North America: USA

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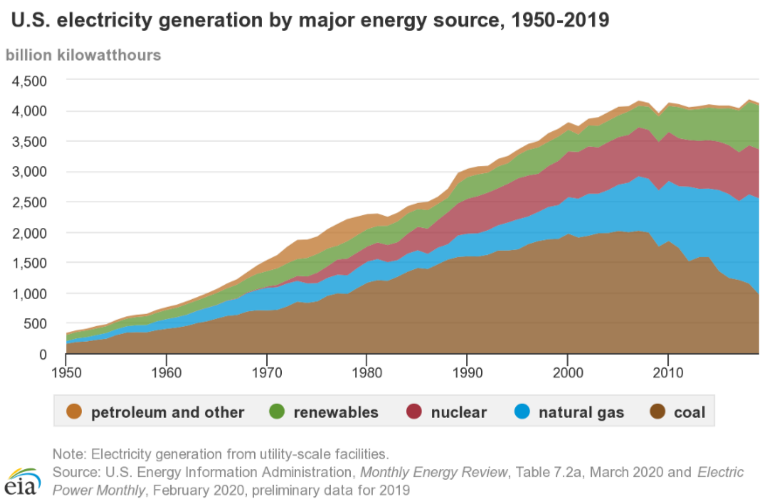
Overview of the country's/region's electricity market

Current Electricity Environment, Generation Mix and Evolution

The United States' electric grid is a majority fossil fuel driven electric system with about 63% of electricity generated from fossil fuel sources in 2019, with 38% from natural gas, the most of all sources. Nonhydroelectric renewables make up 11% of generation with hydroelectric resources contributing an additional 7%. Nuclear resources provide 20% of U.S. electric generation. Figure 1 identifies electricity generation by energy source from 1950 through 2019. Traditionally, electricity was produced by major baseload power plants including coal, nuclear, and hydropower. More recently, as natural gas prices dropped significantly due to the shale gas revolution starting from around 2008, and renewable resources, namely wind and solar, have seen significant development being supported by favorable government policy to address climate change, the energy generation mix has shifted to natural gas and renewables and away from coal. Nuclear plants have seen some retirements but largely remain operating, with few new project developments. Hydropower resources, including pumped storage, have largely maintained capacity. Other storage resources, mainly batteries, have seen over a GW of deployment over the past decade, largely in support of renewable energy variability and supported by government incentives.



Moving forward, it is expected that renewable resources continue to supply an increasing share of electricity, while coal, natural gas and nuclear resources see further retirements with an increasing state and federal emphasis on climate change mitigation. Further, with increasing renewables and retirements of natural gas, balancing resources will be needed. Many of these balancing resources will be from various energy storage technologies or in some areas of the country, natural gas.

Market Challenges

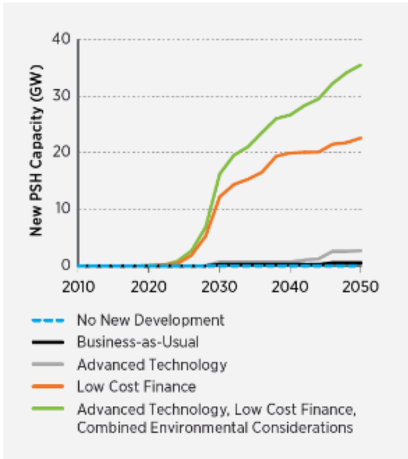
One central challenge facing the U.S. electric market is how to ensure energy planning mechanisms and competitive markets send appropriate signals to ensure enough balancing resources are built to integrate variable generation. This challenge manifests as cost and reliability hurdles. Costs include not only the development of significant clean generation, but also the transmission to deliver this generation. On the reliability side, the deployment of variable renewables presents the potential for energy imbalances across temporal scales, from subseconds to hours to days to seasons. Already in several states, the challenges of maintaining reliability are being felt. Addressing these imbalances may require the overbuild of variable resources, new transmission to deliver energy from where it is plentiful and new dispatchable clean energy. In addition, it is likely to require significant energy storage across temporal scales. Although the timetable for long duration storage needs vary, last year the CPUC (California Public Utilities Commission) released a decision on long term planning frameworks that identified 1 GW of pumped storage by 2026[1].

Federal and state governments, market operators and utilities are seeking to address these challenges by supporting the development of energy storage, different types of clean energy resources, and increased customer engagement through demand response. With new natural gas difficult to build due to environmental uncertainty, several states have issued mandates, provided incentives, or otherwise encouraged utilities to build new wind, solar and batteries given the incrementality, low upfront capital cost and short lead-times. While over 93% of the current storage capability comes from PSH, there is still a lack of understanding about PSH's ability to provide cost-effective grid services beyond the capabilities of other energy storage technologies. This manifests in system planning and operational models that do not fully account for PSH capabilities. Long duration storage resources have seen little development as the need has not been well elucidated, capacity markets provide insufficient incentives, market products for certain services that long duration storage can provide are not currently compensated and there is a general hesitance to engage in the development of high capital cost, long payback resources in favor of quick return alternatives. More recently, California and other states have recognized a need for longer duration storage resources and have launched initiatives to better illuminate the need for long duration storage and consider mechanisms to incentivize development.

Current status of pumped storage & development potential

PSH provides 93% of the U.S.'s energy storage capacity, totalling 22.9 GW's, and was originally developed to complement operation of large, baseload coal and nuclear power plants and to help balance the grid by providing peaking power during daytime generation and load during night time pumping. These plants were built primarily by the US Government and IOU's (investor owned utilities) between 1960 and 1990 but since then, no new plants have been built. Currently in the US, PSH is considered a generation asset and not transmission.

The states began deregulating/restructuring their electrical systems in the 1990s, to create competition and lower consumer energy costs. This led to the formation of IPP's (Independent Power Producers). Currently IOU ancillary service renumeration is very limited or not compensated at all. In addition, IOU's have to provide these services 'on demand' to the ISOs which makes it difficult if not impossible for IPP's to make their financial models work for existing PSH plants they have purchased or new greenfield development they are considering building. On the other hand, IOU's, if they get approval to build new PSH from their Public Utility Commission, can finance the project through rate base (customer bills). An IOU can also use PSH to optimize the existing assets thus adding an additional benefit over an IPP.



ReEDS modeled deployment of new pumped storage hydropower capacity, selected scenarios, 2017–2050 (GW)

Source: 2016 DOE Hydropower Vision Report

Some owners of existing PSH facilities are experiencing greater utilization in areas with increased variable renewable energy resources including increased pumping during the day, more starts and stops, increased evening ramping and condensing operations. Since the PSH equipment was not designed for this operation, maintenance costs and failure rates are increasing, thus exacerbating the profitability of units.

Currently there are three Projects Licensed at the Federal Energy Regulatory Commission, three in final phase and almost 70 other greenfield PSH projects in various other license phases totalling about 54 GW's. The 2016 DOE Hydropower Vision Report, using capacity expansion modelling, estimates a potential addition of 16.2 GW

[1] CPUC Order, March 2020, at page 41 - https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M330/K357/330357384.PDF

by 2030 and another 19.3 GW by 2050, for a total installed base of 57.1 GW of domestic pumped storage. This forecast assumes an improved policy and economic environment for deployment as well as availability of low-cost finance. Several U.S. states have established energy storage goals, targets or mandates, although they generally do not specify long duration technologies like PSH. Virginia, however, does explicitly permit the development of an 800 MW single project as a part of its legislative mandate for utilities to procure 3.1 GW of storage, alluding to Dominion Energy's proposed Tazwell PSH project.[2]

Challenges, barriers and emerging opportunities for pumped storage development

As state policymakers push for greater renewable portfolio goals, a growing share of the generation mix will be made up of non-dispatchable wind and solar by 2030. This poses a unique opportunity for long duration storage technologies like pumped storage as intermittent resources will need to be supported during days with reduced solar and wind output. Despite this, there remain many challenges to developing pumped storage in the United States, including but not limited to:

- **Licencing process**: Nearly all non-Federal PSH projects must receive a license from the Federal Energy Regulatory Commission (as well as other State and Federal permits). A new license can take from 3-5 years and include significant investments in planning and studies. While license timelines remain challenging, the U.S. has seen several projects successfully navigate the process. Many competitive storage technologies are not required to obtain and participate in rigorous government reviews which add significant costs, even though many closed loop PSH projects are considered environmentally benign.
- **Demonstrating value over other technologies**: PSH competes against other energy storage technologies, namely lithium-based batteries. Assessing the value of all the services PSH can provide over lithium batteries is difficult. A recent EPRI study found that, in vertically integrated areas of the U.S., IRP (Integrated Resource Planning) models and tools do not fully capture the operational value of PSH. Thus, in over 70 different IRP models they studied only one selected PSH for their resource portfolio. Many IRP settings fail to account for the full life cycle costs of PSH versus a battery system that needs replacing several times over the same time horizon.
  - **Valuation of network services and benefits**: The size, agility and location of new state-of-the-art PSH in some cases allows for the host grid to realize substantial performance benefits. Economic and reliability benefits can include increased transmission power limits, increased wind and PV hosting capability, and relaxation of carbon-intensive operating constraints, to name a few. Benefits are application specific, and there is no mechanism or motivation to exploit or assign value. Process and market improvements are needed to ensure these values are modeled and compensated.
- **Development timelines**: PSH projects can take up to 3-5 years for construction in addition to the 3-5 years for license application process, if a FERC license is required From the initial project development to the completion of construction can take 7 years or longer. Utility planning cycles and the rapid pace of renewable deployments means that shorter term grid balancing needs are better met by other resources with faster deployment schedules.
- **Costs**: PSH project costs are site specific however, the cost estimate range is from $1,700/kilowatt (kW) to $2,500/kW or $165/kWh based on a 1,000 MW project[3]. Some total project costs can surpass $1 billion dollars requiring significant access to capital and long-term revenue certainty.
- **Revenue uncertainty**: PSH's traditional arbitrage model for revenues (pumping during low-cost overnight hours and generating during peak load) is being undermined by a changing load and supply mix. The growing share of zero marginal resources like wind and solar means the price spread between on and off-peak periods is smaller. In addition, wind resources, which generate more during off peak periods, can provide an opportunity for PSH to provide load following or regulation services. However, this entails increasing starts and stops and other operational changes. Moreover, PSH can

[2] *See* https://energystorage.org/energy-storage-goals-targets-and-mandates-whats-the-difference/.
[3] *See* https://www.pnnl.gov/pumped-storage-hydropower-psh

provide a vast array of generation and transmission services. Some of these services are compensated (operating reserves) while others are not (primary frequency response, synchronous condensing, inertia, etc.). Finally, organized wholesale markets are not designed to send long-term price signals (5+years) for capital intensive assets like pumped storage[4].

- **Inequitable policy treatment**: Despite PSH's history of integrating variable energy resources, it is not an eligible technology under most State Renewable Portfolio Standards (RPSs). Even in States that have mandated energy storage procurements, those mandates and timelines tend to favor batteries. Additionally, pumped storage (and other storage technologies) are not eligible for the federal investment tax credits whereas wind and solar projects are.
- **Environmental perceptions**: All new PSH projects will have some environmental impact with open-loop projects typically having a greater impact than closed-loop or "off-river" projects. Unfortunately, local opposition from stakeholders can be a significant obstacle if these environmental impacts and project benefits are not communicated effectively.

Recommendations

1. A standard 'model' for storage should be agreed to for all decision makers to use when comparing technologies.
2. Congress should pass a federal storage tax credit 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. As a matter of fact, any government mandates or incentives should be consistent/the same for all technologies which prevents government policy from picking technology winners and losers
3. Vertically integrated states should require consideration of energy storage resources in long-term planning processes, including requiring equal consideration with traditional resources and ensure that their modelling fairly represents all technologies.
4. 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. For instance, only MISO and CAISO have created ramping products to manage variability in net load. Other examples of undercompensated services include 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.
5. RTOs and ISOs should work with FERC to 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.
6. 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.
7. 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.
8. Request FERC to streamline the licensing process even further for low-impact pumped storage hydropower, such as off-channel, modular or closed-loop projects.

[4] As an example to the trend toward shorter-term markets, FERC recently ended a 7-year capacity price lock in ISO-NE.