



# Hawai'i Natural Energy Institute Research Highlights

## Grid Integration & Energy Efficiency

### Clean Firm Needs

**OBJECTIVE AND SIGNIFICANCE:** This study was intended to help inform and frame the ongoing discussions and planning related to the need of dispatchable firm capacity. The objective is to inform future procurement and potential legislation for both variable and firm renewable energy. The analysis sought to determine the minimum amount of firm capacity that the system would require – at various levels of wind, solar, and storage – to maintain adequate generation resources during periods of extended poor weather. This analysis also evaluated what levels of variable renewable energy can be implemented without impacting (shutting the door) on future options. This information can be used to inform decisions on oil-fired power plant retirements, guide procurement of new resources, and to 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 in a very high variable renewable energy and storage grid, there is a need for very significant amounts of firm capacity, up to 600-750 MW. In this future clean energy system with very high penetration of variable renewables, these resources would only need to run sparingly, but are essential for reliability. When they are necessary, it could be for multiple consecutive days at a time making it difficult, if not impossible, to solve the reliability challenge by exclusively relying on variable renewables and battery storage, even long term storage. Today, this grid service is provided by the existing HECO oil plants. These plants are aging and becoming less reliable and cannot be converted to meet the state’s 100% renewable energy target. At some point, they will need to be retired and replaced with other forms of firm renewable energy.

The analysis for O‘ahu was extended to each of the other islands to compare the total firm capacity need and operational characteristics of these resources. Results for the state confirm that firm capacity needs are approximately 50% of peak load for all the islands.

**BACKGROUND:** Despite the growth in wind, solar, and battery technologies over the past ten years, there is increased interest in firm renewable energy technologies in Hawai‘i and the power industry in general. This is being driven by several factors,

including resource saturation, resource diversity, reliability, and agricultural and forestry sector objectives. Dispatchable firm capacity refers to power generation that is available for a sustained period 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 firm renewable energy. For example, HB 1611 and SB 2510 proposed to establish a state energy policy that requires at least 33.3% of renewable energy be generated by firm renewable energy. These bills also proposed to limit the percentage of any one type of renewable energy source to 45% of all generation for each island, except for geothermal generated energy. It was unclear if the intent of this requirement was to limit the percentage of distributed PV and utility-scale PV to 45%, but since some of the islands already have high levels of these resources, it could prevent the installation of additional solar systems. These bills were approved by both the Senate and the House, but later vetoed by the governor. While these laws are not in statute today, there is continued interest in firm renewable energy and likely will be the topic of future legislative sessions.

In addition, on March 1, 2022, Hawaiian Electric (HECO) issued a request for proposals (RFP) seeking proposals to acquire 500 to 700 megawatts of energy from firm renewable generation resources on O‘ahu 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.”

The RFP also states that the objective of the firm renewable procurement is to ensure that “sufficient firm capacity must be available during periods of low wind and solar production. Modernizing the ageing fossil fuel generation fleet (some of which are over 75 years old) by adding new renewable firm generation is consistent with decarbonization goals and policies as new firm generators will be installed alongside significant quantities of low-cost renewables to

ensure reliability and resilience, resulting in overall reductions in carbon emissions.”

There is also increased attention being afforded to the role of hydrogen in decarbonizing the Hawai‘i energy sector, including for electric power uses (see “[Hawai‘i Hydrogen Integration Study](#)” project summary) along with locally sourced biomass and/or biodiesel, and potentially the development of new geothermal resources.

**PROJECT STATUS/RESULTS:** Given the recent legislative actions and proposed firm renewable procurements by the utility, HNEI conducted a series of analyses to identify the amount of firm renewable capacity that may be required in Hawai‘i. 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.

To quantify potential firm renewable needs, the study team developed a simplified screening methodology and then verified the results with robust probabilistic resource adequacy and detailed operational modeling of a specific resource mix. The screening methodology was conducted in a five-step process, illustrated in Figure 1.

The study team developed a small number of potential future resource mixes that reach or exceed 90% renewable energy, by varying the amount of solar + storage and offshore wind resources that are proposed to be available. This step was done at increasing levels of available wind and solar resources. Using O‘ahu as an example, resources were added in 1,000 GWh per year intervals. These scenarios were then evaluated without the existing oil capacity on the system, to calculate the remaining amount of capacity and energy needed after accounting for solar, wind, and battery energy storage. These units were replaced with blocks of perfectly available and flexible capacity – which would operate in a manner to limit total capacity additions while meeting the needs of the system.

The scenarios and perfect capacity resources were modeled across 21-years of weather resources (which represented historical weather conditions from 1998-2018) for the solar and offshore wind resources. The model was evaluated across all hours of the year in the 21-year period, creating dispatch profiles for nearly 184,000 hours of chronological operations, illustrated in Figure 2. The use of multiple years of resource for this analysis, inherently considers the impact of historic periods of low resource.



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

The results of the simulations were used to quantify system performance and firm renewable capacity needs. In particular, the metrics resulting from this analysis included the amount of curtailment of variable wind and solar resources, as well as the utilization of the perfect capacity resource. For the perfect capacity resource, particular attention was given to the maximum dispatch of the unit, which implies the overall capacity need. Operational metrics like number of starts, ramp needs, operating hours, and capacity factor by incremental block were also evaluated. Cost metrics were also incorporated as proxy values for the perfect capacity resource – as if it was provided by the existing oil-fired generating

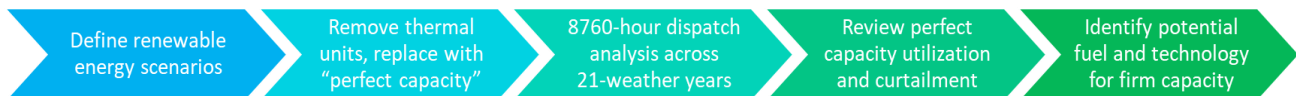


Figure 1. Five-step screening methodology to calculate firm renewable needs.

mix or a future firm renewable resource mix such as biodiesel.

Results of the analysis are provided in Figure 3, showing several islands firm capacity requirement as a percentage of peak load (y-axis) at varying levels of solar and storage builds (x-axis). Only the maximum dispatch of the perfect capacity resource is shown as a percent of system peak load – illustrating the aggregate *capacity* need of 40-50% of peak load – depending on the amount of variable renewable energy and battery energy storage on the system. These values can be used as a proxy for the firm renewable resource needs of the system. This clearly shows the relationship between increasing variable renewables and storage capacity to the diminishing needs for firm renewable capacity.

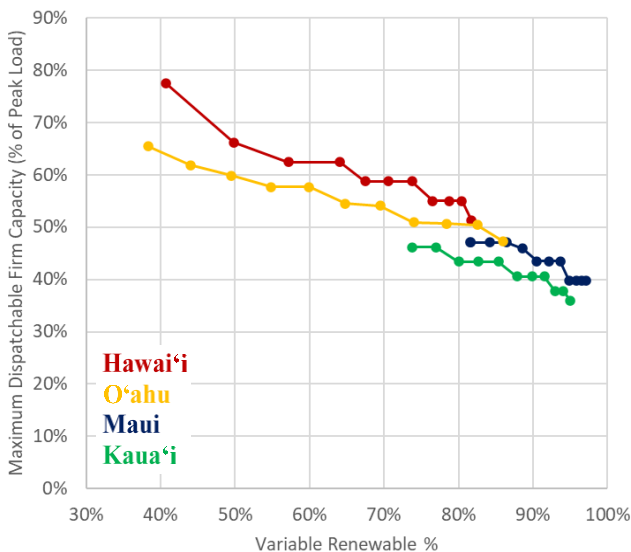


Figure 3. Firm capacity needs at increasing levels of variable renewable energy (PV+BESS) across islands.

However, the analysis also showed that even at very high penetrations of variable renewable energy – reaching almost 95% of annual energy – there is still a substantial need for firm capacity. This is approximately 50% of the system’s peak demand and emphasizes the point discussed previously that there are diminishing returns associated with additional variable renewable energy at high penetrations.

The analysis was repeated at various levels of electric vehicle penetration. The results for O’ahu indicate that a 20% increase in EV charging during peak demand periods would only increase the firm

renewable requirement by approximately 50 MW, and would increase by approximately 250 MW with the 60% EV peak charging scenario. In addition, these peak demand needs were only modestly changed by differences if different charging profiles were implemented. While daytime charging is slightly better than peak demand or overnight charging profiles, there is relatively little difference between the time of charging and the additional firm renewable capacity needed.

The reason for this is twofold; first, the system is largely energy constrained rather than capacity constrained. As a result, the firm renewable needs are largely driven by low wind and solar days rather than hourly demand. Second, there is a significant amount of grid battery energy storage assumed in these portfolios, and thus plenty of flexibility to move energy from one time of day to another. Overall, while EV adoption rates would change the total amount of renewable energy needed to reach the state’s renewable energy targets, the timing of EV charging has a relatively modest impact on overall firm renewable needs for reliability.

Today, there are limited zero emission resources available to provide dispatchable firm capacity, and each has limitations that must be considered. Biomass and biodiesel, even if run sparingly, would require large feedstocks exceeding available land use and requiring imported fuels. Geothermal is available on Hawai’i Island, but would likely require subsea, interisland cables for O’ahu and Maui. Hydrogen and other forms of multi-day storage could also provide firm capacity, but would exacerbate land use challenges, community acceptance, and costs remain highly uncertain.

In addition, these options are all significantly more expensive and more uncertain, than near-term additions of solar, wind, and battery energy storage. While these resources will not eliminate the need for firm resources (currently provided by oil capacity), they will diminish the need while increasing renewable energy and CO<sub>2</sub> emissions in the near-term. These additions also do not close the door on future options if new technologies or firm renewable resources become available.

This study is intended to be a screening analysis of the potential firm renewable needs for the future O‘ahu system and to help inform proposed legislation and utility procurements. In light of the Hawai‘i State Legislature’s efforts – through SB 2510 – to require a minimum amount of firm renewable energy, ongoing work will be continued by HNEI to inform on the appropriate levels of firm renewables that may be required. In addition, as the utility’s Stage 3 RFP and Firm Renewable RFP continue to progress, additional analysis can be conducted on specific portfolios and resource types.

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