# National Hydropower Association
# 2021 Pumped Storage Report

## Executive Summary

This is the third Pumped Storage Report White Paper prepared by the National Hydropower Association's Pumped Storage Development Council (Council). The first White Paper was prepared in 2012 and the second in 2018. This report focuses on energy markets, energy storage legislation and policy, development opportunities and challenges, technological advancements, and the Council's recommendations to unlock this proven long duration renewable storage resource. We have designed the 2021 report so that it can be; easily updated in response to a low carbon grid of the future and evolving storage needs, easily referenced for advocating and educating at the federal, state and local levels and ultimately – be the go-to resource for new pumped storage development. A new addition in this report is the "frequently asked questions" section. A primary goal of this paper is to offer the reader a pumped storage hydropower (PSH) handbook of historic development and current projects, new project opportunities and challenges, as well as technological advancement and resource capabilities.

As the United States grid continues its rapid evolution to meet ambitious clean energy goals, the industry must manage this change while maintaining reliability, keeping energy costs competitive and ensuring that capital is directed toward technologies that can meet all these goals. Nationally, roughly 18% of the electric energy is provided by renewable sources. In 2030 this is projected to jump to about 25% and by 2050 38%. (1) These percentages are much greater in states with aggressive Renewable Portfolio Standards (RPS) and Greenhouse Gas reduction targets. Many states are now adopting clean energy goals targeting 100% carbon free emissions in the 2040-2050 timeframe. These goals are not limited to state policies. In some areas, utilities are investing in cleaner assets based on ESG (Environmental, Social and Governance) issues. Likewise, utility customers and investors are supporting clean energy through choice of suppliers, deciding where to locate businesses and purchasing green energy directly through power purchase agreements. In some ways, customer and investor driven ESG issues are incenting change faster than regulation.

The challenge will be for utility planners, industry stakeholders, regional market operators, and state and federal regulators to put into place policies that ensure that the grid maintains reliability in the face of all this rapid development. Planning models demonstrate that adding more wind and solar requires greater amounts of storage and operational flexibility to assure grid resilience. The combination of increasing variable renewable resources and the retirement of fossil fueled dispatchable capacity makes hydropower and pumped storage the unique proven technology that can provide clean energy, flexibility and storage.

With resiliency and the push for a low carbon future being the major focus for today's grid operators, future energy scenarios with increasing variable renewable resources and decreasing base load options creates challenges and a need for dependable solutions. The above-mentioned models are forecasting the need for flexibility, fast ramping, capacity, and both short and long duration energy storage. PSH's existing installed base of 22 gigawatts (GW) is currently providing many of these grid services. The new PSH projects in development are positioned to utilize advanced technologies that are currently deployed in projects outside of the United States resulting in even greater benefits to the grid. As the U.S. energy mix continues to evolve and more variable renewable resources are brought online, now is the right time to develop new long-duration energy storage resources to enable a reliable, clean energy grid. In fact, as demonstrated in DOE's Hydrovision Report, there is potential for 50GWs of new pumped storage in the United States by 2050.

## The Nation’s Largest Energy Storage Resource Section

Globally, PSH provides 160 GW of the approximately 167 GWs of energy storage in operation. And with growing demand for electricity storage and the electrification of the transportation sector, the total amount of electricity storage capacity in energy terms will need to quadruple if the share of renewable energy in the energy system is to be doubled by 2030.(2)

PSH provides 94% of the U.S.’s energy storage capacity and batteries and other technologies make-up the remaining 6%.(3) The 2016 DOE Hydropower Vision Report estimates a potential addition of 16.2 GW of pumped storage hydro by 2030 and another 19.3 GW by 2050, for a total installed base of 57.1 GW of domestic pumped storage. In some markets, owners of existing PSH facilities are experiencing greater utilization of these flexible assets, especially in areas with increased variable renewable energy resources. They are experiencing increased pumping during the day, more starts and stops, increased ramping for evening load and condensing operations just to name a few.

## Supporting the Case for PSH in a Low Carbon Future

Some 50 years ago PSH unlocked the evolution of the nuclear and large thermal base load generation fleet by providing flexible firming services to allow the generation plants to operate more efficiently. When a nuclear plant was added to the grid a PSH unit was commonly built to provide the shock absorber flexibility for balancing supply and demand. When energy demand varied, the PSH units would either pump (low demand) or generate (high demand), as these large generating unit’s abilities to cycle up or down were limited. The pairing of these technologies provided vertically integrated utilities and their customers low cost affordable energy. With the decline of the historical thermal power fleet, PSH’s new partner is becoming solar and wind and now they are not only pumping at night but also throughout the day to match energy demand when there is more solar than needed on the grid. As load demand grows in the late afternoon, those PSH plants (or water batteries) can return that stored excess solar energy to the grid when it is most needed.

As noted, some states and owner/operators have established aggressive clean energy goals to reduce climate impacts from carbon-based fuels, and this not only means retiring of their coal fired units but also their gas turbines. The flexible gas turbines have been providing not only capacity but also ramping services and reduction of this resource may compromise grid resiliency - as some models are predicting. PSH is poised to play an even greater role with this future grid, especially with its highly flexible capability to provide long duration storage and rapid response to changing energy demands.

In California’s most recent Integrated Resource Plan developed by the California Public Utilities Commission (CPUC) there is a recognition of the different attributes between 4-hour battery energy storage and the need for longer duration energy storage, typically 8 hours or more of energy storage. California has several large PSH plants in operation that can supply long duration energy storage. During times of stress on the grid these plants are relied on to help stabilize the grid. As GHG emissions are reduced to meet low carbon emissions targets in 2030 significant amounts of 4-hour energy storage will be used to help flatten peak energy demand and peak net energy demand (load minus solar generation, typically 1 hour after peak demand). As GHG emissions are further reduced and natural gas plants are retired to help meet emission goals, long duration energy storage provided by PSH is required to extend the delivery of renewable energy and provide grid resiliency throughout the night and morning. PSH was identified as the preferred source of this needed long duration energy storage. The 2019-2020 IRP currently shows a need for 0.9 GW of PSH starting in 2026 for California to meet the 2030 GHG reduction goals.

## Current Challenges to PSH Development

Today in the U.S., three new PS projects totaling 1.8GWs have received their Federal Energy Regulatory Commission (FERC) license and all of the other permits needed and yet construction has not started. In addition, FERC reports that 44 GW of pump storage development are in the Preliminary Permit process. The developers of these projects are prepared to advance their PSH projects, especially those that have received their license. Unfortunately, markets that value their product have not matured adequately to compensate for the full suite of services able to be provided, and thus power purchase agreements or other procurement mechanisms are not being signed.

The need for additional storage is being universally recognized as evidenced by XXX from DOE and CAISO / CPUC. NHA is reaching out to stakeholders including the National Association of Regulatory Utility Commissioners (NARUC) to further understand how the many products and services from all forms of storage can be incorporated into individual state regulatory frameworks.

The PSH community and NHA have been making strides in recent years to highlight the lack of market adequacy and the inability of utilities to procure PSH and get PUC approval, however; legislative policies and market maturity ….. (reasons for needing PSH) . One notable outcome of this outreach and advocacy is FERC's ability to issue a license for a closed loop project in as little as 2 years for low-impact developments. Other focused areas by these groups include educating and advocating at the national, state and local levels. The PSH industry is developing an outreach program to the NARUC to raise the awareness of the value and contributions of the existing PSH fleet which will also support the financing of new projects.

Since the 2018 NHA report, the battery energy storage system (BESS) industry has expanded their footprint, technology and realized lower costs. Batteries are the perfect complement to PSH when viewed through the distributed storage lens. As low carbon future which will drive the deployment of huge amounts of wind and solar resources, models are predicting multiple cycles per day and load ramps of GWhrs, all better suited for PSH and grid resiliency. What BESS projects continue to have going for them are early state and utility policies and incentives, including requirements for procuring energy storage resources – often unfairly excluding PSH technologies.

## NHA Recommendations to Address PSH Development Challenges

The NHA and its members have been actively involved in finding, supporting and recommending PSH solutions from modernizing the existing fleet to promoting the most advanced technologies, to advocacy and education and policy and legislation activities. It is this group's opinion that PSH offers the best proven renewable storage.

References
(1) EIA AEo2020 projections
(2) REN21 Renewables 2019 Global Status Report; *GE Internal Forecast GPO19*
(3) U.S. DOE (2018) "Global Energy Storage Database Projects."
(4) CPUC 2019-2020 ELECTRIC RESOURCE PORTFOLIOS TO INFORM INTEGRATED RESOURCE PLANS AND TRANSMISSION PLANNING, Rulemaking 16-02-007, PROPOSED DECISION OF ALJ FITCH (Rev 1)

## 1.0 Pumped Storage Hydropower: Proven Technology for an Evolving Grid

Pumped storage hydropower (PSH) long has played an important role in America's reliable electricity landscape. The first PSH plant in the U.S. was constructed nearly 100 years ago. Like many traditional hydropower projects, PSH provides the flexible storage inherent in reservoirs. And with its pumping mode, PSH brings the added benefit of absorbing off-peak and excess electric generation and is an important asset in integrating non-greenhouse gas generation.

PSH is proven technology - cost effective, efficient, and operationally flexible. There are 43 PSH projects in the U.S.[1] providing 22,878 megawatts (MW) of storage capacity[2]. Individual unit capacities at these projects range from 4.2 to 462 MW. Globally, there are approximately 270 pumped storage plants, representing a combined generating capacity of 161,000 (MW)[3]. This grid scale storage technology is used extensively to both store and redistribute electricity from periods of excess supply to periods of peak demand, and to provide grid reliability services with its generation and pumping modes.

Here in the U.S., existing and proposed PSH projects are poised as a perfect complement to the significant amounts of wind and solar energy being ushered to the grid to reduce greenhouse gas emissions and combat climate change

***INSERT FIGURE ILLUSTRATING GLOBAL PUMPED STORAGE CAPACITY FOR EXISTING AND UNDER CONSTRUCTION PROJECTS. Source: IHA***

### 1.1 Pumped Storage Hydropower: A Historical Overview

Pumped storage hydropower projects use electricity to store potential energy by moving water between an upper and lower reservoir. Using electricity from the grid to pump water from a lower elevation, PSH creates potential energy in the form of water stored at an upper elevation, which is why it is often referred to as a "water battery".

During periods of high electricity demand, the stored water is released back through the turbines to generate electricity like a conventional hydropower station. Current pumped storage round-trip or cycle energy efficiencies often exceed 80% and do not degrade over the lifetime of the equipment, comparing very favorably to other energy storage technologies.

Beginning in 1929 and for 60 years thereafter, vertically integrated utility companies and the federal power administrations conceived, designed, permitted, and constructed PSH to make more efficient use of large steam-powered generating plants. These large thermal plants operate most efficiently when run continuously – 24/7. PSH was a perfect technology to absorb the electricity being generated at night when demand for electricity is low and to return electricity to the grid during the daytime peak hours. A large PSH plant can store energy to support 8-16 hours of full load operation, and a week or longer at the largest plants.

With these PSH plants in place, grid and market managers recognized the value of PSH to not only pair with large load thermal in a 24-hour cycle, but to meet increased transmission system demands for reliability and system reserves. PSH resources effectively shift, store, and reuse energy generated until there is demand. This shifting, when performed at a grid-scale, can avoid transmission congestion, provide quick access to significant and sustained energy ramping, and support uninterrupted electricity supply.

### 1.2 Pumped Storage Hydropower: Perfect Complement to Grid-Scale Renewables

Beginning in the 1990s, wind and solar generation have increased significantly in the U.S.[4] This trend is projected to continue with wind and solar generation supplying nine percent of U.S. electric generation in 2018, and increasing to 23 percent by 2050.[5] However, these important generation facilities depend on Mother Nature and therefore storage to optimize their use while maintaining reliability. The unscheduled nature of many renewable energy technologies has increased the need for fast responding system reserves to maintain a stable grid and limit the potential for rolling backouts. PSH is an excellent grid balancing tool for wind and solar resources that generate intermittently and often at times of low electricity demand. With its ability to quickly and even simultaneously give and take electricity, PSH can maximize wind and solar emission-free electricity by allowing this clean energy to be stored for later use. As far back as 2012, PSH operators in regional markets already penetrated by solar power began to see a shift from traditional nighttime pumping to daytime pumping. For example, at PG&E's Helms PSH, a dramatic shift from nighttime to daytime pumping occurred from 2012 to 2017 (Figure 2).

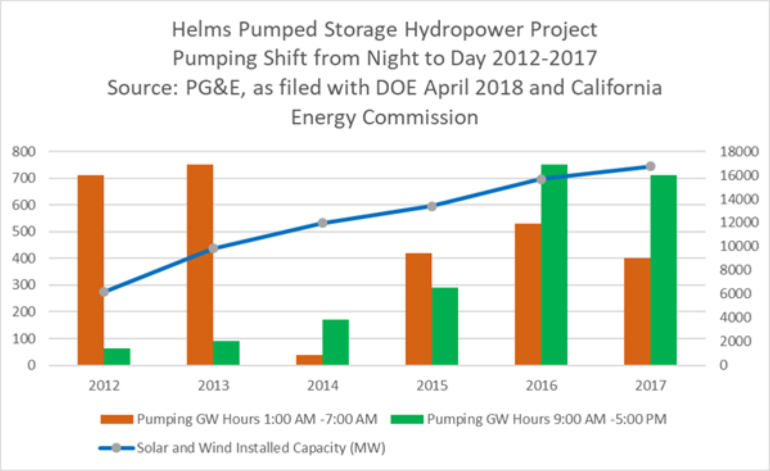


**Figure 2 Helms PSH ratio of pumping nighttime and daytime hours with solar and wind overlay.**

As wind and solar increase in other regions, the same shift in nighttime-daytime pumping has occurred. For example, Duke Power's Jocassee and Bad Creek PSH saw a steady shift from nighttime to daytime pumping over the period 2015 to 2020 (Figure 3).

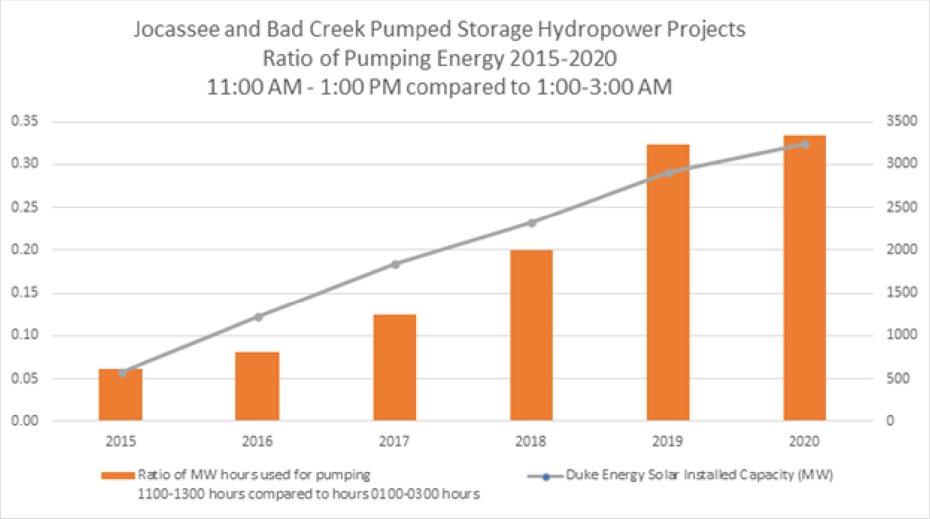


**Figure 3 Jocassee and Bad Creek PSH ratio of pumping GWH daytime and nighttime.**

Recent technological advances in the PSH adjustable speed pump-turbine allow an even greater range of fast ramping and frequency regulation services in both the generation and pumping modes. Variable speed PSH can respond across a scale of nearly infinite increments to replace dropped or reduced generation and absorb electricity suddenly being produced by wind and solar. A modern variable speed PSH plant can reduce curtailment of valuable solar energy while at the same time providing grid reliability services. This adjustable PSH response aids in alleviating frequency and voltage fluctuations, and bolsters grid stability.

Since deregulation of the electric industry, there are few effective regulatory mechanisms or market price incentives for energy storage or for integration of wind and solar power. Yet these are components of a reliable energy generation and transmission system that require coordinated, long-term planning. In addition, in certain market regions (e.g., California and the Pacific Northwest), large amounts of variable renewable energy generation are creating new challenges for regional transmission systems and grid operators.[6] PSH's grid-scale energy storage can address some of these challenges and maximize the value of existing and future clean, renewable generation projects.

## 2.0 Current Challenges to PSH Development

New PSH development is challenged from the start by regulatory complexity and delays, electricity market structures that undervalue or ignore PSH's contributions to the grid, and lack of avenues for project financing.

### 2.1 Current Regulatory Treatment of PSH

PSH's most obvious regulatory path to approval for construction and operation follows FERC's hydropower licensing process under the Federal Power Act. The licensing process ensures the best use of our nation's water resources and balances development with environmental protection. However, as electricity providers and project developers attempt to license new PSH projects, they face significant procedural impediments, beyond what is reasonable to assure beneficial uses and environmental protections. The time necessary to obtain approval and the uncertainty associated with the timeline discourages development of valuable PSH resources.

Permitting and construction timelines for new PSH projects from inception to generation is seven to ten years. Few investors are willing to finance such long-lead projects, especially since market structures, and a lack of procurement policies at State PUC's, provides an additional layer of uncertainty. And regulated utilities face challenges with requirements for return on investment imposed by state utility commissions.[CN1]

NHA and the hydropower industry are working to modernize the licensing process for PSH projects that can demonstrate minimal adverse environmental effects, especially closed-loop technology. Reform is needed on the legislative and regulatory front to unlock PSH's renewable energy and grid-stabilizing powers.

### 2.2 Existing Market Rules Determine Value of Energy Storage and Ancillary Services

In today's electric grid, the PSH projects are providing value by storing and time-shifting energy delivery based on demand and through ancillary services. 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 currently either undervalued due to price formation limitations or not valued at all. Such contributions include the following: bulk power capacity and energy storage over PSH lifetime, value of ancillary services, system stability services, impacts on reduced cycling/ramping costs, transmission benefits, as well as non-energy related services (water management, socioeconomic and environmental impacts). The exclusion of such benefits may unfairly lower perceived value of PSH as it relates to other energy storage systems.

In late 2018, the DOE Water Power Technologies Office (WPTO) commissioned a group of DOE national laboratories (led by Argonne National Lab) to develop a standardized step-by-step methodology for the valuation of all grid services and contributions provided by PSH plants (including all those mentioned above), for use by electric utilities, PSH developers, plant owners and operators, regulatory bodies, and other stakeholders.

This study is currently in an intermediate phase in which techno-economic case studies are being performed to assess the long-term value of two select PSH projects, utilizing a draft PSH valuation guidebook. Results from these studies are currently under review and will help improve the draft valuation methodology, following which a final valuation guidebook will become publicly available for stakeholder use.

The industry-wide adoption of a rigorously studied, tested, and refined step-by-step methodology will become key to demonstrate benefits PSH resources bring to the electric grid by appropriately valuing their advantages over other energy storage technologies, potentially helping to unlock barriers to secure long-term project financing.

Sources:

"DEVELOPING VALUATION GUIDANCE FOR PUMPED STORAGE PROJECTS", VLADIMIR KORITAROV, Presented April 17, 2019 at EPRI hydropower Flexibility Workshop.

< https://www.anl.gov/sites/www/files/2019-05/Koritarov_PSH%20Valuation%20Guidance_EPRI_Apr2019.pdf >

Office of Energy Efficiency & Renewable Energy. "Pumped Storage Projects Selected for Techno-Economic Studies". December 3, 2018.

< https://www.energy.gov/eere/articles/pumped-storage-projects-selected-techno-economic-studies >

### 2.2 Challenges with Financing New PSH Projects

The pumped storage community is able to find investors who are willing to take a long-term view of a large scale project, but those investors do require increased certainty of market revenues associated with that long-term view. 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 as power purchase agreements are difficult to line up, and require developers to commit substantial financial resources in developing necessary project details prior to doing so.

There is also a growing recognition that the collaborative efforts with project stakeholders associated with FERC licensing are able to be met with success, as demonstrated that a low impact PSH project can be licensed. An example of this might be a closed-loop PSH facility which holds the record for the quickest FERC licensing of a project (Final License Application filed with FERC on October 1, 2015, Original License issued on December 14, 2016). While working to secure project funding and power purchase agreements, the facility has since obtained 2 extensions of time to commence construction (current required start is 12/14/2022) – demonstrating that the regulatory process may not always be the key impediment to PSH development – it is the lack of market revenue clarity to support the financing that is the holdup.

### 2.3 Obstacles to PSH development – Industry Survey

NHA conducted a survey of PSH developers to rank the following seven challenges to PSH development, with #1 being the most challenging/most in need of assistance and #7 being the least challenging/least in need of assistance. Based on the information received each identified ‘challenge’ is listed below:

| **Challenges to PSH Development** | **Average Rank** |
|---|---|
| **Licensing Process**<br>*Requirements for obtaining the license* | **3.11** |
| **Competing Technology**<br>*Demonstrating the value of PSH compared to other ES Technologies* | **3.11** |
| **Development timelines**<br>*How long it takes to come online* | **3.44** |
| **Costs**<br>*Comparison to other Energy storage technologies (total & $$/kW)* | **3.61** |
| **Policy**<br>*State or Federal policies preferring other technologies over PSH* | **4.38** |
| **Environmental**<br>*Perception of impacts compared to other ES technologies* | **4.61** |
| **Project Finance**<br>*From PPAs to internal business case to access to long-term capital* | **5.72** |

It is clear there are several barriers to PSH development, but developers ranked the licensing process and being able to demonstrate the value of PSH compared to other energy storage technologies amongst the most difficult (highlighting the conclusions from Section 2.1 and 2.2) – whereas environmental and project financing issues consistently were not amongst the most challenging.

## 3.0 SUPPORTING THE CASE FOR PUMPED STORAGE

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 and procurement policies 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 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. While project costs can be 'fairly' straightforward, the benefits of energy storage have proven very challenging to quantify based on current market design. A primary challenge to the 'value' picture is that energy storage technologies offer multiple services that fall into both energy supply and capacity based products, therefore should be eligible for multiple value streams – and these can be deployed interchangeably based on the overall grid services provided are not fully (monetarily) recognized in today's energy based markets. Most market design as based in energy sales, MWhr, and do not fully recognize the value of capacity based services, MW, like inertia, voltage support, etc. Energy based market designs pose a challenge to attract the necessary investment to develop large capital energy storage projects like PSH by not providing value to a significant portion of PSH services that are critical for grid resiliency.

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 (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**

One way to see that Pumped Storage Hydro (PSH) is not recognized for all of its value is to compare the operations of these facilities in vertically integrated utility systems to those in energy markets. PSH in vertically integrated utility systems is dispatched based on standard economic drivers but is also committed based on benefits that are harder to calculate. For example, pump storage in vertically integrated utility systems will run because these System Operators can account for value from ancillary services and other system wide benefits – such as avoided start/stops or limiting operation at off-design conditions for other units on the system – that current market rules and structures do not properly value and/or consider. Studies have been completed comparing the differences in dispatch for PSH in markets and traditional regulatory structures that support the conclusion that markets do not completely value PSH. One recent study that further demonstrates this conclusion was completed by EPRI titled, "Pumped Storage Hydro Operations and Benefits in the United States: Review and Case Studies"

### 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). 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[1] 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 ranging 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 project 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, 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.

**Commented [CS1]:** add EPRI link

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 over appropriate asset life cycles.

### 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 which enables load following to integrate 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). 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. 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

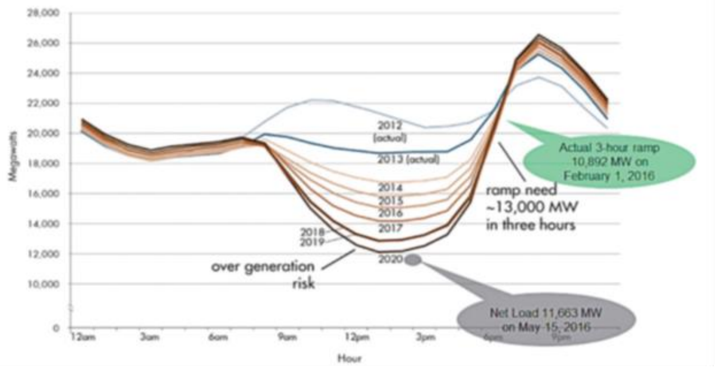
The United States' energy resource mix continues to undergo significant change with ongoing retirements of large thermal and nuclear capacity and growth in natural gas and renewable resources. There has also been a transformation in how the electric grid and power systems are operated over the past decade, 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 (CAISO) identified a need for fast-ramping, flexible resources to balance the grid and mitigate the potential impacts of over-generation from renewables. Recently, CAISO provided an update on renewable generation at a California Energy Commission (CEC) workshop on flexible generation and load 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 offline and customer load increases the situation reverses and the plants that can respond must quickly go from minimum load to increasing output. This afternoon ramp is the "neck" of the Duck Curve. To highlight the impacts of increased solar generation on the California electric grid, CAISO recorded data from a recent low load, high renewable generation day , as a predictor of potential grid management challenges to come. The California electric grid reached a minimum load of 5,439 MW (belly of the "Duck curve") in May 2019 impacting conventional generations ability to help manage grid reliability. Another example of the need for highly flexible resources occurred, during the late afternoon to early evening hours in March 2019 , when CAISO recorded a 3-hour evening ramp of almost 15,070 MW. It is forecast that the 3-hour evening ramps will continue to increase with increasing renewavle resources. By 2023 the 3-hour evening ramp is expected to exceed 20,000 MW (Reference CAISO Final Flexible Capacity Needs

Assessment for 2021, May 2020) .  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 CAISO has proposed a number of solutions to help manage this increasing challenge including installing large amounts of additional energy storage capacity on the grid.

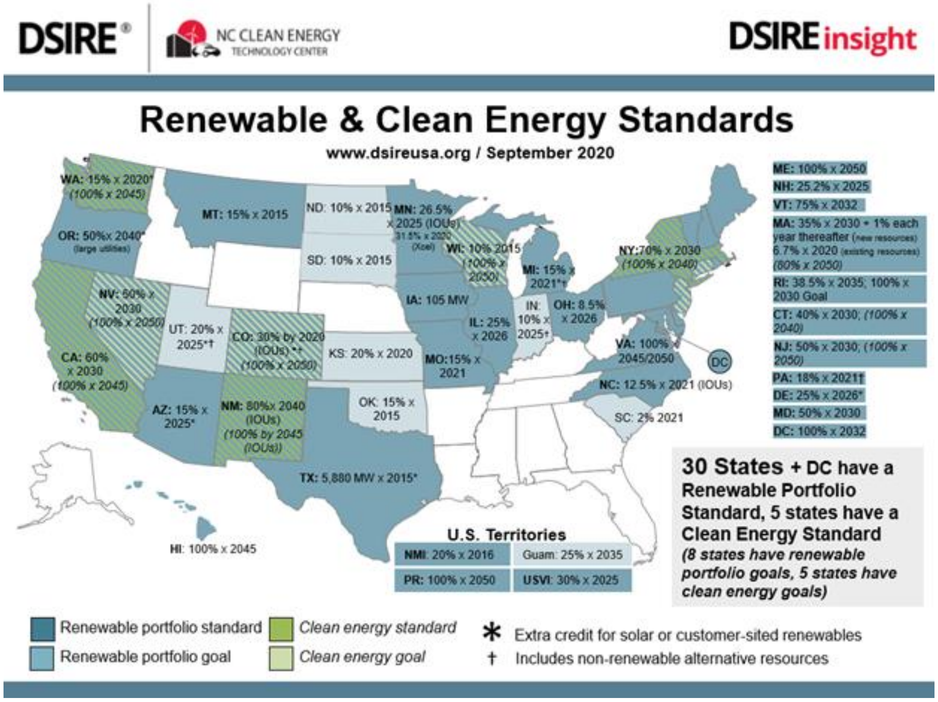


### 3.4.2 PSH and Wind Resources

In many areas of the U.S., wind powered generation resources primarily produce during the late evening or early morning, which are not coincident with peak power demand. In other areas, wind resources generate 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 represented 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.

### 3.5 Regional Market Drivers

The drivers for energy storage development vary significantly from region to region, and are driven by both energy policies and market structure. A map showing the current renewable and clean energy policies is shown below in figure X. 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 201418 and 2017 solar eclipse19). In the Midwest, regional transmission organizations feature capacity markets that include vertically integrated utilities (VIUs) as well as merchant generators. As state and federal policies drive markets for clean energy, PSH projects and other energy storage technologies can help secure energy reliability and resiliency – 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. In May 2019 the CAISO curtailed over 225,000 MWhr of wind and solar resources,  This amount of renewable energy curtailments has increased each year in California (CAIS 2019 annual report on market issues and performance, June 2020) . 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 and it believed that this need will only increase as additional renewables come online 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 this situation, PSH is the perfect proven capacity that can help achieve the clean energy goals while continuing to improve grid reliability and resiliency. 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.

### 3.5.2 ISO-NE Market and Existing Resources

Achieving the regional clean energy goals in New England will require contributions from both new and existing resources and from a variety of clean technologies. Most New England states have programs in place or planned to expand solar and off shore wind resources to increase the supply of clean energy. However, those resources are important, but not sufficient, to create an integrated and reliable fully-clean electric grid without support from other renewables and storage. Other clean energy resources like pondage hydro and pumped-hydro storage can be scheduled to provide their clean energy when it is the most valuable, both for reliability and for emission reduction purposes. Currently, the value of being able to dispatch to optimize emission reduction contributions is not reflected in any market structure, and as a result, these resources are under-utilized as a perfect complement to variable solar and offshore wind. To avoid locking in fossil-resources as the provider of needed back-up reliability, New England needs to fully tap and rely on existing renewable and storage resources that can deliver more (if they are signaled to do so) and accelerate the path to integrating renewables with the use of zero-emissions resources like hydro and pumped-hydro storage.

To meet the peak electric demand needs of the region with clean energy, the region will require the transportation of clean energy delivered during low demand or the highest clean generation periods to periods of greater reliability or emission reduction needs through electric storage. As noted above, while the regional market provides *some* reliability signals, there is no market signal rewarding electric storage for carbon reduction contributions. Additionally the regional market fails to provide adequate signals for the storage duration (i.e., hours of charge stored) that will be required for purposes of reliability alone.

Further, the integration of large-scale intermittent resources requires large-scale, longer duration energy storage resources to effectively capture the full value these assets provide. Offshore wind and solar can provide additional value if paired with large-scale energy storage. The region's growing solar resource is moving the net peak load hours later into the evening creating a multi-hour period of high demand not offset by a commensurate supply of clean energy deliveries.

Longer duration storage, such as the three existing pumped-hydro storage assets, can improve carbon reductions and reduce peak demand for fossil-fired resources during critical periods if they are paired with output from offshore wind and other large-scale renewables. One potential market design change being considered in New England is the Forward Clean Energy Market (FCEM) design that accounts for delivery-time-differentiated value. The FCEM design provides higher value for clean energy deliveries in periods of greatest carbon reduction impact relative to clean energy deliveries in periods of less carbon reduction improvement. In the meantime, this value can be realized for New England consumers by extending programs or procurements to existing large-scale electric storage, which will lower both costs and emissions beginning immediately.

### 3.5.2 Southeastern United States

In the Southeast, vertically integrated utilities (VIU) must get regulatory approval from utilities commissions to own and rate base generating assets, including pumped storage. While some portions of the Southeast belong to regional markets (i.e. Dominion Virginia Power joined PJM South), the bulk of the region is still driven by demonstrating to state utility commissions a least cost plan for resource planning. Figure X demonstrates that unlike the Western Grid, Renewable Portfolio Standards are not a significant factor driving the development of clean energy in the Southeast. The drivers in the Southeast are generally clean air regulations, customer preference, implementation of the Public Utility Regulatory Policies Act (PURPA) and Environmental, Social and Governance (ESG) investor pressures. Air regulations (not including carbon) with least cost planning has driven the transition to natural gas and reduction in coal use. Implementation of PURPA has largely driven the development of solar in the Southeast. In recent years, customer preferences and ESG pressures have become stronger drivers. Customers are demanding cleaner energy from their respective utilities. Many commercial/industrial customers have adopted sustainability or climate goals and desire clean energy options. Even though the region is highly regulated, states still compete for new large customers for economic development and those customers are driving more investment in clean energy options. At the same time, many states are considering new or expanded clean energy policies, not just for meeting carbon goals but also for economic development. Investors are increasing considering carbon emissions and climate risk as material. Companies that offer cleaner energy are valued higher by the investment community and tend to have better credit ratings. Collectively, these drivers are resulting in larger penetration of renewables in the Southeast, particularly solar on both the utility and company side of the meter. This transition in the generating portfolio and increasing amounts of solar on the system is also creating a need for more energy storage, which could include Pumped Hydro due to the geographical resources in the region.

### 3.6 Energy Storage Technology Cost Comparison

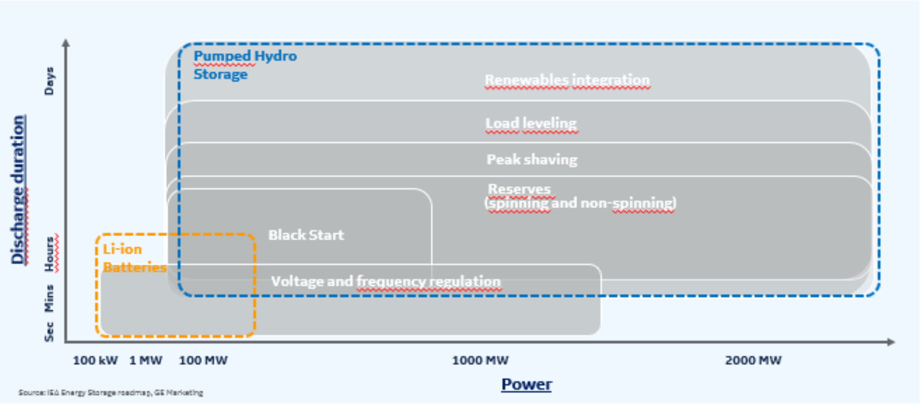
Pumped storage technology is now in its third generation. The first-generation of pumped storage hydro (PSH) was the reversible Francis runner introduced in the 1950s. Equipment manufactures were able to design a Francis runner that worked in both generating and pumping modes. This first-generation was mainly built for pairing with the baseload nuclear and coal fired fleet build out in the 60s, 70s and 80s. As these units aged and rehabilitations were needed as well as new global markets emerged for PSH, the second-generation focused on efficiency in the 2000s. Equipment manufactures were designing units with turbine and pump efficiencies above 90%. These efficiency gains offered operators competitive solutions to ultimately improve their bottom lines. Today, we are in the third generation of PSH design focusing on optimum stability, flexibility and reliability.

This latest generation of PSH is a culmination of design advancements bringing the end users the most flexible, carbon free long duration energy storage. Operators will be able to participate in more markets increasing the value stream of their investment. As noted earlier, the first generation was primarily an energy arbitrage play, generating when MW prices were high and pumping when prices were low. Additional revenues were and are being realized from regulation control, spinning reserve, capacity, black start and flexibility. Today's technology can provide these services but better, faster and longer. In addition, 3rd generation of PS users are benefitting from frequency control, voltage support and increased renewable generation.

One noteworthy area of discussion is mode change with reversible units significantly decreased over the last 3 years. So, going from standstill to pumping, standstill to generation, pumping to generation, generation to pumping is happening faster and faster with the 3rd generation designs. In addition, manufactures are now able to design this flexibility with longevity, so multiple starts and stops per day with design lives 30 – 50 years.

With over 170GW of energy storage globally, PSH makes up 95%, while electrochemical systems are becoming more ubiquitous and affordable, they are still challenged with providing the needed long duration storage. The below chart provides a contrast of PSH and Li-ion batteries with respect to size, storage duration and grid support services.

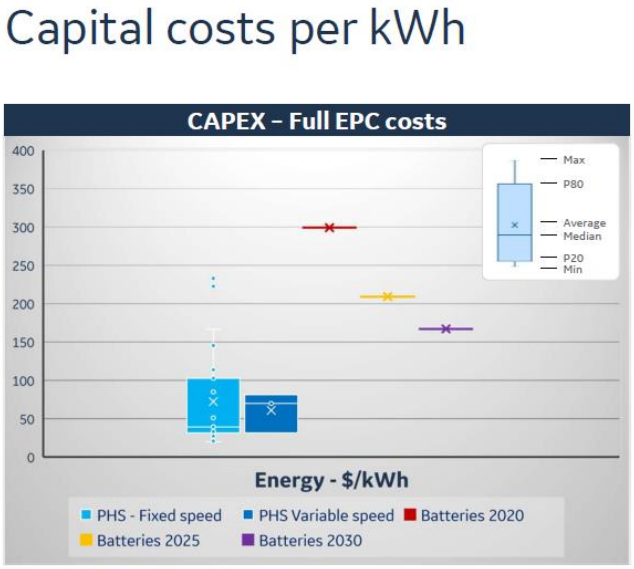
California experiences most afternoon/evening ramp demands of 13GWs in 3 hours or 19.5 GWhrs. The largest Li-ion battery was recently commissioned in California – 300 1.2 GWhrs. The largest advanced Pumped storage hydropower project in Switzerland (1000MWs) is capable of 34GWhrs.



Source: IEA Energy Storage roadmap, GE Marketing

As noted, Li-ion batteries are becoming more affordable, can be easily deployed, and provide distribution services described above. Challenges with this energy storage include limitations on long duration storage, annual efficiency declines, start and stop limitations and lifetime expectancies.

When evaluating energy storage systems, one needs to look at \$/kWh -the cost of the technology, lifetime and amount of energy storage. As the chart shows, Pumped storage hydropower has a much lower \$/kWh than batteries, nearly 2 to 3 times less expensive. Also, Pumped storage hydropower's annual O&M, \$20/kWh-yr., costs are also 3 times lower than batteries. (DOEs Energy Storage Benchmark)



Source : GE RE Marketing, BNEF 2020 (4-hour duration Li-ion batteries)

Global Utility Scale Storage Capacity by Technology (2018)

## 3.7 NEW TECHNOLOGY ADVANCEMENTS SUPPORTING PSH PROJECTS

Globally, there are 170GW of Pumped Storage Units in operation or under construction whereas 22 GW are in operation in the US. Growth of Pumped Storage in the US occurred between 1955 and 1995 all conventional fixed speed designed and built to pair with the nuclear and large coal fired utility build out. These units are not known for their ability to operate at lower loads thus the paired pumped storage unit was/is a perfect solution for excess generation, typically at night.

As discussed in section 1, today's PSH fleet is being used more and more for the integration of renewables and future models are predicting even more demand, thus end users are looking at the 3rd generation of advanced pumped storage designs. The following describes the 4 various equipment configurations that are available.

C-PSH: Conventional fixed speed pumped storage hydro

Conventional reversible pump-turbines are composed of a Francis type reversible pump-turbine. Generation mode typically varies from 50% - 100%. However, the 3rd generation of the C-PSH enhances this operation from 0% to 100% of rated power in certain cases. So, if you have a 100MW C-PSH it can operate from 50MW – 100MW and if of advanced design 0MW – 100MW.

Pump operation is limited to a single point which is the maximum output of the turbine thus the pump absorbed power is fixed and cannot be regulated. So, if you have a 100MW C-PSH unit you would need 100MW to operate in pump mode and if there is 70MWs of excess solar on the grid, these MWs could not be absorbed by the C-PSH configuration.

Additional advancements include faster mode changes, additional starts and stops and longer design lives.

A-PSH: Advanced pumped storage hydro (Variable Speed)

This type of hydro pump storage is based on a C-PSH utilizing a Francis type reversible pump-turbine, with variable speed capabilities. This capability is made possible with the use of power electronics that varies the AC frequency on the pump end. Generally, the continuous pump power absorption range will be in the 70%-100% range. In some cases, it could be as much as 60%-100%. So, going back to our example, if you have a 100MW A-PSH unit and there are 70MWs of excess solar on the grid, these MWs could be used to operate the A-PSH pump.

T-PSH: Ternary pumped storage hydro

This type of arrangement is more flexible than C-PSH and A-PSH. It generally has the -100% to + 100% capability. It is composed of a multi-stage pump, a torque converter, a turbine (whether of Francis type or Pelton type), and a motor/generator all on one shaft. The motor/generator is operated in one speed direction, only the torque is inverted. In our 100MW example, the T-PSH configuration would be able to operate from 100MWs of Pumping to 100MWs of Generation.

Q-PSH: Quaternary pumped storage hydro

This type of arrangement is composed of separate pumping and generating units. Instead of having a torque converter between the pump and turbine such as the T-PSH unit, the Q-PSH uses separate shaft lines. Operation of the pump is made possible electrically with fully-fed power electronics rather than mechanically with torque converter.

Both the pump and the turbine are operated at an optimal speed. There is no need to have a compromise between the pump and the turbine so that they could share the same speed. With the separate pumps and turbines, you will also realize the best efficiencies of the 4 options.

In our 100MW example, the Q-PSH configuration would be able to operate from 100MWs of Pumping to 100MWs of Generation.

The developers of the pumped storage project will study their site conditions, markets they will serve, economics and make equipment configurations selections from the aforementioned technologies. They will also make selections on the number of units and MW size. For example, if a developer is considering a 500MW PSH facility, they will conduct economic and technical feasibility studies of a 4 x 125MW or 2 x 250MW or 1 x 500MW configuration. All have their independent advantages and disadvantages.

In recent years, Europe has been seeing steady growth of PSP whereas China has been experiencing exponential growth. In the past 10 years, China has commissioned 14GW of PSH, all fixed speed except for one .6GW variable speed plant under construction. China typically locates their PSH near large cities and are able to manage the grid with this configuration. It should also be noted that China views PSH as a generation asset and they have plans for similar if not more build in the next 10 years. In this same period, there has been .3GW of Ternary designs installed in Europe.

It is possible to retrofit an existing fixed speed pumped storage unit with variable speed, but often the costs associated with this changeout and the space required for the variable speed electrical adjustment equipment

When considering all the details that affect efficiency, a global cycle efficiency generally between 75% and 80% wire to wire is obtained. This efficiency varies whether the units are operated all together, at maximum load, or if a few of them are operated at best efficiency.

## 4.0 Recommendations

1. Congress should pass a federal investment tax credit for storage to be on a level playing field with wind and solar. The credit should a 10-year safe harbour to account for PSH's long development timeline.
2. Vertically integrated states should require consideration of long duration energy storage resources in integrated resource planning processes, including requiring equal consideration with traditional resources.
3. Organized markets should design technology neutral products and services for future system needs. A decarbonized grid will require many essential reliability services that currently are under-compensated or not compensated at all (examples include fast ramping, primary frequency response, inertia, and load following). Grid operators and FERC should implement longer term market designs to ensure capital is attracted to critical grid services in advance of the demand.
4. FERC should develop clear policies on how generation assets like pumped storage can compete to provide transmission services while avoiding double recovery of revenues and limiting impacts to current market participants.
5. States Legislatures should allow all energy storage technologies, including PSH, to participate in renewable portfolio standard programs (or clean energy standards) on a technology neutral-basis. In addition, state energy storage targets should incorporate longer term goals to ensure the most cost effective long-duration storage technology, pumped storage, can compete with other technologies.
6. Request FERC to 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.
7. Request FERC to streamline the licensing process even further for low-impact pumped storage hydropower, such as off-channel, modular or closed-loop projects.
8. Reduce out of market dispatches for pumped storage by creating products that truly value PSH services and reliability and create products for inertia, primary frequency, synchronous condensing, etc.