



Hawai'i Natural Energy Institute Research Highlights

Grid Integration

Multi-Day Energy Storage for O'ahu Reliability

OBJECTIVE AND SIGNIFICANCE: In 2025, HNEI and Telos Energy conducted a study examining the extent to which long-duration energy storage (LDES) could serve as a clean firm capacity resource to ensure reliability in O'ahu. This work was pursued in part due to growing interest at the Hawai'i Public Utilities Commission to investigate use cases for long duration (e.g. 100-hour) storage.

KEY RESULTS: Results from this analysis show that a 100-hour battery storage system can provide a moderate contribution of firm capacity of approximately 50% to 60% effective load carrying capability (ELCC) at renewable portfolio standard levels of 45%, 55%, and 70%. The finding that the ELCC of 100-hour storage remains relatively constant as solar and short-duration storage increases is consistent with previous HNEI/Telos work showing the need for resources capable of dispatching for long periods of time to maintain reliability even at high RPS percentage levels. While these results show reliability benefits of 100-hour LDES relative to existing 4-hour battery energy storage systems, it is less than similar deployment of firm generation such as combustion turbines (CT). These results were presented at the Energy Systems Integration Group (ESIG) Forecasting & Markets workshop in Nashville, TN in June 2025 and at the IEEE Power & Energy Society general meeting in Austin, TX in July 2025.

Modeling indicated that 350 MW of 100-hour storage can enable retiring 250-360 MW of existing fossil fuel resources while maintaining a 0.1 days/year loss of load expectation (LOLE) criteria. This indicates the potential for multi-day storage to complement the deployment of planned solar and storage resources, however, procurement decisions still require evaluation of costs and impact on other generations sources, relative to new or repowered oil-fired generation.

Total carbon emissions were compared for the cases with 100-hour storage or new oil-fired combustion turbines. Results indicated that an addition of 350 MW of 100-hour storage results in 1.5-2% increase in annual oil consumption for electricity generation (140,000-280,000 barrels of oil) relative to a scenario with only solar and storage additions. In contrast, an addition of 350 MW of new oil-fired combustion

turbines results in a 3-4.4% decrease in annual oil consumption (200,000-326,000 barrels of oil) due to the improved efficiency of new combustion turbines relative to the existing oil-fleet.

BACKGROUND: LDES technologies have seen growing interest across the energy industry, for their potential to provide firm capacity and reduce the need for new generation capacity. Both renewable and short (e.g. 4-hour) duration storage resources have declining firm capacity values at high penetration due to saturation in low-resource risk periods.

To date, LDES resources have had limited assessment to determine their firm capacity value using traditional resource adequacy and ELCC methods. This is largely attributed to the low level of new builds for existing technologies (e.g., pumped storage hydro and compressed air) and the nascent state of new technologies (e.g., iron-air batteries). Additionally, while not ubiquitous across LDES technologies, the long duration technologies tend to have lower round-trip efficiency, reducing their economic viability.

However, demand for additional firm capacity, brought on by renewed load growth coupled with retention of the energy storage investment tax credits, appears to have buoyed the interest in deploying LDES in the United States. With Hawai'i's aspirations to reduce dependency on imported fossil fuels, LDES needs to be evaluated for the islands to determine its ability to contribute to the State's long-term reliability.

PROJECT STATUS/RESULTS: In this work, the HNEI/Telos team conducted a probabilistic resource analysis to determine the incremental retirements enabled by deploying 100-hour storage on O'ahu. In addition, the ELCC of the 100-hour storage was calculated to compare against other dispatchable resources such as 4-hour storage and new combustion turbines. The HNEI/Telos team used Telos Energy's PLEXOS model of O'ahu to perform hourly chronological production cost and probabilistic resource adequacy simulations of the island system assuming increasing RPS levels. This approach allows tracking of long-duration storage asset state of charge where charging and discharging cycles may be days or weeks apart. By complementing the

production cost modeling with resource adequacy assessments, the ability of multi-day storage to ensure system adequacy under varying renewable energy and generator outage conditions is also considered.

Due to the nascent nature of multi-day storage, there are limited standard modeling approaches and limited or no real-world historical operating data. Therefore, an exploration of different modeling techniques was conducted to balance simulation realism with expected unit performance so that the firm capacity values and reliability benefits of multi-day storage could be properly assessed. Challenges in the modeling included:

1. *Low round-trip efficiency*: Standard modeling methods struggle to reflect multi-day storage operations due to low efficiency (40%) biasing the model to not charge the assets;
2. *Long durations and short optimization windows*: Energy system modeling uses a timestep wherein unit commitment and dispatch decisions are made. It is common to evaluate a single day plus one day ahead, whereas multi-day LDES assets may need to be charged well in advance of an event, limiting the usefulness of advanced forecasting; and
3. *Real-world operational considerations*: Limited information from grid-scale application of multi-day storage means there is little information to replicate operations to reflect how these assets perform in real-world environment.

Several LDES scheduling analyses were evaluated prior to performing the resource adequacy analysis to determine how to best model multi-day storage. Based on multi-day storage scheduling analysis and discussions with Form Energy, it was determined that multi-day storage assets will likely operate primarily as long-term reliability assets with a small amount of energy allocated to day-to-day and hour-to-hour fluctuations. This means restricting the discharge of the asset to primarily reduce unserved energy (load shed) risks. Once the multi-day storage scheduling approach was established, the team assessed the capability of multi-day storage to enable retiring existing oil-fired capacity.

Following selection of the LDES scheduling approach, the final step in the assessment was to

perform a retirement analysis to identify how much existing oil-fired capacity on O‘ahu could be retired assuming the addition of 100-hour storage to the grid at increasing RPS levels. The modeling efforts investigating near-term retirement decisions are not intended to supplant HECO plans for replacing the existing Waiiau units. Instead, they are intended to inform the potential to utilize multi-day storage in place of new generation to maintain reliability.

The reliability improvement with the addition of 350 MW of 100-hour storage was calculated at various levels of solar + storage additions corresponding to 45%, 55%, and 70% RPS levels, corresponding to an expansion of utility-scale solar and 4-hr storage to 440 MW, 880 MW, and 1,320 MW. For context, today, O‘ahu has approximately 220 MW of utility-scale solar and 4-hour storage.

Figure 1 shows the LOLE for O‘ahu in days/year for six scenarios of retirement and solar + storage additions. The analysis shows that solar and storage alone can enable the retirement of Waiiau 8 but only is if existing solar + storage is expanded by 500%.

	Plant Name	Cumulative Retirement	45% RPS	55% RPS	70% RPS
Incremental Retirement		0			
	AES	180			
	W3-4	274	0.04		
	W5-6	382	0.24		
	W7	466		0.10	
	W8	551		0.47	0.12
	K1	635			0.37
	K2	720			
	K3	805			
	K4	889			
	K5	1024			
K6	1159				

Figure 1. Loss of load expectation for O‘ahu with incremental oil capacity retirements at increasing RPS levels with only solar + storage additions.

Figure 2 shows the incremental retirements enabled by adding the multi-day storage to O‘ahu at the same RPS levels as shown in Figure 1. In this analysis, the LDES scheduling was selected to ensure that the multi-day storage acts as a reliability asset, but does not overly constrain it to only operate during emergencies.

	Plant Name	Cumulative Retirement	45% RPS	55% RPS	70% RPS
Incremental Retirement		0			
	AES	180			
	W3-4	274			
	W5-6	382			
	W7	466			
	W8	551			
	K1	635	0.05		
	K2	720	0.58	0.03	
	K3	805		0.24	0.03
	K4	889			0.26
	K5	1024			
	K6	1159			

Figure 2. LOLE for O‘ahu with incremental oil capacity retirements at increasing RPS levels with 350 MW of 100-hour storage.

As shown in Figure 2, the addition of 350 MW of 100-hour storage to the O‘ahu grid enables 250-360 MW of incremental oil capacity retirements relative to the case with only solar and 4-hour storage.

The largest impact from the multi-day storage is at the 45% RPS level, where 360 MW of retirements are enabled. The ability for 100-hour storage to reduce the LOLE is less at higher RPS levels. This is due in part to the risks of back-to-back generator outages. In this case, energy limited resources are depleted without time to recharge.

Finally, the model results were summarized with an effective load carrying capability (ELCC) metric commonly used resource planning. For this analysis, the ELCC of 350 MW of 100-hour storage was calculated at the same RPS levels shown in Figures 1 and 2. For comparison to a new fuel-based unit, the ELCC of new oil-fired combustion turbines was also calculated.

Figure 3 shows the ELCC of 100-hour LDES and a similar repower using combustion turbines. This shows that 100-hour storage maintains an ELCC above 50% even at high solar penetration. Relative to new combustion turbines, 100-hour storage enable fewer retirements of existing oil-fired capacity due to its lower ELCC value.

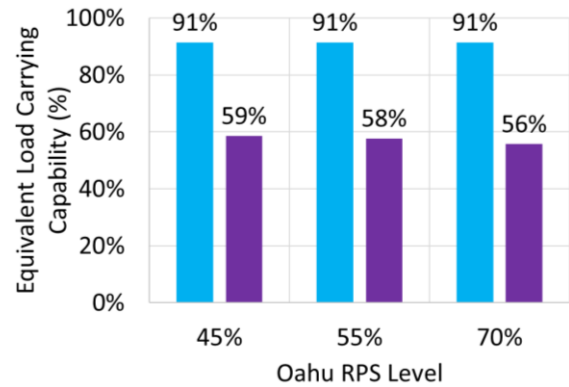


Figure 3. Equivalent Load Carrying Capability (ELCC) of 100-hour storage versus new oil combustion turbines on O‘ahu at increasing RPS levels.

It should be noted that the resource adequacy analysis indicates that 100-hour storage deployed on O‘ahu at the various RPS levels results in a net increase in oil consumption. This is attributed to the low round-trip efficiency (40%) of the multi-day storage assessed. Even at a relatively high penetration of renewables, the multi-day storage resource requires increased oil generation to charge the resource to maintain state of charge targets and be ready to operate during reliability events. This contrasts with the effect of adding 350 MW of new combustion turbines, in which case the total system oil consumption is reduced. This reduction is attributed to the significant efficiency improvements of new combustion turbines relative to existing oil steam turbines.

HNEI continues to monitor the development of LDES technologies, which includes 100-hour batteries, and further its technical capabilities in modeling these assets to provide guidance to industry, the PUC, and stakeholders. The end goal is to provide a deeper technical understanding of how to model LDES and how to include it in future assessments of both economic and reliability plans.

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