Hawaiʻi Natural Energy Institute Research Highlights

Grid Integration & Energy Efficiency

Oʻahu and Maui Load Flexibility

OBJECTIVE AND SIGNIFICANCE: HECO's latest Integrated Grid Plan (IGP) relies heavily on customer-sited resources as part of the resource mix to achieve the RPS. These customer resources include significant levels of energy efficiency and rooftop solar, and increasing levels of distributed batteries, and electric vehicles. Historically, these DER resources were unobservable and uncontrollable, but new technologies and grid service programs at the utility may allow for increased customers responsiveness that can help to balance the grid, defer new capacity, and help integrate additional solar PV. The objective of this study is to quantify potential grid benefits of load flexibility and identify characteristics that are most valuable to the future grid.

KEY RESULTS: Analysis conducted by the HNEI-Telos team shows that a static daily load shifting from evening peak to mid-day, such as might be encouraged by time of use (TOU) rate, would provide limited bulk-system benefits on Oʻahu. This is because the amount of battery storage expected to be deployed over the next few years saturates the opportunity of reducing peak load and moving load to the middle of the day.

On Maui, there is a near-term capacity need and current battery proposals (Waena 40 MW BESS) are smaller than Oʻahu as a percentage of load. As a result, while load flexibility will compete with future battery storage, there is a near-term opportunity for load shifting to help maintain reliability when oil capacity is retired in 2028.

Across islands, dynamic load flexibility – that moves load throughout the day based on the day's conditions or across the week – is shown by HNEI/Telos analysis to be considerably more helpful than static load shifting for reliability purposes. This flexibility, however, would require more sophisticated controls or communication in place of, or in addition to, the current proposed TOU rate.

BACKGROUND: With advances in DER technologies and the proliferation of smart devices, customer load can adjust to better align with the capabilities of the power system. However, this load flexibility can only be leveraged if appropriate programs and rates are established to incent the behavior. The PUC and HECO are currently evaluating options for load flexibility across a variety of initiatives, including through advanced rate design (TOU rates), DER Phase 3 program design, and a competitive solicitation of grid services (i.e. Maui Grid Services RFP). While each of these programs contributes to load flexibility, each will have different impacts on the power system given the parameters and operating characteristics of the program.

In parallel, HECO is planning to retire aging oil generators and replace them with a mix of renewable energy and battery energy storage. Over the next few years, Oʻahu will be bringing online 400 MW of hybrid solar + storage plants and 185 MW of standalone storage through the Stage 1 and 2 procurements and has plans to retire 371 MW of generation at the Waiau power plant by 2030 (in addition to the 185 MW AES coal retirement in 2022).

On Maui, the Kahului K1-4 steam oil power plant is planned to retire as soon as possible and the Māʻalaea M10-M13 diesel generators may need to be retired sooner than expected due to lack of replacement parts. At the same time, hybrid solar + storage replacement resources have been delayed or cancelled due to supply chain disruptions, community opposition, and increased project costs. These challenges have led to the consideration of load flexibility as a capacity resource to replace the aging generation.

PROJECT STATUS/RESULTS: The HNEI-Telos team analyzed the benefits of load on Oʻahu and Maui. The study considered potential fuel cost savings and avoided capacity needs attributed to shifting up to 20% of evening residential load from the evening peak load period to the middle of the day. This analysis was conducted across multiple scenarios, first evaluating grid operations prior to storage additions, a near-term grid with planned solar and storage additions, and a higher solar and storage portfolio. This provides a view of changing system benefits of load flexibility relative to the amount of storage on the grid.

Oʻahu Results

In the case of fuel cost savings on Oʻahu, TOU rates have minimal benefits. The reason for this is two-fold. First, while solar generation is abundant in the middle of the day, there is limited curtailment – even before battery storage is added – and oil generation is still needed. Shifted load, therefore, is still served almost exclusively by oil generation, albeit with a modest improvement in plant efficiency (heat rate). Second, round-trip energy losses required to shift the energy (either via behind-the-meter batteries, pre-cooling of evening air conditioning, or otherwise), leads to a net increase in demand due to load shifting.

When batteries are added to the O'ahu system, these modest benefits are reduced further as curtailment of wind and solar is largely eliminated, and there are limited fuel savings from additional load shifting.

However, TOU rates are designed, in large part, to reduce capacity needs rather than fuel savings. The power system includes many "peaking" generators that are built to run sparingly, only in times of high load and when needed for reliability. Load shifting, in theory, could reduce peak demand and avoid the need for new "peakers" or enable oil plant retirements. However, similar to fuel cost savings, the peak capacity needs on O'ahu are also being addressed with battery storage additions.

To quantify the capacity impact, the study implemented a sequential Monte Carlo probabilistic model which incorporates 22 years of chronological solar data, 8 years of chronological wind data, and hundreds of samples of thermal generator outages to quantify the resource adequacy of both O'ahu and Maui. This process was used to test if the power system is reliable across a variety of conditions, including unexpected generator failures or low wind and solar conditions. The expected unserved energy (EUE) measures the likelihood of having insufficient resources to serve load and the potential for rolling blackouts.

The results show how TOU rates that discourage energy use from 5pm - 9pm can effectively mitigate reliability risk prior to battery storage additions ("Recent Past"), but would not meaningfully help after grid-scale batteries are added ("Near Future"). This is because the remaining reliability risk is spread evenly across the day and the remaining capacity need is no longer isolated to evening peak demand hours. In other words, there is less of a "peaking" need.

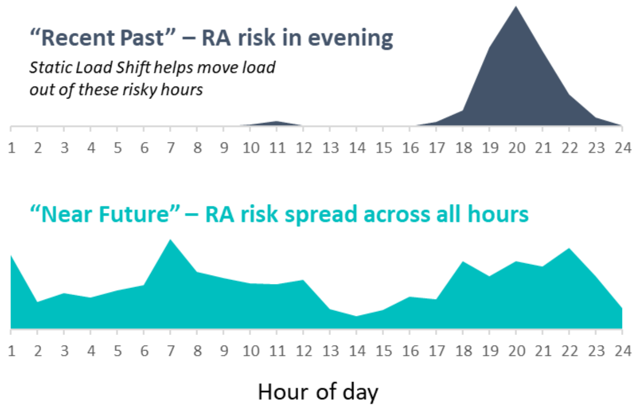

Figure 1. Distribution of EUE by time of day.

Maui Results

On Maui, where the near-term resource mix does not yet include large amounts of energy storage, load flexibility can be part of the mix to retire oil generation, but competes directly with grid-scale battery storage additions that are planned with the Stage 1, Stage 2, and Stage 3 procurements. Furthermore, the type of load flexibility could have a significant impact on the reliability of the system.

Currently, there is approximately 80 MW of hybrid solar + storage additions under construction on Maui. These additions would be enough to retire K1-4 or M10-13, but not all 81 MW of generation across the two existing power plants. To address the gap in reliability from that remains from only adding 80 MW of hybrid resources, various types of load flexibility were assessed for their resource adequacy benefits, or loss of load expectation (LOLE). LOLE assesses the resource adequacy of power systems under various system conditions by using a probabilistic resource adequacy methodology. This is the same probabilistic methodology used to evaluate the AES coal plant retirement on O'ahu (see "**O'ahu Near-Term Grid Reliability with AES Retirement**" project summary). The results of which are shown in Figure 3 across a range of potential mitigation options.

Several load flexibility options were considered, a general time of use rate "Static Load Shifting (TOU)," a dynamic, controllable DER program ("Grid Services RFP"), grid-scale standalone storage ("20 MW BESS"), and through "Daily Managed EV Charging." These options were differentiated in the following way:

- The Grid Services RFP is modeled as a 20 MW resource that can only contribute for 2 consecutive hours during specific times of the day. It also has 10% energy losses and must charge during the daytime hours.
- The Static Load Shifting (TOU) is modeled as a 20 MW resource that moves roughly 75 MWh from the 5-9pm peak into the daytime and overnight hours.
- Battery energy storage is modeled as a 20 MW resource that is fully controllable by the grid operator, subject to energy limitations and round-trip efficiency losses.
- Lastly, for reference a 20 MW perfect generator was considered, with no energy limitations or outage rates.

Results show that 20 MW of load flexibility is comparable to the capacity grid services provided by a standalone storage resource, but that a hybrid resource (which also brings additional energy) and a perfect capacity resource are more beneficial.

Another sensitivity was run that assessed load flexibility throughout the week. This type of intra-week load flexibility was shown to improve LOLE by 90+% depending on the scenario on both Oʻahu and Maui. Intra-Week load flexibility behaves like long-duration storage in this regard.

The findings indicate that load flexibility can capture some of the energy arbitrage value that batteries provide, improving resource adequacy. Effectively, the energy arbitrage benefit is quickly saturated by whichever resource (Load Shifting or batteries) arrives first.

HNEI plans to continue to refine this analysis, with the goal of supporting decision makers at the PUC and HECO as they continue to design customer programs to support evolving grid needs. HNEI hopes to assess the value of load flexibility in deferring distribution grid upgrades in a future version of this analysis.

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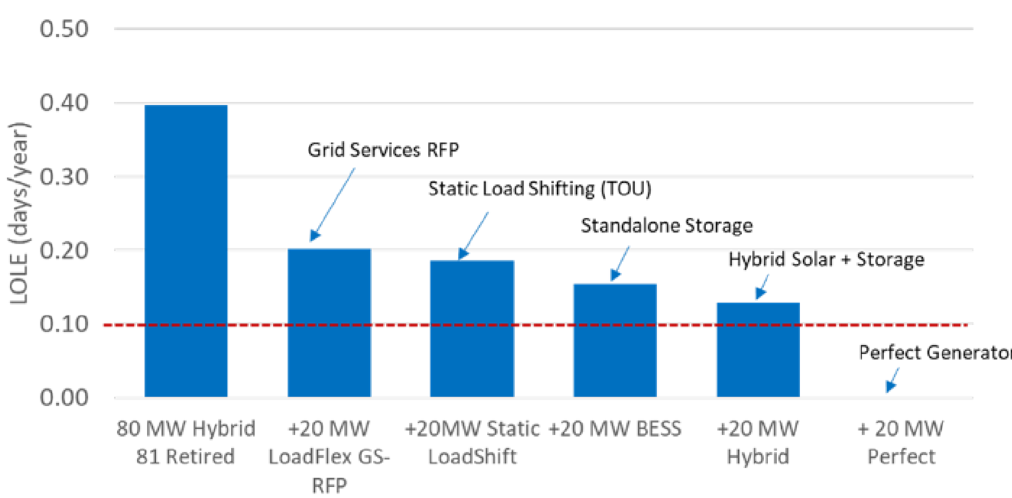

Figure 2. Loss of load expectation (LOLE) in days per year with different load flexibility options.