NAVIGANT RESEARCH

WHITE PAPER

What Is Driving Demand for Long Duration Energy Storage?

Commissioned by National Grid Ventures

Published 2Q 2019

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Section 1
INTRODUCTION

1.1 Defining Long Duration Energy Storage

A key feature of any energy storage system is its duration, which refers to the ratio between the system's maximum power output capacity in megawatts and its stored energy capacity in megawatt-hours. This metric indicates how long the system can discharge at full output capacity, and hence its relative value as a source of power. An energy storage system's duration also impacts its ability to provide grid services necessary to ensure reliability.

Navigant defines long duration energy storage as technologies capable of discharging at full power output for at least 5 hours. Currently available long duration storage technologies include pumped hydro storage, flow batteries, lithium ion (Li-ion) batteries, sodium sulfur batteries, power-to-gas, and compressed air energy storage (including liquid air storage).

Globally, installed energy storage capacity is approximately 156 GW, roughly 93% of which (144 GW) is pumped hydro storage. While the energy storage market has seen a significant increase in activity in the past 5 years, the majority of new energy storage projects offer relatively short duration output in the range of 1–4 hours. As such, there are limits to the grid services that these types of projects can provide, which will likely dampen demand for such projects in the long run as needs change.

Long duration energy storage systems play a key role in effectively integrating large amounts of renewable energy generation and ensuring that the overall operation of the grid is as efficient and reliable as possible.

1.2 Drivers of Demand for Long Duration Energy Storage

Integrating high percentages of renewable energy to a transmission grid has significant benefits in terms of reducing greenhouse gas emissions and helping to stabilize and lower energy costs, but it requires adapting the system to accommodate the characteristics of variable generation resources that may be located far from load. Long duration energy storage is uniquely suited to support this transition.

1.2.1 Grid Services

In addition to energy production, dispatchable fossil fuel generation has traditionally provided additional grid services that enhance reliability and stability. These grid services range from regulation service, which manages second-to-second imbalances in generation and load, to load following service, which meets daily ramps in demand.

While variable renewable energy resources like wind and solar are able to provide some grid services—especially shorter-term services like regulation—their intermittent nature limits their ability to fully replicate the longer duration system services like load following that fossil fuel generation provides. Although the grid impacts of adding renewable generation are relatively small at penetrations below 15%, above this level the loss of grid services from displaced fossil fuel generation creates a need for an alternate source.

Long duration energy storage can be used to shape and firm electricity from renewable sources so that it delivers a generation profile and grid services that are comparable to traditional fossil fuel generation during hours of peak demand.

An increasing number of jurisdictions (including California, Hawaii, and Washington) have set ambitious goals to reduce carbon emissions by sourcing 50% or even 100% of their electricity from renewable sources, creating a de facto demand for long duration energy storage facilities and the full suite of grid services they can provide.

1.2.2 Transmission Congestion

Transmission line congestion is an issue routinely faced by grid operators around the world, and can present particular challenges for renewable generation facilities, which are often located in areas far from load centers and served by inadequate regional transmission infrastructure. During periods of peak production, demand for transmission from remote renewable resources can exceed the capacity of the transmission grid to deliver that energy to load. At such times, the lack of transmission capacity will require utilities to curtail renewable generation, or turn to more expensive fossil generation resources located closer to load centers that can transmit energy over non-congested lines. In either case, the dollar and carbon cost of serving the load increases.

1.2.3 Renewable Energy Curtailment

In April 2019, California solar and wind farms curtailed 190,070 MWh of electricity, breaking previous records, according to the California Independent System Operator.

Curtailment refers to the practice of stopping renewable energy production at times when supply exceeds demand, as well as when there is insufficient transmission capacity to deliver electricity to load centers, as discussed above. Curtailment is already occurring in markets with moderate penetrations of variable renewable energy, such as the central US, where abundant wind generation at night often exceeds demand, and midday in places such as Australia, California, and Hawaii, where solar photovoltaic generation outstrips consumption. Notably, in the month of April 2019, 190,070 MWh of electricity from California solar and wind farms was curtailed, breaking previous records. This curtailment trend is increasing substantially as California adds 1,500 MW–2,000 MW of solar (both rooftop and utility scale) to its grid every year.

Transmission congestion and variable renewable energy curtailment result in lower clean energy production and higher greenhouse gas emissions. By storing large amounts of energy for dispatch when transmission capacity is available, long duration energy storage offers an effective way to support high percentages of renewable generation and optimize the use of transmission assets, resulting in a more efficient electricity system.

1.2.4 The Limitations of Competing Storage Technologies

Additional drivers of demand for long duration energy storage are the limitations of existing battery technologies, and particularly those of Li-ion batteries, which include concerns about their relatively short lifespan and safety, as well as the availability of raw materials, security of the supply chain, and their environmental impact, topics that will be addressed in more detail in a subsequent white paper.

1.2.4.1 Lifespan

The lifespan of a battery is expressed in terms of the number of times it can be charged and discharged, which is referred to as a cycle. The cycle life of Li-ion batteries varies depending on the specific sub-chemistry used, and ranges from as low as 500 cycles for the least expensive Li-ion technologies to up to 10,000 for the most expensive, which translates into a 3–15-year lifespan depending on the application for which it is used. This is relatively short in the context of grid applications, so it is typical to extend a Li-ion battery's life by replacing or augmenting its capacity when performance degrades. While these strategies can be effective, they also result in significantly higher operation and maintenance costs.

1.2.4.2 Safety

As with cycle life, different Li-ion chemistries vary in terms of safety profiles. More expensive and robust battery chemistries like lithium iron phosphate and lithium titanite oxide have strong safety records, while less expensive chemistries typically do not. Although significant advances have been made to improve the safety of large-scale stationary Li-ion batteries, instability and thermal runaway remain significant concerns in the industry. Numerous fires at large Li-ion battery energy storage facilities in 2018 and 2019 have highlighted these concerns and resulted in increasingly restrictive fire safety codes in jurisdictions around the world. The potential for safety incidents such as these serve to highlight the value of other long duration energy storage technologies that are inherently safer.

1.2.5 Resilience

Longer storage durations equate to the ability to provide backup power for a longer period, which is a major driver of interest in long duration storage. Furthermore, many long duration technologies such as pumped hydro storage, flow batteries, and compressed air do not have the same restrictions on cycle life as Li-ion and other batteries, thereby providing greater flexibility and resilience.

Section 2

THE ROLE OF LONG DURATION ENERGY STORAGE ON THE GRID

2.1 Reliable and Dispatchable Capacity

Long duration energy storage is essential to a grid that relies heavily on variable renewable generation, because it makes it possible to align supply with demand, and it can provide grid services historically offered by conventional fossil fuel power plants.

2.1.1 Matching Renewable Energy Supply with Demand

Unlike dispatchable fossil fuel facilities, renewable energy generation depends on resource availability, and periods of peak production may not align with periods of peak demand. The ability to store large amounts of renewable energy for release during periods of high demand may emerge as one of the most essential applications for long duration energy storage in the long term and is a particularly attractive benefit in areas that experience high levels of wind power curtailment at night, or solar curtailment during the day.

2.1.2 Reserves and Capacity

Reserves and capacity are services that help ensure the reliability of the grid by helping operators meet variations in electricity supply and demand. These grid services, which have traditionally been provided by conventional thermal generators, include spinning reserves, non-spinning reserve capacity, and load following.

Variable renewable energy resources like wind and solar can provide some grid services, but their non-dispatchable nature limits their ability to do so on a reliable basis. Similarly, shorter duration energy storage technologies are well suited for short duration ancillary services, but not for providing dispatchable capacity over periods longer than 5 hours. Reserve and capacity assets are often called upon for extended periods of time due to plant outages, extreme weather, and other issues.

As renewables gradually displace fossil fuel generation, the need for technologies that can economically provide a full suite of grid services will increase. Replacing most or all of a system’s fossil fuel baseload and peaking power plants with renewable energy will require pairing these resources with long duration, large-scale energy storage.

2.3 Transmission Optimization

As discussed in Section 1.2, large-scale renewable facilities are often located in remote areas with limited access to transmission lines. At times of peak production, these lines can become congested, forcing renewable generators to curtail their output, and resulting in the loss of clean energy as well as revenue losses for the generator and reduced energy security.

Long duration energy storage located at strategic points in the grid can be used to address this by saving renewable energy for release at times when transmission lines are less congested. Doing so improves the functionality of existing transmission infrastructure, making it possible to efficiently integrate new resources while postponing the need for costly transmission upgrades.

Section 3
CASE STUDIES

3.1 Pumped Hydro Storage in Europe

Long duration energy storage already serves as a critical resiliency resource for power systems with high percentages of renewable energy, notably on islands such as El Hierro in the Canary Islands and Kauai in Hawaii. However, long duration energy storage also plays a key role in the operation of much larger electricity grids.

Germany's power system is the largest in Europe and boasts more than 100 GW of wind and solar generation capacity. Under the Energiewende (energy transition) policy, the country aims to generate 35% of its electricity from renewables by 2020, rising to 80% by 2050. Achieving this will require new investments that may include additional transmission infrastructure, interconnections with neighboring countries, and energy storage.

While Germany has seen major growth in its battery energy storage market, most of this activity has been focused around short duration systems for grid stability services and residential customers integrating solar power. When it comes to effectively integrating over 100 GW of renewable generation, pumped hydro systems in Germany and neighboring countries are the long duration energy storage technology of choice.

These resources support the German energy transition by storing excess electric generation from variable renewable sources and dispatching it as needed to provide reliable capacity during periods of peak demand or reduced production. As the country moves toward increasingly higher percentages of renewables, new pumped hydro storage projects are being explored.

Germany's use of pumped hydro storage may provide a useful point of comparison for energy planners in the US. As an example, California has 30 GW of installed solar and wind, and the ability to leverage the long duration energy storage benefits of pumped hydro storage projects both in California and the Pacific Northwest.

3.2 Potential Capacity Shortages in the Western US

3.2.1 Pacific Northwest

In the US Pacific Northwest, a transition to a heavy reliance on renewable generation is underway and gaining momentum. Oregon has set ambitious carbon-reduction goals, and Washington recently passed legislation mandating that by 2030, 80% of electricity sold in the state must be carbon free.

Achieving these targets will require a major increase in variable renewable generation sources like solar and wind. According to the consulting and analytics firm E3, load growth and the replacement of retired fossil fuel power plants with renewable generation could result in an 8 GW capacity deficit in the US Pacific Northwest by 2030 unless new dispatchable capacity resources are developed.

Washington's legislation will impact Puget Sound Energy, Avista, and PacifiCorp, all of which own shares of the Colstrip 3 and 4 coal plants. If the move to decarbonize Washington's energy supply leads to the Colstrip facilities closing in 2025 rather than their current planned retirement in 2035, it will add another 1.5 GW to E3's projected 8 GW capacity deficit in 2030. An additional impact of the legislation is that after 2030, these utilities will need to offset any carbon emissions associated with the use of gas-fired resources for commercial energy transactions.

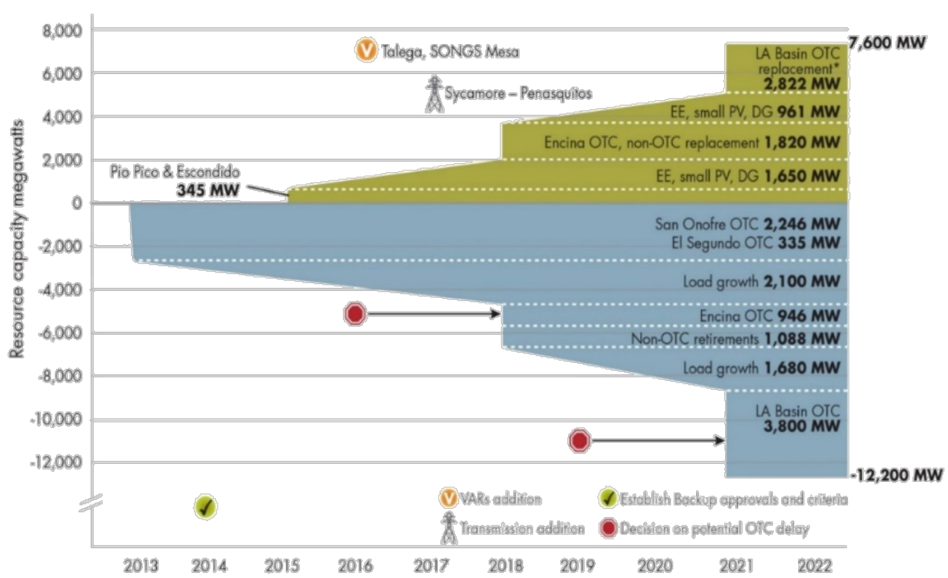
While the region has sufficient renewable energy resources to meet electricity demand, long duration energy storage technologies will have an important role in to play in providing the replacement capacity needed to ensure grid stability.

3.2.2 California

California has benefited from significant surplus capacity and energy from the Pacific Northwest for many years, but the magnitude of the anticipated capacity requirements described above will likely decrease capacity and energy available for export to California entities between 2020-2030.

California has set a target of getting 100% of its energy from carbon-free sources by 2045 (with at least 60% of supply from eligible renewable resources). Similar to the situation in the Pacific Northwest, as shown in Figure 3-1, as the state's renewable energy capacity increases, fossil fuel power plants are being retired, resulting the loss of dispatchable capacity they provide. According to the California Independent System Operator (CAISO), up to 9.6 GW of natural gas-fired generation may be retired for economic reasons, and if even 4 GW (or less) of natural gas comes offline, the state could see load following shortfalls.

Figure 3-1. Electrical Capacity Retirement and Additions Forecasts, California Independent System Operator: 2013–2022



(Source: California Independent System Operator)

California already receives resource adequacy and capacity services from both standalone energy storage and renewable-plus-storage projects, with most storage projects having a 4-hour duration. In the long run, CAISO has predicted that as more thermal resources retire, reliability requirements may mean that demand for longer duration energy storage increases.

Long duration energy storage has a particularly important role to play in California, which faces a dual challenge of excess generation from solar during the day, and a steep increase or ramp in demand in the evening hours. Part of this increase in demand is caused by the charging of electric vehicles, the numbers of which are expected to grow dramatically over the next decade.

California has recently experienced winter 3-hour ramps of as much as 14,000 MWh. Long duration energy storage can store excess solar generated during the day and release it to meet the evening ramp.

Section 4
CONCLUSION

The transition to greater reliance on variable renewable generation is creating a need for expanded energy storage infrastructure in power grids around the world. It is important to recognize that different energy storage technologies offer features that make them best suited for different applications.

Short duration technologies are ideally suited for providing grid stability services and smoothing small fluctuations in renewable generation output. In contrast, long duration storage technologies like pumped hydro storage are uniquely able to stand in as a direct replacement for the bulk capacity reserves and other grid services provided by fossil fuel generators.

Grid operators managing systems as small as the island grids of El Hierro and the Hawaiian Islands, and as large as those of European countries have already recognized the value of longer duration energy storage as they make the transition to high levels of renewable energy.

To successfully follow suit, US grid operators charged with ensuring the reliability of their system under ambitious decarbonization goals will need to have both long and short duration energy technologies at their disposal.

Section 5

ACRONYM AND ABBREVIATION LIST

CAISO .... California Independent System Operator

GW .... Gigawatt

GWh .... Gigawatt-hour

Li-ion .... Lithium Ion

MW .... Megawatt

MWh .... Megawatt-hour

US .... United States

Section 6
SCOPE OF STUDY

This white paper examines the market for long duration energy storage technologies on the power grid. Specific attention is paid to the drivers of long duration energy storage, the role for long duration energy storage on the grid, and case studies that illustrate the convergence of these issues. Navigant Research prepared this white paper to provide an independent analysis of the opportunities for long duration energy storage. This white paper does not consist of any endorsement of any specific technology, project, or company. Rather this paper provides readers with an understanding of the market for long duration storage and why it will be required for a future grid reliant on renewable energy generation.

Published 2Q 2019

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