendix C Att 5 Molokai Underlying Inputs and Predicted.xlsx" which accompanies this report.

Table 101: Moloka'i Residential Customer Econometric Sales Model Variables

Variable	Description	Source	Variable Labels
Dependent Variable:			
Annual Adjusted Underlying Sales	Adjusted underlying residential sales	Hawaiian Electric's monthly reports filed with the Commission	Adjusted Billed R Sales MWh
Economic Variables:			
Real Personal Income	Real Personal Income (1982-84 = 100)	UHERO, October 2019	Molokai Personal Income Mil 82-84$
Real Residential Electricity Price	Average annual real residential dollars per kwh from previous year (1982-84=100) (Moloka'i)	Internal Records, see FAWG presentation on August 27, 2019	Molokai R Electricity Price 82-84cents/kWh
1-Year Lagged Dependent	Adjusted underlying residential sales from previous year (MWH)	Internal Records	Lagged Dependent

Weather Variables:*			
Maui Temperature-Humidity Cooling Degree Days	Annual sum of daily temperature-humidity index in excess of 85	Historical Kahului airport weather data from NOAA	THI Degree Days

Growth rates from the econometric model are applied to the 2020 forecast to extend the forecast out to the full 30 year range.

Small and Medium Commercial Sales

The Moloka'i small and medium commercial underlying sales forecast is developed using the customer service method for the entire forecast period. Actual sales through September 2019 were used, with a monthly forecast for October through December of 2019 and an annual growth model thereafter. Without the advent of large changes in load for the small and medium commercial sector in the foreseeable future, a growth rate of 0.2% was assumed for 2020 to 2050.

Large Commercial Sales

The large commercial sales forecast is developed using market analysis techniques for the first three years and a trending model for the forecast period after 2021. The market analysis is developed through ground up forecasting of each customer in the rate class. CAMs develop sales forecast with customers in the rate class to forecast underlying usage and sales to account for individual projects, renovations, expansions, and changes in customer equipment. CAMs forecast Moloka'i customers' underlying load, additional DER equipment, and energy efficiencies independent and alongside the underlying sales. Engineering request, news articles, and county permitting information is also used to help forecast potential additions or loss of large loads. Rate transfers between large commercial rate schedules and small and medium rate schedules along with impending future transfers are also factored into the market analysis forecast.

For 2022 forward, the trend analysis is used to forecast underlying sales in the large commercial sector for Moloka'i. The 5-year average growth rate of 0.18% annual increase in underlying sale was applied to carry the market analysis forecast out to 2050.

Street Lighting Sales (Schedule F)

The Schedule F forecast is developed using the customer service method for 2019 to 2023 and a trending model for the remaining duration of the forecast period. Schedule F makes up a small portion (1.3-2.0%) of total Moloka'i. The customer service portion of the forecast reflects a significant decline in sales, as the planned replacement of existing streetlight fixtures with LED fixtures are executed. The customer service approach takes into consideration the information and replacement schedule provided by the engineering department tasked with the conversion. Schedule F sales are expected to decrease to less than half of the historical level (450-560 MWh annually) during the years of the customer service portion of the forecast. Thereafter, sales are expected to remain flat at 240 MWh annually for the remained of the forecast.

COVID-19 Update to the Underlying Sales for Lāna'i and Moloka'i

The unique character of each island has to be considered when choosing methods for forecasting the impact of a major disruption such as the Covid -19 pandemic._The impact of Covid to 2020 sales has varied significantly among the islands. The most likely explanation is the relative dependency of each island's economy on tourism. Moloka'i, being the least tourism dependent, exhibited little to no impact in total kWh sales from the Covid shutdowns. Maui and Lāna'i, being the most dependent on tourism, experienced the largest impacts to total kWh sales.

On Lāna'i, the Pulama Lāna'i resorts are the most significant driver of the island's electricity consumption. The forecast for Lāna'i assumes that the resorts would resume operation as soon as travel to the island was allowed without post-travel quarantine. Therefore, Covid-19 impacts to the Lāna'i underlying forecast were limited to 2020 with no change to the forecast thereafter.

On Moloka'i, the forecast for 2020 was updated to include an increase in residential kWh sales and reduction to commercial sales due to stay-at-home orders. The Covid-19 impacts in the forecast for Moloka'i were limited to 2020 with no change to the forecast thereafter.

Appendix D:Sales Forecasts (2020 – 2050)

Table 102: Oʻahu Sales Forecast

Year	Underlying	Distributed Energy Resources (PV and BESS)	Energy Efficiency	Electric Vehicles	Customer Level Sales Forecast
GWH	A	B	C	D	E =A + B + C + D
2020	8,106	(937)	(1,396)	30	5,804
2021	8,690	(986)	(1,509)	38	6,233
2022	8,936	(1,043)	(1,613)	49	6,329
2023	9,094	(1,086)	(1,703)	61	6,366
2024	9,276	(1,115)	(1,793)	75	6,442
2025	9,456	(1,141)	(1,887)	92	6,521
2026	9,638	(1,170)	(1,980)	111	6,599
2027	9,745	(1,200)	(2,067)	134	6,612
2028	9,873	(1,234)	(2,153)	159	6,645
2029	9,988	(1,263)	(2,232)	187	6,681
2030	10,133	(1,293)	(2,307)	221	6,753
2031	10,237	(1,324)	(2,383)	257	6,788
2032	10,345	(1,356)	(2,462)	297	6,824
2033	10,447	(1,380)	(2,530)	342	6,879
2034	10,533	(1,407)	(2,595)	392	6,923
2035	10,617	(1,433)	(2,654)	447	6,977
2036	10,731	(1,461)	(2,713)	501	7,058
2037	10,792	(1,481)	(2,760)	561	7,112
2038	10,875	(1,504)	(2,809)	624	7,186
2039	10,972	(1,526)	(2,861)	700	7,286
2040	11,110	(1,551)	(2,917)	789	7,432
2041	11,152	(1,568)	(2,963)	892	7,512

Year	Underlying	Distributed Energy Resources (PV and BESS)	Energy Efficiency	Electric Vehicles	Customer Level Sales Forecast
GWH	A	B	C	D	E =A + B + C + D
2042	11,232	(1,588)	(3,012)	1,006	7,637
2043	11,322	(1,608)	(3,058)	1,120	7,776
2044	11,443	(1,630)	(3,105)	1,238	7,946
2045	11,499	(1,643)	(3,142)	1,366	8,079
2046	11,582	(1,659)	(3,183)	1,498	8,237
2047	11,662	(1,674)	(3,223)	1,631	8,396
2048	11,773	(1,692)	(3,266)	1,760	8,574
2049	11,823	(1,701)	(3,297)	1,872	8,696
2050	11,905	(1,714)	(3,332)	1,964	8,822

Table 103: Hawai'i Island Sales Forecast

Year	Underlying	Distributed Energy Resources (PV and BESS)	Energy Efficiency	Electric Vehicles	Customer Level Sales Forecast
GWH	A	B	C	D	E =A + B + C + D
2020	1,345	(179)	(185)	2	983
2021	1,373	(195)	(204)	3	978
2022	1,410	(205)	(221)	4	988
2023	1,433	(211)	(237)	5	989
2024	1,456	(218)	(253)	6	992
2025	1,471	(223)	(268)	10	990
2026	1,483	(229)	(284)	15	985
2027	1,496	(236)	(300)	19	980
2028	1,516	(242)	(316)	25	983
2029	1,524	(247)	(331)	32	978
2030	1,535	(252)	(345)	39	977
2031	1,547	(257)	(359)	47	978
2032	1,561	(263)	(374)	56	980
2033	1,566	(267)	(387)	66	978
2034	1,575	(272)	(400)	77	981
2035	1,584	(278)	(411)	93	989
2036	1,598	(284)	(422)	107	999
2037	1,603	(289)	(431)	121	1,005
2038	1,612	(295)	(440)	137	1,013
2039	1,621	(301)	(450)	154	1,024
2040	1,634	(307)	(461)	172	1,038
2041	1,637	(312)	(469)	192	1,048
2042	1,646	(318)	(478)	214	1,063
2043	1,654	(325)	(486)	238	1,081

Year	Underlying	Distributed Energy Resources (PV and BESS)	Energy Efficiency	Electric Vehicles	Customer Level Sales Forecast
GWH	A	B	C	D	E =A + B + C + D
2044	1,666	(332)	(495)	262	1,102
2045	1,670	(337)	(501)	288	1,120
2046	1,678	(342)	(509)	315	1,142
2047	1,685	(348)	(516)	345	1,166
2048	1,698	(354)	(524)	374	1,194
2049	1,700	(359)	(529)	404	1,216
2050	1,708	(364)	(535)	435	1,244

Table 104: Maui Sales Forecast

Year	Underlying	Distributed Energy Resources (PV and BESS)	Energy Efficiency	Electric Vehicles	Customer Level Sales Forecast
GWH	A	B	C	D	E =A + B + C + D
2020	1,343	(202)	(219)	3	925
2021	1,409	(221)	(238)	4	953
2022	1,415	(231)	(255)	6	934
2023	1,425	(237)	(270)	8	926
2024	1,453	(245)	(285)	10	933
2025	1,474	(251)	(300)	14	937
2026	1,499	(258)	(315)	20	946
2027	1,521	(265)	(329)	28	955
2028	1,542	(272)	(344)	37	963
2029	1,556	(278)	(358)	46	966
2030	1,572	(285)	(371)	56	973
2031	1,586	(291)	(384)	70	981
2032	1,606	(299)	(397)	87	997
2033	1,620	(304)	(409)	107	1,013
2034	1,635	(309)	(421)	127	1,031
2035	1,649	(315)	(431)	147	1,051
2036	1,668	(321)	(440)	168	1,075
2037	1,678	(326)	(448)	189	1,093
2038	1,693	(331)	(456)	211	1,116
2039	1,707	(336)	(464)	233	1,140
2040	1,726	(341)	(473)	255	1,166
2041	1,733	(345)	(480)	277	1,185
2042	1,746	(349)	(486)	299	1,209
2043	1,760	(354)	(493)	319	1,233
2044	1,778	(359)	(500)	338	1,258
2045	1,787	(362)	(505)	357	1,277

Year	Underlying	Distributed Energy Resources (PV and BESS)	Energy Efficiency	Electric Vehicles	Customer Level Sales Forecast
GWH	A	B	C	D	E =A + B + C + D
2046	1,800	(365)	(510)	375	1,299
2047	1,813	(369)	(516)	392	1,321
2048	1,832	(373)	(521)	410	1,346
2049	1,839	(376)	(525)	426	1,365
2050	1,852	(379)	(529)	443	1,388

Table 105: Moloka‘i Sales Forecast

Year	Underlying	Distributed Energy Resources (PV and BESS)	Energy Efficiency	Electric Vehicles	Customer Level Sales Forecast
GWH	A	B	C	D	E =A + B + C + D
2020	35.6	(4.6)	(2.7)	0.1	28.4
2021	36.2	(5.1)	(2.8)	0.1	28.4
2022	36.0	(5.3)	(2.9)	0.1	27.9
2023	36.0	(5.4)	(2.9)	0.1	27.7
2024	36.1	(5.5)	(3.0)	0.1	27.6
2025	36.0	(5.6)	(3.1)	0.1	27.4
2026	36.1	(5.7)	(3.2)	0.1	27.3
2027	36.2	(5.7)	(3.3)	0.2	27.3
2028	36.3	(5.8)	(3.4)	0.2	27.3
2029	36.3	(5.9)	(3.5)	0.2	27.1
2030	36.4	(6.1)	(3.6)	0.3	27.0
2031	36.5	(6.2)	(3.7)	0.3	27.0
2032	36.7	(6.2)	(3.7)	0.3	27.0
2033	36.8	(6.3)	(3.8)	0.4	27.1
2034	37.0	(6.4)	(3.9)	0.5	27.1
2035	37.1	(6.6)	(4.0)	0.5	27.1
2036	37.3	(6.6)	(4.0)	0.6	27.3
2037	37.4	(6.7)	(4.1)	0.7	27.4
2038	37.5	(6.7)	(4.1)	0.8	27.5
2039	37.6	(6.9)	(4.2)	0.9	27.5
2040	37.8	(7.0)	(4.2)	1.1	27.7
2041	37.8	(7.0)	(4.3)	1.3	27.8
2042	37.9	(7.1)	(4.3)	1.4	27.9
2043	38.1	(7.2)	(4.4)	1.7	28.2
2044	38.3	(7.3)	(4.4)	1.9	28.4
2045	38.3	(7.4)	(4.5)	2.1	28.5

Year	Underlying	Distributed Energy Resources (PV and BESS)	Energy Efficiency	Electric Vehicles	Customer Level Sales Forecast
GWH	A	B	C	D	E =A + B + C + D
2046	38.4	(7.4)	(4.5)	2.3	28.8
2047	38.5	(7.5)	(4.6)	2.6	29.0
2048	38.8	(7.6)	(4.6)	2.8	29.4
2049	38.8	(7.6)	(4.7)	3.0	29.5
2050	38.9	(7.7)	(4.7)	3.2	29.7

Table 106: Lānaʻi Sales Forecast

Year	Underlying	Distributed Energy Resources (PV and BESS)	Energy Efficiency	Electric Vehicles	Customer Level Sales Forecast
GWH	A	B	C	D	E =A + B + C + D
2020	39.2	(1.4)	(1.1)	0.1	36.8
2021	40.0	(1.4)	(1.2)	0.1	37.5
2022	40.1	(1.5)	(1.3)	0.1	37.4
2023	40.2	(1.5)	(1.4)	0.1	37.4
2024	40.6	(1.5)	(1.5)	0.1	37.7
2025	40.8	(1.6)	(1.6)	0.1	37.7
2026	41.1	(1.7)	(1.7)	0.1	37.8
2027	41.4	(1.7)	(1.8)	0.1	38.1
2028	41.9	(1.7)	(1.9)	0.1	38.4
2029	42.0	(1.8)	(1.9)	0.1	38.5
2030	42.2	(1.9)	(2.0)	0.2	38.5
2031	42.4	(1.9)	(2.1)	0.2	38.5
2032	42.7	(2.0)	(2.2)	0.2	38.7
2033	42.8	(2.0)	(2.3)	0.3	38.7
2034	43.0	(2.1)	(2.4)	0.3	38.8
2035	43.1	(2.1)	(2.4)	0.4	38.9
2036	43.4	(2.2)	(2.5)	0.4	39.1
2037	43.5	(2.2)	(2.6)	0.5	39.2
2038	43.6	(2.3)	(2.6)	0.5	39.3
2039	43.8	(2.3)	(2.7)	0.6	39.5
2040	44.1	(2.4)	(2.8)	0.7	39.7
2041	44.1	(2.5)	(2.8)	0.8	39.6
2042	44.3	(2.5)	(2.9)	0.9	39.8
2043	44.4	(2.5)	(2.9)	1.0	40.0
2044	44.7	(2.5)	(3.0)	1.1	40.3
2045	44.7	(2.6)	(3.0)	1.3	40.4

Year	Underlying	Distributed Energy Resources (PV and BESS)	Energy Efficiency	Electric Vehicles	Customer Level Sales Forecast
GWH	A	B	C	D	E =A + B + C + D
2046	44.9	(2.7)	(3.1)	1.4	40.5
2047	45.1	(2.7)	(3.2)	1.6	40.7
2048	45.3	(2.8)	(3.2)	1.7	41.1
2049	45.4	(2.8)	(3.3)	1.8	41.2
2050	45.6	(2.9)	(3.3)	1.9	41.3

Appendix E: Peak Forecasts (2020 – 2050)

Table 107: O‘ahu Peak Forecast (MW)

Year	Underlying	Distributed Energy Resources (PV and BESS)	Energy Efficiency	Electric Vehicles	Peak Forecast
MW	A	B	C	D	E =A + B + C + D
2020	1330	(3)	(258)	15	1084
2021	1400	(8)	(283)	18	1127
2022	1491	(10)	(298)	20	1203
2023	1511	(12)	(311)	23	1212
2024	1547	(15)	(335)	27	1224
2025	1574	(14)	(340)	31	1251
2026	1564	(16)	(352)	36	1232
2027	1584	(20)	(367)	43	1240
2028	1593	(23)	(379)	50	1240
2029	1612	(30)	(389)	58	1252
2030	1637	(30)	(403)	68	1272
2031	1662	(29)	(415)	77	1295
2032	1678	(35)	(425)	90	1308
2033	1698	(38)	(435)	104	1329
2034	1707	(45)	(441)	119	1340
2035	1713	(44)	(449)	134	1353
2036	1733	(42)	(456)	152	1387
2037	1757	(42)	(466)	171	1421
2038	1775	(52)	(477)	193	1439
2039	1787	(54)	(484)	217	1466
2040	1791	(58)	(488)	245	1489
2041	1795	(59)	(496)	279	1520

Year	Underlying	Distributed Energy Resources (PV and BESS)	Energy Efficiency	Electric Vehicles	Peak Forecast
MW	A	B	C	D	E =A + B + C + D
2042	1813	(57)	(502)	316	1571
2043	1847	(55)	(509)	352	1634
2044	1862	(66)	(510)	392	1678
2045	1868	(68)	(528)	432	1703
2046	1867	(67)	(532)	479	1747
2047	1878	(72)	(539)	527	1793
2048	1919	(64)	(546)	566	1876
2049	1938	(78)	(551)	596	1906
2050	1947	(78)	(556)	621	1935

Table 108: Hawai‘i Island Peak Forecast (MW)

Year	Underlying	Distributed Energy Resources (PV and BESS)	Energy Efficiency	Electric Vehicles	Peak Forecast
MW	A	B	C	D	E =A + B + C + D
2020	221.7	(0.8)	(29.5)	0.6	191.9
2021	218.8	(2.8)	(36.8)	0.9	180.1
2022	219.8	(4.2)	(35.7)	1.1	181.1
2023	228.1	(4.0)	(43.0)	1.7	182.7
2024	229.7	(4.7)	(45.9)	2.2	181.3
2025	228.2	(4.9)	(44.7)	3.0	181.6
2026	229.4	(5.6)	(45.8)	4.1	182.2
2027	233.4	(6.0)	(50.2)	6.3	183.6
2028	234.5	(7.4)	(50.7)	7.4	183.8
2029	235.4	(8.0)	(53.7)	9.8	183.5
2030	236.8	(8.5)	(55.5)	11.9	184.7
2031	239.8	(9.4)	(59.8)	14.6	185.2
2032	239.3	(8.2)	(60.7)	16.7	187.2
2033	243.8	(10.0)	(62.3)	20.2	191.6
2034	233.9	(8.8)	(62.6)	29.0	191.4
2035	244.7	(11.2)	(67.3)	27.3	193.5
2036	247.4	(15.2)	(67.1)	31.0	196.2
2037	240.2	(3.4)	(72.8)	43.4	207.5
2038	240.1	(3.4)	(74.0)	49.1	211.8
2039	240.7	(3.4)	(76.1)	55.0	216.2
2040	241.2	(12.4)	(76.3)	63.0	215.5
2041	237.3	(6.3)	(78.6)	67.5	220.0
2042	240.4	(14.3)	(74.1)	73.9	225.9
2043	247.7	(3.5)	(82.2)	85.7	247.7
2044	247.2	(15.5)	(77.2)	96.5	251.0
2045	247.2	(3.5)	(85.3)	103.7	262.1

Year	Underlying	Distributed Energy Resources (PV and BESS)	Energy Efficiency	Electric Vehicles	Peak Forecast
MW	A	B	C	D	E =A + B + C + D
2046	242.9	(3.6)	(85.7)	113.7	267.4
2047	249.3	(19.9)	(87.2)	125.9	268.2
2048	253.4	(3.6)	(89.0)	125.8	286.5
2049	253.0	(3.6)	(90.7)	145.6	304.3
2050	253.3	(3.7)	(90.5)	156.7	315.8

Table 109: Maui Peak Forecast (MW)

Year	Underlying	Distributed Energy Resources (PV and BESS)	Energy Efficiency	Electric Vehicles	Peak Forecast
MW	A	B	C	D	E =A + B + C + D
2020	229.9	(1.8)	(34.2)	0.2	194.1
2021	237.4	(2.6)	(38.6)	0.4	196.6
2022	237.3	(3.6)	(41.7)	0.9	192.9
2023	238.2	(3.8)	(42.6)	1.7	193.5
2024	242.7	(5.2)	(44.9)	2.5	195.1
2025	247.0	(5.4)	(47.6)	3.8	197.8
2026	251.2	(6.3)	(52.4)	5.7	198.2
2027	254.2	(6.6)	(52.9)	8.6	203.3
2028	256.1	(6.9)	(54.8)	11.7	206.1
2029	259.7	(7.5)	(57.0)	14.8	210.0
2030	261.5	(8.8)	(58.5)	18.4	212.6
2031	264.9	(9.5)	(61.3)	23.2	217.3
2032	267.3	(10.0)	(64.1)	28.5	221.7
2033	270.0	(12.1)	(65.2)	35.6	228.3
2034	272.0	(10.7)	(67.1)	42.7	236.9
2035	275.2	(11.3)	(68.8)	49.7	244.8
2036	277.7	(12.6)	(69.4)	57.1	252.8
2037	280.7	(14.5)	(76.4)	63.4	253.2
2038	282.3	(13.6)	(73.7)	71.4	266.4
2039	284.2	(16.2)	(74.0)	78.5	272.5
2040	287.0	(14.1)	(74.5)	85.8	284.2
2041	287.8	(15.6)	(75.8)	93.7	290.1
2042	291.3	(16.2)	(78.0)	101.1	298.2
2043	285.1	(20.1)	(77.8)	114.4	301.6
2044	286.9	(16.4)	(78.7)	120.8	312.6
2045	297.0	(16.8)	(80.9)	121.1	320.4

Year	Underlying	Distributed Energy Resources (PV and BESS)	Energy Efficiency	Electric Vehicles	Peak Forecast
MW	A	B	C	D	E =A + B + C + D
2046	300.1	(17.3)	(82.3)	127.4	327.9
2047	302.3	(20.8)	(83.3)	134.2	332.4
2048	300.6	(19.5)	(83.8)	139.5	336.8
2049	306.6	(19.6)	(84.4)	143.7	346.3
2050	304.1	(22.6)	(87.4)	160.2	354.3

Table 110: Moloka‘i Peak Forecast (MW)

Year	Underlying	Distributed Energy Resources (PV and BESS)	Energy Efficiency	Electric Vehicles	Peak Forecast
MW	A	B	C	D	E =A + B + C + D
2020	6.0	–	(0.1)	0.1	6.0
2021	6.0	–	(0.1)	–	5.9
2022	5.9	–	(0.1)	0.1	5.9
2023	5.9	–	(0.1)	–	5.8
2024	5.9	–	(0.1)	–	5.8
2025	6.0	(0.1)	(0.2)	0.1	5.8
2026	6.0	(0.1)	(0.2)	0.1	5.8
2027	6.0	(0.1)	(0.2)	–	5.7
2028	6.0	(0.1)	(0.2)	–	5.7
2029	6.0	(0.1)	(0.2)	–	5.7
2030	6.0	(0.1)	(0.3)	0.1	5.7
2031	6.0	(0.1)	(0.3)	0.1	5.7
2032	6.1	(0.2)	(0.3)	0.1	5.7
2033	6.1	(0.2)	(0.3)	0.1	5.7
2034	6.1	(0.2)	(0.3)	0.1	5.7
2035	6.1	(0.2)	(0.3)	0.2	5.8
2036	6.2	(0.3)	(0.3)	0.2	5.8
2037	6.2	(0.3)	(0.3)	0.2	5.8
2038	6.2	(0.3)	(0.3)	0.3	5.9
2039	6.2	(0.3)	(0.3)	0.3	5.9
2040	6.3	(0.4)	(0.3)	0.3	5.9
2041	6.3	(0.4)	(0.3)	0.3	5.9
2042	6.3	(0.4)	(0.3)	0.4	6.0
2043	6.3	(0.4)	(0.3)	0.4	6.0
2044	6.3	(0.4)	(0.3)	0.5	6.1
2045	6.4	(0.4)	(0.4)	0.5	6.1

Year	Underlying	Distributed Energy Resources (PV and BESS)	Energy Efficiency	Electric Vehicles	Peak Forecast
MW	A	B	C	D	E =A + B + C + D
2046	6.4	(0.4)	(0.4)	0.6	6.2
2047	6.4	(0.4)	(0.4)	0.7	6.3
2048	6.4	(0.4)	(0.4)	0.7	6.3
2049	6.4	(0.4)	(0.4)	0.8	6.4
2050	6.5	(0.5)	(0.4)	0.9	6.5

Table 111: Lānaʻi Peak Forecast (MW)

Year	Underlying	Distributed Energy Resources (PV and BESS)	Energy Efficiency	Electric Vehicles	Peak Forecast
MW	A	B	C	D	E =A + B + C + D
2020	6.5	–	–	–	6.5
2021	6.6	–	–	–	6.6
2022	6.6	–	–	–	6.6
2023	6.8	–	(0.1)	–	6.7
2024	6.8	–	(0.1)	–	6.7
2025	6.8	–	(0.1)	–	6.7
2026	6.8	–	(0.1)	–	6.7
2027	6.9	–	(0.1)	–	6.8
2028	7.0	–	(0.2)	–	6.8
2029	7.1	–	(0.2)	–	6.9
2030	7.1	–	(0.2)	–	6.9
2031	7.1	–	(0.2)	–	6.9
2032	7.1	–	(0.2)	–	6.9
2033	7.1	(0.1)	(0.2)	0.1	6.9
2034	7.2	(0.1)	(0.2)	0.1	7.0
2035	7.3	(0.1)	(0.2)	0.1	7.1
2036	7.3	(0.1)	(0.2)	0.1	7.1
2037	7.3	(0.1)	(0.2)	0.1	7.1
2038	7.3	(0.1)	(0.3)	0.2	7.1
2039	7.4	(0.1)	(0.3)	0.2	7.2
2040	7.5	(0.1)	(0.3)	0.2	7.3
2041	7.5	(0.1)	(0.3)	0.2	7.3
2042	7.5	(0.1)	(0.3)	0.2	7.3
2043	7.5	(0.1)	(0.3)	0.3	7.4
2044	7.5	(0.1)	(0.3)	0.3	7.4
2045	7.6	(0.1)	(0.4)	0.4	7.5

Year	Underlying	Distributed Energy Resources (PV and BESS)	Energy Efficiency	Electric Vehicles	Peak Forecast
MW	A	B	C	D	E =A + B + C + D
2046	7.7	(0.1)	(0.4)	0.4	7.6
2047	7.8	(0.1)	(0.4)	0.4	7.7
2048	7.7	(0.1)	(0.4)	0.5	7.7
2049	7.6	(0.1)	(0.3)	0.5	7.7
2050	7.8	(0.1)	(0.4)	0.5	7.8