Hawaiʻi Natural Energy Institute Research Highlights

Grid Integration

Grid Reliability with High Solar and Storage Deployment

OBJECTIVE AND SIGNIFICANCE: Hawaiʻi's power systems are undergoing significant change, characterized by the replacement of aging coal and oil generation with variable and less predictable solar and storage resources. This ongoing study shows that grid reliability (resource adequacy) as measured by loss-of-load expectation can be maintained equivalent to or better than the current system even with very high penetrations of variable renewable generation with storage. Maintaining this reliability will require back up support of firm generation resources, during times of low solar and/or wind resource.

KEY RESULTS: Hawaiʻi's electric systems can further expand their renewable energy portfolio, incorporating more solar and storage without any loss of reliability (resource adequacy). Maximizing renewable energy utilization while incorporating the availability of firm capacity resources for those times when renewable output is insufficient will reduce fuel use. To ensure grid stability during periods of low renewable generation, the integration of firm power resources will be crucial. These firm resources will require flexible, dispatchable generation, to provide a consistent energy supply during periods of extended low variable resources (see "***Clean Firm Resource Needs in Hawaiʻi***").

BACKGROUND: Over the past decade, Hawaiʻi has experienced rapid growth in solar energy driven by high oil prices, decreasing costs of solar technologies, and a commitment to reducing the use of fossil fuels. The first major phase of solar integration began with the adoption of distributed rooftop systems – encouraged by net energy metering policies that allowed homeowners to offset electricity costs and receive credit for surplus energy produced. This initial program led to a significant increase in rooftop solar across the islands, as early adopters installed systems that contributed to the state's renewable energy goals.

The second phase of solar expansion saw the development of larger-scale utility solar projects, particularly on Oʻahu. Between 2017 to 2020, Oʻahu added 175 MW of utility-scale solar without battery storage, addressing daytime energy needs and further reducing the reliance on oil-fired generation. However, at this point, mid-day solar generation regularly exceeded half of total demand and there was limited ability to integrate additional solar without storage into the grid.

Currently, a third phase is underway, involving hybrid solar and battery storage projects that can both generate electricity during the day and store a significant amount of the energy for later use during late evening or early morning peak demand periods. Through recent competitive procurements, this new generation of hybrid projects is expected to significantly increase the renewable energy share on the grid.

Relative to the size of the Hawaiʻi grids, these hybrid solar and storage systems are being deployed at a scale not yet seen in other parts of the United States or globally. Simultaneously, coal and oil generation plants are being retired from operation. In 2022, the AES coal plant, Oʻahu's largest single source of electricity, was retired and replaced by solar and storage resources. Similarly, forthcoming oil plants at Kahului and Māʻalaea on Maui are slated for retirement and will be replaced primarily by solar and storage resources with some additional firm flexible generation.

Over the past several years, HNEI has conducted resource adequacy studies for both Oʻahu and Maui, calculating the amount of solar and storage capacity that would be needed at various levels of coal and oil retirements. For Oʻahu, the analysis specifically modeled the retirement of the AES coal plant and the commissioning of the KES standalone battery and determined that the current Oʻahu grid, with the AES coal plant retired and the KES standalone battery in operation would be resource-adequate even with only practical buildout of the Stage 1 projects, but continued oil retirements would require large variable generation additions and backup firm generation.

Results of the 54 evaluated scenarios for Oʻahu are provided in the matrix in Figure 1, which shows the loss of load expectation – measured in average days of capacity shortfall in a year – across a range of solar + storage replacement, load levels, forced outage rates, and with and without the KES battery. Higher numbers, highlighted in yellow and orange, represent conditions with high risk.

			Low PV	Mid PV	High PV
No KES	Low Load	Low FOR	0.18	0.04	0.02
		Mid FOR	0.59	0.24	0.15
		High FOR	2.09	0.85	0.38
	Mid Load	Low FOR	0.71	0.25	0.12
		Mid FOR	1.95	0.75	0.34
		High FOR	6.02	2.60	1.37
	High Load	Low FOR	2.23	0.85	0.40
		Mid FOR	5.72	2.56	1.25
		High FOR	15.21	7.47	4.01
KES	Low Load	Low FOR	0.01	0.00	0.00
		Mid FOR	0.05	0.03	0.02
		High FOR	0.21	0.12	0.06
	Mid Load	Low FOR	0.04	0.02	0.01
		Mid FOR	0.19	0.09	0.09
		High FOR	0.71	0.43	0.26
	High Load	Low FOR	0.20	0.08	0.04
		Mid FOR	0.66	0.43	0.27
		High FOR	2.25	1.37	0.83

Figure 1. LOLE (days per year) for 2023 evaluated across 54 scenarios.

HNEI and Telos Energy also conducted a resource adequacy analysis to assess the reliability of the Maui system with the Kahului Power Plant (KPP) and Māʻalaea M10-M13 retirement and replacement solely with variable renewable energy and energy storage.

The analysis indicates that with the KPP retirement in isolation (-33.5 MW), any combination of 40 MW of solar + storage or standalone storage resources brings the system back to its current level of reliability (i.e. a near 1-1 replacement of oil with solar + storage). The retirement of M10-M13 in isolation (-50 MW), would require more replacement resources, between 40 and 60 MW – again, a near 1-1 replacement. With both oil plants retired (-81.8 MW), between 80 and 100 MW of replacement solar + storage capacity would be required to maintain reliability. This highlights that full deployment of the under-construction hybrid solar + storage resources plus additional resources would be required to meet current system reliability levels if both plants are retired. The results for Maui are shown in Figure 2.

PROJECT STATUS/RESULTS: Since 2020, HNEI has been conducting and regularly updating analysis on the expected reliability of the Hawaiʻi power systems with additional deployment of solar and storage resources. These studies also explore the potential for additional oil plant retirements. In 2024, HNEI continued to assess the reliability of Hawaiʻi's grids as new solar and storage resources were brought online.

The HNEI analysis utilizes detailed power system models and utilizes sequential Monte Carlo probabilistic modeling which incorporates 25 years of chronological solar data, 8 years of chronological wind data, and hundreds of samples of thermal generator outages to forecast the reliability of the

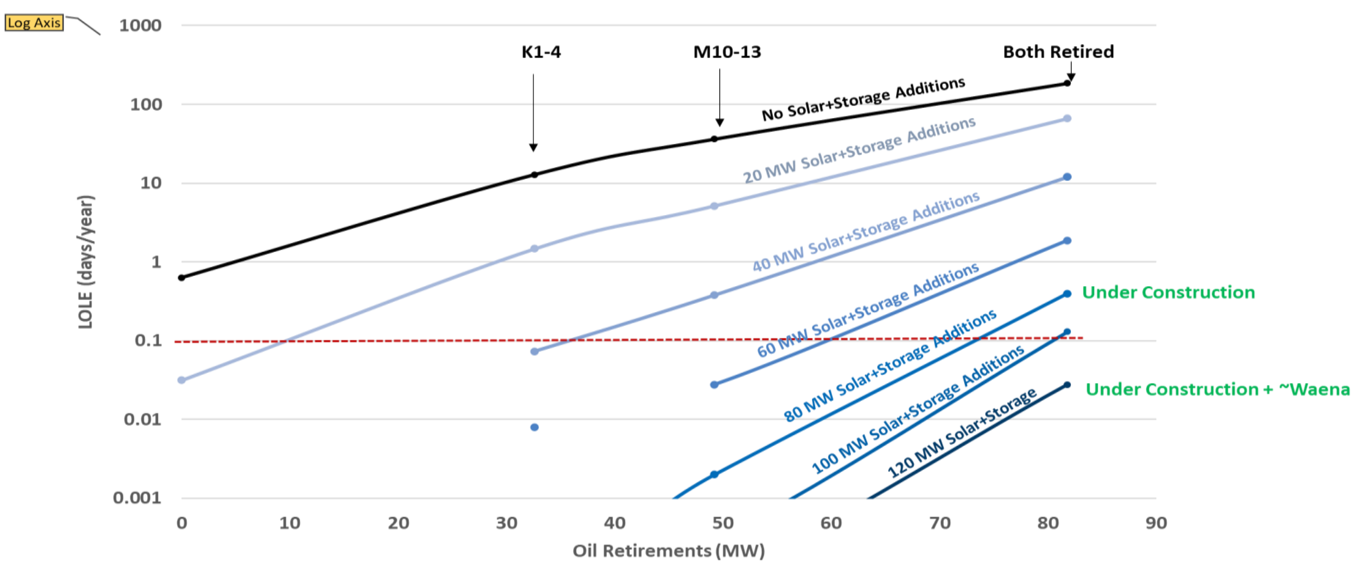

Figure 2. Loss of Load Expectation with oil retirements and solar + storage replacement.

future power system. This process utilized by HNEI was adopted by HECO for grid modeling in 2023.

The analysis suggests that integrating large-scale solar paired with storage can allow Hawai‘i's grids to receive up to 70% or more of their energy needs from variable renewable generation while keeping solar curtailment, the excess energy production that cannot be delivered to the grid, relatively low (Figure 3). Adoption of solar, combined with 4-hour battery storage systems can improve grid reliability when managed effectively with firm resources during periods of low or intermittent variable generation.

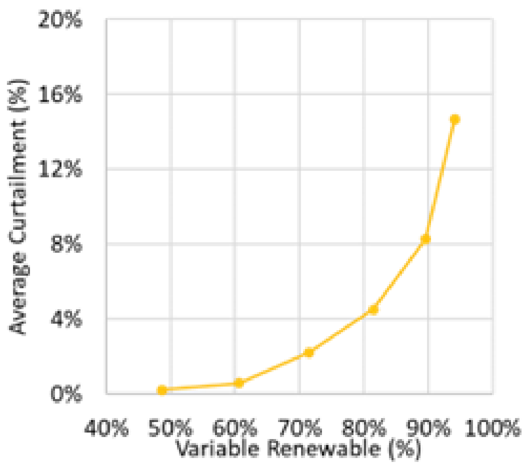

Figure 3. Solar curtailment at increasing shares of variable renewable energy.

Despite these benefits, some stakeholders have expressed concern over intermittent generation resources and the perceived impact on grid reliability. However, HNEI analysis shows that solar and storage resources can continue to be integrated into Hawai‘i's grid at high levels without any loss to resource adequacy when coupled with firm generation resources. The amount of firm capacity required by the system at various levels of solar, storage, and wind and how it would be optimally operated is discussed further in "***Clean Firm Resource Needs in Hawai‘i***".

Results of this work were presented to the Public Utilities Commission, Hawaiian Electric Company, the Power Past Coal Task Force, and other public forums over the past three years.

HNEI will continue to track the reliability of Hawai‘i's grids and update this analysis as new solar and storage systems come online, new projects are proposed, and additional retirements are planned.

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