



Hawai'i Natural Energy Institute Research Highlights

Grid Integration

Clean Firm Resource Needs in Hawai'i

OBJECTIVE AND SIGNIFICANCE: The objective of this project is to inform procurement and legislation for both variable and firm renewable energy. The study sought to determine the minimum amount of firm capacity that the system would require at various levels of wind, solar, and storage. The results of this study help frame the ongoing discussions and planning related to the role of dispatchable firm capacity in ensuring reliability of the island's grids. This analysis can also be used to inform decisions on oil-fired power plant retirements, guide procurement of new resources, and quantify challenges of relying solely on variable renewable energy and storage alone for a 100% renewable grid.

KEY RESULTS: The findings of this analysis indicate that on O'ahu, even with a very high penetration of variable renewable energy and storage, there will be a minimum firm capacity need of 600-750 MW to ensure resource adequacy. In this future clean energy system with high variable renewables, these firm resources would run sparingly but when they do run, it could be for multiple consecutive days at a time. Today, this firm resource is provided by the existing Hawaiian Electric (HECO) oil plants but these plants are aging and becoming less reliable. Some or all of them will need to be retired and replaced with more reliable, more flexible forms of firm generation.

The analysis was extended to each of the other islands with results confirming that firm capacity needs are approximately 50% of peak load for each of the islands. In 2025, the analysis was expanded to assess planned retirements and include actual proposed firm resources, including the 250 MW Stage 3 Waiau Repower project proposed by HECO and the 99 MW Pu'uloa reciprocating engine plant proposed at Joint Base Pearl Harbor-Hickam (JBPHH). This work is described in more detail in "[O'ahu Thermal Retirement and Repower Analysis](#)" project summary.

BACKGROUND: With the deployment of wind, solar, and battery technologies on the island grids over the past ten years, there has been considerable interest and debate on the need for dispatchable firm renewable energy technologies. Dispatchable firm capacity refers to power generation that is available for sustained periods of time, irrespective of weather

conditions or the availability of wind and solar resources.

In the 2022 legislative session, the Hawai'i State Senate and House of Representatives introduced a series of bills that sought to promote—and in some cases mandate—increased adoption of dispatchable firm renewable energy. These bills also proposed to limit the percentage penetration of any one type of renewable energy source to forty-five percent of all generation for each island, except for geothermal generated energy. While these laws are not in statute today, there is continued interest in firm renewable energy and will likely be a topic of future legislative sessions.

On March 1, 2022, HECO issued a request for proposals (RFP) seeking 500 to 700 megawatts of energy from firm renewable generation resources with a targeted online date between 2029 and 2033. According to HECO, "while solar and wind energy resources will help us hit our near-term clean energy milestones, we'll also need firm renewable resources available for customers when the sun isn't shining, or the wind isn't blowing."

Through the Stage 3 procurement, six projects were selected, representing 700 MW of firm, renewable capable resources. Selected projects are currently in contract negotiations with the utility. The selected projects include a repower of the Waiau plant on O'ahu, a proposed 250 MW replacement of Waiau steam units with aeroderivative gas turbines, and a 99 MW reciprocating engine plant at JBPHH. More recently, the Hawai'i State Energy Office is also proposing to potentially incorporate efficient combined cycle liquefied natural gas (LNG) resources to serve the firm resource needs over the next 20 years.

PROJECT STATUS/RESULTS: Based on the interest in dispatchable firm energy and the broad range of proposed solutions, HNEI developed a simplified screening methodology to estimate the amount of firm renewable capacity that may be required (Figure 1). The analysis was first conducted for O'ahu and the methodology was later extended to the islands of Kaua'i, Maui, Moloka'i, Lāna'i, and Hawai'i. The simplified screening process was verified with robust

probabilistic resource adequacy and detailed operational modeling of specific resource mixes.

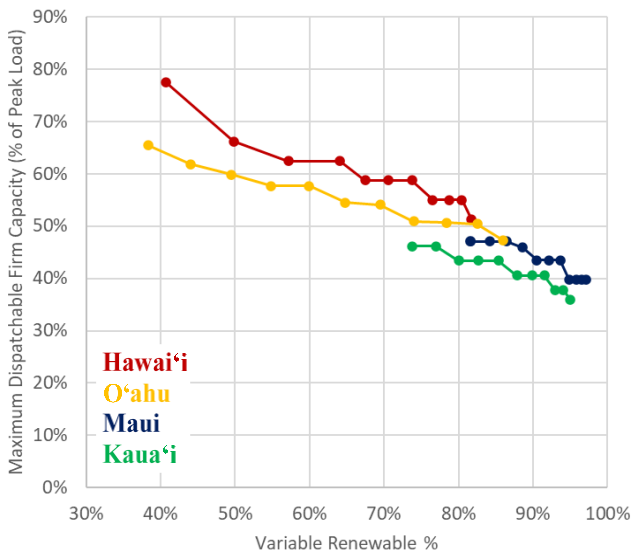


Figure 1. Minimum firm capacity needs by island at increasing levels of variable renewables

The study team evaluated a number of potential future resource mixes that included up to 90% variable renewable mixes of solar plus storage and wind. These scenarios were then modeled using the screening tool to estimate the amount of firm capacity and energy needed to meet load, assuming maximum technically feasible usage of the solar, wind, and battery energy storage (BESS).

The scenarios and firm capacity resources were modeled using 21-years of historical weather resources (1998-2018) creating dispatch profiles for nearly 184,000 hours of chronological operations. Representative operations, for a high-solar and a low-solar week are shown in Figure 2, illustrating the need for significant firm generation during extended periods of low renewable resources.

The metrics available from the analysis include the amount of curtailment of variable wind and solar resources at each resource level, as well as the utilization (capacity factor) of the firm resources. Particular attention was given to the maximum dispatch of the unit, used to estimate the overall firm capacity need. Operational metrics like number of starts, ramp needs, operating hours, and capacity factor by incremental block were also evaluated.

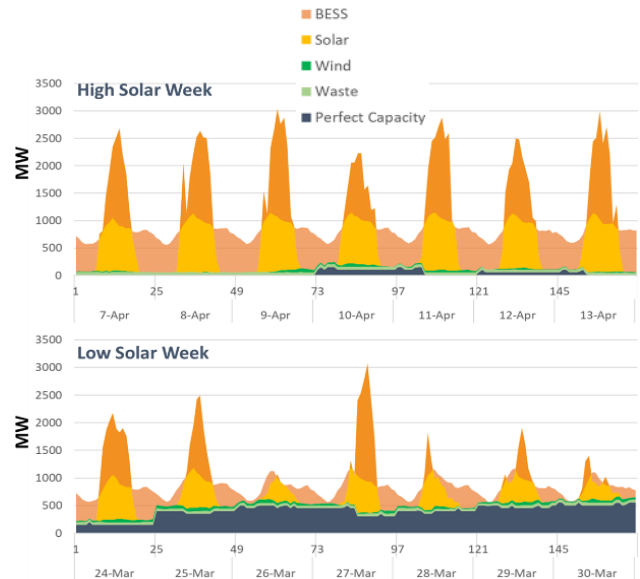


Figure 2. Representative high and low solar weeks and the need for firm renewables.

The estimated firm capacity need, at different levels of variable renewable availability are shown in Figure 1 for each of the major islands as a percent of system peak load. At 70% availability of variable renewables, for example, the firm capacity need ranges from approximately 45% to 60% of peak load. These values can be used as a proxy for the firm renewable resource needs of the system.

Even at very high penetrations of variable renewable energy—as high as 90% of annual energy, there is still a substantial need for firm capacity, as much as 40% to 50% of the system’s peak demand. While increased solar, wind, and battery energy storage will not eliminate the need for firm resources, increased deployment will reduce the required fuel usage and have a direct impact on GHG emissions.

In 2024, the HNEI project team updated this analysis to evaluate the required operating flexibility (quick dispatch and ramp rate, for example) of the new firm resources.

The study evaluated three types of firm resources: 1) baseload resources which were unable to cycle on or off or load follow; 2) inflexible resources which had long startup/shutdown times and limited ramp rates; and 3) flexible resources that could start/stop and ramp quickly.

Results of this analysis show that when forecast errors of solar resources are introduced, there may be an increased need for quick-start resources. The impacts of forecast error and generation flexibility will be evaluated in future modeling work for the existing and proposed firm generation resources.

Today, there are limited low or zero emission resources available to provide the required dispatchable firm energy. Generation using biomass or biodiesel would require large amounts of feedstock requiring imported fuels. Geothermal is available on Hawai'i Island, but is not well characterized for the other islands. While hydrogen and other forms of multi-day storage have been considered for firm capacity, the technical viability and costs of these technologies remain highly uncertain.

This study has been intended to be a screening analysis of the potential firm renewable needs for future Hawaiian Islands' energy systems. During 2025, this work was expanded to include specific options for repowering on O'ahu, including the Waiiau gas turbine repowering, deployment of the Pu'uloa internal combustion engine (ICE) units, and additional evaluation of long-duration energy storage (LDES). Analysis of the proposed import of LNG has also been initiated. The results of these analyses are included in separate project summaries in the [Grid System Analysis subsection](#).

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