Pumped Storage Hydro: Reliable Choice for the New Electric Storage Era

Thomas N. Russo

The use of electric storage is a critical component to the integration of intermittent clean energy technologies on the electric grid. That being said, however, just mentioning Pumped Storage Hydro (PSH) to some stakeholders often unleashes a torrent of criticism of how its use adversely affects riverine and lake aquatic systems. In addition, opponents cite the high cost of PSH as an argument against using PSH as an energy storage technology. This opposition explains, in part, why only 42 PSH projects were built in the United States since 1929 by electric utilities, and public power and water authorities like the New York Power Authority, California Department of Water Resources, and Grand River Dam Authority.

At the end of 2015, PSH projects comprised 21.6 gigawatts (GW) of the total installed capacity of 101 GW of US hydropower generation. Despite the focus on electric battery storage by regulators and electric grid stakeholders, PSH comprises the majority (~97 percent) of the utility-scale electricity storage.

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A major hurdle for PSH developers is how to value and price the many ancillary services PSH provides to electric system reliability.

The Federal Energy Regulatory Commission (FERC) licensed 24 of the PSH projects. Since 1992, FERC has licensed only seven brand-new PSH projects proposed by merchant developers. However, three of these projects were never constructed due to failure to begin construction.[1] The remaining four projects are in the process of financing the projects and negotiating power purchase agreements. Another major hurdle for PSH developers is how to value and price the many ancillary services PSH provides to electric system reliability. Ancillary services include regulation service, reactive service, synchronized reserve service, day-ahead scheduling reserve, voltage control, and black start service.[2] These ancillary services will become even more critical as intermittent wind and solar power generation

[1] The Summit Pumped Storage Project (P-9423), Mount Hope Pumped Storage Project (P-9401), and the Blue Diamond Pumped Project Storage (P-10756) were never built and surrendered.

[2] AEP Energy. (2017, September 21). *Ancillary service—Understanding the basics.* Retrieved from https://www.aepenergy.com/2017/09/21/september-2017-edition/.

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comprise a more significant percentage of future electricity resources.

Developers are currently studying the feasibility of more than 30 PSH projects as a result of FERC Order 841 (**Figure 1**). If constructed, these projects would add 20,041 megawatts (MW) of energy storage to the US grid. An additional 14 preliminary permit applications[3] totaling approximately 19,000 MW are currently pending at FERC; most of the studies are for projects located in Arizona and California. As of June 1, 2019, FERC was processing 11 license applications of PSH projects with a total capacity of 7,065 MW. Brand-new PSH project license applications account for 2,073 MW of total capacity.

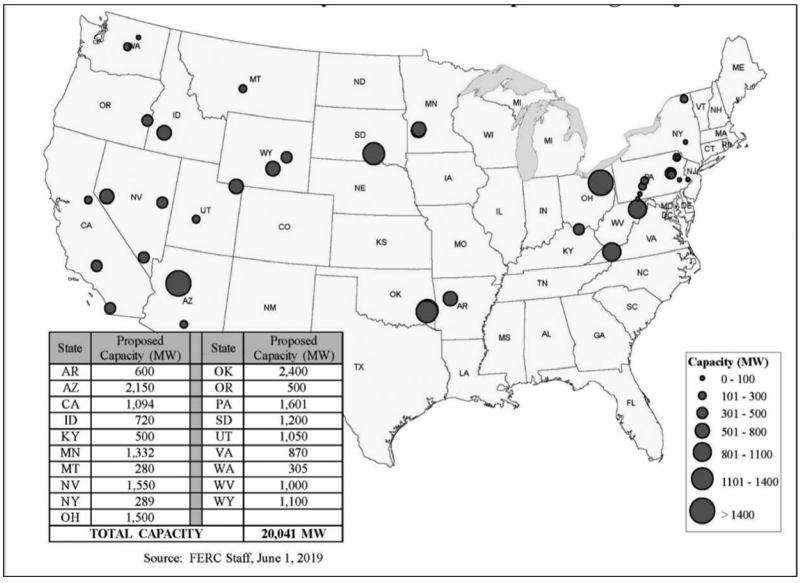
MARKET IMPACTS OF FERC ORDER 841

On February 15, 2018, FERC issued Order 841, which established a benchmark for electric storage technologies, including PSH, to participate in wholesale electricity markets. The order removed barriers to PSH participation in capacity, energy, and ancillary service markets operated by regional transmission organizations (RTOs) and independent system operators (ISOs). The order requires each RTO and ISO to revise tariffs to establish a participation model consisting of market rules that recognizes the physical and operational characteristics of storage resources, and facilitates their participation in wholesale electricity markets.

Progress to date in updating the tariffs has been slow. Most grid operators filed proposed tariff revisions to FERC in December 2018. The Energy Storage Association (ESA) and other stakeholders identified various concerns with the proposed tariffs. For example, in response to PJM, the ESA protested a proposed method to use a 10-hour duration test to qualify energy storage for capacity market participation, while in CAISO, the ESA sought clarification that transmission services charges would not be applied. In April 2019, FERC issued "deficiency letters" asking the grid operators to explain potential problems with their Order 841 compliance plans identified by commenters. The grid operators have subsequently responded to FERC; however, most of the issues identified by ESA and the stakeholders remain. Some states petitioned FERC for a

[3] A preliminary permit, issued for up to four years by FERC, does not authorize construction; rather, it maintains priority of application for license (i.e., guaranteed first-to-file status) while the permittee studies the site and prepares to apply for a license.

Figure 1. Issued FERC Preliminary Permits for Pumped Storage Projects



State	Proposed Capacity (MW)	State	Proposed Capacity (MW)
AR	600	OK	2,400
AZ	2,150	OR	500
CA	1,094	PA	1,601
ID	720	SD	1,200
KY	500	UT	1,050
MN	1,332	VA	870
MT	280	WA	305
NV	1,550	WV	1,000
NY	289	WY	1,100
OH	1,500		
TOTAL CAPACITY			20,041 MW

Source: FERC Staff, June 1, 2019

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state-by-state opt-out of Order 841; however, FERC denied their requests on May 6, 2019.[4]

The states and RTO/ISO markets will play a significant role in approving electric batteries and some closed-loop PSH storage projects that FERC previously found nonjurisdictional. However, Congress passed the America's Water Infrastructure Act of 2018, which contains specific provisions requiring FERC to play a more significant role in incenting and licensing new closed-loop PSH projects and those that use abandoned mine sites.

GAINING ACCEPTANCE OF PSH BY REDUCING ENVIRONMENTAL IMPACTS

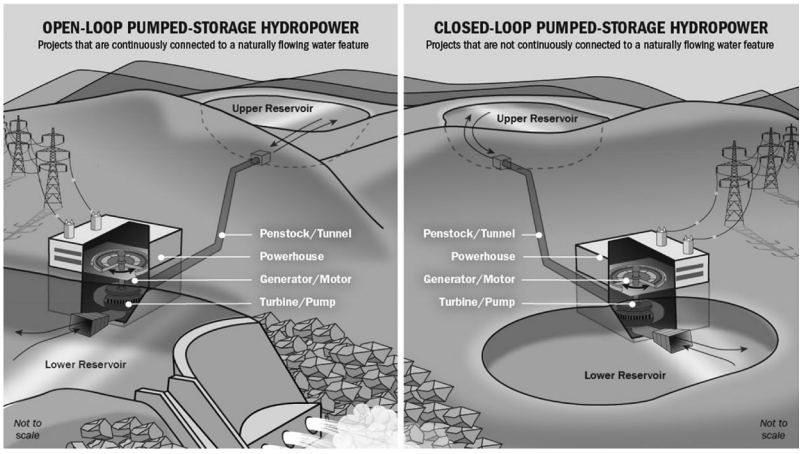
There are two kinds of Pumped Storage Hydropower resources—open-loop and closed-loop. Most of the existing PSH projects are open-loop projects connected to a naturally flowing water feature such as a river or lake. Generally speaking, these projects are vehemently opposed by federal and state agencies, environmental groups, and other stakeholders due to the potential significance and magnitude of adverse impacts on water quality, aquatic life, and recreational use on the upper reservoir and downstream of the project powerhouse (**Figure 2**).

Closed-loop PSH projects virtually avoid adverse impacts to the aquatic environment, due to the fact they are not connected or dependent upon a naturally flowing river or lake for a water source. Instead, closed-loop PSH involves the construction of two new man-made reservoirs that generally rely on groundwater for initial filling and makeup water lost through evaporation. With closed-loop PSH projects, the focus of any environmental review required by the National Environmental Policy Act (NEPA) shifts to land use and wildlife resources, and cultural and recreational resources caused by the construction of artificial reservoirs and the preliminary transmission line.

Because closed-loop PSH projects are not connected to naturally flowing water features, proposed projects often reduce the scope of FERC's environmental review and involvement of some agencies. Developers are not required to obtain a Clean Water Act Section 401 water quality certificate or, where applicable, a determination under the Coastal Zone Management Act. Hence, the developers and FERC's workloads are reduced. Nevertheless, if FERC processes the license

[4] Gheorghiu, I. (2019, May 17). FERC commissioners deny opportunity for state-by-state opt out of storage order. *Utility Dive*. Retrieved from https://www.utilitydive.com/news/ferc-commissioners-deny-opportunity-for-state-by-state-opt-out-of-storage-o/554984/.

Figure 2. Open-Loop and Closed-Loop Pumped Storage Hydropower



Source: Federal Energy Regulatory Commission.

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application, then all other federal and state recommendations on the proposed PSH project are considered and, where appropriate, are included in any project license issued if the project is on federal land or a reservation. PSH developers must obtain a special use permit from the federal land management agency.

DOES A CLOSED-LOOP PSH REQUIRE A FERC LICENSE?

Recently, FERC responded to several requests by developers for a Declaration of Intention on whether specific proposed closed-loop PSH projects located in Pennsylvania were jurisdictional and required a FERC license.[5] In those cases, FERC staff ruled that a hydropower project—and particularly a closed-loop pumped storage project—that uses only groundwater as its water source will not require FERC licensing *if* the project does not trigger other jurisdictional tests listed below.[6] However, a closed-loop PSH project that relies on groundwater is still required to apply for a FERC license if it has one of the following characteristics:

- Located on federal land or a federal reservation (military base)
- Uses surplus water or water power from a government dam
- Affect the interests of interstate or foreign commerce

Not having to obtain a FERC license might at first appear to be a bonus to a project developer. However, the proposed project must still be reviewed and approved by state and local authorities before construction can begin. This could be problematic for some developers, because most states have not yet developed their hydropower review process to examine environmental, engineering, and dam safety issues. In these instances, states will most likely borrow heavily from the existing FERC process, which includes such reviews. In the event these states do develop such reviews, the process will take time and perhaps be even longer than FERC's current review process.

Project investors may have a say in the decision of whether or not to apply for a FERC license. In the past, investors have often viewed a hydropower project's FERC license as evidence the project is economically feasible and safe, and meets the required engineering and environmental standards. FERC has historically ensured the project would be adequately constructed and maintained over the life cycle of the project through its compliance program. A FERC license also grants the hydro developer the right of eminent domain to obtain land rights necessary to build the project facilities, including the primary transmission line. That said, some project investors may insist on or encourage a developer to apply voluntarily for a FERC license. The license will provide investors the assurance that FERC will ensure the project is constructed, operated, and maintained properly over the 40–50-year license term.

WILL PSH BE SUPPORTED BY STATE AND REGIONAL ELECTRICITY MARKETS?

Open-Loop PSH

Generally speaking, most stakeholders recognize that energy storage projects are vital to ushering in more renewable electricity generation, and ultimately achieving state goals of decarbonizing the electric power sector and addressing climate change. However, whether state and regional stakeholders support PSH ultimately depends on the significance of the project's environmental impacts and whether the project contributes to decarbonizing the electric grid. Most

[5] FERC Docket No. DI17-11-000—the proposed 500-MW Pennsylvania Pump Storage Project, to be located near the Borough of Shenandoah, in Schuylkill County, PA; FERC Docket No. DI18-2-000—the proposed 450-MW Old Forge Bore Hole Reclamation Pump Storage Project, to be located near the Borough of Duryea, in Luzerne and Lackawanna Counties, PA; and FERC Docket No. DI18-3-000—the proposed 200-MW Vandling Drift Reclamation Pumped Storage Project, to be located near the City of Vandling, in Wayne County, PA.

[6] Gerard, M., & Hites, J. (2018, July 2). FERC confirms no licensing requirement for certain groundwater-only pumped storage projects. *Troutman and Sanders Washington Energy Report*. Retrieved from https://www.troutmansandersenergyreport.com/2018/07/ferc-confirms-no-licensing-requirement-certain-groundwater-pumped-storage-projects/.

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open-loop PSH projects will likely continue to be controversial and publicly opposed, even in the event a developer agrees with applicable federal, state, and local recommendations to mitigate impacts to less than significant levels. Furthermore, project developers will likely be faced with delays through the FERC appeal process, and the potential for litigation after any license is issued.

While FERC's NEPA environmental review might well be legally sufficient, the most significant hurdle for any open-loop PSH developer will be to obtain a Clean Water Act Section 401 water quality certificate (WQC). The WQC could take years for a project developer to receive, even though many in the hydropower industry have recently celebrated the D.C. Circuit Court's *Hoopa Valley Tribe* case decision.[7] For developers that have been actively seeking WQC permits, this is a positive development, as FERC has relied on the court case and determined that the WQC in a few hydropower and natural gas pipeline cases[8] has been waived. Nevertheless, I believe states could frustrate open-loop PSH by not issuing the WQC within the one-year period. In these instances, the state will deny the WQC without prejudice, citing the need for additional information, and leave it up to the developer to refile. States could also frustrate open-loop PSHs if such projects are not consistent with their state's specific Renewable Energy Portfolio or long-term energy plans. The latter strongly depends on whether PSHs are considered a necessity to achieve long-term renewable energy goals.

[7] On January 25, 2019, in *Hoopa Valley Tribe v. FERC*, No. 14-1271 (D.C. Cir., Jan. 25, 2019), the court ruled that the states of Oregon and Washington waived their authorities under Section 401 of the Clean Water Act (CWA), by failing to rule on the applicant's submitted application for water quality certification within one year from when it was initially filed in 2006. The applicant for many years had followed, at the request of the states, the common industry practice of "withdraw-and-resubmit" of its water quality certification application in an attempt to annually reset the one-year time period for the states to act, as established under CWA Section 401. The D.C. Circuit in *Hoopa Valley Tribe* invalidated this practice as a means of resetting the statutory clock, instead holding that the clear text of the CWA establishes that "a full year is the absolute maximum" time for a state to decide on a water quality certification application.

[8] See *Troutman and Sanders Washington Energy Report* at https://www.troutmansandersenergyreport.com/?s=Hoop.

Closed-Loop PSH

Stakeholders and the general public in the Pacific Northwest are no strangers to hydropower projects, and are well-acquainted with their environmental, social, and recreational impacts. Nevertheless, some stakeholders are taking a fresh look at hydropower as a regional energy storage solution that can help usher in more wind and solar generation projects and address climate change.

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Recent evidence shows that closed-loop PSH projects located on federal lands in Oregon and Washington have not been controversial mainly because they are not affecting wild populations of Pacific salmon and steelhead protected under the Endangered Species Act. For example, on May 1, 2019, Rye Development received a FERC license for its 393.3-MW Swan Lake Project, which is being jointly developed with National Grid Ventures. Despite no impacts to naturally flowing water features, FERC prepared an environmental impact statement (EIS) to meet its NEPA obligations to address the construction of 33 miles of new high-voltage power lines that will run across federal and private land. The project located approximately 11 miles northwest of Klamath Falls, Oregon, will serve as a regional electric storage project in the Pacific Northwest capable of storing up to 9 hours, or 3,556 megawatt-hours (MWh), by 2025.

Absaroka Energy was one of the first developers to build and license a closed-loop PSH project in Montana, the 400-MW Gordon Butte project. Since the project did not affect a free-flowing waterbody and environmental impacts were limited, FERC prepared an Environmental Assessment (EA) instead of an EIS. FERC issued the project license in December 2016.

Rye Development is in the early stages of developing the 1,200-MW Goldendale Closed-Loop PSH Project near the John Day Dam on the Columbia River, which will serve the Pacific

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Northwest (**Figure 3**). The proposed project will cost an estimated $1 billion and, when completed, will serve as a regional electric storage project in the Pacific Northwest capable of storing up to 20 hours, or 25,506 MWh, by 2028.

Under Section 3004 of the America's Water Infrastructure Act of 2018, FERC developed an expedited licensing process for closed-loop PSH projects in 2019.[9] The new process ensures FERC will issue a license order no later than two years after the commission receives a completed license application.

Developers of closed-loop PSH projects must consult closely with applicable agencies and undertake a rigorous pre-filing process to gain the expedited two-year review. They must also demonstrate the proposed project meets the following qualifications under Section 35(g)(2) of the Federal Power Act:

(i) The project will cause little to no change to the existing surface and groundwater flows and uses.

(ii) The project is unlikely to adversely affect species listed as a threatened species or endangered species, or designated critical habitat of such species, under the Endangered Species Act of 1973.

The new regulations should incent the development of closed-loop PSH projects. However, the two years stated in the America's Water Infrastructure Act of 2018 is similar to current Office of Management and Budget performance goals in FERC's budget request.[10] I believe FERC should prioritize closed-loop PSH projects and set a goal of issuing a license no later than one year after it receives a completed license application—entirely achievable given the fact FERC does not need to await the issuance of a WQC.

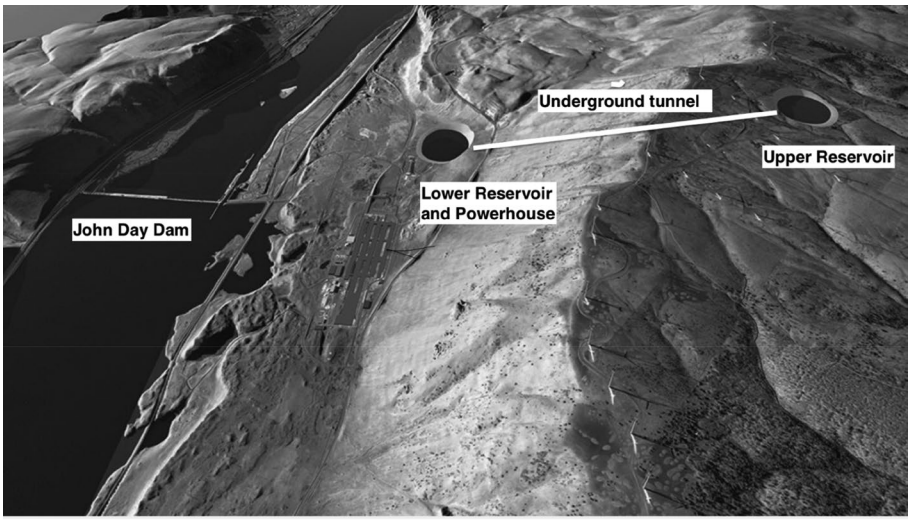
CLOSED-LOOP PSH AT ABANDONED MINE SITES

The America's Water Infrastructure Act of 2018 required FERC to hold a technical conference to explore potential opportunities for development of closed-loop PSH development at

[9] Federal Energy Regulatory Commission. (2019, April 18). *FERC finalizes expedited hydro licensing process.* Docket No. RM19-6-000. Retrieved from https://www.ferc.gov/media/news-releases/2019/2019-2/04-18-19-H-1.asp#.XRumupNJGqA.

[10] FERC's *Budget and Performance Report*, https://www.ferc.gov/about/strat-docs/requests-reports.asp.

Figure 3. Proposed Goldendale Closed-Loop PSH Project Near the Columbia River



Source: Modified from Rye Development.

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abandoned mine sites. Closed-loop PSH at abandoned mines relies on using the mine as one of the reservoirs (**Figure 4**), provided there is sufficient hydraulic head[11] and volume to store water.

There are a significant number of abandoned mine sites in the United States that might be suitable for closed-loop PSH. At FERC's April 4, 2019, technical conference, the Bureau of Land Management (BLM) staff reported their database contains approximately 56,842 abandoned mines, predominantly in the western United States and Alaska. There are also nearly 39,000 additional abandoned mines on US Forest Service lands. The Office of Surface Mines representative reported there are tens of thousands of abandoned coal mines, mostly in Appalachia; 60 percent of the mines are in Pennsylvania, West Virginia, and Kentucky.

Many of the potential abandoned mine sites may be problematic in that they might present greater risks than brand-new projects. For example, 90 percent of the abandoned mines on BLM land have a physical safety hazard, while 10 percent have an environmental hazard that must be addressed. Other participants at the conference indicated that abandoned mines with insoluble rock such as iron-ore were suitable for closed-loop PSH. They also cited the challenges of determining the hydraulic head, depth, and volume of the mines since records were not always readily available.

Closed-loop PSH projects that use an abandoned mine as a reservoir may have an advantage in that construction impacts are limited. Understanding the geology of the mine is one of the most critical issues to a project developer, enabling the developer to determine the site's ability to retain water, and associated water quality that can be expected. The latter are important because the ensuing water quality can affect penstocks and pump/turbines and create other risks associated with using the abandoned mine.

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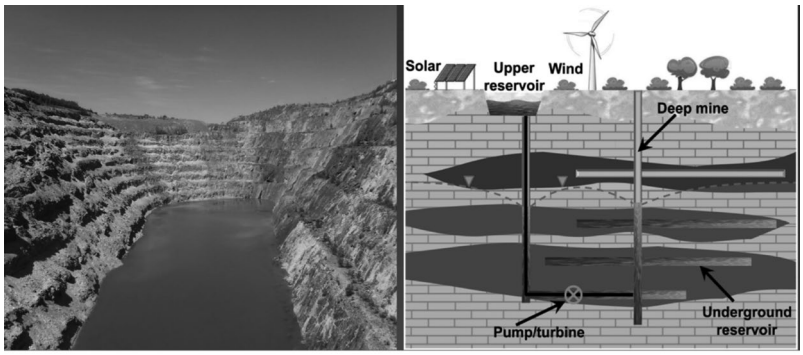
At FERC's technical conference, Absaroka Energy President and CEO Carl E. Borgquist underscored the challenges and difficulty he is facing in financing the 400-MW Gordon Butte project in Montana, which FERC licensed on December 14, 2016. He noted the project was relatively simple and clean, and did not rely on an abandoned mine site, which he believed would be much riskier. He cautioned that developers

[11] Vertical change in elevation, expressed in feet or meters, between the head (reservoir) water level and the tailwater (downstream) level.

Figure 4. Examples of Closed-Loop PSH at Abandoned Mine Sites



Source: Federal Energy Regulatory Commission.

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interested in using abandoned mine sites would be better served by asking what a banker needs to finance such a risky project first instead of developing the project and obtaining a FERC license.[12]

FERC has some experience with PSH at abandoned mines. It licensed the Mount Hope, Summit, and Blue Diamond PSH projects years ago. These three projects were never constructed and were surrendered due to their inability to finance the project and enter into a power sales agreement within the deadlines required by the Federal Power Act. Recent changes enacted by the America's Water Infrastructure Act of 2018 now give developers a total of 10 years to begin construction. While this change is welcome, the number of closed-loop PSH projects at abandoned mines that ultimately are built will strongly depend on the ability of hydro developers to find adequate information about the specific mines and the financial community's willingness to assume the higher risks of such projects.

GREATER ROLE FOR FERC IN GRID RESILIENCE AND CLIMATE CHANGE

Over the last few decades, FERC's hydropower program has primarily focused on relicensing existing hydropower projects. While the relicensing process is an opportunity to ensure existing projects are compatible with current environmental standards and uses of a waterway, the process falls short of adding a great deal of hydropower generating capacity to the grid. The renewed interest in developing PSH is definitely an opportunity for FERC to become an active agent in ensuring that energy storage projects are built and participate in the RTO/ISO markets as mandated by Order 841.

In doing so, FERC would be addressing several issues identified when Order 841 was promulgated, including grid resiliency, and removing barriers of entry for new and old storage technologies to wholesale electricity markets. FERC could also track the progress of any licensed PSH project and barriers to its participation in the wholesale electricity markets. Since most stakeholders think of electric batteries when discovering energy storage, FERC's expeditious licensing review of all PSH projects, especially closed-loop projects, could help diversify grid energy storage projects in the RTO/ISO markets

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FERC is routinely criticized for not assessing greenhouse gas (GHG) emissions associated with proposed interstate natural gas pipelines and liquefied natural gas export terminals. FERC could offset these criticisms by disclosing in its NEPA reviews and licensing orders the estimated reduction in GHG as a result of approving PSH projects. These same arguments could be used by developers of closed-loop projects to gain support from regulatory agencies and other stakeholders during the licensing process, and lay the groundwork for participating in the RTO and ISO markets. The overall effect of the latter could significantly reduce project controversy and expedite closed-loop PSH as a viable energy storage technology.

CONCLUSION

PSH, especially closed-loop projects, can make a substantial contribution to meeting the goals of FERC Order 841 and ushering in greater solar and wind energy generation. PSH provide significant electric storage capacity over long periods of time, as opposed to current electric battery storage technologies, which has shorter application times. For PSH to succeed in future energy markets, it will require FERC to not only aggressively ensure tariffs in the RTO and ISO markets are not discriminatory, but to monitor how those projects affect PSH projects it has licensed. In addition, FERC should actively prioritize and expedite project reviews on brand-new closed-loop PSH projects covered under the America's Water Infrastructure Act of 2018.

[12] At FERC Staff's April 4, 2019, Technical Conference on Closed-Loop Pumped Storage Hydropower at Abandoned Mines; see http://bit.ly/2XEbEq8.

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