Hawai'i Powered

Maui Near Term Grid Needs Assessment

July 2022 Report

Hawaiian Electric

July 29, 2022

Maui Grid Needs Assessment

- Executive Summary – Key Findings
- Key Inputs and Assumptions, Methodology
- Capacity Expansion Plans
- Energy Reserve Margin Analysis
- Probabilistic Resource Adequacy Analysis
- Recommendations for Near-term Action Plan

Executive Summary - Background

On February 18, 2022 the Commission directed Hawaiian Electric to prepare a Stage 3 RFP to address reliability needs:

> As such, in order to meet the future replacement capacity needs, the Commission finds it is necessary for Hawaiian Electric to perform another round of competitive procurements on Oahu and Maui as soon as possible. Accordingly, the Commission directs Hawaiian Electric to develop RFP materials for a Stage 3 competitive bidding process.
>
> The Stage 3 RFP scope should be based on the latest grid needs assessment for Oahu and Maui and should account for the anticipated development schedules for the Stage 1 and 2 projects.
>
> In summary, the Commission directs Hawaiian Electric to move with urgency to ensure an adequate amount of replacement renewable projects are pursued in order to meet the reliability needs and fossil fuel retirement goals in line with Hawaii's energy policy goals.

On March 23, 2022 the Commission provided additional guidance, to conduct a Stage 3 RFP:

> On Maui, notwithstanding the Company's March 10 Letter recommending delaying the Stage 3 RFP, Hawaiian Electric has separately identified "the need to urgently issue an RFP for additional resources to be in place by 2027[,]" due to the Company's concern that 50 MW of capacity at the Maalaea Power Plant may reach end of life in this timeframe. The Commission also notes the heightened need for reducing the reliance on fossil fuels in light of recent geopolitical tensions impacting the price of Hawaii's fuel supply.
>
> The scope of the Stage 3 RFPs can be tailored to meet the near-term needs without precluding future procurements or conflicting with forthcoming results from the IGP docket, as directed by the Commission regarding the Firm Renewable RFP on Oahu. In developing the Stage 3 RFPs, the Commission directs Hawaiian Electric to be explicit in its justification for the scope of this and any parallel procurements.

Executive Summary – Objectives

Objectives of this assessment include:

- Develop resource portfolios that meet near-term RPS and GHG reduction goals and put Maui in an advantageous position to meet longer-term RPS and GHG goals
- Ensure reliability of the system through a balanced portfolio of resources that can be reasonably in-service by 2027 to mitigate the removal of up to 80 MW of firm thermal generation
- Add new low-cost renewable dispatchable generation (wind, solar, battery energy storage) to further decarbonize the electric sector
- Acquire more flexibility for the current and future generation system, building upon the recently acquired renewable dispatchable solar generation and aggregated grid services
- Diversify the type and geography of the resource portfolio to be more resilient
- Inform Stage 3 procurement and Company contingency plans

Executive Summary – Key Findings

- Low-cost renewable energy backed by firm generation continues to be the optimal resource mix over the next decade across different futures of low, base, and high adoption of customer technologies.

- By 2030, 170 GWh of energy efficiency, 56 MW of private rooftop solar, and 43 MW of private battery energy storage is needed to reduce supply-side energy and capacity needs to ensure resource adequacy. All scenarios analyzed include the impacts of 30 MW Battery Bonus/Grid Services Program.

- In addition to the energy provided by the original portfolio of Stage 1 and 2 projects, the optimized resource plan calls for an additional 240 GWh of renewable energy to be acquired by 2027, which includes replacement energy from the expiring 30 MW Kaheawa Wind Power 1 power purchase agreement, and approximately 13 MW of firm generation. The energy provided by projects that withdrew from the recent RFP process would add to the 240 GWh to inform the Stage 3 procurement target.

- Probabilistic resource adequacy analysis indicates that 9 MW of renewable firm generation would minimize occurrences of annual unserved energy if the optimized resource plan indicated above can be interconnected by 2027. By 2035, another 9 MW for a total of 18 MW of renewable firm generation would be needed to accommodate future load growth. When combining Stage 1 and 2 projects plus future resources, a total of 290 MW of PV+BESS and wind and 40 MW of standalone storage must be interconnected by 2027 to meet reliability metrics.

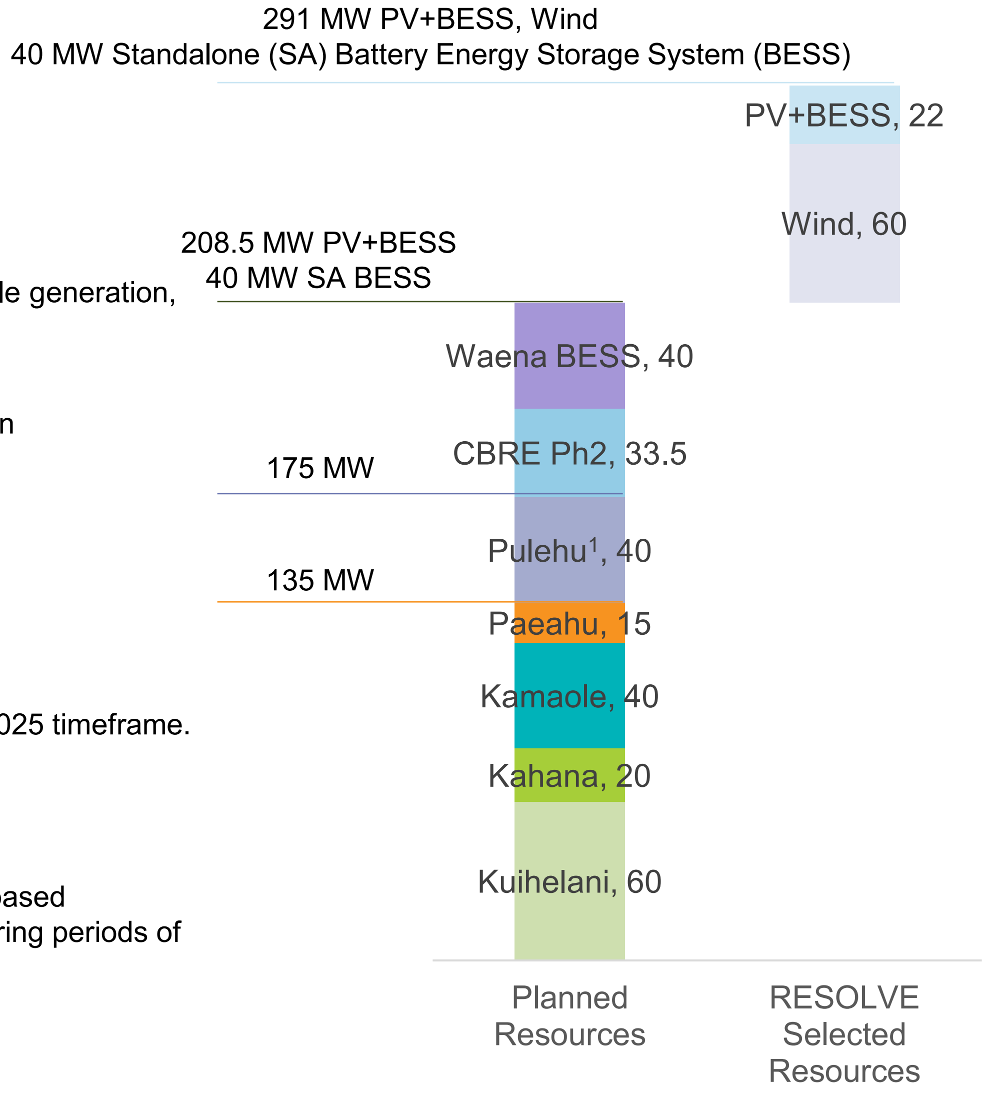
- The Stage 3 procurement targets and contingency plans should consider a number of risks and uncertainties; including but not limited to, on-going supply chain issues, economic and inflationary factors, force majeure, among others. By 2027, Kahului Power Plant (32 MW) must be retired to comply with environmental regulations and 49 MW of firm generation at Maalaea Power Plant are at risk in the 2025-2026 timeframe due to unavailability of spare parts.

- Hawaiian Electric recommends the Stage 3 procurement seek up to 40 MW of firm generation (along with continued efforts for battery bonus and grid services aggregation programs) to mitigate reliability and supply chain risks and uncertainties. In a scenario where 142 MW of renewable resources are interconnected by 2027, the addition of 40 MW of firm generation would not satisfy reliability targets; however, would minimize annual unserved energy and place the expected reliability slightly worse than the 2021 benchmark of 0.15 days/year. In a scenario where 242 MW of renewable resources are interconnected by 2027, 18 MW of firm generation is needed to achieve the same level of reliability as 2021 benchmarks.

Executive Summary – Key Findings

- Reliability Standards Used by Various Jurisdictions
  - Loss of Load Expectation (LOLE) ≤ 0.10 Days/Yr (US Mainland)
  - Loss of Load Hours (LOLH) ≤ 3 hrs (Belgium, France, GB, Poland)
  - Expected Unserved Energy (EUE) ≤ 20 MWh or 0.002% of load (AEMO)
- In 2030, compliance with all three standards is achievable with various resource mixes
  - **RESOLVE Base Case, 18 MW Firm Generation Addition Scenario ($214MM)[2]**: 291 MW of variable generation, 40 MW of standalone BESS, and 18 MW of firm generation
    - Variable Generation: 209 MW planned, 82 MW future (includes 60 MW wind)
  - **Low Renewable Scenario ($248MM)[2]**: 142 MW of variable generation and 63 MW of firm generation
    - Variable Generation: 60 MW planned (Kuihelani), 82 MW future (includes 60 MW wind)
  - **No Firm Addition Scenario ($280MM)[2]**: 328 MW of variable generation
    - Variable Generation: 60 MW planned (Kuihelani), 268 MW future (includes 60 MW wind)
- Assumed Removals from Service
  - Kahului 1-4 (32 MW) – Must be retired in 2027 due to environmental regulations
  - Maalaea 10-13 (49 MW) – Manufacturer will no longer produce spare parts; end of life expected in 2025 timeframe.
  - Maalaea 4-9 (33 MW)
  - Kaheawa Wind Power 1 (30 MW) – Expiring PPA in 2027
- Firm Generation – In this report, firm generation or thermal generation refers to a synchronous machine based technology that is available at any time under system operator dispatch for as long as needed, except during periods of outage and deration, and is not energy limited or weather dependent.

Planned Variable Resource Additions and Future Resources Optimized in RESOLVE

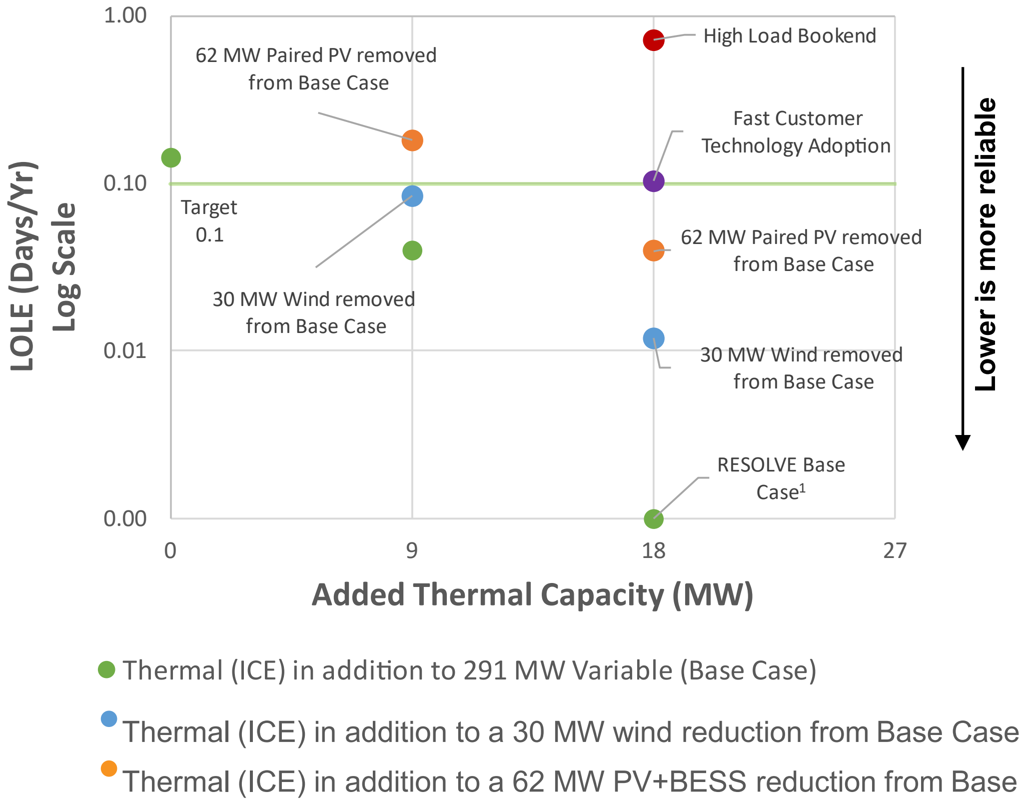


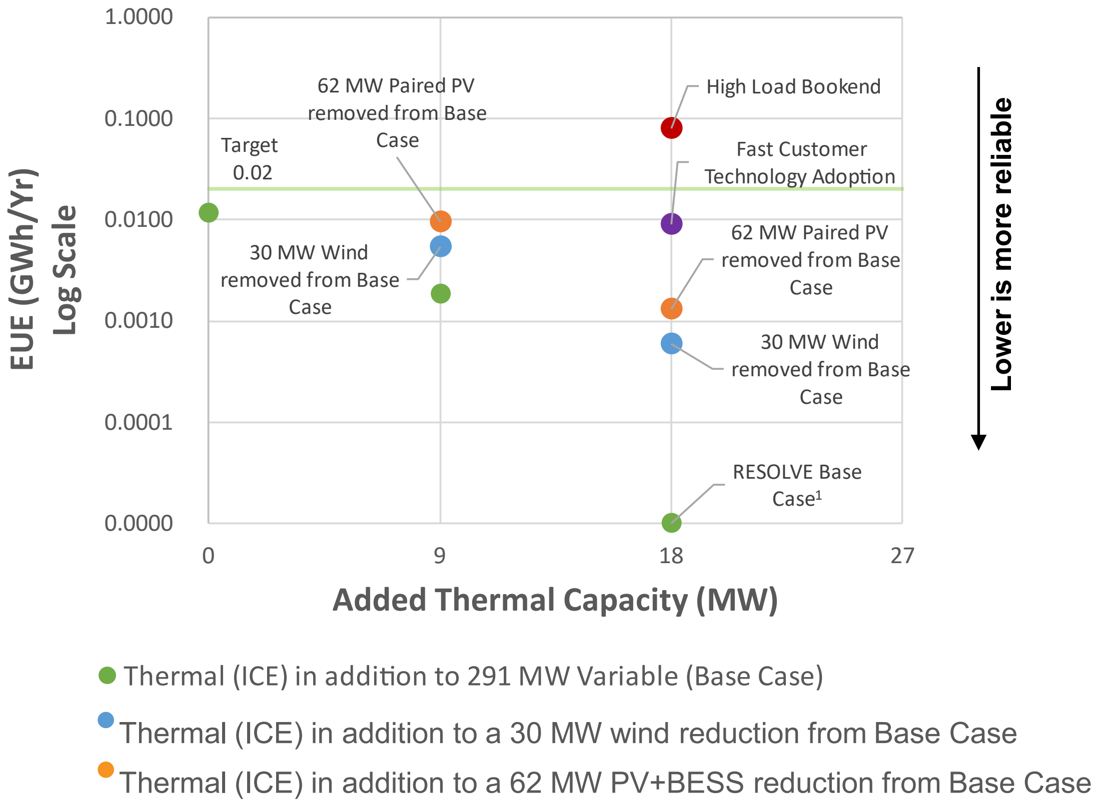
1. Pulehu Solar withdrew from the RFP process on May 4, 2022
2. 1 year revenue requirements for year 2030

Executive Summary – Key Findings: **18 MW of new firm generation provides a reasonable level of reliability over a range of potential future pathways and uncertainties**

<u>Probabilistic Resource Adequacy Analysis of the RESOLVE Base Case Sensitivities: Incremental changes to wind, PV+BESS, firm generation</u>
Planned Resources: 209 MW of PV+BESS from Stage 1 and 2, and 40 MW standalone BESS
Future resources beyond planned: 82 MW of variable generation

Incremental additions of internal combustion engines (ICE) firm (thermal) generation of 9-18 MW meets both LOLE and EUE targets as shown in the green data points. In orange and blue data points are removals of wind or PV+BESS capacities from the base RESOLVE (optimized) case to simulate market conditions where not all projects reach commercial operations.





1. RESOLVE Base case selected 13 MW combined cycle by 2030, in addition to 60 MW onshore wind and 22 MW PV+BESS, which is roughly equivalent to the 18 MW ICE addition evaluated here.

Executive Summary – Key Findings: **New Firm Generation can address EUE shortfalls in low variable renewable periods**

Base Case with 0 MW Firm Generation

Hours Beginning	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.00	0.00	0.00	0.10	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.07	0.22	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.25	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.37	0.32	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.13	0.25	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.52	0.22	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.27	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.16	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.13	0.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	0.00	0.00	0.33	0.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.02	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.09	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.48	1.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.28	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Base Case with 9 MW Firm Generation

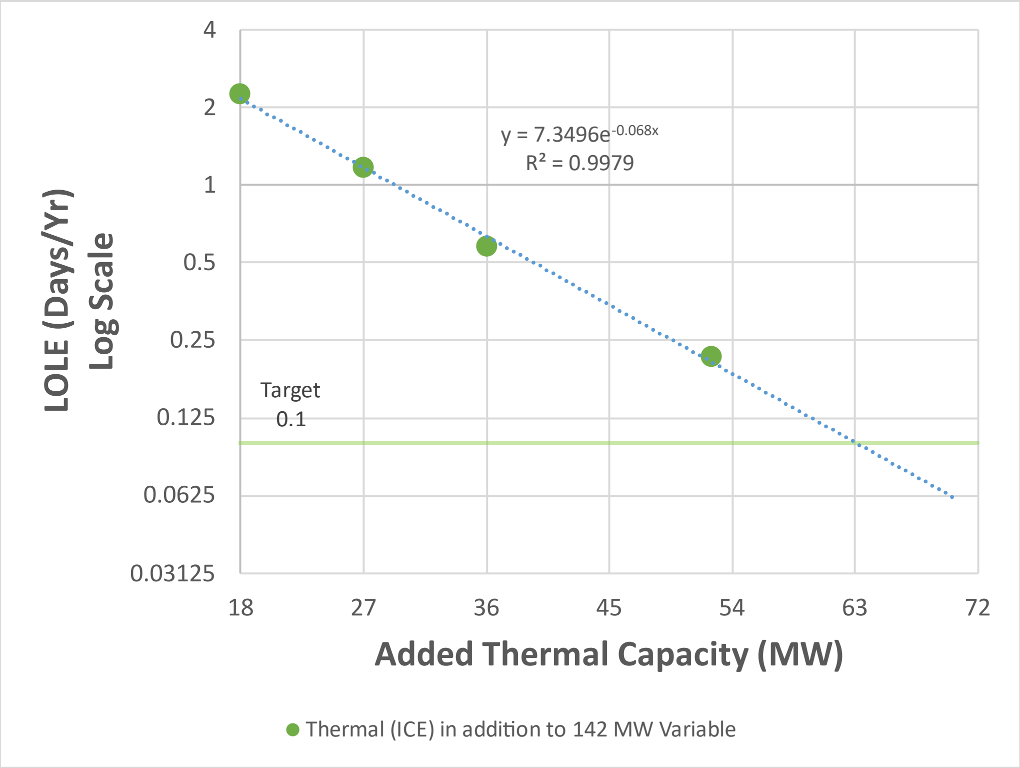
Hours Beginning	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.18	0.06	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.12	0.05	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.02	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.27	0.17	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.01	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.25	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

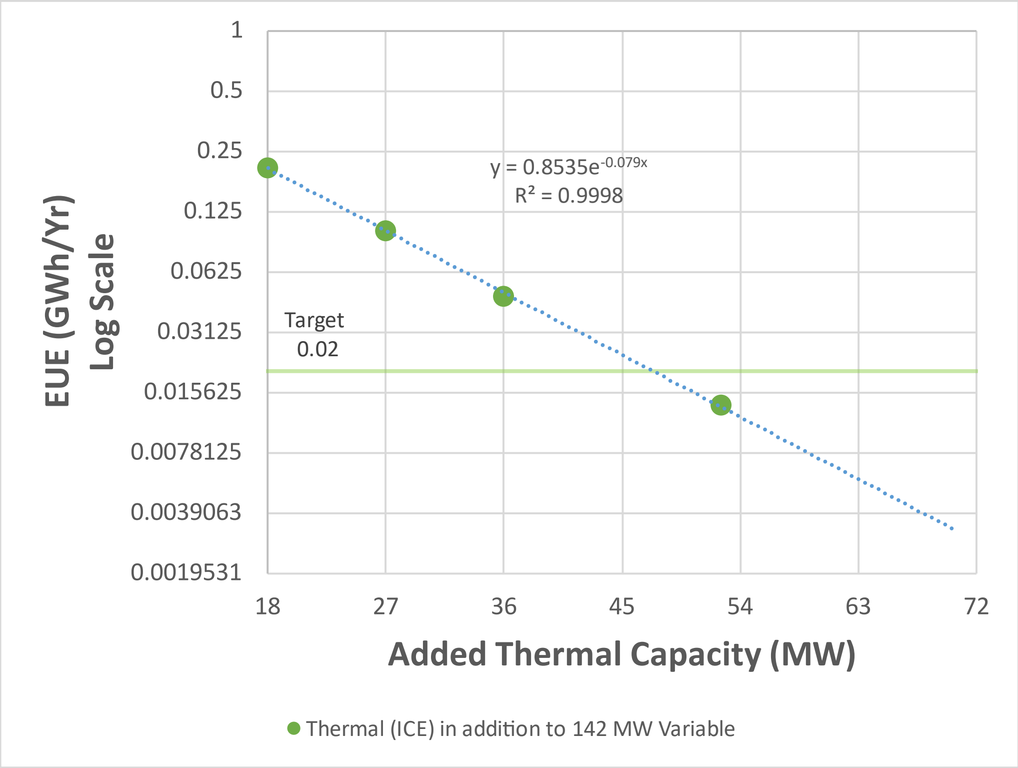
Pictured are heatmaps of unserved energy to show likelihood of when unserved energy may occur based on probabilistic resource adequacy analysis. Shortfalls are shown during the months of March, April and May where wind has a lower capacity factor and the PV+BESS do not have enough energy to load shift and meet unserved demand.

Executive Summary – Key Findings: **With limited new renewables (Kuihelani Solar, future 82 MW PV+BESS / wind), 63 MW firm generation is needed to improve reliability to established standards for LOLE and EUE**

Probabilistic Resource Adequacy Analysis
Kuihelani Only with Firm Generation (ICE) Sensitivities: Kuihelani, 60 MW wind, 22 MW PV+BESS, plus 9-18 MW incremental ICE additions
Planned Resources: 60 MW (Kuihelani)
Beyond Planned Resources: 82 MW of variable generation

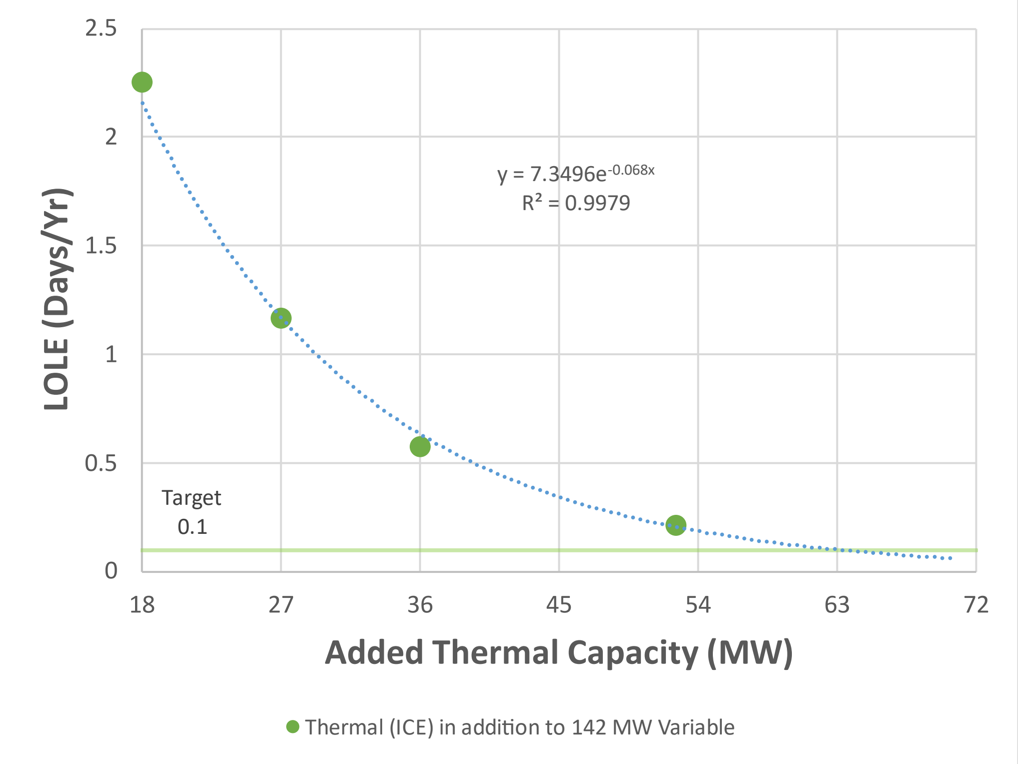
In a case where project delays persist and a total of 142 MW of variable generation reaches commercial operations by 2027, approximately 48 MW of firm generation meets the EUE target but not the LOLE target. Approximately 63 MW of firm generation is needed to meet the LOLE target.

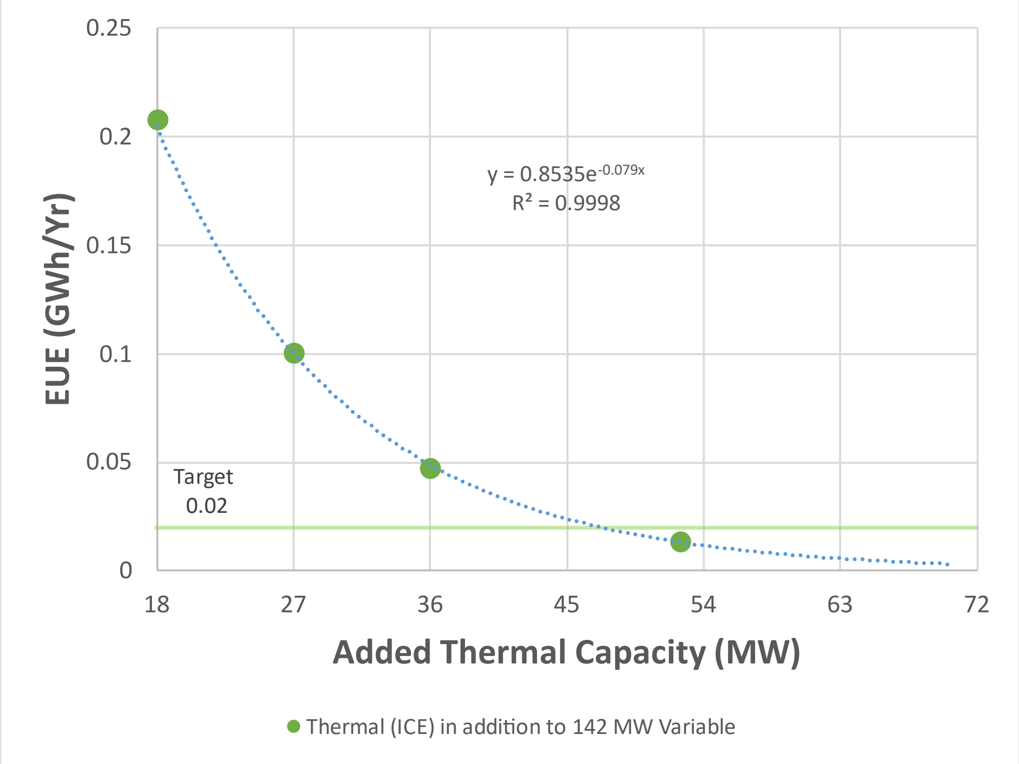




Executive Summary – Key Findings: **Resource portfolio diversity is important to balance diminishing returns on reliability improvements when adding increasing amounts of a single resource type**

Using the same data and analysis from the previous slide, the following figures expressed in non-log scale, show that increasing additions of the same resource type have diminishing returns on improvements to reliability.

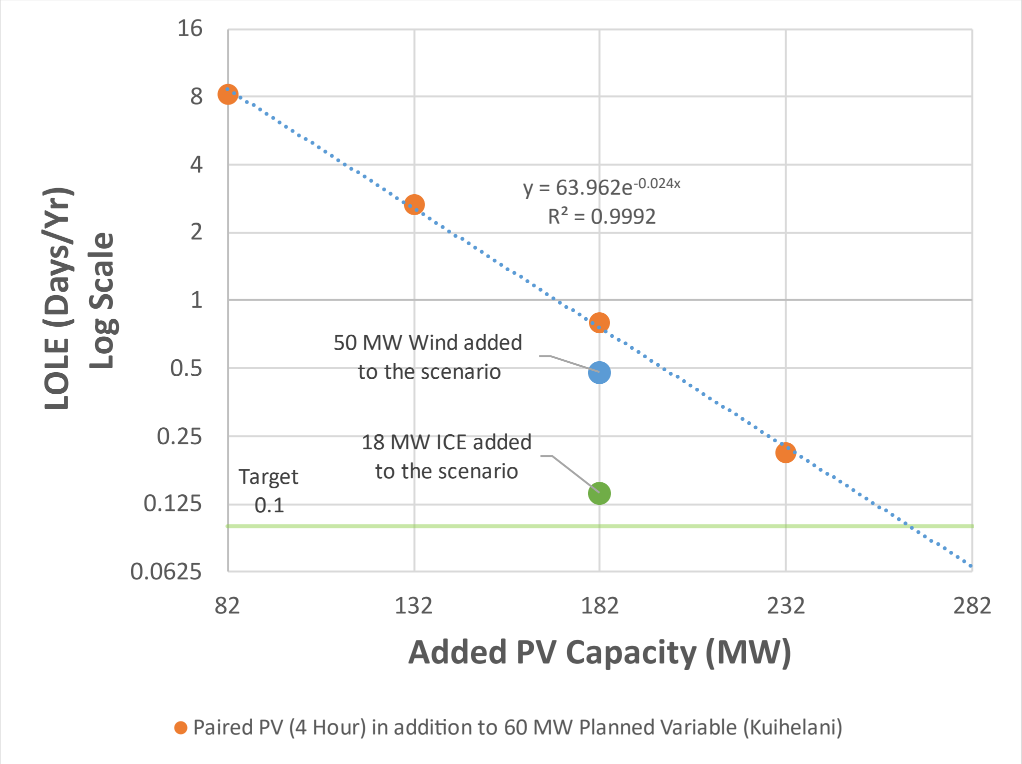


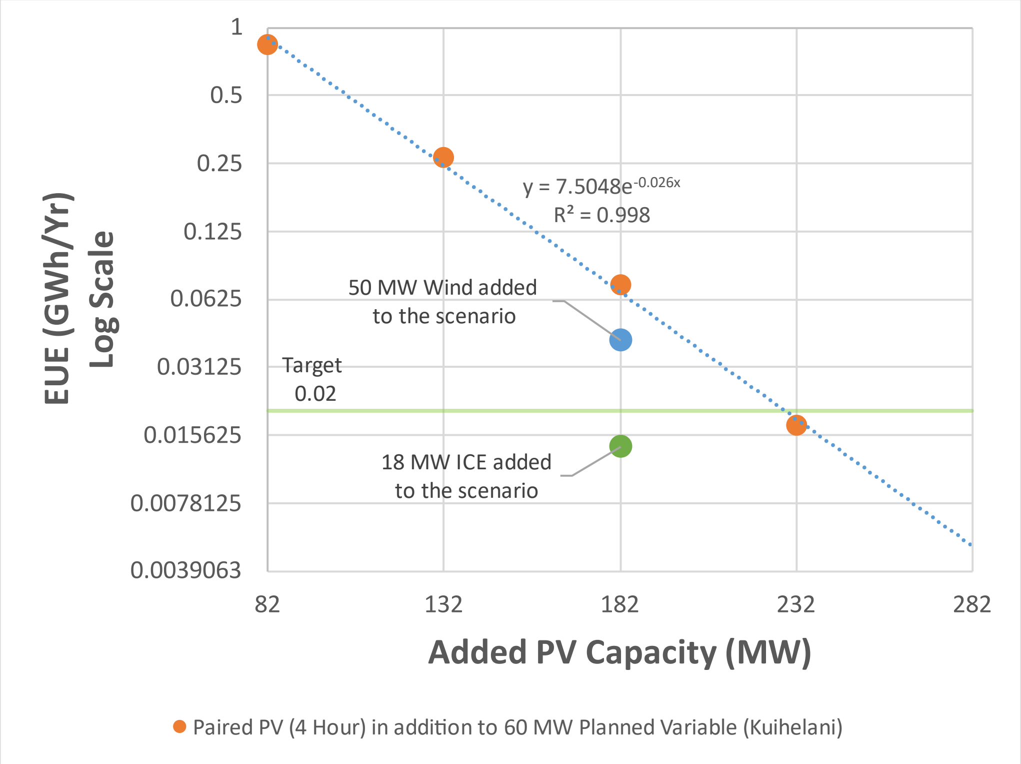


Executive Summary – Key Findings: **A high amount of new variable generation (328 MW of variable generation including Kuihelani Solar and 82 MW PV+BESS / wind) is needed with no new firm additions to meet LOLE and EUE standards**

Probabilistic Resource Adequacy Analysis, year 2030
Kuihelani Only with PV+BESS Sensitivities : Kuihelani, 60 MW wind, 22 MW PV+BESS, plus incremental 50 MW PV+BESS additions
Planned Resources: 60 MW
Beyond Planned Resources: 82 MW (60 MW of wind and 22 MW PV+BESS)

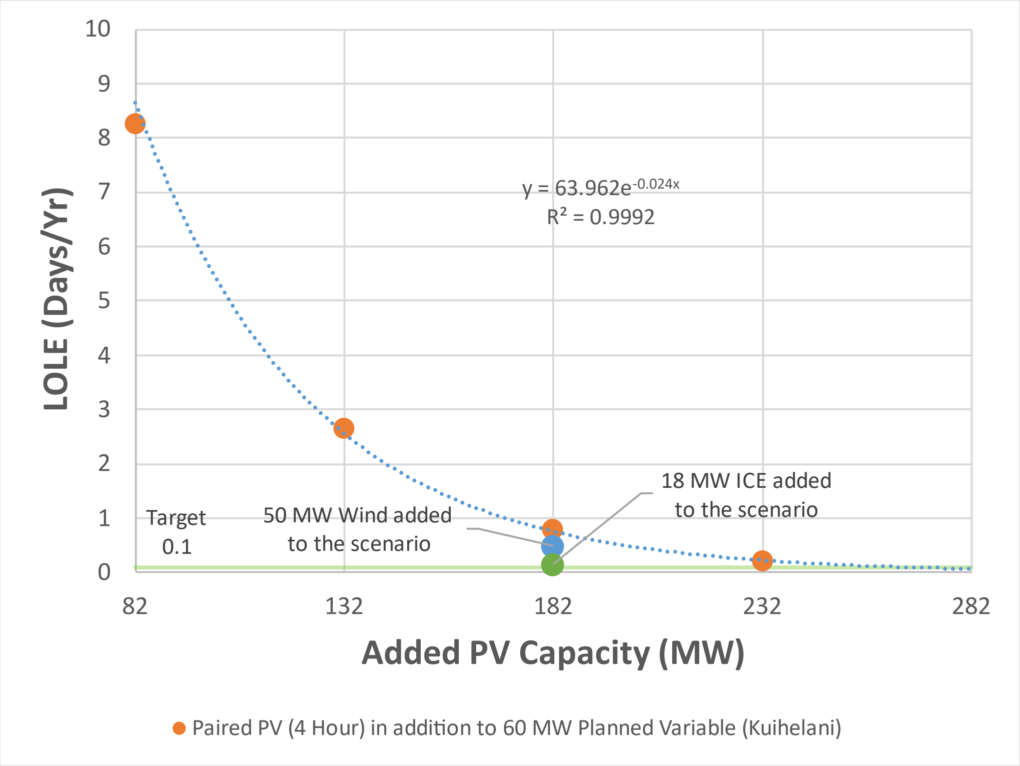
Given no new firm generation additions, incremental PV+BESS additions were tested in the orange data points. The analysis suggests 232 MW of additional PV+BESS meets the EUE target but not the LOLE target. To meet the LOLE target, extrapolating the data, an additional 36 MW of PV+BESS is needed to meet the LOLE target. In total, 328 MW of variable renewables in this case (60 MW Kuihelani, 82 MW PV+BESS / wind, 186 MW additional PV+BESS based on curve fit) is similar to the Base case with 291 MW of variable renewables and 40 MW of standalone storage. Shown in the green data points, 100 MW of additional PV+BESS for a total of 242 MW of renewable resources plus 18 MW of firm generation will provide a reasonable level of reliability.

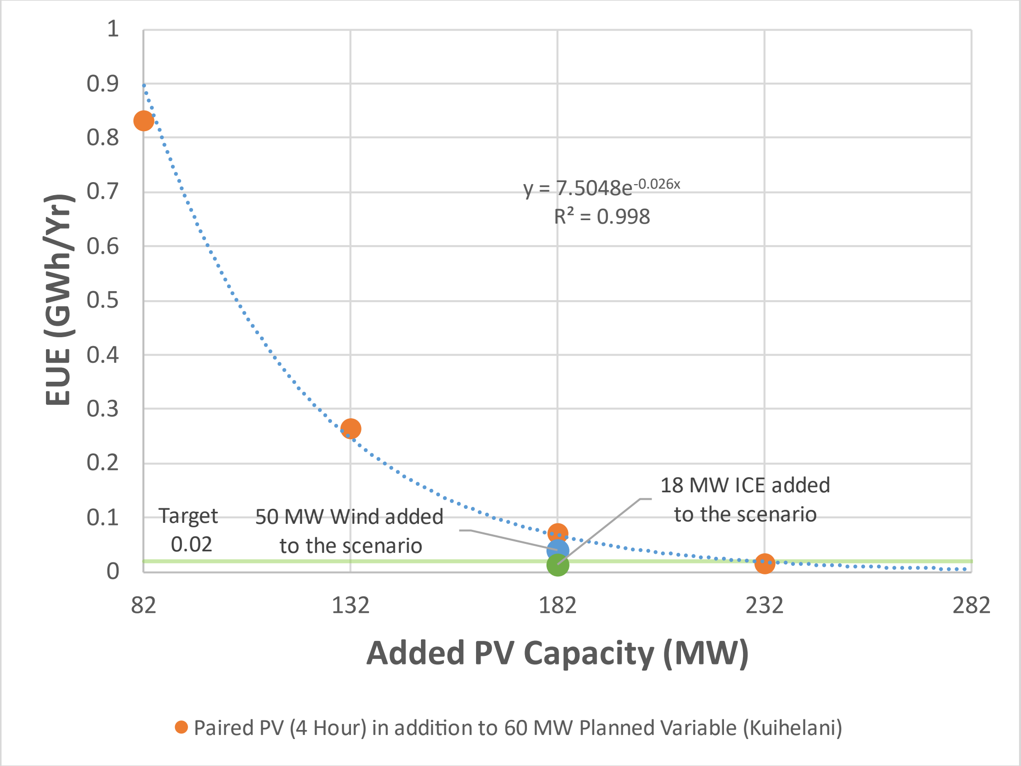




Executive Summary – Key Findings: **Resource portfolio diversity is important to balance diminishing returns on reliability improvements when adding increasing amounts of a single resource type**

As observed in the Kuihelani Solar Only with ICE firm generation sensitivities, the increasing additions of the same resource type have diminishing returns on improvements to reliability. At 182 MW of new renewables, adding 18 MW of ICE (green data point) improves reliability more than another 50 MW of PV+BESS (right most orange data point).





Key Inputs and Assumptions, Methodology

Key Inputs and Assumptions

- Sales Forecast
- Fuel Price Forecast
- Resource Cost Forecast
- Regulating Reserve Requirement
- Hourly Dependable Capacity for Energy Reserve Margin
- Variable Renewable Resource Potential
- Renewable Energy Zone Enablement
- Planned Resources
- Near-Term Conditional Fossil Fuel Generation Removal from Service

Key Inputs and Assumptions

The PUC approved March 2022 IGP inputs and assumptions were used for the following assumptions.

- Sales Forecast
- Fuel Price Forecast
- Resource Cost Forecast

Additional assumptions are described below.

- Regulating reserve requirement –The 1-minute and 30-minute regulating reserve requirement was included, as described in the November 2021 GNA Methodology Report
- Hourly Dependable Capacity for Energy Reserve Margin – The hourly dependable capacity (HDC) for variable renewables was based on the 80^{th} percentile calculation methodology discussed with the TAP.
- Variable Renewable Resource Potential – Consistent with the approved March 2022 IGP inputs and assumptions, the analyses used the Alt-1 scenario that was developed in NREL's revised Assessment of Wind and Photovoltaic Technical Potential for the Hawaiian Electric Company. Because a high amount of capacity was identified for slopes up to 15%, the resource potential was not split further for slopes up to 30%.

See Assessment of Wind and Photovoltaic Technical Potential for the Hawaiian Electric Company

Key Inputs and Assumptions – Renewable Energy Zones

Renewable Energy Zone (REZ) upgrades are composed of two costs:

- Transmission Network Expansion costs – transmission upgrades not associated with a particular REZ group but are required to support the flow of energy within the transmission system
- REZ Enablements – new or upgraded transmission lines and new or expanded substations required to connect the transmission hub of each REZ group to the nearest transmission substation

In this analysis, only the REZ enablement costs were included.

- No transmission network expansion costs were included
- Additional details on the REZ and identified infrastructure, requirements, and costs were discussed in the Hawaiian Electric Transmission REZ Study, filed as part of the November 2021 GNA Methodology Report

See Hawaiian Electric Transmission REZ Study

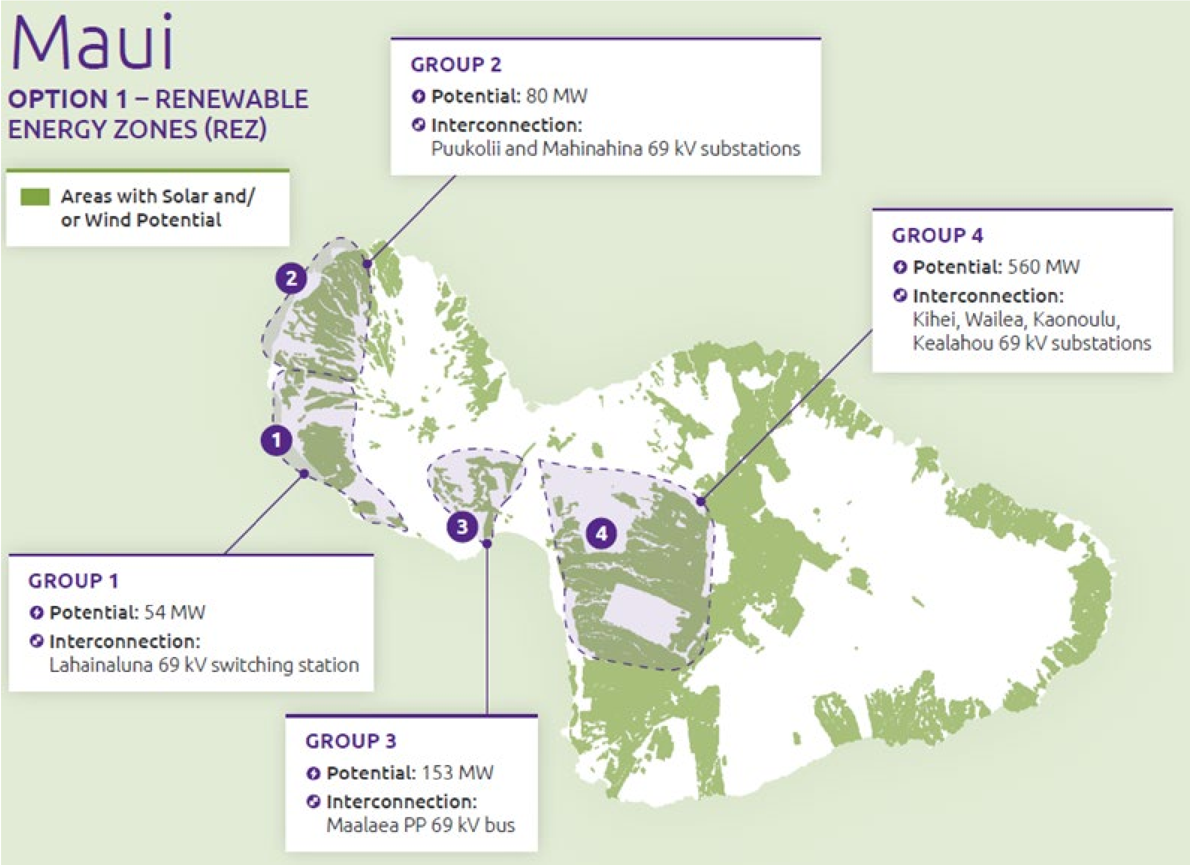
Key Inputs and Assumptions – Renewable Energy Zones

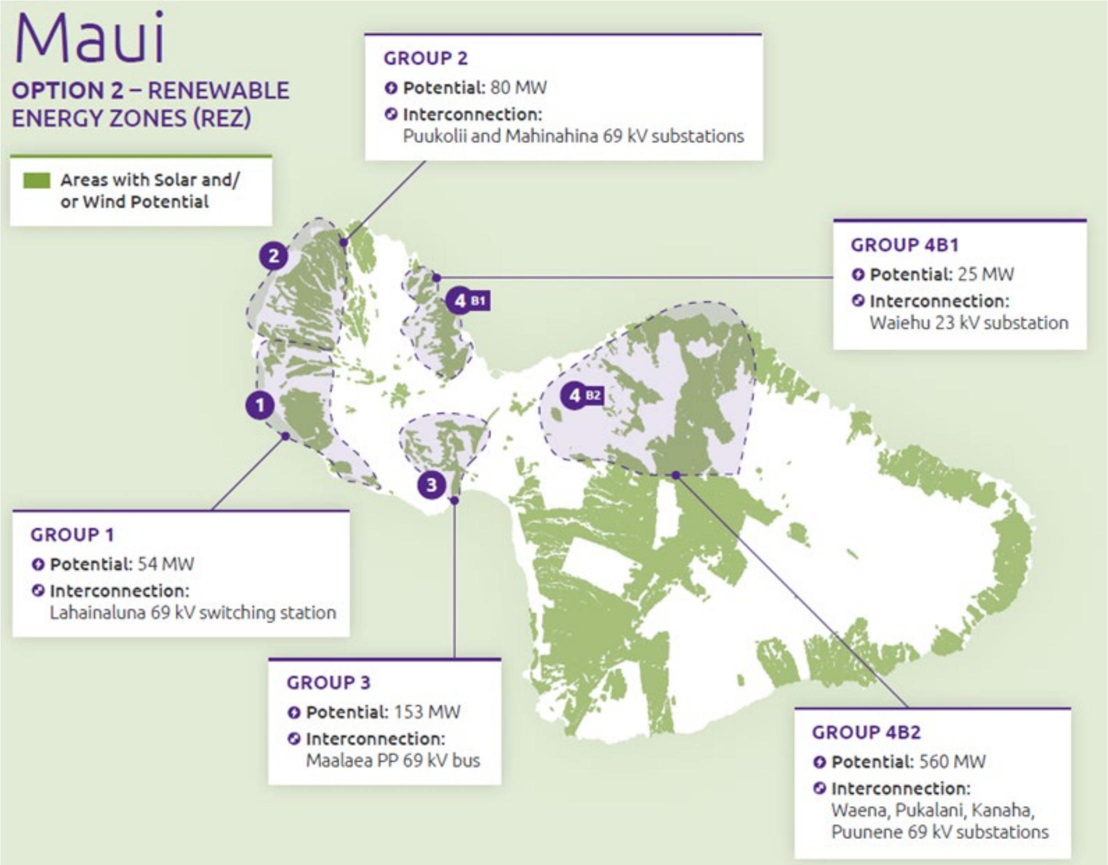
In order to model a reasonable number of candidate resource options, the REZ groups were aggregated by similar REZ enablement cost for modeling in RESOLVE.

- Group A in RESOLVE (287 MW) – Group 1, 2, 3 from the REZ Study
- Group B in RESOLVE (560 MW) – Group 4A from the REZ Study
- Group C in RESOLVE (585 MW) – Group 4B1, 4B2 from the REZ Study

Key Inputs and Assumptions – Renewable Energy Zones Modeled in RESOLVE

The maps below indicate the location of Group 1, 2, 3, 4/4A, 4B1, and 4B2 that were modeled in RESOLVE.





Key Inputs and Assumptions – Planned Resources

The RESOLVE model assumes 2027 as the first year to build new resources. Resources assumed in-service prior to 2027 are shown below. Existing PPAs are assumed to terminate at the end of their contract term, allowing RESOLVE to re-optimize the capacity, energy and other grid services the projects previously provided. For example, Kaheawa Wind Power 1 (30 MW) is assumed to expire in 2027.

Resource	PV (MW)	BESS (MW/MWh)
Kuihelani Solar	60	60/240
Paeahu Solar	15	15/60
Kamaole Solar	40	40/160
Kahana Solar	20	20/80
Pulehu Solar[1]	40	40/160
Waena BESS[2]	N/A	40/160
CBRE Phase 2 Small Projects	8.475	-
CBRE Phase 2 RFP	25	25/100

1. Pulehu Solar withdrew from the RFP process on May 4, 2022
2. Waena BESS application is pending approval

Key Inputs and Assumptions – Near-Term Conditional Fossil Fuel Removal from Service

Hawaiian Electric assumed that certain amounts of firm fossil fuel generation would not be available for dispatch for the purposes of identifying Grid Needs. The planning assumptions noted below do not imply that Hawaiian Electric will retire the amount of firm generation capacity in the years indicated. Actual removal is conditioned upon a number of factors including, whether sufficient resources have been acquired and placed into service to provide replacement grid services, reliability, resilience considerations, among others.

- Remove Kahului Power Plant no later than 2027 (32 MW) (environmental regulations)
- Remove Maalaea 10-13 by 2027 (49 MW) (estimated end of life based on lack of spare parts)
  - M13 – May 2025
  - M11 – September 2025
  - M12 – May 2026
  - M10 – September 2026
- Remove Maalaea 4-9 in 2030 (33 MW)

Key Inputs and Assumptions – Near-Term Conditional Fossil Fuel Removal from Service

The lack of available spare parts for Maalaea 10-13 may cause these units to be removed from service. The figure below provides an illustration of when end of life may be reached for each unit, given the Company's current stock of spare parts. A similar situation where spare parts become unavailable could occur for Maalaea 4-9.

Therefore, as a planning exercise, it is prudent to evaluate the near-term grid needs assuming Maalaea 10-13 and Maalaea 4-9 are removed from service.

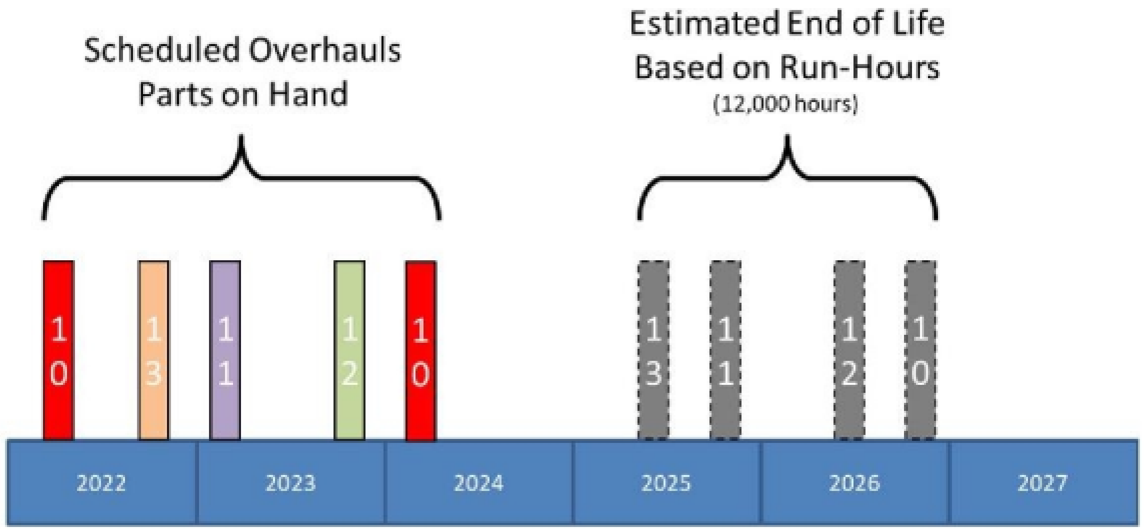
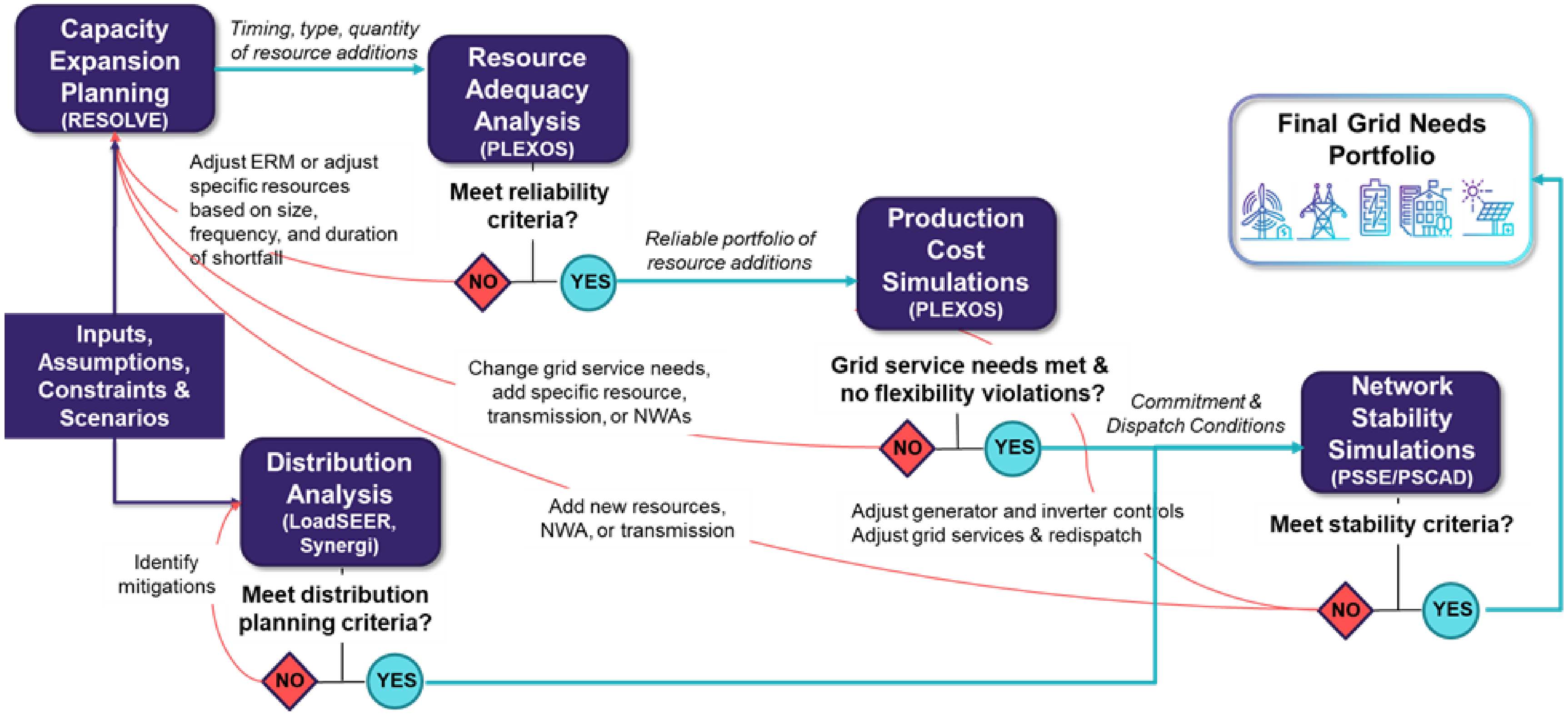


Figure 1 – Estimated End of Life for M10 thru 13

Methodology

- ❖ Grid Needs Assessment Methodology
- ❖ Define Grid Needs
- ❖ Capacity Expansion (RESOLVE)
- ❖ Resource Adequacy (PLEXOS)
- ❖ Production Cost Simulation (PLEXOS)

Grid Needs Assessment (GNA) Methodology



- The grid needs assessment focuses on the first three steps of the methodology through capacity expansion planning, resource adequacy, and production cost simulations.
- The PUC approved March 2022 IGP Inputs and Assumptions were used in this analysis.
- The methodology is consistent with the November 2021 Grid Needs Assessment and Solution Evaluation Methodology.

GNA Methodology – RESOLVE and PLEXOS Models

1. RESOLVE – Used to determine the optimal type, quantity, and timing of resource additions across a range of constraints to provide directional Grid Needs under various scenarios
   a. The planning assumptions are used to determine a Base portfolio of Grid Needs as well as evaluate resource portfolios under low load, high load, and faster customer technology adoption scenarios
   b. The outputs of RESOLVE are intended to be directional only and are not intended to be a prescriptive pathway
2. PLEXOS – Used to evaluate the energy reserve margin (ERM) and conduct probabilistic analyses on the RESOLVE resource plans for resource adequacy, verify the hourly operations and dispatch of the resources on the system and evaluate production cost
   a. The capacity need was informed by the magnitude and duration of unserved energy observed where the net load, increased by the 30% ERM guideline, was not met by existing resources.
   b. The need was further analyzed using a probabilistic approach endorsed by the TAP. The probabilistic analyses examined 5 weather years for PV and wind, 50 random generator outages for a total of 250 model iterations. The results were then used to calculate loss of load expectation, loss of load events, loss of load hours, and expected unserved energy.
   c. After evaluating the reliability of the resource plan, the operations and dispatch of the resource portfolio was analyzed to examine how the new resources would be operated in future years and evaluate the production cost

Grid Needs means the specific grid services (including but not limited to capacity, energy, and ancillary services) identified in the Grid Needs Assessment, including transmission and distribution system needs that may be addressed through a Non-Wires Alternative.

Capacity Expansion Plans

Customer Technology Adoption is a Priority

2030 Customer Technology (incremental from 2021 levels)	Peak Load Impact (MW)	Impact to Sales (GWh)	Approximate Quantity
Energy Efficiency	24	170	N/A
Electric Vehicles	10	52	17,466
Private Rooftop Solar	56 (Installed Capacity)	95	7,114
Private BESS	43 MW / 114 MWh (Installed Capacity)	-5	7,275
Non-DER/EV Time-of-Use	1.2	N/A	N/A

Customer technology adoption is considered first in meeting grid needs. Procurement targets identified through the GNA analyses are to meet the residual grid needs after accounting for forecasted EE, EV, DER, and non-DER/EV TOU. 30 MW of Battery Bonus and grid services aggregation are currently being pursued and future DER programs (and included in the analyses) will provide additional flexibility to contribute to grid energy and capacity needs. These customer resources, when acquired cost-effectively, are critical to meeting the needs of the grid.

Further analyses can be completed during the solution sourcing phase of IGP to identify appropriate incentives to design new programs that achieve the forecasted amounts of DER and EE, i.e., evaluate the “freeze” cases.

Capacity Expansion Plans – Scenario Analysis

- **Base Scenario** – Assumes the base set of IGP sales and fuel price forecasts from the PUC approved March 2022 Inputs and Assumptions, in-service of S1/S2/CBRE projects. Existing power purchase agreements are assumed to terminate at the end of their current contract term. Existing fossil fuel generating units continue through the study period, unless otherwise noted. New variable renewable resources are allowed to be built up to the NREL Alt-1 resource potential.

- **Low Load Scenario** – Assumes the set of IGP sales forecasts that reduce customer demand including the high Distributed Energy Resource (DER), high Energy Efficiency (EE), and low Electric Vehicle (EV) forecasts. Together, these forecast layers provide a low load to bookend or bound future, plausible demand that Hawaiian Electric should plan to serve. Other planning assumptions follow the Base Scenario.

- **High Load Scenario** – Assumes the set of IGP sales forecasts that increase customer demand including the low DER, low EE, and high EV forecasts. Together, these forecast layers provide a high load to bookend or bound future, plausible demand that Hawaiian Electric should plan to serve. Other planning assumptions follow the Base Scenario.

- **Faster Customer Technology Adoption Scenario** – Assumes the set of IGP sales forecasts for high adoption levels of customer technologies including DER, EE, and EV. As a result, this sales forecast trends between the base and high load bookend.

Capacity Expansion Plans – Scenario Analysis

The table below provides the forecast assumptions for EE, DER, EV and Time-of-Use (TOU) load shapes associated with customers who do not have DER or EV for the Base, Low Load, High Load, and Faster Customer Technology Adoption (Faster Tech) cases.

Forecast Layer	Base	Low Load	High Load	Faster Tech
EE	Base	High	Low	High
DER	Base	High	Low	High
EV	Base	Low	High	High
EV Charging Shape	Managed	Managed	Unmanaged	Managed
Non-DER, Non-EV TOU	Base	High	Low	High

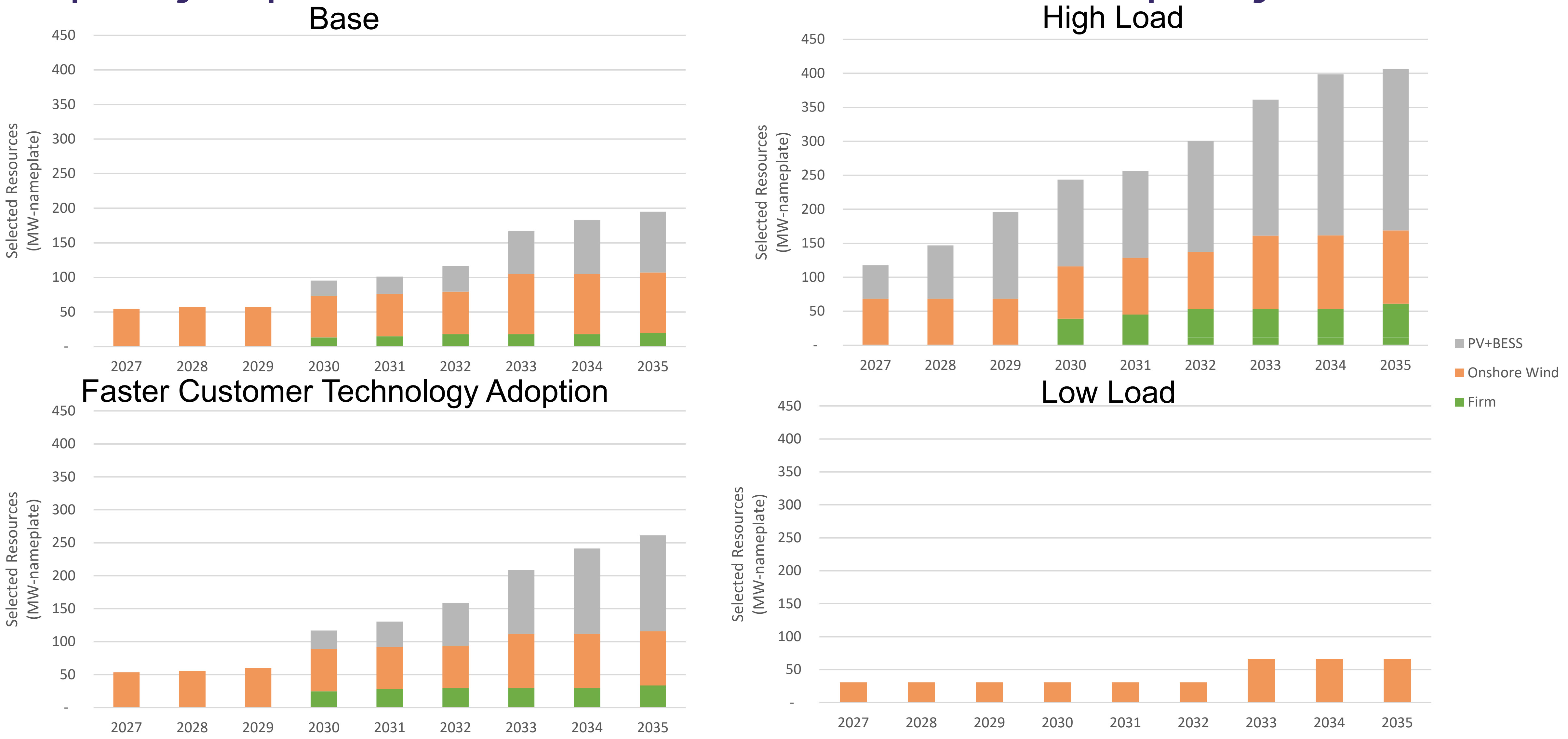
Capacity Expansion Plans – Resource Plans

The following slides show the least-cost plans as optimized in the RESOLVE model for the various scenarios and high/low load bookends. The modeling results demonstrate that the resource mix is consistent across the various futures depending on the level of load to be served. Wind is the first choice because of its lower cost ($/kWh basis) and higher capacity factor compared to PV+BESS. However, PV+BESS continues to be selected to meet the grid needs through 2035. These resources continue to be cost-effective with the REZ costs that were modeled.

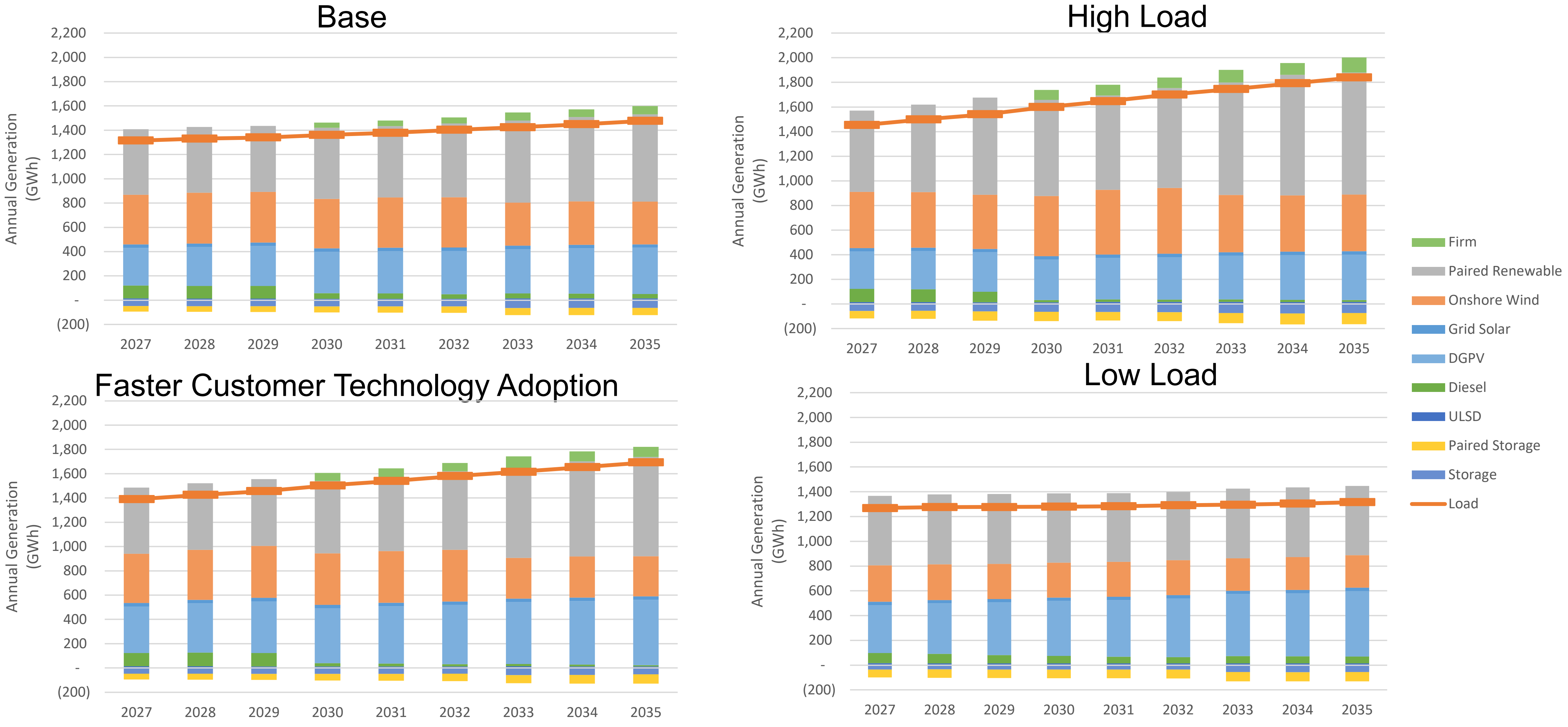
Customer resources are significant contributors to reducing supply-side needs. Additional grid-scale resources would be needed if customer resources are not adopted in significant amounts as shown on Slide 26. This is observed on the energy chart on Slide 31, and the reduced amount of resources selected by the model in the low load scenario. However, in a decarbonized scenario where load grows due to electrification of transportation, the effects can be seen in the high load scenario where significant additional resources are needed.

In all cases, fossil fuel use declines significantly as firm generation is used primarily as stand-by generation when other renewable resources (i.e., wind and solar) are not available.

Capacity Expansion Plans – Incremental Installed Capacity



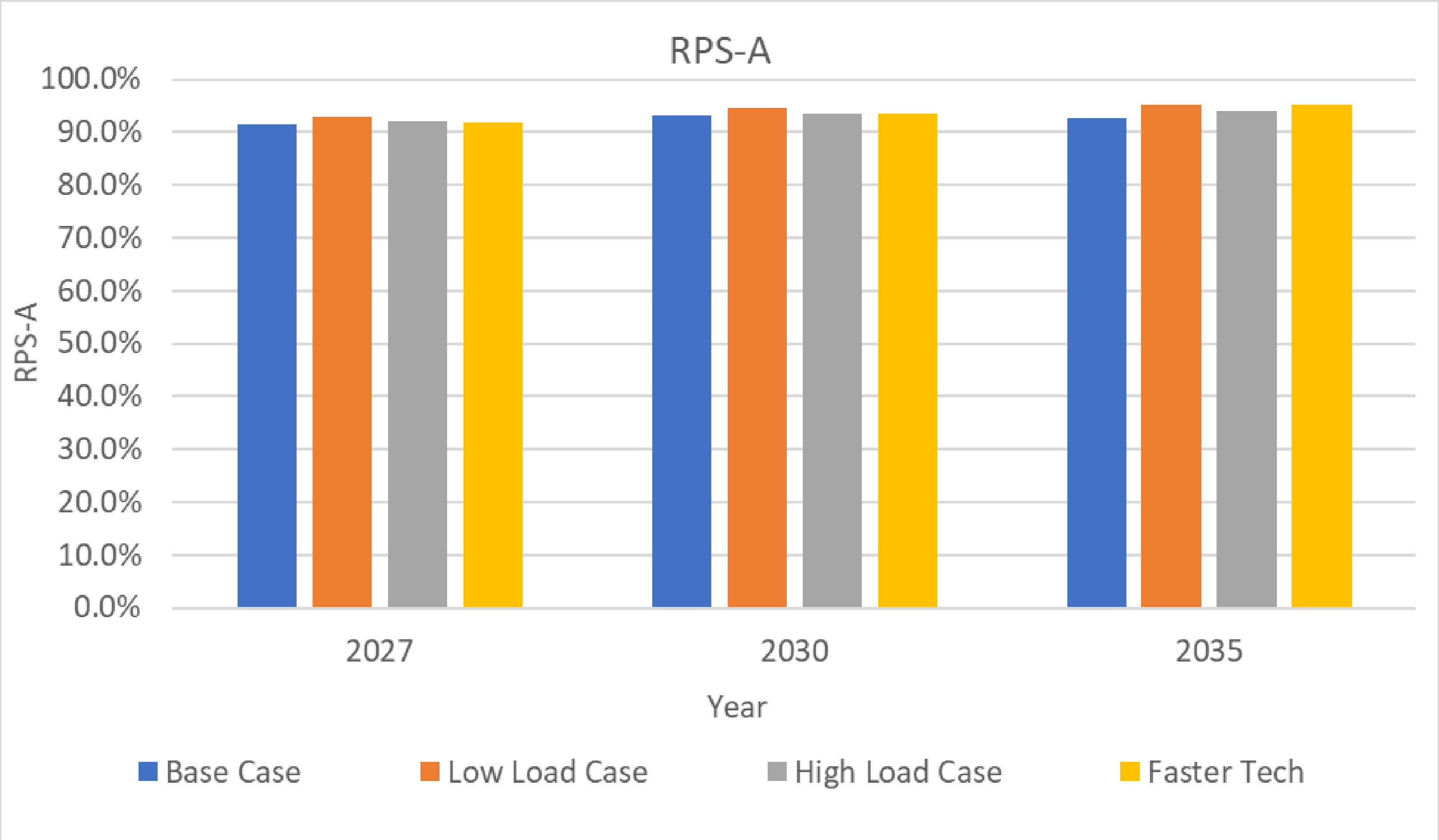
Capacity Expansion Plans – Annual Generation



Detailed Resource Plan

Year	Base Case	High Load	Low Load	Faster Tech
2027	30 MW Kaheawa Wind Power 1 Removed 9.47 MW Kahului 1-2 Removed 23 MW Kahului 3-4 Removed 49.36 MW Maalaea 10-13 Removed Install 54 MW Onshore Wind - Zone C	30 MW Kaheawa Wind Power 1 Removed 9.47 MW Kahului 1-2 Removed 23 MW Kahului 3-4 Removed 49.36 MW Maalaea 10-13 Removed Install 69 MW Onshore Wind - Zone C Install 27 MW Paired PV with 94 MWh Battery - Zone B Install 22 MW Paired PV with 54 MWh Battery - Zone C	30 MW Kaheawa Wind Power 1 Removed 9.47 MW Kahului 1-2 Removed 23 MW Kahului 3-4 Removed 49.36 MW Maalaea 10-13 Removed Install 31 MW Onshore Wind - Zone C	30 MW Kaheawa Wind Power 1 Removed 9.47 MW Kahului 1-2 Removed 23 MW Kahului 3-4 Removed 49.36 MW Maalaea 10-13 Removed Install 54 MW Onshore Wind - Zone C
2028	Install 3 MW Onshore Wind - Zone C	Install 10 MW Paired PV with 21 MWh Battery - Zone B Install 19 MW Paired PV - Zone B		Install 2 MW Onshore Wind - Zone C
2029		Install 34 MW Paired PV with 109 MWh Battery - Zone B Install 15 MW Paired PV with 5 MWh Battery - Zone C		Install 4 MW Onshore Wind - Zone C
2030	33 MW Maalaea 4-9 Removed Install 13 MW CC Install 3 MW Onshore Wind - Zone C Install 22 MW Paired PV with 22 MWh Battery - Zone C	33 MW Maalaea 4-9 Removed Install 39 MW CC Install 8 MW Onshore Wind - Zone C	33 MW Maalaea 4-9 Removed	33 MW Maalaea 4-9 Removed Install 25 MW CC Install 4 MW Onshore Wind - Zone C Install 28 MW Paired PV with 28 MWh Battery - Zone C
2031	Install 2 MW CC Install 2 MW Onshore Wind - Zone C Install 3 MW Paired PV with 3 MWh Battery - Zone C	Install 3 MW CC Install 7 MW Onshore Wind - Zone C Install 4 MW CT		Install 3 MW CC Install 10 MW Paired PV with 10 MWh Battery - Zone C
2032	Install 3 MW CC Install 12 MW Paired PV with 20 MWh Battery - Zone C	Installed 8 MW CT Installed 22 MW Paired PV with 68 MWh Battery - Zone B Installed 14 MW Paired PV with 18 MWh Battery - Zone C		Install 2 MW CC Install 19 MW Paired PV with 35 MWh Battery - Zone C Install 8 MW Paired PV with 18 MWh Battery - Zone B
2033	21 MW Kaheawa Wind Power 2 Removed 21 MW Auwahi Wind Removed Install 25 MW Onshore Wind - Zone C Install 25 MW Paired PV with 54 MWh Battery - Zone C	21 MW Kaheawa Wind Power 2 Removed 21 MW Auwahi Wind Removed Install 24 MW Onshore Wind - Zone C Install 13 MW Paired PV with 27 MWh Battery - Zone C Install 23 MW Paired PV with 61 MWh Battery - Zone B	21 MW Kaheawa Wind Power 2 Removed 21 MW Auwahi Wind Removed Install 36 MW Onshore Wind - Zone C	21 MW Kaheawa Wind Power 2 Removed 21 MW Auwahi Wind Removed Install 18 MW Onshore Wind - Zone C Install 1 MW Paired PV with 3 MWh Battery - Zone C Install 32 MW Paired PV with 102 MWh Battery - Zone B
2034	Install 5 MW Paired PV with 13 MWh Battery - Zone B Install 11 MW Paired PV with 8 MWh Battery - Zone C	Install 36 MW Paired PV with 102 MWh Battery - Zone B Install 2 MW Paired PV - Zone C Install 1 MW Biomass		Install 16 MW Paired PV with 38 MWh Battery - Zone B Install 16 MW Paired PV with 55 MWh Battery - Zone C
2035	Install 2 MW CC Install 7 MW Paired PV with 23 MWh Battery - Zone B Increase Paired PV by 3 MW - Zone C	Install 8 MW Biomass		Install 4 MW Biomass Install 14 MW Paired PV with 21 MWh Battery - Zone B Install 2 MW Paired PV with 14 MWh Battery - Zone C

Capacity Expansion Plans – RPS-A



Despite the change in forecasted loads and resource selection across the Base, Low Load, High Load, and Faster Customer Tech cases, the resulting RPS-A is consistently high and ahead of mandated targets. This indicates that the favorable economics of adding low-cost renewables is driving their selection in the resource plans ahead of RPS mandates.

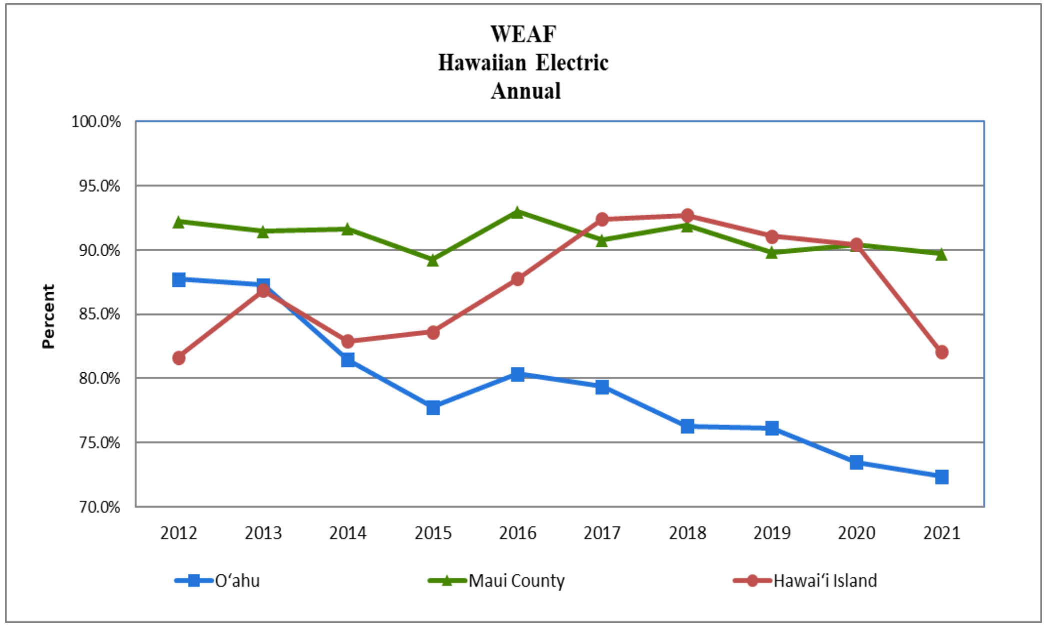
Capacity Expansion Plans – Thermal HDC and ERM Target Sensitivity

- Based on TAP feedback, applying an hourly dependable capacity (HDC) for firm thermal generation and evaluation of different levels of energy reserve margin (ERM) were tested to ensure that the optimal least-cost resource mix did not change significantly. This analysis iterates, in part, on the probabilistic resource adequacy analysis discussed later in this report.

- Currently, existing and new firm generation have an HDC of 1 or 100%, where there are no assumed derates for maintenance or forced outages. Capacity expansion plans were developed to test the sensitivity of the thermal resource selection to the ERM target and HDC.

- A thermal HDC was applied in RESOLVE to represent the availability of thermal units after planned and unplanned outages using the 2021 Weighted Equivalent Availability Factor (WEAF). This metric is the percentage of time a fleet of generating units is available to generate electricity, weighted for generator size where larger generators have a greater effect on WEAF.

- The table on the following slide are the results of this analysis. It is observed that the resource mix of wind, solar, and energy storage is unchanged. The amount of firm generation that is selected by RESOLVE changes based on the ERM. This suggests that the ERM and HDC do not impact building of low-cost renewables (i.e., firm generation does not displace lower cost solar and wind resources); however, firm generation depends on the level of reliability desired.



Capacity Expansion Plans – Thermal HDC and ERM Target Sensitivity

Year 2030	Base	30% ERM, Thermal HDC	20% ERM, Thermal HDC	15% ERM, Thermal HDC	10% ERM, Thermal HDC
Existing firm HDC (%)	100%	89.72%	89.72%	89.72%	89.72%
New firm HDC (%)	100%	97.4%	97.4%	97.4%	97.4%
ERM Requirement (%)	30%	30%	20%	15%	10%
New Firm (selected by RESOLVE)	13	26	12	4	0
Existing Firm	126	126	126	126	126
Paired PV	22	25	18	17	14
Onshore Wind	60	60	62	62	64
Paired Storage (MW/MWh)	22 MW / 22 MWh	25 MW / 25 MWh	18 MW / 18 MWh	17 MW / 17 MWh	14 MW / 14 MWh

Capacity Expansion Plans – Key Findings

- In the near-term, the same type of resources are being selected by RESOLVE through 2034 and the resource build only varies in quantity and timing across the different scenarios.
  - While the plans diverge slightly in 2035 when the faster customer technology adoption and high load scenarios build a new resource (biomass), the selected capacity is small (4-8 MW).
  - This indicates that in the near-term, the grid needs are similar and that further load scenarios may not be needed.
  - The resulting RPS-A for these plans is consistently high and further supports that the load bookends are an appropriate framework for considering load scenarios.
- Regardless of the HDC applied to thermal units or ERM target percentage, high amounts of renewables (wind, PV+BESS) are still consistently selected in RESOLVE
  - Firm thermal capacity is still needed for ERM targets between 15-30%

RESOLVE to PLEXOS – Detailed Resource Plan

Adjustments were made to the RESOLVE resource plan to reflect minimum installed capacities for thermal generating units.

*The combined cycle resource selected by RESOLVE is much smaller than the assumed block size for a 1x1 LM2500 CC (48 MW). However, because RESOLVE built this resource to meet a capacity need for ERM, the combined cycle was converted to two 9 MW ICE units.

Year	Base Case (RESOLVE)	18 MW ICE (PLEXOS)
2027	30 MW Kaheawa Wind Power 1 Removed 9.47 MW Kahului 1-2 Removed 23 MW Kahului 3-4 Removed 49.36 MW Maalaea 10-13 Removed Install 54 MW Onshore Wind - Zone C	30 MW Kaheawa Wind Power 1 Removed 9.47 MW Kahului 1-2 Removed 23 MW Kahului 3-4 Removed 49.36 MW Maalaea 10-13 Removed Install 54 MW Onshore Wind - Zone C
2028	Install 3 MW Onshore Wind - Zone C	Install 3 MW Onshore Wind - Zone C
2029		
2030	33 MW Maalaea 4-9 Removed **Install 13 MW CC*** Install 3 MW Onshore Wind - Zone C Install 22 MW Paired PV with 22 MWh Battery - Zone C	33 MW Maalaea 4-9 Removed **Install 18 MW ICE** Install 3 MW Onshore Wind - Zone C Install 22 MW Paired PV with 22 MWh Battery - Zone C
2031	**Install 2 MW CC*** Install 2 MW Onshore Wind - Zone C Install 3 MW Paired PV with 3 MWh Battery - Zone C	Install 2 MW Onshore Wind - Zone C Install 3 MW Paired PV with 3 MWh Battery - Zone C
2032	**Install 3 MW CC*** Install 12 MW Paired PV with 20 MWh Battery - Zone C	Install 12 MW Paired PV with 20 MWh Battery - Zone C
2033	21 MW Kaheawa Wind Power 2 Removed 21 MW Auwahi Wind Removed Install 25 MW Onshore Wind - Zone C Install 25 MW Paired PV with 54 MWh Battery - Zone C	21 MW Kaheawa Wind Power 2 Removed 21 MW Auwahi Wind Removed Install 25 MW Onshore Wind - Zone C Install 25 MW Paired PV with 54 MWh Battery - Zone C
2034	Install 5 MW Paired PV with 13 MWh Battery - Zone B Install 11 MW Paired PV with 8 MWh Battery - Zone C	Install 5 MW Paired PV with 13 MWh Battery - Zone B Install 11 MW Paired PV with 8 MWh Battery - Zone C
2035	**Install 2 MW CC*** Install 7 MW Paired PV with 23 MWh Battery - Zone B Increase Paired PV by 3 MW - Zone C	Install 7 MW Paired PV with 23 MWh Battery - Zone B Increase Paired PV by 3 MW - Zone C

Energy Reserve Margin Analysis

Energy Reserve Margin

Historically, Maui's capacity planning criteria was defined by Rule 1 with consideration for a reserve margin:

- The total capability of the system must at all times be equal to or greater than the summation of the following:
  - The capacity needed to serve the estimated system peak load less the total amount of interruptible load;
  - The capacity of the unit scheduled for maintenance; and
  - The capacity that would be lost by the forced outage of the largest available unit in service
- Consideration will be given to maintaining a reserve margin of approximately 20 percent based on Reserve Ratings

The current Energy Reserve Margin criteria was developed to consider the dynamic nature of variable resources and limited duration storage

- The ERM is the percentage which the system capacity must exceed the system load in each hour
- The hourly evaluation of available energy allows for a statistical representation of the impact of variable and finite resources at all hours of the day
- The ERM for Maui is 30% to provide reasonable reliability reserve to address some level of contingencies, forecast errors, and uncertainties inherent in planning assumptions

Energy Reserve Margin – Scenario Analysis

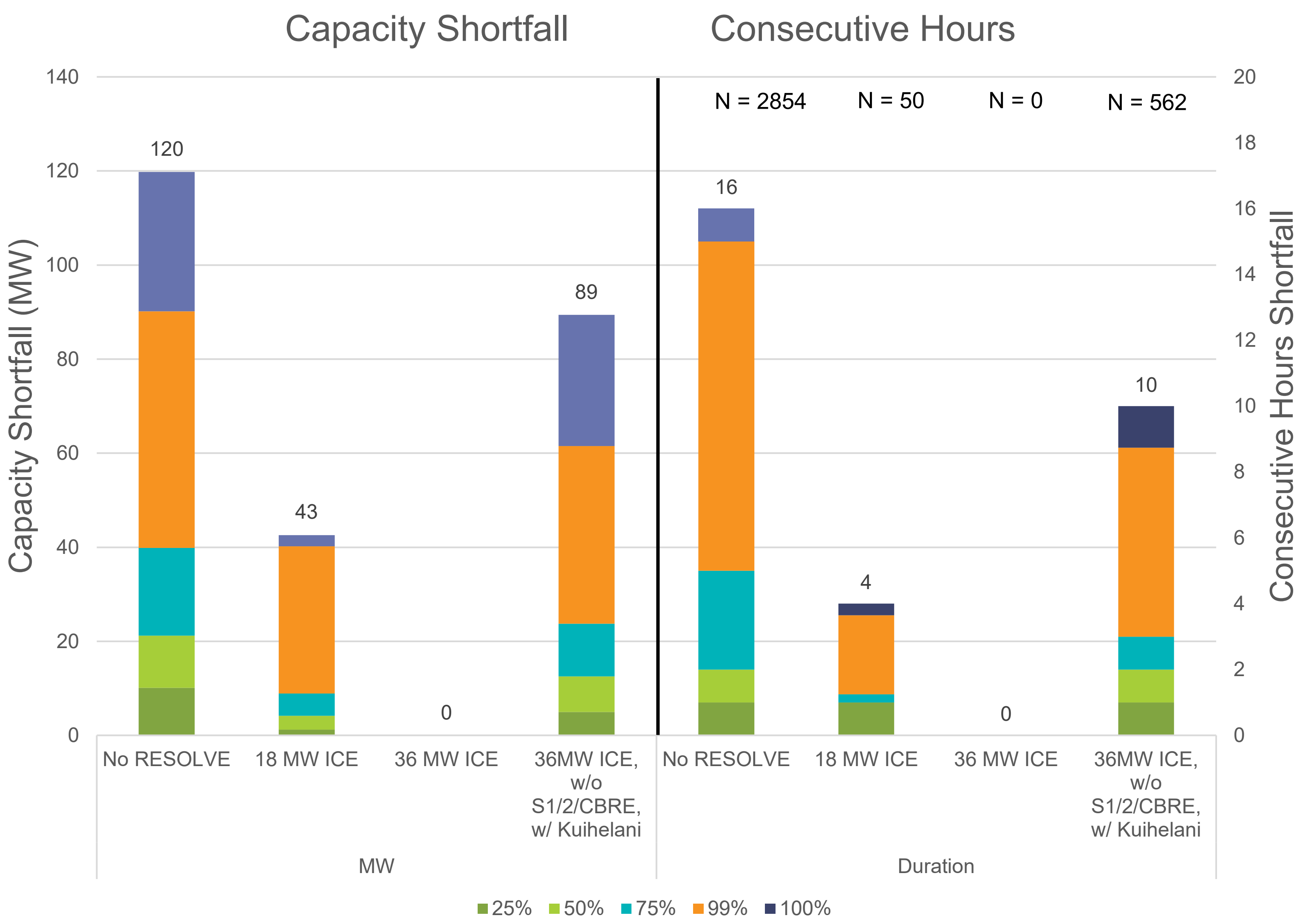
Using the Base scenario as a guide, various scenarios were evaluated to determine the capacity shortfall and consecutive hours of shortfall. These two metrics provide insight into both the size and duration of a capacity shortfall.

- **No Future RESOLVE Resources** – Using the Base scenario, planned resource additions for S1/S2/CBRE and planned removals are included but any selected RESOLVE resources are not included. This scenario will identify the capacity that RESOLVE selected to meet ERM.
- **18 MW ICE** – Using the Base scenario, partial installations of combined cycle that were selected by RESOLVE were accelerated from 2031, 2032 and combined into year 2030 for a total of 18 MW. For capacity planning purposes, this thermal generating resource was represented by 2 x 9 MW ICE units.
- **36 MW ICE** – Using the Base scenario, the partial installations of combined cycle were again converted to 18 MW of ICE. An additional 18 MW of ICE was added and the combined 36 MW was installed in 2027.
- **36 MW ICE, w/o S1/S2/CBRE Ph2, w/ Kuihelani Solar (Kuihelani)** – Using the 36 MW ICE scenario, less certain planned resources were removed from Stage 1, Stage 2, and CBRE Ph 2. Kuihelani was still included because there was relatively more certainty it would be in service compared to other projects.

Energy Reserve Margin – Detailed Resource Plan

Year	No RESOLVE	18 MW ICE	36 MW ICE	36 MW ICE w/o S1/S2/CBRE P2
2027	30 MW Kaheawa Wind Power 1 Removed 9.47 MW Kahului 1-2 Removed 23 MW Kahului 3-4 Removed 49.36 MW Maalaea 10-13 Removed	30 MW Kaheawa Wind Power 1 Removed 9.47 MW Kahului 1-2 Removed 23 MW Kahului 3-4 Removed 49.36 MW Maalaea 10-13 Removed Install 54 MW Onshore Wind - Zone C	30 MW Kaheawa Wind Power 1 Removed 9.47 MW Kahului 1-2 Removed 23 MW Kahului 3-4 Removed 49.36 MW Maalaea 10-13 Removed Install 54 MW Onshore Wind - Zone C Install 36 MW ICE	30 MW Kaheawa Wind Power 1 Removed 9.47 MW Kahului 1-2 Removed 23 MW Kahului 3-4 Removed 49.36 MW Maalaea 10-13 Removed Install 54 MW Onshore Wind - Zone C Install 36 MW ICE
2028		Install 3 MW Onshore Wind - Zone C	Install 3 MW Onshore Wind - Zone C	Install 3 MW Onshore Wind - Zone C
2029				
2030	33 MW Maalaea 4-9 Removed	33 MW Maalaea 4-9 Removed Install 18 MW ICE Install 3 MW Onshore Wind - Zone C Install 22 MW Paired PV with 22 MWh Battery - Zone C	33 MW Maalaea 4-9 Removed Install 3 MW Onshore Wind - Zone C Install 22 MW Paired PV with 22 MWh Battery - Zone C	33 MW Maalaea 4-9 Removed Install 3 MW Onshore Wind - Zone C Install 22 MW Paired PV with 22 MWh Battery - Zone C
2031		Install 2 MW Onshore Wind - Zone C Install 3 MW Paired PV with 3 MWh Battery - Zone C	Install 2 MW Onshore Wind - Zone C Install 3 MW Paired PV with 3 MWh Battery - Zone C	Install 2 MW Onshore Wind - Zone C Install 3 MW Paired PV with 3 MWh Battery - Zone C
2032		Install 12 MW Paired PV with 20 MWh Battery - Zone C	Install 12 MW Paired PV with 20 MWh Battery - Zone C	Install 12 MW Paired PV with 20 MWh Battery - Zone C
2033	21 MW Kaheawa Wind Power 2 Removed 21 MW Auwahi Wind Removed	21 MW Kaheawa Wind Power 2 Removed 21 MW Auwahi Wind Removed Install 25 MW Onshore Wind - Zone C Install 25 MW Paired PV with 54 MWh Battery - Zone C	21 MW Kaheawa Wind Power 2 Removed 21 MW Auwahi Wind Removed Install 25 MW Onshore Wind - Zone C Install 25 MW Paired PV with 54 MWh Battery - Zone C	21 MW Kaheawa Wind Power 2 Removed 21 MW Auwahi Wind Removed Install 25 MW Onshore Wind - Zone C Install 25 MW Paired PV with 54 MWh Battery - Zone C
2034		Install 5 MW Paired PV with 13 MWh Battery - Zone B Install 11 MW Paired PV with 8 MWh Battery - Zone C	Install 5 MW Paired PV with 13 MWh Battery - Zone B Install 11 MW Paired PV with 8 MWh Battery - Zone C	Install 5 MW Paired PV with 13 MWh Battery - Zone B Install 11 MW Paired PV with 8 MWh Battery - Zone C
2035		Install 7 MW Paired PV with 23 MWh Battery - Zone B Increase Paired PV by 3 MW - Zone C	Install 7 MW Paired PV with 23 MWh Battery - Zone B Increase Paired PV by 3 MW - Zone C	Install 7 MW Paired PV with 23 MWh Battery - Zone B Increase Paired PV by 3 MW - Zone C

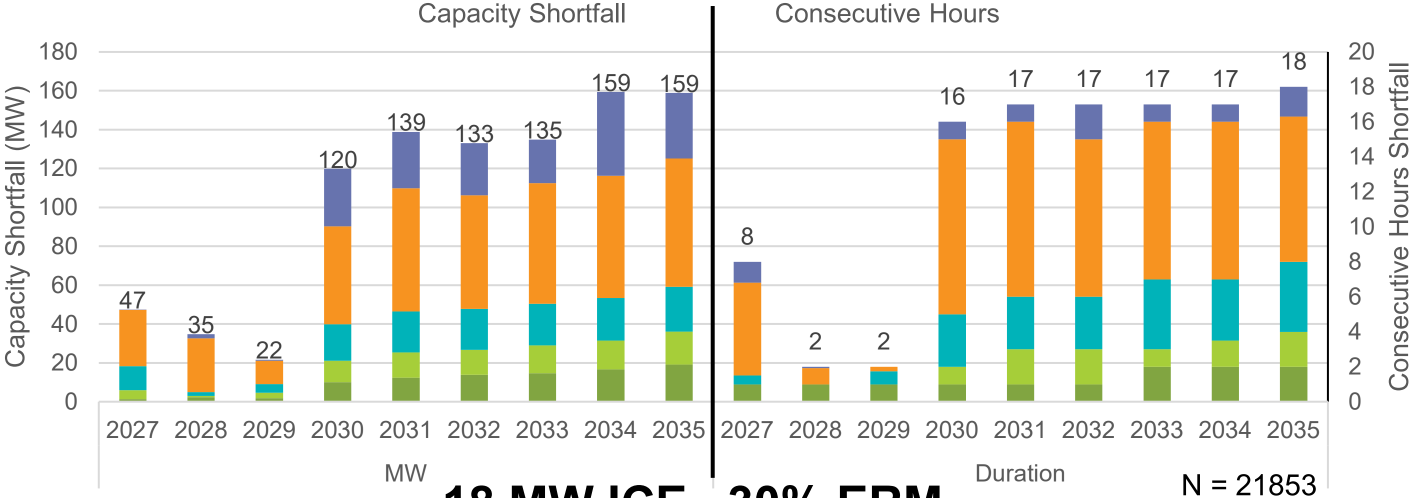
Energy Reserve Margin – ERM Needs (2030)



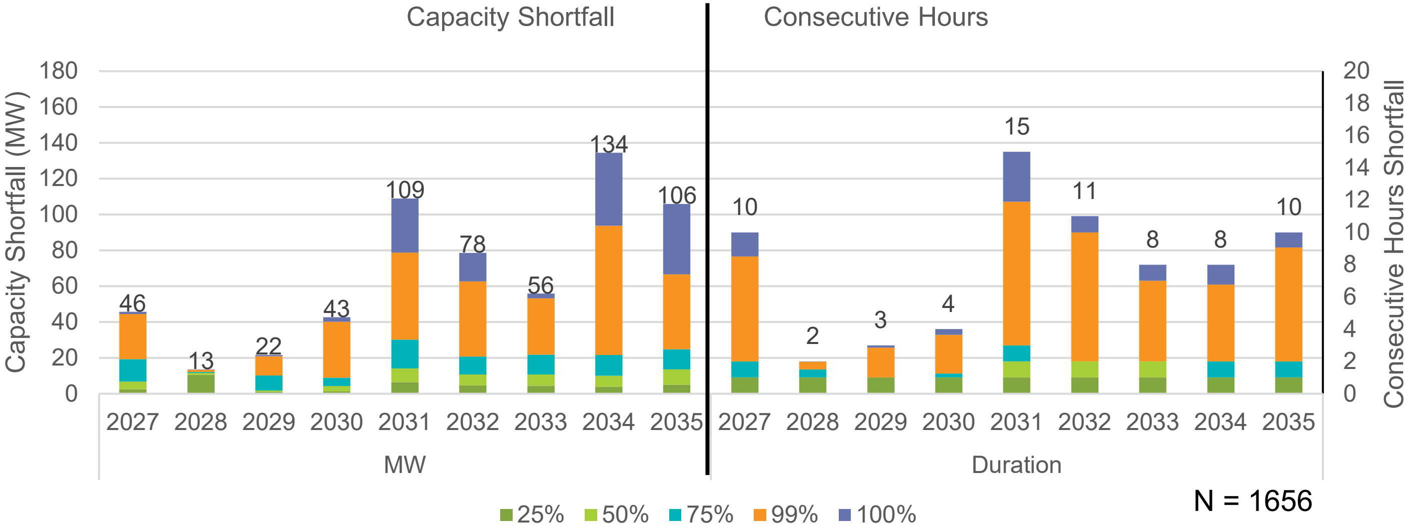
- 30% ERM and p80 HDCs were included in this analysis
- N: Total hours of unserved energy.
- The capacity shortfalls for each hour in 2030 is shown on the left.
- The duration of each capacity shortfall is shown on the right.
- The colors represent percentiles that show the distribution of hourly shortfalls and shortfall durations throughout 2030.

Energy Reserve Margin – Annual ERM Needs

No RESOLVE Selected Resources – 30% ERM



18 MW ICE– 30% ERM



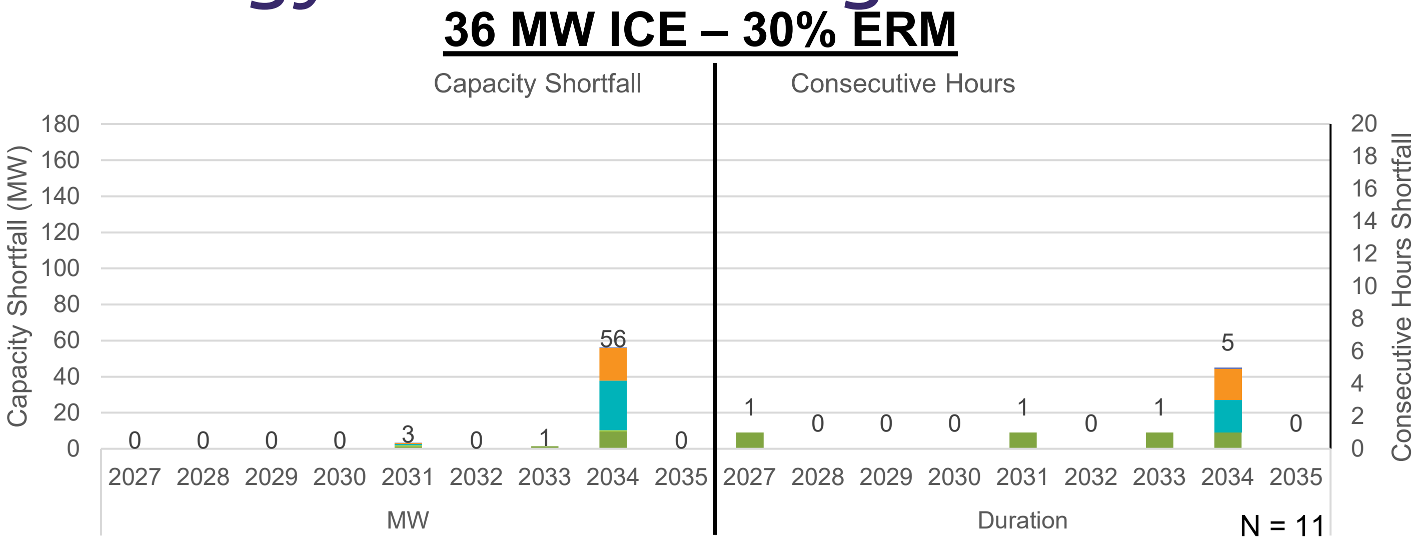
2027-2029

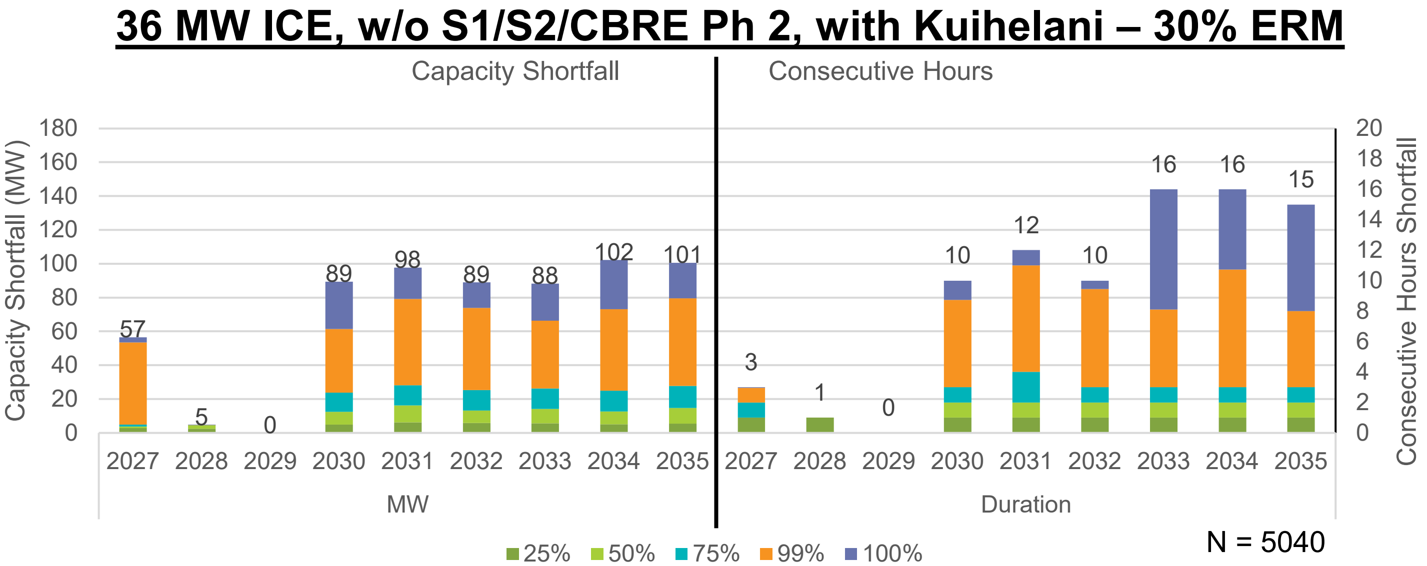
- Capacity shortfalls are due to the removal of Maalaea 10-13 and maintenance of the dual train combined cycles

2030-2035

- Capacity shortfalls are due to the removal of Maalaea 4-9
- The addition of 18 MW ICE in 2030 reduces 2030+ shortfalls relative to the no RESOLVE resources case

Energy Reserve Margin – Annual ERM Needs





- **36 MW ICE:**
  - **2034** – Capacity shortfall is due to maintenance on the dual train combined cycles
- **36 MW ICE w/ S1/S2/CBRE Ph 2**
  - **2030-2035** – Capacity shortfalls are due to the removal of Maalaea 4-9

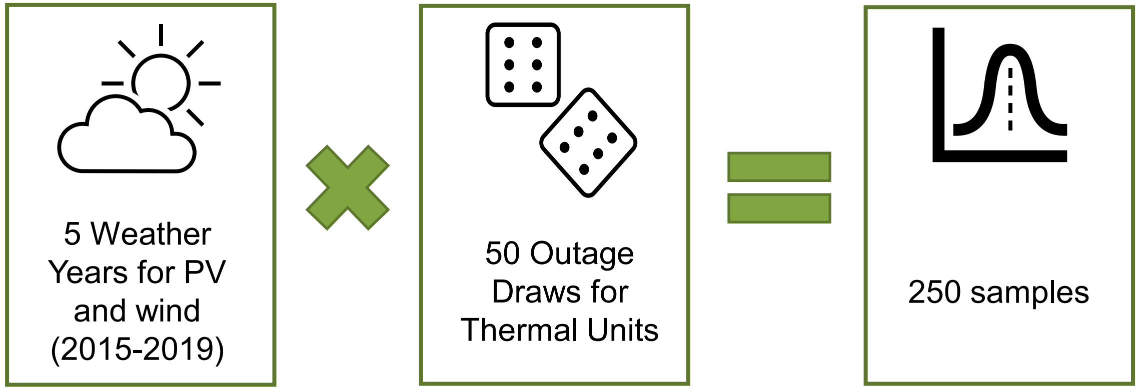
Although 36 MW of ICE is installed in 2027 in both cases, the wind and PV+BESS has a significant impact on the remaining capacity need.

Energy Reserve Margin – Key Findings

- The No RESOLVE selected resources scenario identified the capacity and duration to be met by future resources.
- Excluding the extreme outliers, at the 99^{th} percentile, a capacity need of 90 MW and 15 consecutive hours in 2030 was determined.
- The 18 MW ICE scenario confirms that there is still a residual ERM need after accounting for the RESOLVE additions so additional capacity is needed.
- The 36 MW ICE scenario shows that additional ICE can solve for residual ERM needs in 2030.
- The 36 MW ICE w/o S1/S2/CBRE Ph 2, w/ Kuihelani scenario shows that a 36 MW additional ICE may not be enough if other planned renewable projects in the resource plan withdraw.
- Grid needs from 2027 – 2035 agree with the general trends highlighted in 2030, that 36 MW of new thermal generation satisfies most of the future ERM needs and that even more capacity, above 36 MW, may be needed if projects from Stage 1, Stage 2, and CBRE are not able to go into service in this timeframe.

Probabilistic Resource Adequacy Analysis

Probabilistic Analyses



- A probabilistic framework was developed with and endorsed by the TAP to further examine the resource adequacy of the plans in a selected year.
- Probabilistic resource adequacy is a method to quantify the risk of capacity shortfalls given the uncertainty in future system operating conditions.
- This method utilizes a random sampling approach to define distributions of generating resource availability using an outage rate for thermal generators and historical weather years for variable renewable resources.
- 50 outage draws for thermal generators and 5 weather years for variable renewable resources were examined for a total of 250 samples for each case.

Probabilistic Analyses – Key Metrics

Several metrics can be calculated to characterize the reliability of the resource plan

- LOLE or Loss of Load Expectation is the average number of event-periods per year with unserved load across all simulated random samples. In the Company's analyses, this is defined as days per year.
- LOLEv or Loss of Load Frequency is the average count of events per year with unserved load across all simulated random samples. An event is defined as consecutive hours of unserved load.
- LOLH or Loss of Load Hours is the average number of hours with unserved load across all simulated random samples.
- EUE or Expected Unserved Energy is the average load not served per year across all simulated random samples.

LOLE: Target of 0.1 represents commonly used standard on the US Mainland.

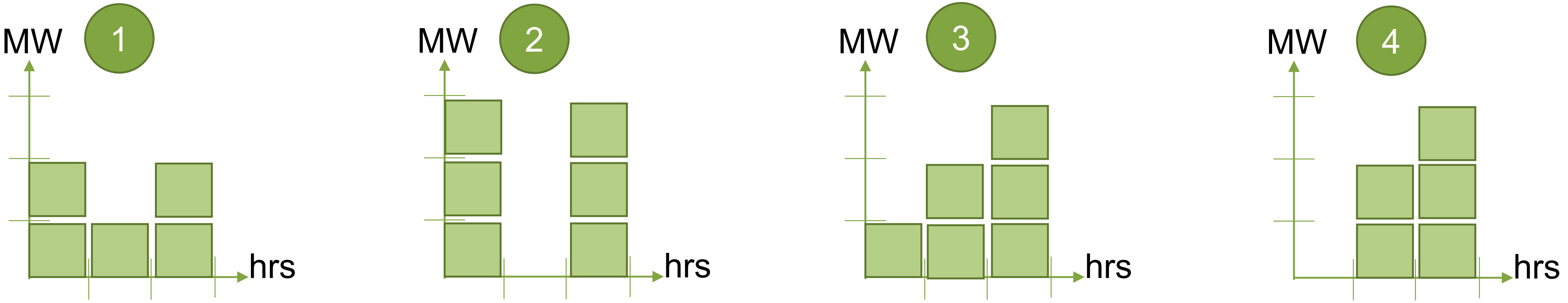
LOLH: Belgium, France, Great Britain, and Poland have a standard of equal to or less than 3 hr/yr.

EUE: Australia/AEMO have a standard of equal to or less than 0.002% of total energy demand. Using the 2030 forecasted net load on Maui, this is equivalent to 20 MWh.

The TAP recommends multiple metrics to assess resource adequacy. Although different jurisdictions use different metrics for their reliability standard, reporting a suite of metrics provides a fuller picture of the reliability of a resource plan. For example, LOLE indicates the number of days of unserved energy but does not indicate the magnitude (EUE), duration (LOLH), or number of events (LOLEv).

See EPRI Report 3002023230, Resource Adequacy for a Decarbonized Future, A Summary of Existing and Proposed Resource Adequacy Metrics, April 2022

Probabilistic Analyses – Key Metrics



Example	LOLEv	LOLH	EUE
1	1	3	5
2	2	2	6
3	1	3	6
4	1	2	5

Illustrative examples of LOLEv, LOLH, and EUE. Each of these metrics characterize the size and duration of unserved energy. One day of unserved energy (LOLE) can consist of one or more unserved energy events. One unserved event (LOLEv) can have a duration of one or multiple hours of unserved energy as long as the unserved energy occurs within a continuous set of hours. The total number of unserved hours is LOLH and the total amount of unserved energy is EUE.

- Examples 1 and 3 have the same LOLEv and LOLH but different EUE
- Examples 1 and 4 have the same LOLEv and EUE but different LOLH
- Examples 2 and 3 have the same EUE but different LOLEv and LOLH

Adapted from Telos Energy

Probabilistic Analyses – Key Findings

The key findings of the probabilistic analyses include:

- Each resource type improves reliability to a different degree. There are diminishing returns with each new addition of a single resource technology to improve reliability.
    - An incremental 50 MW PV+BESS addition to a base of Kuihelani Solar (60 MW) plus 22 MW PV+BESS, 60 MW wind reduced LOLE from **8.27** to **2.66** days/year. Further 50 MW additions had a reduced reduction in LOLE relative to the same base (+100 MW / **0.8** days/yr, +150 MW / **0.21** days/yr). (Slide 52)
    - An incremental 18 MW ICE addition from a base of Kuihelani Solar plus 22 MW PV+BESS, 60 MW wind reduced LOLE from **8.27** to **2.26** days/yr. Further 9 MW additions had a reduced reduction in LOLE relative to the same base (+27 MW / **1.17** days/yr, +36 MW / **0.58** days/yr). (Slide 55)
    - A 9 MW, 12-hour long duration energy storage (LDES) did not provide the same degree of reliability as a 9 MW ICE (36 MW ICE / **0.58** days/yr, 27 MW ICE + 9 MW LDES / **0.62** days/yr)
    - Adding 242 MW of variable generation and 18 MW of firm generation (**0.14** days/yr) or adding 291 MW of variable generation and 40 MW of standalone BESS (**0.14** days/yr) will achieve a similar LOLE as Maui in 2021 (**0.15** days/yr). (Slide 52)
- Due to potential community opposition to new wind plants, the model selected wind was converted to PV + BESS on an energy basis (ratio of 1 MW wind to 2 MW of PV). Probabilistic cases examining the substitution of 50 MW wind for 50 MW PV+BESS and comparison of the removal of 30 MW of wind vs 62 MW PV indicate that while wind improves reliability, PV + BESS improves reliability to a greater degree. (Slide 52)

Probabilistic Analyses – Stakeholder Feedback

The Company has incorporated significant stakeholder feedback into the Maui GNA that was provided by the TAP on the ongoing O‘ahu GNA analyses.

This feedback is reflected in additional cases conducted for the probabilistic analyses including evaluation of:

- Long duration storage
- Finer increments of thermal additions
- Finer increments of PV+BESS additions
- Tradeoffs between continuing existing generation against removal and replacement with new generation

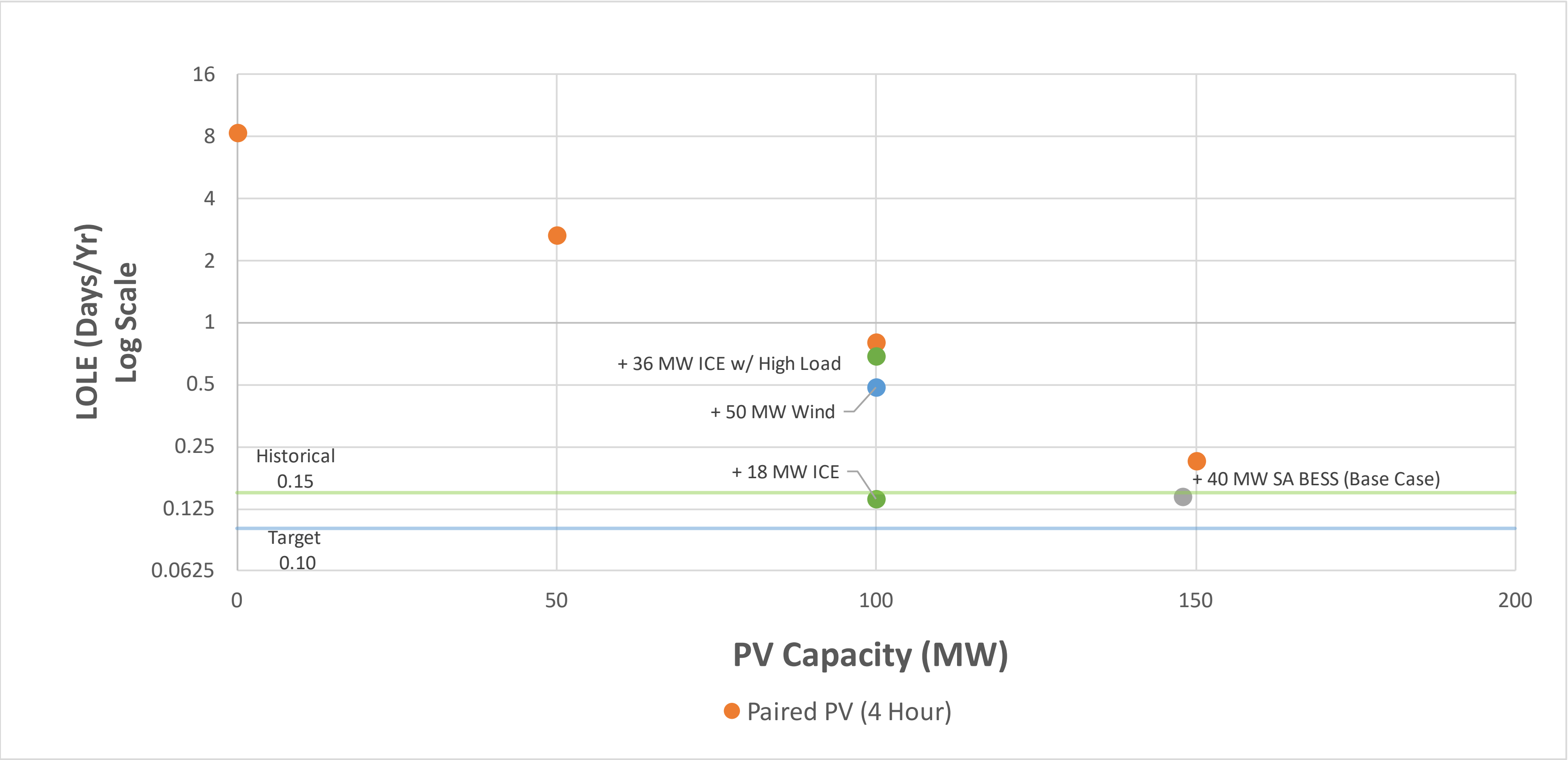
Probabilistic Analyses – Variable Resource Additions

Green = LOLE ≤ 0.10 Days/Yr (US Mainland), LOLH ≤ 3 hrs (Belgium, France, GB, Poland), EUE ≤ 0.002% of load/20 MWh (AEMO)

Year 2030	Existing Firm (MW)	Firm Removed (MW)	Future Firm (MW)	Planned Variable (MW)	Future Variable (MW)	SA BESS (MW)	LOLE (Days/Yr)	LOLEv (Events/Yr)	LOLH (Hours/Yr)	EUE (GWh/Yr)
Reference Case - 2021	240	-	-	-	-	-	0.15	0.16	0.25	0.00
Base Case – w/o S1/S2/CBRE Ph2, w/ Kuihelani	126	-114	0	60	82	0	8.27	13.83	38.37	0.83
Add 50 MW PV+BESS	126	-114	0	60	132	0	2.66	4.90	10.85	0.26
Add 100 MW PV+BESS	126	-114	0	60	182	0	0.80	1.44	2.72	0.07
Add 150 MW PV+BESS	126	-114	0	60	232	0	0.21	0.38	0.67	0.02
Add 100 MW PV+BESS, 18 MW ICE	126	-114	18	60	182	0	0.14	0.24	0.53	0.01
Add 100 MW PV+BESS, 36 MW ICE (High Load Bookend)	126	-114	36	60	182	0	0.68	1.30	2.62	0.08
Add 100 MW PV+BESS, 50 MW wind	126	-114	0	60	232	0	0.48	0.78	1.42	0.04
Base Case, No ICE	126	-114	0	208.5	82	40	0.14	0.31	0.62	0.01

Planned Variable includes: Kuihelani (60 MW), Paeahu (15 MW), Kamaole (40 MW), Kahana (20 MW), Pulehu (40 MW), CBRE Ph 2 (33.5 MW)
Future Standalone BESS includes: Waena BESS (40 MW)
Future Variable selected by RESOLVE includes: Wind (60 MW), PV+BESS (22 MW)

Probabilistic Analyses – Variable Resource Additions



LOLE

Add 100 MW PV+BESS

Add 100 MW PV+BESS, 50 MW onshore wind

Add 150 MW PV+BESS

Historic Level = 0.15

Add 40 MW SA BESS (Base Case, No ICE - includes S1/S2/CBRE Ph2)

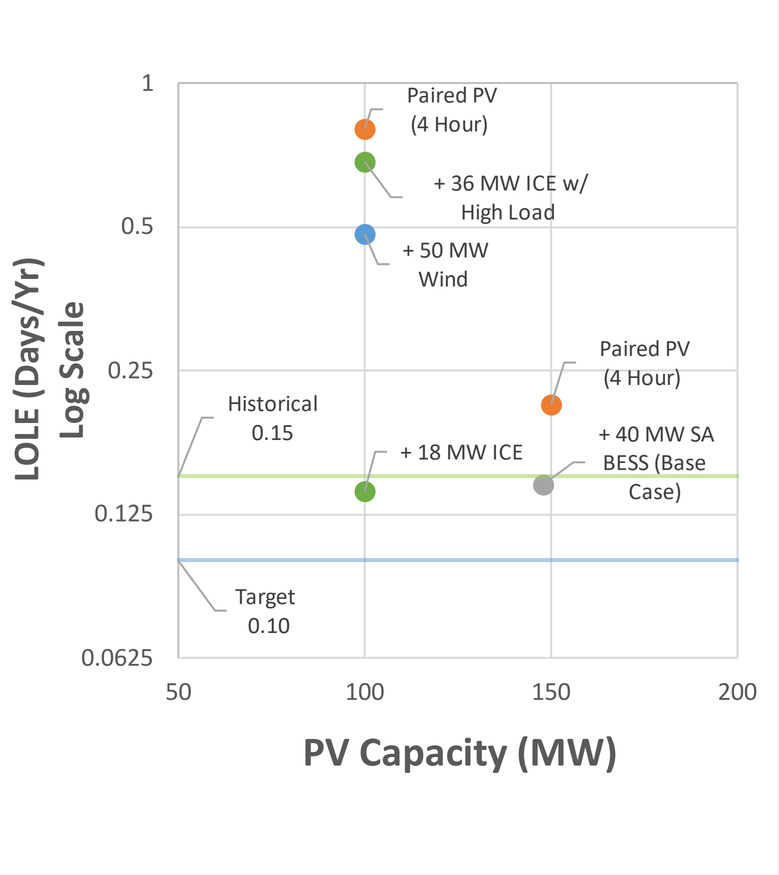
Add 100 MW PV+BESS, 18 MW ICE

US Mainland LOLE = 0.1

Probabilistic Analyses – Variable Resource Additions

LOLE is satisfactory if all the Stage 1, Stage 2, and CBRE Ph2 projects are in service (Base, No ICE Case) relative to historical reliability. Those resources could be replaced by 100 MW of PV paired with 4-hour storage and 18 MW of ICE and achieve a comparable level of reliability (lower green data point).

- With the addition of 100 MW of paired PV and a total of 36 MW of ICE, LOLE would be unsatisfactory in the High Load Bookend (upper green datapoint).
- 50 MW of paired PV improves LOLE more than 50 MW of wind (blue data point compared with the rightmost orange data point).
- 18 MW of thermal improves LOLE more than 50 MW of wind or 50 MW of paired PV (green data point compared with blue and rightmost orange datapoint)
- LOLE is worse than the historical level in the case with 150 MW of paired PV added. In comparison, the Base Case achieves an acceptable LOLE with slightly less paired PV but with the addition of 40 MW of standalone storage (gray datapoint).



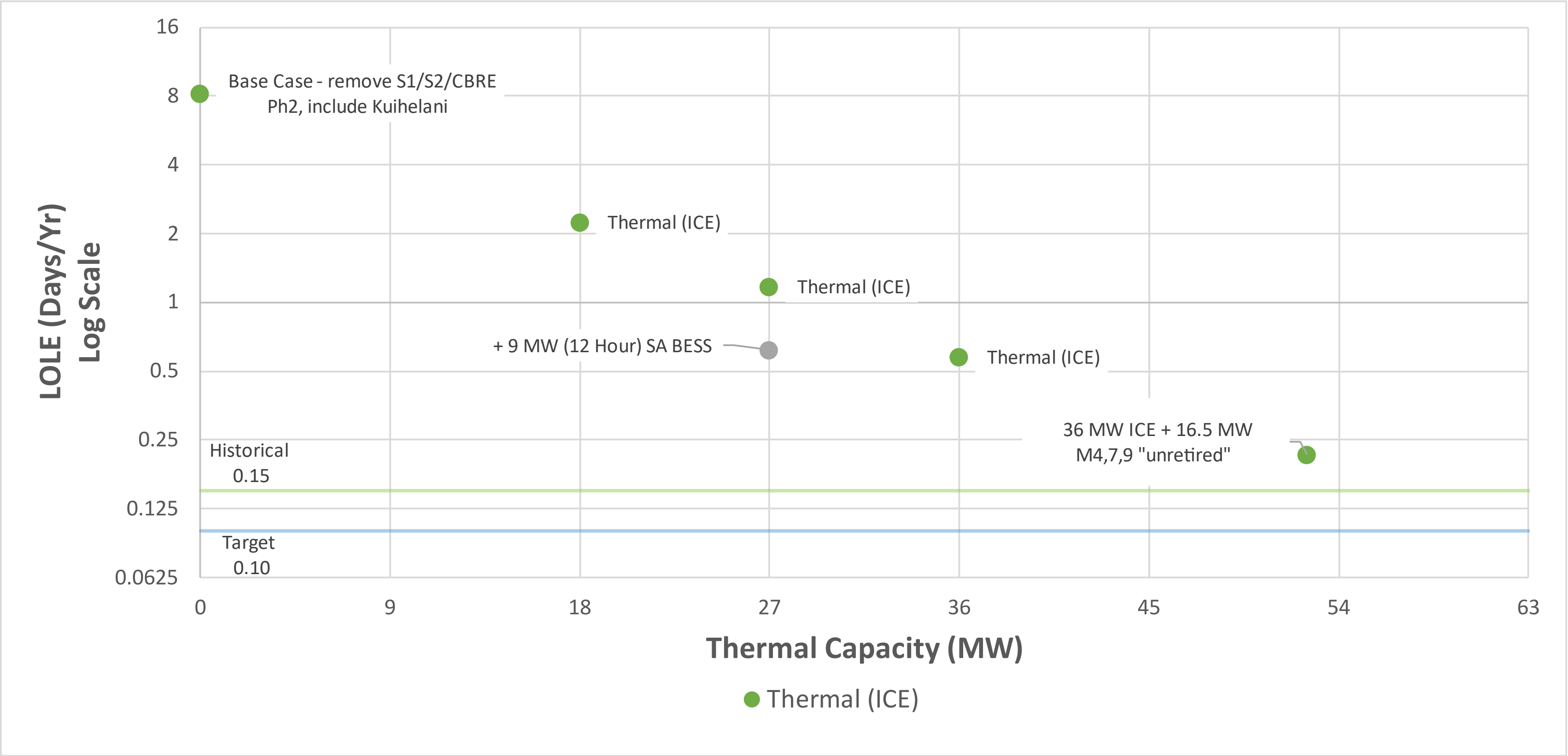
Probabilistic Analyses – Firm Resource Additions

Green = LOLE ≤ 0.10 Days/Yr (US Mainland), LOLH ≤ 3 hrs (Belgium, France, GB, Poland), EUE ≤ 0.002% of load/20 MWh (AEMO)

Year 2030	Existing Firm (MW)	Firm Removed (MW)	Future Firm (MW)	Planned Variable (MW)	Future Variable (MW)	SA BESS (MW)	LOLE (Days/Yr)	LOLEv (Events/Yr)	LOLH (Hours/Yr)	EUE (GWh/Yr)
Reference Case - 2021	240	-	-	-	-	-	0.15	0.16	0.25	0.00
Base Case - remove S1/S2/CBRE Ph2, include Kuihelani Solar	126	-114	0	60	82	0	8.27	13.83	38.37	0.83
Add 18 MW ICE	126	-114	18	60	82	0	2.26	3.57	9.97	0.21
Add 27 MW ICE	126	-114	27	60	82	0	1.17	1.84	4.70	0.10
Add 36 MW ICE	126	-114	36	60	82	0	0.58	0.91	2.41	0.05
Add 36 MW ICE, not retired: M4, M7, M9	142.5	-97.5	36	60	82	0	0.22	0.33	0.73	0.01
Add 27 MW ICE, add 9 MW 12-Hour BESS	126	-114	27	60	82	9	0.62	1.01	2.68	0.06

Planned Variable includes: Kuihelani (60 MW), Paeahu (15 MW), Kamaole (40 MW), Kahana (20 MW), Pulehu (40 MW), CBRE Ph 2 (33.5 MW)
Future Standalone BESS includes: Waena BESS (40 MW)
Future Variable selected by RESOLVE includes: Onshore Wind (60 MW), PV+BESS (22 MW)

Probabilistic Analyses – Firm Resource Additions



LOLE

Base Case - remove S1/S2/CBRE Ph2, include Kuihelani

Add 18 MW ICE

Add 27 MW ICE

Add 27 MW ICE, add 9 MW 12-Hour BESS

Add 36 MW ICE

Add 36 MW ICE, unretire M4, M7, M9

Historic Level = 0.15

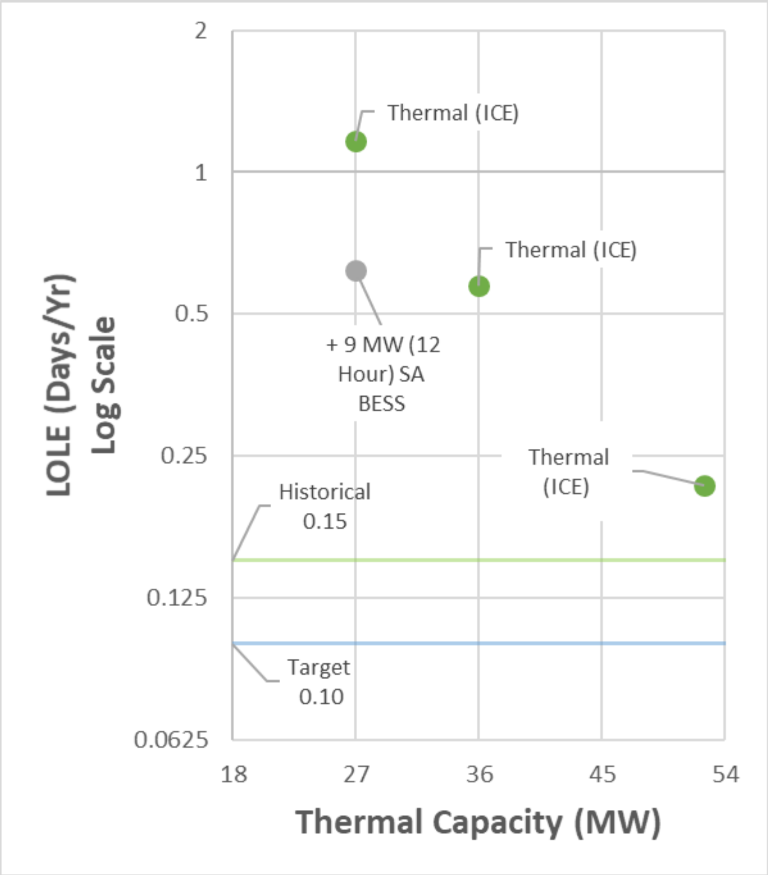
US Mainland LOLE = 0.1

Probabilistic Analyses – Firm Resource Additions

With the Stage 1, Stage 2, and CBRE Ph2 projects not in service (except Kuihelani which is in service), LOLE (8 days/year, see previous slide) does not meet the historical level.

- LOLE still does not meet the historical level with an additional 36 MW thermal and with existing units M4, M7, and M9 remaining in service and does not meet the US Mainland standard of 0.1 (lowest green datapoint).
- 9 MW of firm thermal generation improves LOLE more than 9 MW of 12-hour stand-alone BESS (middle green datapoint compared with gray datapoint).

Long duration energy storage may not necessarily reduce firm generation needs; however, additional solar + BESS would help to reduce firm generation needs. To meet immediate reliability needs, firm generation can adequately address reliability risks if solar + BESS resources are unable to reach commercial operations.



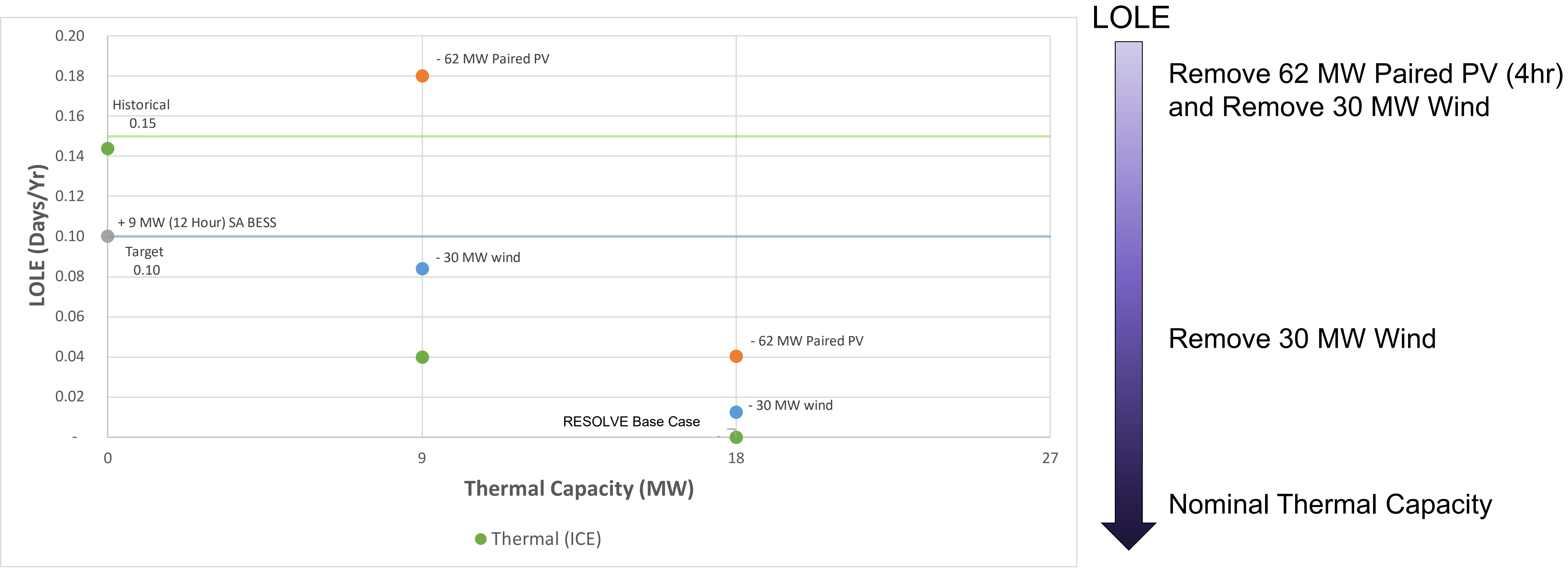
Probabilistic Analyses – Firm/Variable Resource Additions

Green = LOLE ≤ 0.10 Days/Yr (US Mainland), LOLH ≤ 3 hrs (Belgium, France, GB, Poland), EUE ≤ 0.002% of load/20 MWh (AEMO)

Year 2030	Existing Firm (MW)	Firm Removed (MW)	Future Firm (MW)	Planned Variable (MW)	Future Variable (MW)	SA BESS (MW)	LOLE (Days/Yr)	LOLEv (Events/Yr)	LOLH (Hours/Yr)	EUE (GWh/Yr)
Reference Case - 2021	240	-	-	-	-	-	0.15	0.16	0.25	0.00
Base Case, No ICE	126	-114	0	208.5	82	40	0.14	0.31	0.62	0.01
Add 9 MW ICE	126	-114	9	208.5	82	40	0.04	0.07	0.13	0.00
Add 9 MW ICE, remove 62 MW PV	126	-114	9	208.5	20	40	0.18	0.34	0.62	0.01
Add 9 MW ICE, remove 30 MW wind	126	-114	9	208.5	52	40	0.08	0.15	0.33	0.01
Add 18 MW ICE (RESOLVE Base Case)	126	-114	18	208.5	82	40	0	0	0	0
Add 18 MW ICE, remove 62 MW PV	126	-114	18	208.5	20	40	0.04	0.08	0.12	0.00
Add 18 MW ICE, remove 30 MW wind	126	-114	18	208.5	52	40	0.01	0.03	0.04	0.00
Add 9 MW 12-Hour BESS	126	-114	0	208.5	82	49	0.10	0.22	0.49	0.01

Planned Variable includes: Kuihelani (60 MW), Paeahu (15 MW), Kamaole (40 MW), Kahana (20 MW), Pulehu (40 MW), CBRE Ph 2 (33.5 MW)
Future Standalone BESS includes: Waena BESS (40 MW)
Future Variable selected by RESOLVE includes: Onshore Wind (60 MW), PV+BESS (22 MW)

Probabilistic Analyses – Firm/Variable Resource Additions



Firm thermal resources can be added as a contingency for project uncertainty. Removing renewable resources has a reduced impact on LOLE when there are firm thermal resources on the grid.

Probabilistic Analyses – Additional Unit Removals

Green = LOLE ≤ 0.10 Days/Yr (US Mainland), LOLH ≤ 3 hrs (Belgium, France, GB, Poland), EUE ≤ 0.002% of load/20 MWh (AEMO)

Year 2030	Existing Firm (MW)	Firm Removed (MW)	Future Firm (MW)	Planned Variable (MW)	Future Variable (MW)	SA BESS (MW)	LOLE (Days/Yr)	LOLEv (Events/Yr)	LOLH (Hours/Yr)	EUE (GWh/Yr)
Reference Case - 2021	240	-	-	-	-	-	0.15	0.16	**0.25**	**0.00**
Base Case, No ICE	126	-114	0	208.5	82	40	**0.14**	0.31	**0.62**	**0.01**
Add 9 MW ICE	126	-114	9	208.5	82	40	**0.04**	0.07	**0.13**	**0.00**
Add 18 MW ICE, retire M15	113	-127	18	208.5	82	40	**0.04**	0.04	**0.12**	**0.00**
Add 36 MW ICE, retire M15 & M18	100	-140	36	208.5	82	40	**0.02**	0.03	**0.06**	**0.00**
Add 36 MW ICE retire M15 & M18, no Future Variable	100	-140	36	208.5	0	40	**0.03**	0.03	**0.04**	**0.00**

Firm resources can be added as a contingency to meet reliability due to uncertainty in several planned projects and can accelerate removal from service of existing firm units if variable generation targets are reached.

Probabilistic Analyses – Firm/Variable Resource Additions

In 2030, compliance with all three standards is achievable with various resource mixes

- **RESOLVE Base Case, 18 MW Firm Generation Addition Scenario ($214MM)**: 291 MW of variable generation, 40 MW of standalone BESS, and 18 MW of firm generation
  - Variable Generation: 209 MW planned, 82 MW future (includes 60 MW onshore wind)
- **Low Renewable Scenario ($248MM)**: 142 MW of variable generation and 63 MW of firm generation
  - Variable Generation: 60 MW planned (Kuihelani), 82 MW future (includes 60 MW onshore wind)
- **No Firm Addition Scenario ($280MM)**: 328 MW of variable generation
  - Variable Generation: 60 MW planned (Kuihelani), 268 MW future (includes 60 MW onshore wind)

LOLE continues to decrease and reliability improves as more resources are added.

- Removing variable resources has a reduced adverse impact on LOLE when there is a higher capacity of firm thermal resources in the system.
  - Firm thermal resources can be added to the system as a contingency for project or forecast uncertainty.
- There are diminishing returns to LOLE improvement as more resources are added to the system.

Probabilistic Analyses – EUE Heatmap

Base Case with 0 MW Firm Generation

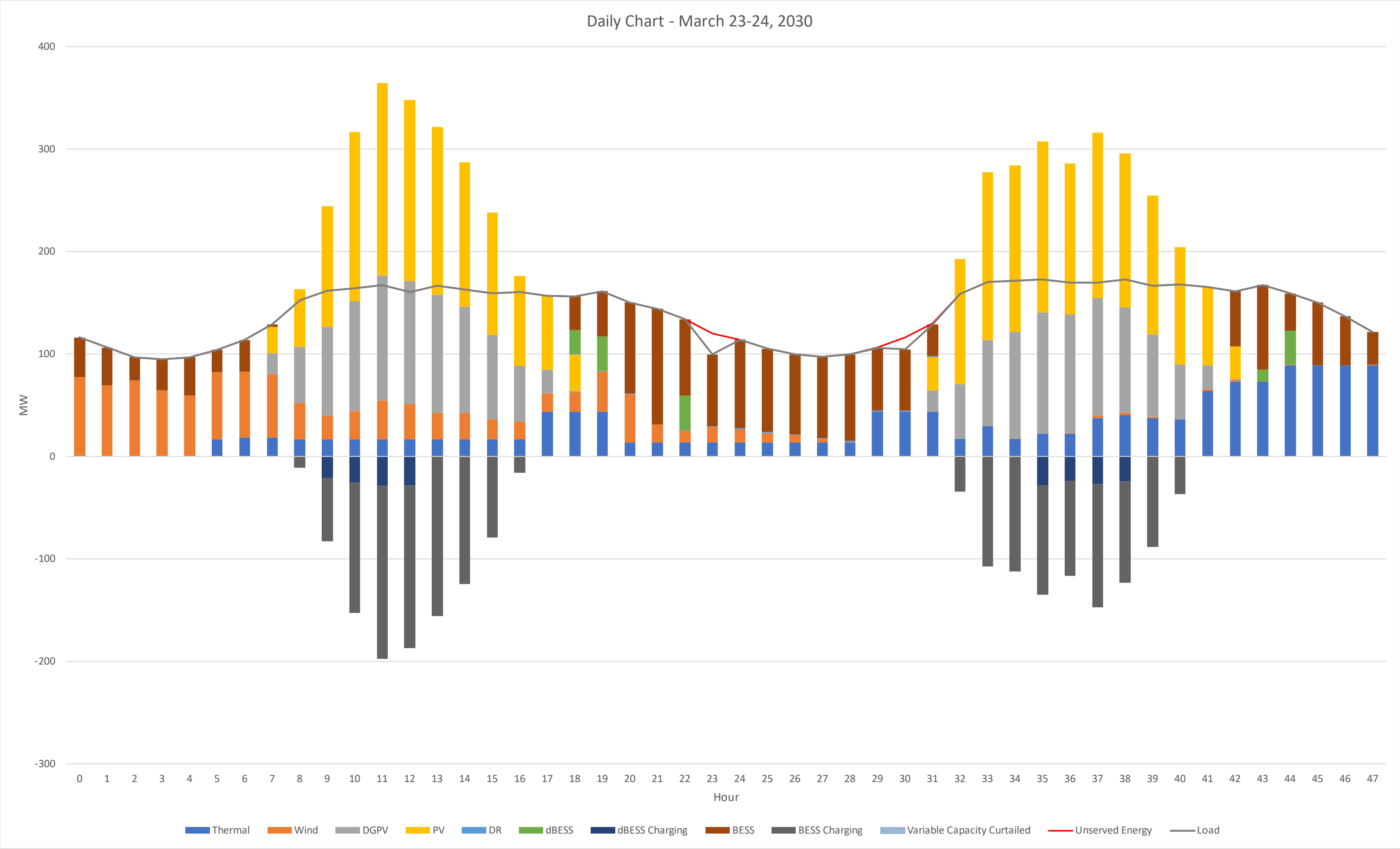
Hours Beginning	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.00	0.00	0.00	0.10	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.07	0.22	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.25	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.37	0.32	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.13	0.25	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.52	0.22	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.27	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.16	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.13	0.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	0.00	0.00	0.33	0.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.02	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.09	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.48	1.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.28	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Base Case with 9 MW Firm Generation

Hours Beginning	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.18	0.06	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.12	0.05	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.02	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.27	0.17	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.01	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.25	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

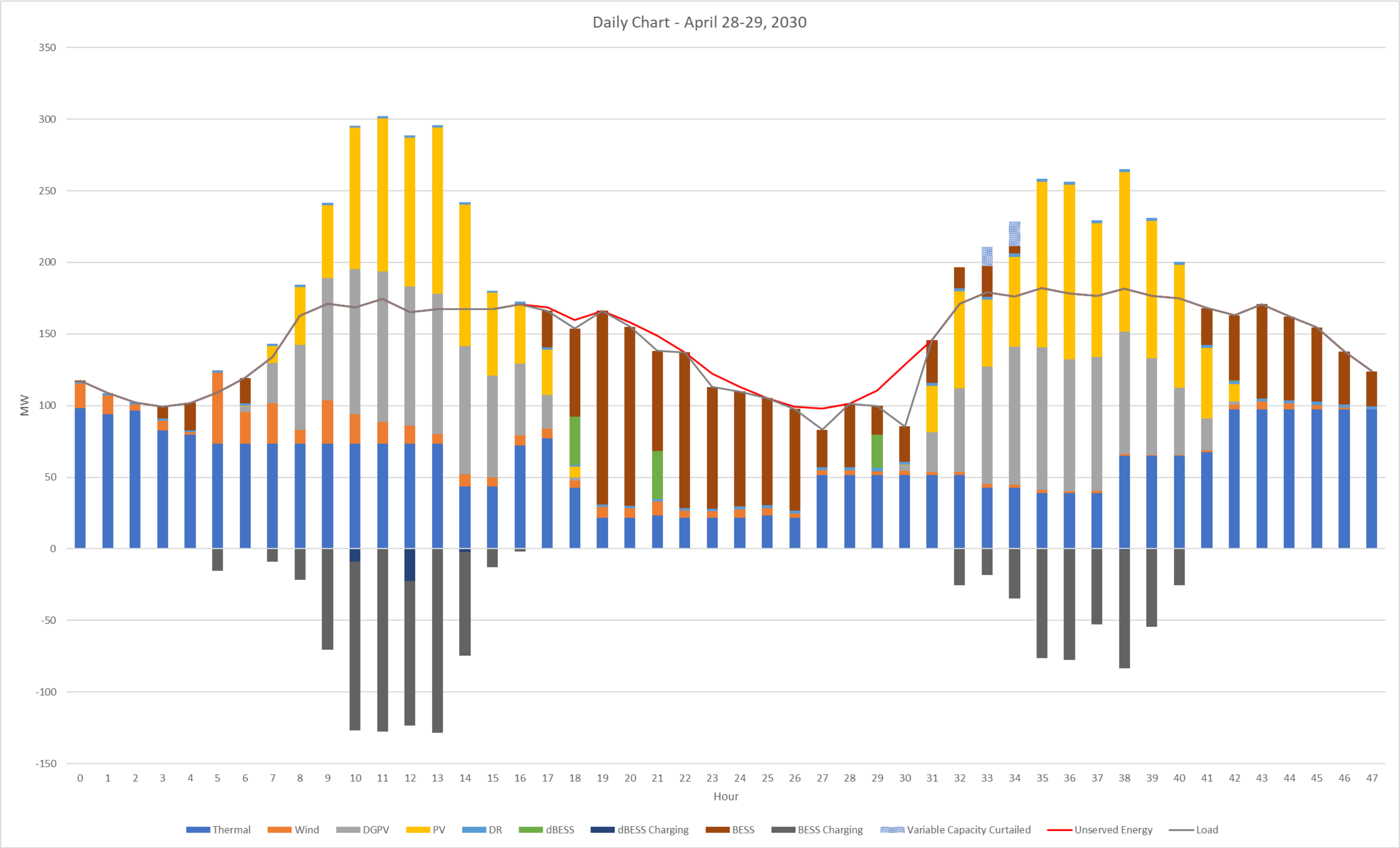
Pictured are heatmaps of unserved energy to show likelihood of when unserved energy may occur based on probabilistic resource adequacy analysis. Shortfalls are shown during the months of March, April and May where wind has a lower capacity factor and the PV+BESS do not have enough energy to load shift and meet unserved demand.

Probabilistic Analyses – Expected Unserved Energy



- The daily chart of the Base Case with 9 MW ICE
- 34 MWh of unserved energy observed late at night and early the next morning, driven by maintenance outages of thermal units.
- All BESS at 100% state of charge (SoC) after hour 17 but there is still not enough energy to serve the load overnight.

Probabilistic Analyses – Expected Unserved Energy



- The daily chart of the Base Case with 9 MW ICE
- 105 MWh of unserved energy observed late at night and early the next morning, driven by maintenance outages of thermal units.
- All BESS at 100% SoC after hour 17 but there is still not enough energy to serve the load overnight.

Production Cost Modeling and Operations of the Procurement Plan
Capacity Factor of Firm Units - 18 MW ICE

Year	9 MW ICE Unit 1	9 MW ICE Unit 2	Hana	Kahului1	Kahului2	Kahului3	Kahului4	Maalaea 01	Maalaea 02	Maalaea 03	Maalaea 04	Maalaea 05	Maalaea 06	Maalaea 07
2027	0%	0%	1%	N/A	N/A	N/A	N/A	0%	0%	0%	1%	0%	0%	0%
2028	0%	0%	1%	N/A	N/A	N/A	N/A	0%	0%	0%	2%	0%	0%	0%
2029	0%	0%	1%	N/A	N/A	N/A	N/A	0%	0%	0%	2%	0%	0%	0%
2030	2%	2%	1%	N/A	N/A	N/A	N/A	1%	0%	1%	N/A	N/A	N/A	N/A
2031	6%	6%	1%	N/A	N/A	N/A	N/A	1%	0%	1%	N/A	N/A	N/A	N/A
2032	1%	2%	1%	N/A	N/A	N/A	N/A	1%	0%	1%	N/A	N/A	N/A	N/A
2033	1%	1%	1%	N/A	N/A	N/A	N/A	1%	1%	1%	N/A	N/A	N/A	N/A
2034	2%	2%	1%	N/A	N/A	N/A	N/A	0%	0%	0%	N/A	N/A	N/A	N/A
2035	2%	2%	1%	N/A	N/A	N/A	N/A	1%	0%	1%	N/A	N/A	N/A	N/A

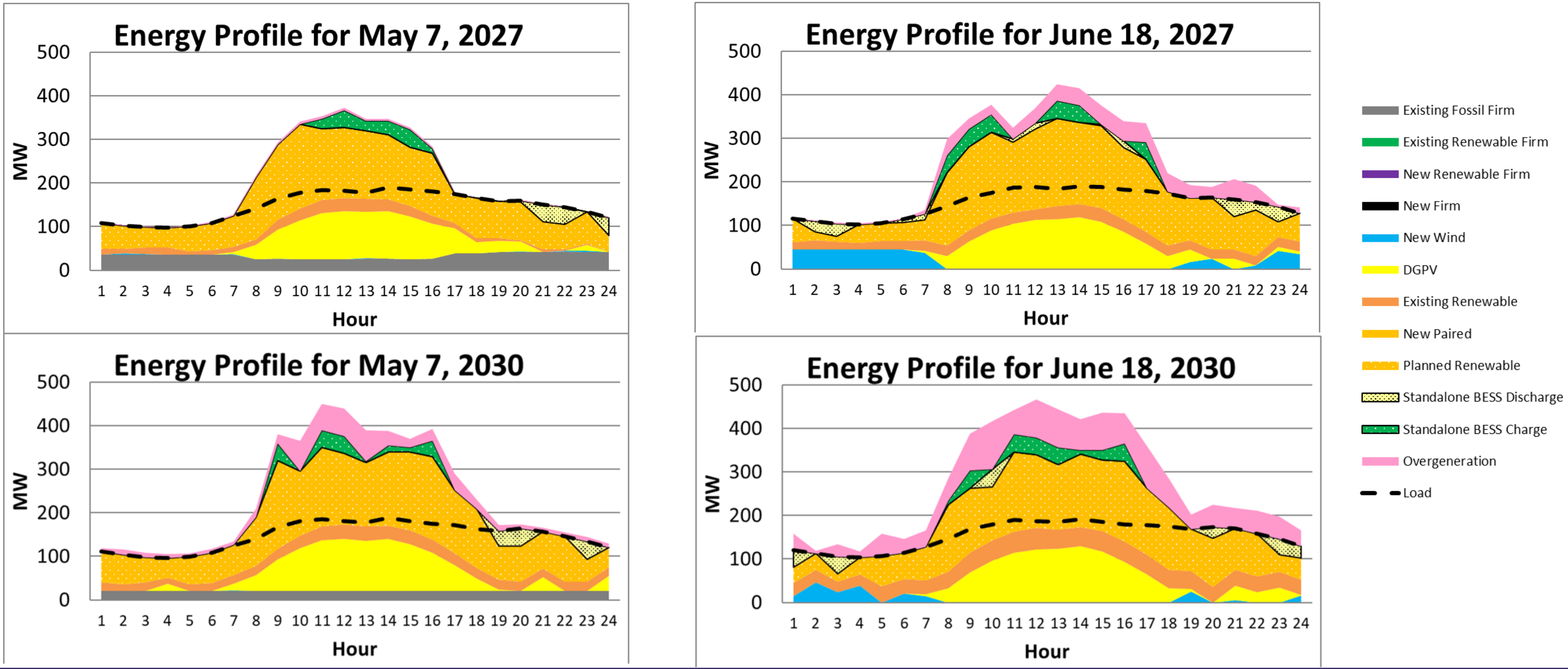
The utilization of new and existing thermal generating units is expected to be low due to the high amounts of variable renewables and storage that are added to the portfolio. The capacity factors shown in these tables support that firm thermal units will primarily act as standby capacity.

Production Cost Modeling and Operations of the Procurement Plan
Capacity Factor of Firm Units - 18 MW ICE

Year	Maalaea 08	Maalaea 09	Maalaea 10	Maalaea 11	Maalaea 12	Maalaea 13	Maalaea X1	Maalaea X2	Maalaea 14cc	Maalaea 15cc	Maalaea 16cc	Maalaea 17cc	Maalaea 18cc	Maalaea 19cc
2027	0%	0%	N/A	N/A	N/A	N/A	0%	0%	41%	55%	38%	6%	0%	0%
2028	0%	0%	N/A	N/A	N/A	N/A	0%	0%	41%	54%	37%	5%	0%	1%
2029	0%	0%	N/A	N/A	N/A	N/A	0%	0%	40%	56%	39%	5%	0%	1%
2030	N/A	N/A	N/A	N/A	N/A	N/A	0%	0%	40%	55%	39%	1%	0%	0%
2031	N/A	N/A	N/A	N/A	N/A	N/A	0%	0%	38%	49%	36%	1%	0%	0%
2032	N/A	N/A	N/A	N/A	N/A	N/A	0%	0%	39%	55%	39%	0%	0%	0%
2033	N/A	N/A	N/A	N/A	N/A	N/A	1%	1%	41%	56%	38%	0%	0%	0%
2034	N/A	N/A	N/A	N/A	N/A	N/A	0%	0%	41%	56%	40%	0%	0%	0%
2035	N/A	N/A	N/A	N/A	N/A	N/A	0%	0%	41%	57%	40%	0%	0%	0%

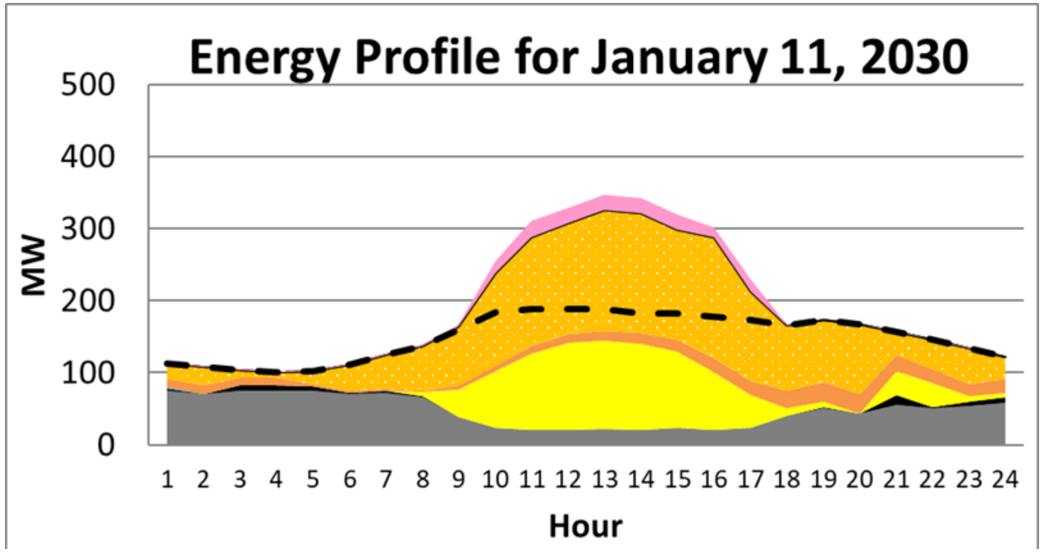
Production Cost Modeling and Operations of the Procurement Plan
Daily Charts - 18 MW ICE

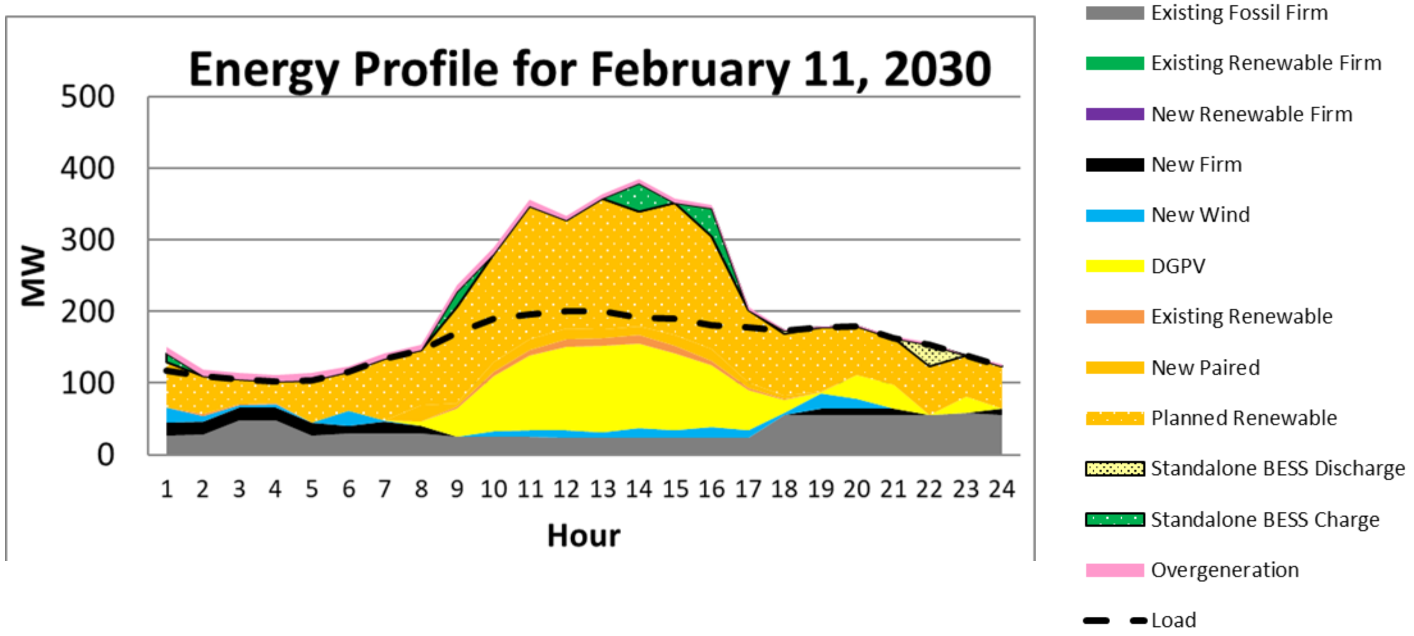
Hourly dispatch of resources in a day



Production Cost Modeling and Operations of the Procurement Plan
Daily Charts - 18 MW ICE

The new ICE additions runs minimally during the peak and overnight, primarily acting as standby generation.





Recommended Actions and Next Steps

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- Continue to displace fossil fuel through acquisition of low cost, low carbon renewable energy, starting with 240 GWh through the Stage 3 RFP in Docket No. 2017-0352
- Continue to pursue customer adoption of DER (i.e., Battery Bonus) through new programs and advanced rate design, consistent with the outcomes of the DER Docket No. 2019-0323
- Pursue generation modernization as soon as practicable to mitigate present reliability risks. Firm renewable generation needs include 18 MW in the near term, starting with the Stage 3 RFP in Docket No. 2017-0352. A total of 40 MW of new firm generation may be prudent to mitigate uncertainty in planned renewable projects that are expected to come into service over the same timeframe
- Pursue development of renewable energy zones to facilitate interconnection of additional renewable energy in collaboration with communities and project partners
- Consider procurement of energy efficiency in amounts up to the forecasted target to reduce supply side needs
- Continue to pursue managed EV charging programs, time-of-use rates, DER, and energy efficiency
- Incorporate system security and system stability analyses, which may yield additional resource needs to mitigate risks associated with a high renewable energy system