E3 December 2016 PSIP Update

Summary of findings from RESOLVE modeling of Oahu, Maui, and Hawai'i Islands

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Energy+Environmental Economics

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1: INTRODUCTION

Q1. WHAT WAS ENERGY AND ENVIRONMENTAL ECONOMICS INC (E3) SCOPE OF WORK?

A1. The Companies initially hired E3 in June of 2016 to use its RESOLVE model to look at the potential net benefits provided by interconnecting the island systems via undersea transmission cables. This scope was expanded in August of 2016 to include a range of sensitivities provided by the Companies and stakeholders. E3 used this same model in the previous PSIP filing in April of 2016 and have described the model, results and input assumptions in two different workshops.

E3's deliverables for this round of the PSIP include least cost resource plans for Oahu, Maui and Hawaii as independent, non-interconnected island systems, as well as for grid-interconnected systems, using reference assumptions developed through several weeks of consultations with the Company team. The model results serve a specific purpose in the PSIP – to produce an initial set of least cost recommendations for the 5-year plans that will be both validated and refined by the Companies using both practical interconnection and transmission limitations, feasible block sizes for generation additions and more detailed operational models that look more closely at reliability.

A second set of deliverables includes sensitivity analysis around the reference cases to investigate the impact of different assumptions about how the future will unfold on the decisions made in the 5-year plan. These sensitivities have been determined by the Companies working closely with stakeholders throughout the process.

Q2. WHAT IS THE KEY DIFFERENCE BETWEEN THE ROLE YOU PLAYED IN THE PREVIOUS PSIP FILING AND YOUR WORK HERE?

A2. Our earlier results were produced by the E3 team working independently of the process used by the Companies using a mixture of input assumptions from the company work and our own database looking only at Oahu. In this revision, we have expanded the analysis to include Maui and Hawaii and all input assumptions have been provided by the Company team and revised through close collaboration with them and input from stakeholders, over the last 5 months. We show results of cases defined by the companies and those defined by stakeholders separately. We have also extended our analysis beyond studies of the islands individually to provide a rough upper bound bookend of the value of interconnecting the islands with undersea transmission cables as a first screen to test whether a more detailed intertie study is warranted.

Q3. WHAT WAS THE PROCESS YOU USED TO DEVELOP YOUR FINDINGS IN THIS UPDATED PSIP FILING?

A3. The process was developed based on feedback from stakeholders regarding the lack of transparency in the previous PSIP filing. To increase both the transparency of results and allow third parties to participate more effectively in the process, the methodology, the cases being run, and the inputs assumptions were discussed over two workshops at the HPUC with stakeholders and commission staff. The role of the E3 analysis as a precursor to more detailed modeling being conducted by the Companies was also presented. The input data assumptions are presented in detail for each island in the Appendix to this report.

Our role in this process was not to choose the best plan, but to provide an independent and unbiased assessment of the least cost incremental system capacity investments and dispatch decisions for each island necessary to meet Hawaii's RPS goals under the assumptions defined for the reference and sensitivity cases and make those results and cases equally transparent and accessible to all parties.

Costs were examined from a Total Resource Cost perspective meaning that customer costs for customer-sited generation were considered in the optimizations in both the core and sensitivity cases that allow optimal DGPV resource selection.

Q4. PLEASE BRIEFLY DESCRIBE THE CASES YOU DEVELOPED FOR THE COMPANIES AND STAKEHOLDERS.

A4. Each case was focused on varying certain input parameters to investigate various uncertainties. The key variations in the input parameters for each case are summarized here with further details describing each case listed below.

For each island, we investigate the sensitivity of the least cost resource plan to two major uncertainties for the Companies – the scale of DGPV buildout and the option to invest in LNG resources beginning in 2022. To test both sensitivities, we used the Companies-produced "Market" DGPV forecast and the "High" DGPV forecast as inputs into the RESOLVE model, and for each forecast, we run one case assuming an LNG import hub is built and LNG thermal resources are available (including conversion of various existing resources, with cost data provided by the Companies), and one in which no LNG hub is available. Thus, four cases were run for each island (LNG Market DGPV, LNG High DGPV, No-LNG Market DGPV, No-LNG High DGPV). All of these cases are run assuming that each utility must meet its own RPS constraint independently.

There were several other sensitivities tested. These sensitivities, some performed at the request of the Companies and some at the request of stakeholders, are listed below. To minimize the number of cases produced, these sensitivities, except when noted otherwise, were run using the No-LNG option with the Market DGPV forecast on each island.

- Value of renewable hedge: Ulupono requested that we investigate the sensitivity of the results to a 35% adder to all forecasted fuel prices on each island.

- No-RPS case: The Consumer Advocate requested that we develop a case in which there is no RPS constraint on each island for cost comparison to other cases.

- Enhanced renewable energy potential on Oahu: In the base cases, we use the National Renewable Energy Laboratory (NREL) produced estimates for solar and wind resource potentials on Oahu consistent with using land that has less than a 5% slope. Dr. Fripp, at the request of Ulupono and Blue Planet, has provided us data with increased resource potentials on Oahu consistent with using land up to a 10% slope.

- Paniolo pumped storage and wind plant: Paniolo requested that we substitute the company assumptions for their own cost and performance estimates of a pumped storage and wind resources on Hawai'i Island.

- Military units on Oahu: The base cases assume two military fuel oil units on Oahu (located at Marine Corps Base Hawaii and Joint Base Pearl Harbor-Hickam) will be in service in the early 2020's. A sensitivity case was run in which these units are not assumed to be in service, but the model is given the option of purchasing units of their equivalent size and efficiencies.

- DGPV as model choice: A scenario was run on each island in which the DGPV forecast is completed through 2020, but there is no DGPV forecasted beyond 2020. Instead, in the time-period beyond 2020 the model is given the option of procuring DGPV, similarly to the way in which the model is given the option to procure grid-scale solar or other renewable resources.

- Uncurtailable DGPV case: A scenario was run on each island in which all DGPV resources are assumed to be uncontrollable, as opposed to the base cases in which all DGPV installed after 2020 is assumed to be curtailable. These cases were run using the No-LNG High DGPV forecasts on each island.

Finally, in addition to the individual island cases we run a "Copperplate" case where we treat all three islands (Oahu, Maui, Hawai'i) as one large zone connected with infinite transmission capacity between the islands with no import or export limits. This case is run to investigate the maximum potential benefits of building interisland cables between these islands without regard to the cost of the cable itself. The case is useful as a screen to determine if the cable should be studied further and to determine changes in generation portfolios by island that have the potential to provide the most benefits.

Q5. PLEASE SUMMARIZE THE RESULTS.

A5. The findings are grouped into results of the Company defined cases and results of cases defined by stakeholders. Where possible, we have tried show only a set of simplified model output data to define and highlight the differences between the cases. This output data includes costs normalized to a base or reference case plan and proposed least cost investments over through 2045 designed to minimize the cost of compliance with the 100 percent RPS requirement by island and in the copper plate transmission case.

Results from Company Defined Cases

1. Since the Companies are not requesting an LNG import hub in the near term, the No-LNG cases are used as the reference cases on each island. In this document the No-LNG Market DGPV plan on each island is used as a common point of comparison between costs and build decisions across cases. The comparison of the costs of this plan with the costs of other plans is shown in Table 1 below. The costs of any two cases can be compared by their costs in relation to the No LNG, Market DGPV plan, which has a normalized net present value cost of 1. Table 1 below shows each of the reference case costs as 1 in the middle column of Table 1 below. Investments in LNG, given the EIA fuel price forecast with not hedge adder have lower costs and the higher DGPV forecasts are also higher costs than the reference cases.

Table 1. Total resource cost comparison between Company defined cases (normalized with respect to No-LNG Market DGPV case on each island)

Oahu	**Market DGPV**	**High DGPV**
No-LNG	1.00	1.05
LNG	0.92	0.97
Maui	Market DGPV	High DGPV
No-LNG	1.00	1.10
LNG	0.85	0.95
Hawaii	**Market DGPV**	**High DGPV**
No-LNG	1.00	1.18
LNG	0.85	1.05

2. Over the next five years, it is cost effective to take advantage of the federal tax incentives for renewable resources on each of the islands. This incentive drives the results that show that each of the company plans are ahead of the straight-line year by year RPS goal. On Maui and Hawai'i, this is true regardless of LNG status. On Oahu, the No-LNG case results in Oahu staying ahead of the RPS goal, but in the LNG cases Oahu does not significantly exceed the RPS goal.

3. Over the next five years, the amount of tax advantaged renewable energy chosen by RESOLVE is limited by the amount of renewable energy that Companies estimate can be interconnected and delivered safely to loads through 2020. This interconnection limit was estimated by the Companies to be 130MW of wind for Maui, 20MW of wind for Hawaii and 300MW of solar for Oahu; other renewable resources, such as solar on Maui and Hawaii, were not constrained by any interconnection limit, but were also not chosen by RESOLVE.

4. Energy storage or some form of advanced demand response is cost-effective as early as 2020 for Hawaii and in 2022 for Oahu and Maui.

5. The Marine Corps Base Hawaii (MCBH) at Kaneohe Bay and the Joint Base Pearl Harbor-Hickam (JBPHH) were included as planned resources in the base cases. A sensitivity was run where the model was given the option to purchase those units, but they were not selected in the base thermal build; increased amounts of renewable energy (in the No-LNG cases) and other dispatchable LNG resources (in the LNG cases) were chosen to replace this capacity in the short term. In the longer term, in all cases some dispatchable thermal capacity was chosen in 2045.

   As we discuss in response to Question 6 below, the RESOLVE model does not investigate detailed contingencies or system security constraints, and there are reliability benefits to keeping sufficient levels of thermal projects online which RESOLVE is not considering. Furthermore, when RESOLVE chooses not to invest in the military based thermal resources, the model assumes that beyond 2020 there are no interconnection limits or land use issues to constrain the grid in absorbing further renewable energy installations and that all of these new resources, whether located behind or in front of the customer meter, are fully curtailable.

6. The interisland "Copper Plate" cable case substantially increases the renewable builds on the neighbor islands. For example, the proposed renewable resource build on Oahu in the 2020-2022 is reduced from 348 MW to 0; Maui increases from 96MW to 217MW; and, Hawaii increases from 70MW to 814MW. Note that these are unrealistic build amounts given both the near-term timing and the unlimited amounts of grid capacity assumed on each island system.

7. The interisland cable produces sufficiently large benefits related to procurement and energy and capacity savings that we recommend Hawaii continue to conduct more detailed focused analysis on specific configurations that would provide a combination of maximum net benefits and renewable procurement flexibility. Using our screening process, we estimate that a large cable system interconnecting each island could have benefits as large as three billion dollars in present value over the lifetime of the cable. A phase 2 study of the interisland cables would break down the copperplate case into

scenarios that would include (1) specific transmission project costs and operating limitations, and (2) assumptions about the feasibility, timing, and cost constraints of significantly expanded renewable resources on Maui and Hawaii.

In the near term, the resource decisions in the interisland cable case versus the individual island cases do not change on Maui or the Big Island. While the interisland cable case identifies greater renewable build on these islands due to better resource qualities over the long term, the renewable build is constrained by interconnection limitations on each of the islands in the early years. In addition, given the uncertainty of the Phase 2 study findings, we do not recommend that Hawaii conduct its procurement and transmission planning on the individual islands today as if the cable were going to be in place. To avoid any risk of stranding capital investments, we believe that a safer more prudent approach would be focus on optimizing the plans for each island separately over the next 5 years..

8. A number of stakeholders were concerned that the company request for approval in the first 5 years not commit it to an inflexible longer term pathway. In general, we believe that the RESOLVE choices in the first 5 years are fairly robust and provide what now looks like a unique and quickly vanishing opportunity to take advantage of federal tax incentives to benefit electricity consumers. We strongly recommend that Hawaii take maximum advantage of these subsidies as soon as possible.

   Parties asked if anything recommended in the first years would change if we know that the cable were going to be constructed later. There is a change in the portfolios. In the interisland cable case, RESOLVE wants to build less grid scale solar first 5 years in favor of lower cost and higher quality wind on the neighbor islands. However, given the uncertainty around the cable feasibility and timing, and the potential fleeting opportunity of the tax subsidies, the cost of overbuilding tax subsidized solar early is relatively small and a risk of counting on an uncertain future cable can be quite large. More impactful differences in resource decisions start to occur in 2022. We recommend that these resource choices be analyzed in detail in future planning rounds, with more development of the cost assumptions and operational constraints of the cable options.

9. Letting the model choose to build DGPV beyond 2020 results in lower DGPV buildout than the market DGPV forecast. On Oahu, the decrease of DGPV over the market DGPV forecast results in increased build of grid-scale solar resources, which are less expensive than DGPV on a total resource cost basis. On Maui there are increasing amounts of both grid-scale solar and wind, whereas on Hawai'i the wind resource is sufficiently dominant over the other options that the market forecast DGPV is completely replaced with wind.

10. Companies asked us to assume that all DGPV installed beyond 2020 is fully curtailable. If we remove this assumption, the model builds more battery resources throughout the plan. The cost differences over the high DGPV curtailable case are material and grow over time. Moreover, our modelling assumes that the system operator can operate the system with perfect foresight under normal operating conditions. Under more strenuous, information poor conditions, the operator is going to have to curtail larger quantities of energy than we estimate. If curtailment control is limited, there a possibility that reliability can be jeopardized. We want to highlight the curtailment assumption for all new post 2020 DGPV because we believe that renewable curtailment for all resources is a fundamental renewable integration tool that our modelling assumes and uses to minimize projected costs.

Results from Stakeholders' Cases

11. Ulupono asked us to run a case where LNG costs were higher by 35% to reflect a fuel price hedge against future volatility that would naturally be avoided with investments in renewable resources. The results are similar to those from the No-LNG case, where fuel prices are approximately double those in the LNG scenario per MMBTU. The Companies have an economic incentive to interconnect as much tax advantaged renewable resources as they can before the federal tax incentives expire. Under Internal Revenue Service (IRS) rules, a facility will be considered to satisfy the Continuity Safe Harbor if it is placed in service during a calendar year that is no more than four calendar years after the calendar year in which construction of the facility began[1]. Thus, the Companies have an incentive to begin construction of tax advantaged renewable resources before they are strictly needed as the construction can be completed up to four years later and still allow the facility to receive federal subsidies.

12. Hawaii Gas asked us to run a case using a Hawaii Gas produced LNG price forecast on Oahu Island, with no LNG on the neighbor islands. The LNG price forecast from Hawaii Gas was based on a volume assumption of 0.9 MTPA with a price of $12.32/MMBTU in 2022 (this price, in $2016, represents the "total cost" of LNG import including delivery to power plant; it does not include power plant conversion costs, which are included separately), a high of $13.06/MMBTU in 2030, and decreasing back to $12.66/MMBTU in 2040. The resulting build is similar to the HECO LNG Market DGPV case results, and in the first five years there are effectively no differences in thermal and renewable procurement decisions.

13. Dr. Fripp, on behalf of Ulupono, requested that we include additional solar and wind resources on Oahu by extending the supply estimates produced by NREL. The base

[1] https://www.irs.gov/pub/irs-drop/n-16-31.pdf

cases were limited to 164 MW of onshore wind and 2756 MW of utility scale solar; the increased supply estimates include smaller and potentially higher cost sites and have total resource potentials of 2680 MW of onshore wind and 6583 MW of utility scale solar. We did not have accurate estimates of costs for these sites, but the addition of these new sites increased the early renewable build for wind on Oahu, from 30 MW to 370 MW in 2022, assuming no additional development costs per kWh of output. This increase can be attributed to the higher capacity factors of the best resource tranche relative to the average capacity factor used in the Companies reference case. However, this significantly larger renewable build is still limited by the near-term interconnection limits on the system.

14. Paniolo asked us to substitute their own estimates of performance and costs for 6-hour pumped-storage hydro (PSH) and wind for the input assumptions given to us by the Companies for the base cases. The Paniolo performance characteristics showed higher capacity factors for the wind resource and similar resource costs for both wind and PSH when compared to the Companies assumptions for the same resources. However, the resource cost of PSH remained significantly more expensive than 4-hour batteries. In the Companies base case runs, the PSH is an option but never selected due to its relatively high costs compared to batteries. Paniolo wanted to see the impact on total costs of including their project. To derive this result, we forced the model to take the combination of 30 MW of wind and 30 MW of PSH in 2022, per the Paniolo specifications. As a result, the Paniolo PSH displaces some of the RESOLVE battery build decisions throughout the planning horizon, but at a higher capital cost due to both the increased capacity (30 MW of PSH versus 14 MW batteries in 2022 in the base case) and higher unit cost of the PSH when compared to batteries. The Paniolo sensitivity is approximately 13 percent higher than the Company base case plan.

15. DBEDT requested that we develop a process to use RESOLVE to test the robustness of our findings. DBEDT's main concern was with regard to the proposed 5-year plan and anything that might change in it that was sensitive to long term forecasts of uncertain variables. We discussed the following four uncertain variables in our analysis: fuel price forecasts, renewable price forecasts, storage price forecasts, and the impact of the interisland transmission cable. Because LNG was not being requested in the 5-year plan and RESOLVE did not recommend new thermal resources in the 5-year plan, DBEDT only requested that we look at whether the cable would change the 5-year recommended plan. We confirmed with DBEDT in our follow up call that the copper plate cable case only increased the amount of renewable build on the neighbor islands in the five-year plan. The renewable build on the neighboring islands will already be constrained during the five-year plan by the amount of renewables interconnectable during that time period, thus there will be no difference in renewable build on Maui

and the Big Island. However, we do agree with DBEDT that the cable is a potential game changer for the longer-term plan.

The types of renewable build the model selects do change with the interisland cable. Oahu has reduced grid scale solar build, for example, in the cable case in the first 5 years. We recommend following the individual island case build cases for two reasons. First, there is a substantial level of uncertainty regarding cable feasibility and timing. Second, over the next decade, we don't see a substantial loss of renewable build on Oahu being replaced with low cost renewables on the neighbor islands because of the near-term interconnection and integration constraints.

16. DBEDT also requested a sensitivity on the inclusion of the military units in the reference case. The Marine Corps Base Hawaii (MCBH) at Kaneohe Bay and the Joint Base Pearl Harbor-Hickam (JBPHH) were included as planned resources in the base cases. A sensitivity was run where the model was given the option to purchase those units, but they were not selected in the base thermal build; increased amounts of renewable energy (in the No-LNG cases) and other dispatchable LNG resources (in the LNG cases) were chosen to replace this capacity.

    As we discuss in response to Question 6 below, the RESOLVE model does not investigate detailed contingencies or system security constraints, and there may be reliability and other benefits to keeping these projects online which RESOLVE is not considering. Furthermore, reliance on additional renewables to replace these units is contingent on being able to install and fully integrated those renewables in the near term. Getting the transmission in place to do so is uncertain and MCBH and PBPHH units would increase the flexibility of the system while transitioning to greater reliance on renewables.

17. Finally, we developed the single lowest cost plan for the Consumer Advocate (CA Sensitivity) that did not comply with the RPS and utilized LNG/Market DG. These lowest cost plans were run under both No-LNG and LNG conditions, utilizing the Market DG forecast. In all cases, the plans are less expensive than the individual island Market No-LNG RPS-constrained base cases, but by only a small amount. In the last cost plan on both Maui and Hawaii gets you to nearly a 100 percent RPS compliant portfolio by 2045.

18. Table 2 below shows normalized costs for each individual island's Non-RPS constrained bases.

    Table 3 below shows the portion of annual electricity coming from RPS-eligible sources. Note that in the No-LNG cases a significant portion of electricity is being sourced from renewable resources, even without an RPS constraint, because the economics of renewable sources are favorable.

Table 2. Costs for Consumer Advocate No-RPS constraint cases, normalized with respect to No-LNG Market DGPV cases

Oahu	No-RPS Market DGPV
No-LNG	0.87
LNG	0.84
Maui	**No-RPS Market DGPV**
No-LNG	0.99
LNG	0.80
Hawaii	**No-RPS Market DGPV**
No-LNG	0.98
LNG	0.81

Table 3. Portion of annual electricity from RPS-eligible sources, in Consumer Advocate No-RPS constraint cases.

Oahu	2020	2022	2025	2030	2035	2040	2045
No-LNG	34%	41%	50%	55%	61%	66%	72%
LNG	28%	29%	31%	34%	35%	34%	45%
Maui	**2020**	**2022**	**2025**	**2030**	**2035**	**2040**	**2045**
No-LNG	54%	72%	73%	75%	74%	83%	95%
LNG	45%	64%	63%	65%	63%	63%	67%
Hawaii	**2020**	**2022**	**2025**	**2030**	**2035**	**2040**	**2045**
No-LNG	63%	71%	76%	78%	79%	80%	95%
LNG	63%	76%	78%	80%	79%	80%	76%

Q6. DO YOU HAVE ANY CAVEATS REGARDING YOUR FINDINGS?

A6. Yes, performing the variety of cases analyzed using an optimal expansion planning model required that we use a simplified planning reserve margin (PRM) measure of reliability for plans that require high amounts of variable energy resources, and estimates of operating reserves. We also did not model transmission networks, stability constraints, or contingency requirements. The Companies are supplementing our analysis with modelling using the PLEXOS simulation model and analysis performed by Ascend Analytics to address these limitations. The Companies are also performing system security analyses to determine minimum inertia, fast frequency response, primary frequency response and fault current needed to maintain stable and reliable isolated island grids. However, even the collection of these models does not adequately stress the reliability of each high renewable plan over time.

The assumptions that define each case are necessarily simplifying for several reasons:

- The system operating requirements for reliable service in the future are currently uncertain. Between now and 2045, the technologies at grid scale and behind the meter will change significantly, requiring new operating procedures and reliance on new technologies such as storage for grid services previously met with thermal generation. The assumptions used to define the need for ancillary services in RESOLVE are therefore more certain in early years when the system is still relatively familiar, and less certain in later years when significantly more renewables and other novel technologies are installed. The rate with which the system changes differs by island, depending on the relative economics of different resource options.

- RESOLVE does not include detailed power flow and stability analysis that would consider transmission networks, unit reliability, and contingency measures.

- The computational complexity of capacity expansion and hourly dispatch logic in RESOLVE means that additional detailed transmission network constraints would significantly slow down the model. Furthermore, many of the constraints around reliability are not quantified by a simple formula suitable for modeling. RESOLVE is an appropriate combination of complexity and runtime such that many iterations and sensitivities can be run to determine least cost resource portfolios through to 2045 and inform the more detailed, near term HECO modeling effort.

- RESOLVE does not incorporate the complex contract structures with existing renewable resources. All renewable resources in RESOLVE are assumed to recover their full capital cost over their lifetimes and incur only variable costs per MWh generated.

- The RESOLVE input datasets do not include more detailed generator characteristics such as "black start", maintenance schedule, generator reliability etc.

- RESOLVE can identify when a generator is no longer needed under normal operation conditions according to Companies' reserve constraints. However, without considering the more detailed generator characteristics, power flow implications, and contingency constraints, RESOLVE can only act as a guide to identify candidate units for removal from service. Whether a unit is removed from service is therefore addressed in the Plexos modeling.

Given these limitations of the results, the RESOLVE least cost resource plans act as a guide and starting point for the Company team. Although we believe that our results are unbiased with regard to technology choice and suitable for the economic comparison between the different plans, we recommend that the Companies, working closely with key stakeholders, regulators, and state agencies, continue to refine their long-term planning models and data to incorporate more real world operational constraints. We do not recommend the use of the RESOLVE cases by themselves be used to make permanent plant retirement decisions.

Q7. HOW IS THIS DOCUMENT ORGANIZED?

A7. In Section 2 we describe the overall results of the base case scenarios we were asked to develop for the Companies using the input data and assumptions define by the Companies. Section 3 then lays out the sensitivity case for the base case scenarios. Section 4 describes the sensitivity cases that we put together for third parties who requested and defined them. Finally, an attached appendix contains the input assumptions that were used to define each of the RESOLVE cases described below.

2: COMPANIES BASE CASE

Q8. PLEASE DESCRIBE THE KEY DIFFERENCES IN THE ASSUMPTIONS USED TO DEFINE THE COMPANY BASE CASES.

A8. The base case for each island is the No-LNG option using the "Market" DGPV forecast for installed DGPV. All installed DGPV through 2020 are assumed to be uncontrollable and uncurtailable, whereas all DGPV resources installed beyond 2020 are allowed to be economically curtailed if required. This is a critical assumption that allows us to minimize the costs of these high renewable energy cases.

Q9. PLEASE DESCRIBE THE RESOLVE MODEL RESULTS FOR EACH OF THE BASE CASES.

A9. Capacity graphs show installed capacities aggregated by resource type. The capacities shown in the graph are resources which the model utilizes for either energy or to meet PRM purposes. There are some resources which the model does not find necessary to use under normal operating conditions and, while on the system, are not displayed on the utilized capacity graphs. These resources are potential candidates for deactivation and further study for potential retirement if found to be unnecessary for system needs in the more detailed modeling performed by the Companies. The breakdown between utilized capacity and un-utilized capacity can be seen in the Appendix. As addressed in Q6 please note that normal operating conditions, while including contingency reserve and operating reserve constraints as specified by the Companies, are not meant to encapsulate system security and contingency conditions, and therefore the RESOLVE results should not be taken to mean that a resource whose capacity is not being utilized should be retired. For the main takeaways from these base case results see Q10.

Figure 1. Utilized installed capacity for Oahu No-LNG Market DGPV case

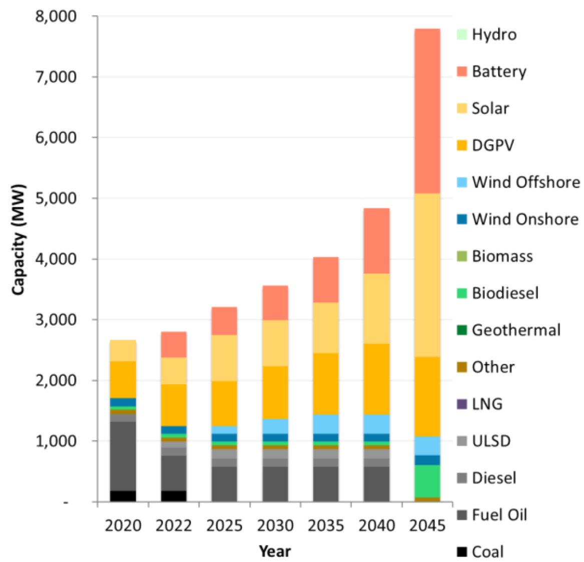


Figure 2. Utilized installed capacity for Maui No-LNG Market DGPV case

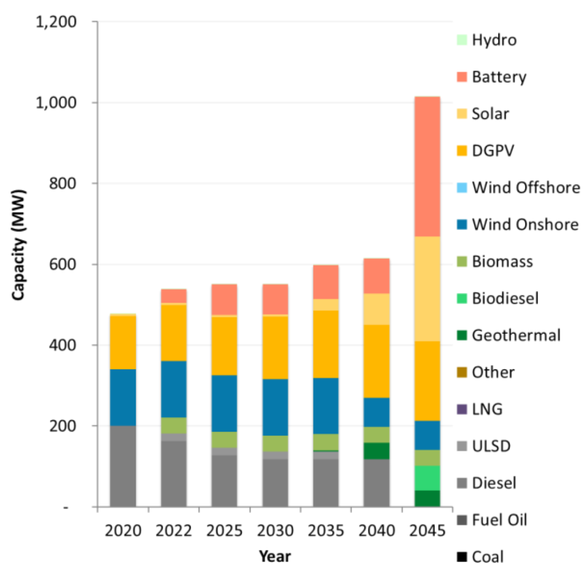
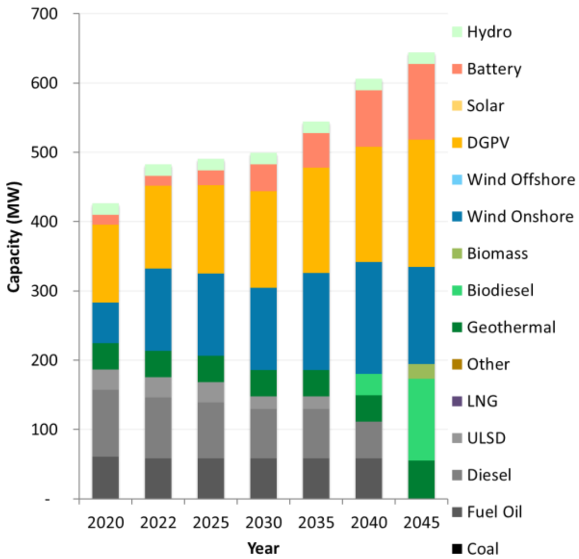


Figure 3. Utilized installed capacity for Hawai'i Island No-LNG Market DGPV case



Q10. WHICH OF YOUR MAIN FINDINGS DID YOU REACH BASED ON YOUR BASE CASE ANALYSIS AND PLEASE HIGHLIGHT THE RESULTS THAT YOU RELIED ON TO SUPPORT THOSE FINDINGS?

A10. On all islands, during the first five years (through 2022), RESOLVE moves aggressively to build renewable resources. This is especially pronounced on Hawai'i Island and Maui, where there is a markedly increased amount of wind built in 2022. RESOLVE is moving to take advantage of tax-credited renewable resources early, but is constrained in its ability to do so by interconnection constraints (as stated in Q5 above, the interconnection limits modeled here are maximum additional renewable resources by 2020 of 130MW of wind for Maui, 20MW of wind for Hawaii, and 300MW of solar for Oahu).

On all islands, there are no new thermal resources selected by RESOLVE beyond those already planned to be in service. On Oahu in particular this result is true assuming that the military units (MCBH and JBPHH) are planned to be in place by 2022 and 2025.

On all islands, the value of renewable resources relative to thermal resources rises over the study horizon, so the conventional thermal fleet size decreases. There is a slight uptick on Hawai'i in 2045 as there is more biodiesel capacity in 2040 than conventional oil capacity in 2040. This is because as there are some underutilized resources which are converted to biodiesel in 2045. These biodiesel resources are used primarily for capacity to meet PRM; the majority of RPS-eligible energy comes from wind, with DGPV and geothermal sources filling in the rest.

Oahu and Maui see a “hockey stick” like build in which the last year sees a large amount of energy storage built. This large build late build is due to: 1) the large increase in RPS from 70% in 2040 to 100% in 2045; 2) the high cost of biodiesel (nearly 2x the cost of conventional diesel); and 3) the steeper decrease in battery costs relative to the pace of cost changes for other resources. Nevertheless, batteries (representative of energy storage and other demand response more broadly that can provide the same services) are cost effective as early as 2020 on Hawai’i and 2022 on Maui and Oahu.

3: COMPANIES SENSITIVITIES

Q11. PLEASE DESCRIBE THE INPUT ASSUMPTIONS USED TO DEFINE THE COMPANIES SENSITIVITY CASES

A11. In addition to the base case, the Companies identified several sensitivity cases. The list of the Companies-defined sensitivities are defined below, with more details in each case results section.

1. No-LNG with "High" DGPV Forecast: Use the "High" DGPV forecast on each island instead of the "Market" DGPV forecast.
2. LNG with "Market" DGPV Forecast: Allow the model to procure LNG resources after 2022, with the option of converting various existing thermal generators. Cost data for this conversion is provided by the Companies. The LNG fuel is available starting in 2022, but not available in 2045.
3. LNG with "High" DGPV Forecast: Similar to the LNG with "Market" DGPV forecast, but with the "High" DGPV forecast on each island.
4. DGPV as an endogenous choice: Model is given the option of procuring DGPV resources, with cost data for the DGPV resources provided by the Companies. The DGPV installed through 2020 is assumed to be still on the system.
5. DGPV as uncurtailable: Model is run using No-LNG "High" DGPV forecast on each island, but all DGPV installed after 2020 are not assumed to be curtailable.
6. Copperplate with "Market" DGPV Forecast: Assume all islands are connected with infinite capacity, infinite reliability transmission cables.

Q12. PLEASE DESCRIBE THE RESOLVE MODEL RESULTS FOR EACH OF THE SENSITIVITY CASES

A12. For each sensitivity case, we present a capacity chart and a normalized cost table with entries for each evaluation year.

Capacity graphs, as described in Q9, show utilized installed capacities for each case, aggregated by resource type.

Cost tables compare the cost of the cases relative to the base cases as defined in Q9: No-LNG Market DGPV forecast cases. Values greater than 1.00 signify the cost for the sensitivity case in question is greater than that of the No-LNG Market DGPV case. The costs reported by RESOLVE and summarized in these tables are for the cumulative incremental resource build and the cumulative total system operating and O&M costs up to the year in question. Costs are reported on a total resource cost basis. The total cost at the end of the time horizon of the base case under this definition is $10.6 billion on Oahu, $1.7 billion on Maui, and $1.1 billion on the Big Island.

1. No-LNG with High DGPV Forecasts

The No-LNG "High" DGPV cases were run using the same input assumptions as each of the islands' base cases, with the substitution of the "High" DGPV forecast instead of the "Market" DGPV forecast.

On Oahu, the difference between this case and the base case is mostly cost, as the more expensive DGPV resources are built instead of lower cost grid-scale solar resources. Table 4 below, for example, shows that the High DGPV case has higher cost renewables by 12% and higher costs storage by 3% by 2045 compared to the No-LNG Market DGPV case. The total cost of this case is 5% higher than the market DGPV case by 2045.

On the neighbor islands, the mix of resources changes more significantly. On Maui, the increased DGPV forecast results in much higher capital costs of renewable energy (157%) and decreased grid-scale solar and grid-scale wind build. The Hawaii case has even more DGPV in the high case, which shows an even higher renewable energy capital cost (189% for the capital cost of renewable energy) compared to grid-scale wind in the Hawaii base case.

On all islands the High DGPV cases have a higher total resource cost than the Market DGPV cases, which is consistent when the higher cost and lower capacity factors of DGPV resources compared to the alternative grid-scale renewable resources.

Oahu Results

Figure 4. Utilized installed capacity for Oahu No-LNG High DGPV case

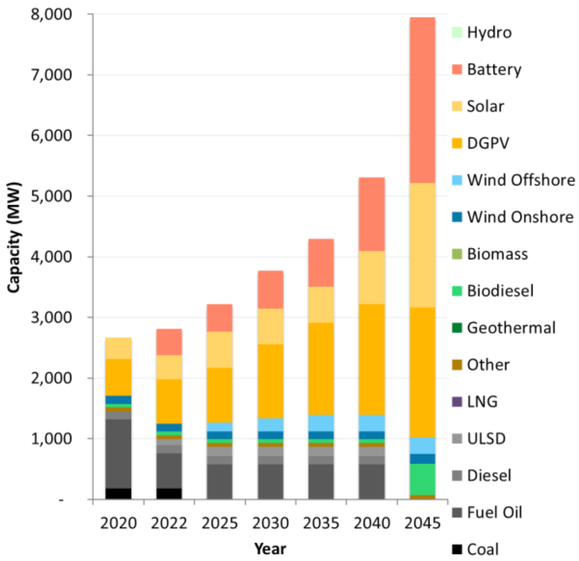


Table 4. Cumulative total resource cost for the Oahu No-LNG High DGPV case (relative to Oahu No-LNG Market DGPV case)

	Relative cumulative total resource cost						
	2020	2022	2025	2030	2035	2040	2045
Thermal							
Variable	1.00	1.00	1.00	0.99	0.99	0.99	1.00
Fixed	1.00	1.00	1.00	1.00	1.00	1.00	0.99
Renewables							
Variable	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fixed	1.00	1.02	1.06	1.08	1.10	1.14	1.12
Battery							
Capital	0.00	1.00	1.00	1.02	1.03	1.04	1.03
Total	1.00	1.00	1.01	1.02	1.03	1.04	***1.05***

Maui Results

Figure 5. Utilized installed capacity for Maui No-LNG High DGPV case

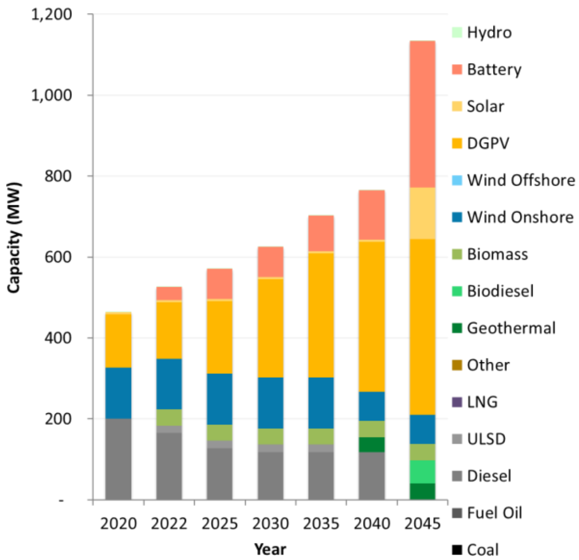


Table 5. Cumulative total resource cost for the Maui No-LNG High DGPV case (relative to Maui No-LNG Market DGPV case)

	Relative cumulative total resource cost						
	2020	2022	2025	2030	2035	2040	2045
Thermal							
Variable	1.06	1.06	1.04	1.01	1.00	1.00	0.99
Fixed	1.00	1.00	1.00	1.00	0.99	0.99	0.99
Renewables							
Variable	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fixed	0.81	0.82	0.98	1.20	1.38	1.57	1.57
Battery							
Capital	0.00	0.94	0.98	0.99	0.99	1.03	1.04
Total	1.01	1.00	1.01	1.03	1.06	1.09	***1.10***

Hawai'i Island Results

Figure 6. Utilized installed capacity for Hawai'i Island No-LNG High DGPV case

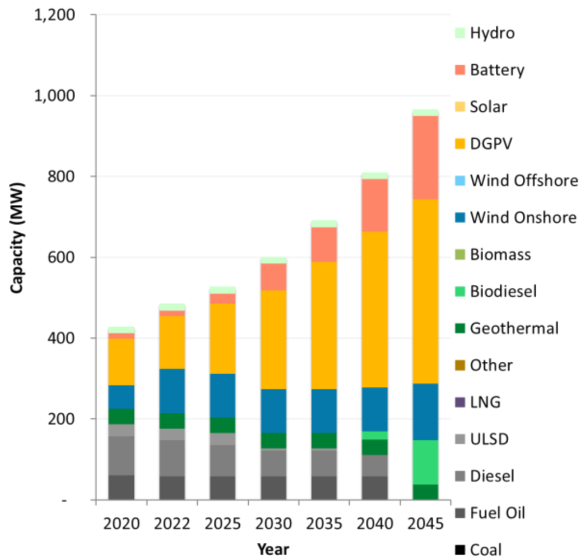


Table 6. Cumulative total resource cost for the Hawai'i Island No-LNG High DGPV case (relative to Hawai'i Island No-LNG Market DGPV case)

	Relative cumulative total resource cost						
	2020	2022	2025	2030	2035	2040	2045
Thermal							
Variable	0.99	1.01	0.99	0.96	0.95	0.94	0.93
Fixed	1.01	1.00	1.00	0.98	0.97	0.97	0.72
Renewables							
Variable	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fixed	1.00	1.01	1.20	1.43	1.61	1.75	1.89
Battery							
Capital	0.97	0.97	1.05	1.24	1.34	1.39	1.50
Total	1.00	1.01	1.03	1.08	1.12	1.17	***1.18***

2. LNG with Market DGPV Forecasts

The LNG "Market" DGPV cases were run allowing the model to procure LNG resources. We give the model the option of converting various existing generators or maintaining the fuel oil versions of those generators, with cost data for this conversion provided by the Companies. The choice of LNG conversion occurs in 2022, the COD year for the LNG import hubs and when LNG is available as a fuel option.

On all islands, no new LNG power plants are built, but a number of existing large generators are fuel-switched; on Maui and Hawai'i these are the large dual train combined cycle plants - Maalaea and Keahole, respectively. On Oahu, the LNG converted plants include the Kalaeloa Partners (KPLP) plant, and some amount of the newer Kahe steam turbines. The precise units which are converted should be decided on the basis of conversion costs, expected reliability, and system security constraints.

The value of the LNG resource to each island is dependent in part on the cost of the LNG fixed infrastructure costs. The cost of the plant unit conversions is born by the island in question, but there is some uncertainty in the allocation of the cost of the LNG import hub and ISO container infrastructure to each island. As a first pass to use in the RESOLVE cases, we have allocated all of the cost of the LNG import fixed infrastructure pieces to Oahu, as Oahu has the largest LNG demand and the greatest absolute cost reduction when LNG is available. However, this means that the relative benefits on Oahu are lower than they would be if the cost of the hub was split among islands; similarly, the relative benefits of LNG on Maui and Hawai'i are greater than they would be if the cost of the hub was apportioned to those islands as well. Thus, the relative cost savings of an LNG import hub listed below are a lower bound on Oahu and an upper bound on Maui and Hawai'i.

Another cost difference worth highlighting is that of the thermal fixed costs. The thermal fixed costs on Oahu are quite large, ranging from 3.27 (see table below; note these are relative costs) in 2022 to 5.76 in 2045. The thermal fixed cost is the fixed cost of thermal resources in the LNG case normalized to the fixed cost of the thermal resources in the Non-LNG case. The LNG case thermal resources includes the cost of the LNG fixed infrastructure, which is a cost of nearly $300 million annually. In addition to this, the thermal fixed costs include the conversion cost of the individual power plants on Oahu. Finally, the fixed cost of the No-LNG cases includes only the avoidable fixed O&M costs for the existing thermal resources; the RESOLVE framework includes incremental resource costs only, so if there are any fixed sunk costs which cannot be avoided by making different decisions, then those costs are not included in the fixed cost as described below.

As various thermal resources retire the No-LNG case fixed thermal cost declines, whereas in the LNG case the annualized cost of the LNG hub and the annualized cost of the LNG conversion stays constant for the lifetime of the resources (20 years). This means the LNG thermal fixed cost stays nearly constant, but when calculating the ratio cost difference between cases, it is divided by a No-LNG case base case cost that is decreasing over time; this results in the relative cost of the LNG thermal fixed cost component appear to increase over time. Thus, because of a combination of (1) large LNG hub fixed infrastructure costs; (2) constant annualized cost of LNG hub and conversion cost; (3) low fixed costs for continuing non-LNG resources; and (4) the

RESOLVE optimization framework which minimizes the incremental total resource costs, the thermal fixed infrastructure cost in the Oahu LNG case is large and increasing in comparison to the No-LNG case.

By contrast, the renewables and thermal variable cost components in the Oahu LNG cost table are both below one. However, the amount of renewable resources and the amount of fuel burn are so large that these cost components more than out-weigh the increased cost of the thermal fixed resource cost component, so that the total relative resource cost for the LNG case is significantly below that of the Non-LNG case. For all three islands, the LNG case is substantially lower in total cost than the Non-LNG base case.

Oahu Results

Figure 7. Utilized installed capacity for Oahu LNG Market DGPV case

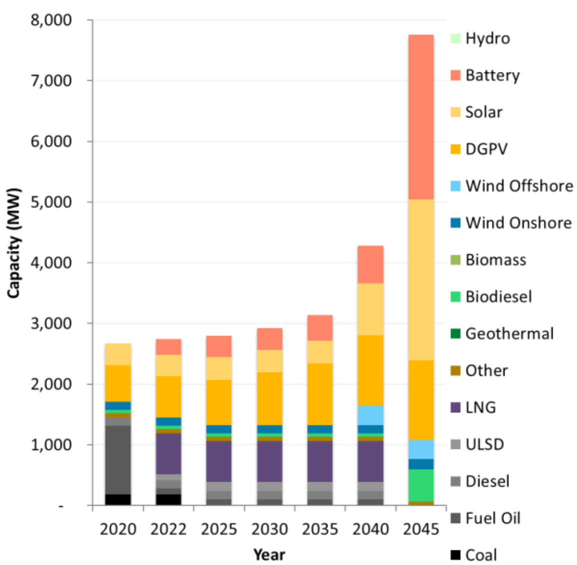


Table 7. Cumulative total resource cost for the Oahu LNG Market DGPV case (relative to Oahu No-LNG Market DGPV case)

	Relative cumulative total resource cost						
	2020	**2022**	**2025**	**2030**	**2035**	**2040**	**2045**
Thermal							
Variable	1.00	0.81	0.73	0.70	0.68	0.65	0.67
Fixed	1.00	3.27	4.79	5.63	6.04	6.27	5.76
Renewables							
Variable	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fixed	1.00	0.90	0.58	0.48	0.46	0.54	0.67
Battery							
Capital	0.00	0.60	0.69	0.67	0.66	0.64	0.76
Total	1.00	1.01	0.97	0.94	0.91	0.91	***0.92***

Maui Results

Figure 8. Utilized installed capacity for Maui LNG Market DGPV case

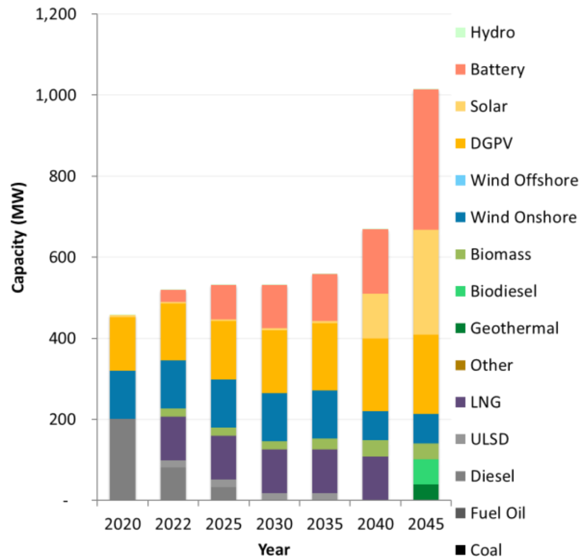


Table 8. Cumulative total resource cost for the Maui LNG Market DGPV case (relative to Maui No-LNG Market DGPV case)

	Relative cumulative total resource cost						
	2020	2022	2025	2030	2035	2040	2045
Thermal							
Variable	1.10	0.97	0.89	0.82	0.77	0.75	0.76
Fixed	1.00	0.99	0.97	0.93	0.92	0.86	0.89
Renewables							
Variable	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fixed	0.70	0.72	0.73	0.74	0.74	0.78	0.84
Battery							
Capital	0.00	0.87	1.04	1.16	1.19	1.25	1.17
Total	1.02	0.94	0.89	0.86	0.83	0.82	***0.85***

Hawai'i Island Results

Figure 9. Utilized installed capacity for Hawai'i Island LNG Market DGPV case

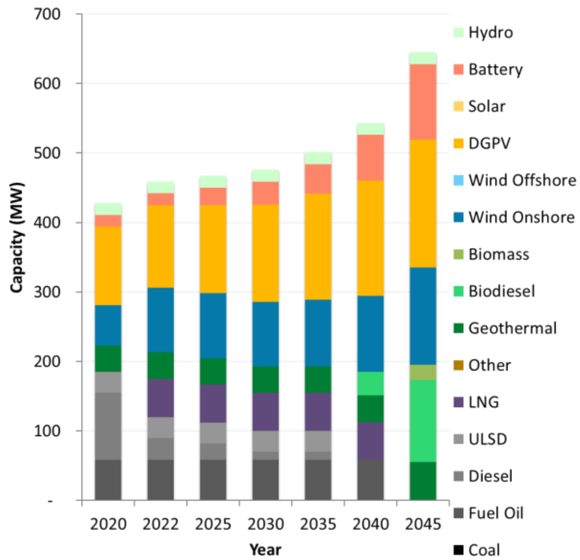


Table 9. Cumulative total resource cost for the Hawai'i Island LNG Market DGPV case (relative to Hawai'i Island No-LNG Market DGPV case)

	Relative cumulative total resource cost						
	2020	2022	2025	2030	2035	2040	2045
Thermal							
Variable	1.00	0.90	0.82	0.76	0.73	0.71	0.73
Fixed	0.97	1.15	1.24	1.29	1.32	1.33	1.23
Renewables							
Variable	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fixed	1.00	0.78	0.76	0.76	0.75	0.75	0.80
Battery							
Capital	1.19	1.19	1.18	1.09	1.04	1.00	1.00
Total	1.00	0.93	0.89	0.86	0.83	0.82	***0.85***

3. LNG with High DGPV Forecasts

The LNG with High DGPV forecast shows decreased solar and grid-scale renewable sources on all islands, which is consistent with the No-LNG High DGPV case. In addition, there are fewer batteries before 2040 compared to the No-LNG cases, as the LNG resources can be used to provide power during low renewable output hours. However, the final build of 2045 is similar to that of the No-LNG High DGPV forecast, as all islands have a large battery build and biodiesel conversion of various existing resources.

Oahu Results

Figure 10. Utilized installed capacity for Oahu LNG High DGPV case

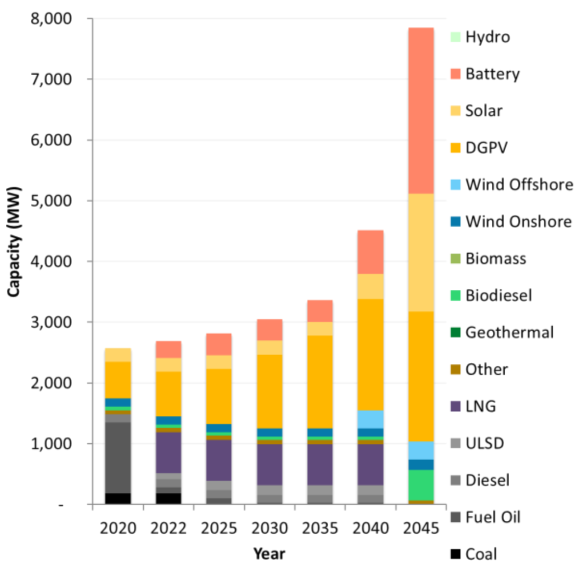


Table 10. Cumulative total resource cost for the Oahu LNG High DGPV case (relative to Oahu No-LNG Market DGPV case)

	Relative cumulative total resource cost						
	2020	2022	2025	2030	2035	2040	2045
Thermal							
Variable	1.05	0.85	0.76	0.72	0.69	0.66	0.68
Fixed	1.04	3.29	4.81	5.63	6.03	6.26	5.74
Renewables							
Variable	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fixed	0.61	0.65	0.51	0.51	0.56	0.67	0.79
Battery							
Capital	0.00	0.67	0.72	0.70	0.66	0.66	0.77
Total	1.00	1.02	0.98	0.96	0.94	0.96	***0.97***

Maui Results

Figure 11. Utilized installed capacity for Maui LNG High DGPV case

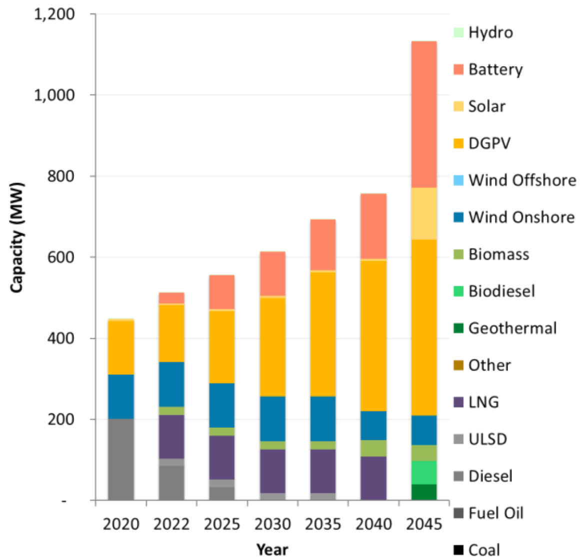


Table 11. Cumulative total resource cost for the Maui LNG High DGPV case (relative to Maui No-LNG Market DGPV case)

	Relative cumulative total resource cost						
	2020	2022	2025	2030	2035	2040	2045
Thermal							
Variable	1.14	1.01	0.91	0.82	0.76	0.74	0.75
Fixed	1.00	1.01	0.98	0.93	0.91	0.85	0.88
Renewables							
Variable	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fixed	0.58	0.60	0.77	1.00	1.20	1.41	1.45
Battery							
Capital	0.00	0.76	1.00	1.14	1.19	1.26	1.19
Total	1.02	0.94	0.91	0.90	0.90	0.91	***0.95***

Hawai'i Island Results

Figure 12. Utilized installed capacity for Hawai'i Island LNG High DGPV case

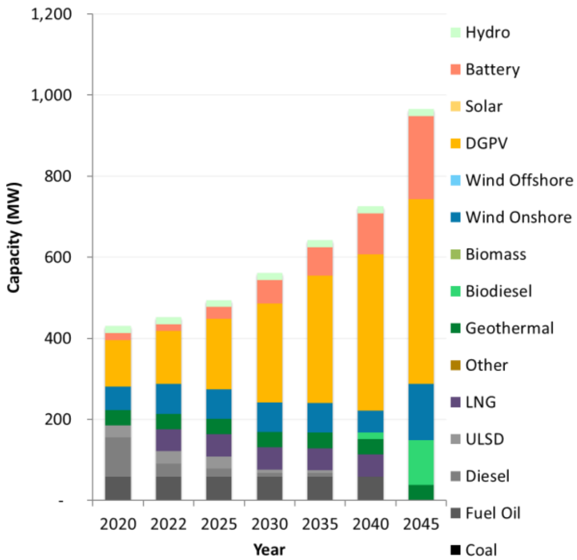


Table 12. Cumulative total resource cost for the Hawai'i Island LNG High DGPV case (relative to Hawai'i Island No-LNG Market DGPV case)

	Relative cumulative total resource cost						
	2020	2022	2025	2030	2035	2040	2045
Thermal							
Variable	0.99	0.93	0.85	0.77	0.73	0.70	0.70
Fixed	0.97	1.15	1.24	1.27	1.29	1.30	0.94
Renewables							
Variable	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fixed	1.00	0.72	0.86	1.10	1.30	1.45	1.65
Battery							
Capital	1.17	1.17	1.24	1.32	1.34	1.33	1.45
Total	0.99	0.94	0.92	0.94	0.97	1.00	***1.04***

4. DGPV as Endogenous Model Choice

In the following cases, the forecasted DGPV build by 2020 is left as is, but all DGPV beyond 2020 is left as a model decision. On each island, there is no DGPV resource built after 2020, as grid-scale renewable resources are cheaper and higher quality than the DGPV resources. On Oahu and Maui, the difference is largely within resource category, as DGPV is replaced with more solar. On Hawai'i Island, the wind resource is of sufficient capacity factor that the DGPV is replaced by wind capacity instead of grid-scale solar capacity.

Oahu Results

Figure 13. Utilized installed capacity for Oahu No-LNG Endogenous DGPV case

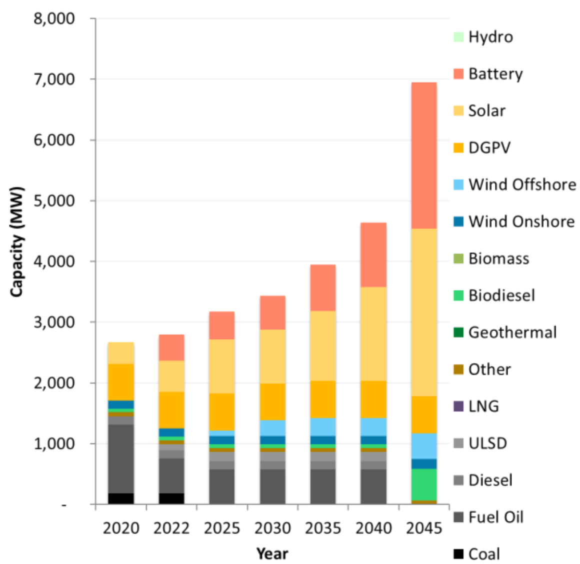


Table 13. Cumulative total resource cost for the Oahu No-LNG Endogenous DGPV case (relative to Oahu No-LNG Market DGPV case)

	Relative cumulative total resource cost						
	2020	2022	2025	2030	2035	2040	2045
Thermal							
Variable	1.00	1.00	1.01	1.01	1.01	1.01	1.03
Fixed	1.00	1.00	1.00	1.00	1.00	1.00	0.99
Renewables							
Variable	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fixed	1.00	0.97	0.94	0.94	0.91	0.88	0.89
Battery							
Capital	0.00	1.00	1.00	0.99	1.00	1.00	0.96
Total	1.00	0.99	0.99	0.99	0.98	0.97	***0.97***

Maui Results

Figure 14. Utilized installed capacity for Maui No-LNG Endogenous DGPV case

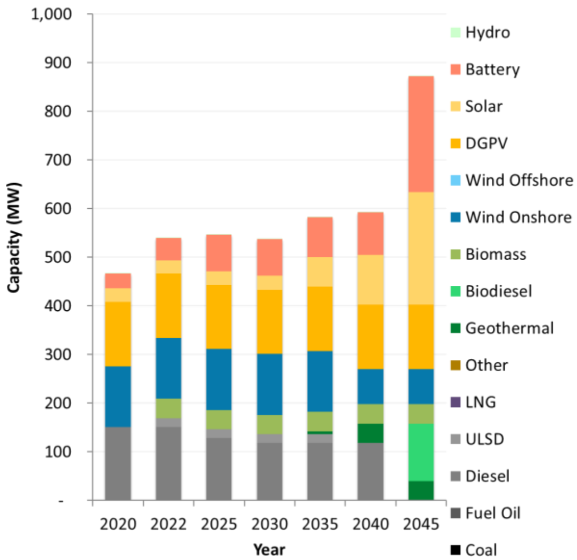


Table 14. Cumulative total resource cost for the Maui No-LNG Endogenous DGPV case (relative to Maui No-LNG Market DGPV case)

	Relative cumulative total resource cost						
	2020	**2022**	**2025**	**2030**	**2035**	**2040**	**2045**
Thermal							
Variable	0.99	0.99	0.99	1.00	1.00	1.00	1.13
Fixed	0.64	0.82	0.89	0.91	0.94	0.95	0.95
Renewables							
Variable	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fixed	1.04	0.99	0.96	0.91	0.88	0.84	0.80
Battery							
Capital	*Div by 0*	3.00	1.63	1.42	1.29	1.26	1.06
Total	0.97	0.98	0.98	0.98	0.98	0.97	***1.00***

Hawai'i Island Results

Figure 15. Utilized installed capacity for Hawai'i Island No-LNG Endogenous DGPV case

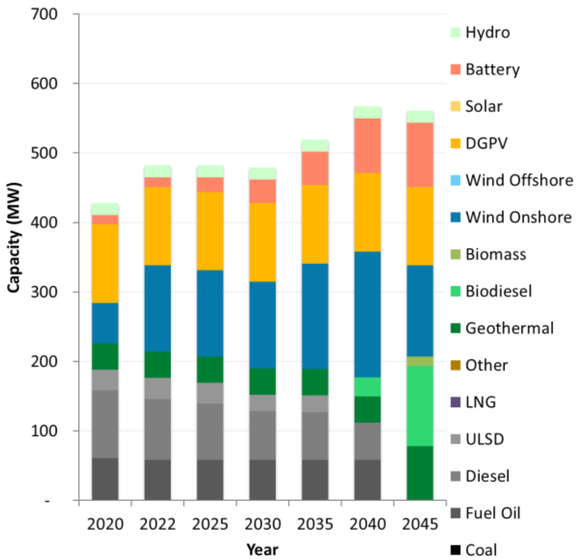


Table 15. Cumulative total resource cost for the Hawai'i Island No-LNG Endogenous DGPV case (relative to Hawai'i Island No-LNG Market DGPV case)

	Relative cumulative total resource cost						
	2020	2022	2025	2030	2035	2040	2045
Thermal							
Variable	1.00	0.99	1.00	1.00	1.00	1.01	0.99
Fixed	1.00	1.00	1.00	1.01	1.01	1.01	1.15
Renewables							
Variable	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fixed	1.00	0.98	0.94	0.90	0.86	0.82	0.77
Battery							
Capital	0.99	0.99	0.99	0.96	0.96	0.96	0.94
Total	1.00	0.99	0.99	0.98	0.97	0.96	***0.96***

5. Uncurtailable High DGPV

In the base case, we assume that all DGPV installed after 2020 is controllable. Curtailing DGPV in future years is a useful and valuable integration mechanism that reduces system costs. To investigate how valuable curtailment of DGPV is, we ran the bookend case on DGPV controllability, assuming all DGPV installed over the model time horizon is uncontrollable. This increases the amount of batteries built over the base case. On Oahu, the table below shows the relative costs of resources selected versus the base case. By 2045, an additional 19% cumulative investment in batteries is made over the base case to integrate the uncontrolled DGPV. Overall, the cost of the uncontrolled DGPV case on Oahu is 6% higher in 2045 than the base case. Similarly, we see significantly higher battery builds on Maui and Hawai'i Island, with increases of 9% and 19% in total cumulative cost by 2045, respectively.

Oahu Results

Figure 16. Utilized installed capacity for Oahu No-LNG Uncurtailable High DGPV case

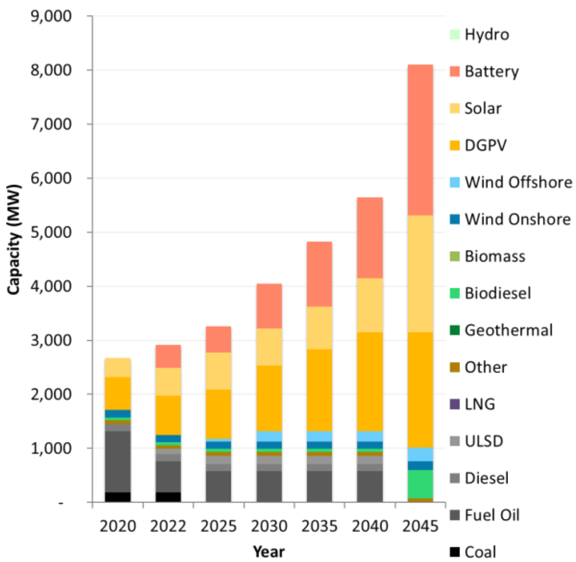


Table 16. Cumulative total resource cost for the Oahu No-LNG Uncurtailable High DGPV case (relative to Oahu No-LNG Market DGPV case)

	Relative cumulative total resource cost						
	2020	2022	2025	2030	2035	2040	2045
Thermal							
Variable	1.00	0.98	1.01	1.00	1.00	1.00	1.00
Fixed	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Renewables							
Variable	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fixed	1.00	1.14	1.02	1.06	1.08	1.12	1.11
Battery							
Capital	0.00	1.00	1.03	1.16	1.23	1.26	1.19
Total	1.00	1.00	1.02	1.03	1.04	1.06	***1.06***

Maui Results

Figure 17. Utilized installed capacity for Maui No-LNG Uncurtailable High DGPV case

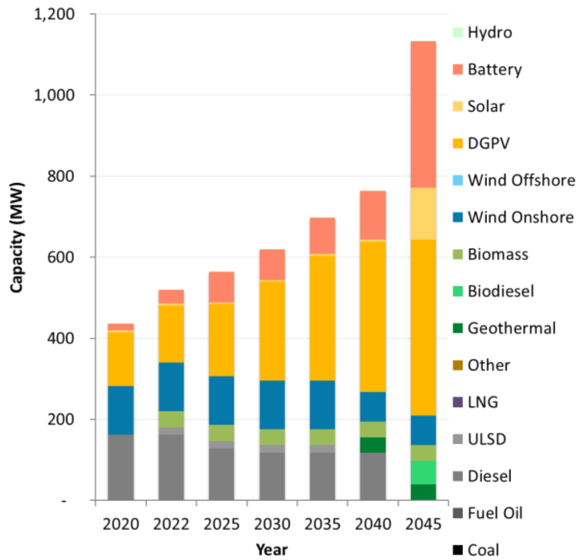


Table 17. Cumulative total resource cost for the Maui No-LNG Uncurtailable High DGPV case (relative to Maui No-LNG Market DGPV case)

	Relative cumulative total resource cost						
	2020	2022	2025	2030	2035	2040	2045
Thermal							
Variable	1.08	1.08	1.06	1.03	1.02	1.01	1.01
Fixed	0.72	0.88	0.92	0.94	0.94	0.94	0.95
Renewables							
Variable	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fixed	0.72	0.74	0.90	1.12	1.31	1.50	1.52
Battery							
Capital	*Div by 0*	1.95	1.30	1.19	1.14	1.16	1.13
Total	0.97	0.98	1.00	1.03	1.05	1.08	***1.09***

Hawai'i Results

Figure 18. Utilized installed capacity for Hawai'i Island Uncurtailable High DGPV case

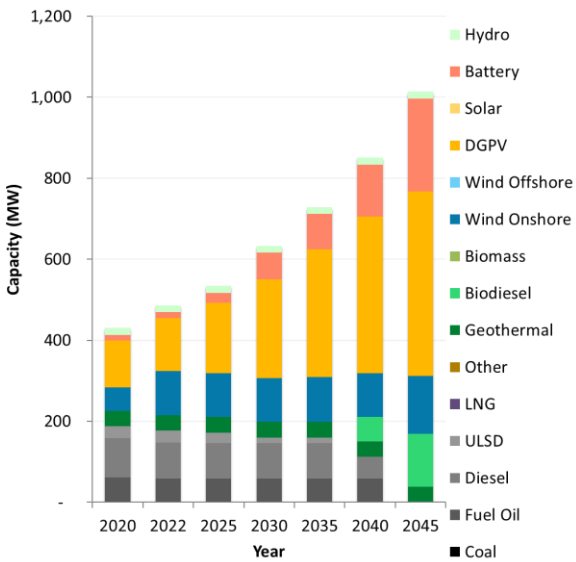


Table 18. Cumulative total resource cost for the Hawai'i No-LNG Uncurtailable High DGPV case (relative to Hawai'i No-LNG Market DGPV case)

	Relative cumulative total resource costs						
	2020	2022	2025	2030	2035	2040	2045
Thermal							
Variable	1.00	1.01	1.00	0.97	0.95	0.94	0.93
Fixed	1.01	1.00	1.00	1.01	1.01	1.01	0.75
Renewables							
Variable	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fixed	1.00	1.02	1.20	1.43	1.61	1.76	1.90
Battery							
Capital	0.97	0.97	1.02	1.21	1.32	1.37	1.54
Total	1.00	1.01	1.04	1.08	1.13	1.18	***1.19***

6. Copperplate with Market DGPV Forecasts

The copperplate results show significant cost differences and build differences as compared to the individual island cases. There is a large increase in Hawai'i Island wind build, and a small increase in Maui solar, whereas the Oahu renewable build sees a large reduction. The thermal fleet capacity does not change significantly compared to the sum of the individual island cases, but in later years much of this thermal fleet is used for capacity with only the most efficient units across islands being dispatched for energy purposes.

The total cost saving across all islands is roughly $3 billion in present value 2016 dollars. This cost difference is an approximate upper bound value and more detailed scoping should be done to investigate both the engineering feasibility of building the cable and the engineering and siting feasibility of the large grid-scale renewable resource build, which RESOLVE assumes is the individual island base case result in absence of the Copperplate case.

Figure 19. Utilized installed capacity for Copperplate No-LNG Market DGPV case

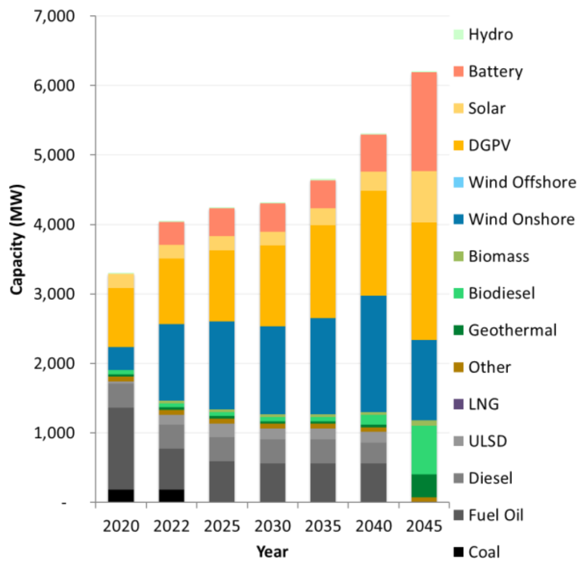


Table 19. Cumulative total resource cost for the Copperplate No-LNG Market DGPV case (relative to sum of individual island No-LNG Market DGPV case costs)

	Relative cumulative total resource costs						
	2020	**2022**	**2025**	**2030**	**2035**	**2040**	**2045**
Thermal							
Variable	0.78	0.80	0.81	0.81	0.80	0.80	0.80
Fixed	0.62	0.53	0.49	0.47	0.46	0.44	0.40
Renewables							
Variable	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fixed	0.74	0.73	0.80	0.84	0.85	0.85	0.86
Battery							
Capital	0.00	0.85	0.84	0.84	0.84	0.85	0.85
Total	0.75	0.76	0.77	0.78	0.79	0.79	***0.79***

4: KEY STAKEHOLDER DEFINED CASES

Q14. PLEASE DESCRIBE THE STAKEHOLDER DEFINED INPUT ASSUMPTIONS USED TO DEFINE EACH CASE

A14. Key stakeholders defined six sensitivity cases for E3 to run through the RESOLVE model to compare against the results of the Company-defined cases. Each key stakeholder and the input assumptions used to alter the Company defined base cases are outlined below.

1. Ulupono: Increase all fuel costs by 35% above the base assumptions on all islands, to account for the hedging value provided by renewable resource against volatile future fuel prices. All other system assumptions were held constant.

2. Hawaii Gas: Hawaii Gas provided an alternate LNG fuel pricing structure from the one developed by the Companies. This sensitivity case only applies to O'ahu, as Hawaii Gas' proposal only includes delivery of LNG to O'ahu.

3. Fripp/Ulupono/Blue Planet: On behalf of Ulupono and Blue Planet, Dr. Fripp provided increased renewable technical potentials on O'ahu from resources of lower quality than the resources identified in NREL's study. Further, Dr. Fripp provided a methodology for adjusting the hourly output profiles that the Companies have provided to E3 to model more granular capacity factors of both higher and lower quality resources than the single category of shapes used in the NREL-sourced data.

4. Paniolo: Paniolo Power provided alternate capital cost information for onshore wind on Hawai'i Island. The capital cost forecasts for pumped-storage hydro was the same as provided by the Companies. The only differences in pumped-storage hydro characteristics captured in RESOLVE are:

1) fixed O&M costs ($28/kW-yr provided by Paniolo vs. $30/kW-yr provided by the Companies), and

2) higher roundtrip efficiency of 85% instead of the 80% provided by the Companies.

In this sensitivity case, E3 paired 30 MW of onshore wind with 30 MW of pumped-storage hydro. Because Paniolo did not provide an alternate hourly profile for its wind unit performance, E3 used the same hourly profiles provided by the Companies to model the paired Paniolo project.

Table 20. Paniolo PSH capital costs

Year	Capital Cost (2016 $/kW)
2020	$2,295
2022	$2,224
2025	$2,117
2030	$1,938
2035	$1,868
2040	$1,798
2045	$1,728

5. Consumer Advocate No LNG: The Consumer Advocate asked E3 to use RESOLVE to test the impact of not meeting the state's Renewable Portfolio Standard as part of its long-term plan, with the goal of estimating how different a least-cost portfolio might look from one that meets the state's clean energy goals.

To run this sensitivity, the RPS target in each study year was removed, such that RESOLVE could choose the least-cost portfolio to meet energy and capacity needs. Some minor input assumptions were also changed, such as allowing the AES coal plant on Oahu to continue beyond 2022.

5. Consumer Advocate LNG: Using similar input assumption as the Consumer Advocate No LNG case, E3 ran a case where the LNG fuel forecast was extended through 2045 to estimate how LNG would affect the least-cost portfolio.

6. DBEDT: DBEDT asked E3 to run a case in which the military power units on Oahu (MCBH and JBPHH) are not planned, but the model is given the option of procuring resources with similar cost and performance characteristics.

Q15. PLEASE DESCRIBE THE RESOLVE MODEL RESULTS FOR EACH OF THE THIRD PARTY DEFINED CASES

A15. Capacity graphs and cost tables, as described in Q9 and Q10, show utilized installed capacities and the cost of the cases relative to the base cases as defined in Q9: No-LNG Market DGPV forecast cases.

1. Ulupono Fuel Hedge Cases

Ulupono fuel hedge case results in little difference as compared to the base case no-LNG. The model chooses to maximize renewable build during the first five-year period and is constrained more by transmission and operations than by economics. During the middle years, each island adds steadily more renewable capacity. The final build is very similar, the difference being that renewable sources are built a few years earlier. For example, on Oahu offshore wind sources are built in 2020 and 2022, whereas in the base case they are not built until later years.

From a renewable energy perspective, the fuel hedge cases show that considering the hedge value of renewables on each island further increases the amount of energy from variable resources above the fraction generated in the No-LNG base case. The effect is relatively small on Maui and the Big Island because renewables are already very competitive against thermal generation prior to the fuel price hedge on these islands. Sales from renewables increase significantly on Oahu, however, because of the lower quality/higher cost renewable resource options. The increase in fuel price in the hedge scenario improves the competitiveness of renewables such that it is economical to procure significantly above RPS levels.

In the cost tables below we show the fuel price hedge as an actual cost, making these scenarios appear to be substantially more costly than the base case. If the hedge is not used as an actual cost, but only as a planning assumption, then the thermal variable cost increases shown in the tables below would not exist (they would be actually lower than 1 because there is less fuel burn due to the higher renewable build) and this plan would only be slightly higher cost than the base case on Oahu and nearly close to the base case on the neighbor islands.

Table 21. Portion of annual electricity from RPS-eligible sources in Ulupono fuel hedge cases compared to Company cases.

Oahu	2020	2022	2025	2030	2035	2040	2045
LNG Base	33%	35%	37%	40%	41%	70%	100%
No-LNG Base	33%	37%	55%	65%	71%	75%	100%
No-LNG fuel hedge	43%	53%	74%	79%	81%	85%	100%
Maui	**2020**	**2022**	**2025**	**2030**	**2035**	**2040**	**2045**
LNG Base	49%	61%	61%	63%	64%	70%	100%
No-LNG Base	54%	75%	74%	76%	77%	83%	100%
No-LNG fuel hedge	57%	77%	79%	81%	85%	87%	100%
Hawaii	**2020**	**2022**	**2025**	**2030**	**2035**	**2040**	**2045**
LNG Base	63%	76%	78%	80%	79%	80%	100%
No-LNG Base	63%	82%	83%	85%	87%	88%	100%
No-LNG fuel hedge	71%	86%	87%	88%	90%	90%	100%

Oahu Results

Figure 20. Oahu No-LNG Market DGPV Ulupono fuel hedge utilized capacity results

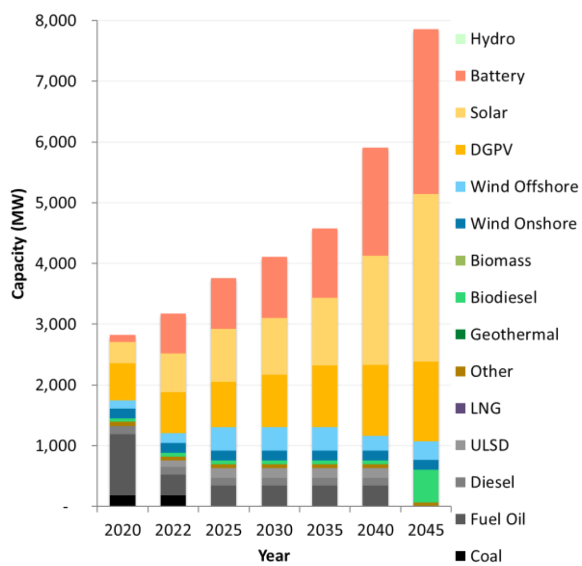


Table 22. Cumulative total resource cost for the Oahu No-LNG Market DGPV Ulupono fuel hedge case (relative to Oahu No-LNG Market DGPV case)

	Relative cumulative total resource costs						
	2020	2022	2025	2030	2035	2040	2045
Thermal							
Variable	1.09	1.01	0.92	0.90	0.89	0.89	0.90
Fixed	0.86	0.80	0.76	0.74	0.73	0.72	0.75
Renewables							

Variable	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fixed	2.67	2.62	2.15	1.83	1.68	1.57	1.41
Battery							
Capital	*Div by 0*	2.04	1.91	1.86	1.77	1.76	1.50
Total	1.27	1.24	1.21	1.19	1.18	1.16	***1.14***

Maui Results

Figure 21. Maui No-LNG Market DGPV Ulupono fuel hedge utilized capacity results

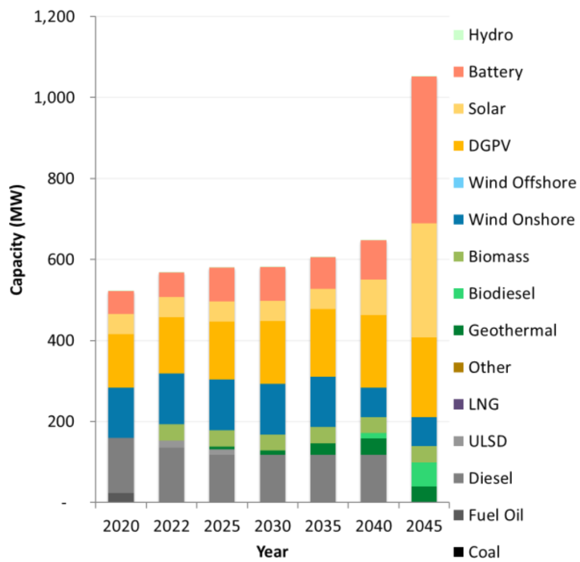


Table 23. Cumulative total resource cost for the Maui No-LNG Market DGPV Ulupono fuel hedge case (relative to Maui No-LNG Market DGPV case)

	Relative cumulative total resource costs						
	2020	**2022**	**2025**	**2030**	**2035**	**2040**	**2045**
Thermal							
Variable	1.36	1.31	1.26	1.22	1.18	1.18	1.17
Fixed	0.67	0.80	0.92	0.98	1.06	1.06	1.04
Renewables							
Variable	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fixed	1.29	1.28	1.27	1.26	1.21	1.19	1.16
Battery							
Capital	*Div by 0*	4.84	2.28	1.88	1.63	1.58	1.40
Total	1.29	1.22	1.20	1.18	1.17	1.16	***1.14***

Hawai'i Island Results

Figure 22. Hawai'i Island No-LNG Market DGPV Ulupono fuel hedge utilized capacity results

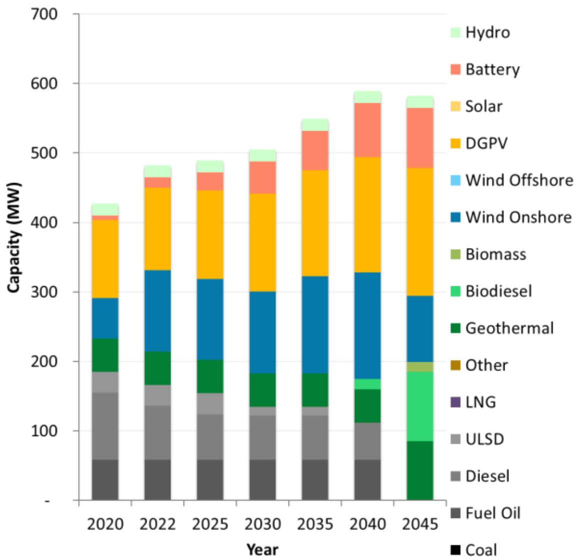


Table 24. Cumulative total resource cost for the Hawai'i Island No-LNG Market DGPV Ulupono fuel hedge case (relative to Hawai'i Island No-LNG Market DGPV case)

	Relative cumulative total resource costs						
	2020	2022	2025	2030	2035	2040	2045
Thermal							
Variable	1.13	1.13	1.13	1.13	1.13	1.14	1.11
Fixed	1.78	1.78	1.78	1.79	1.79	1.80	1.74
Renewables							
Variable	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fixed	1.00	0.98	0.98	0.98	0.99	0.98	0.93
Battery							
Capital	0.45	0.66	0.85	0.96	1.02	1.01	0.96
Total	1.19	1.19	1.19	1.19	1.19	1.18	***1.16***

2. Hawaii Gas Cases for Oahu

The Hawaii Gas case looks very similar to that of the base LNG case on Hawaii. The Hawaii Gas proposal is less expensive than the base LNG proposal on Oahu, but the actual difference is slightly smaller than the difference portrayed here, as the HECO LNG proposal gives Oahu responsibility for all hub import costs for all three islands as described above. The Hawaii Gas proposal results in LNG units being converted, but no new thermal resources being built during the early years. The renewable build is pushed to later years, but once again the final build in 2045 is similar to the base case build.

Oahu Results

Figure 23. Oahu Hawaii Gas LNG Market DGPV utilized capacity results

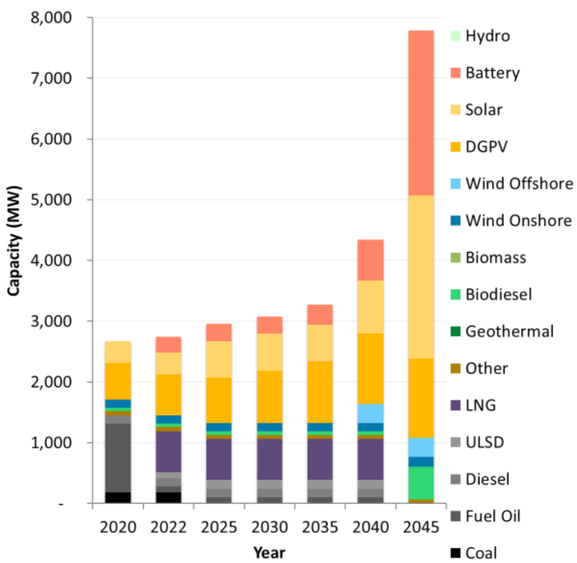


Table 25. Cumulative total resource cost for the Oahu Hawaii Gas LNG Market DGPV case (relative to Oahu No-LNG Market DGPV case)

	Relative cumulative total resource costs						
	2020	2022	2025	2030	2035	2040	2045
Thermal							
Variable	1.00	0.92	0.91	0.92	0.93	0.90	0.90
Fixed	1.00	1.44	1.73	1.89	1.97	2.02	1.92
Renewables							
Variable	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fixed	1.00	0.90	0.70	0.61	0.58	0.63	0.74
Battery							
Capital	0.00	0.61	0.62	0.58	0.56	0.56	0.71
Total	1.00	0.95	0.91	0.88	0.85	0.85	***0.87***

3. Fripp/Ulupono/Blue Planet Enhanced Renewable Potentials on Oahu Cases

The main difference to note in the enhanced renewables potential case is the large increase in onshore wind capacity. The previous new onshore wind potential was only 30 MW (incremental to wind online by 2020), whereas now there are more than 2000 MW of potential capacity. The model does not build to the maximum onshore potential, but it does build close to 500 MW of new onshore wind resource. Once again, while these results are indicative of the kinds of renewable build Oahu might expect to build, we expect that the actual build will be contingent on the kinds of real world resources and costs which are received during an RFO.

Oahu Results

Figure 24. Enhanced renewable potential case No-LNG Market DGPV utilized capacity results

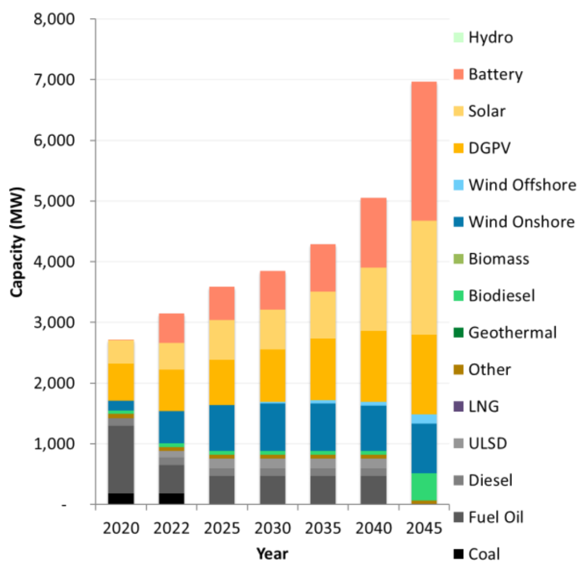


Table 26. Cumulative total resource cost for the Oahu Enhanced renewable potential No-LNG Market DGPV case (relative to Oahu No-LNG Market DGPV case)

	Relative cumulative total resource costs						
	2020	2022	2025	2030	2035	2040	2045
Thermal							
Variable	0.96	0.86	0.82	0.82	0.82	0.82	0.82
Fixed	0.97	0.93	0.90	0.88	0.87	0.87	0.83
Renewables							
Variable	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fixed	1.22	1.71	1.49	1.33	1.25	1.20	1.13
Battery							
Capital	*Div by 0*	1.17	1.18	1.16	1.14	1.13	1.03
Total	0.99	0.99	0.98	0.98	0.97	0.97	***0.96***

4. Paniolo Wind + Pumped Storage on Hawai'i Island

The Paniolo wind and pumped-storage on Hawai'i Island case adds 30 MW of wind and 30 MW of pumped-storage hydro (PSH), with slight cost and performance changes to the base case assumptions. In this case, the combination of 30 MW of wind and 30 MW of PSH is added as a planned installation, that comes online in 2022, around which RESOLVE can optimize a least cost resource portfolio.

The results below show that the onshore wind build is very similar to the base case, with the 30 MW of Paniolo wind simply displacing 30 MW of other grid-scale onshore wind in the near-term. Compared to the base case, the 30 MW pumped-storage facility is much larger than the batteries built as a RESOLVE decision (14 MW by 2022). Further, PSH costs are higher than those of batteries, resulting in over 300% higher capital cost related to batteries* (which encompasses both batteries and Paniolo PSH in this case). On a total resource cost basis, the higher PSH cost results in a 13% increase relative to the base case under the normal operations considered by RESOLVE.

Hawai'i Island Results

Figure 25. Paniolo Wind + Pumped Storage case No-LNG Market DGPV utilized capacity results

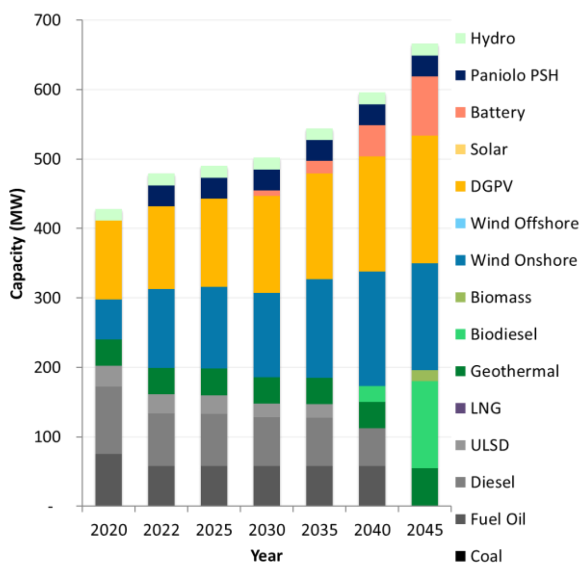


Table 27. Cumulative total resource cost for the Paniolo Wind + Pumped Storage case (relative to Hawai'i Island No-LNG Market DGPV case)

	Relative cumulative total resource costs						
	2020	2022	2025	2030	2035	2040	2045
Thermal							
Variable	1.02	1.01	1.00	1.00	1.00	1.00	1.00
Fixed	1.19	1.09	1.05	1.04	1.04	1.03	0.99
Renewables							
Variable	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fixed	1.05	1.02	1.04	1.05	1.05	1.05	1.05
Battery*							
Capital	0.00	2.86	3.82	3.72	3.72	3.59	3.37
Total	1.01	1.08	1.12	1.13	1.13	1.13	***1.13***

** Battery category includes pumped-storage hydro, which is a planned addition and not a RESOLVE decision*

5. Consumer Advocate No LNG No-RPS Constraint Cases

The Consumer Advocate no-RPS case results in a significantly different resource build on Oahu. The AES coal plant is kept online through 2045, which reduces the amount of other thermal usage as the price of coal remains below that of the liquid fuels. Furthermore, the thermal plants are used at a higher capacity factor than in the RPS constrained cases. There is still a significant amount of solar, batteries, and a smaller amount of offshore wind resources which are used because the renewable resources are cost competitive for energy, especially in later years of the plan. On Oahu, removing the RPS constraint leads to a case with total resource cost which is 87% of the RPS-constrained case.

On Maui and Hawai'i, however, the higher quality renewable resources are cost competitive with fuels such that the model chooses to build similar amounts of renewable sources, even in a non-RPS constrained world. The cost difference between the RPS-constrained and non-RPS-constrained cases is much smaller on these islands, with only a 1% difference on Maui and 2% difference on Hawai'i.

Oahu Results

Figure 26. Consumer Advocate Oahu No-RPS No-LNG Market DGPV utilized capacity results

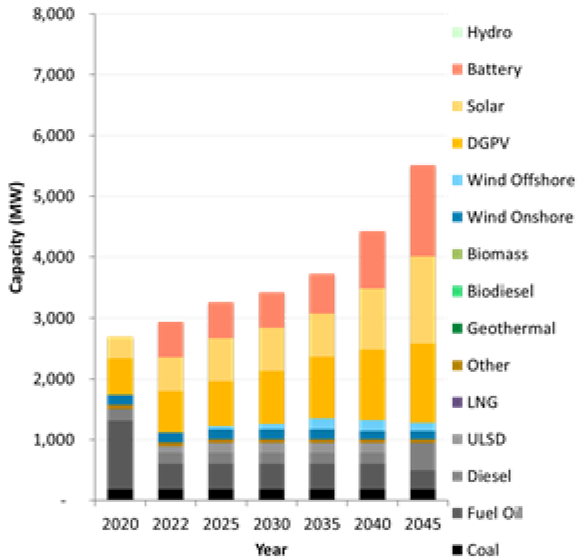


Table 28. Cumulative total resource cost for the Oahu No-RPS No-LNG Market DGPV case (relative to Oahu No-LNG Market DGPV case)

	Relative cumulative total resource costs						
	2020	2022	2025	2030	2035	2040	2045
Thermal							
Variable	0.99	0.97	0.89	0.87	0.86	0.86	0.94
Fixed	1.00	0.92	0.91	0.90	0.90	0.90	0.91
Renewables							
Variable	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fixed	1.13	1.22	0.97	0.87	0.84	0.84	0.77
Battery							
Capital	0.00	1.38	1.33	1.25	1.18	1.13	0.94
Total	1.00	1.01	0.93	0.90	0.88	0.87	***0.87***

Maui Results

Figure 27. Consumer Advocate Maui No-RPS No-LNG Market DGPV utilized capacity results

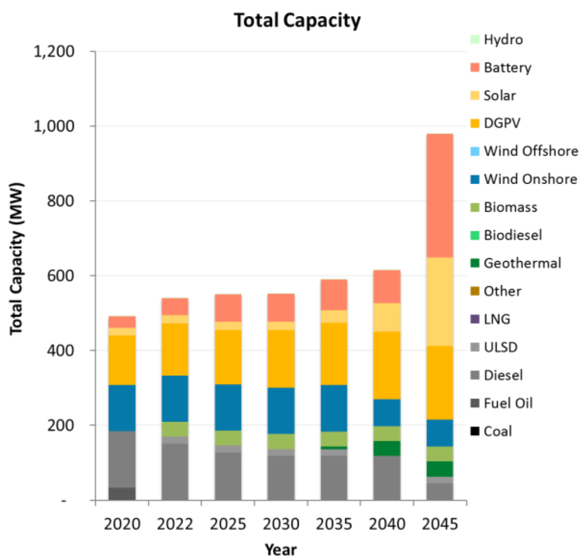


Table 29. Cumulative total resource cost for the Maui No-RPS No-LNG Market DGPV case (relative to Maui No-LNG Market DGPV case)

	Relative cumulative total resource costs						
	2020	2022	2025	2030	2035	2040	2045
Thermal							
Variable	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fixed	0.64	0.82	0.89	0.91	0.94	0.95	0.96
Renewables							
Variable	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fixed	0.96	0.96	0.97	0.97	0.96	0.96	0.96
Battery							
Capital	*Div by 0*	2.98	1.62	1.41	1.28	1.26	1.15
Total	0.97	0.98	0.99	0.99	0.99	0.99	***0.99***

Hawai'i Island Results

Figure 28. Consumer Advocate Hawai'i Island No-RPS No-LNG Market DGPV utilized capacity results

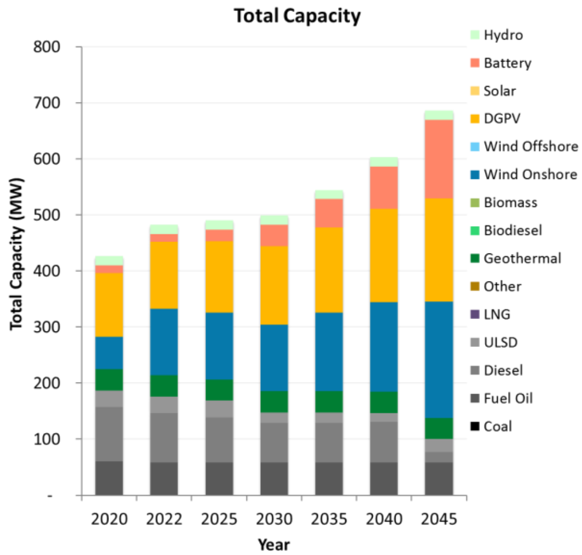


Table 30. Cumulative total resource cost for the Hawai'i Island No-RPS No-LNG Market DGPV case (relative to Hawai'i Island No-LNG Market DGPV case)

	Relative cumulative total resource costs						
	2020	2022	2025	2030	2035	2040	2045
Thermal							
Variable	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fixed	1.00	1.00	1.00	1.00	1.00	1.00	0.74
Renewables							
Variable	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fixed	1.00	1.00	1.00	1.00	1.00	1.00	1.08
Battery							
Capital	1.00	1.00	1.00	1.00	1.00	0.98	1.06
Total	1.00	1.00	1.00	1.00	1.00	1.00	***0.98***

6. Consumer Advocate LNG No-RPS Constraint Cases

In the Consumer Advocate LNG No-RPS Constraint case, we extend the LNG fuel price forecast through 2045 to allow thermal units that burn LNG to continue economic operation throughout the planning horizon.

Similar to the Consumer Advocate No LNG case above, the LNG case shows significantly different build on each island; however, more thermal plants stay online throughout the planning horizon on all islands due to the low fuel cost associated with LNG. Further, low cost LNG discourages significant grid-scale renewable buildout, which is most apparent with the reduction in grid-scale solar on Oahu and Maui in 2045. As noted in Table 3, while both Consumer Advocate No-RPS Constraint cases results in sub-100% RPS-eligible energy, the LNG case results in significantly lower energy from RPS-eligible resources on all islands. From a cost perspective, the LNG No-RPS Constraint case results in a 5-7 percentage point reduction below the Company No-LNG Market DGPV case.

Oahu Results

Figure 29. Consumer Advocate Oahu No-RPS No-LNG Market DGPV utilized capacity results

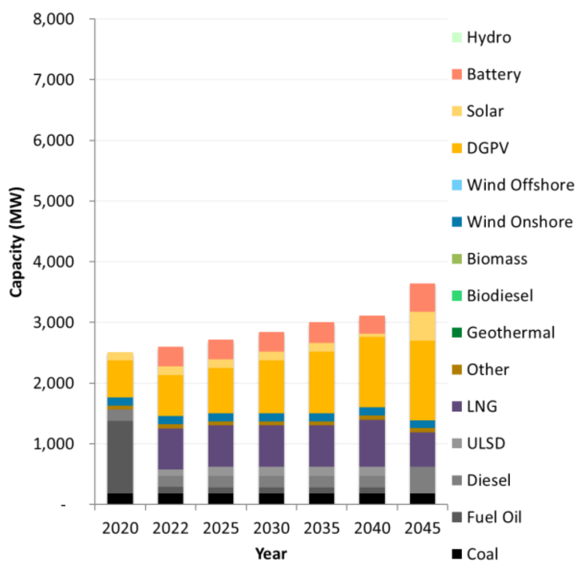


Table 31. Cumulative total resource cost for the Oahu No-RPS No-LNG Market DGPV case (relative to Oahu No-LNG Market DGPV case)

	Relative cumulative total resource costs						
	2020	2022	2025	2030	2035	2040	2045
Thermal							
Variable	1.09	0.88	0.76	0.72	0.70	0.69	0.74
Fixed	1.06	3.31	4.87	5.71	6.13	6.40	6.90
Renewables							
Variable	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fixed	0.34	0.37	0.27	0.26	0.27	0.29	0.29
Battery							
Capital	0.00	0.76	0.74	0.69	0.65	0.60	0.45
Total	1.01	1.02	0.94	0.90	0.87	0.85	***0.84***

Maui Results

Figure 30. Consumer Advocate Maui No-RPS No-LNG Market DGPV utilized capacity results

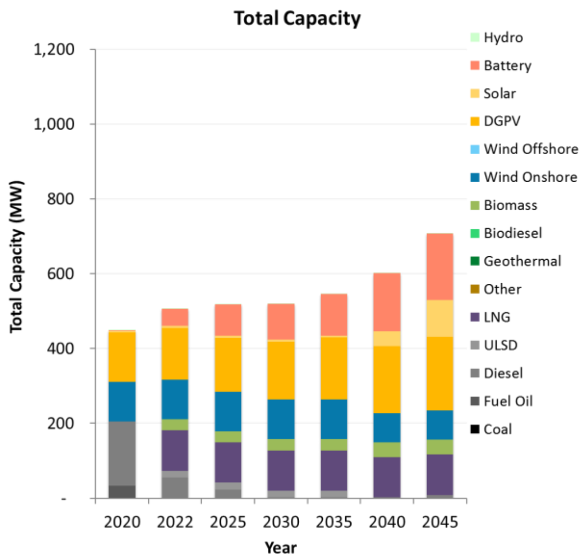


Table 32. Cumulative total resource cost for the Maui No-RPS No-LNG Market DGPV case (relative to Maui No-LNG Market DGPV case)

	Relative cumulative total resource costs						
	2020	2022	2025	2030	2035	2040	2045
Thermal							
Variable	1.17	1.01	0.90	0.82	0.78	0.76	0.81
Fixed	0.80	0.92	0.97	0.97	0.96	0.90	0.83
Renewables							
Variable	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fixed	0.51	0.53	0.55	0.57	0.58	0.61	0.60
Battery							
Capital	*Div by 0*	1.39	1.21	1.23	1.24	1.29	1.02
Total	0.99	0.92	0.88	0.85	0.83	0.81	***0.80***

Hawai'i Island Results

Figure 31. Consumer Advocate Hawai'i Island No-RPS No-LNG Market DGPV utilized capacity results

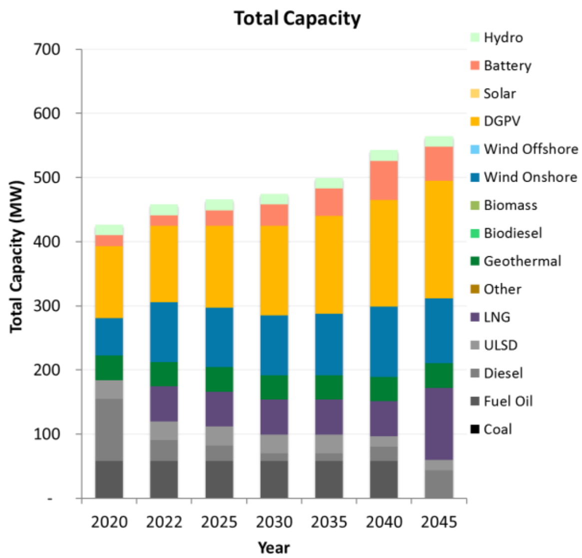


Table 33. Cumulative total resource cost for the Hawai'i Island No-RPS No-LNG Market DGPV case (relative to Hawai'i Island No-LNG Market DGPV case)

	Relative cumulative total resource costs						
	2020	2022	2025	2030	2035	2040	2045
Thermal							
Variable	1.00	0.90	0.82	0.76	0.73	0.71	0.75
Fixed	0.97	1.15	1.24	1.29	1.32	1.34	1.04
Renewables							
Variable	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fixed	1.00	0.78	0.76	0.76	0.75	0.75	0.75
Battery							
Capital	1.19	1.19	1.18	1.09	1.04	1.00	0.87
Total	1.00	0.93	0.89	0.86	0.83	0.82	***0.81***

7. DBEDT No Military Units on Oahu

In the DBEDT no military unit case the Marine Corps Base Hawaii (MCBH) and Joint Base Pearl Harbor-Hickam (JBPHH) diesel power plants are not built. The model is given the option of procuring units with the same cost and performance characteristics, but RESOLVE chooses not to invest until 2045, when it procures biodiesel units with similar cost and performance characteristics to the military units. In the base case the Companies have assumed that the military units have planned fuel switching to biodiesel in 2045. RESOLVE optimizes to minimize costs by assuming normal operating conditions, with hourly reserve requirements specified by the Companies. However, RESOLVE does not capture the detailed transmission, power flow, and contingency constraints necessary to fully determine the need for new generation. These results act as a preliminary starting point based on planning level economics that will require further investigation by both parties and the Companies.

Oahu Results

Figure 32. DBEDT Oahu no military unit No-LNG Market DGPV utilized capacity

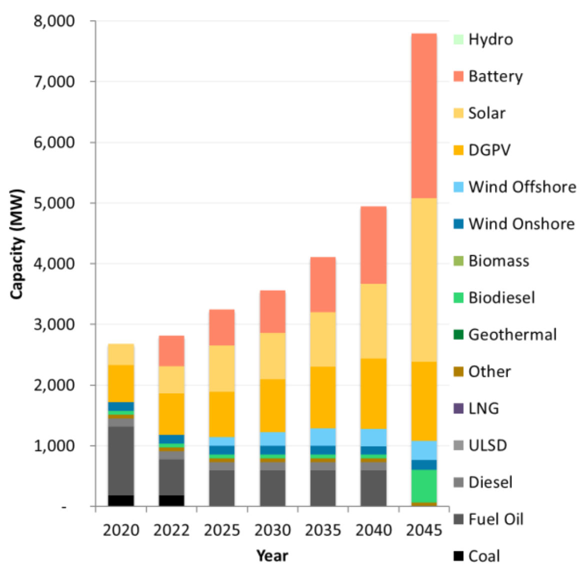


Table 34. Cumulative total resource cost for the DBEDT Oahu no military unit No-LNG Market DGPV case (relative to Oahu No-LNG Market DGPV case)

	Relative cumulative total resource costs						
	2020	2022	2025	2030	2035	2040	2045
Thermal							
Variable	0.99	0.99	0.98	0.99	0.99	0.99	0.99
Fixed	1.00	0.99	0.98	0.97	0.96	0.96	1.04
Renewables							
Variable	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fixed	1.07	1.05	1.06	1.03	1.02	1.02	1.01
Battery							
Capital	0.00	1.19	1.24	1.24	1.23	1.23	1.15
Total	1.00	1.01	1.01	1.02	1.02	1.02	***1.02***

APPENDIX A: COMPANIES SENSITIVITY CASE DATA

The results shown in this appendix give the total MWs of each resource through 2045. Utilized capacity are resources that RESOLVE chooses to operate for least cost economic dispatch, and to meet system reserve needs. Unutilized capacity are defined in MWs that RESOLVE does not need to meet system constraints. These are candidate MWs for retirement, should the more detailed analysis conducted by the Companies show retirement is warranted.

No-LNG Market DGPV Installed Capacities

Oahu Results

Table 35. Oahu No-LNG Market DGPV

	Utilized Capacity (MW) / Unutilized Capacity (MW)						
	2020	**2022**	**2025**	**2030**	**2035**	**2040**	**2045**
Coal	180/-	180/-	-/-	-/-	-/-	-/-	-/-
Fuel Oil	1138/148	579/94	579/-	579/-	579/-	579/-	-/-
Diesel	130/-	130/-	130/-	130/-	130/-	130/-	-/-
ULSD	-/-	100/-	154/-	154/-	154/-	154/-	-/-
LNG	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Other	69/-	69/-	69/-	69/-	69/-	69/-	69/-
Geothermal	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Biodiesel	57/-	57/-	57/-	57/-	57/-	57/-	534/-
Biomass	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Wind Onshore	134/-	134/-	134/-	134/-	134/-	134/-	164/-
Wind Offshore	-/-	-/-	119/-	237/-	314/-	314/-	312/-
DGPV	606/-	680/-	745/-	869/-	1015/-	1163/-	1308/-
Solar	354/-	446/-	763/-	763/-	829/-	1161/-	2693/-
Battery	-/-	426/-	456/-	571/-	747/-	1079/-	2714/-
Hydro	-/-	-/-	-/-	-/-	-/-	-/-	-/-

Maui Results

Table 36. Maui No-LNG Market DGPV

Utilized Capacity (MW) / Unutilized Capacity (MW)							
	2020	**2022**	**2025**	**2030**	**2035**	**2040**	**2045**
Coal	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Fuel Oil	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Diesel	201/-	163/38	128/73	118/71	118/82	118/82	-/-
ULSD	-/-	18/-	18/-	18/-	18/-	-/-	-/-
LNG	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Other	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Geothermal	-/-	-/-	-/-	-/-	3/-	40/-	40/-
Biodiesel	-/-	-/-	-/-	-/-	-/-	-/-	61/-
Biomass	-/-	40/-	40/-	40/-	40/-	40/-	40/-
Wind Onshore	139/-	139/-	139/-	139/-	139/-	72/-	72/-
Wind Offshore	-/-	-/-	-/-	-/-	-/-	-/-	-/-
DGPV	132/-	139/-	144/-	155/-	166/-	180/-	196/-
Solar	5/-	5/-	5/-	5/-	28/-	77/-	259/-
Battery	-/-	34/-	75/-	75/-	85/-	87/-	346/-
Hydro	1/-	1/-	1/-	1/-	1/-	1/-	1/-

Hawai'i Island Results

Table 37. Hawai'i Island No-LNG Market DGPV

Utilized Capacity (MW) / Unutilized Capacity (MW)							
	2020	**2022**	**2025**	**2030**	**2035**	**2040**	**2045**
Coal	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Fuel Oil	61/46	58/49	58/49	58/49	58/49	58/-	-/-
Diesel	97/-	88/8	81/16	71/25	71/25	54/-	-/-
ULSD	30/-	30/-	30/-	19/11	19/11	-/-	-/-
LNG	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Other	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Geothermal	38/-	38/-	38/-	38/-	38/-	38/-	55/-
Biodiesel	-/-	-/-	-/-	-/-	-/-	31/-	118/-
Biomass	-/-	-/-	-/-	-/-	-/-	-/-	22/-
Wind Onshore	58/-	119/-	119/-	119/-	140/-	161/-	140/-
Wind Offshore	-/-	-/-	-/-	-/-	-/-	-/-	-/-
DGPV	113/-	119/-	127/-	140/-	152/-	166/-	184/-
Solar	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Battery	14/-	14/-	21/-	38/-	50/-	82/-	109/-
Hydro	17/-	17/-	17/-	17/-	17/-	17/-	17/-

No-LNG High DGPV Installed Capacities

Oahu Results

Table 38. Oahu No-LNG High DGPV

	Utilized Capacity (MW) / Unutilized Capacity (MW)						
	2020	**2022**	**2025**	**2030**	**2035**	**2040**	**2045**
Coal	180/-	180/-	-/-	-/-	-/-	-/-	-/-
Fuel Oil	1138/148	579/94	579/-	579/-	579/-	579/-	-/-
Diesel	130/-	130/-	130/-	130/-	130/-	130/-	-/-
ULSD	-/-	100/-	154/-	154/-	154/-	154/-	-/-
LNG	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Other	69/-	69/-	69/-	69/-	69/-	69/-	69/-
Geothermal	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Biodiesel	57/-	57/-	57/-	57/-	57/-	57/-	514/-
Biomass	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Wind Onshore	134/-	134/-	134/-	134/-	134/-	134/-	164/-
Wind Offshore	-/-	-/-	143/-	214/-	265/-	265/-	273/-
DGPV	606/-	730/-	907/-	1216/-	1524/-	1833/-	2142/-
Solar	354/-	401/-	595/-	595/-	595/-	876/-	2052/-
Battery	-/-	426/-	455/-	620/-	788/-	1208/-	2733/-
Hydro	-/-	-/-	-/-	-/-	-/-	-/-	-/-

Maui Results

Table 39. Maui No-LNG High DGPV

	Utilized Capacity (MW) / Unutilized Capacity (MW)						
	2020	**2022**	**2025**	**2030**	**2035**	**2040**	**2045**
Coal	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Fuel Oil	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Diesel	201/-	165/36	128/73	118/71	118/82	118/82	-/-
ULSD	-/-	18/-	18/-	18/-	18/-	-/-	-/-
LNG	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Other	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Geothermal	-/-	-/-	-/-	-/-	-/-	37/-	40/-
Biodiesel	-/-	-/-	-/-	-/-	-/-	-/-	57/-
Biomass	-/-	40/-	40/-	40/-	40/-	40/-	40/-
Wind Onshore	126/-	126/-	126/-	126/-	126/-	72/-	72/-
Wind Offshore	-/-	-/-	-/-	-/-	-/-	-/-	-/-
DGPV	132/-	140/-	178/-	243/-	307/-	371/-	435/-
Solar	5/-	5/-	5/-	5/-	5/-	5/-	127/-
Battery	-/-	32/-	75/-	75/-	89/-	121/-	362/-
Hydro	1/-	1/-	1/-	1/-	1/-	1/-	1/-

Hawai'i Island Results

Table 40. Hawai'i Island No-LNG High DGPV

Utilized Capacity (MW) / Unutilized Capacity (MW)							
	2020	**2022**	**2025**	**2030**	**2035**	**2040**	**2045**
Coal	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Fuel Oil	61/46	58/49	58/49	58/49	58/49	58/-	-/-
Diesel	97/-	89/7	77/19	64/33	64/33	54/-	-/-
ULSD	30/-	30/-	30/-	5/25	5/25	-/-	-/-
LNG	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Other	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Geothermal	38/-	38/-	38/-	38/-	38/-	38/-	38/-
Biodiesel	-/-	-/-	-/-	-/-	-/-	20/-	110/-
Biomass	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Wind Onshore	58/-	109/-	109/-	109/-	109/-	108/-	139/-
Wind Offshore	-/-	-/-	-/-	-/-	-/-	-/-	-/-
DGPV	115/-	131/-	174/-	244/-	315/-	386/-	456/-
Solar	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Battery	14/-	14/-	25/-	66/-	86/-	131/-	205/-
Hydro	17/-	17/-	17/-	17/-	17/-	17/-	17/-

LNG Market DGPV Installed Capacities

Oahu Results

Table 41. Oahu LNG Market DGPV

Utilized Capacity (MW) / Unutilized Capacity (MW)							
	2020	**2022**	**2025**	**2030**	**2035**	**2040**	**2045**
Coal	180/-	180/-	-/-	-/-	-/-	-/-	-/-
Fuel Oil	1138/148	103/94	103/-	103/-	103/-	103/-	-/-
Diesel	130/-	130/-	130/-	130/-	130/-	130/-	-/-
ULSD	-/-	100/-	154/-	154/-	154/-	154/-	-/-
LNG	-/-	679/-	679/-	679/-	679/-	679/-	-/-
Other	69/-	69/-	69/-	69/-	69/-	69/-	69/-
Geothermal	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Biodiesel	57/-	57/-	57/-	57/-	57/-	57/-	529/-
Biomass	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Wind Onshore	134/-	134/-	134/-	134/-	134/-	134/-	164/-
Wind Offshore	-/-	-/-	-/-	-/-	-/-	320/-	320/-
DGPV	606/-	680/-	745/-	869/-	1015/-	1163/-	1308/-
Solar	354/-	354/-	372/-	372/-	372/-	853/-	2654/-
Battery	-/-	257/-	357/-	357/-	424/-	619/-	2715/-
Hydro	-/-	-/-	-/-	-/-	-/-	-/-	-/-

Maui Results

Table 42. Maui LNG Market DGPV

Utilized Capacity (MW) / Unutilized Capacity (MW)							
	2020	2022	2025	2030	2035	2040	2045
Coal	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Fuel Oil	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Diesel	201/-	81/14	33/62	-/84	-/95	-/95	-/-
ULSD	-/-	18/-	18/-	18/-	18/-	-/-	-/-
LNG	-/-	108/-	108/-	108/-	108/-	108/-	-/-
Other	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Geothermal	-/-	-/-	-/-	-/-	-/-	-/-	40/-
Biodiesel	-/-	-/-	-/-	-/-	-/-	-/-	61/-
Biomass	-/-	20/-	20/-	20/-	26/-	40/-	40/-
Wind Onshore	119/-	119/-	119/-	119/-	119/-	72/-	72/-
Wind Offshore	-/-	-/-	-/-	-/-	-/-	-/-	-/-
DGPV	132/-	139/-	144/-	155/-	166/-	180/-	196/-
Solar	5/-	5/-	5/-	5/-	5/-	110/-	259/-
Battery	-/-	30/-	84/-	107/-	117/-	159/-	346/-
Hydro	1/-	1/-	1/-	1/-	1/-	1/-	1/-

Hawai'i Island Results

Table 43. Hawai'i Island Market DGPV

Utilized Capacity (MW) / Unutilized Capacity (MW)							
	2020	2022	2025	2030	2035	2040	2045
Coal	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Fuel Oil	58/49	58/49	58/49	58/49	58/49	58/-	-/-
Diesel	97/-	32/11	24/19	12/31	12/31	-/-	-/-
ULSD	30/-	30/-	30/-	30/-	30/-	-/-	-/-
LNG	-/-	55/-	55/-	55/-	55/-	55/-	-/-
Other	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Geothermal	38/-	38/-	38/-	38/-	38/-	38/-	55/-
Biodiesel	-/-	-/-	-/-	-/-	-/-	34/-	118/-
Biomass	-/-	-/-	-/-	-/-	-/-	-/-	22/-
Wind Onshore	58/-	93/-	93/-	93/-	96/-	109/-	140/-
Wind Offshore	-/-	-/-	-/-	-/-	-/-	-/-	-/-
DGPV	113/-	119/-	127/-	140/-	152/-	166/-	184/-
Solar	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Battery	17/-	17/-	25/-	33/-	43/-	66/-	109/-
Hydro	17/-	17/-	17/-	17/-	17/-	17/-	17/-

LNG High DGPV Installed Capacities

Oahu Results

Table 44. Oahu LNG High DGPV

Utilized Capacity (MW) / Unutilized Capacity (MW)							
	2020	2022	2025	2030	2035	2040	2045
Coal	180/-	180/-	-/-	-/-	-/-	-/-	-/-
Fuel Oil	1173/114	103/94	103/-	29/74	29/74	29/74	-/-
Diesel	130/-	130/-	130/-	130/-	130/-	130/-	-/-
ULSD	-/-	100/-	154/-	154/-	154/-	154/-	-/-
LNG	-/-	679/-	679/-	679/-	679/-	679/-	-/-
Other	69/-	69/-	69/-	69/-	69/-	69/-	69/-
Geothermal	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Biodiesel	57/-	57/-	57/-	57/-	57/-	57/-	502/-
Biomass	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Wind Onshore	134/-	134/-	134/-	134/-	134/-	134/-	164/-
Wind Offshore	-/-	-/-	-/-	-/-	-/-	297/-	297/-
DGPV	606/-	730/-	907/-	1216/-	1524/-	1833/-	2142/-
Solar	227/-	227/-	227/-	227/-	227/-	410/-	1938/-
Battery	-/-	285/-	357/-	357/-	357/-	723/-	2736/-
Hydro	-/-	-/-	-/-	-/-	-/-	-/-	-/-

Maui Results

Table 45. Maui LNG High DGPV

Utilized Capacity (MW) / Unutilized Capacity (MW)							
	2020	2022	2025	2030	2035	2040	2045
Coal	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Fuel Oil	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Diesel	201/-	85/10	33/62	-/84	-/95	-/95	-/-
ULSD	-/-	18/-	18/-	18/-	18/-	-/-	-/-
LNG	-/-	108/-	108/-	108/-	108/-	108/-	-/-
Other	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Geothermal	-/-	-/-	-/-	-/-	-/-	-/-	40/-
Biodiesel	-/-	-/-	-/-	-/-	-/-	-/-	57/-
Biomass	-/-	20/-	20/-	20/-	20/-	40/-	40/-
Wind Onshore	110/-	110/-	110/-	110/-	110/-	72/-	72/-
Wind Offshore	-/-	-/-	-/-	-/-	-/-	-/-	-/-
DGPV	132/-	140/-	178/-	243/-	307/-	371/-	435/-
Solar	5/-	5/-	5/-	5/-	5/-	5/-	127/-
Battery	-/-	26/-	84/-	110/-	125/-	161/-	362/-
Hydro	1/-	1/-	1/-	1/-	1/-	1/-	1/-

Hawai'i Island Results

Table 46. Hawai'i Island LNG High DGPV

Utilized Capacity (MW) / Unutilized Capacity (MW)							
	2020	2022	2025	2030	2035	2040	2045
Coal	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Fuel Oil	58/49	58/49	58/49	58/49	58/49	58/-	-/-
Diesel	97/-	33/10	20/23	10/33	10/33	-/-	-/-
ULSD	30/-	30/-	30/-	8/22	6/24	-/-	-/-
LNG	-/-	55/-	55/-	55/-	55/-	55/-	-/-
Other	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Geothermal	38/-	38/-	38/-	38/-	38/-	38/-	38/-
Biodiesel	-/-	-/-	-/-	-/-	-/-	17/-	110/-
Biomass	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Wind Onshore	58/-	73/-	73/-	73/-	73/-	53/-	139/-
Wind Offshore	-/-	-/-	-/-	-/-	-/-	-/-	-/-
DGPV	115/-	131/-	174/-	244/-	315/-	386/-	456/-
Solar	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Battery	17/-	17/-	29/-	58/-	70/-	101/-	205/-
Hydro	17/-	17/-	17/-	17/-	17/-	17/-	17/-

Uncurtailable DGPV Installed Capacities

Oahu Results

Table 47. Oahu Uncurtailable High DGPV

Utilized Capacity (MW) / Unutilized Capacity (MW)							
	2020	**2022**	**2025**	**2030**	**2035**	**2040**	**2045**
Coal	180/-	180/-	-/-	-/-	-/-	-/-	-/-
Fuel Oil	1138/148	579/94	579/-	579/-	579/-	579/-	-/-
Diesel	130/-	130/-	130/-	130/-	130/-	130/-	-/-
ULSD	-/-	100/-	154/-	154/-	154/-	154/-	-/-
LNG	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Other	69/-	69/-	69/-	69/-	69/-	69/-	69/-
Geothermal	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Biodiesel	57/-	57/-	57/-	57/-	57/-	57/-	526/-
Biomass	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Wind Onshore	134/-	134/-	134/-	134/-	134/-	134/-	164/-
Wind Offshore	-/-	-/-	57/-	190/-	190/-	190/-	250/-
DGPV	606/-	730/-	907/-	1216/-	1524/-	1833/-	2142/-
Solar	354/-	512/-	689/-	689/-	788/-	999/-	2157/-
Battery	-/-	426/-	487/-	833/-	1205/-	1495/-	2790/-
Hydro	-/-	-/-	-/-	-/-	-/-	-/-	-/-

Maui Results

Table 48. Maui Uncurtailable High DGPV

Utilized Capacity (MW) / Unutilized Capacity (MW)							
	2020	2022	2025	2030	2035	2040	2045
Coal	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Fuel Oil	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Diesel	162/38	162/38	128/73	118/71	118/82	118/82	-/-
ULSD	-/-	18/-	18/-	18/-	18/-	-/-	-/-
LNG	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Other	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Geothermal	-/-	-/-	-/-	-/-	-/-	37/-	40/-
Biodiesel	-/-	-/-	-/-	-/-	-/-	-/-	57/-
Biomass	-/-	40/-	40/-	40/-	40/-	40/-	40/-
Wind Onshore	120/-	120/-	120/-	120/-	120/-	72/-	72/-
Wind Offshore	-/-	-/-	-/-	-/-	-/-	-/-	-/-
DGPV	132/-	140/-	178/-	243/-	307/-	371/-	435/-
Solar	5/-	5/-	5/-	5/-	5/-	5/-	127/-
Battery	17/-	34/-	75/-	75/-	89/-	121/-	362/-
Hydro	1/-	1/-	1/-	1/-	1/-	1/-	1/-

Hawai'i Results

Table 49. Hawai'i Uncurtailable High DGPV

Utilized Capacity (MW) / Unutilized Capacity (MW)							
	2020	2022	2025	2030	2035	2040	2045
Coal	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Fuel Oil	61/46	58/49	58/49	58/49	58/49	58/-	-/-
Diesel	97/-	89/7	88/9	88/9	88/9	54/-	-/-
ULSD	30/-	30/-	26/3	14/16	14/16	-/-	-/-
LNG	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Other	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Geothermal	38/-	38/-	38/-	38/-	38/-	38/-	38/-
Biodiesel	-/-	-/-	-/-	-/-	-/-	60/-	131/-
Biomass	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Wind Onshore	58/-	109/-	109/-	109/-	111/-	109/-	143/-
Wind Offshore	-/-	-/-	-/-	-/-	-/-	-/-	-/-
DGPV	115/-	131/-	174/-	244/-	315/-	386/-	456/-
Solar	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Battery	14/-	14/-	24/-	65/-	88/-	129/-	229/-
Hydro	17/-	17/-	17/-	17/-	17/-	17/-	17/-

Copperplate No-LNG Installed Capacities

Copperplate Results

Table 50. Copperplate capacity results

Utilized Capacity (MW) / Unutilized Capacity (MW)							
	2020	**2022**	**2025**	**2030**	**2035**	**2040**	**2045**
Coal	180/-	180/-	-/-	-/-	-/-	-/-	-/-
Fuel Oil	1183/233	591/109	591/16	558/49	558/49	558/-	-/-
Diesel	345/82	345/82	345/82	345/71	345/82	302/82	-/-
ULSD	30/-	148/-	202/-	159/43	159/43	154/-	-/-
LNG	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Other	69/-	69/-	69/-	69/-	69/-	69/-	69/-
Geothermal	38/-	38/-	38/-	38/-	38/-	38/-	337/-
Biodiesel	57/-	57/-	57/-	57/-	57/-	142/-	693/-
Biomass	-/-	40/-	40/-	40/-	40/-	40/-	80/-
Wind Onshore	335/-	1099/-	1266/-	1266/-	1386/-	1672/-	1159/-
Wind Offshore	-/-	-/-	-/-	-/-	-/-	-/-	-/-
DGPV	851/-	939/-	1017/-	1163/-	1334/-	1509/-	1688/-
Solar	203/-	203/-	203/-	203/-	245/-	272/-	739/-
Battery	-/-	324/-	406/-	406/-	406/-	539/-	1426/-
Hydro	17/-	17/-	17/-	17/-	17/-	17/-	17/-

APPENDIX B: THIRD PARTY STAKEHOLDER SENSITIVITIES RESULTS

Ulupono Fuel Hedge Installed Capacities

Oahu Results

Table 51. Oahu No-LNG Market DGPV Ulupono fuel hedge capacity results

	Utilized Capacity (MW) / Unutilized Capacity (MW)						
	2020	**2022**	**2025**	**2030**	**2035**	**2040**	**2045**
Coal	180/-	180/-	-/-	-/-	-/-	-/-	-/-
Fuel Oil	1013/273	343/94	343/-	343/-	343/-	343/-	-/-
Diesel	130/-	130/-	130/-	130/-	130/-	130/-	-/-
ULSD	-/-	100/-	154/-	154/-	154/-	154/-	-/-
LNG	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Other	69/-	69/-	69/-	69/-	69/-	69/-	69/-
Geothermal	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Biodiesel	57/-	57/-	57/-	57/-	57/-	57/-	536/-
Biomass	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Wind Onshore	164/-	164/-	164/-	164/-	164/-	164/-	164/-
Wind Offshore	137/-	161/-	386/-	386/-	386/-	249/-	304/-
DGPV	606/-	680/-	745/-	869/-	1015/-	1163/-	1308/-
Solar	354/-	639/-	879/-	935/-	1120/-	1796/-	2758/-
Battery	117/-	650/-	830/-	1000/-	1139/-	1781/-	2720/-
Hydro	-/-	-/-	-/-	-/-	-/-	-/-	-/-

Maui Results

Table 52. Maui No-LNG Market DGPV Ulupono fuel hedge capacity results

	Utilized Capacity (MW) / Unutilized Capacity (MW)						
	2020	**2022**	**2025**	**2030**	**2035**	**2040**	**2045**
Coal	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Fuel Oil	23/-	-/-	-/-	-/-	-/-	-/-	-/-
Diesel	136/65	135/65	118/82	118/71	118/82	118/82	-/-
ULSD	-/-	18/-	13/6	-/18	-/18	-/-	-/-
LNG	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Other	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Geothermal	-/-	-/-	7/-	10/-	28/-	40/-	40/-
Biodiesel	-/-	-/-	-/-	-/-	-/-	13/-	59/-
Biomass	-/-	40/-	40/-	40/-	40/-	40/-	40/-
Wind Onshore	125/-	125/-	125/-	125/-	125/-	72/-	72/-
Wind Offshore	-/-	-/-	-/-	-/-	-/-	-/-	-/-
DGPV	132/-	139/-	144/-	155/-	166/-	180/-	196/-
Solar	50/-	50/-	50/-	50/-	50/-	88/-	282/-
Battery	56/-	61/-	83/-	83/-	79/-	97/-	363/-
Hydro	1/-	1/-	1/-	1/-	1/-	1/-	1/-

Hawai'i Island Results

Table 53. Hawai'i Island No-LNG Market DGPV Ulupono fuel hedge capacity results

	Utilized Capacity (MW) / Unutilized Capacity (MW)						
	2020	**2022**	**2025**	**2030**	**2035**	**2040**	**2045**
Coal	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Fuel Oil	58/49	58/49	58/49	58/49	58/49	58/-	-/-
Diesel	97/-	78/19	66/30	64/33	64/33	54/-	-/-
ULSD	30/-	30/-	30/-	13/16	13/16	-/-	-/-
LNG	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Other	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Geothermal	48/-	48/-	48/-	48/-	48/-	48/-	85/-
Biodiesel	-/-	-/-	-/-	-/-	-/-	15/-	100/-
Biomass	-/-	-/-	-/-	-/-	-/-	-/-	14/-
Wind Onshore	58/-	117/-	117/-	118/-	140/-	153/-	95/-
Wind Offshore	-/-	-/-	-/-	-/-	-/-	-/-	-/-
DGPV	113/-	119/-	127/-	140/-	152/-	166/-	184/-
Solar	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Battery	6/-	15/-	26/-	47/-	57/-	78/-	87/-
Hydro	17/-	17/-	17/-	17/-	17/-	17/-	17/-

Hawaii Gas Installed Capacities

Oahu Results

Table 54. Hawaii Gas capacity results for Oahu

Utilized Capacity (MW) / Unutilized Capacity (MW)							
	2020	**2022**	**2025**	**2030**	**2035**	**2040**	**2045**
Coal	180/-	180/-	-/-	-/-	-/-	-/-	-/-
Fuel Oil	1138/148	103/94	103/-	103/-	103/-	103/-	-/-
Diesel	130/-	130/-	130/-	130/-	130/-	130/-	-/-
ULSD	-/-	100/-	154/-	154/-	154/-	154/-	-/-
LNG	-/-	674/-	674/-	674/-	674/-	674/-	-/-
Other	69/-	69/-	69/-	69/-	69/-	69/-	69/-
Geothermal	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Biodiesel	57/-	57/-	57/-	57/-	57/-	57/-	532/-
Biomass	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Wind Onshore	134/-	134/-	134/-	134/-	134/-	134/-	164/-
Wind Offshore	-/-	-/-	-/-	-/-	-/-	315/-	315/-
DGPV	606/-	680/-	745/-	869/-	1015/-	1163/-	1308/-
Solar	354/-	354/-	608/-	608/-	608/-	874/-	2679/-
Battery	-/-	262/-	282/-	282/-	327/-	674/-	2715/-
Hydro	-/-	-/-	-/-	-/-	-/-	-/-	-/-

Fripp/Ulupono/Blue Planet Enhanced Renewable Potential on Oahu Installed Capacities

Oahu Results

Table 55. Enhanced renewable potential case No-LNG Market DGPV capacity results

Utilized Capacity (MW) / Unutilized Capacity (MW)							
	2020	**2022**	**2025**	**2030**	**2035**	**2040**	**2045**
Coal	180/-	180/-	-/-	-/-	-/-	-/-	-/-
Fuel Oil	1114/173	469/94	469/-	469/-	469/-	469/-	-/-
Diesel	130/-	130/-	130/-	130/-	130/-	130/-	-/-
ULSD	-/-	100/-	154/-	154/-	154/-	154/-	-/-
LNG	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Other	69/-	69/-	69/-	69/-	69/-	69/-	69/-
Geothermal	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Biodiesel	57/-	57/-	57/-	57/-	57/-	57/-	444/-
Biomass	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Wind Onshore	164/-	533/-	763/-	782/-	782/-	752/-	818/-
Wind Offshore	-/-	-/-	-/-	27/-	61/-	62/-	156/-
DGPV	606/-	680/-	745/-	869/-	1015/-	1163/-	1308/-
Solar	384/-	444/-	653/-	653/-	772/-	1049/-	1883/-
Battery	7/-	486/-	544/-	642/-	781/-	1150/-	2286/-
Hydro	-/-	-/-	-/-	-/-	-/-	-/-	-/-

Paniolo Wind + Pumped Storage on Hawai'i Island Installed Capacities

Hawai'i Island Results

Table 56. Paniolo case No-LNG Market DGPV capacity results

Utilized Capacity (MW) / Unutilized Capacity (MW)							
	2020	**2022**	**2025**	**2030**	**2035**	**2040**	**2045**
Coal	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Fuel Oil	75/32	58/49	58/49	58/49	58/49	58/-	-/-
Diesel	97/-	76/21	75/22	70/27	69/28	54/-	-/-
ULSD	30/-	27/3	27/3	20/9	20/9	-/-	-/-
LNG	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Paniolo PSH	-/-	30/-	30/-	30/-	30/-	30/-	30/-
Geothermal	38/-	38/-	38/-	38/-	38/-	38/-	55/-
Biodiesel	-/-	-/-	-/-	-/-	-/-	23/-	125/-
Biomass	-/-	-/-	-/-	-/-	-/-	-/-	16/-
Wind Onshore	58/-	114/-	118/-	121/-	142/-	165/-	154/-
Wind Offshore	-/-	-/-	-/-	-/-	-/-	-/-	-/-
DGPV	113/-	119/-	127/-	140/-	152/-	166/-	184/-
Solar	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Battery	-/-	-/-	-/-	8/-	18/-	45/-	85/-
Hydro	17/-	17/-	17/-	17/-	17/-	17/-	17/-

Consumer Advocate No LNG No-RPS Constraint Installed Capacities

Oahu Results

Table 57. Consumer Advocate Oahu No-RPS No-LNG Market DGPV capacity results

Utilized Capacity (MW) / Unutilized Capacity (MW)							
	2020	**2022**	**2025**	**2030**	**2035**	**2040**	**2045**
Coal	180/-	180/-	180/-	180/-	180/-	180/-	180/-
Fuel Oil	1135/151	421/94	421/-	421/-	421/-	421/-	319/-
Diesel	187/-	187/-	187/-	187/-	187/-	187/-	444/-
ULSD	-/-	100/-	154/-	154/-	154/-	154/-	-/-
LNG	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Other	69/-	69/-	69/-	69/-	69/-	69/-	69/-
Geothermal	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Biodiesel	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Biomass	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Wind Onshore	164/-	164/-	164/-	164/-	164/-	134/-	134/-
Wind Offshore	-/-	-/-	46/-	89/-	176/-	176/-	130/-
DGPV	606/-	680/-	745/-	869/-	1015/-	1163/-	1308/-
Solar	354/-	553/-	709/-	709/-	709/-	1002/-	1429/-
Battery	-/-	587/-	587/-	587/-	646/-	935/-	1497/-
Hydro	-/-	-/-	-/-	-/-	-/-	-/-	-/-

Maui Results

Table 58. Consumer Advocate Maui No-RPS No-LNG Market DGPV capacity results

Utilized Capacity (MW) / Unutilized Capacity (MW)							
	2020	**2022**	**2025**	**2030**	**2035**	**2040**	**2045**
Coal	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Fuel Oil	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Diesel	151/49	151/49	128/73	118/71	118/82	118/82	63/-
ULSD	-/-	18/-	18/-	18/-	18/-	-/-	-/-
LNG	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Other	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Geothermal	-/-	-/-	-/-	-/-	7/-	40/-	40/-
Biodiesel	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Biomass	-/-	40/-	40/-	40/-	40/-	40/-	40/-
Wind Onshore	124/-	124/-	124/-	124/-	124/-	72/-	72/-
Wind Offshore	-/-	-/-	-/-	-/-	-/-	-/-	-/-
DGPV	132/-	139/-	144/-	155/-	166/-	180/-	196/-
Solar	22/-	22/-	22/-	22/-	35/-	77/-	238/-
Battery	30/-	45/-	75/-	75/-	81/-	87/-	331/-
Hydro	1/-	1/-	1/-	1/-	1/-	1/-	1/-

Hawai'i Island Results

Table 59. Consumer Advocate Hawai'i Island No-RPS No-LNG Market DGPV capacity results

Utilized Capacity (MW) / Unutilized Capacity (MW)							
	2020	**2022**	**2025**	**2030**	**2035**	**2040**	**2045**
Coal	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Fuel Oil	61/46	58/49	58/49	58/49	58/49	58/-	-/-
Diesel	97/-	88/8	81/16	71/25	71/25	89/-	100/-
ULSD	30/-	30/-	30/-	19/11	19/11	-/-	-/-
LNG	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Other	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Geothermal	38/-	38/-	38/-	38/-	38/-	38/-	38/-
Biodiesel	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Biomass	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Wind Onshore	58/-	119/-	119/-	119/-	140/-	160/-	208/-
Wind Offshore	-/-	-/-	-/-	-/-	-/-	-/-	-/-
DGPV	113/-	119/-	127/-	140/-	152/-	166/-	184/-
Solar	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Battery	14/-	14/-	21/-	38/-	50/-	75/-	141/-
Hydro	17/-	17/-	17/-	17/-	17/-	17/-	17/-

Consumer Advocate LNG No-RPS Constraint Installed Capacities

Oahu Results

Table 60. Consumer Advocate Oahu No-RPS No-LNG Market DGPV capacity results

Utilized Capacity (MW) / Unutilized Capacity (MW)							
	2020	**2022**	**2025**	**2030**	**2035**	**2040**	**2045**
Coal	180/-	180/-	180/-	180/-	180/-	180/-	180/-
Fuel Oil	1196/91	106/91	103/-	103/-	103/-	103/-	-/-
Diesel	187/-	187/-	187/-	187/-	187/-	187/-	444/-
ULSD	-/-	100/-	154/-	154/-	154/-	154/-	-/-
LNG	-/-	679/-	679/-	679/-	679/-	771/-	563/-
Other	69/-	69/-	69/-	69/-	69/-	69/-	69/-
Geothermal	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Biodiesel	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Biomass	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Wind Onshore	134/-	134/-	134/-	134/-	134/-	134/-	134/-
Wind Offshore	-/-	-/-	-/-	-/-	-/-	-/-	-/-
DGPV	606/-	680/-	745/-	869/-	1015/-	1163/-	1308/-
Solar	141/-	141/-	141/-	141/-	141/-	54/-	478/-
Battery	-/-	326/-	326/-	326/-	344/-	294/-	464/-
Hydro	-/-	-/-	-/-	-/-	-/-	-/-	-/-

Maui Results

Table 61. Consumer Advocate Maui No-RPS No-LNG Market DGPV capacity results

	Utilized Capacity (MW) / Unutilized Capacity (MW)						
	2020	**2022**	**2025**	**2030**	**2035**	**2040**	**2045**
Coal	0/-	0/-	0/-	0/-	0/-	0/-	0/-
Fuel Oil	32/-	-/-	-/-	-/-	-/-	-/-	-/-
Diesel	173/28	55/40	23/72	2/82	2/93	2/93	9/-
ULSD	-/-	18/-	18/-	18/-	18/-	-/-	-/-
LNG	-/-	108/-	108/-	108/-	108/-	108/-	108/-
Other	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Geothermal	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Biodiesel	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Biomass	-/-	30/-	30/-	30/-	30/-	40/-	40/-
Wind Onshore	105/-	105/-	105/-	105/-	105/-	78/-	78/-
Wind Offshore	-/-	-/-	-/-	-/-	-/-	-/-	-/-
DGPV	132/-	139/-	144/-	155/-	166/-	180/-	196/-
Solar	5/-	5/-	5/-	5/-	5/-	39/-	99/-
Battery	1/-	46/-	84/-	96/-	112/-	156/-	177/-
Hydro	1/-	1/-	1/-	1/-	1/-	1/-	1/-

Hawai'i Island Results

Table 62. Consumer Advocate Hawai'i Island No-RPS No-LNG Market DGPV capacity results

	Utilized Capacity (MW) / Unutilized Capacity (MW)						
	2020	**2022**	**2025**	**2030**	**2035**	**2040**	**2045**
Coal	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Fuel Oil	58/49	58/49	58/49	58/49	58/49	58/-	-/-
Diesel	97/-	32/11	24/19	12/31	12/31	22/-	43/-
ULSD	30/-	30/-	30/-	30/-	30/-	17/-	17/-
LNG	-/-	55/-	55/-	55/-	55/-	55/-	113/-
Other	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Geothermal	38/-	38/-	38/-	38/-	38/-	38/-	38/-
Biodiesel	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Biomass	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Wind Onshore	58/-	93/-	93/-	93/-	96/-	110/-	102/-
Wind Offshore	-/-	-/-	-/-	-/-	-/-	-/-	-/-
DGPV	113/-	119/-	127/-	140/-	152/-	166/-	184/-
Solar	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Battery	17/-	17/-	25/-	33/-	43/-	61/-	52/-
Hydro	17/-	17/-	17/-	17/-	17/-	17/-	17/-

DBEDT No Military Units on Oahu Installed Capacities

Oahu Results

Table 63. DBEDT Oahu No Military Unit No-LNG Market DGPV capacity results

Utilized Capacity (MW) / Unutilized Capacity (MW)							
	2020	**2022**	**2025**	**2030**	**2035**	**2040**	**2045**
Coal	180/-	180/-	-/-	-/-	-/-	-/-	-/-
Fuel Oil	1137/150	598/94	598/-	598/-	598/-	598/-	-/-
Diesel	130/-	130/-	130/-	130/-	130/-	130/-	-/-
ULSD	-/-	-/-	-/-	-/-	-/-	-/-	-/-
LNG	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Other	69/-	69/-	69/-	69/-	69/-	69/-	69/-
Geothermal	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Biodiesel	57/-	57/-	57/-	57/-	57/-	57/-	534/-
Biomass	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Wind Onshore	149/-	149/-	149/-	149/-	149/-	134/-	164/-
Wind Offshore	-/-	-/-	140/-	226/-	286/-	286/-	312/-
DGPV	606/-	680/-	745/-	869/-	1015/-	1163/-	1308/-
Solar	354/-	446/-	764/-	764/-	898/-	1229/-	2693/-
Battery	-/-	506/-	592/-	701/-	908/-	1279/-	2714/-
Hydro	-/-	-/-	-/-	-/-	-/-	-/-	-/-

APPENDIX C: PRM METHODOLOGY USED IN RESOLVE

Planning reserve margin (PRM) is designed to ensure that enough dependable generation capacity is available to meet expected demand in the planning horizon. It is defined as the differences between the resources available and the expected peak period loads. Under conventional conditions, a system planner can calculate expected peak load and ensure there are enough reliable dispatchable resources available to meet the expected peak load plus some margin for reserves, contingencies, planned maintenance, and unplanned events. Typically this process involves choosing a reliability standard based on an expected loss of load probability LOLP (e.g., 1 day in 10 years), and a corresponding PRM designed to maintain that LOLP over the planning horizon in each plan. However, for jurisdictions that are increasing their dependence on renewable or Variable Energy Resources (VERs) to meet their RPS requirements, the simple PRM calculation above needs to account for the specific VERs contributions to PRM at each stage in the plan.

Because VERs produce energy that is stochastic by nature, it is unreasonable to count their entire nameplate capacity in calculating the amount of resources available to meet PRM (i.e., a 20MW wind plant should not contribute 20MW to the PRM). Conversely, completely ignoring the renewable resources in the PRM calculation would result in an excessive thermal build that is unused for large amounts of time because of expensive fuel costs or RPS constraints. The RESOLVE methodology creates a simple metric representing the amount of capacity a planner can rely on to attribute to renewable resources in maintaining "dependable capacity."

Unlike a traditional PRM calculation which is focused on maintaining sufficient capacity to serve the expected peak load, the PRM methodology outlined below is calculated for every hour in the planning horizon. While only one of these hours is binding, we cannot identify that hour because it is determined by an interplay of energy demand, demand response, DGPV, and the "dependable capacity" produced for each renewable resource. For example, the binding hour for PRM in a system with only solar renewable resources will likely occur in the evening, and the binding hour for a system with a combination of wind and solar resources could easily occur much earlier in the day. Below, we describe the methodology used to value the PRM contribution of renewable resources in this planning study that incorporates that interplay.

We begin with normalized hourly generation shapes for each renewable resource. In this case, the normalized hourly generation shapes were produced by the National Renewable Energy Laboratory and are hourly forecasted generation for 2045.

CALCULATION STEPS:

1. Calculate the distribution of the hourly renewable output for each renewable resource for each season-hour (e.g., summer hours 1-24).
2. Calculate the 10th percentile of each distribution above (10th percentile to represent the energy a planner can rely on for the identified renewable resource to provide with a 90% confidence level).
3. Use the identified 10th percentile calculated for each renewable resource in each season-hour and map it to the entire year (e.g., apply the 10th percentile value for Summer Hr 12 to the 12th hour of all summer days in the year in question in the plan on each island).
4. For each renewable resource, multiply the hourly 10th percentile values calculated above in Step 3 by the installed nameplate capacity of the renewable resource to calculate the hourly "dependable capacity" MW contribution of that renewable resource to the PRM.
    a. For example: assume the 10th percentile for solar Summer Hr 12 was 0.10, and the system had 110MW of nameplate solar installed. Then, the solar contribution to PRM during each Summer Hr 12 would be 0.10*110MW = 11MW.
5. For each hour, add together the PRM contributions from renewable resources, thermal resources, and batteries (thermal and battery contributions described below) to calculate the hourly PRM generation available.
6. Compare the available PRM generation with the PRM requirement, which is specified as a multiplier (greater than 1) of the hourly load.
7. If the generation side of the PRM constraint is greater than the load side for all hours, the PRM requirement has been met for the year in question. If there are one or more hours in which the PRM load requirement is greater than the generation resources available to meet PRM, the model must procure additional generation resources at least cost.

In this way, RESOLVE can rely on some level of renewable output for capacity instead of relying solely on an increasingly lower capacity factor thermal fleet in a high RPS world.

THERMAL AND BATTERY CONTRIBUTION TO PRM

Thermal resources contribute their maximum rated power output towards the PRM constraint.

In this planning study, we find that batteries are built more for energy purposes (i.e., absorbing high renewable output hours and shifting the energy to lower output hours) than for providing capacity. Nevertheless, we allow batteries to contribute to PRM. A battery's contribution to the PRM constraint is the power output a battery could discharge for 4 hours. For example, if a battery held 4kWh of energy in its pack, then its contribution to PRM would be 1kW as that is the power output the battery could maintain for 4 hours. This 4-hour cutoff is consistent with planning methodology used in the California market, which is one of the few markets with explicit formulations for how to evaluate the planning and capacity contributions of batteries.

Suitability of using a simple single hour and fixed PRM Number

The methodology described above is relatively simple and designed to determine the economic comparison of costs and benefits of a large number of cases over a relatively short period. It is largely unbiased towards different resources and is therefore suitable for comparing the costs of each plan.

Although the proposed process accounts for a VERs contribution to meeting a simple single PRM calculation for a single hour, the approach is too simple to assure that the reliability between each plan or over the course of each plan is maintained. For this reason, the companies have proposed using a number of other models to test the reliability of each of the studied plans; however, even that analysis is probably insufficient and limited by time, data and analytical tools. In particular, the simple single hour contribution of each VER and the fixed PRM percentage over the course of the expansion plan are simplifications that need to be tested.

In California, as part of their long term planning process, we are currently building a version of RESOLVE that incorporates information from our RECAP model that determines the amount specific LOLP and PRM needed for each plan over time and the Equivalent Load Carrying Capability (ELCC) of each VER over time in each plan as a more accurate way to counting VERs in their contribution to dependable capacity. A description of how RESOLVE is being adapted to incorporate a more detailed check on reliability in California can be found here:

http://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=6442451565