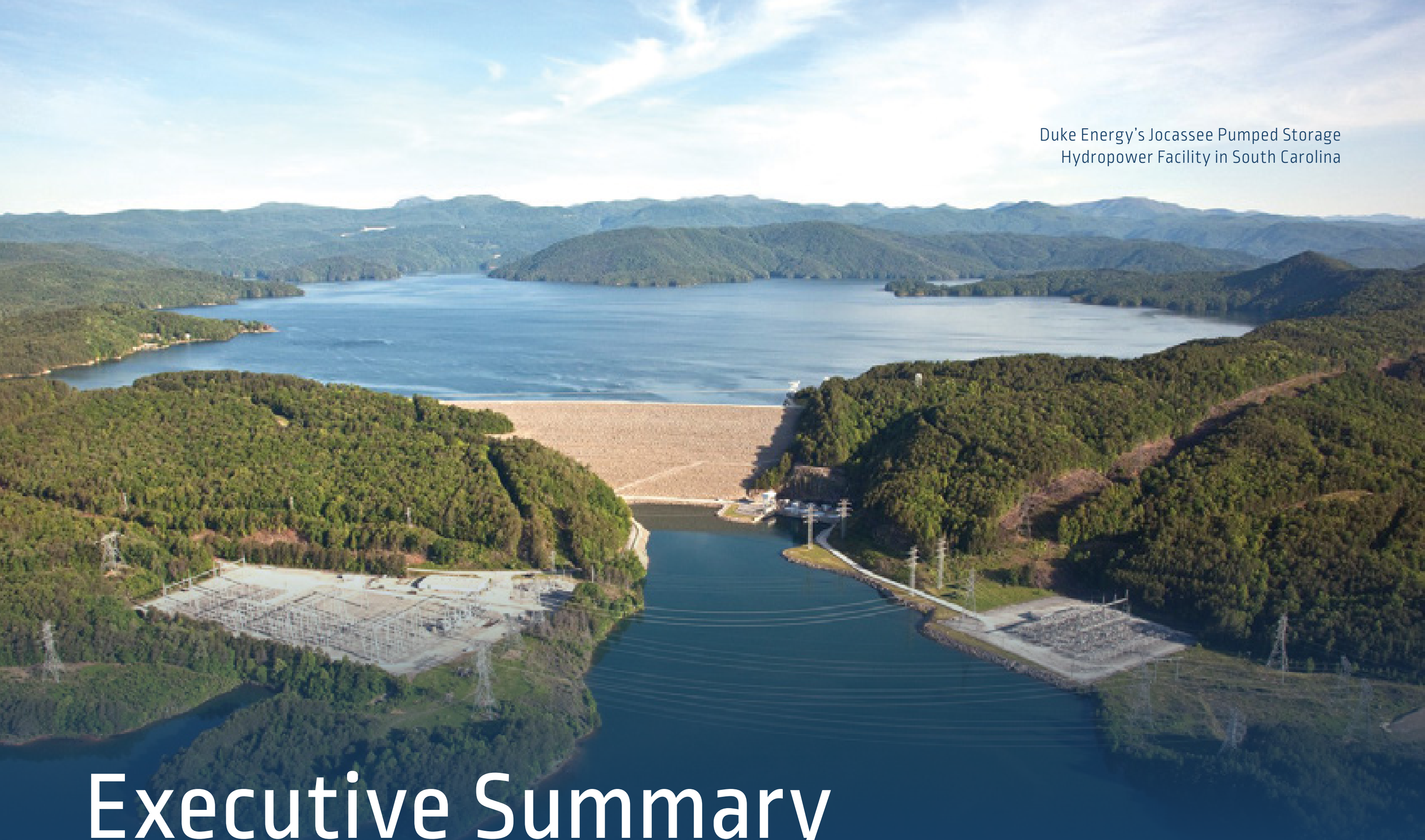
2018
Pumped Storage Report

National Hydropower Association



Duke Energy's Jocassee Pumped Storage Hydropower Facility in South Carolina

Executive Summary

This White Paper was prepared by the National Hydropower Association's Pumped Storage Development Council. The primary author is Michael Manwaring (Council Chair, Stantec) with significant input provided by Kelly Rodgers (Council Co-Vice Chair, San Diego County Water Authority), Scott Flake (Independent Pumped Storage Consultant), Don Erpenbeck (Stantec), Rick Miller (HDR), as well NHA staff and numerous industry participants.

An essential attribute of our nation's electric power system is grid reliability - ensuring that electric supply securely matches electric demand and in real-time. The primary challenge in ensuring reliability is that electric supply has no shelf life - it must be generated when needed - and electricity demand continually changes, as do the system conditions impacting secure delivery of that generation. Electric transmission grid operators have long met the challenge of aligning energy supply and demand and responding to steep increases in demand on a real-time basis with a limited number of long-life, proven generation technologies - specifically hydropower and gas-fired combustion turbines - that have the ability to start up quickly and/or vary their electric output as the demand changes. Large reservoir hydropower, thermal (generally coal and gas) and nuclear resources have commonly served as baseload resources, providing the stabilizing backbone to grid reliability. As greater amounts of renewable energy resources are integrated into the energy supply, and recent energy policy decisions and regulation have impacted coal and nuclear resources, pumped storage and other energy storage technologies will continue to emerge as critical resources to provide flexible solutions to meet grid reliability challenges.

According to the U.S. Energy Information Administration (USEIA) more than 97% of all installed capacity of energy storage, is provided by pumped storage hydropower, with thermal storage, batteries and other storage technologies making up the remaining mix of grid-managing solutions. As the technological advancement of all energy storage solutions continues, policymakers and system planners are looking for reliable, affordable and grid-scale energy storage options to maintain the electric grid. Fortunately, a technology exists that has been providing grid-scale energy storage at highly affordable prices for decades: pumped storage hydropower. While batteries, compressed air, flywheels and other emerging technologies often capture the headlines, pumped storage hydropower has continued to advance its capabilities as the leading grid storage solution allowing for even more optionality in the effort to integrate intermittent renewable energy in a reliable and cost-effective manner.

Pumped storage hydropower (PSH), also referred to as a "water battery", has continued to advance its technology in recent years, including the capability for very fast response to grid signals, and an increased flexibility for development in broader, less traditional geographies with the application of "closed loop" systems. Developing additional energy storage technologies like PSH, particularly in areas with significant deployments of wind and solar generation capacity that do not have significant grid-scale energy storage, would significantly improve grid reliability while reducing the reliance on fossil-fueled generation. **PSH and other storage applications also enable greater integration of wind and solar resources into the system by reducing the curtailments of excess variable renewable generation.**

During the spring of 2017, in California alone, the California Independent System Operator (CAISO) saw a 147% increase in renewable curtailments over the same time period in 2016. The CAISO has indicated that they expect this trend to increase. The increasing trend in renewable curtailments is forecasted to impact California's ability to meet it's 33% renewable goals by 2020 and ultimately California's goal of 100% carbon free energy by 2045 (CA Senate Bill 100).[1]

Unfortunately, the very characteristics of energy storage that make these resources so critical to support grid reliability and the integration of additional renewable resources also make them a challenge to properly compensate them within the current market and regulatory constructs. The transmission grid and electric system were not designed with energy storage in mind, nor were markets and policies developed after deregulation in some regions of the U.S. to facilitate development of these types of resources. The ability to deploy these resources is often stifled because of very long project lead times and the regulatory framework developed for traditional generation-based resources. To truly unlock the potential of energy storage resources where they are needed, federal, state, and regional energy and economic policies and paradigms need to evolve – just as the energy storage technologies have evolved.

The National Hydropower Association (NHA) strongly believes that expanding deployment of energy storage resources like PSH, particularly in regions with aggressive deployment of variable renewable resources, will support improved grid reliability and facilitate development of additional clean energy technologies. While benefits of expanding pumped storage and similar technologies are clearly apparent in regions that do not have adequate storage capacity, current market structures and regulatory frameworks in many regions do not present an effective means of achieving this goal.

In the 2016 Hydropower Vision Report[2] (DOE Report), the Department of Energy (DOE) documents that PSH is not properly valued in the energy wholesale market, which is ultimately stifling project deployment due to a lack of financial viability and market uncertainty (DOE Report, pp 9-13). This affirmation is important and noteworthy as the DOE Report also investigates a range of growth scenarios, finding that the existing 21.6 GW of domestic pumped storage capacity can increase in both the near term (2030), by 16.2 GW, and in the longer term (2050), by an additional 19.3 GW, for a total of 35.5 GW deployed by 2050 (DOE Report, pp 17-19). **Put simply, the potential is there and the valuation question is critical to unlocking it.**

State and Federal regulatory and market policy changes are needed to support the timely development of additional grid-scale energy storage of all sizes and durations. This is especially true in regions with significant renewable resource penetration and limited energy storage resources. In some cases, existing policy discriminates against PSH over other energy storage technologies and this needs to be remedied to

[1] As of November 13, 2017, CA Senate Bill 100 had passed the California Senate and was in Committee with the CA Assembly (see https://leginfo.legislature.ca.gov/).
[2] See full report at: https://energy.gov/eere/water/downloads/hydropower-vision-report-full-report

be technology neutral so that the appropriate storage technology is identified for the locational and grid-specific challenges. To this end, NHA has developed a series of recommendations to guide the energy industry, regulators, and policy makers. NHA's key policy recommendations are presented in detail in Section 4 of this paper, and include:

- Develop market mechanisms that compensate flexible resources providing services that help meet electric grid requirements, including very fast responding systems that provide critical capacity during key energy periods.
- Develop market mechanisms and broadly accepted economic models that evaluate energy storage technologies based on their abilities to provide key supporting services to the overall electric grid, particularly when taking into consideration project lifecycle costs, performance and energy storage system degradation.
- Develop market mechanisms and products that recognize the regional differences within the U.S. generation portfolio and value the unique roles energy storage technologies play in different regions.
- Develop market mechanisms and products that recognize the potential energy reliability and security role PSH plays in the domestic electric grid, and how this could be enhanced with additional advanced PSH developments in areas with significant renewable resources and limited or no existing energy storage.
- Establish an alternative, streamlined licensing process for low-impact pumped storage hydropower, such as off-channel, modular, or closed-loop projects.
- In regions without competitive wholesale (energy or capacity) markets require consideration of energy storage resources in state integrated long-term planning processes; including requiring equal consideration with traditional resources.
- Develop standard evaluation criterion for all forms of energy storage so that different types of energy storage can easily be compared and evaluated.

This White Paper is intended to replace and update NHA's 2012 version, and includes the policy work FERC, along with State and Federal agencies have developed to address some of the issues raised related to the need for stronger policies related to the regulatory and market treatment of PSH and other energy storage technologies. NHA firmly believes more work needs to be done if we are to truly realize the potential PSH can offer with additional deployments – but that can only happen if markets recognize their true value and policies provide a level playing field for all energy storage technologies.

NHA believes that existing pumped storage hydropower projects and proposed new developments: (1) face significant regulatory hurdles that other energy storage technologies do not encounter; (2) are not properly valued (recognized) for the roles they play in providing grid reliability and security services; and (3) are not compensated adequately, nor uniformly, in current wholesale energy market constructs for these benefits in the various markets across the country.

Consumers Energy's Ludington Pumped Storage
facility located in Ludington, Michigan.

Raccoon Mountain Pumped Storage facility, located in Marion County, is owned and operated by the Tennessee Valley Authority.

1.0

PSH - The Nation's Largest Energy Storage Resource

Pumped storage hydropower (PSH) has a long history of successful development in the U.S. and around the world. Energy storage has been a part of the U.S. electric industry since the first hydropower projects, primarily through the flexible storage inherent in reservoirs.

In the U.S., there are 42 existing PSH projects providing over 21,000 MWs of storage capacity3, with the largest projects being over 3,000 MW (e.g. Bath County, Virginia) and the oldest completed in 1929 (Rocky River pumped storage hydroelectric facility in New Milford, Connecticut). Additionally, as of October 30, 2017 there currently are approximately 9,636 MWs representing 34 pumped storage projects with preliminary permits and an additional 11 project representing 7,315 MW in the FERC queue for pending preliminary permits.[4] Globally, there are approximately 270 pumped storage plants either operating or under construction, representing a combined generating capacity of over 127,000 megawatts (MW). As a proven technology, it has been shown to be cost effective, highly efficient, and operationally flexible. This grid scale storage technology has been used extensively to both store and redistribute electricity from periods of excess supply to periods of peak demand and provide grid reliability services in generation and pumping mode. Similar to energy policy development in the U.S., European energy policy is also focused on adding clean, renewable energy to the grid, and the significant amounts of wind and solar being brought on-line is the motivating force that is driving new PSH in many areas around the world.

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[3] www.USEIA.org
[4] https://www.ferc.gov/industries/hydropower/gen-info/licensing/pump-storage.asp

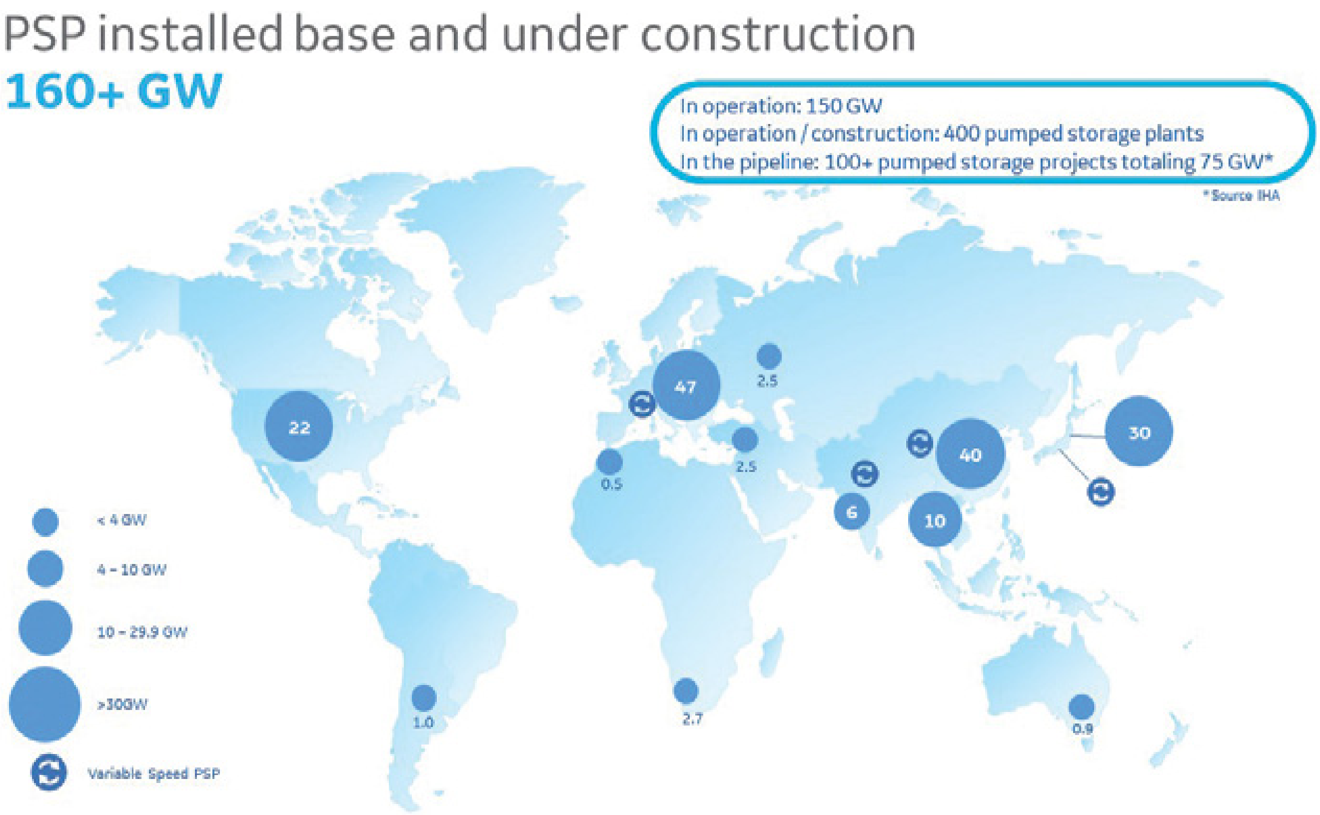

FIGURE ILLUSTRATING GLOBAL PUMPED STORAGE CAPACITY FOR EXISTING AND UNDER CONSTRUCTION PROJECTS.

1.1 PSH: A HISTORIC OVERVIEW

Pumped storage hydropower is a modified use of conventional hydropower technology to store and manage energy or electricity. Pumped storage hydropower projects use electricity to store potential energy by moving water between an upper and lower reservoir. In pumping mode, electric energy is converted to potential energy and stored in the form of water at an upper elevation, which is why it is sometimes called a "water battery". Pumping the water uphill for temporary storage "recharges the battery". During periods of high electricity demand, the stored water is released back through the turbines and converted back to electricity in generating mode like a conventional hydropower station. In fact, at many existing pumped storage projects, the pump-turbines are already being used to meet increased transmission system demands for reliability and system reserves. Current pumped storage round-trip or cycle energy efficiencies exceed 80% (i.e. combined pumping uphill and generation downhill), comparing very favorably to other energy storage technologies, as well as traditional thermal technologies. Additionally, PSH provides longer storage duration more economically than other storage technologies.[5]

Energy storage resources effectively shift, store, and reuse energy generated until there is the corresponding demand for system reserves and variable energy integration. This shifting, when performed at a grid-scale, can also avoid transmission congestion periods (i.e., absorb or consume surplus generation to levels consistent with transmission transfer capability), to help more efficiently manage the electric grid (e.g., quick access to significant and sustained energy ramping), and to avoid potential interruptions to energy supply (e.g., supply operating reserves, spinning inertia, etc.). Advanced adjustable-speed technology also allows pumped storage to provide an even greater range of fast ramping, both up and down, and frequency regulation services in both the generation and pumping modes.[6] This is important because many of the variable renewable energy resources being developed (e.g., wind and solar) are generated at times of low demand and peak energy demand periods are still being met in various regions of the U.S. with thermal resources, often at less efficient performance levels that increase the release of greenhouse gas emissions.

[5] Lithium ion battery costs are typically expressed in $/kWh or the cost of storage for one hour. Typical PSH facilities commonly store energy to support 6-10 (or more) hours of full load operation.
[6] Traditional PSH technology allows for very fast start-up as either a generator or a pump, and a significant range for energy scheduling once the generator is started and online.

1.2 PSH TO SUPPORT GROWTH AND INTEGRATION OF RENEWABLE GENERATION

During the last decade, variable renewable energy projects have gained strong momentum in response to favorable tax incentives and other policy preferences for renewable energy. However, these resources have increased the need for fast responding system reserves (i.e., firming resources) to satisfy existing grid requirements and the variable nature of many renewable energy technologies, particularly in regions with significant entry of variable renewable resources and limited existing energy storage **As the capacity of available firming resources continue to be stretched to their limit to support the growth of variable renewable energy resources, the U.S. electric industry is seeking alternatives to construct new natural gas plants to meet this need – and more toward the deployment of emission-free energy storage resources.**

Hydropower, biomass, and geothermal energy are capable of providing predictable, consistent generation; however, wind and solar generation, while less variable with adequate geographic diversity, can present new challenges for the U.S. grid. The power output in variable generation resources can fluctuate widely as weather patterns change and, while the changing weather patterns may be well understood, the magnitude of renewable energy generation ramps (in particular, when not in correlation with changing load) can be challenging to grid operators when renewable energy resources are a large component of their generation portfolio. This variable output can lead to frequency and voltage fluctuations, which adversely affect grid stability.

In some areas of the western U.S., primarily the Pacific Northwest and California, the impact of having excess amounts of electricity is becoming a significant concern for electric grid operations and these conditions will only be exacerbated by continued development of variable renewable energy as recently presented by the California ISO in their Fast Facts paper on renewable integration.[7] Bulk energy storage technologies, such as PSH, could significantly reduce the need for conventional reserve generation capacity, support the development and optimal integration of renewable energy resources, and reduce the amount of new transmission required to support aggressive renewable energy generation goals (i.e. Renewable Portfolio Standards).

Since deregulation of the electric industry, there is no regulatory mechanism or market price incentive for the effective integration of new generation, energy storage, and transmission. Yet these are three components of a reliable energy generation and transmission system that require coordinated, long-term planning. In addition, in certain market regions (i.e. California and Pacific Northwest), large amounts of variable renewable energy generation are creating new challenges for the overall transmission system and its grid operators. It is now widely understood that grid-scale energy storage could address some of these challenges and promote the development of more variable energy resources in those areas and maximize the value of these projects by mitigating against inefficient overbuild in the achievement of clean energy policies. Other regions in the U.S., in particular in the Northeast have access to existing PSH and the integration of variable renewable energy resources have proven less of a challenge.

7 http://www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf

Dominion Energy's Bath County Pump Storage facility in Virginia

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Current Challenges To PSH Development

NHA believes that existing PSH projects and proposed new developments face significant regulatory, market and financing hurdles that other energy storage technologies typically do not encounter. The issues and challenges to successful deployment of additional PSH resources are discussed in the following sections. While many of the environmental challenges facing PSH development are being addressed at the federal policy level, many state and regional policies – along with other key federal policies – remain a major hurdle to realizing the full potential of PSH resources.

2.1 CURRENT REGULATORY TREATMENT OF PSH

A significant challenge facing PSH project developers is the regulatory timeline for development of new projects. Under the U.S. Federal Power Act, any non-Federal PSH developer must obtain a FERC license, as well as multiple other State or Federal permits. With the current process, obtaining a new project license to construct can take three to five years, or even longer before the developer will have the authority to begin project construction when a project requires permits from other Federal or State agencies prior to FERC action. There is currently no expedited licensing approach specifically for low-impact or closed-loop sites to shorten this time frame.[8] In addition, a three- to five-year construction period is common for most large projects. The end result could be an environmentally benign project being developed to support renewable energy integration could take up to 10 years to become operational. Very few financial institutions are willing to finance these types of long-lead projects through the licensing timeframe, especially since the market structure discussed in this paper provides an additional layer of uncertainty for developers. NHA

[8] Report of the Pilot Two-Year Hydroelectric Licensing Process for Non-Powered Dams and Closed-Loop Pumped Storage Project and Recommendations Pursuant to Section 6 of the Hydropower Regulatory Efficiency Act of 2013, AD13-9-000, page 43. https://www.ferc.gov/legal/staff-reports/2017/final-2-year-process.pdf

and the hydropower industry are continuing to work to modernize the licensing process for those projects with obvious minimal environmental constraints, especially when many new projects can help support the development and integration of additional renewable energy resources. Over the past few years, FERC has provided the industry some key opportunities to provide input on a 2-year licensing process, where low-impact projects - including closed-loop PSH - can participate.[9]

2.2 EXISTING MARKET RULES AND IMPACT ON ENERGY STORAGE VALUE

In today's electric grid, existing and advanced-technology PSH projects have the potential to bring added value through ancillary services, beyond time-shift of energy delivery. While some key services these projects provide have market recognition, there are other services that both traditional (existing) and advanced-technology PSH projects are capable of providing that are either undervalued due to price formation limitations or not valued at all. The lack of a national energy policy may lead to some services never being valued or valued in one independent system operators (ISO) market rules and product definitions but not in another. However, these are typically real-time or day-ahead markets and there are no long-term market products where a bulk storage project can attract investors seeking revenue certainty through long-term power purchase agreements or defined value streams.

NHA urges FERC to consider how the various ISOs and RTOs can better align market compensation with reliability needs and services and whether and how those additional services can be valued in the market. This is particularly important in regions experiencing widespread installation of utility-scale and customer-sited variable renewable energy, like in California. Energy market (economic) spreads between off-peak and on-peak hours have diminished, and reliance on resources such as PSH (or conventional hydropower storage reservoirs) capable of long duration load balancing, fast-starts and fast-ramping, has increased.

In addition, in some regions of the U.S. with deficiencies in market design and significant need for storage, like the western U.S., it may be appropriate to include the grid services provided by energy storage projects in long-term transmission and planning studies to better understand the potential grid benefits and risks, along with helping utilities and future asset owners value their investment. NHA requests FERC encourage ISOs and RTOs to update their long-term planning process to more accurately reflect the grid reliability and energy security services provided by pumped storage facilities.

NHA also points out that inclusion in the transmission planning process does not imply that a project will then be included in a transmission rate base. Inclusion of energy storage technology in long term planning and identification of a PSH project as an advanced transmission technology is anticipated to improve the likelihood of a project's ability to secure long term financing, while also recognizing the overall grid benefits various energy storage projects may provide. Identification of advanced transmission technologies will likely be based on regional balancing authorities' needs rather than an overall policy. To the extent that PSH is included as an advanced transmission technology, NHA would support the inclusion of all PSH, should the region require the services provided.

2.3 CHALLENGES WITH FINANCING NEW PSH PROJECTS

Current energy markets present a significant challenge for independent power producers (IPPs) to develop capital intensive storage projects like PSH, primarily because of a lack of long-term revenues available. Where ISOs and RTOs capacity markets do not provide the multi-year price lock-in that is possible like ISO New England, this often leads to a preference for less capital-intensive projects that have short construction timelines and quick returns. The result has been an overbuild of natural gas plants because they can be permitted and constructed in a short timeframe; but may be idled once their short-term revenues diminish – as is increasingly occurring in the western U.S.

Furthermore, most IPPs seek to finance their large projects with non-recourse project financing. This means that, for both equity and debt investors, the revenues and assets of the PSH project are the only source of principal and interest payments on debt and of returns on capital to equity investors. Given the regulated nature of electricity markets in the U.S., where capacity markets do not provide the multi-year price lock-in that is possible in regions like ISO New England, project lenders are more likely to require IPPs to have long-term power purchase agreements (PPA) with creditworthy entities to provide additional security for repayment of project debt. Unfortunately for IPP developers of PSH projects, long-term PPAs are not common practice in current energy market construct.

[9] https://www.ferc.gov/legal/staff-reports/2017/final-2-year-process.pdf

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Raccoon Mountain Pumped Storage facility, located in Marion County, is owned and operated by the Tennessee Valley Authority.

Supporting The Case For PSH

Changes and trends in the U.S. electric power sector provide new opportunities for hydropower and PSH. Energy storage technologies will continue to emerge as critical resources to provide flexible solutions to meet grid reliability challenges as greater amounts of renewable energy resources are integrated into the energy supply. Regulation and energy policy decisions and low natural gas prices have caused non-renewable baseload resources to decline, which leaves additional system inertia challenges that variable renewable resources cannot meet.

Because of the many environmental and grid reliability benefits advanced PSH offers, the hydropower industry is embarking on a re-investment in the existing PSH fleet and developers are investigating dozens of new project opportunities. However, in some regions, the market products that will support upgrades to existing projects, or investment in new, advanced technologies, need to be developed to justify such major capital expenditures.

We believe the future for PSH is one of sustained and potentially significant growth, if the proper market products are put in place.

3.1 VALUING ENERGY STORAGE – A COMPLEX UNDERTAKING

When discussing the value of energy storage, the conversation typically revolves around the project cost and, with varying degrees of success, the monetized benefits the project provides. While project costs can be ‘fairly’ straightforward, the benefits of energy storage have proven very challenging to quantify. A primary challenge to the ‘value’ picture is that energy storage technologies offer multiple services, therefore should be eligible for multiple value streams – and these can be deployed interchangeably based on the overall grid needs. Unfortunately, the multiple grid services provided are not fully (monetarily) recognized in today's energy markets, which poses a challenge to attract the necessary investment to develop large capital energy storage projects like PSH. To best represent the value of an energy storage project, most developers try to stack, or combine, various revenue streams to try and more accurately represent the benefits offered to support a reliable electric grid. To further this 'valuing' challenge for energy storage technologies, some grid service benefits are not currently recognized (monetarily) in all ISO/RTOs, and other services (i.e. grid security benefits) are not valued at all. The primary reason for this is that for years, the Investor Owned Utilities have been providing these services for 'free' (without adequate compensation) from their existing PSH fleet, only recognizing income from the generation sold. This has been tolerated since new PSH has not been built in the US for over 25 years. Now that investors are considering building new PSH, the lack of valuation for these services needs to be modified to a broadly accepted financial model that recognizes the true services provided.

For example, an April 2017 energy storage policy guide prepared by the Interstate Renewable Energy Council[10] (IREC) stated that ancillary services such as frequency regulation and ramping, are valued not for the electrical output (generation) but for their capability to inject or withdraw electricity over short intervals – which provide major grid benefits. Similarly, spinning reserve capabilities are not valued for their electrical outputs but for the ability to provide "stand-by" deliveries if called upon. Grid-scale energy storage technologies like PSH can simultaneously provide these services, but are generally not compensated for providing multiple critical services at once – which adversely impacts a project's capability to show a true rate of return and persuade investors to fund a project. Some of the primary value stacks for energy storage projects like PSH include, but are not limited to:

- Providing Power at Peak Demand Periods
- Ancillary Services
- Energy Time Shifting
- Grid Reliability and Resiliency
- Grid Infrastructure Congestion Relief
- Carbon-Free Flexible Resources
- Ability to Reduce Renewable Curtailments

3.1.1 PSH AS GENERATION AND TRANSMISSION

While the previous sections of this paper focused on generation sources and how PSH fits into the energy market, energy storage technologies have the ability to provide components of transmission assets along with their ability to supply ancillary services and alleviate congestion by absorbing excess generation. Market rules generally prohibit transmission assets from participating in wholesale energy and ancillary service markets to maintain the independence of grid operators and avoid the potential for market manipulation, whether real or perceived. Furthermore, FERC requires market power studies to be performed when third parties provide ancillary services at market-based rates to transmission providers (i.e. commonly known as the Avista Restriction[11]). In addition, the policy prohibits sales of ancillary services by a third-party supplier to a public utility that is purchasing ancillary services to satisfy its own obligations to customers under its open access transmission tariff.

To better address when an energy storage facility can both access energy markets and receive rate based treatment for certain services FERC recently updated their view on multi-use facilities in their policy statement, Utilization of Electric Storage Resources for Multiple Services When Receiving Cost-Based Rate Recovery, issued January 19, 2017.[12] This updated policy statement allows for the treatment of both market based returns and rate based treatment of certain attributes of energy storage provisos under certain circumstances. Regardless, NHA acknowledges all PSH should be treated equally in markets, whether new or existing.

FERC Order 1000 introduces robust regional planning into the transmission process. It also mandates coordination among neighboring transmission planning regions with their interconnection. Because Order 1000 establishes requirements for reforming transmission cost allocation processes, it creates an opening for energy storage to be included in the transmission planning process and in changes in regional and interregional cost allocation processes. If, as a result of the transmission planning process, a project is accepted into a regional plan, or incorporated as a resource supporting the regional plan, it would therefore appear to meet the threshold requirements of Section 219 of the Federal Power Act, making it eligible for incentive rate treatment. In addition, having storage included in, or incorporated

[10] http://www.irecusa.org/wp-content/uploads/2017/04/IREC_Charging-Ahead_Energy-Storage-Guide_FINALApril2017.pdf
[11] Avista Corp., 87 FERC ¶ 61,223, order on reh'g, 89 FERC ¶ 61,136 (1999)
[12] Docket No. PL17-2-000 - Utilization of Electric Storage Resources for Multiple Services When Receiving Cost-Based Rate Recovery, https://www.ferc.gov/whats-new/comm-meet/2017/011917/E-2.pdf

as part of, transmission planning could enable a developer seeking to sell a variety of storage-only services to be deemed eligible for long-term incentive rate recovery, similar to transmission assets.

3.2 ENERGY STORAGE TECHNOLOGY COST COMPARISON

Development of modern PSH project costs can vary based on site-specific conditions such as the availability of existing civil and generation/transmission infrastructure, land, and water, as well as project size, environmental regulations, site geology, water availability, access to the transmission grid, and overall construction cost. A feasible project site would include an approximate cost estimate range from $1,700/kilowatt (kW) to $2,500/kW, based on an estimated 1,000 MW sized project. A smaller project typically does not have the same economies of scale and could result in higher unit costs (in $/kW) than a large project, but the overall projects costs would be much less. These costs are representative for all PSH project aspects except land acquisition, transmission interconnection charges, and some owner's costs, which can range from very minor charges to significant, based on site specific conditions. According to a 2016 Electric Power Research Institute (EPRI) report[13], the levelized cost of PSH represent one of the lowest cost forms of energy storage.

What continues to present a challenge to those seeking to understand the varying costs for different energy storage technologies is the recognized inconsistency between how each energy storage technology (PSH, batteries, compressed air, flywheels, etc.), main industry trade associations (NHA, Energy Storage Association), suppliers/manufacturers, and DOE-funded national labs present their costs. Clearly it is in the interest of long-life assets (i.e. PSH) to use levelized cost of energy (LCOE) using a 25-plus year asset life cycle because the physical assets (major cost components) can depreciate over a longer time period, showing a lower LCOE compared to shorter-life assets (i.e. batteries, flywheels) that would need asset equipment replacement over the same period because their physical assets are not expected to last the full life cycle.

As an example, several technology groups have presented information in a way that enhances a particular technology and minimizes the downside. Examples include the use of logarithmic scale graphs to make a particular technology look like it might have a larger impact. Another example is to adjust timelines for lifecycle to eliminate undesirable attributes like short lifecycles, end of life costs and technology lifecycle costs. A recent energy storage policy guide concluded that energy storage costs can be expressed by using two metrics: rated power and discharge duration. By only utilizing these two metrics, the true representation of energy storage costs is misrepresented - and most benefited the short-life assets when excluding the proper levelized cost of the assets.

NHA requests FERC or the U.S. Department of Energy (DOE) support the development of technology neutral, economic and performance models that would allow equal comparison of all energy storage technologies.

3.3 NEW TECHNOLOGY ADVANCEMENTS AFFECTING PSH PROJECTS

While PSH is a proven, reliable technology that currently represents more than 97% of all ES solutions globally, the overall technology continues to advance, and now includes improved efficiencies with modern reversible pump-turbines, adjustable-speed pumped turbines, advanced equipment controls such as static frequency converters and generator insulation systems, as well as innovative underground construction methods and design capabilities. The benefit of these advances is faster response time of which to load follow intermittent renewables more efficiently and cost effectively.

3.3.1 ADVANCED PUMP-TURBINE EQUIPMENT TECHNOLOGY

Globally, there are approximately 270 pumped storage plants either operating or under construction, representing a combined generating capacity of over 127,000 MW. Of these total installations, 36 units consist of adjustable-speed machines, 17 of which are currently in operation (totaling 3,569 MW) and 19 of which are under construction (totaling 4,558 MW).[14] Adjustable -speed pump-turbines have been used since the early 1990s in Japan and the late 1990s in Europe. A main reason that adjustable speed pumped storage was developed in Japan in the early 1990's was the realization that significant quantities of oil burned in combustion turbines in off-peak hours could be reduced by shifting the responsibility for regulation to pumped storage plants. Another advantage of adjustable-speed units is the increase in overall unit efficiency due to the fact that the turbine can be operated at its optimum efficiency level under all head conditions, resulting in increased energy generated on the order of 3% annually.

[13] https://www.epri.com/#/pages/product/3002008877/

[14] October 2017 General Electric Database of Pumped Storage Projects, used by permission.

The current U.S. fleet of operating (single- speed) pumped storage plants does not provide regulation in the pump mode because the pumping power is "fixed" – a project must pump in "blocks" of power - though a single pumped storage facility may consist of multiple units and smaller blocks of power. However, advanced adjustable-speed pumped storage units, while similar to single speed units in most aspects, are able to modulate input pumping power for each unit and provide significant quantities of frequency regulation to grid operators while pumping or generating much more efficiently and cost effectively.

3.4 PSH AND VARIABLE RENEWABLE ENERGY RESOURCES - OPPORTUNITIES FOR COLLABORATION

The United States' energy resource mix continues to undergo significant change with ongoing retirements of large thermal and nuclear capacity and growth in natural gas and renewable resources. There has also been a transformation in how the electric grid and power systems are operated over the past decade, as the U.S. has moved from baseload resources to the need for flexible assets to integrate variable renewable energy generation technologies. Hydropower generation, including PSH can facilitate integration of variable generation resources such as wind and solar into the national power grid due to its ability to provide grid flexibility, reserve capacity, and system inertia. Overall, the value of hydropower and PSH to the integration of variable renewable energy resources will primarily depend in part on the limits of each project's operational flexibility, competition from other flexible resources, and market constructs that encourages participation.

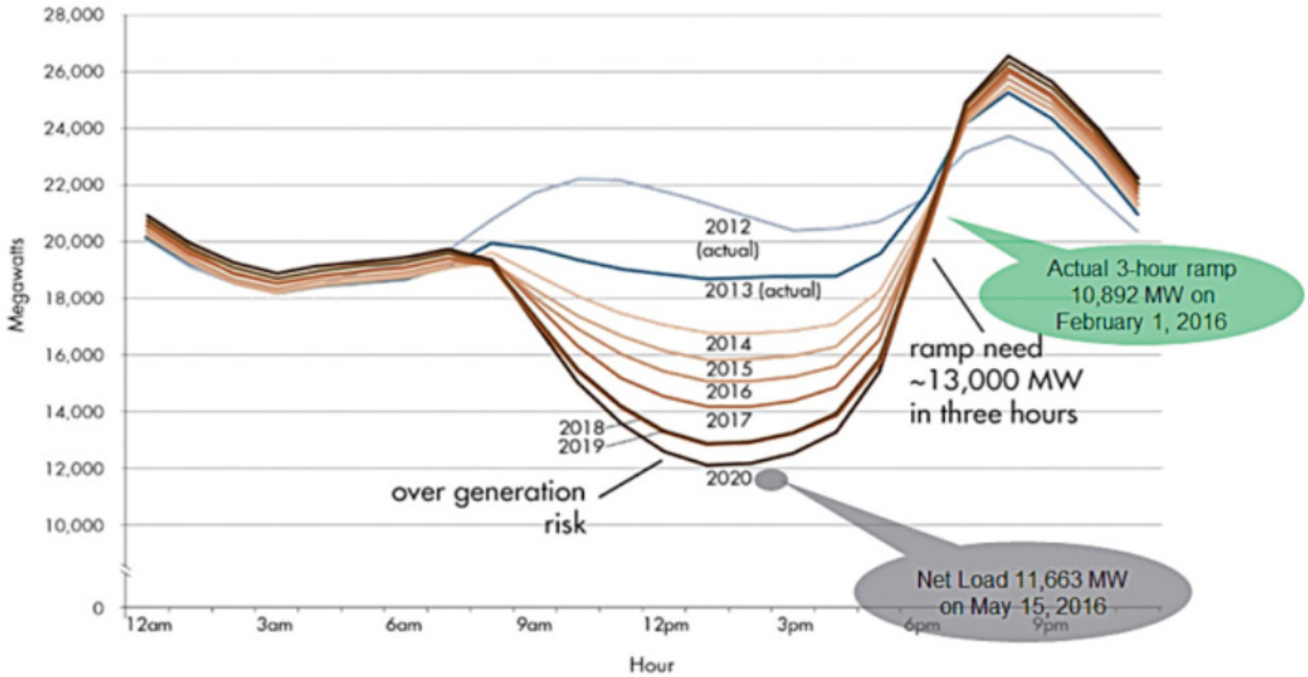
3.4.1 PSH AND SOLAR RESOURCES

Across the United States, solar generation has been increasing steadily due to favorable tax incentives as well as declining product and installation costs. California, like many other states, has seen a steady increase in solar resources to meet State RPS goals as well. The current California RPS standard requires Investor Owned Utilities (IOU), Publicly Owned Utilities, electric Service Providers and Community Choice Aggregators to meet a 33% RPS by 2020. Currently the 3 largest IOU's in California have over 40% of their RPS requirements under contract according to the California Public Utilities Commission (CPUC) as of April 11, 2017. The California Independent System Operator (CA ISO) identified a need for fast-ramping, flexible resources to balance the grid and mitigate the potential impacts of over-generation from renewables. CA ISO provided an update on renewable generation at a California Energy Commission (CEC) workshop on flexible generation and load on Friday, May 12, 2017[15] stating that there is currently about 10,000 MW of grid-connected solar. An additional 4,000 MW of solar is expected to come on line by 2020 with an additional 10,000 to 15,000 MW by 2030. In addition to the grid connected solar, there is currently 4,000 MW of behind the meter solar that is expected to increase to over 10,000 MW by 2020. As California moves toward higher penetrations of renewable energy and less reliance on traditional fossil generation, energy storage is expected to play an increasingly important role in maintaining reliability and power quality.

As renewable generation has increased to meet California's 33% RPS goal by 2020, the delivery of energy into the grid to meet customer demand has shifted resulting in the over generation of energy from solar resources in the middle of the day. This over-generation causes other generation to minimize output or go off line to allow for the delivery of renewable energy. This oversupply is especially acute during time of low customer load and high levels of hydro output during the spring months. This condition is often referred to as the "Belly" of the Duck Curve. During the afternoon as the solar plants are going off line and customer load increases during the afternoon the situation reverses and the plants that can respond must quickly go from minimum load to increasing output to make up for decreasing solar output and increasing customer load. This afternoon ramp is the "neck" of the Duck Curve.

To highlight the impacts of increased solar generation on the California electric grid, CA ISO has published data from a recent low load, high renewable generation day (April 23, 2017), as a predictor of potential grid management challenges to come. The California electric grid reached a minimum load of 9,187 MW (belly of the "Duck curve"), which was lower than the previous forecast for 2020 – four years sooner than expected.[16] Another example of the need for highly flexible resources occurred, during the late afternoon to early evening hours of December 18, 2016, when CA ISO recorded a 3-hour evening ramp of almost 13,000 MW. It is anticipated that significant evening ramps will likely increase in frequency, thereby underlying the need for more bulk energy storage systems like PSH to provide large, fast ramping capabilities to manage the extreme transitions from minimum loads to evening peak loads. The CA ISO has proposed a number of solutions to help manage this

[15] http://www.energy.ca.gov/2017_energypolicy/documents/2017-05-12_workshop/2017-05-12_presentations.php
[16] See "Renewable Integration TN-217546" presentation at: http://www.energy.ca.gov/2017_energypolicy/documents/2017-05-12_workshop/2017-05-12_presentations.php



CAISO DUCK CURVE GRAPHIC ILLUSTRATING POTENTIAL DAILY FUTURE SCENARIOS OF NET LOAD CURVES.

increasing challenge including installing large amounts of additional energy storage capacity on the grid.[17]

3.4.2 PSH AND WIND RESOURCES

In many areas of the U.S. wind powered generation resources primarily come in the late evening or early morning, which are not coincident with peak power demand. In other areas, wind resources are generated throughout the day, but are still susceptible to ebbs and flows of generation based on weather patterns. A key ancillary service opportunity in the U.S. and other regions is the added need for load following and regulation to accommodate variable renewable energy inputs – such as wind generation. In particular, the need for system reserves at night is increasing to ensure adequate grid stability with higher percentages of variable renewable energy generation, including the demand for energy absorption capabilities during periods of high wind generation during low load (demand) periods. In addition to energy absorption needs, with the increased amounts of variable renewable energy being supplied at night while load is decreasing, there is a complimentary greater need for load following and regulation services to accommodate the greater changes to net load on the system. Thermal generating units typically operate at minimum load during low energy demand periods such as late night or early morning, and wind is commonly increasing output during these periods, creating a greater need for a physical asset to provide system reserves to manage the resulting energy imbalance.

In 2015, wind and solar generation represented approximately 15% of total installed capacity in the Bonneville Power Administration (BPA) service territory, and hydropower represents nearly 70%. The level of wind penetration in the BPA system requires grid operators to manage seasonal generation supply, especially in the spring months during heavy snowmelt (high hydropower generation) and moderate to low loads. During spring months with high river flows in the Pacific Northwest due to snowmelt, the environmental requirements governing operations along the Federal Columbia River Power System (FCRPS) often require that hydropower managers address high dissolved gas concentrations produced by unforced spill by operating at maximum hydraulic capacity to pass as much water through turbines as possible. High hydropower generation, coupled with low loads and high wind during the spring months, forces FCRPS operators to take corrective actions, limiting flexibility in an otherwise flexible system. If the BPA system had access to a highly flexible bulk energy storage system, like PSH, there would be potentially significant capability to manage loads on a daily, weekly or seasonally level – allowing wind generation to be more fully deployed and recognized in the regional electric system.

[17] https://www.caiso.com/Documents/CurtailmentFastFacts.pdf

3.5 REGIONAL MARKET DRIVERS

The drivers for energy storage development vary significantly from region to region. The New England region has created a merchant market for capacity and ancillary services allowing operators to participate without the need to seek new capacity, long-term capacity contracts or rate base treatment. New capacity additions can be developed based on market signals. In areas without capacity markets, like the western U.S., a different approach is needed to provide the required signals for energy storage development. Other markets such as PJM and ERCOT have seen recent grid reliability challenges due to a number of issues, including transmission system constraints, significant expansion of variable renewable resources, and recent extreme weather events (Polar Vortex in 2014[18] and 2017 solar eclipse[19]). PSH projects and other energy storage technologies can help secure energy deliveries – if the appropriate market signals and incentives support their development.

3.5.1 CALIFORNIA AND THE WESTERN GRID

The California energy market is significantly different from other areas of the U.S. in that they and other western states like Washington and Oregon have established aggressive renewable energy targets and greenhouse gas reduction goals. Currently in California the renewable energy objective is 33% by 2020 and 50% by 2030. The California legislature is currently considering increasing the clean energy mix in California to 100% by 2045 (Senate Bill 100). For California to achieve this goal a regional approach must be considered and the CA ISO is currently utilizing the Energy Imbalance Market's (EIM) for 15-minute scheduling and also promoting a regional RTO throughout the West. California's ambitious energy goals will therefore impact every state connected to the Western Interconnect grid. At the same time, these goals are in jeopardy due to the CA ISO's inability to manage so much renewable energy. Speaking at a meeting of the Western EIM board in April 2017, CA ISO staff reported that it curtailed about 60,000 MWh in February and about 80,000 MWh in March, up from about 21,000 MWh and 47,000 MWh a year earlier.[20]

Energy storage can take many forms from bulk energy storage to regional and local applications. Each application requires different technologies that are more or less suitable for each application. In the case of PSH technology, the area of bulk energy storage is the best fit. California currently enjoys an abundance of renewable energy and the CA ISO has indicated that California will continue to add renewable energy capacity as renewable energy goals increase. The case for bulk energy storage is being supported in early studies by the CA ISO[21] and it believed that this need will only increase as additional renewables come on line and conventional resources are retired. The combination of increasing renewable energy resources and retirement of once-thru-cooling plants both increased the need for resilient capacity and ancillary services and decreases the supply at the same time. In the situation, PSH is the perfect proven capacity that can help achieve the clean energy goals while continuing to improve grid reliability and resiliency.

With the need for bulk energy resources now established, what are the best means to promote new storage development? Without market signals, like those in the New England ISO, other regions must rely on policymakers and long-term planning to provide the signals for developers and investors to act. There are several ways this can happen including long-term capacity contracts, inclusion in the Integrated Planning Process (IRP) to establish the need and cost effective development of these projects in a rate base setting, or the utilization of existing transmission capacity planning allowing PSH projects to develop in areas where a portion of the project can offset the need for transmission development and allow for a portion of the project to be treated as transmission capacity and be included as a transmission asset.

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18 http://www.nerc.com/pa/rrm/January%202014%20Polar%20Vortex%20Review/Polar_Vortex_Review_29_Sept_2014_Final.pdf
19 http://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/Solar_Eclipse_2017_Final_4-25-17.pdf
20 See "Renewable Integration TN-217546" presentation at: http://www.energy.ca.gov/2017_energypolicy/documents/2017-05-12_workshop/2017-05-12_presentations.php.
21 A Bulk Energy Storage Resource Case Study updated from 40% to 50% RPS, *Shucheng LiuPrincipal, Market Development, 2015-2016 Transmission Planning Process*

4.0

Bear Swamp Pumped Storage Hydropower facility in northern Massachusetts is jointly owned by Brookfield Power and Emera Energy

NHA Recommendations To Address PSH Development Challenges

NHA has developed a series of potential policy recommendations to stimulate new PSH development to help provide a more robust and reliable electric grid. Providing better recognition of PSH benefits and services will provide the needed market signals for these projects to be fully realized, which in turn will help with the additional development and deployment of more renewable resources like wind and solar. In addition to market issues, several existing regulatory challenges slowing PSH development should be addressed to streamline the long approval times, where appropriate.

In general, new hydropower and PSH projects take twice as long to permit as other energy sources (i.e. solar, wind, or natural gas projects) or energy storage resources (i.e. batteries). Improving the current licensing process for low-impact PSH projects (closed-loop or off-channel systems) similar to how Congress has recently addressed other hydropower development opportunities would reduce this disparity.

The following is a summary of recent NHA PSDC filings with FERC and other regulatory bodies that could serve to increase the potential development and deployment of new PSH projects.

1. NHA encourages FERC to require eligibility for participation in new energy storage markets be based on project capabilities and system needs, rather than on any specific technology. NHA supports inclusion of capacity services that may not currently be procured through existing market mechanisms and further encourages FERC to direct ISOs to establish “premium reserve” products.

   These products can offer performance-based payments for specified operational characteristics deemed most necessary for grid operations. Among the services are: primary frequency control, speed governor response and use of kinetic energy stored in unit rotors. In addition to these, pumped storage can also provide primary voltage response using automatic voltage regulators (AVR's) and stored energy of the rotor to respond immediately to deviations in grid voltage. Fast ramping and load curtailment are features that advanced adjustable speed pumped storage projects can also provide, and are doing so in various European countries.

2. NHA anticipates that the recent issuance of the FERC's Policy Statement on cost recovery for energy storage, clarifying that energy storage resources can be compensated at the same time for market and transmission or grid support services, will further encourage the inclusion of energy storage technologies in long term transmission and capacity planning. Through the guidance, FERC has potentially removed a significant barrier by making clear that energy storage can be fully utilized and optimized by grid operators, providing project developers a broader range of revenue streams based on project capabilities. NHA encourages FERC to work with RTOs/ISOs on implementing the guidance and to direct RTOs/ISOs to more closely consider procurement of certain forms of energy storage resources through procurement and cost-allocation mechanisms, traditionally utilized for new transmission build-out.

3. In RTOs and ISOs experiencing significant growth in variable renewable resources and increased grid volatility (system inertia consequences) with potential reliability implications, energy storage products such as PSH can provide fast-start capabilities and the ability to ramp to full capacity within a matter of a few minutes, which should prove highly valuable given that models recognize and value these services. NHA further encourages FERC to direct RTO/ISOs to review whether market services like frequency regulation and transmission functions such as deferral of new transmission (congestion management), voltage support and relief of thermal constraints (transmission line overloading), among others, are being valued appropriately, and whether all resources providing these services are compensated for doing so. These types of products and actions can assure that electricity markets function efficiently and equitably, while at the same time using competitive markets to help to close the growing revenue gap that must be addressed to sustain existing energy storage resources and fully value new grid scale storage project developments.

4. NHA proposes to FERC that compensation for "price-responsive demand" services be considered that more accurately compensates energy storage resource operators for charging services during periods of excess energy supply and grid instability. NHA understands that such a concept for compensating the grid benefits of creating load in excess energy conditions may conflict with the Norton decision. NHA suggests that FERC investigate the viability and effectiveness of the wholesale market energy tariff mechanism to assess the practical application of that market mechanism if it is in fact fairly and accurately compensating technologies that provide that capability.

Duke Energy's Bad Creek Pumped Storage Hydropower in South Carolina

Further, NHA proposes that FERC investigate sufficient capacity and flexibility tariffs to incentivize the investment in long lived assets that provide increased grid flexibility, all within the context of the existing wholesale markets so that all energy storage resources can participate and be assessed on their respective technical capabilities.

POLICY RECOMMENDATIONS

The following presents a broad list of potential market and regulatory policy recommendations from NHA to help address many of the challenges to new PSH development. **A more detailed list of each recommendation is provided in at the end of the following section (Section 5.1).**

MARKET IMPROVEMENTS

1. Develop market mechanisms that allow all flexible resources to provide services that help meet electric grid requirements, including very fast responding systems that provide critical capacity during key energy periods.
2. Develop market mechanisms and broadly accepted economic models that evaluate energy storage technologies based on their abilities to provide key supporting services to the overall electric grid, particularly when taking into consideration project lifecycle costs, performance and energy storage system degradation.
3. Develop market mechanisms and products that recognize the regional differences within the U.S. electric grid and value the unique roles energy storage technologies play in various regions.
4. Develop market mechanisms and products that recognize the current energy security role bulk energy storage technologies (i.e. PSH) play in the domestic electric grid, and how this could be enhanced with additional advanced PSH developments.
5. Request the DOE initiate a study to show how existing PSH projects are working in areas of high renewables penetrations, like California, to show how existing PSH projects are already providing the value of bulk PSH to both integrate renewable energy and also provide grid resiliency.
6. Request FERC establish a common methodology for value of energy storage and capacity products that can be utilized across the spectrum of technologies available to provide these services.

REGULATORY IMPROVEMENTS

1. Establish an alternative, streamlined licensing process for low-impact pumped storage hydropower, such as off-channel, modular or closed-loop projects.
2. In states relying on integrated resource planning versus wholesale markets, require consideration of energy storage resources in state's integration long-term planning processes; including requiring equal consideration with traditional resources.

Dominion Energy's Bath County Pump Storage facility in Virginia

Voith engineers working on the Reisseck II pumped storage facility

Exelon's Muddy Run Pumped Storage facility located along the Susquehanna River in Maryland and Pennsylvania

5.0 Conclusions

As our Nation's electric grid is modernized to address clean energy goals and threats to reliability, it is clear that energy storage is part of the solution. PSH is a proven and modern solution. With new advanced technology PSH energy storage can now boost the flexibility to keep up with all forms of renewable energy sources and address the extreme ramping conditions now prevalent in areas like California - resulting from load and generation divergence.

NHA understands that PSH is only part of the solution and that all forms of storage can, and will, play its part in helping to grow renewable energy and reduce reliance on carbon-based fuels while providing a stable electric grid. Whether it is the electrification of the transportation sector, wide-scale implementation of Time-of-Use rates policies, batteries to aid distribution and "behind-the-meter" energy flow, or deployment of additional new PSH to manage grid-scale energy supplies - all of these technologies can and do work together today and will into the future.

Properly addressing the barriers to appropriate valuation and compensation of new and existing PSH projects is a high priority for NHA, its members, the hydropower industry and the interconnected transmission system at large. NHA strongly believes that as the true technical capabilities and benefits of existing and advanced technology pumped storage are fully understood, the case for market changes and more equitable valuation and compensation is clearly evident.

It is also clear that with the drive toward aggressive Renewable Portfolio Standards, energy storage is a requisite for supporting a reliable energy grid.

Long-life, long-duration, proven technologies such as PSH are essential tools that provide valuable grid support services including the ability to:

- Energy time-shift arbitrage and energy supply capacity
- Provide grid ancillary services like frequency regulation, grid stability and reserves for reliability
- Reduce renewable energy curtailment
- Store for use later rather than shutting off during times when not needed
- Avoid paying for curtailed energy (take or pay contracts)
- Increase capture of renewable over-generation
- Avoid need to buy more renewables to compensate for curtailment and need to meet RPS mandates.

Such services are crucial to energy grid reliability and facilitate:

- Reduced system operating costs
- Less cycling and fuel costs (coal and gas)
- Ramp up and down quickly to accommodate over-generation
- Transmission upgrade deferral
- Reduced Transmission Congestion
- Renewables generated in the east and being delivered west
- Flexibility to be able to Adapt to Market Changes
- Flexibility to change operating profile if the market changes:
- Flexibility to change from day-ahead to hour ahead or real-time ramp up and down to accommodate needs of the CAISO for intra-hour balancing.

A more detailed list of NHA's market and regulatory policy recommendations listed in Section 4 above is provided in the following section.

5.1 ADDITIONAL DETAILS OF NHA POLICY RECOMMENDATION

The following presents additional details of the market and regulatory policy recommendations listed above in Section 4.0.

MARKET AND POLICY IMPROVEMENTS

1. **Develop market products that allow flexible resources to be compensated for providing services that help meet electric grid requirements, including very fast responding systems that provide critical capacity during key energy needs.**

   Energy storage systems have multi-functional characteristics, which complicate rules for ownership and operation among various stakeholders. Regulatory agencies have not defined ownership structures and flexible business models in which storage can be used for both generation and grid support purposes. Policy rules regarding allocation of costs incurred by adding energy storage systems to the grid need to be more clearly developed.

   Energy storage applications could enable bi-directional energy flows, creating potential revenue recognition challenges for current tariff, billing, and metering approaches. The results of future policy discussions should help inform the development of new market structures and rules to accommodate and capture the benefits of pumped storage and other energy storage technologies.

   Policies should take into account the ability of a storage technology to support the electric grid, including speed of response and the limits on the usefulness of excessive response speeds. Recent studies in California recommend definitions as 5 MW/sec (fast) and 15 MW/sec (ultrafast) at the plant level in the regulation market (i.e. FERC Order 755). Many of the existing ISOs/Regional Transmission Organizations (RTOs) such as CAISO, PJM, and others have products and markets that allow resources, such as energy storage, to earn revenues by providing services to the system. To the extent that non-RTO regions do not allow resources to participate and provide system benefits, we encourage these regions to create products that they can procure from flexible resources and provide payment for those services. In addition, NHA recommends further evaluation of treating bulk energy storage as a separate and distinct electricity infrastructure asset class (i.e., Balancing Asset or Compensating Asset), capable of relieving grid stresses through the absorption of excess energy during low demand periods or rapidly providing capacity during periods of peak demand.

2. **Develop market mechanisms that evaluate energy storage technologies based on their abilities to provide key supporting services to the overall electric grid, particularly when taking into consideration project**

lifecycle costs, performance and energy storage system degradation.

While PSH can meet many of the grid-scale energy storage needs, no single storage system can meet all grid demands. A wide variety of storage technology options is being proposed and evaluated for utility-scale storage and end-user energy management applications. Still, greater than 97% of the worldwide energy storage is in the form of PSH. As a proven technology, pumped storage has been shown to be cost effective, highly efficient, and operationally flexible. The FERC and other regulatory agencies have treated pumped storage primarily as a generating resource and have not included it in many significant energy storage discussions.

Different energy storage products have the capability to provide benefits to the electric grid in some manner, however; it can be challenging to understand the manner and magnitude each would provide. In order to better understand the scale and degree various energy storage technologies have for improving the reliability and resiliency of the grid, NHA recommends FERC and the US DOE development a set of broadly accepted economic and performance models for energy storage products. This will assist regulatory agencies, utilities and project developers as they evaluate the true performance capabilities and overall cost and value of different energy storage technologies offer when addressing needs related energy storage.

3. **Develop market mechanisms and products that recognize the regional differences within the U.S. electric grid and value the unique roles energy storage technologies play in various regions.**

NHA recommends that FERC and other regulatory agencies recognize regional differences in the nation's generation portfolio and the different roles storage technologies play in different regions, and remove policy barriers at federal, state, or regional level that promote specific storage technologies. Pumped storage and energy storage in general can play very different roles in different regions of the U.S. In regions with high percentages of variable generating (non-firm) renewables such as wind and solar, PSH can function as a renewable integration tool. In regions with large coal-fired or nuclear steam plants, pumped storage plays a levelizing role and peaking role.

4. **Develop market mechanisms and products that recognize the current energy security role bulk energy storage technologies (i.e. PSH) play in the domestic electric grid, and how this could be enhanced with additional advanced PSH developments.**

In the U.S., pumped storage has been typically built on the 1,000 MW scale but in actuality can be built to virtually any scale. The generating capacity of existing plants worldwide range from less than 1 MW to approximately 3,000 MW (e.g., Bath County Pumped Storage Project, Virginia). Larger capacity plants are currently under consideration globally. As the primary grid-scale storage technology in the world, pumped storage plays a critical energy security role, but there is currently no recognized revenue stream for providing this key service. Existing pumped storage plants in every region become a key "energy security" plant within a given control or balancing area. In the event of a major disturbance such as a major steam unit trip or a transmission line failure, PSH black start capability or spinning or offline, fast start reserve can be called upon to restart or stabilize the grid on very short notice. Full generation from the project can be accomplished to cover the energy deficit for longer periods, depending on reservoir level and size. Pumped storage can also respond to decremental needs such as a significant wind ramping event during low consumer demand periods, maintaining grid stability by rapidly responding to generation oversupply in the pumping mode. In addition, pumped storage facilities are resilient to unexpected changes in weather patterns, including drought or low water years, because the water used for generation is recycled from upper to lower reservoir, and not released to the natural stream flow (U.S. DOE/Homeland Security, 2011). These are critical energy security functions that often go unrecognized, underappreciated, and most notably, undercompensated.

REGULATORY IMPROVEMENTS

5. **Establish an alternative, streamlined licensing process for low-impact pumped storage hydropower, such as off-channel, modular, or closed-loop projects.**

In general, new hydropower projects take twice as long to permit as other energy sources including solar, wind, or natural gas projects. NHA suggests that FERC consider changes to the current licensing process for low-impact pumped storage projects similar to how they have recently streamlined other hydropower development projects. In particular, there are certain categories of PSH projects that would have a minimal effect on the environment such as off-channel projects or closed-loop projects. In these

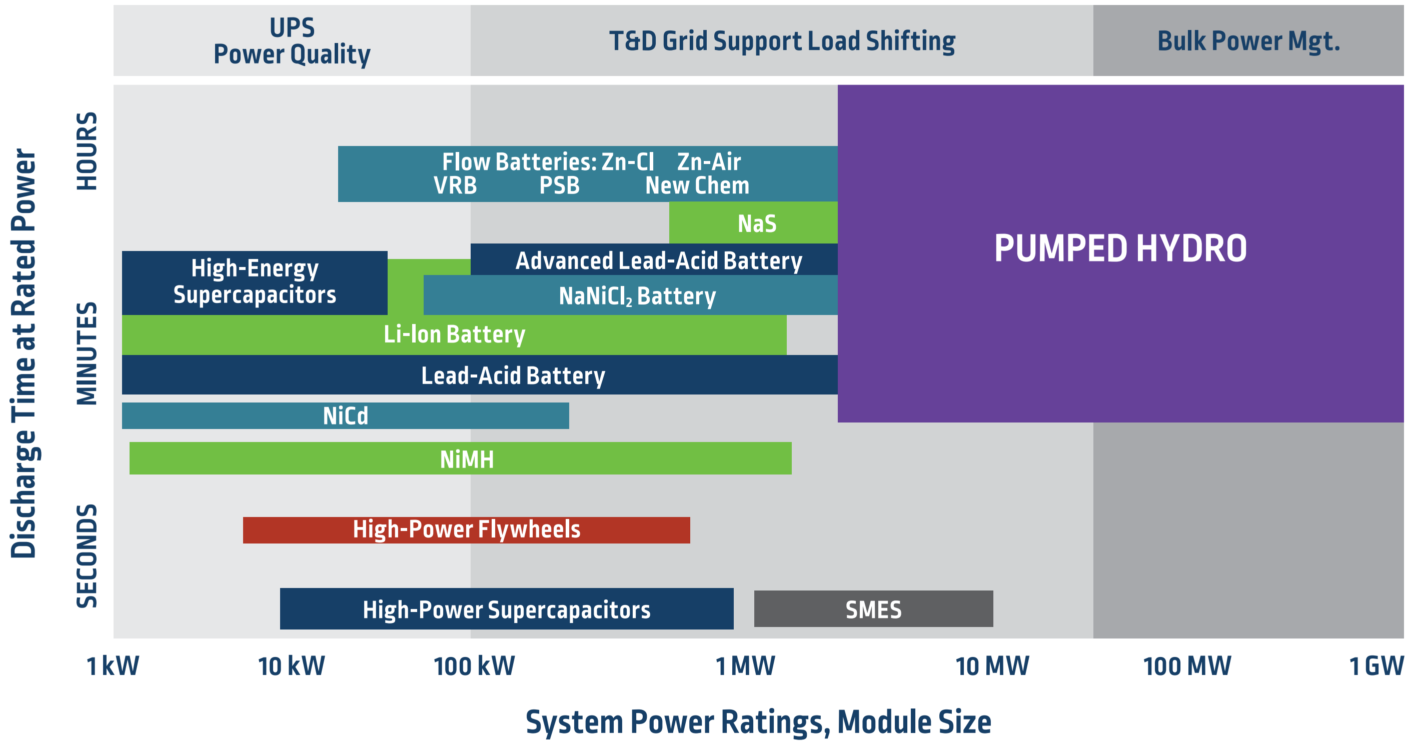

FIGURE ILLUSTRATING VARIOUS CAPABILITIES OF DIFFERENT ENERGY STORAGE TECHNOLOGIES, FROM THE ENERGY STORAGE ASSOCIATION (ESA), UPDATED WITH PUMPED STORAGE CHARACTERISTICS.

instances, environmental review and conditions should be limited to the project's proposed changes to current conditions, and the FERC approval process could mimic the FERC exemption program to streamline project permitting. Broadening the scope of projects that could move through a streamlined process would help lower approval costs and provide greater licensing certainty without compromising environmental protections. Under the FERC's comprehensive development standard stemming from 10(a) of the Federal Power Act (FPA), the FERC can approve a hydroelectric project provided it is "best adapted to a comprehensive plan for improving or developing a waterway." If the water source used for filling and providing make-up water for a closed-loop pumped storage project comes from a non-riverine water source such as groundwater or recycled wastewater, there would be no waterway affected by the project. In these cases, the FERC should consider these projects in a new, minimal-impact category to reduce the length and complexity of the licensing process. The FERC could advance the licensing process through a shorter process but have "off-ramps" if unanticipated issues arise. NHA is encouraged to hear that FERC is currently considering a two-year licensing process for these types of projects and new regulations could codify this process. Other relatively low-impact proposed pumped storage projects, such as those utilizing two existing reservoirs, may also be appropriate candidates for future consideration of a shortened licensing process.

6. **Where states have not restructured to rely on competitive wholesale markets, require consideration of energy storage resources in state integrated long-term planning processes; including requiring equal consideration with traditional resources.**

As the Nation's power grid transitions towards a decarbonized system, the integration of significant of variable renewable energy sources presents challenges to meeting short-term generation needs without overbuilding resources that cause challenges to grid reliability. The objective of this recommendation is to minimize the total system cost with respect to the investment of potential generation facilities and/or new (or upgraded) transmission lines, as well as other operational costs. One path for this that NHA recommends is to include energy storage resources in the Integrated Planning Process (IRP) to establish the need and cost effective development of these projects, potentially in a rate base setting. It is anticipated that the performance and economic models recommended above (Market Policy Improvement #2) would assist the IPR evaluation, specifically when comparing the cost effectiveness for various energy storage technologies.

This White Paper was prepared by the National Hydropower Association's Pumped Storage Development Council. The primary author is Michael Manwaring, Council Chair, with significant input provided by Scott Flake (Independent Pumped Storage Consultant), as well NHA staff and numerous industry participants.

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