Hawaiian Electric

IGP Technical Advisory Panel

July 12, 2022

Agenda

- Present updated analysis for Oahu probabilistic resource adequacy testing based on TAP suggestions.
- TAP Feedback and Suggestions include:
  - Calculate LOLE based on varying firm capacity
  - Calculate LOLE based on varying PV/BESS capacity
  - Calculate LOLE based on higher storage amounts

Key Findings

- If 270 MW of hybrid solar, which is similar to the Stage 3 RFP target, and 286 MW standalone BESS is added beyond S1/S2 and CBRE 1/2, then 400 MW of new firm generation is needed to achieve **0.04** LOLE (Slide 5-6)
  - For the same case above, if 300 MW of new firm generation is added instead of 400 MW, the resulting LOLE is only **0.66.** (Slide 5-6)
  - For the same case above, if an additional 170 MW of existing fossil fuel generation is retired when adding 400 MW of new generation, the resulting LOLE is **0.47.** (Slide 14-15)
  - For the same case above, if 300MW of new firm generation is added instead of 400 MW and the retirement of 170 MW of existing fossil generation in 2029 is delayed, the resulting LOLE is **0.09**. In other words, adding 100 MW of new firm generation achieves a lower LOLE (LOLE of **0.04**) than adding back 170 MW of existing fossil fuel generation (LOLE of **0.09**). (Slide 14-15) This highlights the inherent risks to keeping existing fossil generation in-service.
- If 958 MW of hybrid solar (the NREL technical potential on land < 15% slope) and 163 MW of wind is added, then adding 300 MW of new firm generation results in LOLE of **0.08** (Slide 8-9)
  - For the same case above, if 150 MW of 300 MW of the new firm generation is swapped with 150 MW, 12-hour long duration storage, the resulting LOLE is only **0.36.** (Slides 11-12)
  - For the same case above, if 150 MW of new firm generation is added instead of 300 MW and 1600 MW of hybrid solar is added (as selected by RESOLVE) instead of 958 MW, the resulting LOLE is **0.22.** (Slides 8-9)
- Long duration storage does not significantly reduce the amount of firm generation needed. LOLE increases by 3 to 4 times when substituting 150 MW of the 300 MW firm with 150 MW of LDES (Slides 11-12)
  - This demonstrates that 150 MW of long duration storage provides significantly less capacity value than 150 MW of new firm generation.

Key Findings

- Under high load scenarios (i.e., accelerated electrification of transportation), 400 MW of new firm generation is insufficient to achieve a 0.10 LOLE, even in scenarios where lesser amounts of existing fossil fuel generation are removed/deactivated. (Slide 18-20)
- Under a low load scenario (i.e., high adoption of EE and DER and low adoption of EV), 400 MW of new firm generation could allow for additional or accelerated removal or deactivation of fossil fuel generation than assumed in the base case. (Slide 18-20)
- Based on the robust and exhaustive probabilistic analyses that consider different futures and combination of resources, 300-500 MW of new firm generation is prudent given the trends in availability of the current generation fleet and the need for more flexible units to better integrate even higher levels or variable renewable resources.
- The new firm generation in the probabilistic analyses was assumed to be 50 MW simple cycle combustion turbines. These units are more flexible and have higher availability that the existing steam generation. If larger capacities of existing firm generation units were added by delaying their assumed removal, reliability would still decrease due to their lower availability, higher outage rates.
- In general, even at high hybrid solar penetrations, there is a strong correlation between LOLE and EUE, along with other reliability metrics.

Probabilistic Analyses: Varying Firm Capacity

Resource Adequacy Test Cases

- Base_150_270PVB_0Wnd_Mar22Out
  - Base case with 3x50 MW SCCT added in 2029, 270 MW of PV+3hrBESS, 0 MW of Onshore Wind.
  - 270 MW is approximate size of the Stage 3 RFP target. Onshore Wind removed due to land use and community acceptance concerns.
- Base_300_270PVB_0Wnd_Mar22Out
  - Base_150_270PVB_0Wnd_Mar22Out with additional 3x50 MW SCCT added in 2029.
- Base_400_270PVB_0Wnd_Mar22Out
  - Base_150_270PVB_0Wnd_Mar22Out with additional 5x50 MW SCCT added in 2029.

Base case is the RESOLVE resource plan without any future firm generation in 2029, without Kalaeloa and AES Coal, and without 371 MW of utility-owned fossil fuel steam generation capacity

Base_150_...Mar22Out = 150 MW new firm = 3x50 MW SCCT
Base_300_...Mar22Out = 300 MW new firm = 6x50 MW SCCT
Base_400_...Mar22Out = 400 MW new firm = 8x50 MW SCCT

Probabilistic Resource Adequacy Sensitivities

- Higher levels of firm generation improves reliability.
- If Oahu's Stage 3 RFP targets are achieved, 400MW of firm resources would still be needed to reach a targeted level of reliability of less than 0.1 LOLE (case 3).
- Additional sensitivities were performed to evaluate different levels of hybrid solar and standalone BESS in subsequent sections.

Green = LOLE ≤ 0.10 Days/Yr (US Mainland), LOLH ≤ 3 hrs (Belgium, France, GB, Poland), EUE ≤ 0.002% of load/137 MWh (AEMO)

Case	Year 2029	Existing Firm (MW)	Future Firm (MW)	Future Variable (MW)	Future SA BESS (MW)	LOLE (Days/Year)	LOLEv (Event/Year)	LOLH (Hours/Year)	EUE (MWH/Year)
0	Existing (2021)	1,729	0	0	0	1.18	1.30	2.90	130
1	Base_150_270PVB_0Wnd_Mar22Out	970	150	689	472	9.25	17.75	42.42	5,740
2	Base_300_270PVB_0Wnd_Mar22Out	970	300	689	472	0.66	1.18	2.47	260
3	Base_400_270PVB_0Wnd_Mar22Out	970	400	689	472	0.04	0.05	0.09	10

Future Variable includes: [S1 (Hoohana, Mililani, Waiawa, West O'ahu), S2 (Barbers Point, Kupono, Mountain View, Waiawa Ph 2), CBRE Ph 1/2] = 419 MW hybrid solar
Future Standalone (SA) BESS includes [S2 (Kapolei Energy Storage)] = 185 MW
Future resources beyond S1/2 and CBRE 1/2 includes Future Hybrid solar = 270 MW, Standalone BESS = 286.5MW

Probabilistic Analyses: Varying Paired PV+BESS Capacity

Resource Adequacy Test Cases

- Base_300_Mar22Out
  - Base case with 6x50 MW SCCT added in 2029, 0 MW of PV+BESS, 163 MW of Onshore Wind.
- Base_300_270PVB_Mar22Out
  - Base_300_Mar22Out with additional 270 MW of PV+3hrBESS.
  - 270 MW is approximate size of the Stage 3 RFP target.
- Base_300_958PVB_Mar22Out
  - Base_300_Mar22Out with additional 958 MW of PV+3hrBESS.
  - 958 MW is the NREL resource potential on slopes less than 15%.
- Base_300_270PVB_0Wnd_Mar22Out
  - Base_300_Mar22Out with additional 270MW of PV+3hrBESS, no Onshore Wind.
  - 270 MW is approximate size of the Stage 3 RFP target. Onshore Wind removed due to land use and community acceptance concerns.
- Base_150_270PVB_0Wnd_Mar22Out
  - Base_300_270PVB_0Wnd_Mar22Out with only 3x50 MW SCCT added in 2029 (150 MW less).
- Base_150_1600PVB_Mar22Out
  - Base_300_270PVB_0Wnd_Mar22Out with only 3x50 MW SCCT added in 2029 (150 MW less), additional 1,600 MW of PV+BESS instead of 270 MW, include the 163 MW of Onshore Wind.

Base case is the RESOLVE resource plan without any future firm generation in 2029, without Kalaeloa and AES Coal, and without 371 MW of utility-owned fossil fuel steam generation capacity

Probabilistic Resource Adequacy Sensitivities

Base_300_Mar22Out = 6x50 MW SCCT+163 MW Onshore Wind
Base_300_##PVB_Mar22Out = 6x50 MW SCCT+163 MW Onshore Wind + ##MW PV/BESS
Base_300_270PVB_0Wnd_Mar22Out = 6x50 MW SCCT+0 MW Onshore Wind + 270MW PV/BESS
Base_150_.... = 3x50 MW SCCT

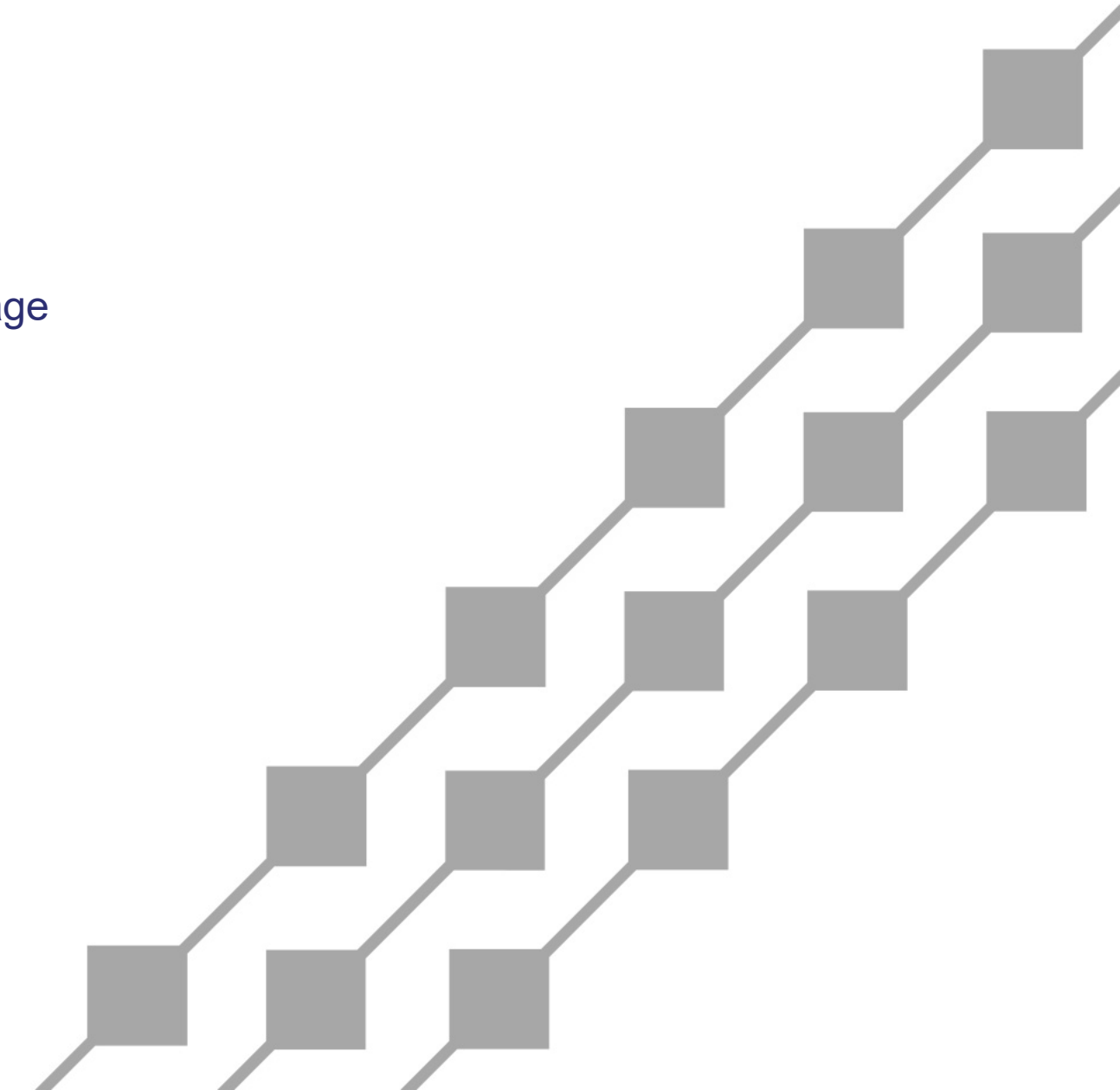
- Higher levels of variable generation improves reliability.
- If the Stage 3 RFP target were exceeded with the addition of 958 MW of paired PV+BESS (developing the remaining PV potential on lower sloped land <15%), 300 MW of firm generation would still be needed to meet an LOLE less than 0.1 (case 3).
- If the Stage 3 RFP target were greatly exceeded with the addition of 1,600 MW of paired PV+BESS, 150 MW of firm generation would have high EUE and be above the US Mainland LOLE of 0.1 (case 6).

Green = LOLE ≤ 0.10 Days/Yr (US Mainland), LOLH ≤ 3 hrs (Belgium, France, GB, Poland), EUE ≤ 0.002% of load/137 MWh (AEMO)

Case	Year 2029	Existing Firm (MW)	Future Firm (MW)	Future Variable (MW)	Future SA BESS (MW)	LOLE (Days/Year)	LOLEv (Event/Year)	LOLH (Hours/Year)	EUE (MWH/Year)
0	Existing (2021)	1,729	0	0	0	1.18	1.30	2.90	130
1	Base_300_Mar22Out	970	300	582	472	1.30	2.19	5.98	630
2	Base_300_270PVB_Mar22Out	970	300	852	472	0.42	0.81	1.88	190
3	Base_300_958PVB_Mar22Out	970	300	1540	472	0.08	0.20	0.37	60
4	Base_300_270PVB_0Wnd_Mar22Out	970	300	689	472	0.66	1.18	2.47	260
5	Base_150_270PVB_0Wnd_Mar22Out	970	150	689	472	9.25	17.75	42.42	5,740
6	Base_150_1600PVB_Mar22Out	970	150	2,182	472	0.22	0.49	0.84	210

Future Variable includes: [S1 (Hoohana, Mililani, Waiawa, West O'ahu), S2 (Barbers Point, Kupono, Mountain View, Waiawa Ph 2), CBRE Ph 1/2] = 419 MW Solar+BESS
Future Standalone (SA) BESS includes [S2 (Kapolei Energy Storage)] = 185 MW
Future resources selected by RESOLVE includes Onshore Wind (163 MW), Standalone BESS (286.5MW)

Probabilistic Analyses: Higher Standalone Storage



Resource Adequacy Test Cases

- Base_300_Mar22Out
  - Base case with 6x50 MW SCCT added in 2029, 0 MW of PV+BESS, 163 MW of Onshore Wind.
- Base_150_150MW12hSaB_Mar22Out
  - Base_300_Mar22Out with additional 150MW-12hr Standalone BESS and 150 MW less of firm.

- Base_300_270PVB_0Wnd_Mar22Out
  - Base_300_Mar22Out with additional 270MW of PV+3hrBESS, no Onshore Wind.
- Base_150_150MW12hSaB_270PVB_0Wnd_Mar22Out
  - Base_300_270PVB_0Wnd_Mar22Out with additional 150MW-12hr Standalone BESS and 150 MW less of firm.

- Base_300_958PVB_Mar22Out
  - Base_300_Mar22Out with additional 958 MW of PV+3hrBESS.
- Base_150_150MW12hSaB_958PVB_Mar22Out
  - Base_300_958PVB_Mar22Out with additional 150MW-12hr Standalone BESS and 150MW less of firm.

Base case is the RESOLVE resource plan without any future firm generation in 2029, without Kalaeloa and AES Coal, and without 371 MW of utility-owned fossil fuel steam generation capacity

Probabilistic Resource Adequacy Sensitivities

Base_300_Mar22Out = 6x50 MW SCCT+163 MW Onshore Wind
Base_300_270PVB_0Wnd_Mar22Out = 6x50 MW SCCT+0 MW Onshore Wind + 270 MW PV+BESS
Base_300_958PVB_Mar22Out = 6x50 MW SCCT+163 MW Onshore Wind + 958 MW PV+BESS
Base_150_150MW12hSaB… = Substitute 150MW firm with 150MW-12hr Standalone BESS

- Firm generation improves reliability more than a 12-hour battery with the same power output (case 1 vs. 2, 3 vs. 4, 5 vs. 6) despite the LDES being modeled with no assumed outage rates.

Green = LOLE ≤ 0.10 Days/Yr (US Mainland), LOLH ≤ 3 hrs (Belgium, France, GB, Poland), EUE ≤ 0.002% of load/137 MWh (AEMO)

Case	Year 2029	Existing Firm (MW)	Future Firm (MW)	Future Variable (MW)	Future SA BESS (MW)	LOLE (Days/Year)	LOLEv (Event/Year)	LOLH (Hours/Year)	EUE (MWH/Year)
0	Existing (2021)	1,729	0	0	0	1.18	1.30	2.90	130
1	Base_300_Mar22Out	970	300	582	472	1.30	2.19	5.98	630
2	Base_150_150MW12hSaB_Mar22Out	970	150	582	622	4.15	8.91	23.19	3,340
3	Base_300_270PVB_0Wnd_Mar22Out	970	300	689	472	0.66	1.18	2.47	260
4	Base_150_150MW12hSaB_270PVB_0Wnd_Mar22Out	970	150	689	622	2.48	5.16	12.17	1,910
5	Base_300_958PVB_Mar22Out	970	300	1,540	472	0.08	0.20	0.37	60
6	Base_150_150MW12hSaB_958PVB_Mar22Out	970	150	1,540	622	0.36	0.84	1.89	400

Future Variable includes: [S1 (Hoohana, Mililani, Waiawa, West O‘ahu), S2 (Barbers Point, Kupono, Mountain View, Waiawa Ph 2), CBRE Ph 1/2] = 419 MW Solar+BESS
Future Standalone (SA) BESS includes [S2 (Kapolei Energy Storage)] = 185 MW

Probabilistic Analyses: Delayed Removal of Utility Generation

Resource Adequacy Test Cases

- Base_150_270PVB_0Wnd_Mar22Out
  - Base case with 3x50 MW SCCT added in 2029, 270 MW of PV+BESS, 0 MW of Onshore Wind.
- Base_150_270PVB_0Wnd_170HE_Mar22Out
  - Base_150_270PVB_0Wnd_Mar22Out with 170 MW of utility generation reactivated.
- Base_150_270PVB_0Wnd_280HE_Mar22Out
  - Base_150_270PVB_0Wnd_Mar22Out with 280 MW of utility generation reactivated.

- Base_300_270PVB_0Wnd_Mar22Out
  - Base_150_270PVB_0Wnd_Mar22Out with additional 3x50 MW SCCT added in 2029 (150 MW more).
- Base_300_270PVB_0Wnd_170HE_Mar22Out
  - Base_300_270PVB_0Wnd_Mar22Out with 170 MW of utility generation reactivated.

- Base_400_270PVB_0Wnd_Mar22Out
  - Base_150_270PVB_0Wnd_Mar22Out with additional 5x50 MW SCCT added in 2029 (250 MW more).
- Base_400_270PVB_0Wnd_wo170HE_Mar22Out
  - Base_400_270PVB_0Wnd_Mar22Out with additional 170 MW of utility generation removed.

Base case is the RESOLVE resource plan without any future firm generation in 2029, without Kalaeloa and AES Coal, and without 371 MW of utility-owned fossil fuel steam generation capacity

Probabilistic Resource Adequacy Sensitivities

Base_##_270PVB_0Wnd_Mar22Out = ##MW new Firm+0MW Onshore Wind + 270MW PV+BESS
170HE = 170MW of Utility generation continues service
280HE = 280MW of Utility generation continues service
wo170HE = Additional 170MW of Utility generation is removed from service

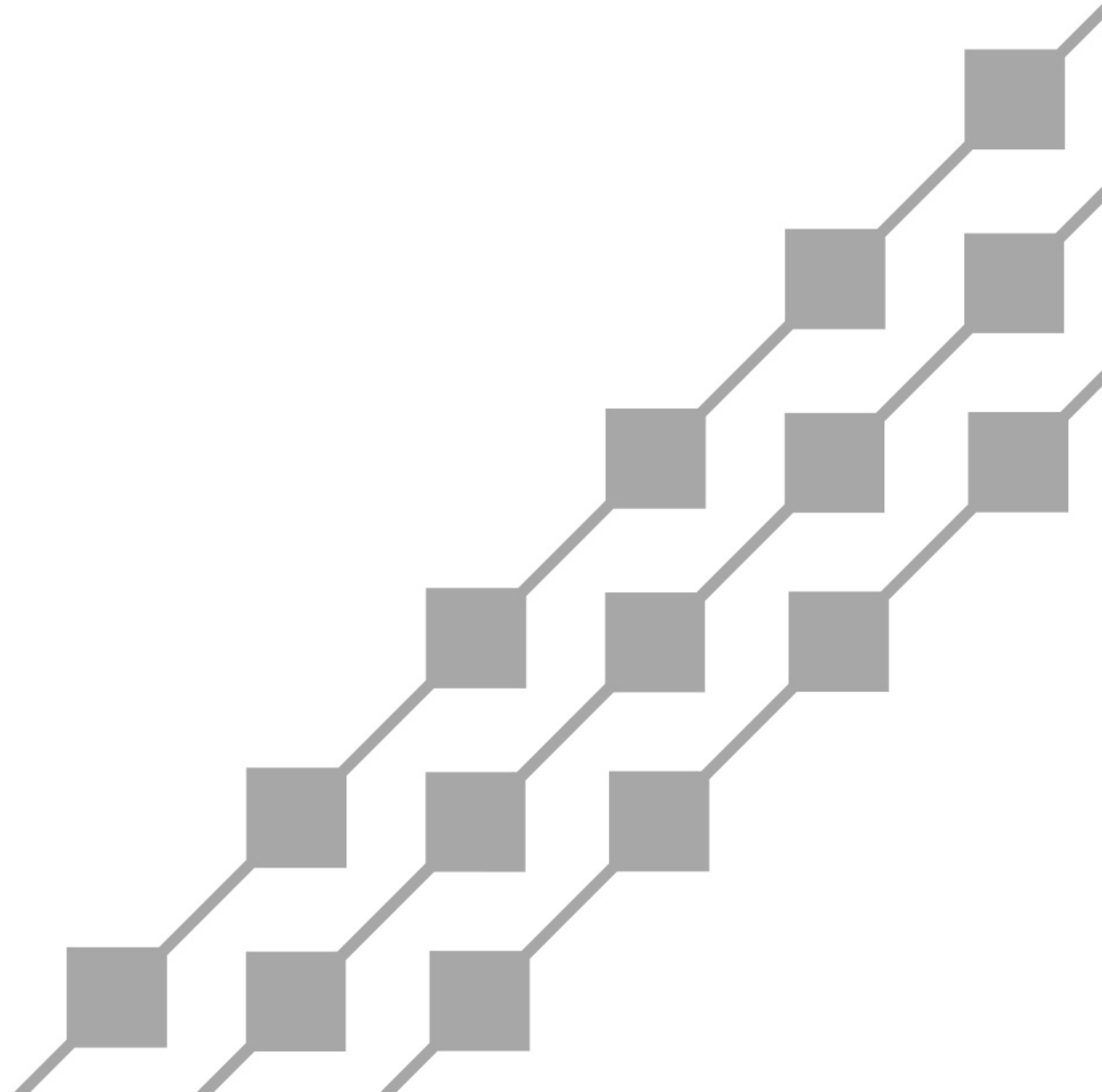
- Higher availability of thermal generation improves reliability.
- If Oahu's Stage 3 RFP targets are achieved and only 150MW of new firm generation is installed, the target reliability metrics will not be met, even with the continued operation of 280 MW of firm generation that was assumed to be removed in 2029 (case 3).
- Comparing cases with similar levels of total firm generation (case 3 vs. 6, case 2 vs. 4), having a greater proportion of new generation significantly improves reliability due to greater availability, lower forced outage rates of the generating fleet.
- Even if total firm generation is lower, higher availability of new generating units still improves reliability to a greater degree in some cases (case 7 vs. 2, 3, 4).

Green = LOLE ≤ 0.10 Days/Yr (US Mainland), LOLH ≤ 3 hrs (Belgium, France, GB, Poland), EUE ≤ 0.002% of load/137 MWh (AEMO)

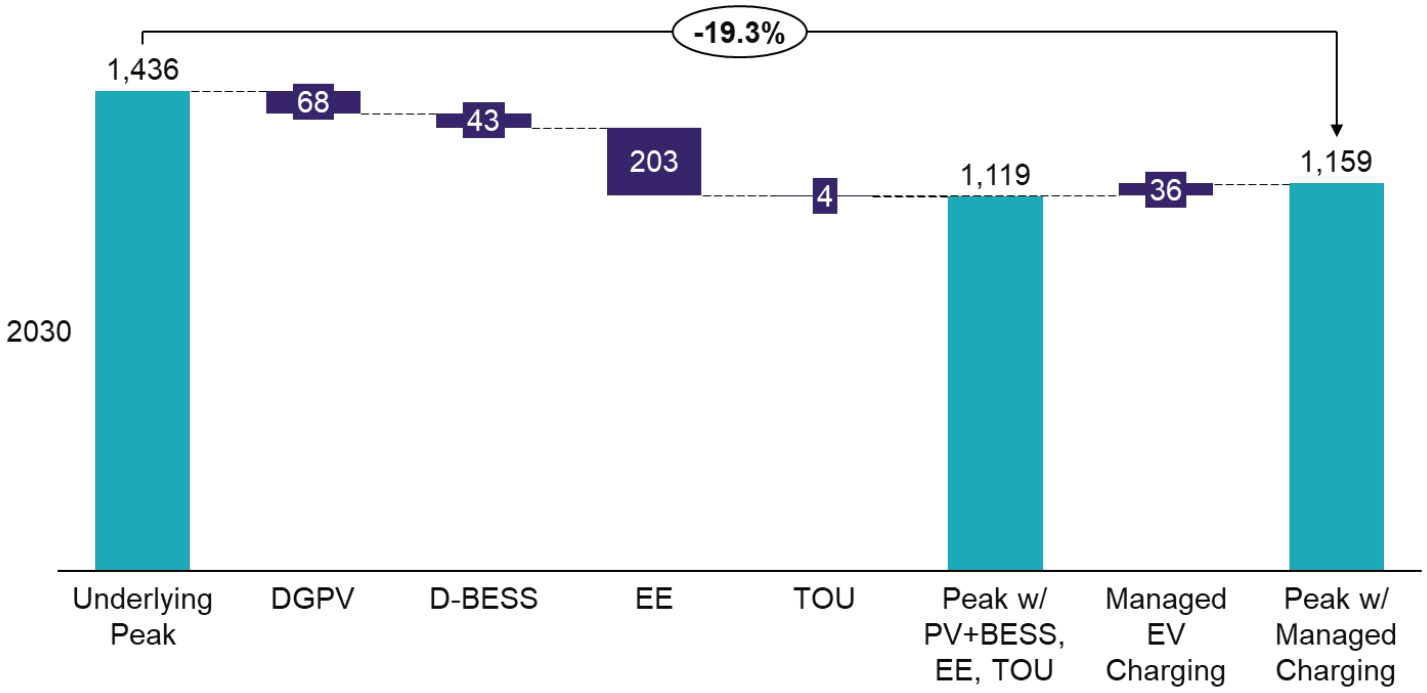
Case	Year 2029	Existing Firm (MW)	Future Firm (MW)	Total Firm (MW)	Future Variable (MW)	Future SA BESS (MW)	LOLE (Days/Year)	LOLEv (Event/Year)	LOLH (Hours/Year)	EUE (MWH/Year)
0	Existing (2021)	1,729	0	1,729	0	0	1.18	1.30	2.90	130
1	Base_150_270PVB_0Wnd_Mar22Out	970	150	1,120	689	472	9.25	17.75	42.42	5,740
2	Base_150_270PVB_0Wnd_170HE_Mar22Out	1,140	150	1,290	689	472	1.70	3.20	6.52	790
3	Base_150_270PVB_0Wnd_280HE_Mar22Out	1,250	150	1,400	689	472	0.54	1.02	2.25	290
4	Base_300_270PVB_0Wnd_Mar22Out	970	300	1,270	689	472	0.66	1.18	2.47	260
5	Base_300_270PVB_0Wnd_170HE_Mar22Out	1,140	300	1,440	689	472	0.09	0.16	0.22	20
6	Base_400_270PVB_0Wnd_Mar22Out	970	400	1,370	689	472	0.04	0.05	0.09	10
7	Base_400_270PVB_0Wnd_wo170HE_Mar22Out	800	400	1,200	689	472	0.47	0.92	1.82	180

Future Variable includes: [S1 (Hoohana, Mililani, Waiawa, West O'ahu), S2 (Barbers Point, Kupono, Mountain View, Waiawa Ph 2), CBRE Ph 1/2] = 419 MW Solar+BESS
Future Standalone (SA) BESS includes [S2 (Kapolei Energy Storage)] = 185 MW
Future resources selected by RESOLVE includes Onshore Wind = 163 MW

Probabilistic Analyses: Load Sensitivities



Contributions of Customer Energy Resources towards reliability



The reliability analysis includes significant contributions to reductions in the peak load in 2030 by customer resources.

If the forecasted uptake of these customer technologies (DER, EE, EV) does not materialize or is aggressively exceeded, resource adequacy may be adversely impacted.

Recognizing this risk to reliability, additional cases were performed to examine resource adequacy under the low load and high load bookends.

Resource Adequacy Test Cases

- Base_300_270PVB_0Wnd_Mar22Out_HiLd
  - Base case with 6x50 MW SCCT added in 2029, 270 MW of PV+3hrBESS, 0 MW Onshore Wind.
  - High Load Forecast
- Base_300_270PVB_0Wnd_170HE_Mar22Out_HiLd
  - Base_300_270PVB_0Wnd_Mar22Out_HiLd with 170 MW of utility generation reactivated.
- Base_300_270PVB_0Wnd_280HE_Mar22Out_HiLd
  - Base_300_270PVB_0Wnd_Mar22Out_HiLd with 280 MW of utility generation reactivated.

- Base_400_270PVB_0Wnd_Mar22Out_HiLd
  - Base case with 8x50 MW SCCT added in 2029, 270MW of PV+3hrBESS, 0 MW Onshore Wind.
  - High Load Forecast
- Base_400_270PVB_0Wnd_170HE_Mar22Out_HiLd
  - Base_400_270PVB_0Wnd_Mar22Out_HiLd with 170 MW of utility generation reactivated.
- Base_400_270PVB_0Wnd_280HE_Mar22Out_HiLd
  - Base_400_270PVB_0Wnd_Mar22Out_HiLd with 280 MW of utility generation reactivated.

- Base_300_270PVB_0Wnd_Mar22Out_LwLd
  - Base case with 6x50 MW SCCT added in 2029, 270 MW of PV+3hrBESS, 0 MW Onshore Wind.
  - Low Load Forecast
- Base_300_270PVB_0Wnd_wo170HE_Mar22Out_LwLd
  - Base_300_270PVB_0Wnd_Mar22Out_LwLd with additional 170 MW of utility generation removed.

- Base_400_270PVB_0Wnd_Mar22Out_LwLd
  - Base case with 8x50 MW SCCT added in 2029, 270 MW of PV+3hrBESS, 0 MW Onshore Wind.
  - Low Load Forecast
- Base_400_270PVB_0Wnd_wo170HE_Mar22Out_LwLd
  - Base_400_270PVB_0Wnd_Mar22Out_LwLd with additional 170 MW of utility generation removed.

Base case is the RESOLVE resource plan without any future firm generation in 2029, without Kalaeloa and AES Coal, and without 371 MW of utility-owned fossil fuel steam generation capacity

Probabilistic Resource Adequacy Sensitivities

Base_##_270PVB_0Wnd_Mar22Out = ##MW new Firm+0MW Onshore Wind + 270MW PV+BESS
170HE = 170MW of Utility generation continues service
280HE = 280MW of Utility generation continues service
wo170HE = Additional 170MW of Utility generation is removed from service

- If the load in 2029 shifts toward the high load forecast, the reliability metric targets for LOLH and EUE can be met with 400 MW of new firm generation, 270 MW of Paired PV+BESS, and 280 MW of existing firm generation remains in service. However, LOLE will not meet the US Mainland standard of 0.1. (Case 3)
- If the load in 2029 shifts toward the low load forecast, the reliability metric targets can be met with 400 MW of new firm generation and 270 MW of Paired PV+BESS. (Case 4)
  - Additional/Accelerated deactivations of 170MW of utility generation that was originally assumed for 2033 may be possible but fall short of the LOLE target by 0.02 days. (Case 5)

Green = LOLE ≤ 0.10 Days/Yr (US Mainland), LOLH ≤ 3 hrs (Belgium, France, GB, Poland), EUE ≤ 0.002% of load/137 MW Base/159 MWh High/123 MWh Low (AEMO)

Case	Year 2029	Existing Firm (MW)	Future Firm (MW)	Total Firm (MW)	Future Variable (MW)	Future SA BESS (MW)	LOLE (Days/ Year)	LOLEv (Event/ Year)	LOLH (Hours/ Year)	EUE (MWH/ Year)
0	Existing (2021)	1,729	0	1,729	0	0	1.18	1.30	2.90	130
1	Base_400_270PVB_0Wnd_Mar22Out_HiLd	970	400	1,370	689	472	2.52	4.63	10.49	1,370
2	Base_400_270PVB_0Wnd_170HE_Mar22Out_HiLd	1,140	400	1,540	689	472	0.65	1.12	2.59	300
3	Base_400_270PVB_0Wnd_280HE_Mar22Out_HiLd	1,250	400	1,650	689	472	0.19	0.30	0.78	110
4	Base_400_270PVB_0Wnd_Mar22Out_LwLd	970	400	1,370	689	472	0.03	0.04	0.09	4
5	Base_400_270PVB_0Wnd_wo170HE_Mar22Out_LwLd	800	400	1,200	689	472	0.12	0.19	0.30	20

Future Variable includes: [S1 (Hoohana, Mililani, Waiawa, West O'ahu), S2 (Barbers Point, Kupono, Mountain View, Waiawa Ph 2), CBRE Ph 1/2] = 419 MW Solar+BESS
Future Standalone (SA) BESS includes [S2 (Kapolei Energy Storage)] = 185 MW
Future resources selected by RESOLVE includes Onshore Wind = 163 MW

Probabilistic Resource Adequacy Sensitivities

Base_##_270PVB_0Wnd_Mar22Out = ##MW new Firm+0MW Onshore Wind + 270MW PV+BESS
170HE = 170MW of Utility generation continues service
280HE = 280MW of Utility generation continues service
wo170HE = Additional 170MW of Utility generation is removed from service

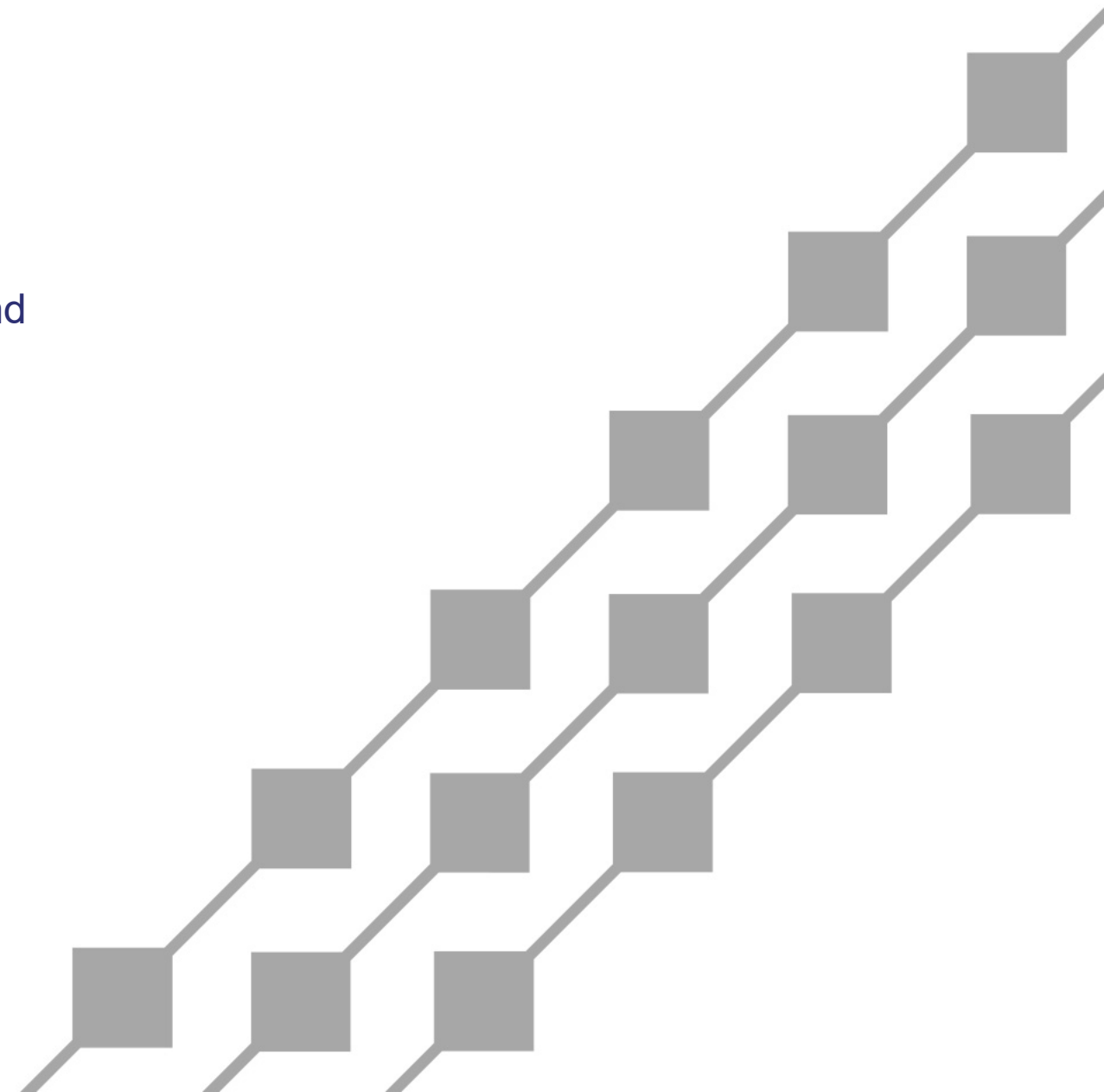
- If the load in 2029 shifts toward the high load forecast, the reliability metrics will not be met with 300 MW of new firm generation, 270 MW of Paired PV+BESS, and the continued in-service of 280 MW of existing firm generation. (Case 8)
- If the load in 2029 shifts toward the low load forecast, the reliability metric targets for LOLH and EUE may be met with 300 MW of new firm generation and 270 MW of Paired PV+BESS. However, LOLE will exceed the US Mainland standard of 0.1. (Case 9)

Green = LOLE ≤ 0.10 Days/Yr (US Mainland), LOLH ≤ 3 hrs (Belgium, France, GB, Poland), EUE ≤ 0.002% of load/137 MW Base/159 MWh High/123 MWh Low (AEMO)

Case	Year 2029	Existing Firm (MW)	Future Firm (MW)	Total Firm (MW)	Future Variable (MW)	Future SA BESS (MW)	LOLE (Days/ Year)	LOLEv (Event/ Year)	LOLH (Hours/ Year)	EUE (MWH/ Year)
0	Existing (2021)	1,729	0	1,729	0	0	1.18	1.30	2.90	130
6	Base_300_270PVB_0Wnd_Mar22Out_HiLd	970	300	1,270	689	472	10.10	19.42	48.01	6,950
7	Base_300_270PVB_0Wnd_170HE_Mar22Out_HiLd	1,140	300	1,440	689	472	2.63	4.61	11.04	1,560
8	Base_300_270PVB_0Wnd_280HE_Mar22Out_HiLd	1,250	300	1,550	689	472	1.00	1.82	4.02	540
9	Base_300_270PVB_0Wnd_Mar22Out_LwLd	970	300	1,270	689	472	0.26	0.48	0.99	120
10	Base_300_270PVB_0Wnd_wo170HE_Mar22Out_LwLd	800	300	1,100	689	472	1.51	3.01	5.91	660

Future Variable includes: [S1 (Hoohana, Mililani, Waiawa, West O'ahu), S2 (Barbers Point, Kupono, Mountain View, Waiawa Ph 2), CBRE Ph 1/2] = 419 MW Solar+BESS
Future Standalone (SA) BESS includes [S2 (Kapolei Energy Storage)] = 185 MW
Future resources selected by RESOLVE includes Onshore Wind = 163 MW

Probabilistic Analyses: Accelerated Offshore Wind



Resource Adequacy Test Cases

- Base_270PVB_0Wnd_Mar22Out
  - Base case with 0 MW of new firm generation, 270 MW of PV+BESS, 0 MW of Onshore Wind, 0 MW of Offshore Wind.
- Base_270PVB_0Wnd_400OSW_Mar22Out
  - Base_270PVB_0Wnd_Mar22Out with 400 MW of Offshore Wind.

- Base_150_270PVB_0Wnd_Mar22Out
  - Base_270PVB_0Wnd_Mar22Out with 3x50 MW SCCT added in 2029 (150 MW new firm).
- Base_300_270PVB_0Wnd_Mar22Out
  - Base_270PVB_0Wnd_Mar22Out with additional 6x50 MW SCCT added in 2029 (300 MW new firm).
- Base_400_270PVB_0Wnd_Mar22Out
  - Base_270PVB_0Wnd_Mar22Out with additional 8x50 MW SCCT added in 2029 (400 MW new firm).

Base case is the RESOLVE resource plan without any future firm generation in 2029, without Kalaeloa and AES Coal, and without 371 MW of utility-owned fossil fuel steam generation capacity

Probabilistic Resource Adequacy Sensitivities

Base_##_270PVB_0Wnd_Mar22Out = ##MW new Firm+0MW Onshore Wind + 270MW PV+BESS + 0MW Offshore Wind
Base_...400OSW_Mar22Out = includes 400MW Offshore Wind

- Installing 400 MW of Offshore Wind in 2029 will help to improve our reliability.
- 400 MW of Offshore Wind improves the reliability less than installing 150 MW of firm generation.

Green = LOLE ≤ 0.10 Days/Yr (US Mainland), LOLH ≤ 3 hrs (Belgium, France, GB, Poland), EUE ≤ 0.002% of load/137 MWh (AEMO)

Case	Year 2029	Existing Firm (MW)	Future Firm (MW)	Future Variable (MW)	Future SA BESS (MW)	LOLE (Days/Year)	LOLEv (Event/Year)	LOLH (Hours/Year)	EUE (MWH/Year)
0	Existing (2021)	1,729	0	0	0	1.18	1.30	2.90	130
1	Base_270PVB_0Wnd_ Mar22Out	970	0	689	472	54.91	112.08	322.86	51,420
2	Base_270PVB_0Wnd_400OSW_ Mar22Out	970	0	1,089	472	12.14	21.96	69.56	11,320
3	Base_150_270PVB_0Wnd_ Mar22Out	970	150	689	472	9.25	17.75	42.42	5,740
4	Base_300_270PVB_0Wnd_ Mar22Out	970	300	689	472	0.66	1.18	2.47	260
5	Base_400_270PVB_0Wnd_ Mar22Out	970	400	689	472	0.04	0.05	0.09	10

Future Variable includes: [S1 (Hoohana, Mililani, Waiawa, West O'ahu), S2 (Barbers Point, Kupono, Mountain View, Waiawa Ph 2), CBRE Ph 1/2] = 419 MW hybrid solar
Future Standalone (SA) BESS includes [S2 (Kapolei Energy Storage)] = 185 MW
Future resources beyond S1/2 and CBRE 1/2 includes Future Hybrid solar = 270 MW, Standalone BESS = 286.5MW

Probabilistic Analyses: 2-hour Storage

Resource Adequacy Test Cases

- Base_300_270PVB_0Wnd_Mar22Out
  - Base case with 6x50 MW SCCT added in 2029, 270 MW of PV+3hrBESS, 0 MW of Onshore Wind.
  - 270 MW is approximate size of the Stage 3 RFP target. Onshore Wind removed due to land use and community acceptance concerns.
- Base_150_150MW2hSaB_270PVB_0Wnd_Mar22Out
  - Base_300_270PVB_0Wnd_Mar22Out with additional 150MW-2hr Standalone BESS and 150 MW less of firm.
- Base_150_150MW12hSaB_270PVB_0Wnd_Mar22Out
  - Base_300_270PVB_0Wnd_Mar22Out with additional 150MW-12hr Standalone BESS and 150 MW less of firm.

Base case is the RESOLVE resource plan without any future firm generation in 2029, without Kalaeloa and AES Coal, and without 371 MW of utility-owned fossil fuel steam generation capacity

Probabilistic Resource Adequacy Sensitivities

Base_300_Mar22Out = 6x50 MW SCCT+163 MW Onshore Wind
Base_300_270PVB_0Wnd_Mar22Out = 6x50 MW SCCT+0 MW Onshore Wind + 270 MW PV+BESS
Base_300_958PVB_Mar22Out = 6x50 MW SCCT+163 MW Onshore Wind + 958 MW PV+BESS
Base_150_150MW12hSaB… = Substitute 150MW firm with 150MW-12hr Standalone BESS

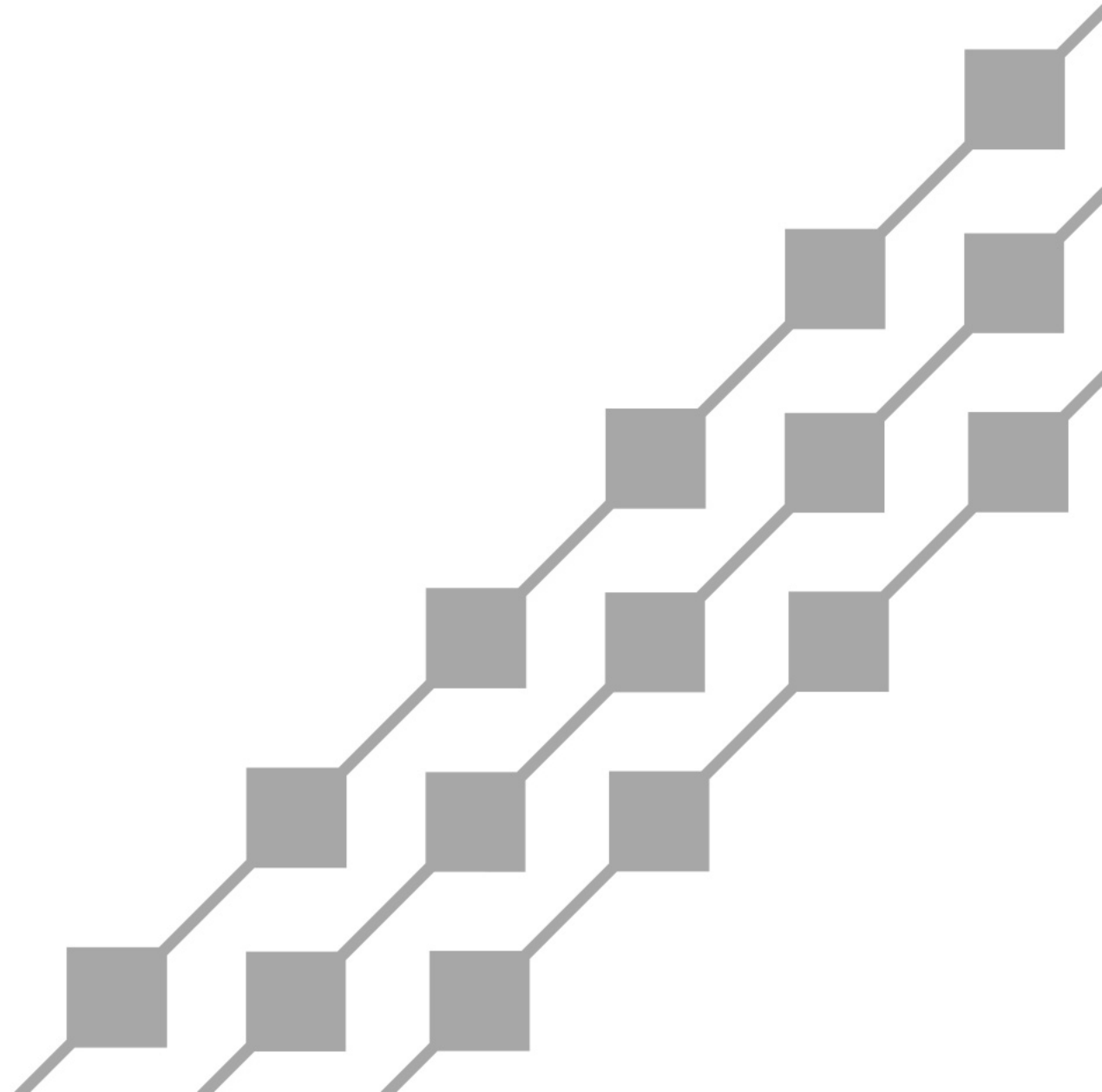
- Addition of a Standalone BESS with 2-hour duration as a proxy for demand response results in a worse reliability standard than a longer duration battery and a firm generator

Green = LOLE ≤ 0.10 Days/Yr (US Mainland), LOLH ≤ 3 hrs (Belgium, France, GB, Poland), EUE ≤ 0.002% of load/137 MWh (AEMO)

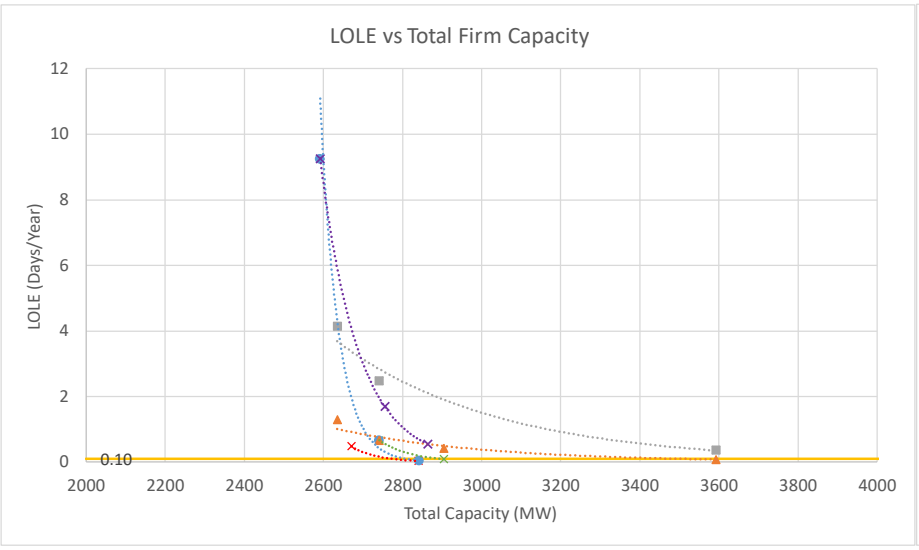
Case	Year 2029	Existing Firm (MW)	Future Firm (MW)	Future Variable (MW)	Future SA BESS (MW)	LOLE (Days/Year)	LOLEv (Event/Year)	LOLH (Hours/Year)	EUE (MWH/Year)
0	Existing (2021)	1,729	0	0	0	1.18	1.30	2.90	130
1	Base_300_270PVB_0Wnd_Mar22Out	970	300	689	472	0.66	1.18	2.47	260
2	Base_150_150MW2hSaB_270PVB_0Wnd_Mar22Out	970	150	689	622	6.96	13.37	31.32	4,490
3	Base_150_150MW12hSaB_270PVB_0Wnd_Mar22Out	970	150	689	622	2.48	5.16	12.17	1,910

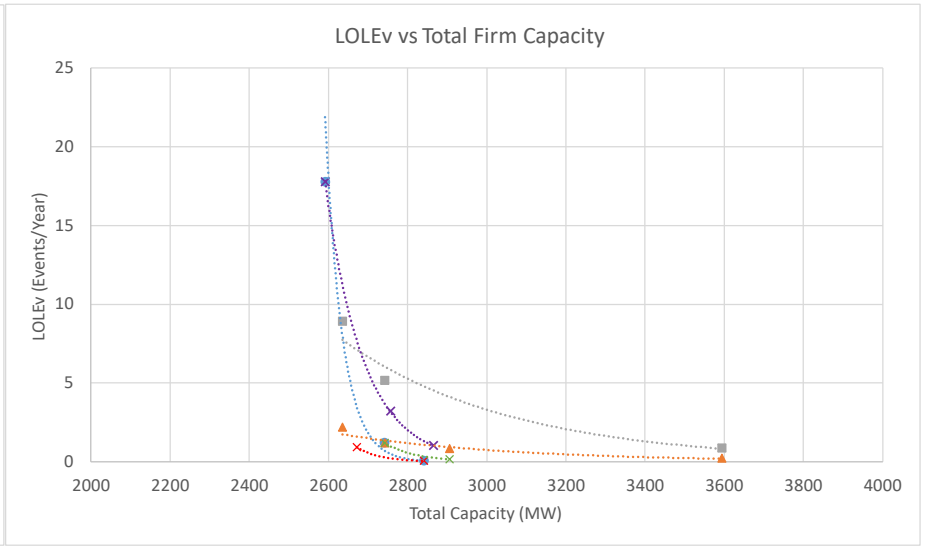
Future Variable includes: [S1 (Hoohana, Mililani, Waiawa, West O‘ahu), S2 (Barbers Point, Kupono, Mountain View, Waiawa Ph 2), CBRE Ph 1/2] = 419 MW Solar+BESS
Future Standalone (SA) BESS includes [S2 (Kapolei Energy Storage)] = 185 MW

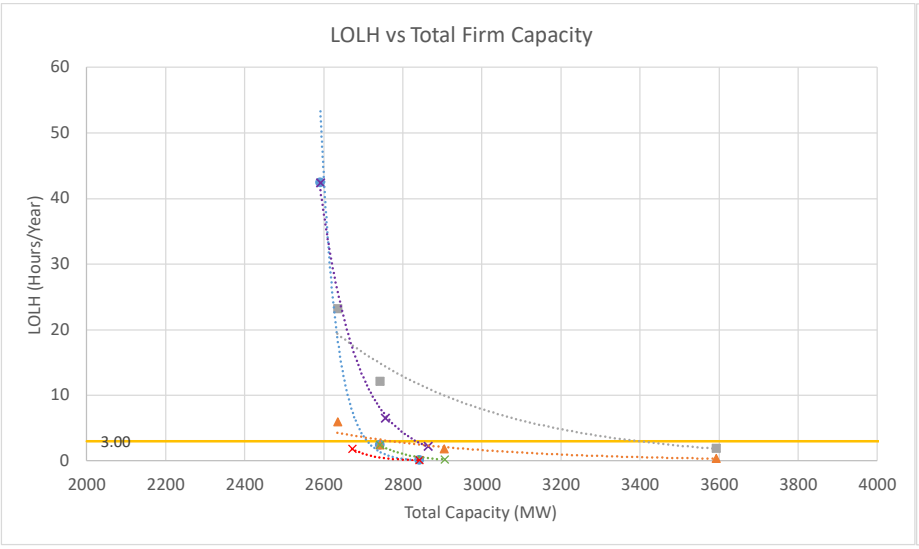
Summary of Results

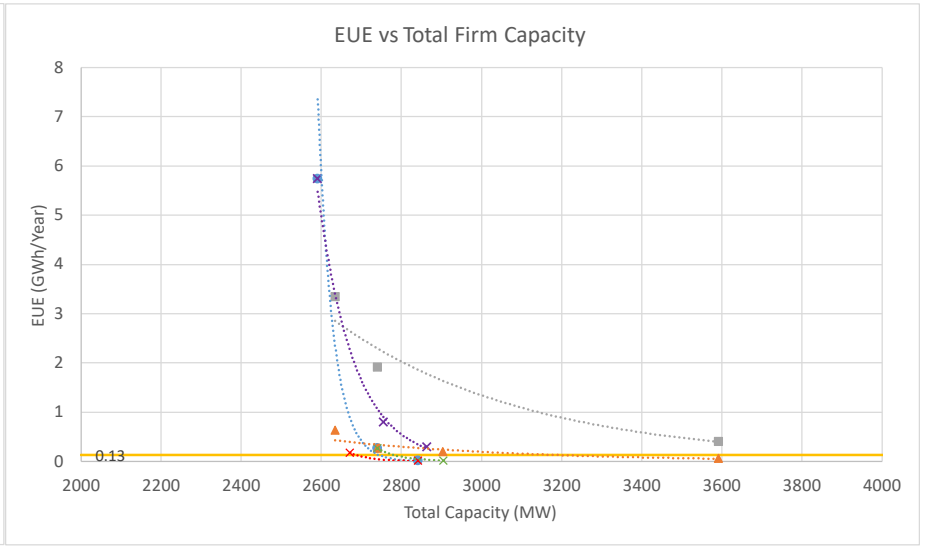


Results





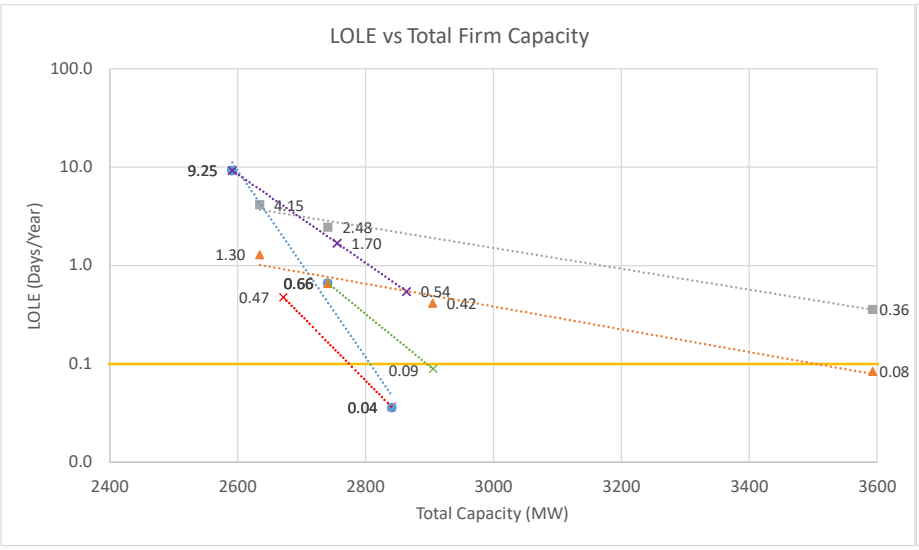


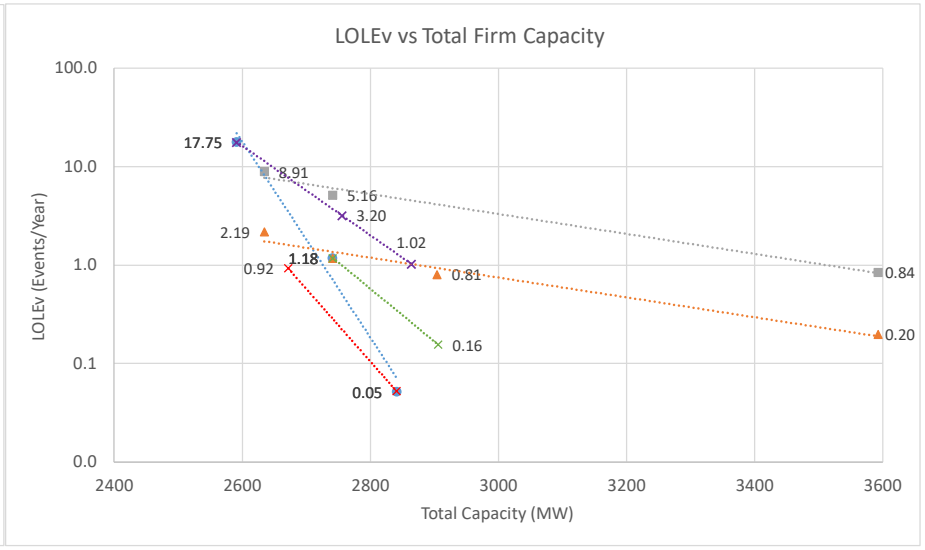


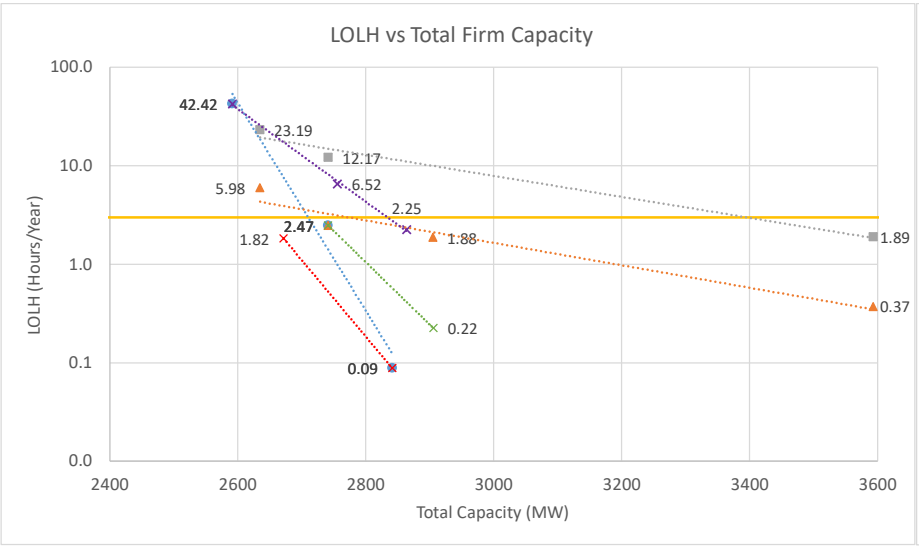
- Firm Test:
  - Tested 150/300/400 MW new firm with 270MW Paired PV
- Paired Test
  - Tested 0/270/958 Paired PV with 300MW new firm
- LDES Test
  - Tested 300MW new firm versus 150MW new firm with 150MW-12hr Storage
- Retirement Test
  - Tested 150/300/400 MW new firm with delayed/accelerated retirements

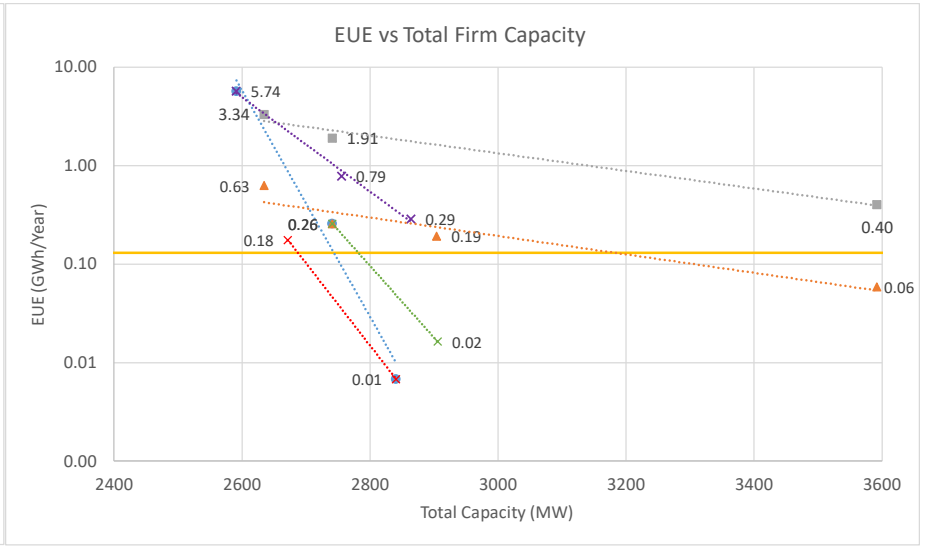
● Firm Test (with 270Paired PV)
▲ Paired Test (300MW Firm)
■ LDES Test (150MW firm/150MW-12hr BESS)
× Retirement Test (150MW Firm 270Paired PV)
× Retirement Test (300MW Firm 270Paired PV)
× Retirement Test (400MW Firm 270Paired PV)

Results





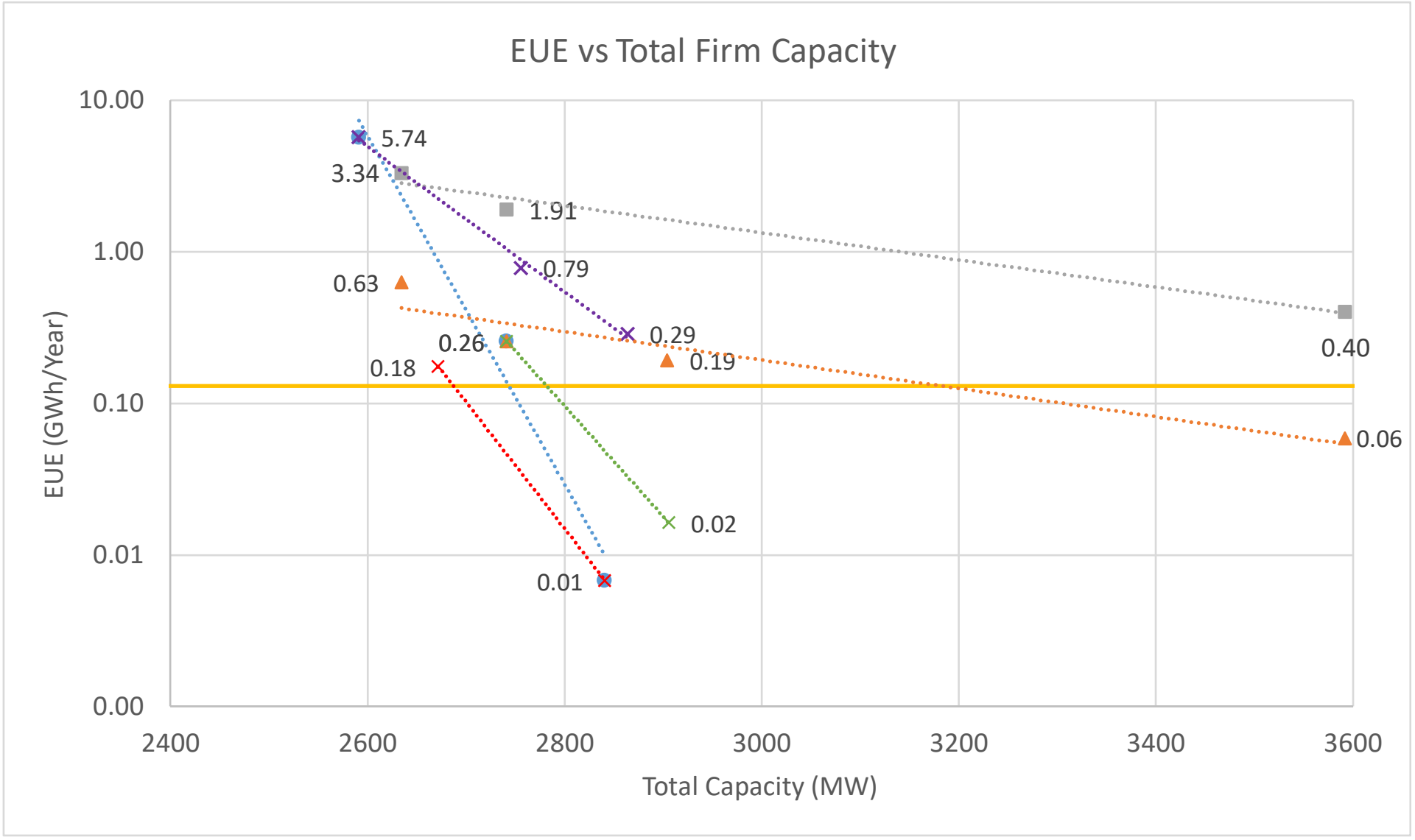




- Across the various portfolios that were analyzed, the following combinations of resources would be needed to meet all reliability targets:
  - 300 MW new firm generation and 958 paired PV
  - 400 MW new firm generation and 270 MW of paired PV
  - 300 MW new firm generation with the delayed removal of 170 MW of existing firm generation and 270 MW of paired PV

● Firm Test (with 270Paired PV)
▲ Paired Test (300MW Firm)
■ LDES Test (150MW firm/150MW-12hr BESS)
× Retirement Test (150MW Firm 270Paired PV)
× Retirement Test (300MW Firm 270Paired PV)
× Retirement Test (400MW Firm 270Paired PV)

Results

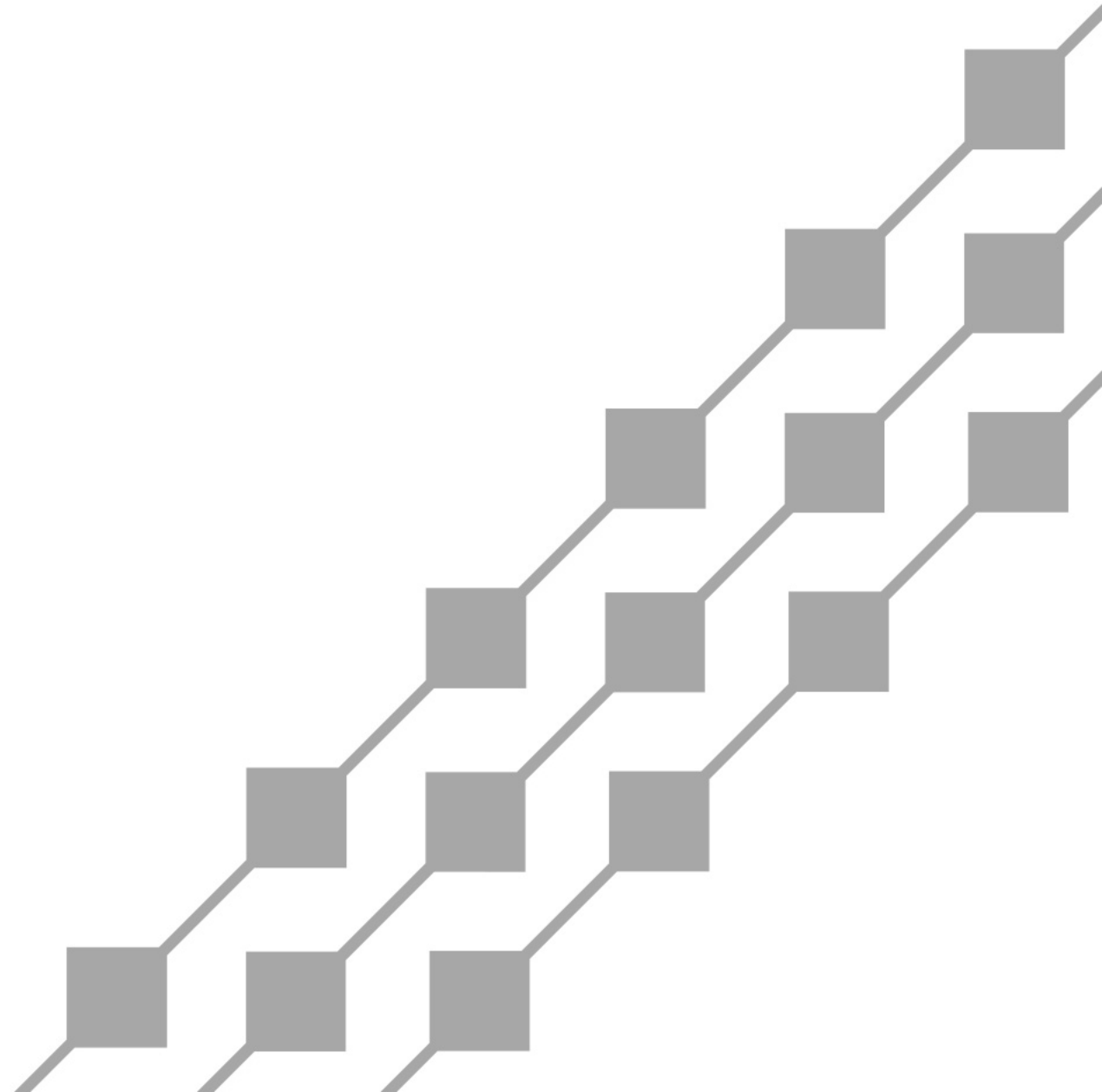

EUE vs Total Firm Capacity
10.00
1.00
0.10
0.01
0.00
EUE (GWh/Year)
2400
2600
2800
3000
3200
3400
3600
Total Capacity (MW)
5.74
3.34
1.91
0.40
0.79
0.63
0.29
0.26
0.19
0.18
0.06
0.02
0.01
Firm Test (with 270Paired PV)
Paired Test (300MW Firm)
LDES Test (150MW firm/150MW-12hr BESS)
Retirement Test (150MW Firm)
Retirement Test (300MW Firm)
Retirement Test (400MW Firm)

Discussion

- Is a minimum of 300 MW of new firm generation by 2029 appropriate?
- Based on the probabilistic analyses completed to date, does the TAP recommend that more than 300 MW of firm generation be acquired by 2029, as prudent or least regrets, given the following uncertainties and risks:
  - Uncertainty in significant future solar development on land with slopes >15% or due to continued supply chain issues, elevated pricing/inflation, land availability regardless of slope or type of renewable.
  - The risk of continued availability and operation of existing fossil fuel units.
  - Diversification and grid resilience enhancement against extreme events.
  - Uncertainty in acquiring forecasted amounts of EE, DER, and EV.
  - For context, the RESOLVE models select most of Groups 1 and 2 by 2030 as being cost-effective:

RESOLVE REZ Group Capacity (MW)	Slope ≤ 15%	15% > Slope ≤ 30%	Total
Group 1 (1, 2, 7 from REZ Study)	84	426	**510**
Group 2 (3, 4, 5, 6 from REZ Study)	439	1,235	**1,674**
Group 3 (8 from REZ Study)	435	725	**1,160**
Total by Slope	**958**	**2,386**	**3,344**

Testing Revised HDC for Thermal Generators

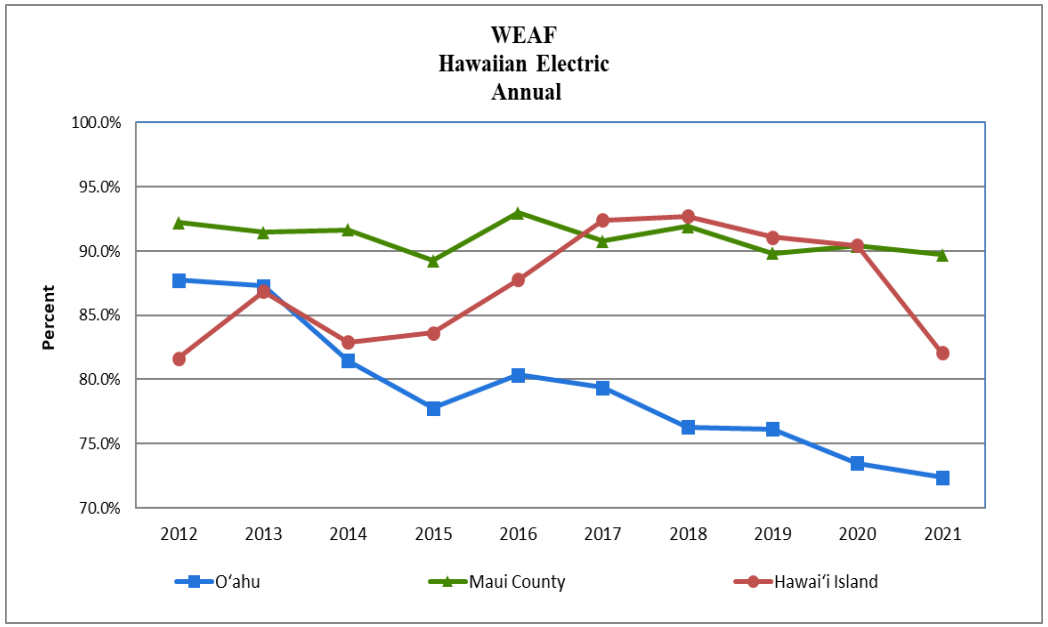


Weighted Equivalent Availability Factor

Currently, existing and new firm generation has an HDC = 1, where there are no assumed derates for maintenance or forced outage.

Current Assumption	Sensitivity Tested
Existing firm generation HDC = 100%	Oahu existing firm HDC = 72.37% Maui County existing firm HDC = 89.72% Hawaii Island existing firm HDC = 82.08%
New firm generation HDC = 100%	New firm generation HDC = 97.4%

- Weighted Equivalent Availability Factor (WEAF) – Percentage of time a fleet of generating units is available to generate electricity
  - Weighted for size of generators – larger generators have greater influence on WEAF
  - Includes planned and unplanned outages
- New firm generation HDC based on assumption of 1.3% FOR and 1.3% MOR



https://www.hawaiianelectric.com/about-us/performance-scorecards-and-metrics/power-supply-and-generation

Thermal HDC Test

- Base_wKPLPMahi
  - Original Base case including KPLP and Mahi
  - Existing firm HDC = 100%, New firm HDC = 100%. ERM Requirement = 30%
- Base.v2
  - Base case without KPLP and Mahi
  - Existing firm HDC = 100%, New firm HDC = 100%. ERM Requirement = 30%
- Base.v3_30ERM
  - Base.v2 with HDC applied to firm units.
  - Existing firm HDC = 72.37%, New firm HDC = 97.4%. ERM Requirement = 30%
- Base.v3_20ERM
  - Base.v2 with HDC applied to firm units.
  - Existing firm HDC = 72.37%, New firm HDC = 97.4%. ERM Requirement = 20%
- Base.v3_10ERM
  - Base.v2 with HDC applied to firm units.
  - Existing firm HDC = 72.37%, New firm HDC = 97.4%. ERM Requirement = 10%
- Base.v3_0ERM
  - Base.v2 with HDC applied to firm units.
  - Existing firm HDC = 72.37%, New firm HDC = 97.4%. ERM Requirement = 0%
- Land Constrained
  - Base case without Future Onshore Wind Potential, with 270MW Limit on Paired PV
  - Firm HDC = 100%. ERM Requirement = 30%
- LC.v3_10ERM
  - Land Constrained without KPLP and Mahi, with HDC applied to firm units.
  - Existing firm HDC = 72.37%, New firm HDC = 97.4%. ERM Requirement = 10%

Thermal HDC Test

Base_wKPLPMahi = Original plan with KPLP/Mahi with 100% firm HDC with 30% ERM
Base.v2 = Base without KPLP/Mahi
Base.v3_#ERM = Base without KPLP/Mahi, with firm HDC, with #% ERM

Year 2030	RESOLVE Resource Plan							
	Base_wKPLPMahi	Base.v2	Base.v3_30ERM	Base.v3_20ERM	Base.v3_10ERM	Base.v3_0ERM	Land Constrained	LC.v3_10ERM
Existing firm HDC (%)	100	100	72.37	72.37	72.37	72.37	100	72.37
New firm HDC (%)	100	100	97.4	97.4	97.4	97.4	100	97.4
ERM Requirement (%)	30	30	30	20	10	0	30	10
New Firm (selected by RESOLVE)	35	264	521	408	300	213	39	342
Existing Firm	1,175	967	967	967	967	967	967	967
Standalone PV	0	0	0	0	0	0	0	0
Paired PV	1,577	1,640	1,401	1,556	1,594	1,741	270	270
Onshore Wind	163	163	163	163	163	163	0	0
Offshore Wind	0	0	0	0	0	0	0	0
Standalone Storage (MW/MWH)	379 MW / 712 MWh	66 MW / 124 MWh	67 MW / 127 MWh	64 MW / 122 MWh	61 MW / 115 MWh	75 MW / 140 MWh	321 MW / 600 MWh	14 MW / 26 MWh
Paired Storage (MW/MWH)	1,577 MW / 4,461 MWh	1640 MW / 5,100 MWh	1401 MW / 3,639 MWh	1,556 MW / 4,502 MWh	1,594 MW / 4,770 MWh	1,741 MW / 5,613 MWh	270 MW / 270 MWh	270 MW / 270 MWh

Utility Firm Removal/Deactivation: 90MW in 2024, 110 MW in 2027, 170 MW in 2029

Summary of Thermal HDC Tests in RESOLVE

- Multiple sensitivities were tested including:
  - Removing KPLP
  - Removing Mahi
  - Range of ERM Targets: 30%, 20%, 10%, 0%.
  - Using calculated HDC's for existing and new thermal resources
- The removal of KPLP and Mahi led to an increase in firm resources being selected.
- When applying HDCs to the firm units, the amount of firm resources selected increased and the amount of variable resources remained relatively flat.
- Decreasing the ERM with firm HDCs decreased the amount of firm resources selected and slightly increased the amount of variable resources selected in the near term (2030).

Next Steps

- Present preliminary results from Maui's probabilistic resource adequacy.
- Continue/Reschedule TAP Resource Adequacy standing meeting series