U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

U.S. Hydropower Market Report

Water Power Technologies Office
January 2021

Introduction

- This is the third complete edition of the U.S. Hydropower Market Report (the first two were the 2014 and 2017 Hydropower Market Reports, published in 2015 and 2018, respectively).
- In intervening years between publishing the full report, updated data are also summarized and released, and can be found at the Oak Ridge National Lab (ORNL) HydroSource website.
- Prior to the first Market Report being published, there was a noted lack of publicly available and easily accessible information about hydropower in the United States and other important trends affecting the industry.
- This edition focuses on updated data from 2017–2019* (the years for which new data has become available since the publication of the last full report), and contextualizes this information compared to evolving high-level trends over the past 10–20 years.

* For some of the datasets in the report, the last year of data available at the time of writing was 2018

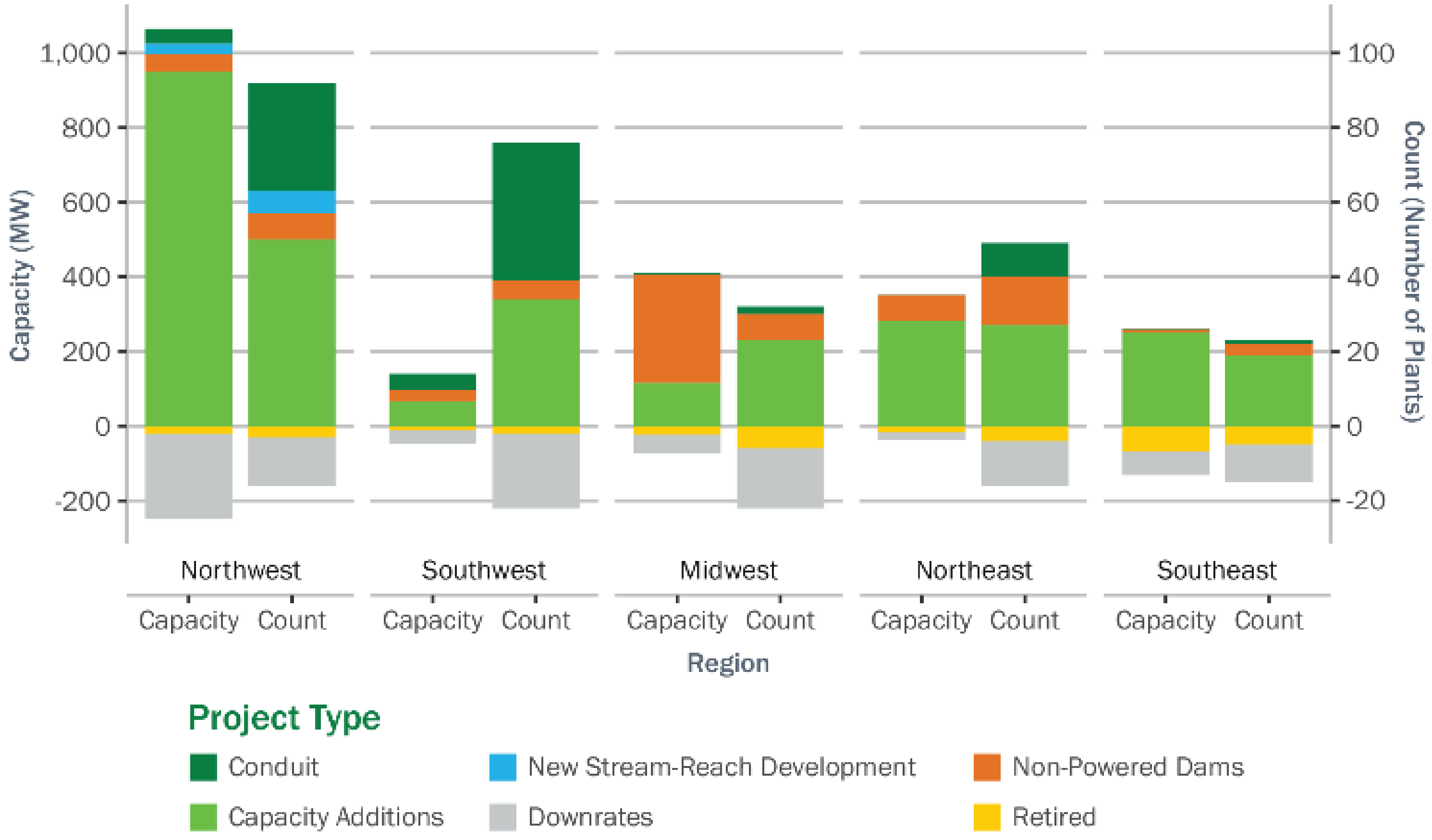
Outline

- Chapter 1 – Looking Back: An Overview of Changes Across the U.S. Hydropower and PSH Fleet
- Chapter 2 – Looking Forward: Future U.S. Hydropower and PSH Development Pipeline
- Chapter 3 - U.S. Hydropower in the Global Context
- Chapter 4 - U.S. Hydropower Price Trends
- Chapter 5 – U.S. Hydropower Cost and Performance Metrics
- Chapter 6 - Trends in U.S. Hydropower Supply Chain
- Chapter 7 – Overview of New Policies Influencing the U.S. Hydropower Market

Key Messages

1. U.S PSH capacity grew over the past decade by almost as much as all other U.S. energy storage combined (almost all growth of other storage occurred over the last decade, and was mostly all batteries)
2. Interest in PSH in the U.S. continues to grow significantly (doubling of project pipeline over 5 years)
3. Geographic interest in U.S. PSH has expanded as well (new projects being explored in PA, VA, WY, OK, OH, NY)
4. Significant and growing interest in PSH internationally (53GW of capacity across 50 projects were under construction globally at the end of 2019)
5. In 2019, hydropower capacity (80.25 GW) accounted for 6.7% of U.S. installed electricity generation capacity (hydropower capacity has increased by a net of 431 MW in 2017-2019 mostly through capacity increases at existing facilities, new hydropower in conduits and canals, and by powering non-powered dams)
6. 670 MW of hydro (129 Projects) have licensing completed but have not moved into construction (more than half of the projects had been in that state for 3 years or more)
7. FERC relicensing activity is set to more than double in the coming decade (almost half of the PSH fleet)
8. Hydropower generation (274 TWh) represented 6.6% of U.S. electricity generation and 38% of electricity from renewables in 2019 (Canadian imports contributed an additional 36 TWh of hydroelectricity in 2019)
9. Hydropower "punches above its weight" regarding provision of various ancillary services (compared to % of installed capacity, in nearly every region and metric analyzed, including black start, 1-hour ramps, frequency regulation and reserves)

Hydropower capacity changes by region and type (2010-2019)



Sources: EIA Form 860 (2010-2018), EIA Form 860 Early Release (2019), Existing Hydropower Assets dataset, FERC eLibrary

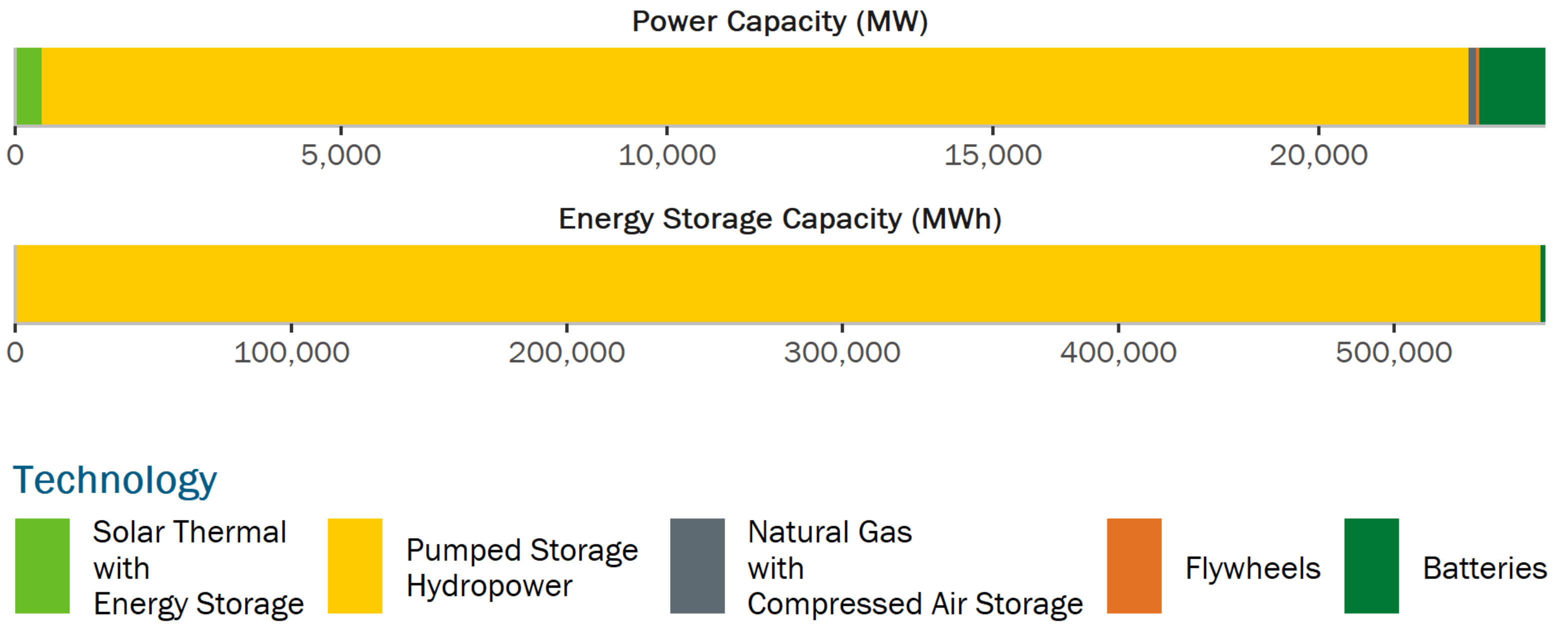
Note: Each instance of a capacity increase or decrease reported in EIA Form 860 is counted separately. Some plants reported multiple capacity changes during this period. Plant downrates are downward adjustments to the reported capacity of existing turbine-generator units or retirement of some of the units in a plant while the rest continue operating.

- ***Hydropower in the United States Continues to Grow***
  - Hydropower capacity increased by net of 431 MW since the publication of the last Hydropower Market Report (2017–2019), and a net total of 1,688 MW from 2010 to 2019.
    - In 2017–2019, there were 40 capacity additions (583.1 MW) and 21 new projects (115 MW). The new projects consisted of two new stream-reach development (NSD) projects, 15 conduit projects and powering of four non-powered dams (NPDs). There were 6 plant retirements (-51 MW) and 26 downrates (-215.8 MW) to the existing fleet.

Chapter 1 – Looking Back: An Overview of Changes Across the U.S. Hydropower and PSH Fleet

- ***Current State of Pumped Storage Hydropower (PSH)***
  - 43 PSH plants with total power capacity of 21.9 GW and estimated energy storage capacity of 553 GWh accounted for 93% of utility-scale storage power capacity (GW) and more than 99% of electrical energy storage (GWh).
    - All other utility-scale energy storage projects (mostly batteries) deployed by the end of 2019 had a combined power capacity of 1.6 GW and energy storage capacity of 1.75 GWh.

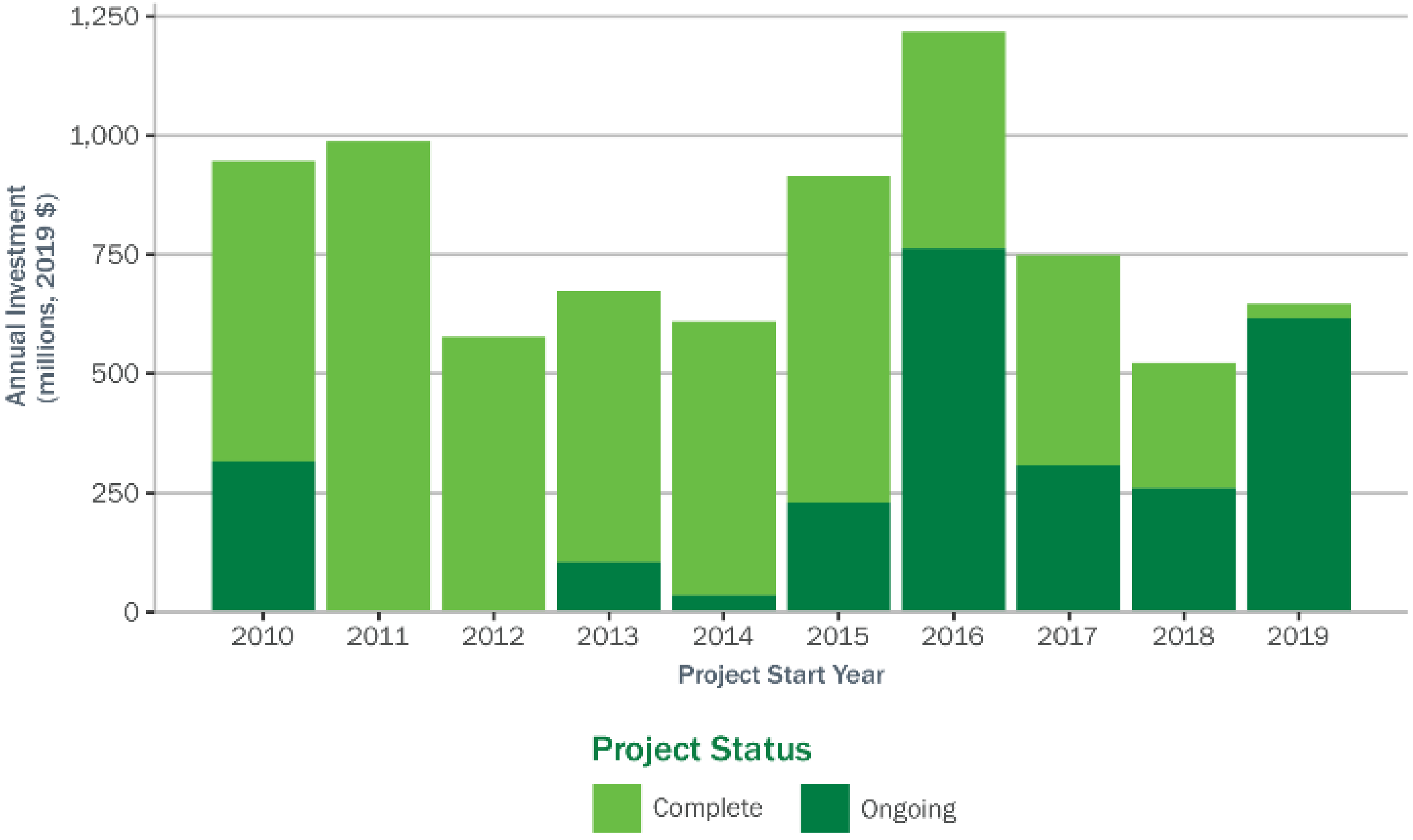
U.S. Utility-scale electrical energy storage capacity by technology type (2019)



Source: EIA Form 860 Early Release (2019)

- ***U.S. PSH capacity increased by 1,400 MW from 2010 to 2019.***
  - Except for the new Olivenhain-Hodges facility in California (42 MW), this net capacity increase resulted from upgrades to six existing PSH plants: Castaic in California, Northfield Mountain in Massachusetts, Muddy Run in Pennsylvania, and Bad Creek, Fairfield, and Jocassee in South Carolina.

Expenditures on rehabilitations and upgrades of the existing hydropower and PSH fleet

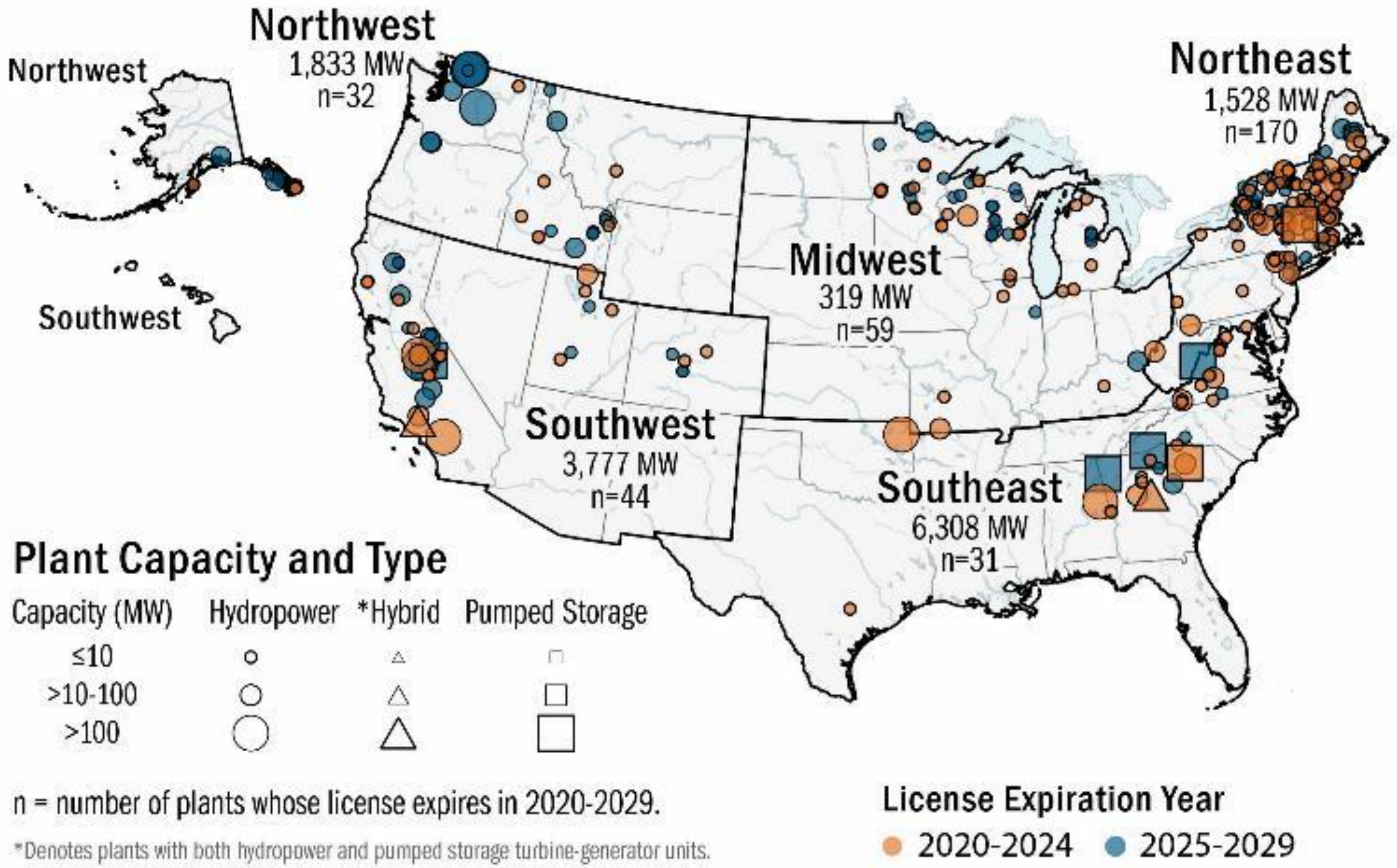


Source: Industrial Information Resources (IIR)

Note: The full value of each project is assigned to the project start year.

- ***Almost $8 Billion Invested in Refurbishments and Upgrades in the Past Decade***
  - Since 2010, $7.8 billion have been invested in refurbishments and upgrades (R&U) of the U.S. hydropower and PSH fleet. Almost $2 billion correspond to projects initiated in 2017–2019.

Hydropower and PSH plants with licenses expiring in 2020–2029

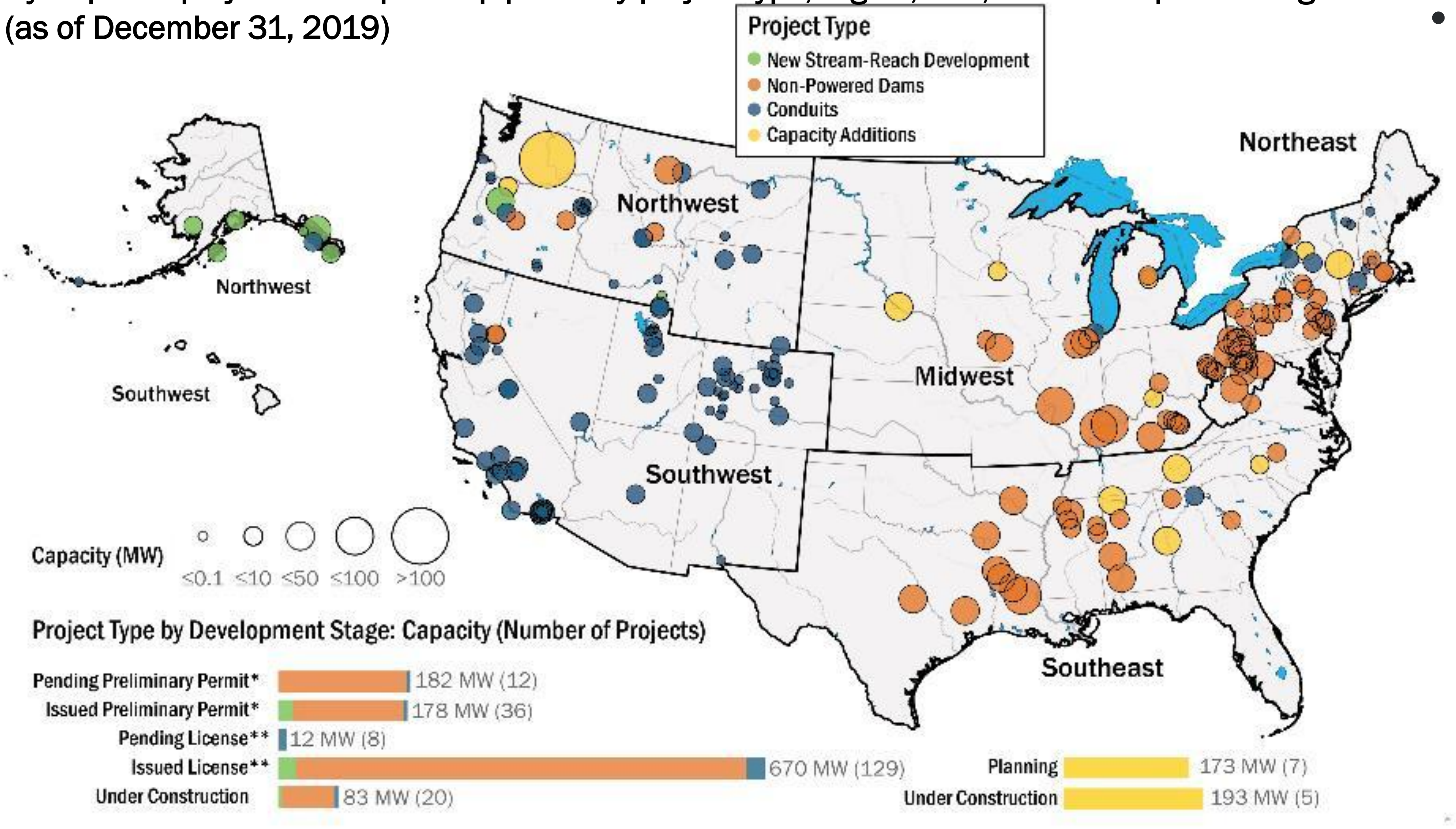


Source: Existing Hydropower Assets dataset

- ***FERC Relicensing Activity Set to More than Double in the 2020s relative to the 2010s***
  - In the 2010s, FERC issued 80 relicenses that extended the authorization to operate an additional 30 to 50 years to projects accounting for 17% (6.9 GW) of FERC-licensed hydropower capacity and 37% (6.7 GW) of FERC-licensed PSH capacity.
  - In the decade of the 2020s, 281 licenses that currently authorize 12% (4.7 GW) of installed FERC-licensed hydropower capacity and 50% (9.1 GW) of FERC-licensed PSH are set to expire.

Chapter 2 – Looking Forward: Future U.S. Hydropower and PSH Development Pipeline

Hydropower project development pipeline by project type, region, size, and development stage (as of December 31, 2019)

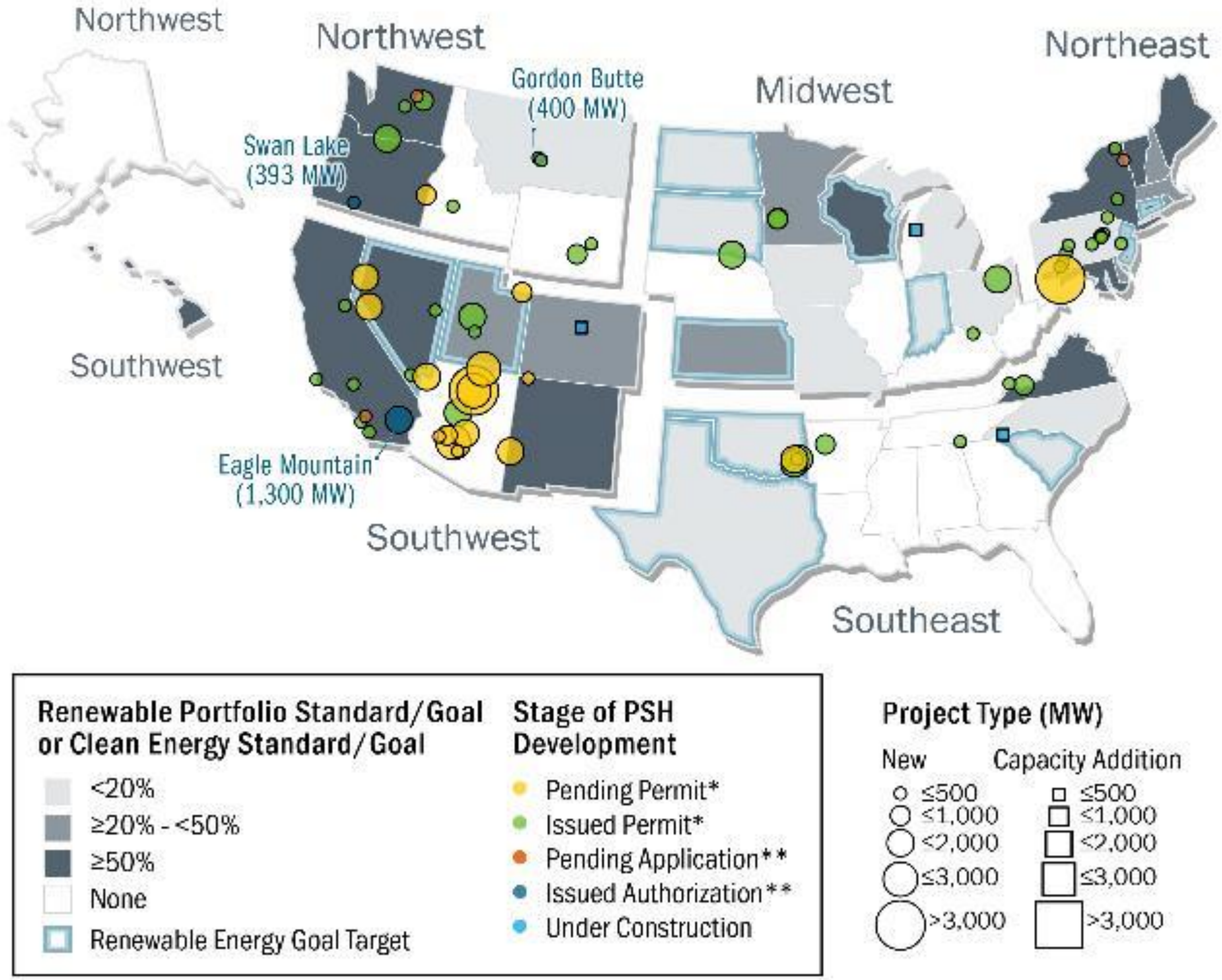


Sources: DOI: 10.21951/HMR_PipelineFY20/1756447, IIR

Note: See development stage definitions in Technical Notes slide

- ***Nearly 1.5 GW of Hydropower in the U.S. Development Pipeline at the End of 2019 (1.49 GW)***
  - More than half of these projects (670 MW) have been issued federal authorization (License) but have not started construction.
    - More than half of the projects in the pre-construction stage have spent three or more years in it.

PSH project development pipeline by region and development stage (as of December 31, 2019)



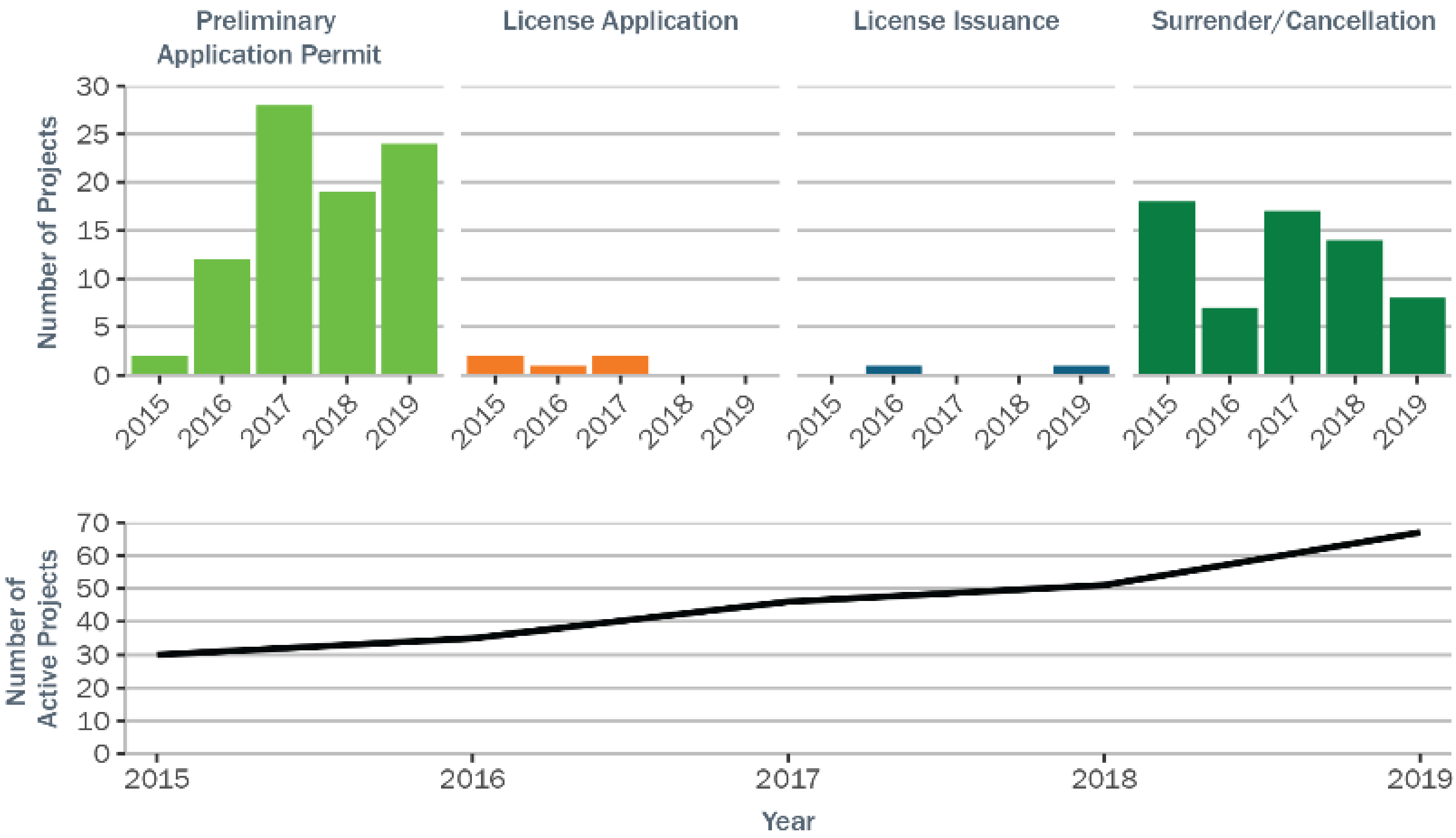
Sources: DOI: 10.21951/HMR_PipelineFY20/1756447, IIR, DSIRE

See Notes in Technical Notes slide

- ***At the End of 2019, there were 67 PSH Projects (52 GW) in the Development Pipeline***
  - Three of these projects had FERC authorization; all three were in the western half of the United States.
    - They all are closed-loop facilities.
    - They all propose 8-9 hours of storage duration.
  - Proposed new projects were distributed across 21 states and had a very wide size range (from 5 MW to 4,000 MW).
  - Additionally, three PSH projects were undergoing capacity upgrades: Cabin Creek in Colorado, Ludington in Michigan, and Bad Creek in South Carolina.

Chapter 2 – Looking Forward: Future U.S. Hydropower and PSH Development Pipeline

U.S. PSH project development activity (2015-2019)

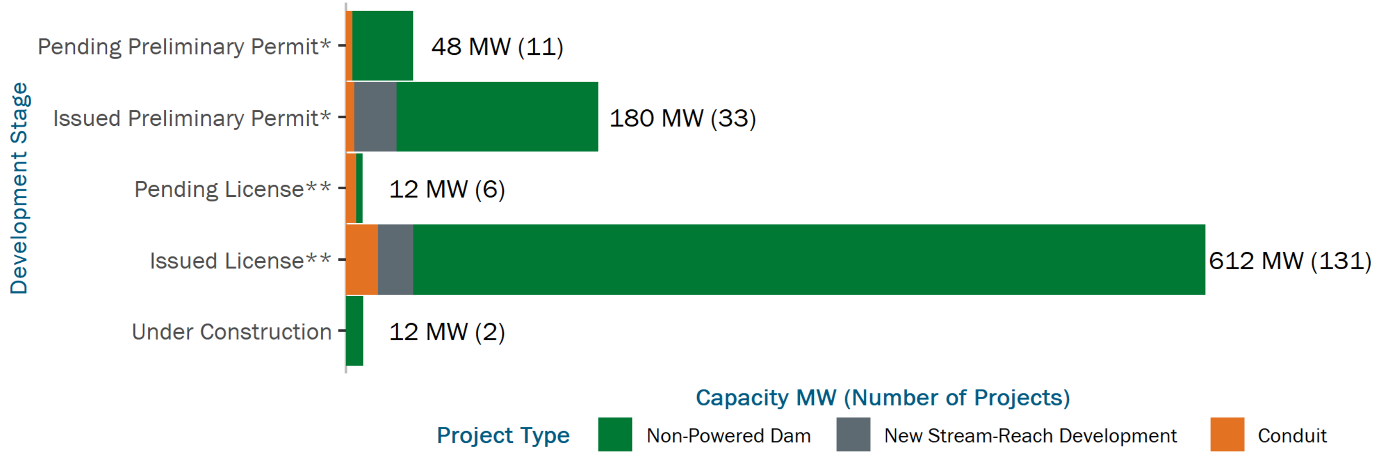


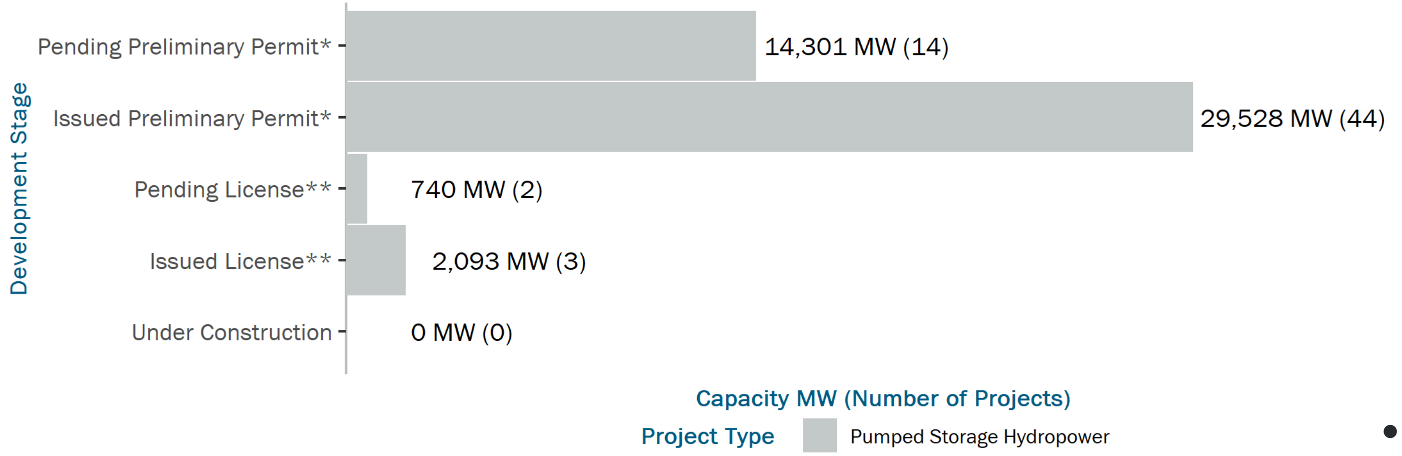
- ***The number of PSH Projects in the Development Pipeline Increased by 31% in 2019***
  - Except for 2015, more PSH projects were added to the pipeline (through preliminary permit applications) than dropped from it (through surrenders or cancellations).
  - Five developers submitted license applications in 2015–2019 and FERC issued two licenses during that period.

Sources: FERC eLibrary

Chapter 2 – Looking Forward: Future U.S. Hydropower and PSH Development Pipeline *(Update: Dec 31, 2020 snapshot)*

Hydropower and PSH project development pipeline by development stage (as of December 31, 2020)





Source: DOI: 10.21951/HMR_PipelineFY21/1772802
Note: See development stage definitions in Technical Notes slide.

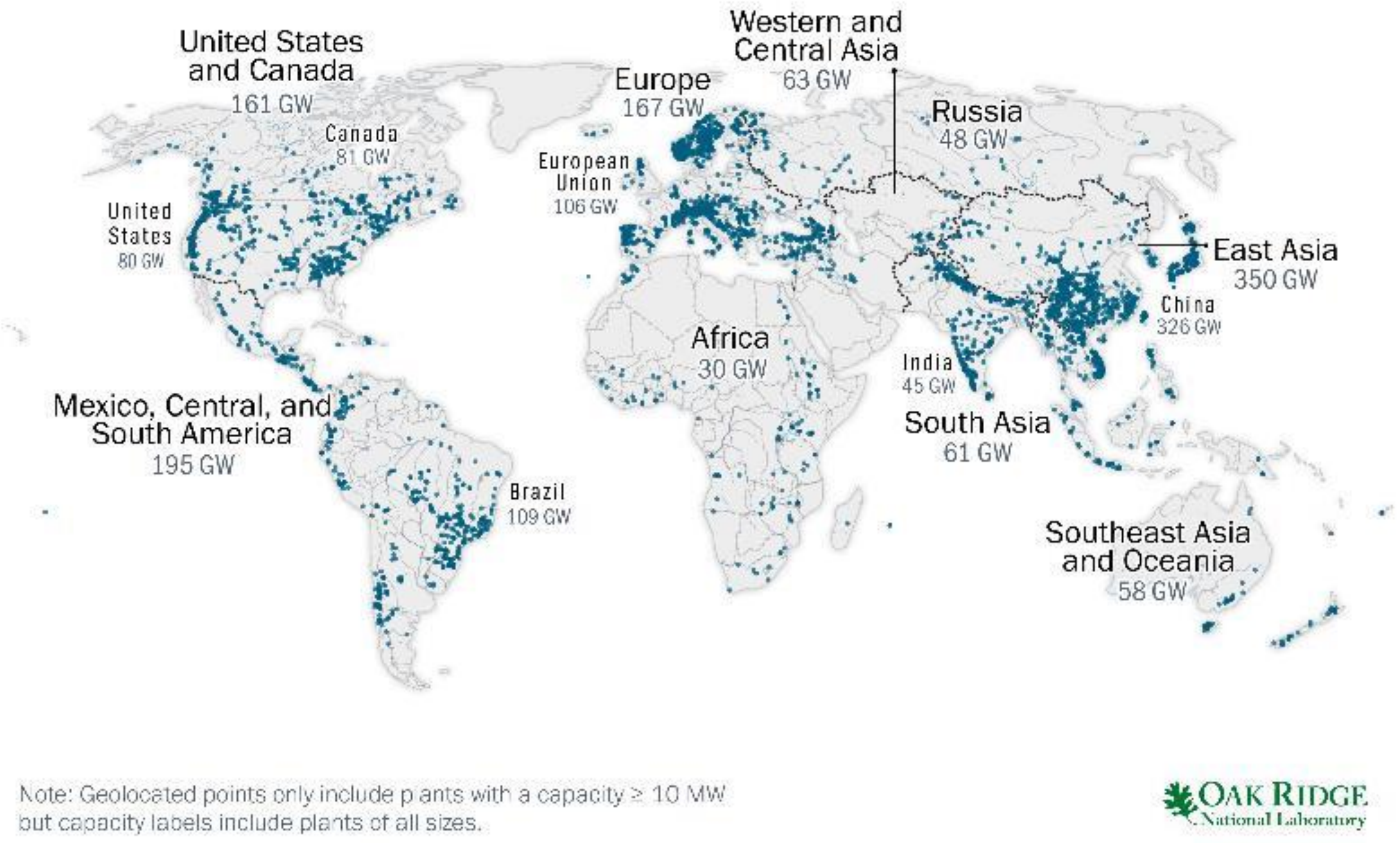
- ***At the end of 2020, 183 hydropower projects (864 MW) and 63 PSH projects (46.6 GW) were in the development pipeline***
  - ***2020 permitting activity:***
  - Sixteen preliminary permits issued:
    - 8 NPD (20.25 MW)
    - 2 NSD (20 MW)
    - 1 Conduit (2.5 MW)
    - 6 PSH (7,800 MW)
  - Eight exemption issued:
    - 1 NSD (0.0015 MW)
    - 1 NPD (0.42 MW)
    - 6 Qualifying conduits (0.80 MW)
  - No original licenses issued
  - Five projects became operational:
    - 3 Qualifying conduits (0.027 MW)
    - 2 NPD (24.17 MW)
- ***Thirteen relicenses were issued in 2020 (1,097 MW)***

Chapter 3 - U.S. Hydropower in the Global Context

- ***Global Hydropower Capacity Reached 1,150 GW at the End of 2019***
  - Hydropower is the largest global renewable by installed capacity, with 46% of global renewable generation capacity. The U.S. fleet represents 7% of global hydropower capacity.
- ***Global Hydropower Capacity Increased by 63 GW in 2017–2019***
  - 52% of the new capacity was added in China and Brazil. Hydropower additions represented 12% of global renewable generation capacity installations during that period; the shares of solar (289 GW) and wind (156 GW) were 55% and 29%, respectively.
- ***The Global Hydropower Development Pipeline Included 4,545 Projects with a Total Capacity of 414 GW***
  - In total, at the end of 2019, there were 117 GW of hydropower being constructed across 616 projects in 66 countries. An additional 297 GW of hydropower were in different phases of scoping.
- ***Global Installed PSH Capacity was 158 GW at the End of 2019***
  - 35 countries have PSH capacity. The U.S. fleet represents 14% of global PSH capacity.
- ***Projects in Planning and Construction Stages Would More than Double Global Capacity***

Chapter 3 - U.S. Hydropower in the Global Context

Map of operational hydropower plants by world region



Sources: International Hydropower Association, IIR

- ***Global Hydropower Capacity Reached 1,150 GW at the End of 2019***
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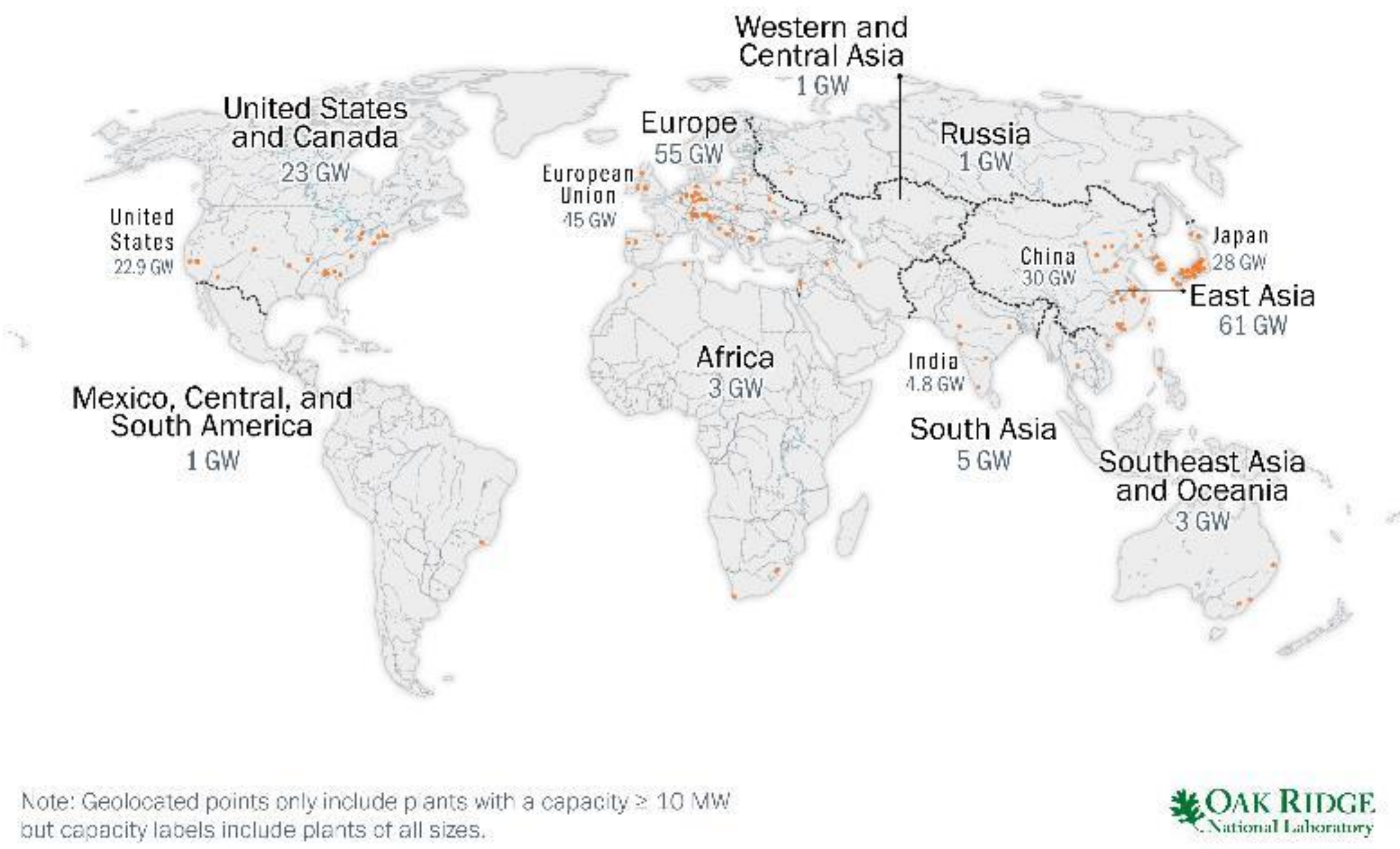
  - Hydropower additions represented 12% of global renewable generation capacity installations during that period; the shares of solar (289 GW) and wind (156 GW) were 55% and 29%, respectively.

Chapter 3 - U.S. Hydropower in the Global Context

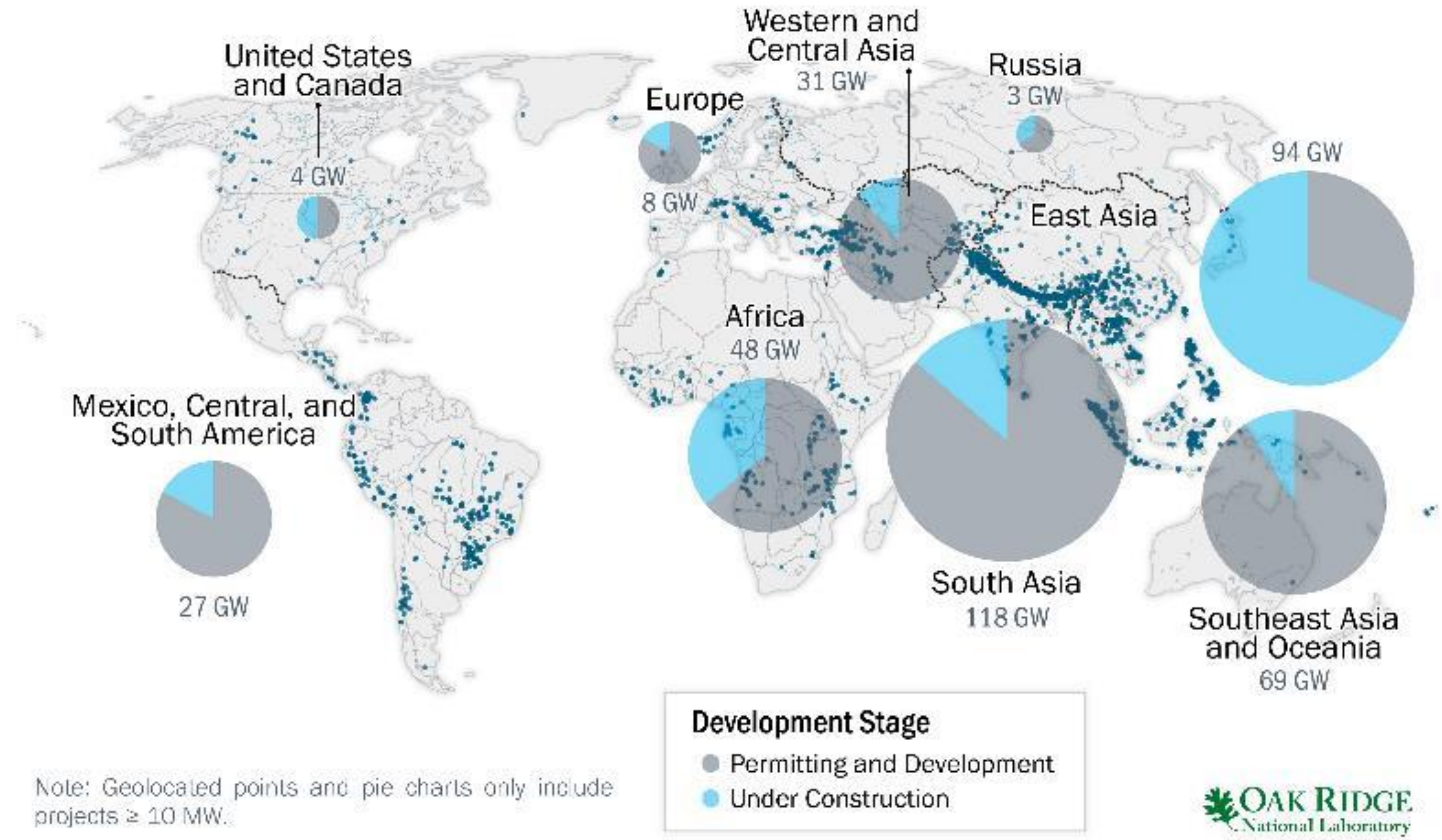
Map of operational PSH plants by world region



Sources: International Hydropower Association, IIR

- ***Global PSH Capacity Reached 158 GW at the End of 2019***
  - The top six PSH fleets (European Union, Japan, United States, China, India, and South Korea) represented 86% of global capacity.
  - The U.S. fleet represents 14% of global hydropower capacity.
- ***Twenty new PSH plants started operation in 2010–2019***
  - Eleven of them are in China and other four in European countries; the rest were distributed between United States, South Africa, Israel, South Korea and Japan.

Map of hydropower project development pipeline by region and development stage (as of December 31, 2019)



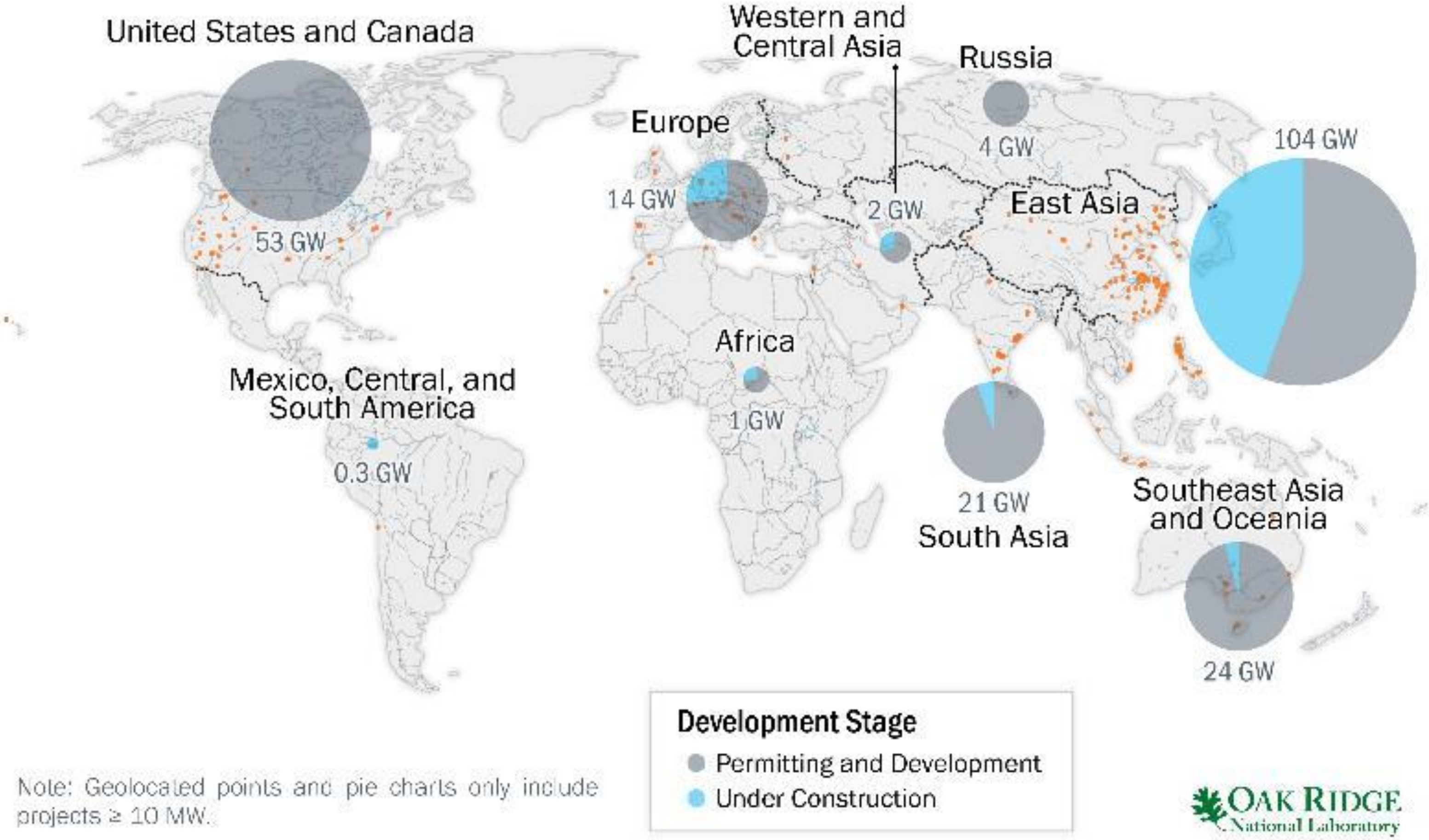
Sources: IIR, FERC

Note: The "Under Construction" category includes projects that have completed the permitting process and secured financing but have not yet broken ground.

- ***The Global Hydropower Development Pipeline Included Over 4,000 Projects with Total Capacity of 414 GW at the End of 2019***
  - Sixty-six countries were constructing 616 projects with total capacity of 117 GW at the end of 2019.
  - East and South Asia dominate the global hydropower development pipeline.

Chapter 3 - U.S. Hydropower in the Global Context

Map of PSH project development pipeline by region and development stage (as of December 31, 2019)



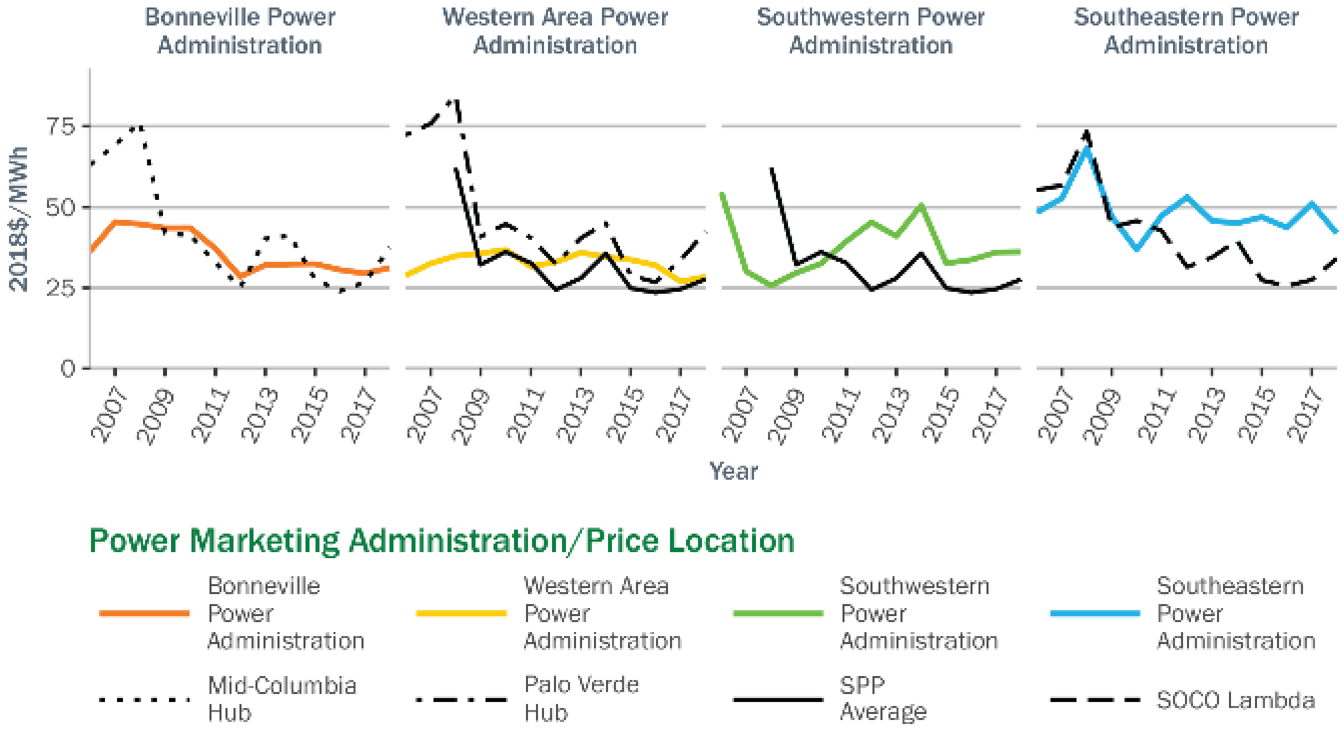
Sources: IIR, FERC

Note: The "Under Construction" category includes projects that have completed the permitting process and secured financing but have not yet broken ground.

- ***Projects in Planning and Construction Stages Would More than Double Global Capacity***
  - At the end of 2019, the global PSH development pipeline included 284 projects (226 GW).
  - Thirteen countries were constructing 50 PSH projects with total capacity of 53 GW at the end of 2019.
  - The United States has a large development pipeline but none of the proposed capacity is under construction.

- ***On Average, Federal Hydropower Prices Remain Competitive with Regional Wholesale Prices***

Average federal hydropower revenue vs. average wholesale electricity prices

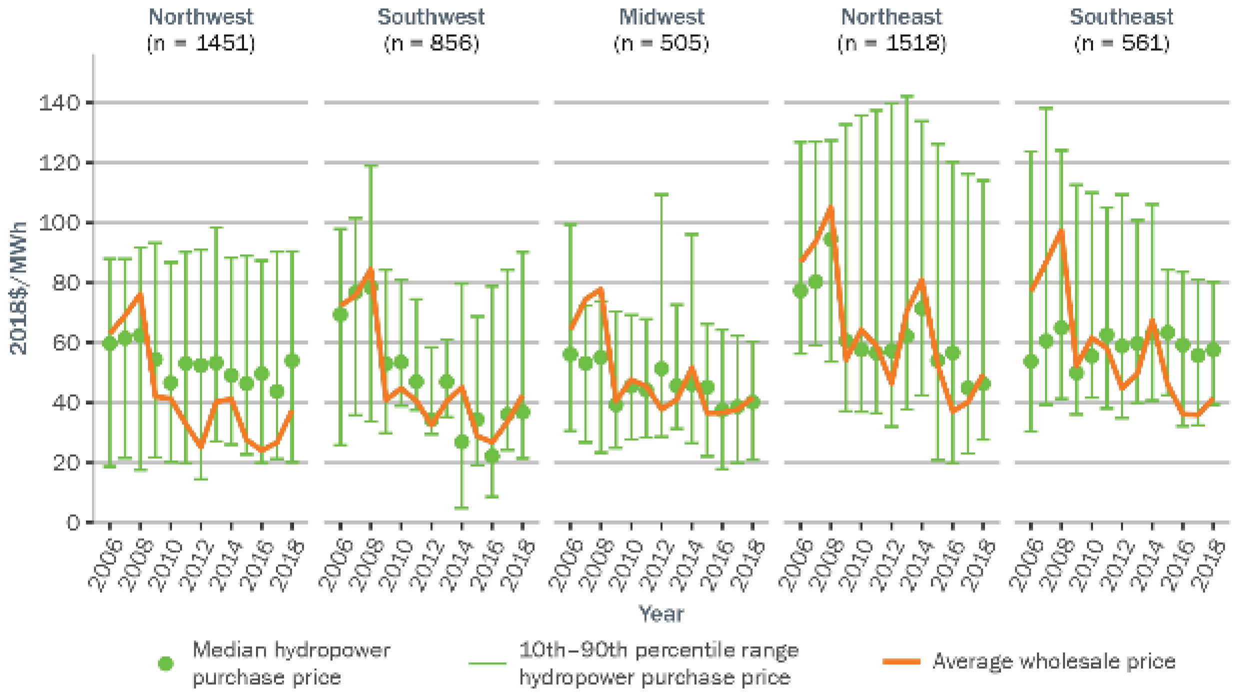


Sources: EIA Form 861, EIA Wholesale Electricity and Natural Gas Market Data, SPP State of the Market Reports, FERC Form 714

- ***U.S. Federal Power Marketing Administrations Increase Participation in Other Organized Electricity Markets***
  - September 2019:
    - WAPA's Colorado River Storage Project, Rocky Mountains Region, and Upper Great Plains–West Region announced plans to join the SPP Energy Imbalance Service market in 2021.
    - WAPA's Sierra Nevada Region announced plans to join the CAISO Western EIM in 2021.
  - December 2019:
    - Bonneville Power Administration (BPA) signed an implementation agreement to start the process of joining the Western EIM with April 2022 as the planned membership start date.

- ***The Median Hydropower PPA Price in 2018 Was $48.47/MWh—the Median PPA Price Across All Electricity Generation Technologies Was $47.61/MWh.***
  - Utilities continue to be the off-takers in most hydropower PPAs but, in recent years, other entities (e.g., universities) are also entering into purchase agreements with hydropower facilities that can help them meet sustainability goals.
  - The only corporate hydropower purchase deal that has been disclosed to date is a five-year power supply agreement between Microsoft and Chelan County Public Utility District announced in 2019.
    - In contrast, corporate and industrial buyers accounted for 22% of U.S. solar and wind procurement in 2019.

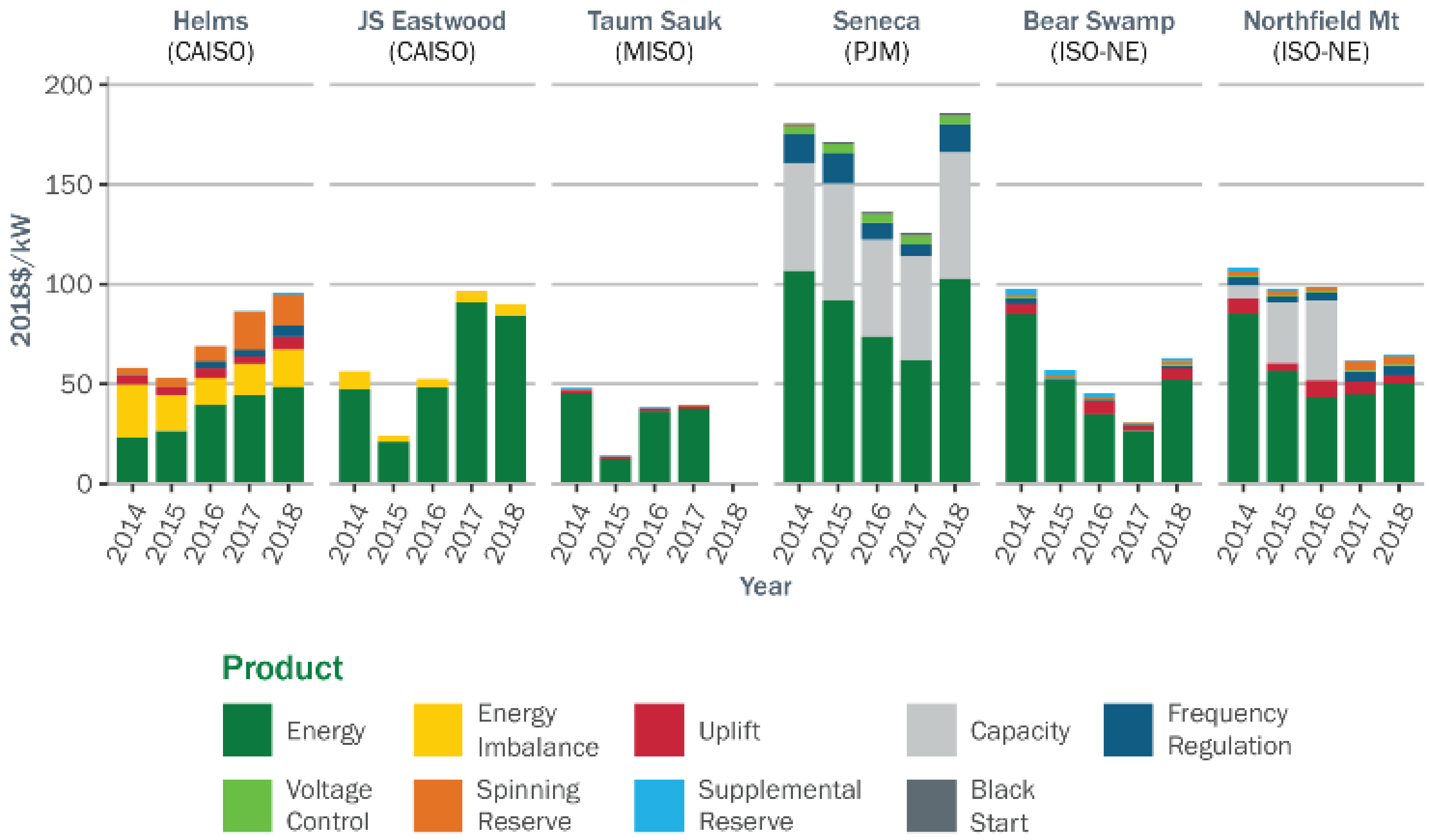
Hydropower price by region and year from power sales reported on FERC Form 1



Sources: FERC Form 1, EIA Wholesale Electricity and Natural Gas Market Data

Chapter 4 - U.S. Hydropower Price Trends

Annual revenue streams for selected PSH plants (energy + capacity + ancillary services)

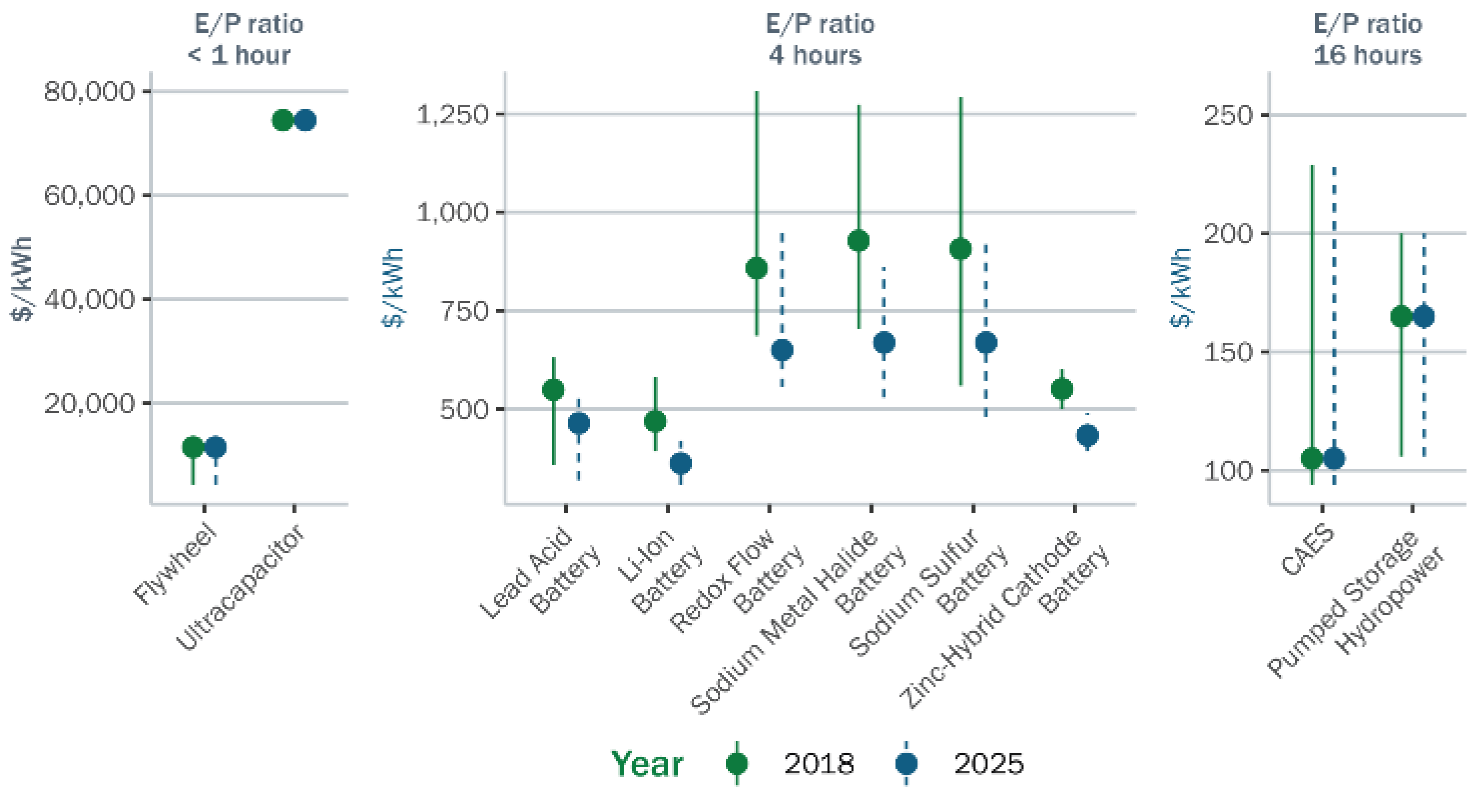


Sources: FERC Electric Quarterly Reports

Note: The plot shows gross revenue (i.e., the cost of pumping is not netted out). Taum Sauk data for 2018 are excluded because they were available only for the first quarter of that year.

- ***Detailed Transaction Data for a Set of U.S. PSH Plants in 2014–2018 Show that Energy Sales Were the Largest Revenue Stream***
  - In a few instances (Northfield Mountain in 2016; Seneca in 2017), a combination of capacity payments and ancillary service revenues accounted for more than half of annual revenue.

Energy-specific capital cost of PSH and other electrical energy storage technologies

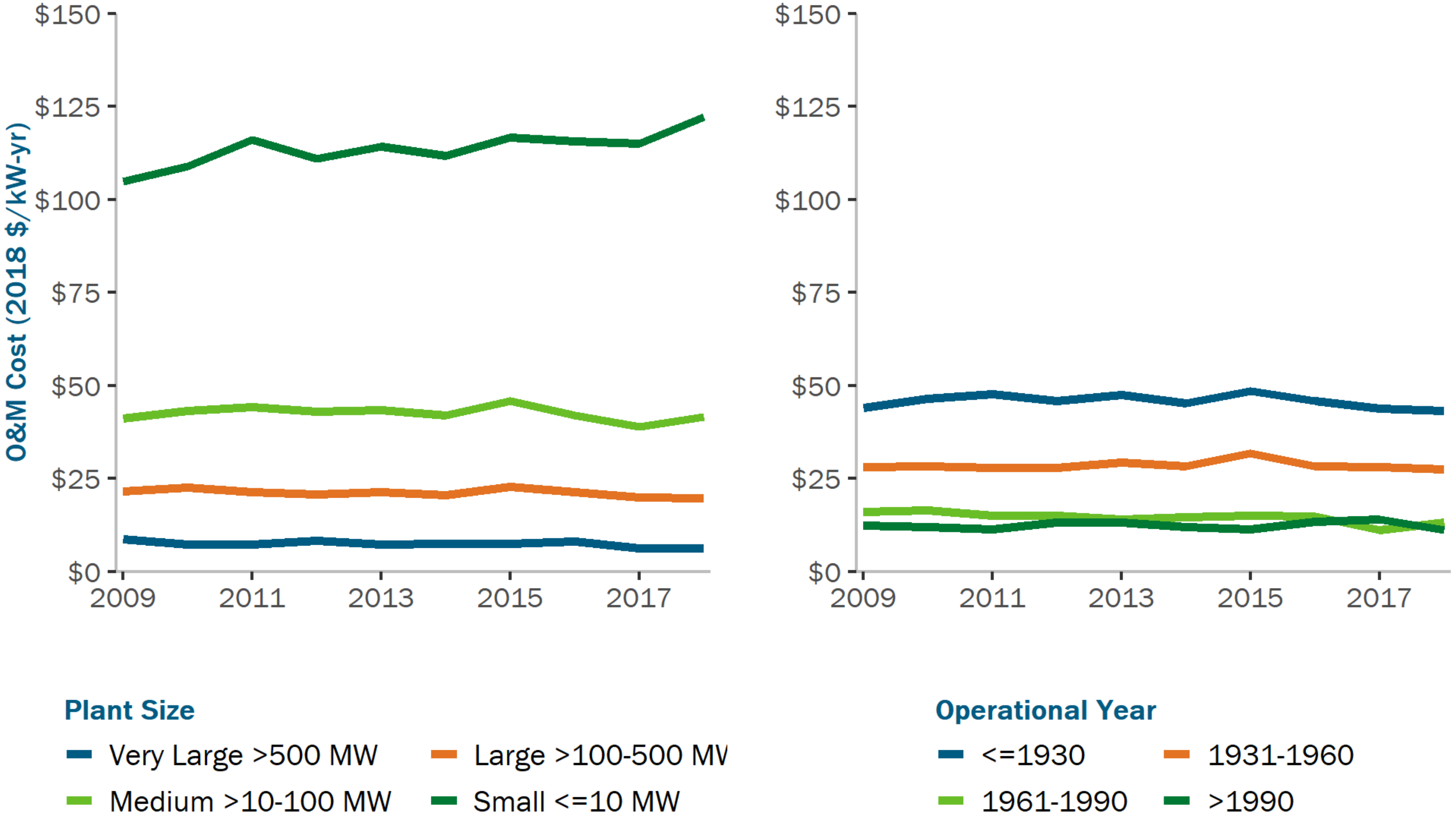


- ***PSH Continues to Be the Preferred Least Cost Technology Option for 4–16 Hours Duration Storage***
  - Energy storage cost is even lower for compressed air energy storage (CAES), but there are only two CAES projects installed worldwide (built in 1978 and 1991) versus more than 150 PSH projects.

Source: Mongird et al. (2019). Energy Storage Technology and Cost Characterization Report. No. PNNL-28866.

Chapter 5 – U.S. Hydropower Cost and Performance Metrics

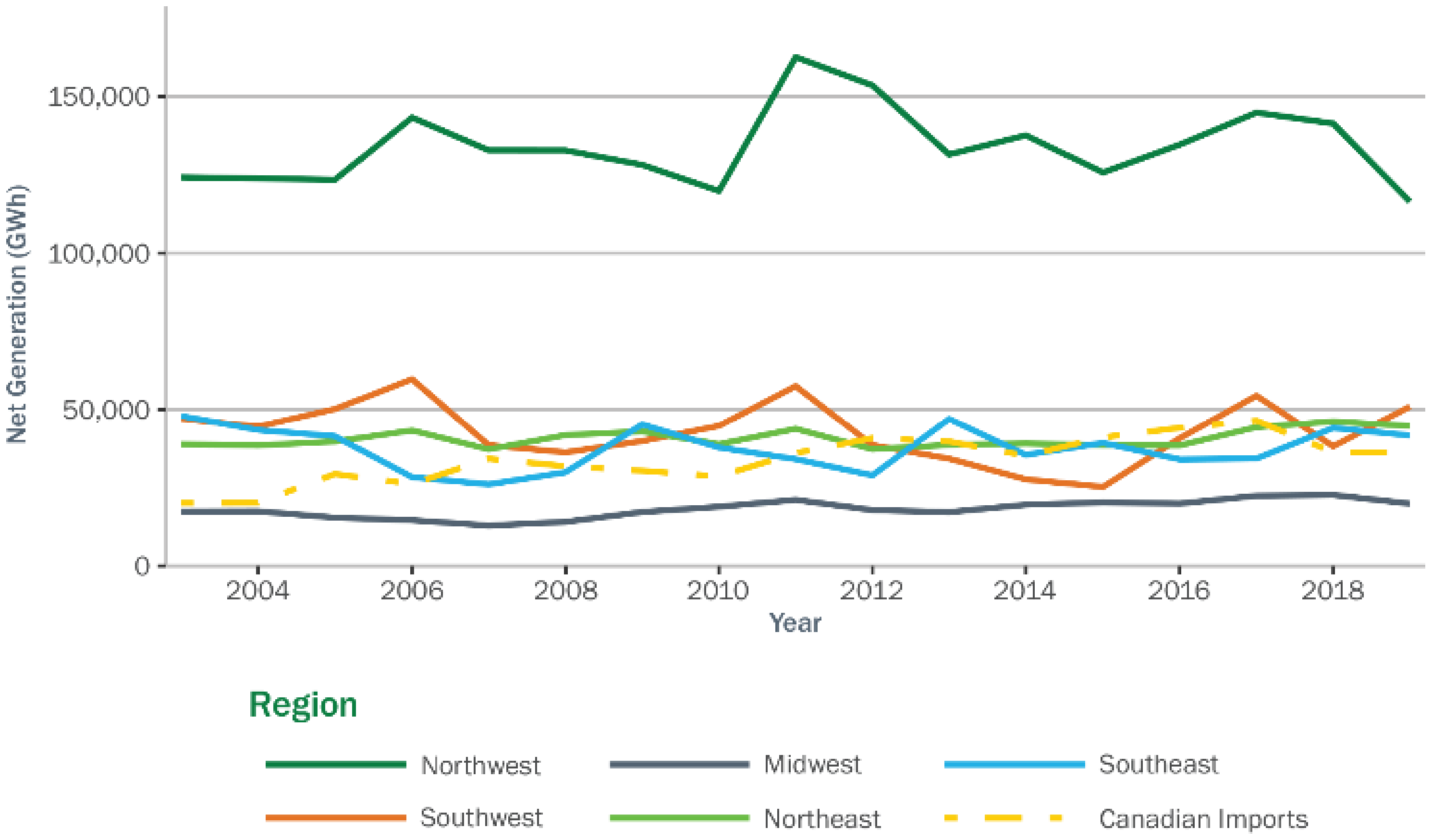
Trends in operations and maintenance costs for hydropower and PSH projects by size class and age



Source: FERC Form 1. Bureau of Labor Statistics

- ***Previously Observed Trends in Rising O&M Costs for Small Hydropower Plants Continue***
  - Small plants are the only size category for which O&M costs grew faster than inflation in 2016–2018.
  - Average O&M costs increase with plant age.
    - However, since average age increases with size, it is difficult to disentangle the effect of age and size on O&M costs.

Annual hydropower generation by region (2003-2019)

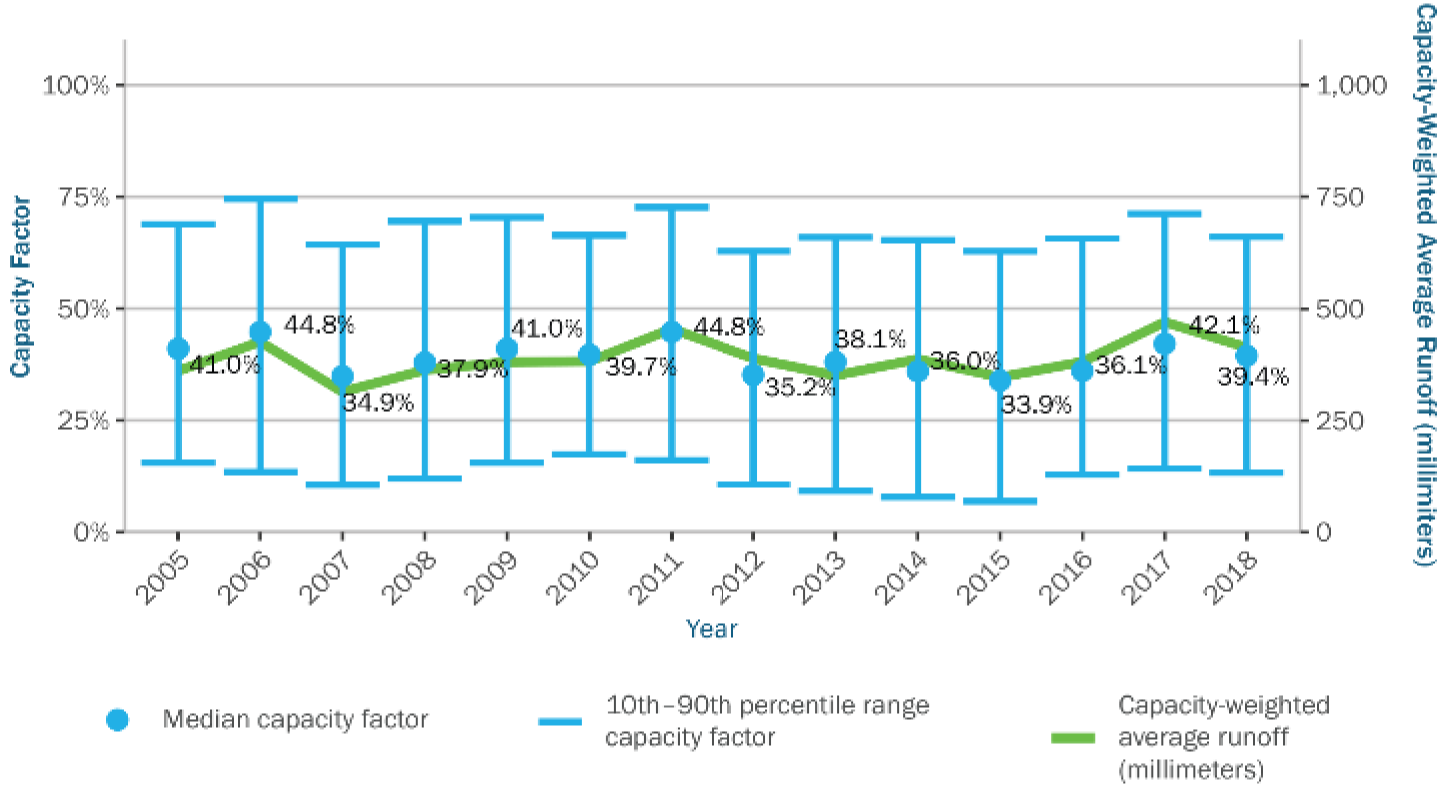


Source: EIA Form 923 (2003-2018), Canada Energy Regulator, EIA Electric Power Monthly (2019)

Note: Canadian imports only include imports from Hydro-Québec , Manitoba Hydro, and BC Hydro. Generation series for U.S. regions are only in-state generation and do not include imports

- ***In 2019, hydropower generation (274 TWh) accounted for 6.7% of U.S. electricity generation and 38% of electricity from renewables***
  – After two years of high domestic hydropower production (~300 TWh) in 2017–2018, the 2019 volume was close to the 2003–2018 average.
  – Canadian imports contributed an additional 35–45 TWh of hydroelectricity in 2017–2019.
    - Canadian imports are expected to continue increasing in the 2020s.

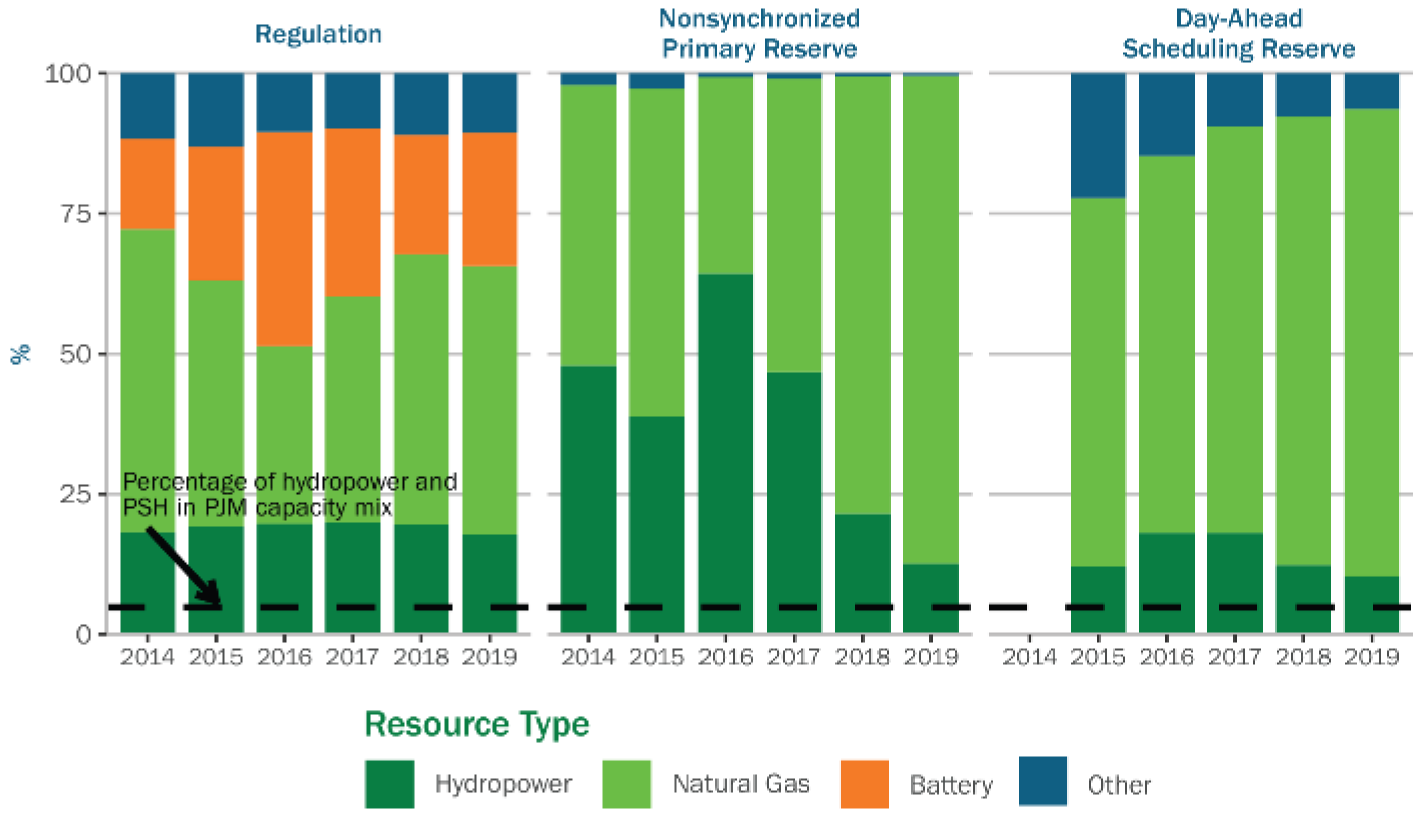
Plant-level distribution of capacity factors by year (nationwide fleet) and capacity-weighted average runoff



Source: EIA Form 923, EIA Form 860, USGS WaterWatch.

- ***Median U.S. Hydropower Capacity Factor from 2005 to 2018 Has Ranged Between 35% and 45% Largely Depending on Hydrological Conditions***
  - On average, the median capacity factor was 39% during this period.
  - Hydrological and market conditions as well as plant-level variables (mode of operation, outage schedule, multipurpose constraints) explain variability across plants and years.

PJM ancillary service provision by hydropower and other resource types (2014–2019)

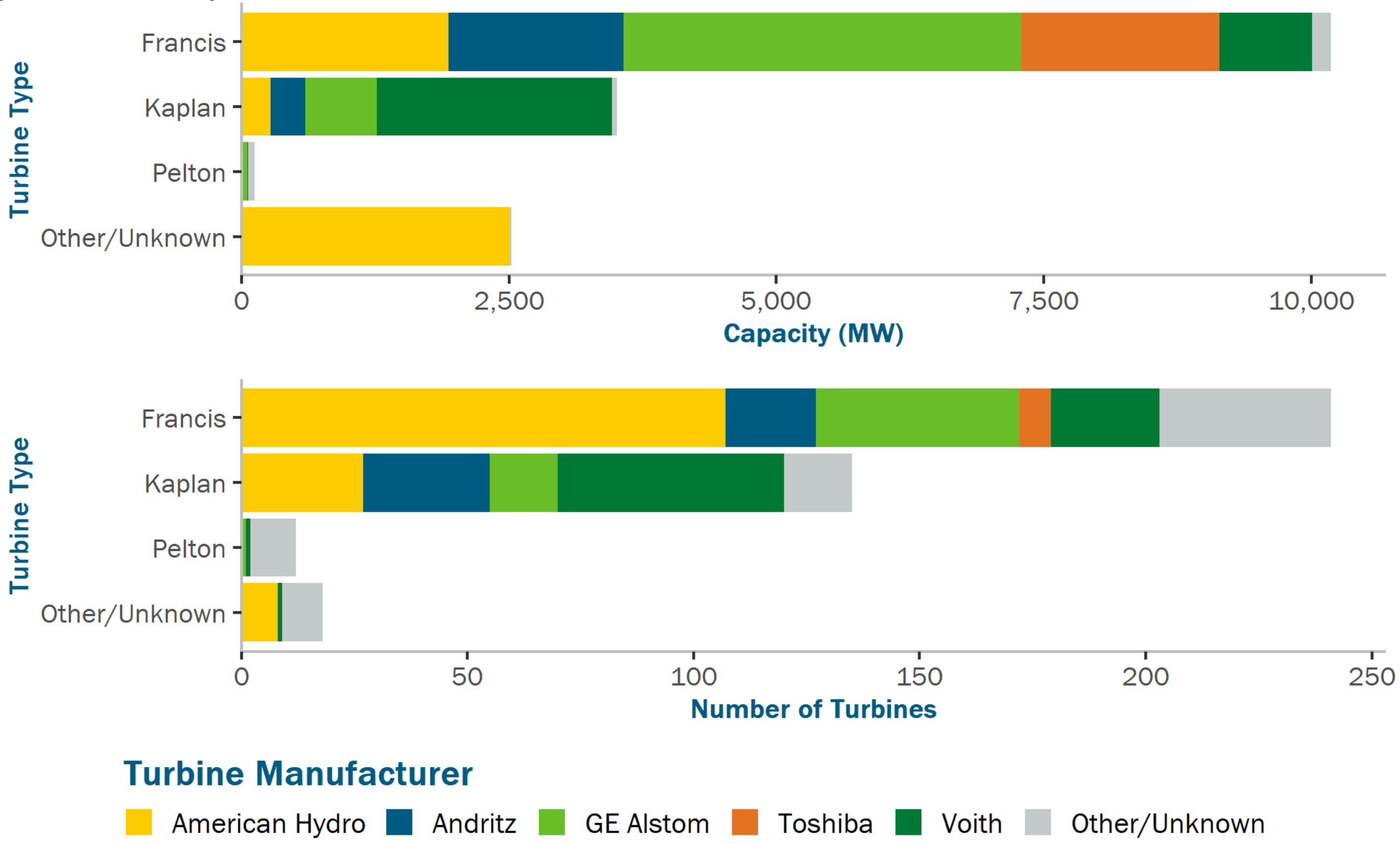


Source: PJM State of the Market Report (2014, 2015, 2016, 2017, 2018, 2019).

Note: Natural gas includes the contribution from combustion turbines and combined cycles; however, it should be noted that a small portion of the fuel used by (dual-fired) combustion turbines is diesel.

- ***In Multiple ISOs, the Shares of Frequency Regulation and Reserves Provided by Hydropower Are Much Higher than Hydropower's Share of Installed Capacity***
  - For instance, in PJM, hydropower supplied a larger percentage of regulation, non-synchronized reserve, and day-ahead scheduling reserve in 2014–2019 that the percentage of installed capacity it represents in that ISO/RTO.

Installed hydropower turbines in the United States by type and manufacturer (2007-2019)



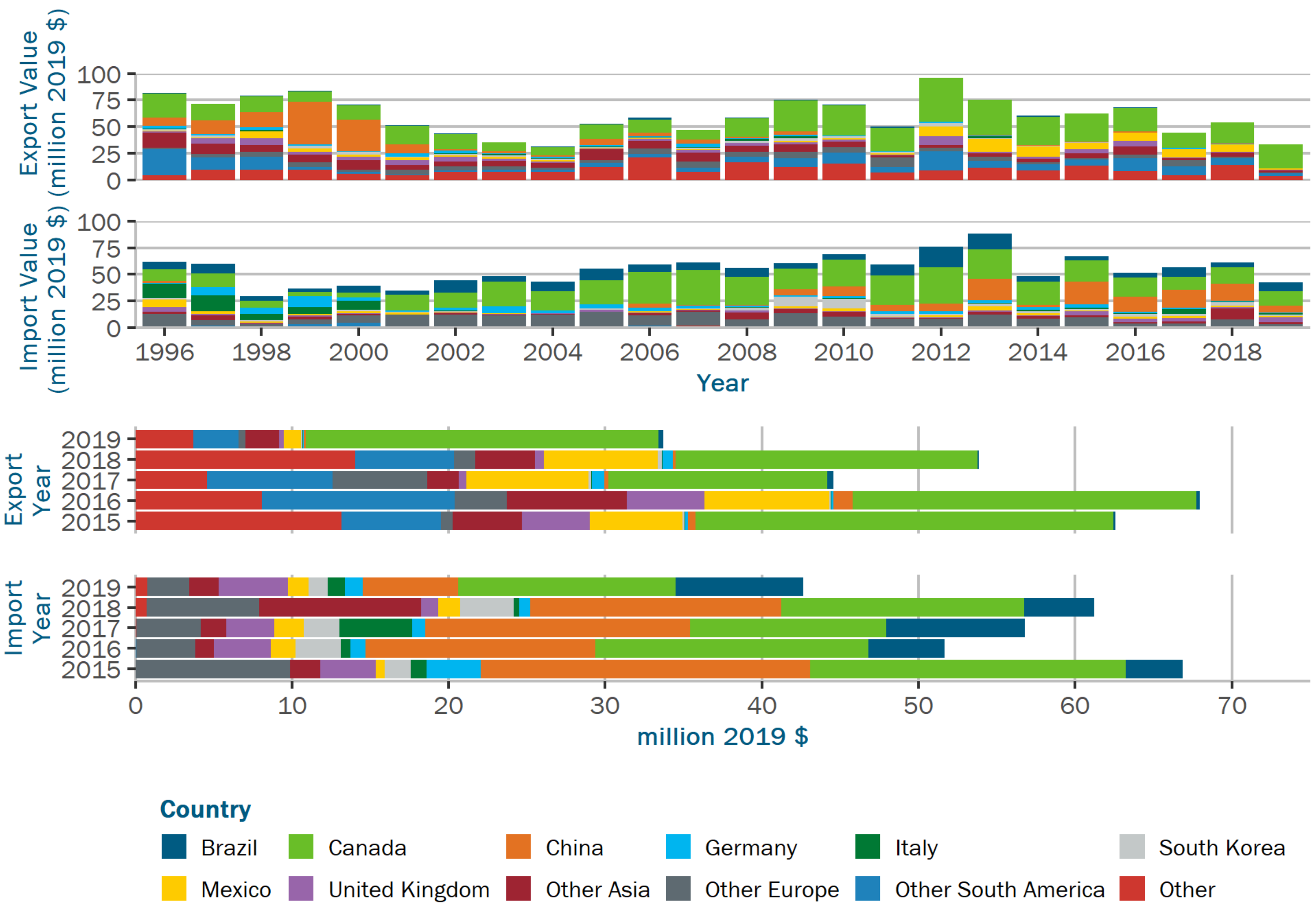
Source: Industrial Info Resources, Existing Hydropower Assets dataset, personal communication with Debbie Mursch (GE Renewable Energy), personal communication with Gerry Russell (American Hydro).

Note: The plot covers new turbines and turbine R&U whose scope includes turbine runner replacement.

- ***More than 16 GW of Turbine Capacity Has Been Installed in the United States in 2007–2019***
  - This total includes new units and the capacity of turbines whose runner has been replaced during that period.
  - Five manufacturers supplied all the turbines with capacity greater than 30 MW; more than a dozen companies served the demand for smaller turbines.
  - More than 90% of turbine replacements were Francis and Kaplan turbines; almost 75% of new units have been Kaplan.
    - Kaplan is typically the chosen turbine type for low-head sites which are characteristic of most of new U.S. hydropower developments.

Chapter 6 - Trends in U.S. Hydropower Supply Chain

U.S. hydropower turbine import and export values by country



Source: U.S. International Trade Commission

Note: The 2019 data are preliminary and could be subject to revision by USITC

- ***For 2015–2019, the U.S. Trade Balance for Hydraulic Turbines and Turbine Parts Was Close to Zero***
  - Imports were $279 million; exports were $263 million. The three top countries exporting to the U.S. in the past five years were China, Canada, and Brazil—the countries with the three largest hydropower fleets in the world.
  - Canada and Mexico were the two top countries to which the United States exported turbines and turbine parts.

Chapter 7 – Overview of New Policies Influencing the U.S. Hydropower Market

- ***In October 2017, FERC announced a revised policy on license terms (for both original licenses and relicenses) in which the default term became 40 years.***
  - Previously, license term ranged from 30 to 50 years; the new policy aims to provide more certainty to process participants and offer licensees more time for recouping investment costs.
- ***The America's Water Infrastructure Act of 2018 (AWIA) directed FERC to introduce an expedited licensing process—2 years from license application to final decision—for qualifying NPDs and closed-loop PSH projects.***
- ***States are committing to higher renewable or clean energy mandates that could increase investment in new hydropower and PSH.***
  - Since 2018, at least nine states have increased their renewable energy targets, and eight states (i.e., California, Hawaii, Maine, New Mexico, New York, Rhode Island, Virginia, Washington), as well as Washington D.C. and Puerto Rico, have set a 100% renewable or clean energy mandate.
  - Hydropower is limited in its eligibility to meet renewable portfolio standard (RPS) targets in most states, but it typically counts toward clean energy mandates (Stori, 2020).

Stori, V. 2020. *The Role of Hydropower in State Clean Energy Policy. How States Include Hydropower in Renewable Portfolio Standards and Energy Storage Mandates*. Clean Energy States Alliance. Available at https://www.cesa.org/resource-library/resource/role-of-hydropower-in-state-clean-energy-policy/

Chapter 7 – Overview of New Policies Influencing the U.S. Hydropower Market

- ***As of March 2020, seven states have adopted energy storage targets, and many others are considering introducing them***
  - PSH is typically eligible to meet those targets but, given target sizes and years, may be practically excluded (due to how storage targets are structured) in some states.

Energy Storage Mandates/Targets in U.S. States as of March 2020

State	Target	Target Year	Target Type	Policy Document
California*	1,325 MW	2020	Mandate	D. 13-10-040
Oregon	5 MWh (for each utility serving more than 25,000 customers)	2020	Mandate	HB 2193
New Jersey	2,000 MW	2030	Target	Assembly No. 3723
New York	1,500 MW (aspirational goal of which 350 MW are mandated)	2025	Mandate	PSC CASE 18-E-0130
Massachusetts	1,000 MWh	2025	Target	H4857
Nevada	1,000 MW	2030	Target	Docket No. 17-07014
Virginia	3,100 MW	2035	Target	SB 851

*: PSH facilities with capacity greater than 50 MW are not eligible.

Technical Notes

Slides 10 and 11:

*Projects in the *Pending Preliminary Permit* and *Issued Preliminary Permit* stages have high attrition rates. *Pending Preliminary Permit* includes projects pending a preliminary lease in the Reclamation LOPP process and projects pending issuance of a preliminary permit. *Issued Preliminary Permit* includes projects that have received a preliminary lease in the LOPP process, projects that have obtained a FERC preliminary permit, and projects with an expired preliminary permit but that have submitted a Notice of Intent to file a license or a draft license application.

***Pending License* includes projects that have applied for an original FERC license or a FERC exemption or have requested to be considered a “qualifying conduit” hydropower facility by FERC. *Issued License* includes projects that have been issued an original FERC license or FERC exemption, been approved by FERC for the qualifying conduit hydropower status, or received a final lease contract under the LOPP process.

Slide 11:

For states that have both an RPS or voluntary renewables goal and a Clean Energy Standard (or voluntary goal), the map shows the maximum percentage to be attained across the two. The years by which the mandate/goal must be attained vary from state to state.

For more information:

- **See full report and data:**
  - https://www.energy.gov/eere/water/hydropower-market-report
  - https://hydrosource.ornl.gov/dataset/US-HMR-data
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