



# THE ROLE OF HYDROPOWER IN STATE CLEAN ENERGY POLICY

HOW STATES INCLUDE HYDROPOWER IN RENEWABLE  
PORTFOLIOS STANDARDS AND ENERGY STORAGE MANDATES

Prepared by  
Val Stori  
Clean Energy States Alliance  
for the  
Pacific Northwest National  
Laboratory

**AUGUST 2020**

## ABOUT THIS REPORT

This report highlights how hydropower facilities qualify for and participate in state renewable portfolio standards and state energy storage policies. It identifies key takeaways and high-level strategies for maximizing hydropower's benefits.

This report was produced with funding from the U.S. Department of Energy through the Pacific Northwest National Laboratory.

## ACKNOWLEDGMENTS

Many hands helped produce this report. The Clean Energy States Alliance thanks all the individuals who provided expertise, contributed content, or reviewed sections of this report: Shannon Ames, Low Impact Hydropower Institute; Hoyt Battey, U.S. Department of Energy; Ludovica Brown, Vermont Law School intern; Ed Holt, Ed Holt & Associates; Andrew Perchlik, Vermont Clean Energy Development Fund; and Warren Leon, Meghan Monahan, and Todd Olinsky-Paul of CESA.

We are grateful to Rebecca O'Neil (Program Manager at Pacific Northwest National Laboratory) for conceiving the concept for this report, securing funding for this project, and her thoughtful questions, guidance, and championing of this report. In addition, we are grateful to Jason Gifford of Sustainable Energy Advantage for his thorough research and expertise on New England's RPS markets; Jason co-authored Part Two of this report—the New England Case Study.

Maria Blais Costello, Manager of Program Administration at CESA, did the final copyediting and worked with David Gerratt on the production of this report. Many thanks to both of them.

## DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, expressed or implied, or assumes and legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately-owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of the author expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

# CONTENTS

5	<b>Executive Summary</b>
9	<b>Part 1: Hydropower in State Renewable Portfolio Standards</b>
9	Key Takeaways
9	Introduction
10	The Context for Hydro’s Participation in State Renewable Portfolio Standards
10	<i>Renewable Portfolio Standards-An Overview of Their Role and Structure</i>
12	<i>Federal and State Regulatory Authority over Hydropower</i>
13	The Treatment of Hydropower in State RPS Programs
14	<i>Size/Capacity</i>
14	<i>In-service Date</i>
15	<i>Impoundments, Run-of-River, and Capacity Additions</i>
16	<i>Geographic Eligibility</i>
17	<i>Environmental Impacts</i>
18	<i>Low Impact Hydropower Institute Certification</i>
19	Hydropower Eligibility in the Midwest and West Coast
20	<i>Washington State</i>
20	<i>Ohio</i>
21	Part 1 Endnotes
25	<b>Part 1 Appendix</b>
32	<b>Part 2: Hydropower Participation and Opportunities in New England RPS Markets – A Case Study</b>
32	Key Takeaways
32	Introduction
33	Overview of New England Renewable Portfolio Standard Markets
33	<i>Eligibility Criteria</i>
34	<i>RPS Compliance Mechanisms</i>
35	RPS Market Dynamics and Economic Opportunities for Hydropower
35	Hydropower Participation in New England RPS Markets
36	<i>RPS-Certified Hydroelectric Supply</i>
37	<i>Hydropower’s Historical Contribution to RPS Compliance</i>
38	<i>Hydropower and Greenhouse Gas Emission Regulations</i>

38	Changes in RPS Markets Affecting Hydropower
39	Market Dynamics: Economic Opportunities for Hydro in New England RPS Markets
41	<b>Part 2 Appendix</b>
41	Class I/"New" Markets
43	Class II/"Existing" Markets
45	Part 2 Endnotes
48	<b>Part 3: Pumped Hydropower Energy Storage in State RPS Mandates and Energy Storage Policies</b>
48	Key Takeaways
48	Introduction
49	Overview of Pumped Hydro in the United States
50	PHES Main Energy Services
52	PHES Treatment in State RPS Programs
54	State Energy Storage Policies
54	<i>California</i>
55	<i>Oregon</i>
56	<i>Massachusetts</i>
56	<i>New Jersey</i>
57	<i>New York</i>
59	<i>Nevada</i>
59	Pumped Hydro's Future
61	Part 3 Endnotes

# Executive Summary

**H**ydropower technologies have the potential to play a larger role in state renewable energy and energy storage policies. Hydropower is an abundant, clean, and renewable resource that can help states meet their renewable energy targets and also integrate higher levels of intermittent renewables, such as solar and wind, into the grid. Hydropower, in some form, is an eligible resource in all state Renewable Portfolio Standard (RPS) programs. However, most states have placed limits on size, in-service date, and/or technology. This trend continued in 2019 as states that expanded their portfolio standards generally retained these restrictions. However, the policy landscape is changing rapidly as many states increase their RPS targets and adopt new 100 percent clean energy standards, and the treatment of different types of hydropower has the potential to similarly evolve.

Pumped hydro energy storage (PHES) is a well-established, long-duration storage technology that can provide many grid flexibility, resiliency, and reliability services, such as black start capability, frequency regulation, and voltage regulation. But despite its potential for large-scale, energy storage capacity, PHES faces policy, economic, and environmental challenges to further development.

This report seeks to highlight how hydropower qualifies for and participates in state RPS programs and state energy storage policies. The report also identifies key takeaways and high-level strategies for maximizing hydropower's benefits. It begins with an overview of state RPS programs and the most common eligibility criteria states use to determine hydropower participation.

Part Two of the report takes a deeper look at hydropower's role in New England's RPS markets and how each state's RPS eligibility criteria affect hydropower's participation. Lastly, in Part Three, the report explores pumped hydro energy storage and discusses why state policies and programs often overlook the technology. It highlights pumped hydro's eligibility in state RPS programs and energy storage mandates and targets, offering policy and regulatory approaches that open opportunities for PHES participation.

## *Hydropower in State Renewable Portfolio Standards*

Hydropower is an eligible resource in all 30 state RPS programs. However, eligibility differs from state-to-state, whether through different tiers or through different eligibility criteria that restrict hydro's participation through capacity limits, age, technology requirements, or environmental considerations. Some states place few, if any, restrictions on hydropower. These differences among states are largely a result of hydropower's in-state or in-region potential for contributing to RPS

goals, states' perceptions of whether hydropower requires special financial support, and views on hydropower's carbon benefits and other environmental impacts.

Generally, RPS programs classify hydropower's participation through tiers or classes that have specific capacity, in-service date, and technology requirements. The "New" or "Growth" tier is usually reserved for new facilities that are "small" with small being defined generally as less than 10 megawatts to up to 80 megawatts. The "Maintenance" or "Existing" tier is generally reserved for older facilities, and the REC trading price is often significantly less than in the "Growth" tier. (There are exceptions, but New/Growth tiers are generally Class I, and Maintenance/Existing tiers are generally Class II.)

RPS programs tend to favor run-of-river (ROR) systems, which do not require new impoundments. In addition, RPS programs favor new capacity that results from efficiency upgrades and incremental capacity additions. Some programs allow both new impoundments and new diversions to qualify, but seek to minimize environmental impacts through mitigation measures such as adequate fish passage. Three states (Massachusetts, Pennsylvania, and Vermont) have adopted the Low Impact Hydropower Institute's environmental criteria and have required certification to this third-party standard; two other states (New Jersey and Oregon) require certification by a national certification organization.

### **Hydropower's Participation and Opportunities in New England RPS Markets**

Hydroelectric projects of all sizes and types provide energy to New England. In 2019, 434 hydropower facilities were registered to participate in New England Power Pool Generation Information System (NEPOOL GIS) (30 of these facilities are located outside of New England but deliver energy into ISO New England). Most of these facilities participate in Class II/Existing RPS markets. It is more difficult to qualify for the Class I/New RPS markets, where only new facilities or new incremental production at existing facilities are eligible. The New or Growth classes provide more opportunities for higher renewable energy certificate (REC) prices than the Existing or Maintenance class, although REC prices for this class are generally more volatile than for the Existing class. Variations in supply and demand leave the potential for wide swings in REC prices.

Hydropower facilities participating in New England RPS markets must understand REC price dynamics and into which markets their hydropower is eligible. Hydro facilities must compete with other renewable energy technologies as they try to sell into the highest REC market. In 2018, three market tiers experienced more supply than demand—Maine Class II, Rhode Island Existing, and Vermont Tier I. RECs traded between \$1-\$2/megawatt-hour in these systematically oversupplied tiers, whereas in Massachusetts Class I and New Hampshire Class IV, RECs traded just below the ACP at \$23/megawatt-hour. Out of the 434 hydro facilities currently registered in NEPOOL GIS, 156 of them are certified only for systematically oversupplied markets.

## ***Pumped Hydropower in State RPS Mandates and Energy Storage Policies***

There are 42 existing PHES projects in the US providing over 21 gigawatts of storage capacity and ancillary services to the grid. Most projects were constructed between the 1960s and 1980s to store excess energy generated by nuclear power plants.

More ambitious state goals for renewable energy and high penetrations of variable renewable resources are driving interest in energy storage technologies, including a renewed interest in PHES. Pumped hydro facilities have black start and quick start capabilities, making them ideal solutions for providing grid reliability and peak load support and for complementing intermittent resources. In addition to balancing generation with demand and aiding renewable integration, pumped hydro facilities provide other energy services, including deferring transmission and distribution investments, providing grid stability, aiding in energy arbitrage and grid resiliency, and reducing overall system costs.

The original motivation for RPS legislation was not only to reduce GHG emissions, but also to spur economic activity for new renewables such as wind and solar to make them more competitive, rather than providing incentives for existing renewable energy technologies. Thus, despite its many services, PHES is eligible only in five out of 30 state RPS programs. Although it is an eligible technology in four out of six state energy storage policies, contracting structures, capacity limits, and commissioning dates indirectly limit pumped hydro's participation. Many of the state storage goals and mandates revolve around peak demand reduction and firming intermittent solar resources; batteries are a good solution for these short duration needs because they can respond quickly for several minutes to hours. PHES, while capable of providing shorter-term flexibility, may also be better suited for long-duration solutions and long-term targets. Longer duration needs may be addressed in future energy storage targets that address wind firming, curtailment reduction, and other grid-scale services.

## ***Key Findings***

There are significant obstacles to hydropower participation in RPS programs and to pumped hydropower participation in energy storage policies. Policy and regulatory changes can reduce and eliminate barriers to hydropower development and can help capture hydropower's range of benefits, including carbon-free electricity and renewable integration. To support hydropower, policy makers could consider the following actions:

- As states increase their RPS targets or adopt 100% Clean Energy Standards, they could consider the addition of hydropower as an eligible carbon-free resource.
- States could consider the procurement of hydropower through other renewable energy solicitations.

In regards to pumped hydro energy storage:

- Issue procurements with targets large enough to attract and support PHES applications. Procurements could include longer lead times to account for the long permitting timeframes for PHES technology.
- Include long-term contracts for PHES in procurements.
- Provide performance-based incentives that help offset high capital costs. In markets with a high penetration of intermittent renewables where there is a need for flexible, fast-response storage solutions, pay for performance compensation can provide additional needed revenue for PHES facilities.
- Establish loan guarantee programs to offer low-cost capital.
- Move to time-of-use pricing to drive additional revenue through energy arbitrage opportunities.
- Streamline the state permitting process for low-impact PHES projects, such as off-stream and closed-loop projects. State environmental permitting agencies could perform their project reviews concurrently with the Federal Energy Regulatory Commission (FERC) to efficiently permit and approve PHES applications.



## PART 1

# Hydropower in State Renewable Portfolio Standards

### KEY TAKE-AWAYS

- Hydropower is a major component of some state Renewable Energy Standards (RPS) programs, especially those where a state has an RPS Class/Tier without eligible facility capacity limits or age restrictions.
- Efficiency improvements and capacity additions from capital investments at existing facilities are generally an eligible renewable resource.
- The Low Impact Hydropower Institute's certification and environmental criteria have been adopted by several states, providing a market incentive for hydropower plants with reduced environmental impacts.
- Hydropower eligibility criteria such as capacity limits, age restrictions, and technology type are used by many states as de-facto environmental safeguards. Others have adopted additional criteria that protect streamflows, wildlife, wildlife habitat, and cultural and recreational resources.
- Hydropower is playing a new, larger role as RPS's expand or are enveloped into 100 percent clean energy mandates (e.g., as in the state of Washington).

## INTRODUCTION

**H** ydropower plays an important and historic role across the nation in providing electricity to many markets. It is an eligible renewable energy resource in all 30 RPS programs, though its eligibility in different tiers and its contribution to state targets has changed over time. States have varying eligibility criteria for hydropower facilities that reflect their unique interests in promoting renewables and safeguarding their environment. Some states limit hydropower's participation through capacity limits, in-service date restrictions, technology requirements, and environmental considerations. Others place few restrictions on qualifying facilities, for example, Hawaii.

This section of the report looks at the different approaches states have taken to include hydropower eligibility in their RPS policies to protect the environment and meet their targets. It begins with an overview of RPS programs and the role the federal government plays in permitting and licensing

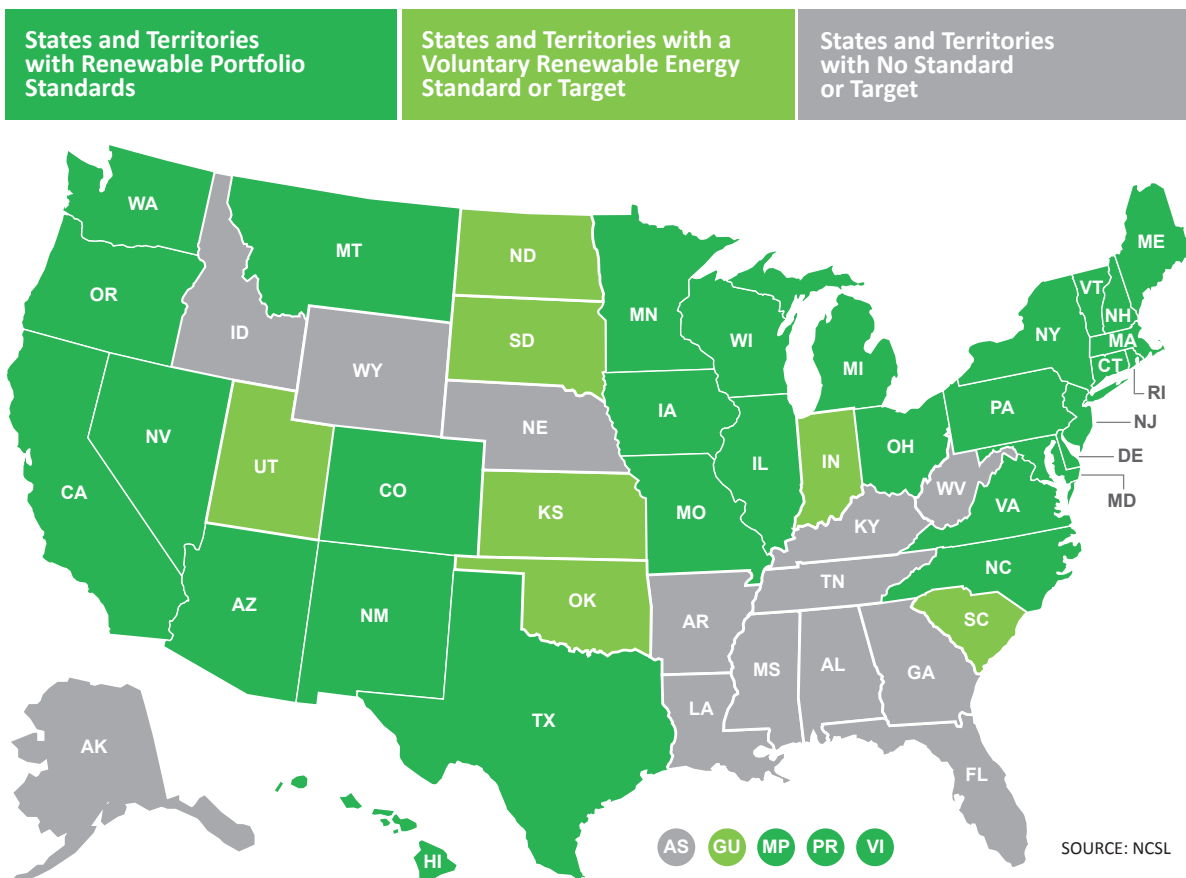
hydropower facilities. The paper then describes the rules for hydropower qualification in different states, providing numerous examples from across the country. It also includes a section on the Low Impact Hydropower Institute’s environmental criteria for certifying dams and the role this certification plays in several states’ RPS programs. A table of each RPS program’s treatment of hydropower is included in the Appendix on page 25.

## THE CONTEXT FOR HYDROPOWER’S PARTICIPATION IN STATE RPS PROGRAMS

### *Renewable Portfolio Standards: An Overview of Their Roles and Structures*

A state renewable portfolio standard (RPS) requires electricity suppliers to acquire a share or amount of their electricity from renewable energy and other designated clean energy technologies.<sup>1</sup> Currently, 30 states plus the District of Columbia have mandated RPSs, or similar policies under a different name such as a clean energy standard. Six additional states have voluntary RPSs. See Figure 1. Collectively, state RPSs have probably been the single most influential state policy mechanism for increasing the development of additional clean energy generating capacity. Most states restrict their RPS to renewable energy generation, but some have included other technologies, including natural gas-fired fuel cells, energy efficiency measures, and energy storage.

FIGURE 1: CURRENT RPS PROGRAMS IN THE U.S.<sup>2</sup>



Because an RPS does not set a specific price that electricity suppliers must pay for renewable energy generation, there is competition among generators to sell to electricity suppliers, and that competition theoretically ensures that renewable energy is secured at the least cost. In almost all states with an RPS, renewable energy certificates (RECs) are the dominant mechanism for RPS compliance. RECs typically occur in electronic form. A qualifying renewable energy facility generates one REC for each megawatt-hour of electricity. Depending on a state's rules, RECs can be sold "bundled" as a package with the actual electricity produced, or they can be traded separately. Once a REC has been used to comply with a specific RPS, it is considered "retired" and cannot be used again. The value of RECs from a particular facility is determined by the RPS rules and electricity market in the state where they are retired.

RPS policies and program structures vary from state to state. Different states have different target percentage levels for clean energy generation and different timeframes for achieving those targets. Other state-by-state variations to RPS programs include the following:

- Eligible technologies
- Compliance enforcement mechanisms
- Mechanisms for limiting the program's costs
- The use of tiers/classes, carve-outs, and/or multipliers
- Geographic restrictions
- In-service date restrictions

Many, but not all, states divide their RPS into classes or tiers, each with different purposes, rules, and eligible technologies. The most common approach is to reserve Class I for "newer" technologies, such as solar and wind. Class II is often applied to resources, such as hydropower and biomass, that were well-established at the time when the RPS was instituted and/or to older facilities.

Within a class or tier, states sometimes include carve-outs or multipliers to give additional preference to certain technologies. A carve-out (sometimes called a set-aside) requires a certain share of a tier's target to be met with the favored technology, frequently solar or distributed generation. A multiplier allows a facility using a favored technology to count each REC as more than one (the multiplier number) for the purposes of RPS compliance. Hydropower is not currently eligible for any carve-outs or multipliers.

Most states with an RPS have at least one mechanism to limit the cost of RPS compliance. States with regulated utility markets often either use a rate cap that limits RPS compliance expenditures to a certain percentage of ratepayers' electricity rates or use an annual utility revenue expenditure cap, which limits a utility's RPS expenditures to at a set percentage of its retail revenue requirements.

Many states use Alternative Compliance Payments (ACPs) to limit RPS costs. If an electricity supplier is unable to procure and retire the obligated number of RECs, it must make ACPs at a rate set by the state. By serving as the ceiling price for RECs, the ACP caps the total cost of the RPS.

States have frequently modified their RPSs. Recently, the dominant trend has been to increase the obligation and extend the date by which compliance is required. Since 2015, 14 states plus the District of Columbia have made significant increases to their RPSs, most often raising the near-term targets and creating new, higher, longer-term targets. Only two states have weakened their RPS: Ohio, which lowered its targets, and Kansas, which replaced its RPS with a voluntary renewable energy goal. However, a few other states, including Montana and Wisconsin, have reached their peak target; by not creating new RPS targets, the RPS has faded as a driver of renewable energy development.

In some of the Midwest and in Texas, RPSs have become less of a driver for new generation, because the favorable economics of renewable technologies, especially large-scale wind, allow projects to be developed without RPS financial incentives. In those places, REC prices are very low. But in other RPS states, RECs can provide significant financial support for renewable energy, depending upon the tier and the technology.

### ***Federal and State Regulatory Authority over Hydropower***

The Federal Energy Regulatory Commission (FERC) has regulatory authority over non-federal hydropower facilities on navigable waterways. Its hydropower permitting and licensing (and relicensing) processes serve as a baseline for identifying and addressing environmental, recreational, and other public interests.<sup>3</sup> As FERC prepares an Environmental Assessment or Environmental Impact Statement for a hydro project, it must solicit input from federal and state natural resource agencies on protecting and mitigating impacts to fish and wildlife; it must also consult with Native American tribes. FERC licensing is a lengthy process that can last up to 10 years with multiple opportunities for stakeholder engagement. The majority of FERC's work related to hydropower focuses on relicensing; default license terms are 40 years, though shorter and longer terms (not to exceed 50 years) are possible.

Before FERC can issue a license, state regulatory bodies must certify that the project complies with state water quality standards. State water quality standards include management objectives for wildlife and habitat, recreational uses, streamflows, and water levels. State and municipal agencies that have a role in permitting/regulating hydropower include fish and wildlife management agencies, water resource agencies, state historic preservation departments, and local conservation commissions.

Although FERC is responsible for licensing (and relicensing) hydropower facilities, it is the states that choose qualifying criteria for RPS programs. These requirements vary among all the states, are complex, and are described in the sections below.

## THE TREATMENT OF HYDROPOWER IN STATE RPS PROGRAMS

All 29 state RPS programs include hydropower as a qualifying technology, although there are significant differences in how they treat hydropower. Along with biomass, hydropower is one of the two renewable technologies with the greatest variations in RPS treatment. The four primary reasons for these variations for hydropower are:

- Differences among the states in the in-state or in-region potential for hydropower to contribute to achieving RPS goals
- Varying perceptions among the states about whether hydro, as a long-established technology, requires special financial support
- Perceptions of the environmental impacts and benefits of hydropower
- Different views about whether hydropower is needed to meet ever more aggressive RPS targets.

Generally, RPS programs classify or limit hydropower's RPS participation by size/capacity, in-service date, or technology. They often use tiers to differentiate hydropower along these attributes. Usually, smaller projects or new projects qualify for Class/Tier I; this tier is also referred to as the "growth" tier.<sup>4</sup> Some states such as Maine allow existing, large hydro projects to qualify (usually in Class/Tier II), and some states such as Vermont, allow Canadian hydro to qualify. Many RPS programs require eligible projects to meet specific environmental criteria, including some that require certification by the Low Impact Hydropower Institute (LIHI).<sup>5</sup>

Largely due to environmental concerns over new impoundments, states are nearly evenly split in their treatment of new dams. Fourteen states prohibit new impoundments.<sup>6</sup> Sixteen programs allow new impoundments, although two of them, California and Colorado, place restrictions on new impoundments.<sup>7</sup>

Some states allow hydropower to participate in multiple tiers. For example, New Jersey allows hydropower facilities up to three megawatts to participate in Tier I and facilities up to 30 megawatts to participate in Tier II. Connecticut only allows run-of-river hydropower facilities up to 30 megawatts that began operation post July 1, 2003 to participate in its Class I.<sup>8</sup> New Hampshire not only allows incremental capacity increases over historical baseline generation from any hydro-power facility to qualify for Class I, but also allows existing small hydro facilities to qualify in its Class IV—a hydro-only tier.<sup>9</sup>

The sections below discuss in greater depth the variations between the treatment of hydro in different state RPSs. Pumped hydro energy storage (PHES) facilities are covered in **Part 3** of this report.

### *Size/Capacity*

State RPS programs often limit the participation of larger hydropower facilities because of concerns about the environmental impacts of those facilities or a belief that larger facilities do not need RPS financial support to compete in the electricity market. Many RPS programs limit eligibility to “small” facilities, although the states define “small” differently. Seventeen states limit eligibility to projects 30 megawatts or less in at least one of their tiers.<sup>10</sup> Six of these states limit capacity to 10 megawatts or less in at least one tier.<sup>11</sup> New York, for example, caps Tier I eligibility at five megawatts, but Iowa defines “small hydropower” as 80 megawatts or less.

On the other hand, 11 states have at least one tier without capacity limits.<sup>12</sup> For example, Hawaii does not place a capacity limit on qualifying hydro facilities, and Vermont does not have a capacity restriction in its Tier I.

Some states are considering amending their RPS statutes to allow for large-scale hydropower as part of efforts to meet recently adopted ambitious clean energy and climate goals, such as 100 percent clean energy mandates. Because large-scale hydropower is readily available and cheap in some locations, and as RPS and other targets draw nearer, large-scale hydropower becomes an attractive solution for meeting state goals. Washington State, for example, recently passed 100 percent clean energy legislation, which allows all existing hydropower to be used for compliance with the state’s RPS.<sup>13</sup>

### *In-Service Date*

Restrictions on the in-service date of a facility represent the most significant barrier for hydropower inclusion in RPS programs. States largely adopted RPSs to incentivize new renewable energy generation. Consequently, Tier I of states’ RPSs are generally reserved for newer facilities that began commercial operation after a certain date or facilities that incrementally added capacity after that date through efficiency or capacity improvements. Because most hydropower facilities pre-date this cutoff point, which generally is no earlier than the mid-1990s, they are eliminated from the more restrictive (and therefore more lucrative) RPS Tier I. Older facilities are often eligible for less valuable tiers, such as Tier II.

New Jersey’s Class I is a good example of an RPS tier with eligibility restricted to “new” facilities, with new being defined as facilities placed in service after July 23, 2012.<sup>14</sup>

Massachusetts is more permissive in its definition of new facilities for its Class I; it defines “new” as facilities that began commercial operation after December 31, 1997, or from existing facilities that incrementally increased capacity as long as certain environmental measures are met.<sup>15</sup> Its Class II tier allows facilities that began commercial operation before December 31, 1997.

Colorado's RPS, which does not have tiers, extends eligibility to "new" hydropower facilities that began operating after 2005 if they are 10 megawatts or less, and allows facilities in operation prior to 2005 to qualify if the facility is 30 megawatts or less.<sup>16</sup>

Arizona's RPS, which also does not have tiers, excludes energy from hydropower facilities installed before January 1, 1997, with the exception of incremental generation or output used exclusively to firm intermittent renewables.

Lastly, some states do not have in-service date requirements in one or more tiers.<sup>17</sup> Many of these are Midwest states—Illinois, Iowa, Michigan, Minnesota, and Missouri.

### ***Impoundments, Run-of-River, and Capacity Additions***

Fifteen RPS programs prohibit new impoundments due to their environmental impacts, while 15 states allow new dams and diversions.<sup>18</sup> Iowa allows new impoundments and diversions but tries to minimize environmental impacts through mitigation measures, such as allowing for adequate fish passage.<sup>19</sup> Colorado explicitly allows new impoundments, but places a size restriction of 10 megawatts on them.

RPS programs tend to favor run-of-river (ROR) systems, which are perceived to have fewer environmental impacts. Many of the states that prohibit new dams allow new ROR systems. For example, Michigan and Connecticut, which prohibit new impoundments, permit new ROR facilities to qualify for their RPS programs. New York, which also prohibits new impoundments, allows new ROR facilities that are five megawatts or less in its Tier I; its Tier II is limited to ROR facilities that are 10 megawatts or less.

Incremental improvements through efficiency upgrades or capacity additions at older facilities are generally permitted in state RPS programs; such upgrades and improvements can qualify only that portion of output made after a certain date. If a state has multiple tiers, capacity additions are generally eligible in the "growth" tiers. For example, Massachusetts, New Hampshire, and New York allow capacity additions and efficiency investments and upgrades in their growth tier. The date by which those efficiency upgrades must be made varies by state as does the age of the facility on which the upgrades have been made. Montana, for example, allows capacity additions made after October 1, 2013 at any existing hydro project. Oregon allows capacity additions made after January 1, 1995 to facilities in service before January 1, 1995. On the other hand, Ohio does not specify incremental capacity additions by a certain date, but it does limit eligible capacity additions to facilities that were in place prior to 1998.



## Geographic Eligibility

States have different geographic eligibility criteria for renewable resources in their RPS programs. Most states allow renewable resources from out of state to qualify in at least one tier if they meet the state's other RPS requirements.<sup>20</sup> Most states limit eligibility to facilities either within the territory of the regional transmission operator (RTO) that serves the state or that are able to deliver power into the state.<sup>21</sup>

Wisconsin and Vermont allow Canadian hydropower to qualify for their RPS programs. Large hydropower facilities in service after January 31, 2010 located in Manitoba, Canada are eligible in Wisconsin's RPS program if the facilities' final licenses are in effect under Canadian law.<sup>22</sup> Vermont's Tier I includes any renewable generator in the region as well as imports from neighboring control areas including Canada, e.g., Hydro Quebec (HQ) and New York Power Authority hydro.<sup>23</sup> Details on Canadian hydro's participation in Vermont's RPS program can be found in the New England Case Study section on page 32.

Other states have considered expanding their RPS eligibility to large Canadian hydropower imports in light of retiring nuclear generators and increased clean energy targets.<sup>24</sup> In 2013, Connecticut, for example, considered expanding its RPS to include large Canadian hydropower as it re-assessed its RPS target and considered additional qualifying resources to meet the Governor's goal of providing cheaper, cleaner, and more reliable electricity for the state.<sup>25</sup> The Connecticut Department of Energy and Environmental Protection (DEEP) recommended that large-scale hydropower, including Canadian hydropower, be eligible in a separate Class I subtier. Within this tier, not only would large hydropower be ineligible to receive RECs, but it also would not be able to compete with the rest of the Class I market. Significant changes were made to the RPS in 2013 (PA 13-303), but it did not include any mechanisms for expanding eligibility to Canadian hydropower. The legislation<sup>26</sup> did, however, expand the RPS to include the following provisions:

- For large hydropower, if DEEP determines that there is a shortage of Class I renewable energy resources, LSEs are allowed to meet one percentage point of their Class I requirement through large-scale hydro.<sup>27</sup> However, not more than a total of five percentage points of the Class I total may be met by large hydro by December 31, 2020.
- Large hydropower RECs may not trade in NEPOOL's REC market.

California considered allowing ROR hydropower facilities in British Columbia (BC) to qualify for its RPS to help meet the state's 33 percent by 2020 RPS goal. In 2011, the California Renewable Energy Resources Act (SBX 1-2) directed the California Energy Commission to report to the Legislature on its analysis of potential eligibility of ROR facilities less than 30 megawatts in ROR BC. The Commission considered the various environmental impacts that could result from including ROR BC hydropower in the RPS, and it ultimately concluded that BC ROR hydro should not be included for environmental reasons.<sup>28</sup> It also concluded that high transmission costs and constraints would make interconnection unfeasible.<sup>29</sup>



## ***Environmental Impacts***

As covered in the previous sections, states tend to use capacity, in-service date, and technology (facility/operational type) to limit hydropower's impacts on the environment. Despite the intent of these eligibility restrictions—capacity limits, age, and technology—they do not necessarily correlate with environmental impact. The location and operation of the hydropower facility can have greater environmental impacts than its size.

Consequently, some states use a combination of restrictions to limit environmental impacts. Arizona's RPS, for example, allows new hydropower facilities of 10 megawatts or less that either are a low-head, micro-hydro, ROR system, or an existing dam that adds new generation equipment without requiring a new dam, diversion structures, or a change in water flow that would adversely impact fish, wildlife, or water quality.

Fifteen states limit hydropower's eligibility for the RPS with additional environmental criteria that attempt to minimize and mitigate environmental impacts. The environmental strategies these states require to safeguard the environment may include:

- Adequate water flows
- Fish passage structures
- Improved facility operations
- Watershed protection
- Public access and recreation enhancements
- Water quality measures
- LIHI certification

For example, Delaware limits hydropower eligibility to facilities that meet the environmental standards set by its Department of Natural Resources and Environmental Control (DNREC) for hydroelectric facilities. In addition to the environmental strategies above, DNREC limits facility eligibility to those that protect cultural and historic resources, and threatened and endangered species and their habitat.<sup>30</sup>

Ohio's RPS requires hydro facilities to comply with the recommendations of the Ohio Environmental Protection Agency on watershed protection and to protect cultural resources and recreational enhancements even if the facility is not required to do so by FERC.<sup>31</sup> In 2018, 16.5 percent of Ohio's in-state retired RECs came from hydropower.<sup>32</sup> These hydropower RECs amount to 40 percent of the non-solar RECs retired in 2018.

New Hampshire Class IV eligibility requirements include two environmental criteria:

1. Upstream and downstream diadromous fish passage requirements (even if FERC license does not require fish passage) for facilities greater than one megawatt<sup>33</sup>
2. Documented state water quality certification<sup>34</sup>

The fish passage requirement was originally applied to all New Hampshire facilities, no matter their size. However, a 2011 RPS review indicated that the Class IV requirements were cost-prohibitive for in-state hydro facilities. According to the review, only one in-state hydro facility participated in the Class IV market despite a Renewable Energy Fund grant opportunity to support the installation of fish passages.<sup>35</sup> In 2012, a legislative amendment (SB 218) modified the fish passage requirement to apply only to those facilities greater than one megawatt and up to five megawatts, which is the size limit for Class IV. After this modification, Class IV experienced a significant increase in participating facilities less than or equal to 1 MW.<sup>36</sup>

### ***Low Impact Hydropower Institute (LIHI) Certification***

As many states began adopting renewable portfolio standards towards the end of the last century, they scrutinized the environmental impacts of hydropower facilities when they considered eligibility for RPS programs. Massachusetts, in particular, was interested in the development of standard environmental criteria to qualify hydro facilities for its RPS. Many states used de-facto environmental criteria such as capacity caps and in-service date to limit eligibility of higher-impact hydropower facilities, but some states also required certification by LIHI.<sup>37</sup>

LIHI is a non-profit organization founded in 1999 by stakeholders from environmental organizations, the hydropower industry, renewable power associations, and other environmental stakeholders to respond to the need for objective hydropower evaluation.<sup>38</sup> LIHI developed a certification standard for hydropower facilities consisting of eight environmental criteria not only to reduce the environmental impacts of existing hydro facilities, but also to create a third-party accepted standard that policy makers could use to evaluate whether a facility has limited environmental, cultural, and recreational impacts. The certification program is voluntary, but there can be significant costs to evaluate whether a specific generator meets LIHI criteria. There are eight criteria facilities must meet to be certified as low impact:

- Water quality protection
- Upstream fish passage
- Downstream fish passage and protection
- Watershed and shoreline protection
- Protection of endangered and threatened species,
- Recreational resource enhancements or protection
- Cultural and historic resource protection
- Ecological flow regimes

These criteria recognize that hydropower facilities have both positive and negative environmental impacts. They seek to provide an objective and credible means for determining which facilities are well sited and well operated, resulting in fewer environmental, cultural, and recreational impacts. The certification process does not consider capacity, and LIHI's criteria do not include a size cap. LIHI has found that the often-used RPS "small" scale eligibility criterion is poorly correlated with environmental impact. Small hydropower facilities may cause more environmental impacts than large hydro facilities, if they are poorly operated or designed—for example, a small hydro facility without fish passage.<sup>39</sup>

Currently, five states require LIHI certification in one or more tier. Hydropower is eligible in Vermont's Renewable Energy Standard Tier II and III only if the hydropower facility has received LIHI certification, and if it has received a water quality certificate from the Agency of Natural Resources. Pennsylvania Tier I, Massachusetts Class I, and Oregon also limit hydropower eligibility to facilities that have LIHI certification.<sup>40</sup>

LIHI has had a positive influence on RPS programs beyond those that require certification. Four states require hydropower facilities to either meet the LIHI standards or standards modeled on LIHI's. New Jersey in effect requires LIHI certification, even though its rules do not explicitly name LIHI; the state's Class I allows for small-scale hydropower that has been certified to meet low-impact criteria by a nationally recognized low-impact hydropower organization.<sup>41</sup> Ohio, Delaware, and New York Tier I's hydropower eligibility requirements include meeting environmental criteria identical to LIHI's, as does Utah's voluntary RPS.<sup>42</sup>

The improvements hydropower facilities must make to meet LIHI's certification criteria can be expensive and the cost is often not covered by the value gained from selling RECs. Thus, even though LIHI certification improves hydropower's environmental performance, many states have not opted for making certification a requirement due to the high cost of certification for generators.<sup>43</sup>

Hydro Quebec and other Canadian hydro facilities are not eligible for LIHI certification.<sup>44</sup>

## HYDROPOWER ELIGIBILITY IN THE MIDWEST AND WEST COAST

**H** ydropower eligibility in RPS programs is very different across the US. For example, the New England region tends to have more restrictive eligibility criteria, at least in certain classes. The Midwest generally has fewer hydro eligibility restrictions, whereas the West Coast tends to have environmental eligibility criteria in place. (A thorough overview of New England hydropower is included in **Part 2.**) Below we highlight one state from the Midwest and another from the West Coast.

## Washington State

Washington is the nation's largest producer of hydroelectric power largely due to high capacity, federally-owned dams constructed in the Columbia River system. In-state hydropower projects produce more energy than Washington needs to satisfy in-state demand; consequently, Washington exports hydropower to the Canadian power grid and supplies power to 14 other western states (mainly to Oregon and California).<sup>45</sup>

Washington's RPS (the *Energy Independence Act*, 2006) has always included hydropower eligibility; however, until the passage of the *Clean Energy Transformation Act* in May 2019, Washington's RPS limited hydropower's eligibility to incremental generation from capacity additions at existing facilities made after March 31, 1999.<sup>46</sup> The *Clean Energy Transformation Act* expands hydropower's eligibility in the RPS, allowing all hydropower from existing dams to be used for the new RPS 100 percent clean electricity by 2045 standard.<sup>47</sup> New hydropower is still limited to incremental generation at existing facilities; however new impoundments, diversions, and expansions are eligible if they will contribute to the operation of a pumped hydro energy storage facility that adheres to existing state and federal fish recovery plans and other local, state, and federal laws.

Washington's utility reports between 2015 and 2019 show little fluctuation in the number of hydropower RECs used to meet compliance targets.<sup>48</sup> Hydropower generally accounts for between 15-18 percent of the renewable resource total or roughly 1,000,000 megawatt-hours annually. In compliance year 2016, hydro's contribution was down to 12 percent, though the regional drought lowered overall hydro generation across the West Coast states.

## Ohio

Effective in September 2014, SB 310 revised Ohio's Alternative Energy Portfolio Standard, eliminating the advanced energy provision and renaming the standard as the Renewable Portfolio Standard.<sup>49</sup> SB 310 also eliminated the in-state REC requirement, allowing its electric distribution utilities and competitive retail electric service providers to meet their requirements with out-of-state resources. In addition, the legislation put a two-year freeze on the percent of renewable resources required until 2017.

The state's RPS requires that 12.5 percent of the electricity sold by Ohio's electric utilities comes from renewable sources by 2027. RPS eligibility includes qualified hydroelectric facilities, ROR systems on the Ohio River with an aggregate capacity greater than 40 megawatts and placed in service on or after January 1, 1980; and small hydro projects with an aggregate capacity of less than six megawatts. The state has stricter environmental eligibility requirements than other Midwestern states and "qualified hydro facilities" must meet these criteria to participate in the RPS. These criteria include adequate river flows, state water quality standards, cultural resources protection, and watershed protection, mitigation, or enhancement. These standards do not apply to facilities that generate less than six megawatts.

Ohio’s non-solar REC price for utilities in compliance year 2018 was \$15.70, compared to \$17.80 in 2017, \$13.99 in 2016, and \$15.47 in 2015.<sup>50</sup> The RPS compliance percent was on a two-year freeze in 2015 and 2016, and hydro accounted for 1.2 percent and 1.3 percent of total REC retirements, respectively. In 2017, HB49 expanded RPS eligibility to hydro facilities six megawatts or less and hydro-specific REC retirements jumped up to 12.36 percent.<sup>51</sup> In 2018, hydro REC retirements accounted for 16.48 percent of total retirements.

## PART 1 ENDNOTES

- 1 For an overview of the state of RPSs and recent trends, see an annual report by Lawrence Berkeley National Laboratory: Galen Barbose, *U.S. Renewables Portfolio Standards: 2019 Annual Status Update* (Lawrence Berkeley National Laboratory, July 2019), <https://emp.lbl.gov/publications/us-renewables-portfolio-standards-2>.
- 2 National Conference of State Legislatures, “State Renewable Portfolio Standards and Energy Goals,” web page accessed November 2019, <http://www.ncsl.org/research/energy/renewable-portfolio-standards.aspx>. In April 2020, Virginia Governor Ralph Norton signed The Virginia Clean Economy Act into law, which among other things, one of the nation’s most ambitious RPS programs. Virginia Clean Economy Act, Virginia Acts of Assembly, HB1526ER (2020), <https://lis.virginia.gov/cgi-bin/legp604.exe?201+ful+HB1526ER+pdf>. Due to the timing of this change, this report does not include the Virginia RPS in our discussion of hydropower.
- 3 FERC must consider environmental factors, but it may weigh such non-power benefits against power benefits as it considers license applications. Moreover, FERC does not have specific environmental performance standards that it must apply to hydropower review.
- 4 There is no unified definition of small hydropower. Ten megawatts appear to be most common and the upper limit appears to be 80 megawatts (Iowa).
- 5 LIHI certification is required by the following: MA Class I & II, NJ Class I, VT Tier 3, OR and PA Tier I.
- 6 AZ, CT, DE, IL, MA, MI, MO, NH, NJ, NY, OR, PA Tier I, RI New, and WA prohibit new impoundments.
- 7 CA, CO, HI, IA, ME Class 1/1A, MD, MN, NM, NC, NV, OH “small,” PA Tier II, VT Tier III, TX, Washington, DC, and WI allow new dams to qualify for RPS programs or do not specify a prohibition.
- 8 Hydropower is only eligible for Class I. “An Act Concerning Connecticut’s Energy Future”, State of Connecticut (2018), Substitute S.B. No. 9, Public Act No. 18-50, <https://www.cga.ct.gov/2018/act/pa/pdf/2018PA-00050-R00SB-00009-PA.pdf> and <https://www.cga.ct.gov/2018/act/pa/pdf/2018PA-00050-R00SB-00009-PA.pdf>.
- 9 Small existing hydro facilities are eligible for New Hampshire’s hydro-only tier, Class IV. Facilities that began operating before January 1, 2006 are eligible up to five megawatts if they have installed upstream and downstream diadromous fish passages, and up to one megawatt if they comply with FERC fish passage restoration requirements and are interconnected with New Hampshire’s electric distribution system. “Electric Renewable Portfolio Standard,” State of New Hampshire (2016) Title XXXIV Public Utilities, Chapter/362-F, Section/362-F:4, <http://www.gencourt.state.nh.us/rsa/html/XXXIV/362-F/362-F-4.htm>.
- 10 AZ, CA, CT, CO, DE, MD, MA, MO, MT, NH Class IV, NJ, NY, NC, OH “Small”, PA Tier I, RI Tier I, and VT Tier II limit eligibility to 30 megawatts or less.
- 11 CO, MA, MO, MT, NY and NC have capacity restrictions less than 10 megawatts.
- 12 HI, IL, MD Tier II, MI, NM, OR, PA Tier II, RI “Existing” tier, VT Tier I, TX, and WA do not have capacity restrictions.
- 13 The Washington State Legislature, Senate Bill 5116 (2019), *Clean Energy Transformation Act*, amended Washington’s *Energy Independence Act* with the *Clean Energy Transition Act*. State of Washington, “Clean Energy Transformation Act,” S.B. 5116 (2019), <http://lawfilesexext.leg.wa.gov/biennium/2019-20/Pdf/Bills/Senate%20Bills/5116.pdf>.

- 14 State of New Jersey, New Jersey Statutes Title 48, Public Utilities 48 § 3-51 (1999), <https://codes.findlaw.com/nj/title-48-public-utilities/nj-st-sect-48-3-51.html>. “Clean Energy Jobs,” State of Maryland, S.B. 516 (2019) , <http://mgaleg.maryland.gov/2019RS/bills/sb/sb0516E.pdf>.
- 15 “Renewable energy portfolio standard for retail electricity suppliers,” Commonwealth of Massachusetts (191<sup>st</sup> General Court), Part I Title II Chapter 25A Section 11F, <https://malegislature.gov/Laws/GeneralLaws/PartI/TitleII/Chapter25A/Section11F>.
- 16 “Renewable energy standards--qualifying retail and wholesale utilities--definitions--net metering—legislative declaration,” State of Colorado (2016), RES statute §40-2-124. C.R.S., <https://codes.findlaw.com/co/title-40-utilities/co-rev-st-sect-40-2-124.html>.
- 17 DE, HI, IL, IA, MI, MN, MO, MT “Existing,” NJ Class II, NY Tier II, PA Tier II, and VT Tier I do not have in-service date restrictions.
- 18 AZ, CT, DE, IL, MA, MI, MO, MT, NH, NJ Class I, NY Tier I, OR, PA Tier I, RI “New,” and WA prohibit new impoundments and diversions. CA, CO, HI, IA, ME Class 1/1A, MD, MN, NM, NC, NV, OH “small,” PA Tier II, VT Tier III, TX, Washington, DC, and WI allow new dams to qualify for their RPS programs or do not specify a prohibition.
- 19 Iowa allows new impoundments or diversions that do not impact certain environmental, recreational, cultural, and scenic criteria set by the state. “Public Utility Regulation,” Iowa Legislature, Chapter 476 (2020), <https://www.legis.iowa.gov/docs/code//476.pdf>. California allows new hydroelectric facilities if they do not cause adverse impacts on instream beneficial uses or cause a change in the volume or timing of stream flow; however, there is no mention of impoundments in the RPS.
- 20 The US Constitution’s Commerce Clause makes it difficult for a state to limit its RPS to in-state resources. See: Carolyn Elefant and Ed Holt, *he Commerce Clause and Implications for State Renewable Portfolio Standard Programs* (CESA, March 2011), <https://www.cesa.org/assets/2011-Files/States-Advancing-RPS/CEG-Commerce-Clause-paper-031111-Final.pdf>.
- 21 This paper discusses where a renewable generator may be able to sell its RECs: Ed Holt, *Potential RPS Markets For Renewable Energy Generators* (prepared for Clean Energy States Alliance, July 2016), <https://www.cesa.org/assets/2016-Files/Potential-RPS-Markets-Report-Holt.pdf>.
- 22 Wisconsin State Legislature, “Renewable Resources” (2019) Chapter 196, section 378, <http://docs.legis.wisconsin.gov/statutes/statutes/196/378>.
- 23 State of Vermont, “Vermont Department of Public Service Report on Vermont Renewable Energy Programs,” Vermont Department of Public Service (March 1, 2019), <https://legislature.vermont.gov/assets/Legislative-Reports/2019-Renewable-Programs-Report-w-cover.pdf>.
- 24 Massachusetts has sought to procure hydropower from Canada outside its RPS through its Section 83D Clean Energy solicitations.
- 25 Connecticut Department of Energy and Environmental Protection, Restructuring Connecticut’s Renewable Portfolio Standard (10 March 2013), accessed on April 16, 2020, <https://webcache.googleusercontent.com/search?q=cache:XmeryliDAhAJ:https://www.ct.gov/deep/lib/deep/energy/rps/rpsexecsummary.pdf+&cd=1&hl=en&ct=clnk&gl=us>.
- 26 “Connecticut Public Act 13-303, *An Act Concerning Connecticut’s Clean Energy Goals*,” State of Connecticut, Substitute S.B. 1138, Public Act No. 13-303, <https://www.cga.ct.gov/2013/act/pa/pdf/2013PA-00303-R00SB-01138-PA.pdf>.
- 27 Large-scale hydropower is defined as more than 30 megawatts, has a service operation date on or after January 1, 2003, and whose geographic eligibility includes, “in an area abutting the northern boundary of the NEPOOL geographic eligibility area...”
- 28 The environmental analysis included greenhouse gas emissions, air pollutants’ emissions, water quality, recreation, and fisheries, and other environmental impacts.



- 29 New transmission capacity from British Columbia directly into the California Balancing Authority was estimated to cost between \$4–\$6 billion. BC Hydro concluded that opportunities did not exist for exporting clean or renewable electricity. Brian McCollough et al, Including British Columbia Run-Of-River Facilities in the California Renewables Portfolio Standard (California Energy Commission, October 2013), <https://www2.energy.ca.gov/2013publications/CEC-300-2013-011/CEC-300-2013-011-SD.pdf>.
- 30 DNREC environmental criteria includes meeting the certification standards set by LIHI or its successor, but does not specify LIHI certification. See “2104 Environmental Standards for Eligible Energy Resources,” Delaware General Assembly, Title 7: 2000 (2014), <https://regulations.delaware.gov/AdminCode/title7/2000/2104.shtml#TopOfPage>.
- 31 “Competitive Retail Electric Service,” Ohio Public Utilities, Ohio’s Revised Code, Section 4928.01 (A)(37), File No. TBD, HB 6, §1 (Amended by 133rd General Assembly, October 22, 2019), ) <http://codes.ohio.gov/orc/4928.01>.
- 32 State of Ohio, “Renewable Portfolio Standard Report to The General Assembly by The Public Utilities Commission of Ohio for The 2018 Compliance Year,” PUCO Case No. 19-1894-El-Acp, Ohio Public Utilities Commission (January 16, 2020), <http://dis.puc.state.oh.us/DocumentRecord.aspx?DocID=ccc2a5cc-c216-468e-8392-fe38a3977236>.
- 33 NH PUC Order No. 25,394 amended the RPS to allow Class IV hydro facilities with a total nameplate capacity of 1MW or less to participate even without fish passages. “Order Waiving Commission Rule on Class IV Eligibility for Certain Hydroelectric Generating Facilities,” New Hampshire Public Utilities Commission, DE 12-219 Order No.25,394 (July 19, 2012), <https://www.puc.nh.gov/Regulatory/Orders/2012orders/25394e.pdf>.
- 34 New Hampshire Public Utilities Commission, “Electric Renewable Portfolio Standard (RPS) Standards,” accessed April 6, 2020, [http://www.puc.state.nh.us/Sustainable%20Energy/Renewable\\_Portfolio\\_Standard\\_Program.htm](http://www.puc.state.nh.us/Sustainable%20Energy/Renewable_Portfolio_Standard_Program.htm).
- 35 Report of the New Hampshire Public Utilities Commission To the New Hampshire General Court, “2011 Renewable Energy Portfolio Standard Review,” (November 1, 2011), <https://www.puc.nh.gov/Sustainable%20Energy/RPS/RPS%20Review%202011.pdf>.
- 36 See Figure 3 in New Hampshire’s 2018 RPS Review: New Hampshire Public Utilities Commission, “Renewable Portfolio Standard 2018 Review,” (November 1, 2018), <https://www.puc.nh.gov/20181101-RPS-Review-2018-FINAL-REPORT-2018-11-01.pdf>.
- 37 Personal communication with Shannon Ames, Low Impact Hydropower Institute’s Executive Director, on Friday, October 4, 2019.
- 38 Low Impact Hydropower Institute (LIHI), “Fact Sheet: About LIHI,” accessed April 13, 2020, <https://lowimpacthydro.org/wp-content/uploads/2018/05/2018LIHIFactSheet.pdf>.
- 39 Personal communication with Shannon Ames, Low Impact Hydro executive director, on Friday, October 4, 2019.
- 40 See Oregon State Legislature, “Chapter 469A — Renewable Portfolio Standards” (2019), [https://www.oregonlegislature.gov/bills\\_ors/ors469A.html](https://www.oregonlegislature.gov/bills_ors/ors469A.html); Pennsylvania General Assembly, “Alternative Energy Portfolio Standards Act – Enactment,” Act 213 (November 30, 2004), <https://www.legis.state.pa.us/cfdocs/legis/li/uconsCheck.cfm?yr=2004&sessInd=0&act=213>; Commonwealth of Massachusetts, “Renewable Energy Portfolio Standard - Class I” 225 CMR 14.00 (July 1, 2016), <https://www.mass.gov/doc/225-cmr-14-renewable-energy-portfolio-standard-rps-class-i/download>; State of Oregon, Renewable Portfolio Standards” Chapter 469A (2019), [https://www.oregonlegislature.gov/bills\\_laws/ors/ors469A.html](https://www.oregonlegislature.gov/bills_laws/ors/ors469A.html).
- 41 State of New Jersey, New Jersey Statutes Title 48, Public Utilities 48 § 3-51 (1999), <https://codes.findlaw.com/nj/title-48-public-utilities/nj-st-sect-48-3-51.html>.
- 42 For example, see DNREC’s environmental criteria that include following LIHI certification standards: Delaware General Assembly, “2104 Environmental Standards for Eligible Energy Resources,” (2014), Title 7: 2000, <https://regulations.delaware.gov/AdminCode/title7/2000/2104.shtml#TopOfPage>.
- 43 Personal communication with Andrew Perchlik, Vermont Clean Energy Development Board’s director, on October 19, 2019.
- 44 Personal communication with Shannon Ames, Low Impact Hydro’s executive director, on Friday, October 4, 2019.

- 45 U.S. Energy Information Agency, “EIA, Washington State Energy Profile and Energy Estimates,” (November 2018, updated December 19, 2019), <https://www.eia.gov/state/?sid=WA>.
- 46 Washington State Legislature, “Washington Energy Independence Act,” Title 19; Chapter 19.285; Section 19.285.030 (November 7, 2006), <https://app.leg.wa.gov/RCW/default.aspx?cite=19.285.030>.
- 47 The Clean Energy Transformation Act is in the process of being harmonized with the Energy Independence Act. Harmonized compliance begins in 2030. Washington State Legislature, “Clean Energy--Electric Utilities--Various Provisions” Engrossed Second Substitute Senate Bill 5116; Chapter 288, Laws of 2019 (May 7, 2019), <http://lawfilesexternal.leg.wa.gov/biennium/2019-20/Pdf/Bills/Session%20Laws/Senate/5116-S2.SL.pdf>.
- 48 Annual utility compliance reports can be found here: Washington State Department of Commerce, “EIA Reporting—Washington State Department of Commerce,” accessed April 10, 2020, <https://www.commerce.wa.gov/growing-the-economy/energy/energy-independence-act/eia-reporting>.
- 49 Ohio General Assembly, “Substitute Senate Bill 310” (2013-2014), <https://legiscan.com/OH/text/SB310/2013>.
- 50 Annual compliance reports: Ohio Public Utilities Commission, “Ohio’s renewable energy portfolio standard,” accessed April 10, 2020, <https://www.puco.ohio.gov/industry-information/industry-topics/ohioe28099s-renewable-and-advanced-energy-portfolio-standard>.
- 51 The Ohio Legislature, “Creates FY 2018-2019 operating budget,” HB 49 (June 29, 2017), <https://www.legislature.ohio.gov/legislation/legislation-summary?id=GA132-HB-49>.



## PART 1 APPENDIX

Conduit hydro and hydro facilities that are operated as part of a water supply or conveyance system are not covered in report or in table below.

State RPS Program	Capacity Cap	In-Service Date	LIHI certification or other environmental eligibility criteria	Notes and RPS Website
<b>Arizona</b> (no tiers)	A) No cap on incremental generation from existing facilities  B) New hydro eligibility is ≤ 10 MW	A) Prior to 1997  B) Installed after 1/1/2006	A) None  B) New hydro must be ROR or from an existing dam that adds generation equipment and whose change in water flow does not adversely impact fish, wildlife, or water quality.	Eligible facilities include increased capacity at existing facilities and generation from pre-1997 facilities that is used to firm intermittent renewables. Link to the state's RPS: <a href="https://azcc.gov/docs/default-source/utilities-files/electric/res.pdf?sfvrsn=cb336c7_4">https://azcc.gov/docs/default-source/utilities-files/electric/res.pdf?sfvrsn=cb336c7_4</a>
<b>California</b>	A) Existing small ≤ 30MW allowed if utility procured from facility as of 12/31/2005  B) Efficiency improvements that result in >30 MW	A) No new facilities after 12/31/2005 if it will cause adverse impact on instream beneficial uses or change in volume or timing of streamflow  B) efficiency improvement capacity after 1/1/2008 allowed if no adverse impacts as above and it meets one of three certification methods from a water control board	No adverse impacts on instream beneficial uses or a change in volume or timing of streamflow. If efficiency improvements are made, the facility must not impact streamflow and must meet one of the following certification measures: certification from the State Water Resources Board or from a regional board; if the facility is not in CA, certification from the applicable state board; or if in the Rock Creek Powerhouse, incremental certification from the State.	PHES is an eligible technology only if the pumping action is driven by renew-able energy. Link to the state's RPS: <a href="https://leginfo.legislature.ca.gov/faces/codes_displayText.xhtml?lawCode=PUC&amp;division=1.&amp;title=&amp;part=1.&amp;chapter=2.3.&amp;article=16">https://leginfo.legislature.ca.gov/faces/codes_displayText.xhtml?lawCode=PUC&amp;division=1.&amp;title=&amp;part=1.&amp;chapter=2.3.&amp;article=16</a>
<b>Connecticut</b>	Class I: ≤ 30 MW	ROR and in service after 7/1/2003, or relicensed ROR facility after 1/1/2018	Relicensed facility must meet all state and federal requirements, including water quality and fish passage. Relicensed facility must not be at a dam identified for removal.	If Class I contracts fall short of goal, large-scale hydro may fill the gap up to five percentage points, but it may not be traded in NEPOOL GIS. Link to the state's RPS: <a href="https://www.cga.ct.gov/current/pub/chap_277.htm#sec_16-1">https://www.cga.ct.gov/current/pub/chap_277.htm#sec_16-1</a>
<b>Colorado</b>	New hydro capped at ≤ 10 MW; existing hydro at ≤ 30 MW	Hydro ≤ 30 MW only prior to 1/1/2005	None	Explicitly prohibits PHES. Link to the state's RPS: <a href="http://www.leg.state.co.us/clics/clics2013a/csl.nsf/fsbillcont3/D1B329AEB8681D4D87257B3900716761?Open&amp;file=252_enr.pdf">http://www.leg.state.co.us/clics/clics2013a/csl.nsf/fsbillcont3/D1B329AEB8681D4D87257B3900716761?Open&amp;file=252_enr.pdf</a>

State RPS Program	Capacity Cap	In-Service Date	LIHI certification or other environmental eligibility criteria	Notes and RPS Website
Delaware	Class I: Small hydro $\leq$ 30 MW	None	Small hydro must meet environmental criteria that includes meeting LIHI criteria, but does not require certification. Hydro must meet a suite of environmental conditions set by DNREC. No new dams	Explicitly prohibits PHES. Link to the state's RPS: <a href="https://delcode.delaware.gov/title26/c001/sc03a/index.shtml">https://delcode.delaware.gov/title26/c001/sc03a/index.shtml</a> See complete regulations at: <a href="https://regulations.delaware.gov/AdminCode/title7/2000/2104.shtml#TopOfPage">https://regulations.delaware.gov/AdminCode/title7/2000/2104.shtml#TopOfPage</a>
Hawaii	None	None	Dams, ROR, and PHES eligible. No environmental criteria	There is little information in the statute other than that "falling water" qualifies as a renewable resource. However, the PUC's 2019 RPS report to the Legislature indicates that eligible hydro projects include those at old dams, ROR projects, refurbished facilities, and PHES facilities. Proposed future projects include PHES and new hydro projects (unclear if these include new impoundments). See the 2019 report: <a href="https://puc.hawaii.gov/wp-content/uploads/2018/12/RPS-2018-Legislative-Report_FINAL.pdf">https://puc.hawaii.gov/wp-content/uploads/2018/12/RPS-2018-Legislative-Report_FINAL.pdf</a> Link to state's RPS: <a href="https://www.capitol.hawaii.gov/hrscurrent/Vol05_Ch0261-0319/HRS0269/HRS_0269-0091.htm">https://www.capitol.hawaii.gov/hrscurrent/Vol05_Ch0261-0319/HRS0269/HRS_0269-0091.htm</a>
Illinois	None	None	No new dams or significant expansion of existing dams	Link to the state's RPS: <a href="http://www.ilga.gov/legislation/publicacts/95/095-0481.htm">http://www.ilga.gov/legislation/publicacts/95/095-0481.htm</a>
Iowa	Small hydro (capacity unspecified)	None	Small new dams or diversions (> 1 MW) are eligible if they do not adversely affect the environment and as long as it is not located on a waterway included or designated for potential inclusion as a state or national wild and scenic river.	Link to the state's RPS: <a href="https://www.legis.iowa.gov/docs/code/476.42.pdf">https://www.legis.iowa.gov/docs/code/476.42.pdf</a> See the list of special requirements for new dams or diversions at (18 CFR §292.208): <a href="https://www.law.cornell.edu/cfr/text/18/292.208">https://www.law.cornell.edu/cfr/text/18/292.208</a>

State RPS Program	Capacity Cap	In-Service Date	LIHI certification or other environmental eligibility criteria	Notes and RPS Website
<b>Maine Class I/IA</b>	Class I/IA: hydro < 100 MW	In service after 9/1/2005 or added to an existing facility after 9/1/2005; or facility not operated or not recognized by ISO-NE as a capacity resource for two years and resumed operation after 9/1/2005 (not applicable to Class IA). Also includes hydro operating beyond its previous useful life.	Class I must meet all state and federal fish passage requirements.	Link to the state's RPS: <a href="http://www.mainelegislature.org/legis/statutes/35-A/title35-Asec3210.html">http://www.mainelegislature.org/legis/statutes/35-A/title35-Asec3210.html</a>
<b>Maine Class II</b>	All existing > 100 MW	No age restrictions	None	Link to the state's RPS: <a href="http://www.mainelegislature.org/legis/statutes/35-A/title35-Asec3210.html">http://www.mainelegislature.org/legis/statutes/35-A/title35-Asec3210.html</a>
<b>Maryland</b>	Tier I: < 30 MW	Tier I: No in-service date restrictions specified	None	Explicitly prohibits PHES. Link to the state's RPS: <a href="https://codes.findlaw.com/md/public-utilities/md-code-public-util-sect-7-704.html">https://codes.findlaw.com/md/public-utilities/md-code-public-util-sect-7-704.html</a>
<b>Massachusetts Class I</b>	< 30 MW for new and incremental	Operational after 12/31/1997	LIHI or equivalent. No new impoundments after 12/31/1997	Explicitly prohibits PHES. Link to the state's RPS: <a href="https://malegislature.gov/Laws/GeneralLaws/PartI/TitleII/Chapter25A/Section11F">https://malegislature.gov/Laws/GeneralLaws/PartI/TitleII/Chapter25A/Section11F</a>
<b>Massachusetts Class II</b>	≤ 7.5 MW	Operational before 1/1/1998	LIHI certification or equivalent	Explicitly prohibits PHES. Link to the state's RPS: <a href="https://malegislature.gov/Laws/GeneralLaws/PartI/TitleII/Chapter25A/Section11F">https://malegislature.gov/Laws/GeneralLaws/PartI/TitleII/Chapter25A/Section11F</a>
<b>Michigan</b>	None	None	No new dams after 10/6/2008 (with some exceptions). Only ROR and existing hydro eligible.	Provides "incentive credits" for renewable energy with certain characteristics including on-peak renewable energy generation and off-peak renewable generation stored in a battery or pumped hydro facility and used during on-peak hours. Link to the state's RPS: <a href="http://www.legislature.mi.gov/(S(4jpjhv3xyanes3epbhne5bdp))/mileg.aspx?page=getObject&amp;objectName=mc1-Act-295-of-2008">http://www.legislature.mi.gov/(S(4jpjhv3xyanes3epbhne5bdp))/mileg.aspx?page=getObject&amp;objectName=mc1-Act-295-of-2008</a> and <a href="https://www.legislature.mi.gov/documents/2015-2016/publicact/pdf/2016-PA-0342.pdf">https://www.legislature.mi.gov/documents/2015-2016/publicact/pdf/2016-PA-0342.pdf</a>

State RPS Program	Capacity Cap	In-Service Date	LIHI certification or other environmental eligibility criteria	Notes and RPS Website
Minnesota	< 100 MW	None	None	Link to the state's RPS: <a href="https://www.revisor.mn.gov/statutes/cite/216b.1691">https://www.revisor.mn.gov/statutes/cite/216b.1691</a>
Missouri	≤ 10 MW	None	No new dams or diversions	Explicitly prohibits PHES. Link to the state's RPS: <a href="https://revisor.mo.gov/main/OneChapter.aspx?chapter=393">https://revisor.mo.gov/main/OneChapter.aspx?chapter=393</a>
Montana	A) Existing: ≤ 10 MW  B) New installations at existing reservoirs without hydro generator: ≤ 15 MW  C) Existing hydro that increases capacity: the avg. annual amount eligible will be determined by the commission	A) None  B) Existing reservoir w/o hydroelectric as of 4/16/2009  C) Expansion at existing hydro project after 10/1/2013	A) None  B) None  C) The Commission determines the eligible amount of capacity additions based on the project's significant changes to stream flow or dam operation	Hydroelectric PHES eligible as defined in 15-6-157(4)(e). Link to the state's RPS: <a href="https://leg.mt.gov/bills/mca/69/3/69-3-2003.htm">https://leg.mt.gov/bills/mca/69/3/69-3-2003.htm</a>
Nevada	A) Hydro ≤ 30 MW  B) PHES ≤ 30 MW	A) Placed into operation after 7/1/1997  B) In operation prior to 1/1/2019	A) and B): None	PHES eligible. Link to the state's RPS: <a href="https://www.leg.state.nv.us/App/NELIS/REL/80th2019/Bill/6651/Text">https://www.leg.state.nv.us/App/NELIS/REL/80th2019/Bill/6651/Text</a>
New Hampshire Class I	Incremental capacity increases from capital investments in efficiency improvement or additions of capacity over historical base-line average	Production began after 1/1 2006	None	Link to the state's RPS: <a href="http://www.gencourt.state.nh.us/rsa/html/NHTOC/NHTOC-XXXIV-362-F.htm">http://www.gencourt.state.nh.us/rsa/html/NHTOC/NHTOC-XXXIV-362-F.htm</a>
New Hampshire Class IV	≤ 5 MW measured by sum of all generators at the facility, or ≤1 MW facilities inter-connected to NH distribution system	Operation before 1/1/2006	Must have up and downstream diadromous fish passages approved by FERC or, if 1 MW or less, meets all FERC fish passage restoration requirements and is interconnected w/NH distribution system. Must have upstream and downstream fish passages, even where FERC has exempted the facility from such a requirement.	Link to the state's RPS: <a href="http://www.gencourt.state.nh.us/rsa/html/NHTOC/NHTOC-XXXIV-362-F.htm">http://www.gencourt.state.nh.us/rsa/html/NHTOC/NHTOC-XXXIV-362-F.htm</a>

State RPS Program	Capacity Cap	In-Service Date	LIHI certification or other environmental eligibility criteria	Notes and RPS Website
New Jersey Class I	≤ 3 MW	Operational after 7/23/12	Must be certified by LIHI	Link to the state's RPS: <a href="https://www.njleg.state.nj.us/2018/Bills/A4000/3723_11.HTM">https://www.njleg.state.nj.us/2018/Bills/A4000/3723_11.HTM</a>
New Jersey Class II	3-30 MW	None	NJ DEP must determine that facility meets highest environmental standards and minimizes impacts to the environment and local communities.	Link to the state's RPS: <a href="https://www.njleg.state.nj.us/2018/Bills/A4000/3723_11.HTM">https://www.njleg.state.nj.us/2018/Bills/A4000/3723_11.HTM</a>
New Mexico	A) No cap for new facilities  B) For existing facilities, the cap is an amount no greater than the amount of energy from hydro facilities that were part of an energy supply portfolio prior to 7/1/2007.	A) Operational on or after 7/1/2007  B) None	A) None  B) None	Link to the state's RPS: <a href="https://laws.nmonesource.com/w/nmos/Chapter-62-NMSA-1978#!fragment/zoupio-_Toc27124680/">https://laws.nmonesource.com/w/nmos/Chapter-62-NMSA-1978#!fragment/zoupio-_Toc27124680/</a>
New York Tier I	New ROR ≤ 5 MW; incremental production from efficiency or capacity gains from refurbishment	None	No new dams. Low impact criteria for ROR facilities	Link to the state's RPS: <a href="https://www.nyserda.ny.gov/All-Programs/Programs/Clean-Energy-Standard/Renewable-Generators-and-Developers/RES-Tier-One-Eligibility">https://www.nyserda.ny.gov/All-Programs/Programs/Clean-Energy-Standard/Renewable-Generators-and-Developers/RES-Tier-One-Eligibility</a>
New York Tier II	Limited to run-of-river hydroelectric ≤ 10 MW	Operational prior to 1/1/2015	None	Link to the state's RPS: <a href="https://www.nyserda.ny.gov/All-Programs/Programs/Clean-Energy-Standard/Renewable-Generators-and-Developers/RES-Tier-One-Eligibility">https://www.nyserda.ny.gov/All-Programs/Programs/Clean-Energy-Standard/Renewable-Generators-and-Developers/RES-Tier-One-Eligibility</a>
North Carolina	New: ≤10 MW	"New": Placed into service on or after 1/1/2007	None	Link to the state's RPS: <a href="https://www.ncleg.net/EnactedLegislation/Statutes/HTML/BySection/Chapter_62/GS_62-133.8.html">https://www.ncleg.net/EnactedLegislation/Statutes/HTML/BySection/Chapter_62/GS_62-133.8.html</a>
Ohio Alternative Energy Portfolio Standard	A) Small hydro < 6 MW  B) ROR hydro ≥ 40 MW	A) None  B) Operational on or after 1/1/1980	A) None  B) ROR hydro must be located in the state, rely upon the Ohio river. Small hydro does not need to meet environmental conditions. Other hydro facilities must comply with the water quality standards of the state and provide for adequate stream flows that are not detrimental to fish and wildlife.	Link to the state's RPS: <a href="http://codes.ohio.gov/orc/4928.01">http://codes.ohio.gov/orc/4928.01</a>

State RPS Program	Capacity Cap	In-Service Date	LIHI certification or other environmental eligibility criteria	Notes and RPS Website
Oregon	None	Efficiency upgrades made on or after 1/1/1995 eligible if made to a facility operational before 1/1/1995; facilities operational before 1/1/1995 may be used if facility is LIHI or other recognized certification	Pre- 1/1/1995 facilities must be LIHI certified	Explicitly prohibits PHES. Link to the state's RPS: <a href="https://www.oregonlegislature.gov/bills_laws/ors/ors469A.html">https://www.oregonlegislature.gov/bills_laws/ors/ors469A.html</a>
Pennsylvania Tier I	Low- impact hydro ≤ 21 MW	FERC license held in whole or part by municipality or electric cooperative as of 1/1/2007	LIHI certification, no adverse aquatic system effects, adequate water flow for aquatic life, safe fish passage, erosion control, cultural and historic resource protection	Link to state's RPS: <a href="https://www.legis.state.pa.us/cfdocs/legis/li/uconsCheck.cfm?yr=2004&amp;sessInd=0&amp;act=213">https://www.legis.state.pa.us/cfdocs/legis/li/uconsCheck.cfm?yr=2004&amp;sessInd=0&amp;act=213</a>
Pennsylvania Tier II	Large-scale hydro, no cap	No age limit	None	PHES allowed in Tier II under large hydro definition. Link to state's RPS: <a href="https://www.legis.state.pa.us/cfdocs/legis/li/uconsCheck.cfm?yr=2004&amp;sessInd=0&amp;act=213">https://www.legis.state.pa.us/cfdocs/legis/li/uconsCheck.cfm?yr=2004&amp;sessInd=0&amp;act=213</a>
Rhode Island New Tier	≤ 30 MW	Operational after 1/1/1998	No new impoundments.	Link to the state's RPS: <a href="http://webserver.rilin.state.ri.us/Statutes/TITLE39/39-26/INDEX.HTM">http://webserver.rilin.state.ri.us/Statutes/TITLE39/39-26/INDEX.HTM</a>
Rhode Island Existing Tier	None	In service since 1/1/1998	None	Link to the state's RPS: <a href="http://webserver.rilin.state.ri.us/Statutes/TITLE39/39-26/INDEX.HTM">http://webserver.rilin.state.ri.us/Statutes/TITLE39/39-26/INDEX.HTM</a>
Vermont Tier I	No cap	Existing facilities have no in-service date requirements	None	Link to the state's RPS: <a href="https://legislature.vermont.gov/statutes/section/30/089/08005">https://legislature.vermont.gov/statutes/section/30/089/08005</a>
Vermont Tier II	≤5 MW directly connected to utility sub-transmission or distribution system	New resources must be in service after 7/1/2015	None	Link to the state's RPS: <a href="https://legislature.vermont.gov/statutes/section/30/089/08005">https://legislature.vermont.gov/statutes/section/30/089/08005</a>
Vermont Tier II	≤ 55 MW	In operation on or after 1/1/2015	Energy Transformation Tier: only existing LIHI certified hydro allowed	Link to the state's RPS: <a href="https://legislature.vermont.gov/statutes/section/30/089/08005">https://legislature.vermont.gov/statutes/section/30/089/08005</a>
Texas	None	Installed after 9/1999	None	Link to the state's RPS: <a href="http://www.puc.texas.gov/agency/rulesnlaws/subrules/electric/25.173/25.173.pdf">http://www.puc.texas.gov/agency/rulesnlaws/subrules/electric/25.173/25.173.pdf</a>

State RPS Program	Capacity Cap	In-Service Date	LIHI certification or other environmental eligibility criteria	Notes and RPS Website
Washington	No cap on existing hydro	No new large hydro generation that requires new impoundments or diversions or bypass reaches or expansion of existing reservoirs constructed after 2019. New capacity from improvements/efficiency upgrades is allowed.	No new impoundments, diversions, or bypass reaches.	New diversions, impoundments or bypass reaches are allowed if they are necessary for the operation of a PHES facility. Link to the state's RPS: <a href="http://lawfilesexternal.wa.gov/biennium/2019-20/Pdf/Bills/Session%20Laws/Senate/5116-S2.SL.pdf">http://lawfilesexternal.wa.gov/biennium/2019-20/Pdf/Bills/Session%20Laws/Senate/5116-S2.SL.pdf</a>
Washington, DC	Tier II: hydro eligible; no cap	None	None	PHES explicitly ineligible. Link to the state's RPS: <a href="https://advance.lexis.com/container?config=014FJABmNTMyNmZlNy00N2U5LTRmNDktYmI0YS1jMzc4ZjNkNDcwZWUKAFBvZENhdGFsb2dWztW4MDtB3pBcSj7IPdOT&amp;crd=f4987751-456e-4a93-b32b-35aac09b1f79&amp;prid=68f05811-cf51-491a-b46b-2ef43b109218">https://advance.lexis.com/container?config=014FJABmNTMyNmZlNy00N2U5LTRmNDktYmI0YS1jMzc4ZjNkNDcwZWUKAFBvZENhdGFsb2dWztW4MDtB3pBcSj7IPdOT&amp;crd=f4987751-456e-4a93-b32b-35aac09b1f79&amp;prid=68f05811-cf51-491a-b46b-2ef43b109218</a>
Wisconsin	A) Small < 60 MW  B) Large ≥ 60 MW	A) in service on or after 1/1/2004  B) in service on or after 12/31/2010	None	Large hydro from Manitoba, Canada is eligible if licenses are in full effect. Link to the state's RPS: <a href="http://docs.legis.wisconsin.gov/statutes/statutes/196/378">http://docs.legis.wisconsin.gov/statutes/statutes/196/378</a>

## PART 2

# Hydropower Participation and Opportunities in New England RPS— A Case Study

## KEY TAKEAWAYS

- Each New England state supports a different policy objective and thus has unique eligibility criteria that vary by technology type, capacity, age, and environmental standards.
- Most New England hydropower facilities participate in Class II /Existing markets; New capacity additions; and new facilities participate in Class I markets.
- The degree of competition to sell RECs varies by market. Some Existing markets exhibit systematic surpluses and, as a result, many certified RECs go unsold.
- Eligible hydropower competes with other eligible renewable energy technologies to sell RECs. (Except for in New Hampshire's hydro-only tier.)
- Hydropower facilities must understand in which markets they can achieve certification as well as REC price dynamics. Facilities ideally would certify to participate in the highest-price REC markets.
- Large hydropower exports from Canada qualify only in Vermont's RPS.

## INTRODUCTION

**H** ydropower has played an important historical role in New England's economic development and energy markets. The region's earliest hydro development powered mills that produced textiles and agricultural products. In the late 19th and early 20th centuries, hydroelectric generators began powering businesses and residences in New England cities and towns. Over the ensuing century, hundreds of hydroelectric facilities were built, encompassing a wide array of sizes and applications. Today, facilities range from less than one megawatt to hundreds of megawatts. Many facilities operate with the use of impoundments, while others operate without modifying the run of the rivers on which they are located. According to ISO-NE, hydroelectric facilities of all sizes and types (both located in New England and delivering energy to New England from adjacent control areas) provided 8,788 gigawatt-hours of energy in 2019, constituting 8.9 percent of total generation and 7.4 percent of Net Energy for Load.<sup>1</sup>



In the late 1990s, the New England states began to legislate renewable energy mandates as part of the electric sector restructuring that led to competitive retail markets. These mandates—referred to as Renewable Portfolio Standards—call for specified percentages of retail load to be served by certified generators meeting minimum eligibility criteria, which differ by state.<sup>2</sup> The purpose of this case study is to explain the role of, and opportunities for, hydropower in New England RPS markets.

## OVERVIEW OF NEW ENGLAND RPS MARKETS

### *Eligibility Criteria*

**E**ach of the six New England states has an active RPS. Each state divides its RPS mandate into two or more “classes.”<sup>3</sup> Each class supports a different policy objective, and therefore has unique eligibility criteria that may vary by facility technology, size, in-service date, or other characteristics.<sup>4</sup>

Class I or “New” targets include supply constructed after a specified date and are generally intended to spur the development of new capacity. As a result, Class I/New RPS targets generally increase over time. Increasing demand is intended to provide the market with a price signal that leads to increasing renewable energy supply to fulfill policy objectives. Class II or “Existing” targets are intended to support continued operation of the generating fleet in existence at the time the RPS policy was enacted. Class II/Existing RPS targets are generally either static or modified periodically to keep demand aligned with supply. The policy objective is to maintain the existing fleet’s contributions to renewable energy and greenhouse gas goals at the lowest possible cost to ratepayers.

A brief discussion of terminology is required to ensure clarity for the remainder of this case study. Not all states adhere to the naming convention described above. “New” classes are also referred to as “growth” classes and existing classes as “maintenance” classes. In Vermont, the Tier I requirement is for “Existing” supply (which would be considered Class II in other markets), and the Tier II requirement is for “New” supply (that would be considered Class I in other markets). In New Hampshire, Class II is dedicated to new solar, Class III is dedicated to existing biomass, and Class IV is dedicated to existing hydro. All other classes generally adhere to regional conventions.

The remainder of this section will focus on the role of hydroelectric facilities in New England’s RPS markets. Tables 1 and 2 summarize the hydro eligibility criteria across these markets.

Eligibility criteria may be modified by state policymakers from time to time, which may trigger eligibility changes for some projects. Because the characteristics of hydroelectric generators in New England vary widely, understanding state- and class-specific RPS eligibility criteria is critical

**TABLE 1: HYDRO-SPECIFIC ELIGIBILITY CRITERIA FOR CLASS I /“NEW” RPS SUPPLY**

State / Class	Hydroelectric Eligibility Criteria
<b>CT Class I</b>	Must have COD <sup>5</sup> post 7/1/2003, be ≤ 30 MW, and operate in run-of-river mode. Or, any run-of-river hydro relicensed by FERC after 2018. <sup>6</sup>
<b>ME Class I/IA</b>	Must have COD post 9/1/2005 and be ≤ 100 MW. Or be Qualified Hydro Output. <sup>7</sup>
<b>MA Class I</b>	COD post 12/31/1997 for new or incremental capacity < 30 MW; and LIHI certified. No impoundments created after 12/31/1997. <sup>8</sup>
<b>NH Class I</b>	Must be incremental production over a historical baseline average (1997-2006).
<b>RI “New”</b>	Must have COD after 12/31/1997, be ≤ 30 MW, with no new impoundments, and must have an average salinity ≤ 20 parts per thousand.
<b>VT Tier II</b>	Must have COD post 7/1/2015; be ≤ 5MW and connected to VT distribution system.

**TABLE 2: HYDRO-SPECIFIC ELIGIBILITY CRITERIA FOR CLASS II /“EXISTING” RPS SUPPLY**

State / Class	Hydroelectric Eligibility Criteria
<b>CT Class I</b>	Hydro is no longer eligible; legislature made this class Waste-to-Energy only effective 10/30/2017.
<b>ME Class I/IA</b>	Must be ≤ 100 MW. No in-service date applies.
<b>MA Class I</b>	Must have COD before 1/1/1998, be ≤ 7.5 MW, and LIHI certified (or equivalent).
<b>NH Class I</b>	Must have COD before 1/1/2006 and be ≤ 5 MW. Facilities ≤ 1 MW must interconnect to the NH distribution system and meet FERC fish passage requirements.
<b>RI “New”</b>	Must have COD before 1/1/1998.
<b>VT Tier II</b>	No in-service date requirement; no size limit; hydro portion of HQ system mix is also eligible.

to understanding the opportunities for different types of hydroelectric generators to participate in New England RPS markets. State-specific market regulations and conditions are discussed in greater detail later in this report.

### ***RPS Compliance Mechanisms***

For all RPS markets, Renewable Energy Certificates (RECs) minted by the New England Power Pool Generation Information System (NEPOOL GIS) are the electronic currency used to demonstrate RPS compliance. RECs are created for both renewable and non-renewable production and may be sold by facility owners to load-serving entities, end-users, brokers, or other buyers through bilateral transactions.<sup>5</sup> Every calendar year, each RPS-obligated entity must purchase and retire one REC for each megawatt-hour of RPS obligation in each state. Each REC may only be used to satisfy one claim or obligation. That is, a REC retired for compliance in one state may not be used to satisfy any obligations or claims of any kind in another state. This language is included in state-specific RPS regulations. RECs also convey the rights to all claims associated with the descriptive characteristics of the associated supply.<sup>6</sup> If there is a shortage of RECs in the market, the states allow RPS-obligated entities to satisfy the requirement by making an Alternative Compliance Payment (ACP).

## RPS MARKET DYNAMICS AND ECONOMIC OPPORTUNITIES FOR HYDROPOWER

**N**ot all RPS markets offer the same economic opportunity. The growth-orientation of Class I/ New markets generally (but not universally) provides more opportunity for demand tension and higher REC prices than Class II /Existing markets. Class I REC prices can be dynamic—even volatile—because while RPS demand target increases are deterministic, the development of new RPS-eligible facilities is subject to numerous external factors which prevent the deployment of supply in predictable annual increments.<sup>7</sup> This leads to variations in supply and demand balance each year, and the potential for a wide range of REC prices as the market moves in and out of equilibrium.

Class II /Existing REC prices are generally more stable, because the universe of eligible supply is fixed and demand targets are generally stable—although policymakers reserve the right to adjust either eligibility criteria or RPS targets over time.<sup>8</sup> For example, the Massachusetts Department of Energy Resources has the explicit obligation to review and set Class II RPS targets each year (up to a cap of 3.6 percent). In 2012, it increased the Class I capacity threshold for hydro resources from 25 megawatts to 30 megawatts.

When evaluating the economic opportunity created by the RPS, each hydroelectric facility must understand in which markets it can achieve certification, as well as the historical and potential future supply, demand, and REC price dynamics.

## HYDROPOWER PARTICIPATION IN NEW ENGLAND RPS MARKETS

**A**s of July 2019, 434 hydroelectric units were registered in the NEPOOL GIS. Each of these facilities is certified for at least one RPS market. Of the 434 units, 404 are located within New England and represent 2,250 megawatts of installed hydroelectric capacity. The remaining 30 units are in adjacent control areas and must complete energy import transactions to generate RECs in NEPOOL GIS and participate in New England RPS markets. Table 3 summarizes the number of NEPOOL GIS certificates minted for hydroelectric production over the last 10 years.

**TABLE 3: NEPOOL GIS HYDROELECTRIC CERTIFICATES, BY YEAR**

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
ISO-NE	8,597	7,488	8,565	6,991	7,397	7,523	6,801	6,178	7,580	7,687
Imports	1,329	977	1,244	480	812	755	617	699	911	1,094
Total	9,927	8,465	9,809	7,470	8,210	8,277	7,419	6,877	8,491	8,781

The Imported Certificates (“imports”) row aggregates unit-specific hydro imports from NYISO, Quebec, and New Brunswick.

As previously described, Vermont allows the hydroelectric portion of Quebec system mix imports to qualify for the Tier I RES. Because Quebec does not have a reciprocal GIS system, this hydropower supply must be conveyed through System Mix Certificates that prevent these values from being included in the totals in Table 3. As a result, hydropower acquired for the Vermont Tier I RES through Quebec system-mix purchases cannot be tracked and verified on a unit-specific basis through the NEPOOL GIS, and it must be reviewed, accepted, and documented by state regulators. As a result, large hydro from Quebec plays a pivotal role in Vermont’s RPS compliance, but it is not recognized within the NEPOOL GIS on a unit-specific basis (unless unit-specific import transactions occur). Large Canadian hydro is not eligible in any other RPS market. Large hydropower is, however, eligible for the Massachusetts Clean Energy Standard (CES) if delivered to ISO-NE over new transmission. A new transmission line has been proposed but not yet approved at this time.<sup>9</sup>

### ***RPS-Certified Hydroelectric Supply***

RPS participation is based on meeting state-specific eligibility criteria and not on facility location. Any facility located in ISO-NE or delivering energy from an adjacent control area may participate in any RPS market for which it can obtain certification from state regulators.

**TABLE 4: CERTIFIED HYDROELECTRIC PROJECTS, BY RPS CLASS AND LOCATION (IN MW)**

	MA	VT	CT	NH	RI	ME	NY	Total
<b>Class I / “New” RPS Categories</b>								
<b>CT - I</b>	6.4	35.5	27.8	6.0	1.3	7.1	2.0	86
<b>MA - I</b>	25.6	7.2	0.1	43.0	0.2	10.4	9.1	85
<b>ME - I</b>	5.6	4.7	2.8	28.8	1.3	6.3	0.0	49
<b>NH - I</b>	0.2	10.3	0.0	18.0	0	12.2	0.0	41
<b>RI New</b>	10.8	10.1	1.2	1.1	0.9	2.8	8.0	35
<b>VT - II</b>	0.0	5.3	0.0	0.0	0.0	0.0	0.0	5.3
<b>Class II / “Existing” RPS Categories</b>								
<b>CT - II</b>	2.1	17.0	0.0	0.2	0.0	0.0	0.0	19
<b>MA - II</b>	55.3	78.8	2.2	34.0	0.8	35.8	39.7	247
<b>ME - II</b>	219.9	216.3	125.3	553.5	2.7	805.6	48.8	1,972
<b>NH - IV</b>	1.5	8.3	0.0	23.2	0.0	11.7	0.0	45
<b>RI Existing</b>	72.7	39.3	2.7	44.6	1.3	203.4	0.0	364
<b>VT - I</b>	274.5	366.9	129.9	580.4	2.8	796.9	0.0	2,151

Note that because each facility may become certified in more than one market, the “total” megawatts shown in the last column is greater than the total available hydroelectric supply.

Table 4 summarizes hydropower facility certification by location. The columns represent the facility's location and the rows represent the RPS markets in which these states are certified. Please note that because each facility may become certified in more than one market, the total megawatts shown below is greater than the total available hydroelectric supply. To preserve competitive market dynamics, the NEPOOL GIS does not disclose the specific market into which facility-specific RECs are sold each year.

Most New England hydro facilities participate in Class II/Existing RPS markets. Where hydropower facilities qualify for Class I/New RPS markets, this is either through new facilities or through incremental production at existing facilities—where the repowering or energy efficiency improvements result in production above a historical baseline. Generally, only the new portion of the generation qualifies for the New tiers.

### *Hydropower's Historical Contribution to RPS Compliance*

Table 5 summarizes the role that certified hydroelectric generators played in state- and class-specific RPS compliance between 2009 and 2018. In all but New Hampshire Class IV, hydroelectric supply competes with other eligible technologies to successfully sell RECs to RPS-obligated entities.

The degree of competition to sell RECs varies by market. Markets in equilibrium or shortage offer the greatest opportunity for economic benefits to qualified hydro facilities. Markets in surplus pose the greatest challenge to successfully selling RECs at an advantageous price. Some Class II/Existing markets have demonstrated systematic surplus over the past 10 years.

**TABLE 5: HYDROELECTRIC CONTRIBUTION TO ACTUAL RPS COMPLIANCE**

	% 2009	% 2010	% 2011	% 2012	% 2013	% 2014	% 2015	% 2016	% 2017	% 2018
<b>CT - I</b>	3.00	3.00	4.00	3.00	5.00	5.00	4.00	3.00	Not available <sup>5</sup>	
<b>CT - II</b>	19.00	17.00	18.00	7.00	4.67	2.33	1.87	3.21	Not eligible <sup>6</sup>	
<b>MA - I</b>	2.46	3.24	3.56	3.08	2.90	3.00	2.71	2.59	Not available <sup>7</sup>	
<b>MA - II</b>	2.05	5.37	9.68	13.99	69.05	62.55	55.89	44.32	Not available <sup>8</sup>	
<b>ME - I</b>	3.12	0.00	1.93	6.19	0.26	0.69	0.47	0.64	0.33	NA
<b>ME - II</b>	76.50	81.00	89.00	72.00	71.65	78.05	86.53	76.50	85.89	NA
<b>NH - I</b>	Hydro is eligible, but the NH PUC does not report RPS compliance contribution by technology.									
<b>NH - IV<sup>9</sup></b>	58.92	68.23	62.58	56.26	58.38	73.37	46.61	45.94	60.02	NA
<b>RI New</b>	8.61	4.61	5.02	4.31	6.20	8.32	8.85	6.48	5.07	NA
<b>RI Existing</b>	100.00	99.90	99.80	100.00	99.96	100.00	99.84	100.00	98.53	NA
<b>VT - I</b>	The VT RES was established in 2017 and is unique in that it allows LSEs to import system power from Quebec and count the hydro portion (which was 95 % as of 2017) toward VT RES compliance. While the VT Public Utilities Commission does not track RES compliance by technology, the majority is known to be from large Canadian hydro.									

In these markets—namely Maine Class II, Rhode Island Existing, and more recently, Vermont Tier I—available supply exceeds demand by a significant margin. As a result, many certified RECs go unsold. Therefore, a hydroelectric generator’s successful certification in markets with these characteristics does not guarantee REC revenue. In 2018, 156 hydro projects representing 1,855 megawatts and approximately 6,915 gigawatts per year of REC supply were only certified in systematically over-supplied markets. As a result, a significant number of these RECs may have gone unsold. The aggregate nature of NEPOOL GIS public reporting prevents market participants from knowing which RECs were ultimately sold.

### *Hydropower and Greenhouse Gas Emission Regulations*

RPS and greenhouse gas (GHG) policies are related but regulated separately across New England (and beyond).<sup>10</sup> As the New England states move to accelerating GHG emission reduction targets, some are offering additional incentives for renewable resources, including hydropower. Some hydro opportunities are broad enough to include large-scale hydropower from Canada. For example, Massachusetts directed its utilities to procure long-term contracts for approximately 1,200 megawatts of hydropower through its Section 83D, and Connecticut included hydropower as an eligible technology in its 2018 zero-carbon solicitation.<sup>11</sup>

Canadian hydropower asset-owners keep a close eye on New England RPS markets and actively participate in the policymaking process in an effort to create opportunities for their facilities. Canada is the world’s second largest producer of hydroelectricity and exports nearly nine percent of its hydropower to the United States.<sup>12</sup> Hydro Quebec (HQ), a state-owned utility in Quebec province that owns and operates hydro, nuclear, fossil fuel, and wind facilities, exports its electricity to New England and New York under long-term contracts. While HQ is not a NEPOOL RPS participant, it provides energy and capacity to the region’s market participants. HQ provides approximately 14 percent of the region’s energy mix.<sup>13</sup> Most HQ exports to New England are through bilateral contracts with New England investor-owned utilities.

As previously discussed, Vermont is the only state in which large hydro from Canada may be counted towards RPS compliance.<sup>14</sup> HQ has been exporting electricity to Vermont since the early 1980s; thus, HQ contracts with Vermont’s load-serving entities (LSEs) predate Vermont’s RES. Vermont currently has a long-term contract for 1.3 terrawatt-hour/year from HQ through 2038.<sup>15</sup>

## CHANGES IN RPS MARKETS AFFECTING HYDROPOWER

**F**rom time to time, state policymakers amend RPS eligibility criteria. This may be done as a result of evolving policy objectives (e.g., technology diversity), or as a cost control mechanism (i.e., to quickly bring a market from shortage to equilibrium). When eligibility changes affect supply that is already operating, the market impacts can be swift and dramatic. This section summarizes recent RPS changes impacting hydropower.

- In 2012, Massachusetts increased the Class I capacity threshold for hydro resources in from 25 to 30MW, and the Class II capacity threshold from 5 megawatts to 7.5 megawatts.
- In 2017, Massachusetts created a Clean Energy Standard, which creates demand for large hydro as a tool to help meet aggressive greenhouse gas objectives.
- Effective November 2017, hydropower was no longer eligible for Connecticut Class II, which became a dedicated waste-to-energy Class thereafter.
- In 2018, Connecticut amended its Class I eligibility to include all FERC-licensed run-of-river hydro. The amendment also limits RPS-obligated entities to using this supply for no more than one percent of load. Total demand for this supply would be equal to around 200–300 gigawatt-hours/year if every LSE used its maximum eligible quantity.
- In 2019, Maine created eligibility for Qualified Hydroelectric Output (QHO). The QHO is defined as output from FERC-licensed hydro generators that are greater than 25 megawatts, with a commercial operation date prior to January 1, 2019, interconnected to an electric distribution system located in the state, and not located in a critical habitat for Atlantic salmon. The total QHO as a percentage of total electrical output of the hydropower generator that is eligible for treatment as Class I or Class IA resource ramps up over time, starting at 40 percent in 2020, increasing at a rate of 10 percent of total QHO per year until 100 percent of QHO is eligible for treatment as a New resource in 2026.

## MARKET DYNAMICS: ECONOMIC OPPORTUNITIES FOR HYDRO IN NEW ENGLAND RPS MARKETS

Variations in eligibility criteria across RPS markets creates a range of potential outcomes for hydroelectric generators. Facility owners must invest in understanding state-specific regulations, certification processes, and market dynamics to identify if an economic opportunity is available and how to maximize it. If viable markets are identified, facility owners must negotiate bilateral contracts with RPS-obligated LSEs to sell RECs.

Where eligibility rules are similar, REC prices tend to converge across states. Historically, such price convergence has been observed most consistently across MA Class I, CT Class I, NH Class I, and RI New. A broader definition for Maine Class I has led to significant surpluses and low REC prices in recent years. Alternative Compliance Payment levels serve as a REC price cap, and the allowance for LSEs to purchase excess RECs in one year and bank that over-compliance to the next helps to mitigate the REC price volatility. Table 6 summarizes the status and representative REC pricing across Class I/New markets as of Summer 2019.

By comparison, Class II /Existing markets have shown themselves to be either systemically long or short. In Maine Class II and Rhode Island Existing tiers, supply dramatically exceeds demand, and RECs generally trade at less than \$1/megawatt-hour. In MA Class II and NH Class IV, however,



**TABLE 6: SNAPSHOT OF MARKET STATUS AND SAMPLE REC PRICES, SUMMER 2019, CLASS I/NEW MARKETS**

State-Class	Current Status & REC Pricing	Notes
<b>MA-I</b>	Modest Surplus RECs: ~\$23/megawatt-hours	Hydro competing with regional wind, solar, etc.
<b>CT-I</b>	Modest Surplus RECs: ~\$23/megawatt-hours	New “FERC relicensed” criteria will add to eligible supply (but only up to 1 percent of load; surplus of FERC relicensed supply will be unable to monetize RECs in RPS market).
<b>ME-I</b>	Materially Surplus <sup>16</sup> ~\$2/megawatt-hours	Hydro refurbished and operating beyond useful life can qualify.
<b>NH-I</b>	Modest Surplus RECs: ~\$23/megawatt-hours	Hydro competing with regional wind, solar, etc.
<b>RI-New</b>	Modest Surplus RECs: ~\$23/megawatt-hours	Hydro competing with regional wind, solar, etc.

not enough existing supply has been certified to fulfill demand—leading to REC prices near the ACP. Asset owners in these categories should understand not only the current market dynamics, but also the potential for these dynamics and prices to change in the near future if additional supply were to become certified. Table 7 summarizes the status and representative REC pricing across Class II/Existing markets as of Summer 2019.

**TABLE 7: SNAPSHOT OF MARKET STATUS AND SAMPLE REC PRICES, SUMMER 2019, CLASS II /EXISTING MARKETS**

State-Class	Current Status & REC Pricing	Notes
<b>MA-II</b>	Short RECs; ~\$26/megawatt-hours	Targets adjusted periodically to maintain demand tension
<b>CT-II</b>	N/A	Hydro no longer eligible
<b>ME-II</b>	Systemic surplus; < \$1/megawatt-hours	The most liberal eligibility in New England; surplus RECs cannot be monetized
<b>NH-IV</b>	Short RECs; ~\$26/megawatt-hours	Eligibility details limit supply; Prices near ACP
<b>RI-Existing</b>	Systemic surplus; < \$1/megawatt-hours	Liberal eligibility; surplus RECs cannot be monetized
<b>VT-I</b>	Systemic surplus; No functional “market” at present	Illiquid, and large Canadian hydro eligibility suppresses market value and ability of New England hydro to monetize



## PART 2 APPENDIX

### A DEEPER DIVE INTO STATE-BY-STATE CONDITIONS AND DYNAMICS

#### Class I / “New” Markets

##### *Connecticut*

In Connecticut, a hydropower facility is eligible for Class I only if it is run-of-river (ROR) and smaller than 30 megawatts (if operating after July 2003), or a ROR facility that received a new license from FERC after 2018.<sup>17</sup> Relicensed ROR hydropower RECs are limited to one percent of load for each utility.<sup>18</sup> There are 54 hydro projects participating in Connecticut’s Tier I, 13 of which are located in Connecticut and 17 in Vermont. The total nameplate capacity for these 54 projects is 86 megawatts.<sup>19</sup> In compliance year 2016, hydropower contributed three percent to the total Class I obligation.

##### *Maine*

Maine’s Governor Janet Mills signed legislation in June 2019 to increase the state’s RPS goal to 100 percent by 2050.<sup>20</sup> The new RPS expands the number of classes to include Class I, IA, and II. Class I resources include hydroelectric facilities between 25 megawatts to 100 megawatts that are located outside of the freshwater range of the Gulf of Maine Atlantic Salmon and are interconnected to an electric distribution system. Hydropower’s eligibility as a Class I resource increases annually to 2026, from 40 percent in 2020, not to exceed 200,000 megawatt-hours, to 100 percent in 2026 and each year thereafter.

The new RPS requirements include a new class of resources called Class IA, which are the same as Class I (including hydropower). Class IA resources did not operate or were not recognized by ISO-NE as capacity resources for two years or more, and either resumed operation or became recognized as a capacity resource after September 1, 2005. Class IA resources’ contribution to the class target increases gradually from 2.5 percent in 2020 to 40 percent by 2040. The Public Utilities Commission must issue its first competitive solicitation and award contracts for Class IA resources by the end of 2020.

The prior Maine RPS policy placed the hydro capacity limit at 100 megawatts, but otherwise had liberal qualifications. Hydro facilities operating beyond their useful life qualified for Class I. The only required environmental criterion was to comply with federal and state fish passage requirements. There are 21 projects participating in Maine’s Class I with a total nameplate capacity of 49 megawatt-hours; 28.8 megawatts came from five projects in New Hampshire.

## **Massachusetts**

In 2018, Massachusetts increased its RPS target to 35 percent by 2030. Its Class I requirement increases by two percent annually between 2020 and 2029, before reverting to an annual one percent indefinite increase.<sup>21, 22</sup> Small hydropower is an eligible resource. Small is defined as nameplate capacity of up to 30 megawatts (up from 25 megawatts in 2012).<sup>23</sup> The facility must meet certain environmental criteria that address healthy flows, water quality, and fish protection and mitigation. Facilities can demonstrate qualification.<sup>24</sup>

In compliance year 2016, approximately 2.5 percent of Class I RECs (133,389 megawatt-hours) came from hydropower facilities. Most the supply came from capacity increases and efficiency upgrades at older facilities that were made after 1997. Maine accounted for 33 percent of this contribution, with Vermont at 31 percent and Massachusetts at 23 percent.<sup>25</sup>

## **New Hampshire**

In New Hampshire, Class I eligible technologies include the incremental new capacity from an eligible hydroelectric generating facility of any capacity over its historical generation baseline.<sup>26</sup> The Public Utilities Commission (PUC) must certify that the facility has made capital investments for efficiency improvements, capacity additions, or increased renewable energy outputs that increase renewable electricity output.<sup>27</sup> Class I renewables must account for 15 percent of retail electric sales by 2025.

## **Rhode Island**

Rhode Island does not have classes or tiers, though it does distinguish between “new” and “existing” technologies. New technology resources include hydropower facilities less than 30 megawatts as Class I eligible resources.<sup>28</sup> Data from 2016 show that 6.2 percent of the “new” RECs settled were hydro RECs; 2017 data show a decrease to 3.9 percent, whereas wind RECs increased significantly in 2017 (an increase of nearly 87,000 RECs over 2016).<sup>29</sup> Hydro RECs were procured from Maine, New Hampshire, Massachusetts, and Vermont.

## **Vermont**

Vermont’s Tier II is its “new” or “growth” tier. Hydropower facilities that are five megawatts or less qualify for this tier; they must be located in Vermont and directly connect to the distribution system of a Vermont retail electricity provider.<sup>30</sup> Facilities that began operation after July 2015 whose RECs are owned and retired by the interconnecting retail electricity supplier are also eligible for this tier. Tier II includes hydro RECs from standard-offer projects whose outputs includes energy, capacity, and RECs.<sup>31</sup> In Compliance Year 2018, the standard-offer program had contracted for 4.9 megawatts of hydro power from small facilities.<sup>32</sup> Since the enactment of the RES in 2015, hydropower capacity through standard-offer contracts has doubled.<sup>33</sup>

## Class II/Existing Markets

Existing hydro falls under Class II in Maine and Massachusetts; Class IV in New Hampshire (which is a dedicated hydropower class); Tier I in Vermont; and the “Existing” category in Rhode Island. Hydropower is no longer eligible in Connecticut’s Class II.

### New Hampshire

New Hampshire Class IV permits *either* existing small hydro up to five megawatts, provided that the generator began operation before January 1, 2006 and has installed diadromous fish passages approved by FERC, *or* facilities 1 MW or less that comply with FERC fish-passage requirements and are interconnected to the distribution grid in New Hampshire.<sup>34</sup>

Class IV RECs have been in short supply; they are currently trading at \$26/megawatt-hour, close to the ACP rate. To stimulate new project development, the New Hampshire Renewable Energy Fund’s grant program has been focused on hydro (and thermal) projects that create Class I, Class I-thermal, and Class IV RECs.<sup>35</sup> This programmatic focus continues for FY 2020.

### Rhode Island

Rhode Island permits incremental hydropower under its “Existing Renewable Energy Resource Tier,” provided that the existing resource was certified by the Commission to have completed capital investments after Dec. 31, 1997 for efficiency improvements or additions of capacity intended to increase the annual electric output by more than 10 percent. This percentage is calculated over the historical generation baseline for the facility.<sup>36</sup>

Prior to 2017, all RECs from “existing” resources were generated at hydropower facilities. These facilities were located in Maine (73.2 percent of RECs), New Hampshire (11.8 percent of RECs), and Massachusetts (15 percent of RECs).<sup>37</sup> In Compliance Year 2017, for the first time in Rhode Island’s RES history, RECs were procured from resources other than solely hydro facilities. 99.5 percent of the total existing RECs were sourced from hydro facilities (0.5 percent came from biomass facilities in Maine).<sup>38</sup> These hydro RECs were sourced from Maine (80.1 percent), Massachusetts (13.4 percent), New Hampshire (5.1 percent), Rhode Island (0.5 percent), and Vermont (0.4 percent).<sup>39</sup>

### Massachusetts

Massachusetts amended its RPS in 2012, which increased Class II capacity limits for hydro projects to 7.5 megawatts pursuant to the *Competitively Priced Electricity Act of 2012*.<sup>40</sup> Eligibility includes any dam or diversion structure built before December 31, 1997; the capacity contributions from these older structures do not rise over time. Class II hydro projects must meet the same environmental criteria (technology, location) as Class I and demonstrate compliance through LIHI certification or by Statement of Qualification from the Department of Energy Resources.

Between 2012 and 2013, hydropower's contributions to RPS Class II compliance increased from nearly 14 percent to just over 69 percent (from 246,037 megawatt-hours to 509,462 megawatt-hours).<sup>41</sup> Hydropower's contribution to Class II steadily increased between 2012 and 2015. Compliance data are available only through 2016, but show a Class II hydropower dip between 2015 and 2016 with increased contributions from biomass and wind, as wind RECs became eligible for a larger portion of compliance. Compliance Year (CY) 2016 data show hydro's contribution to Class II obligation at 44.32 percent (94 percent of RECs in CY 2016 came from New England hydro projects and represented 45 percent of the total obligation requirement; the remaining 55 percent was met with ACPs).<sup>42</sup>

Unlike many other states' Existing classes, Massachusetts' Class II RECs have been in chronically short supply; the state adjusts the Class II targets periodically to maintain market tension. In CY 2016, 45 percent of the tier's obligation was met with RECs, while the remaining 55 percent was met with ACPs.<sup>43</sup> In 2018, DOER qualified its first Class II hydro facilities outside of ISO-NE and this may increase the number of imported RECs (from NY-ISO). Ninety-four percent of Massachusetts' Class II RECs in 2016 were generated and settled in Massachusetts from older hydro facilities.<sup>44</sup>

### **Vermont**

Vermont Tier I is unique in that it is the only tier in New England that classifies large-scale hydro as a renewable resource.<sup>45</sup> Renewable generators in the region and imports from neighboring control areas, e.g. Hydro Quebec (HQ) and New York Power Authority hydro may qualify for this tier. Vermont's RES allows existing Canadian hydro to participate without unit-specific certificates, so the size of the facility participating in Vermont's different tiers is unknown. Because the hydro facilities participating in Vermont's Tier I are largely old and large, they do not meet other New England states' RPS qualifications. Consequently, this tier is oversupplied, and the RECs are inexpensive (the RECs have traded at similar prices to other states' Class II RECs).<sup>46</sup> In CY 2017, Tier I RECs included long-term HQ purchases, regional hydro REC-only purchases, and owned hydro facilities.

## PART 2 ENDNOTES

- 1 ISO New England, “Key Grid and Market Stats,” <https://www.iso-ne.com/about/key-stats/resource-mix> (accessed April 8, 2020).
- 2 Rhode Island and Vermont use the term Renewable Energy Standard (RES).
- 3 Referred to as “Tiers” in Vermont.
- 4 A facility’s “in-service date” refers to its initial date of commercial operation.
- 5 One REC is generated for each megawatt-hour of production.
- 6 The prohibition on double-counting such characteristics has been recognized by the National Association of Attorney’s General and the Federal Trade Commission.
- 7 For hydropower specifically, another factor that contributes to hydro variation is snowpack and rainfall amounts.
- 8 Barring changes to RPS eligibility definitions.
- 9 Central Maine Power, an Avangrid, Inc. subsidiary, received regulatory approval for 145 miles of the New England Clean Energy Connect transmission project, which would deliver hydropower via a grid link between Quebec and Maine, <https://www.necleanenergyconnect.org/necec-milestones> (accessed April 13, 2020).
- 10 RPS programs are one mechanism for achieving greenhouse gas reduction targets through renewable generation, but states have other policy mechanisms for reducing GHG emissions such as 100 percent clean energy or zero carbon emission goals.
- 11 Massachusetts Clean Energy, “Section 83D RFP,” at <https://macleanenergy.com/83d/>, accessed April 9, 2020. Connecticut solicited bids for zero-carbon electricity-generating resources, but ultimately did not select any hydropower projects.
- 12 Natural Resources Canada, “Electricity Facts,” modified March 31, 2020, <https://www.nrcan.gc.ca/electricity-facts/20068>.
- 13 ISO-NE, “Key Grid and Market Stats: Resource Mix,” <https://www.iso-ne.com/about/key-stats/resource-mix>. *ISO-NE Resource Mix, 2019*, <https://www.iso-ne.com/about/key-stats/resource-mix> (accessed April 8, 2020).
- 14 Vermont Department of Public Service, “Renewable Energy Standard,” (June 28, 2016), [https://publicservice.vermont.gov/renewable\\_energy/state\\_goals](https://publicservice.vermont.gov/renewable_energy/state_goals).
- 15 Hydro Quebec, “Exports to New England,” <http://www.hydroquebec.com/international/en/exports/markets/new-england.html> (accessed April 9, 2020).
- 16 ME-1 is presently in surplus. Since this summary was created, however, the Maine Legislature enacted an RPS target increase that may realign with the rest of the New England Class I markets over the next several years.
- 17 Connecticut Department of Energy and Environmental Protection; Public Utilities Regulatory Authority, “Connecticut Renewable Portfolio Standards,” updated March 2020, <https://www.ct.gov/pura/cwp/view.asp?q=415186>.
- 18 If each utility used its maximum eligible quantity, this would amount to a total demand of 200-300 gigawatt-hours/year. Personal email communication with Sustainable Energy Advantage on October 28, 2019.
- 19 The remaining projects are located in Massachusetts (8), New Hampshire (8), Rhode Island (2), Maine (5), and New York (1). Personal email communication with Sustainable Energy Advantage on October 28, 2019.
- 20 State of Maine Legislature, “An Act to Reform Maine’s Renewable Portfolio Standard,” Public Law, Chapter 477 (2019-2020), [http://legislature.maine.gov/legis/bills/bills\\_129th/chapters/PUBLIC477.asp](http://legislature.maine.gov/legis/bills/bills_129th/chapters/PUBLIC477.asp).

- 21 Commonwealth of Massachusetts, “An Act to Advance Clean Energy,” Chapter 227 (2018), <https://malegislature.gov/Laws/SessionLaws/Acts/2018/Chapter227>.
- 22 For example, hydropower contributed 105,326 megawatt-hours to Class I RPS compliance in 2012; 113,936 megawatt hours in 2013; 129,790 megawatt-hours in 2014; and 128,810 megawatt-hours in 2015. Massachusetts Department of Energy Resources, “Massachusetts 2016 Renewable Portfolio Standard (RPS) and Alternative Portfolio Standard (APS) Annual Compliance Report,” (December 27, 2018), at page 33. [https://www.mass.gov/files/documents/2019/01/22/RPS-APS\\_percent202016\\_percent20Annual\\_percent20Compliance\\_percent20Report\\_percent20FINAL\\_REV1.pdf](https://www.mass.gov/files/documents/2019/01/22/RPS-APS_percent202016_percent20Annual_percent20Compliance_percent20Report_percent20FINAL_REV1.pdf).
- 23 Massachusetts Department of Energy Resources, “Renewable Energy Portfolio Standard - Class I,” 225 CMR 14.00, (October 2, 2017), <https://www.mass.gov/doc/225-cmr-14-renewable-energy-portfolio-standard-rps-class-i/download>.
- 24 Ibid.
- 25 Massachusetts Department of Energy Resources, “Massachusetts 2016 Renewable Portfolio Standard (RPS) and Alternative Portfolio Standard (APS) Annual Compliance Report,” (December 27, 2018), [https://www.mass.gov/files/documents/2019/01/22/RPS-APS\\_percent202016\\_percent20Annual\\_percent20Compliance\\_percent20Report\\_percent20FINAL\\_REV1.pdf](https://www.mass.gov/files/documents/2019/01/22/RPS-APS_percent202016_percent20Annual_percent20Compliance_percent20Report_percent20FINAL_REV1.pdf).
- 26 DSIRE, “Renewable Portfolio Standard: New Hampshire Program Overview” (NC Clean Energy Technology Center, July 10, 2018), <https://programs.dsireusa.org/system/program/detail/2523>.
- 27 New Hampshire General Court Statutes, Electric Renewable Portfolio Standard, Section 362-F:4 (2018), <http://www.gencourt.state.nh.us/rsa/html/XXXIV/362-F/362-F-4.htm>.
- 28 DSIRE, “Renewable Portfolio Standard; Rhode Island Program Overview” (NC Clean Energy Technology Center, June 26, 2018), <https://programs.dsireusa.org/system/program/detail/1095>.
- 29 For compliance reports 2016 and 2017, see: State of Rhode Island; Public Utilities Commission and Division of Public Utilities and Carriers, “Renewable Energy Resources,” <http://www.ripuc.org/utilityinfo/res.html> (accessed April 8, 2020).
- 30 Vermont Department of Public Service, “Renewable Energy Standard,” [https://publicservice.vermont.gov/renewable\\_energy/state\\_goals](https://publicservice.vermont.gov/renewable_energy/state_goals) (accessed April 8, 2020).
- 31 Vermont’s standard-offer program was established in 2009 to provide a financing mechanism for small-scale renewable projects up to 2.2 megawatts by offering long-term fixed price contracts with the state. Existing hydropower project may be up to 5 megawatts. Vermont Department of Service, “Report on Vermont Renewable Energy Programs,” (March 1, 2019), <https://legislature.vermont.gov/assets/Legislative-Reports/2019-Renewable-Programs-Report-w-cover.pdf>.
- 32 Ibid, at page 14.
- 33 Vermont’s Tier I also includes hydropower from the Standard Offer program.
- 34 New Hampshire General Court Statutes, Electric Renewable Portfolio Standard, Section 362-F:4 (2018), <http://www.gencourt.state.nh.us/rsa/html/XXXIV/362-F/362-F-4.htm>.
- 35 New Hampshire Public Utilities Commission, “New Hampshire Renewable Energy Fund: Annual Report,” (October 1, 2018), [https://www.puc.nh.gov/Sustainable\\_percent20Energy/Renewable\\_percent20Energy\\_percent20Fund/20181001-ref-report-to-legislature-2018-annual-report.pdf](https://www.puc.nh.gov/Sustainable_percent20Energy/Renewable_percent20Energy_percent20Fund/20181001-ref-report-to-legislature-2018-annual-report.pdf).
- 36 State of Rhode Island; Public Utilities Commission and Division of Public Utilities and Carriers, “Rhode Island Renewable Energy Standard (RI RES) Renewable Energy Resources Eligibility Form Certification Filing Methodology Guide (Version 4 – December 2012),” (July 1, 2017), [http://www.ripuc.ri.gov/utilityinfo/RES-CF-MethodologyGuide\(07-01-13\).pdf](http://www.ripuc.ri.gov/utilityinfo/RES-CF-MethodologyGuide(07-01-13).pdf).
- 37 State of Rhode Island and Providence Plantations, “Rhode Island Renewable Energy Standard Annual RES Compliance Report for Compliance Year 2016,” (April 2018), [http://www.ripuc.org/utilityinfo/2016\\_percent20RES\\_percent20Annual\\_percent20Compliance\\_percent20Report\\_percent20-percent20final.pdf](http://www.ripuc.org/utilityinfo/2016_percent20RES_percent20Annual_percent20Compliance_percent20Report_percent20-percent20final.pdf).

- 38 State of Rhode Island and Providence Plantations, “Rhode Island Renewable Energy Standards, Annual RES Compliance Report for Compliance Year 2016,” (May 2017, 2019), at page 18. [http://www.ripuc.ri.gov/utilityinfo/2017 percent20RES percent20Annual percent20Compliance percent20Report percent20- percent20final.pdf](http://www.ripuc.ri.gov/utilityinfo/2017%20RES%20Annual%20Compliance%20Report%20-%20final.pdf).
- 39 Ibid.
- 40 Massachusetts Department of Energy Resources, “Renewable energy portfolio standard - Class II,” (June 20, 2014), <https://www.mass.gov/regulations/225-CMR-15-renewable-energy-portfolio-standard-class-ii>.
- 41 The Competitively Priced Electricity Act of 2012 increased hydro capacity limits for both Class I and Class II in 2012. The Class II increase was to 7.5 megawatts. See “An Act Relative to Competitively Priced Electricity in the Commonwealth” (August 3, 2012) <https://malegislature.gov/Laws/SessionLaws/Acts/2012/Chapter209>.
- 42 Massachusetts Department of Energy Resources, “Massachusetts 2016 Renewable Portfolio Standard (RPS) and Alternative Portfolio Standard (APS) Annual Compliance Report,” (December 27, 2018), page 34, [https://www.mass.gov/files/documents/2019/01/22/RPS-APS percent202016 percent20Annual percent20Compliance percent20Report percent20FINAL\\_ REV1.pdf](https://www.mass.gov/files/documents/2019/01/22/RPS-APS%202016%20Annual%20Compliance%20Report%20FINAL_REV1.pdf).
- 43 Ibid.
- 44 Ibid.
- 45 ISO-NE, “State of the Grid: 2019, ISO in Depth,” (Feb 2019), page 29, [https://www.iso-ne.com/static-assets/documents/2019/02/20190220\\_pr\\_state-of-the-grid\\_presentation\\_final.pdf](https://www.iso-ne.com/static-assets/documents/2019/02/20190220_pr_state-of-the-grid_presentation_final.pdf).
- 46 Vermont Department of Service, “Report on Vermont Renewable Energy Programs,” (March 2019), page 6, <https://legislature.vermont.gov/assets/Legislative-Reports/2019-Renewable-Programs-Report-w-cover.pdf>.

## PART 3

# Pumped Hydropower Energy Storage In State RPS and Energy Storage Policies

## KEY TAKEAWAYS

- Pumped hydro energy storage (PHES) is not an eligible technology in most state renewable portfolio standard (RPS) programs. In the cases where it is an eligible technology, it is usually credited for only the renewable portion of its output.
- Although most existing energy storage legislation was written with technology-neutral language, eligibility requirements in state mandates tend to favor batteries.
- PHES's participation in energy storage mandates is indirectly limited by contracting structures and commissioning dates.
- Where state policy does not consider PHES as a viable energy storage solution, it is likely due to perceived siting constraints, environmental impacts, and long permitting and construction timelines.
- States could write policies in ways that offer opportunities for PHES to participate and that adequately value the many services PHES provides. States could support PHES development through a variety of market and regulatory interventions that address barriers to PHES in the market.

## INTRODUCTION

The following section reviews pumped hydro energy storage's participation in state renewable portfolio standards (RPS) and state energy storage mandates and targets. For reasons explained further in this section of the report, the technology is eligible in only five out of 30 state RPS programs. The technology fares better in state energy storage mandates and targets, which are technology neutral. However, short timelines and a focus on advanced battery storage technologies make PHES solutions unlikely to be viable candidates for near-term and short-duration targets. Many early stage energy storage goals and mandates revolve around peak demand reduction and firming intermittent solar resources. Batteries are a good solution for these short-duration needs because they can respond quickly for several minutes to hours. PHES may be better suited for long-term targets or those seeking long-duration solutions and is ideally suited for grid reliability, stability, and resiliency. Longer duration needs may be addressed in future energy storage targets that address wind firming, curtailment reduction, and other grid services.



This section of the report provides an overview of PHES, its treatment in state RPS programs, and an overview of energy storage mandates and their relevance for PHES. It concludes with an outlook on state policies' consideration of PHES technologies and suggestions on state market and regulatory interventions to help PHES overcome its significant barriers to entry.

### ***Overview of Pumped Hydro Energy Storage (PHES) in the United States***

Pumped hydro energy storage accounts for the vast majority of installed grid-scale energy storage capacity worldwide and is the oldest electrical energy storage technology. There are 42 existing PHES projects in the US providing over 21 gigawatts of storage capacity and ancillary services to the grid. Worldwide, 270 projects supply over 127 gigawatts of capacity.<sup>1</sup>

PHES is sometimes referred to as a water battery because water is stored uphill in a reservoir and released as needed to a lower reservoir through a channel or waterway. As water flows downhill, it passes through hydropower turbines that generate electricity. PHES uses electricity to pump the water to the upper reservoir, ideally when there is excess, low-cost off-peak electricity. The water is released to the lower reservoir when electricity demand is high.

The first PHES facilities were built in the 1920s, but most projects were constructed between the 1960s and 1980s to store excess energy generated by nuclear power plants. Currently, PHES facilities are valued mainly for their contributions to energy arbitrage (the practice of buying excess power when the price is low, storing the energy, and selling power when demand and prices are high) and as contingency reserves; but with the rising popularity of intermittent renewable resources such as wind and solar, PHES is re-emerging as a critical resource for grid reliability.<sup>2</sup> Furthermore, the closure of some coal and nuclear plants, which have historically provided baseload electrical power and primary and ancillary services, is also driving renewed interest in PHES.<sup>3</sup> The Federal Energy Regulatory Commission (FERC) reports an increase in the number of permits and license applications for PHES. Since 2018, FERC has issued 35 preliminary permits.<sup>4, 5</sup> Since 2014, it has issued three licenses for proposed PHES projects and relicensed nine facilities.<sup>6</sup> See Table 8 for newly licensed facilities.

**TABLE 8. PUMPED HYDRO ENERGY STORAGE FACILITIES LICENSED SINCE 2014**

Facility Name	State	Capacity (megawatts)
Eagle Mountain Pumped Storage	CA	1300
Gordon Butte Pumped Storage	MT	400
Swan Lake North Pumped Storage	MI	393.3

Because PHES facilities have quick start capabilities, they are ideal solutions for providing peak load support and for complementing intermittent resources.<sup>7</sup> PHES is likewise an effective storage solution in systems with high penetrations of variable renewable resources (VERs), especially those with curtailments of excess renewable generation. Pumped hydro can efficiently make use of the excess energy from intermittent renewable sources by pumping with the renewable energy that would otherwise have been curtailed, storing the power during low demand periods, and then supplying it at periods of high demand.

PHES can provide valuable long-duration storage. Long-duration storage is generally grid-level storage that can store energy over days or weeks and discharges energy over longer time periods—10 hours or more. In contrast, short-duration storage units are generally stationary technologies such as batteries that provide fast response for a host of grid services such as frequency regulation. Short-duration batteries can be deployed as behind-the-meter applications or as grid-scale storage.

PHES can store energy for long periods and discharge energy once or twice a day (balancing generation and demand), shift energy at grid scale to avoid transmission congestion (improving transmission efficiency), provide primary and ancillary services such as voltage support (grid stability), and shift power supply over long periods from days to weeks to months.<sup>8</sup>

Though PHES facilities are located across the US, topographic conditions, access to hydrological resources, and environmental regulations limit the number of suitable sites. Most have single-speed pump and turbine units, which were standard equipment when most PHES facilities were constructed 30-40 years ago. However, newer variable-speed units are more efficient overall and are able to operate at partial load by controlling the rotational speed of the pumps without starting/stopping the unit during pumping mode. This adjustable operation makes the technology more useful for integrating with renewables and integrates more smoothly with the grid.<sup>9</sup> The single-speed units already have round-trip efficiencies of 70-85 percent, and variable-speed PHES units further increase output by three percent.<sup>10</sup>

## PHES'S MAIN ENERGY SERVICES

PHES can provide several different energy services:

1. **Balance generation with demand and thereby aid renewable integration.** PHES balances system load in two ways—it can pump when demand and prices are low or when there is excess renewable capacity. In regions with high amounts of wind and solar, excess renewable generation is often curtailed, which results in a lost opportunity for capturing the carbon benefits of that renewable power resource. In California and Hawaii, oversupply of intermittent renewable generation occurs during the midday hours when demand is low, resulting in the curtailment of solar resources.<sup>11</sup> As an example, in 2018, the California ISO (CAISO) curtailed 460,000 megawatt-

hours of renewable energy—the equivalent of \$150 million of solar projects sitting idle.<sup>12</sup> CAISO projects that as the US moves to a higher concentration of renewable generation, curtailments will rise. The Union of Concerned Scientists modeled the curtailment effects of a 50 percent RPS in 2024 in California and found that renewables' curtailment levels would reach 4.8 percent without energy storage or any changes to the grid.<sup>13</sup>

A 2014 study led by Argonne National Laboratory analyzed the technical capabilities of PHES to provide grid services under a base case and a high-wind case scenario.<sup>14</sup> It found that PHES could reduce curtailments of renewable generation in California from 155 gigawatt-hours to 14 gigawatt-hours in the base case, and from 618 gigawatt-hours to 275 gigawatt-hours in the high wind scenario.<sup>15</sup>

In addition to reducing curtailments, PHES can provide a valuable service by discharging energy in the afternoon-to-evening hours when energy demand ramps up steeply and solar generation declines. During those hours, wholesale electricity prices can rise sharply.

2. ***Defer transmission and distribution investments.*** PHES can reduce the need for transmission and distribution upgrades to accommodate a high penetration of renewables. A PHES facility near a variable renewable generator such as a wind farm can provide numerous benefits to the grid, including voltage regulation, congestion relief, and improved stability. Co-locating a PHES facility with a renewable generator would provide the greatest amount of congestion relief. Over 65 percent of the curtailments in the CAISO in 2019 were due to local transmission constraints.<sup>16</sup>
3. ***Provide grid stability.*** PHES can provide a host of primary and ancillary grid services such as frequency and voltage support. As renewable penetration rises, midday excess generation and evening ramping necessitate increased grid stability services. For example, CAISO experiences highly variable grid conditions that require frequency and voltage management. CAISO regularly experiences evening ramps up to 13,000 megawatts in a three-hour period.<sup>17</sup> PHES' spinning rotors, like those in conventional power generators, can provide both frequency and voltage support.
4. ***Energy arbitrage and grid resiliency over long periods.*** PHES already aids in energy arbitrage—buying excess power when the price is low to pump water and selling power when demand and prices are high. Its ability to shift and store energy also stretches beyond the daily cycle to much longer durations from days to weeks. Its ability to charge and discharge daily to take advantage of higher peak prices in the spot market brings additional revenue to PHES owners, but it is not enough revenue to encourage investment in new facilities.<sup>18</sup>

PHES's ability to store excess energy and discharge over long periods, for example during long, low-wind periods or seasonal droughts, provides a service similar to energy arbitrage in that the energy was stored when the price was low and supply high. This serves to prevent load shedding or power outages. In this role, a PHES facility is providing a grid-resiliency firming or a resource-firming benefit.<sup>19</sup> However, seasonal arbitrage is currently not sufficiently remunerative to justify investment in a new facility.<sup>20</sup>

5. **Reduce overall system costs.** The Argonne National Laboratory analysis mentioned above, which analyzed the potential role of PHES, found that existing PHES facilities plus additional advanced PHES facilities could reduce total system operating costs in the three different geographic scales studied: the Western Interconnection, California, and the Sacramento Municipal Utility District (SMUD). The results show overall savings in total system production costs in 2022 of approximately 3.8 percent in the Western Interconnection, 9.1 percent in California, and 16.45 percent in SMUD.<sup>21</sup> In addition, the analysis showed that PHES facilities could reduce the number of startups and shutdowns of thermal generation units, amounting to a savings of \$31 million in the Western Interconnection under a high wind scenario.<sup>22</sup>

### ***PHES Treatment in State RPS Programs***

Many states across the US are increasing their renewable energy targets through RPSs, which support the growth of renewables, spur local economic development, cut carbon emissions, and seek to lower customer electric bills.

Because PHES provides reliability and ancillary services to the grid and can reduce or defer the need for new transmission, it is a good complement to variable renewable energy (VRE) generation. PHES has already been providing many grid services without special market incentives. However, PHES rarely qualifies for RPS programs despite its role in supporting VRE integration. In fact, seven state RPS programs explicitly prohibit PHES from participation.<sup>23</sup> This is likely because they did not view it as adding to the total supply of clean electricity, since it consumes electricity to pump water uphill, because RPSs were designed to support nascent technologies; and because of concerns about issuing renewable energy certificates (necessary for RPS compliance) for output that had already been credited to primary renewable generation (to avoid double counting). At the time the RPSs were established, policymakers associated PHES with well-established older facilities that did not require financial support from an RPS. There was little discussion of adding PHES capacity.

Now there is greater understanding that additional PHES could be desirable. But PHES is expensive to build or refurbish and takes a long time to construct, in part due to long lead times for permitting and licensing. Current regulatory structures offer few incentives for investments in PHES facility upgrades and new facility construction. State policies supporting PHES could encourage greater investment.

There are five states that explicitly allow for PHES to be eligible for the RPS.

- **California:** Due to the important role energy storage technologies play in firming renewables, the state's RPS includes PHES as an eligible technology when the PHES is paired with an eligible renewable resource.<sup>24</sup> In its recent 2018 RPS update, PHES eligibility requirements were clarified to minimize environmental impacts and to ensure that renewable energy drives the pumping mechanism. From the RPS Eligibility Guidebook:  
  
... pumped storage hydroelectric may qualify for RPS if 1) the facility meets the eligibility requirements for conduit hydroelectric, small hydroelectric, or incremental hydroelectric facilities, and 2) the electricity used to pump the water into the storage reservoir qualifies as RPS-eligible. The amount of energy that may qualify for the RPS is the amount of electricity dispatched from the pumped storage facility.<sup>25</sup>
- **Nevada:** Nevada's statute states that waterpower eligibility includes "... without limitation, power derived from water that has been pumped ... if the facility ... is not more than 30 MW" and if it was in existence as a pumped storage facility prior to January 1, 2019.<sup>26</sup>
- **Montana:** PHES is an eligible technology in the state's RPS. Only the portion of electricity generated by a qualified renewable resource counts towards RPS compliance.<sup>27</sup>
- **Michigan:** Michigan amended its RPS in 2016 with SB 438, a broad energy bill that revised the definition of renewable to include "advanced cleaner energy systems." Because pumping is most often powered by non-renewables and therefore not carbon-free, a PHES facility can only qualify for partial RECs. It receives one-fifth of a REC for each MWh of electricity generated from a renewable energy system during non-peak hours and stored using a PHES facility, and used during peak hours. The number of RECs is calculated by the number of megawatt-hours of renewable energy used to "charge" the PHES system.<sup>28</sup>
- **Pennsylvania:** Pennsylvania's Alternative Energy Portfolio Standards Act is explicit in its eligibility of pumped storage. The technology is covered under large-scale hydropower, a Tier II resource.<sup>29</sup>

In addition, Maine's recent RPS legislation includes energy storage technologies that are commercially available and use mechanical, chemical, or thermal processes to qualify for RECs under the condition that the storage solution is paired with a Class IA renewable resource.<sup>30</sup> The storage solution may either be collocated with the renewable resource or it may be located separately if it would result in GHG reductions. If the latter, only the stored renewable Class IA energy is eligible for RECs. Class I/IA renewable resources other than wind and solar are capped at 100 megawatts. Wind and solar resources are not capped.

In general, it can make sense for a state to incorporate PHES into its RPS if it is looking to better integrate renewable energy generation and sees PHES as a means to facilitate further renewable deployment. However, it can be administratively complicated to incorporate any energy storage technology, not just PHES, into an RPS. A 2016 report by the Clean Energy States Alliance,

*“Does Energy Storage Fit in an RPS?”* describes the advantages and disadvantages of including energy storage as an eligible RPS technology.<sup>31</sup> The paper asks states to consider their specific energy storage objectives and decide whether an RPS would be the most effective policy mechanism for achieving those objectives. In some cases, it could work well to incorporate storage into a state’s RPS, but in other cases a separate energy storage mandate or other incentive program would work better.

## STATE ENERGY STORAGE MANDATES

State energy storage mandates and targets that are distinct from RPSs have the potential to support PHES. Several states have enacted such mandates to address the need for a more flexible and stable grid that can not only balance supply and demand, but also optimize the use of renewable resources. State energy storage mandates direct utilities to procure a certain amount of energy storage by a certain date. Energy storage targets set storage procurement goals, but unlike mandates, they do not carry penalties or alternative compliance requirements if the goals are not met.

Currently, seven states have energy storage targets or mandates distinct from RPSs. Massachusetts, Nevada, New Jersey, and New York have targets; California, New York, and Oregon have mandates. If all the targets and mandates are met, more than 5,600 megawatts of storage capacity will be deployed by 2030.

However, most of the mandates and targets do not address the type of grid-scale solutions represented by PHES. There may be several reasons for this. First, PHES projects take an average of 10 years to permit and construct, whereas the mandates are generally focused on the next five years. Second, some states, like California, have stated that part of the purpose of their procurement mandate is to accelerate the deployment of new storage technologies and they have expressed concern that a single large PHES project could completely fulfill the mandate, whereas the state would prefer to have the mandate met through the development of numerous smaller projects employing emerging technologies. And third, grid flexibility (as opposed to grid stability) is often a primary focus. At this point, batteries are best suited for the fast response services that support grid flexibility.<sup>32</sup> Below, we provide an overview of each state’s storage mandate—even if PHES is not considered an eligible technology—to provide insights on duration lengths, the services, and the sectors for which states are seeking energy storage solutions.

### **California**

California was the first state to enact energy storage legislation. It did that in 2010 through AB 2514, which called on the California Public Utilities Commission (CPUC) to determine whether and how much energy storage the state’s investor-owned utilities should procure and required the utilities to consider adopting energy storage targets.<sup>33</sup> The CPUC established an energy storage framework and

procurement targets, requiring the utilities to procure a combined 1,325 megawatts by 2020. Utilities were required to procure the first 200 megawatts of energy storage by the end of 2014.

The CPUC, as it developed the state's storage framework, interpreted the legislature's intent to be to encourage emerging storage technologies and drive market transformation. The legislation sought to reduce fossil-fuel generation for meeting peak demand, use storage technologies to support carbon reductions, and help overcome barriers facing energy storage. The mandate itself is technology neutral—it allows for central or distributed storage systems that use mechanical, chemical, or thermal processes, but PHES systems larger than 50 megawatts were ineligible to ensure that the mandate would primarily be fulfilled by emerging technologies.<sup>34, 35</sup>

Ensuing legislation in California has largely focused on creating market opportunities for short-duration, newer storage technologies as the volume of intermittent renewables rapidly increases. In 2016, new legislation added 500 megawatts of behind-the-meter storage through AB 2868. In 2017, SB 801 directed the Los Angeles Department of Water and Power in conjunction with the Los Angeles City Council to determine the feasibility of deploying 100 megawatts of cost-effective energy storage that would mitigate the reduced storage capacity at the Aliso Canyon natural gas storage facility.<sup>36</sup> The bill clarified that the storage solutions could be grid-connected or be of any type or technology, including transmission-connected, distribution-connected, or behind-the-meter provided that it is capable of providing four-hour discharge at a rated output.<sup>37</sup>

As the cost of batteries has dropped dramatically and their quality and performance has increased, California has directed its support toward battery storage technologies. In 2017, SB 700 called on the CPUC to establish a storage initiative directing utilities to provide battery storage solutions for lower-income communities. Last year, the legislature considered a bill (SB 1347) directing utilities to procure an additional 2,000 megawatts of installed storage capacity by 2020.

California's ground-breaking energy storage activities have paved the way for other states to study and develop energy storage targets.

## **Oregon**

In 2015, Oregon became the second state to establish an energy storage mandate and target (HB 2193), requiring electric utilities with at least 25,000 retail customers to procure at least one five-megawatt-hour energy storage system, operational by January 2020. The mandate was capped at one percent of a utility's peak load. Leading up to the mandate's passing, Oregon was seeking solutions to integrate renewables, increase grid flexibility, manage peak demand, and support the state's GHG emission reduction goals. The storage mandate is technology neutral, though it does acknowledge the favorable trends in batteries with cost declines and technology improvements. Oregon's law is unique in that it directs the Public Utility Commission (PUC) to develop methodologies and guidelines for procuring and evaluating storage. It specifically directs the PUC to examine six



value streams, including environmental values, and the integration of storage with other resources.<sup>38</sup> In 2017, the PUC published guidelines that recognize storage's multiple value propositions in transmission deferrals, ancillary services, and renewables' integration.<sup>39</sup> Despite the storage mandate's bent towards batteries, the Legislature recently passed a joint resolution declaring its support of closed loop PHES systems. The resolution acknowledges the need for PHES to help utilities meet their capacity needs and integrate intermittent renewable energy into the grid.<sup>40</sup>

## **Massachusetts**

In 2016, Massachusetts became the third state to adopt an energy storage target (H. 4568). It directed the Massachusetts Department of Energy Resources (DOER) to set a procurement target for 2020 by July 2017.<sup>41</sup> The mandate is technology-specific and excludes PHES. Prior to the enactment of the legislation, Governor Charlie Baker announced a \$10 million energy storage initiative that included a requirement that DOER and the Massachusetts Clean Energy Center analyze and develop policy solutions to encourage advanced energy storage market growth. The agencies commissioned an advanced energy storage study to analyze the storage industry landscape, review market opportunities for storage, and examine potential policies and programs to support energy storage deployment across the state to secure a renewable, resilient, and reliable grid.

According to the report, *State of Charge*, released in September 2016, "While Massachusetts has benefited from pumped storage in the region, geographic and environmental limitations make it unlikely that new pumped storage will be built. Therefore, the State of Charge study focused on new advanced energy technologies that are now available."<sup>42</sup> The study modeled the optimal amount of advanced storage solutions in megawatts and megawatt-hours for the state through 2020 and found that deploying 1,766 megawatts of advanced energy storage would result in up to \$2.3 billion in ratepayer savings. Despite these findings, the report recommended the deployment of only 600 megawatts of advanced storage technologies by 2025 and policy and regulatory changes to existing market revenue mechanisms. Unlike California's and New Jersey's storage mandates, which allow utilities to own only a portion of the targeted storage capacity, Massachusetts' legislation is unique in that it lays out new energy storage ownership models for utilities.<sup>43</sup>

In 2018, the Massachusetts' legislature passed H.4857, *An Act to Advance Clean Energy*, which included a second, larger storage target of 1,000 megawatts by 2025. The storage system's primary service is to store and discharge renewable energy. PHES is not expressly prohibited, but the bill's language refers to energy storage systems that provide peak load reductions at customer sites.

## **New Jersey**

New Jersey wanted energy storage solutions not only to help the state achieve its 100 percent clean energy by 2050 target, but also to provide back-up power for critical loads during emergencies. Consequently, in 2018, the legislature set a 2,000 megawatts target by 2030—with an interim target of 600 megawatts by 2021—and directed state regulators to conduct a study identifying



optimal energy storage uses before implementing the target. Rutgers University carried out the study, reporting that PHES and thermal storage are currently most cost-effective.<sup>44</sup> New Jersey, the report concluded, is likely to need storage to stabilize offshore wind projects and electric vehicle charging. It also recommended that New Jersey take a technology-neutral approach and pursue a balanced portfolio of bulk-level, distribution-level, and customer-sited applications through pilot projects.<sup>45</sup>

The New Jersey Bureau of Public Utilities (BPU) must now establish a process and a mechanism for reaching the state's energy storage goals. In its *Draft 2019 New Jersey Energy Master Plan* released June 2019, the BPU stated that it would achieve its energy storage targets at the least cost through small capacity goal increases. It further stated that battery storage systems currently provide cost-effective ancillary services for bulk power markets and would be able to assist in the integration of high levels of offshore wind. Lastly, the BPU wrote, "Energy storage currently adds more value if it is sited across the distribution network and integrated with solar rather than centralized on the grid."<sup>46</sup>

At the moment, the state's program implementers are focused on meeting the interim 2021 target, which represents too short a timeline for PHES. PHES may be given greater consideration when attention turns to the larger 2030 target.

### **New York**

Energy storage will play a significant role in achieving New York's climate and renewable targets. The state has 1,400 megawatts of PHES and 100 megawatts of advanced energy storage already online.

In January 2018, New York Governor Andrew Cuomo announced an energy storage mandate for New York State of 1,500 megawatts by 2025 and directed the Public Service Commission (PSC) to establish a statewide energy storage target for 2030 and an accompanying deployment strategy to meet that goal.<sup>47</sup> The targets support the state's aggressive renewable energy goals—50 percent by 2030—and its carbon reduction goals of 40 percent by 2030 and 80 percent by 2050 from 1990 levels.

Prior to launching energy storage procurements, NYSERDA and the New York State Department of Public Service developed the New York State Energy Storage Roadmap, analyzing two deployment scenarios. 1,500 megawatts by 2025 and 2,795 megawatts by 2030, and calculating costs, ratepayer benefits, transmission services and savings, and avoided CO<sub>2</sub> benefits.<sup>48</sup> The Roadmap identifies comprehensive policies, regulations and initiatives for achieving the Governor's 2025 target and up to 3,600 megawatts of energy storage by 2030. It finds that this deployment will result in peak load reductions, increases in overall efficiency and resiliency of the electric grid, fossil-fuel displacements, over \$3 billion in ratepayer benefits, and 2 million metric tons of avoided GHG emissions. But while the Roadmap takes a long-term view to 2030 and is technology-agnostic, the focus of its recommended actions is on near-to-medium term deployments between 2019 and 2025 for three

market segments: customer-sited, distribution system, and bulk system. The near-term focus is important for cost reductions, gaining familiarity with storage, and increasing the number of developers participating in the NY market. (The Roadmap's long-term focus is on market design and compensation for the suite of services to the distribution system and wholesale market.)

The PSC adopted many of the Roadmap's recommendations in its December 2018 Order Establishing Energy Storage Goal and Deployment Policy.<sup>49</sup> The Order affirms the 1,500 megawatts by 2025 mandate and establishes an "aspirational" energy storage target of installing up to 3,000 megawatts by 2030 and describes a suite of deployment policies and actions to address the multiple barriers hampering energy storage solutions. These barriers include market rules, tariffs, and utility business models, and the actions include accelerating the energy storage market learning curve and driving down storage costs, including through the market bridge incentive fund, to enable a self-sustaining market.<sup>50</sup> Like the Roadmap, the Commission's Order takes a technology-neutral approach (though the Order's procurement approaches may indirectly limit PHES eligibility).<sup>51</sup> Pursuant to PSL §74, the deployment policy is meant to accomplish certain things including avoided or deferred transmission costs, GHG reductions, improved transmission reliability, and reduced peak demand.<sup>52</sup>

One of the Order's major policy objectives is to direct procurement approaches. It directs utilities to expand on their non-wires alternatives that provide value to all ratepayers and to procure bulk-dispatch rights to storage.<sup>53</sup> The Order directs each IOU to procure a minimum amount of bulk storage with an operation date of 2022; these are expected to be 4-hour duration systems.<sup>54</sup> While such a tight operational timeline certainly excludes traditional, large open-loop PHES facilities, closed-loop facilities such as those that repurpose abandoned underground mines may be able to meet such tight deadlines if they already have federal and state permits in hand.<sup>55</sup>

The Order also addresses Clean Peak actions.<sup>56</sup> It recognizes the opportunity to offset peaking operation through energy storage technologies by replacing or reducing peaker plants in New York City and Long Island, especially those whose NOx emissions are soon to be subject to stricter emission controls. The Order directs NYSERDA and other stakeholders to analyze and present an "equivalent level of clean resources" to provide the same level of reliability as the peaker plants.<sup>57</sup> The Roadmap identified energy storage technologies' unique ability to provide multiple transmission system services and pointed out that New York's transmission planning process and cost recovery mechanisms limit energy storage technologies' opportunities in addressing transmission needs. The Roadmap not only recommended that storage be appropriately compensated for its multiple value streams, but also that storage be able to provide capacity and participate in other NY ISO markets.<sup>58</sup>

Despite the PSC Order being technology-agnostic, many of its action items are geared towards distributed energy resources and advanced energy storage technologies such as Li+ batteries. Several of the procurement requirements make it difficult, if not impossible, for PHES to participate. Among those requirements are operability by December 31, 2022; seven-year contracts; and operational

local reliability services. That said, PHES is well suited to benefit from new business-case opportunities from the simultaneous services it provides to multiple market segments. In fact, the Order recognizes the role energy storage systems provide regardless of where they are located. Stable revenue and incentives for these added flexibility and reliability services can help older PHES facilities refurbish, redesign, or replace fixed-speed units, which can result in higher efficiency, quicker response time, and improved frequency control.

## Nevada

Nevada is the most recent state to adopt an energy storage target. The Nevada Legislature passed legislation (SB 204) in 2017, requiring the Public Utilities Commission of Nevada (PUCN) to explore whether to require electric utilities to purchase energy storage and whether to set biennial targets for those purchases. Among other things, the law required the PUCN to consider how energy storage systems could help integrate intermittent renewable energy resources into the grid and whether they would allow increased use of renewable energy.<sup>59</sup>

In March 2020, after considerable investigation and deliberation, the PUCN finalized a regulation to set a goal, rather than a mandate, for the procurement of 1000 megawatts of energy storage by 2030. The regulation applies to utilities with annual revenue greater than \$250 million. It does not mention any specific technologies, and the energy storage systems “can be either centralized or distributed and either owned by the affiliated utilities or by any other person.”<sup>60</sup> However, PHES was not a focus of the PUCN’s deliberations, and the way in which the regulation sets out biennial targets will make it difficult for PHES projects to compete. On the path to 1000 megawatts, there are interim targets of 100 megawatts at the end of 2020, 200 megawatts at the end of 2022, 400 megawatts at the end of 2024, 600 megawatts at the end of 2026, and 800 megawatts at the end of 2029.

Beginning in 2022, in the year following each interim target, the utilities are required to “submit an energy storage update” within their energy supply plans. They must include a description of progress in meeting the interim targets, including the amount of installed energy storage, descriptions of where projects are under contracts, “the type of technology being deployed for each energy storage project,” and other detailed information.<sup>61</sup>

## PUMPED HYDRO’S FUTURE

**T**he 2016 US Department of Energy *Hydropower Vision* report found that PHES capacity could grow by 36 gigawatts by 2050 (and 16.2 gigawatts by 2030) and stated that there is significant potential for new PHES. That potential includes PHES’s ability to help with grid stability and support the integration of VERs. However, the construction of new PHES facilities as well as the upgrading of existing fixed-speed units to adjustable-speed technology not only is costly, but also can take upwards of 10 years to get to project commissioning. While streamlined licensing and

permitting are beyond the scope of this paper, reducing investment costs and securing adequate compensation for the full range of services PHES provides to the grid are topics addressed by energy storage mandates and to some extent by RPSs.

State energy storage mandates seek solutions that, in general, 1) provide grid flexibility; 2) increase resiliency for homeowners, critical facilities, and emergency services; and 3) address the integration of an increasing number of DERs. PHES has the technical capability to integrate DERs and increase grid flexibility and reliability. Technology-neutral state energy storage mandates could provide the needed incentives and cost-recovery mechanisms to bring new PHES facilities on-line or refurbish existing units with more efficient, advanced technologies, but most the existing technology-neutral mandates include requirements that limit PHES participation.

Technology-neutral energy storage mandates and RPS programs could be vehicles for driving market investment in a range of storage technologies. PHES and energy storage solutions such as lithium-ion batteries currently complement one another, and investments in advanced PHES technologies will bring innovations with more flexible operational characteristics. And while the two storage technologies provide similar ancillary services, they are deployed and used differently. Both have a role to play in a system with increased intermittent renewables. State policies could support a wide range of storage technologies but storage mandates and RPSs would need to adjust their eligibility requirements to truly be technology neutral. Contracting structures, commissioning dates, and revenue mechanisms often indirectly limit PHES eligibility and ability to compete against other technologies.

As well suited as PHES is to matching intermittent renewable output with load demands, the technology faces many challenges and barriers to future development and to inclusion in both energy storage mandates and RPS. Because it is often viewed as a well-established technology and as an environmentally harmful one, states treat PHES differently and more cautiously than they do other clean energy or zero carbon technologies. And although FERC Order 841 cleared the way for storage to participate in wholesale power markets, adequate revenue mechanisms for PHES' varied services remain uncertain.<sup>62</sup> Furthermore, pumped hydro's perceived space constraints shape how much consideration state policy gives to including the technology in clean energy and storage mandates. However, new approaches to PHES development such as closed-loop/off-stream designs, underground reservoirs, and the repurposing of abandoned quarries or mine pits as reservoirs, can make PHES a viable low-carbon solution for integrating renewables with minimal environmental impacts.

As more states move towards deep decarbonization, increase their RPS targets, and adopt 100 percent clean energy mandates, new state policies and programs could provide PHES an opportunity to participate as a carbon-free storage solution for integrating large amounts of intermittent clean energy resources.<sup>63</sup> A level-playing field among all energy storage technologies is needed to adequately value the myriad grid infrastructure and ancillary electricity services the different

energy storage technologies offer. States can support PHES development through a variety of interventions that address PHES barriers such as long lead times, high capital costs, and uncertain revenue mechanisms. For example, states could:

- Issue procurements with large enough targets that can attract and support PHES applications. California’s storage mandate, for example, capped PHES participation at 50 megawatts. However, data show that the median size of proposed hydropower projects in the 2017 pipeline was 290 megawatts.<sup>64</sup>
- Procurements should include longer lead times to account for PHES’ significant permitting timeframes.
- Include long-term contracts for PHES in procurements.
- Provide performance-based incentives that help offset high capital costs. In markets like California with a high penetration of intermittent renewables where there is a need for flexible, fast-response storage solutions, pay for performance compensation can provide additional needed revenue for PHES facilities.
- Establish loan guarantee programs to offer low cost capital through state green banks or other financial institutions.
- Move to time-of-use pricing to drive additional revenue through energy arbitrage opportunities.
- State environmental permitting and related agencies can work to streamline the state permitting process for low-impact PHES projects such as off-stream and closed-loop projects. Similarly, these agencies could concurrently perform their project review with FERC to efficiently permit and approve PHES’ applications.

State policy and regulatory support for large-scale, long-duration energy storage such as PHES can contribute to states’ clean energy goals. But states would need to begin crafting or amending their policies now to ensure that PHES facilities could be commercially viable when they are most needed. State policy and regulatory support can send strong signals to investors and help jump start critical investment in PHES. As states target the 2030 timeframe for increased penetration of variable energy resources, the time is ripe for putting policies in place that support long-duration storage.

## PART 3 ENDNOTES

- 1 National Hydropower Association, *2018 Pumped Storage Report*, (April 2018), <https://www.hydro.org/wp-content/uploads/2018/04/2018-NHA-Pumped-Storage-Report.pdf>.
- 2 Pumped storage capacity rose by more than six gigawatts in 2016 and 1.9 gigawatts in 2018 worldwide and is used to balance demand and to integrate intermittent renewable energy. See the Hydropower Markets sections in the REN21 Global Status Reports 2017 and 2019, available at REN21, *Renewables Global Status Report*, <https://www.ren21.net/reports/global-status-report> (accessed April 15, 2020).

- 3 For example, a proposed 2.2 gigawatt PHES facility on the Utah-Arizona border would fill a void in energy storage and grid integration of intermittent renewables after the closure of the Navajo (coal) Generating Station. Kavya Balaraman, “Proposed 2.2 GW storage project plans to use Navajo coal station power-lines,” *Utility Dive*, January 21, 2020, <https://www.utilitydive.com/news/2200-mw-storage-project-navajo-coal-facility-power-lines/570720>.
- 4 Federal Energy Regulatory Commission, “Licensing,” <https://www.ferc.gov/industries/hydropower/gen-info/licensing.asp> (accessed April 14, 2020).
- 5 A preliminary permit allows a project developer up to four years to carry out site studies and gives the developer priority status in filing for a license. A preliminary permit does not authorize construction.
- 6 See “Active Licenses” spreadsheet: Federal Energy Regulatory Commission, “Licensing,” <https://www.ferc.gov/industries/hydropower/gen-info/licensing.asp> (accessed April 14, 2020).
- 7 Black start generators are power plants that are capable of turning on without external electric power. Grid operators designate black start generators, often hydropower generators, as black start resources because they can restore electricity to the grid quickly and without external electrical power during a major outage event. For more information on hydropower’s black start capabilities, please see [https://www.energy.gov/sites/prod/files/2019/05/f62/Hydro-Black-Start\\_May2019.pdf](https://www.energy.gov/sites/prod/files/2019/05/f62/Hydro-Black-Start_May2019.pdf).
- 8 While the technical ability to arbitrage energy over months exists, there are few financial models that support long-duration storage. This Greentech Media article points out several major investments in long-duration storage planned for 2020 and a performance-based insurance product for long-duration storage, but points out that off-take contracts for these projects are still under negotiation. See: Julian Specter, “5 Tangible Advances for Long-Duration Energy Storage in 2019,” *GTM<sup>2</sup>*, December 30, 2019, <https://www.greentechmedia.com/articles/read/5-tangible-advances-for-long-duration-energy-storage-in-2019>.
- 9 A 2014 study by Argonne National Laboratory determined that adjustable speed and ternary unit PHES technologies provide greater operating flexibility and efficiency over fixed-speed units, in addition to being able to provide regulation service in pumping mode. A ternary unit has a turbine and a pump coupled with an electrical machine. See Vladimir Koritarov, *Modeling and Analysis of Value Advanced Pumped Storage Hydropower in the United States* (Argonne National Laboratory, June 2014), <https://publications.anl.gov/anlpubs/2014/07/105786.pdf>.
- 10 National Hydropower Association, *2018 Pumped Storage Report* (April 2018), <https://www.hydro.org/wp-content/uploads/2018/04/2018-NHA-Pumped-Storage-Report.pdf>.
- 11 The belly of the infamous “Duck Curve” highlights the acute problem of midday solar oversupply and low levels of customer demand. The Duck Curve shows the difference in demand for electricity and the availability of solar energy over a 24-hour period. At midday, the demand for electricity is low, but the contribution from PV is high. The reverse is true as energy demand quickly ramps up in the evening.
- 12 James H. Nelson, *Achieving 50 Percent Renewable Electricity in California* (Union of Concerned Scientists, August 2015), <https://www.ucsusa.org/sites/default/files/attach/2015/08/Achieving-50-Percent-Renewable-Electricity-In-California.pdf>.
- 13 Ibid.
- 14 This study, commissioned by the US DOE in partnership with several national laboratories and manufacturers, modeled PHES system interactions with the grid and identified various benefits to the grid, including arbitrage, contingency reserves, renewable integration, cost effectiveness, and transmission efficiency. Most notably, the study found that PHES’ value increases and emissions decrease as we reach higher penetration levels of intermittent renewable resources. For more information, see this *Hydro Review* article: Vladimir Koritarov et al., “How Advanced Pumped-Storage Technologies Contribute to the System,” *Hydro Review*, Issue 7 volume 33, September 26, 2014, <https://www.hydroreview.com/2014/09/26/how-advanced-pumped-storage-technologies-contribute-to-the-system/#gref>.
- 15 Vladimir Koritarov et al., *Modeling and Analysis of Advanced Pumped Storage Hydropower in the United States* (Argonne National Laboratory, June 2014), <https://publications.anl.gov/anlpubs/2014/07/105786.pdf>. The study’s analysis focused on the Western Interconnection, California, and the Sacramento Municipal Utility District for three cases: without PHES facilities, with existing PHES facilities, and with existing PHES facilities and additional advanced adjustable speed facilities.



- 16 Wind Solar Real-Time Dispatch Curtailment Report, *Wind and Solar Curtailment—December 31, 2019* (California ISO, December 31, 2019), [http://www.caiso.com/Documents/Wind\\_SolarReal-TimeDispatchCurtailmentReportDec31\\_2019.pdf](http://www.caiso.com/Documents/Wind_SolarReal-TimeDispatchCurtailmentReportDec31_2019.pdf).
- 17 ID at 1 (2018 Pumped Storage Report, NHA).
- 18 Energy arbitrage generally does not contribute enough revenue for most long-duration energy storage solutions with high capital costs. While the focus of this research paper is on battery storage solutions in PJM, which concluded that the rate at which arbitrage revenue would be profitable depends on, among other things, rated discharge duration. It finds that the breakeven costs per kWh of energy capacity drop drastically with discharge duration. See Figures 24 and 25. Mauricio B. C. Salles, et al, “Potential Arbitrage Revenue of Energy Storage Systems in PJM.” *Energies*, July 27, 2017, <https://www.mdpi.com/1996-1073/10/8/1100/pdf>. Similarly, Lazard’s *Levelized Cost of Storage Analysis, V.4.0* compares multiple energy revenue streams across several U.S. markets and finds that energy arbitrage delivers the least value (spinning reserves provide less revenue in ERCOT). Lazard, *Lazard’s Levelized Cost Of Storage Analysis – Version 4.0* (November 2018), <https://www.lazard.com/media/450774/lazards-levelized-cost-of-storage-version-40-vfinal.pdf>.
- 19 For example, in a drought period when hydropower resources are limited, PHES can serve as a hydro-firming resource.
- 20 In general, energy arbitrage in itself is unable to provide sufficient revenue for new storage projects. Multiple value streams are needed to provide sufficient revenue.
- 21 These data are for the high wind scenarios and are higher than in the base case scenarios. Vladimir Koritarov, *Modeling and Analysis of Value Advanced Pumped Storage Hydropower in the United States* (Argonne National Laboratory, June 2014), page ES-7, <https://publications.anl.gov/anlpubs/2014/07/105786.pdf>.
- 22 Ibid., at ES-12. Estimated savings for California are \$20 million and for SMUD, \$2 million.
- 23 CO, D.C., MD, MI, MO, OR, PA, DE, and MA prohibit PHES.
- 24 California State Senate, SB-1078m Ch. 516; “Renewable energy: California Renewables Portfolio Standard Program,” [https://leginfo.ca.gov/faces/billNavClient.xhtml?bill\\_id=200120020SB1078](https://leginfo.ca.gov/faces/billNavClient.xhtml?bill_id=200120020SB1078). Senate Bill 1078 established the RPS explicitly naming hydropower as an eligible resource. The California Clean Energy Commission’s 2004 Eligibility Guidebook (May 2004) states that pumped storage hydro may qualify for the RPS if it meets two eligibility criteria.
- 25 California Energy Commission, “Commission Guidebook: Renewables Portfolio Standard Eligibility,” Ninth Edition (Revised) (January 2017), <https://efiling.energy.ca.gov/getdocument.aspx?tn=217317>.
- 26 Nevada State Senate, Senate Bill No. 358, March 18, 2019, <https://www.leg.state.nv.us/App/NELIS/REL/80th2019/Bill/6651/Text>.
- 27 Montana State Legislature, “Montana Code Annotated, 69-3-2003 Definitions,” (2019), [https://leg.mt.gov/bills/mca/title\\_0690/chapter\\_0030/part\\_0200/section\\_0030/0690-0030-0200-0030.html](https://leg.mt.gov/bills/mca/title_0690/chapter_0030/part_0200/section_0030/0690-0030-0200-0030.html).
- 28 SB 438 did not change the definition of renewable energy systems to include PHES, but rather added a category of “advanced cleaner energy systems.” State of Michigan, Enrolled Senate Bill No. 438 (2016), <https://www.legislature.mi.gov/documents/2015-2016/publicact/pdf/2016-PA-0342.pdf>.
- 29 Pennsylvania General Assembly, “Alternative Energy Portfolio Standards Act – Enactment,” P.L. 1672, No. 213 Cl. 66 (November 30, 2004), <https://www.legis.state.pa.us/cfdocs/legis/li/uconsCheck.cfm?yr=2004&sessInd=0&act=213>.
- 30 Class IA resources are the same as Class I resources, but extends to those that were not operated or recognized by ISO-NE as a capacity resource for at least two years, and, that after September 2005, resumed operation or was recognized by ISO-NE as a capacity resource. State of Maine, “An Act To Reform Maine’s Renewable Portfolio Standard,” S.P. 457 - L.D. 1494 (2019), <http://legislature.maine.gov/bills/getPDF.asp?paper=SP0457&item=3&sum=129>.
- 31 Edward A. Holt and Todd Olinsky-Paul, *Does Energy Storage Fit in an RPS?* (The RPS Collaborative, Clean Energy States Alliance, July 2016), <https://www.cesa.org/assets/2016-Files/Energy-Storage-and-RPS-Holt.pdf>.

- 32 Advanced, adjustable speed technology allows PHES to provide fast ramping response, but the existing U.S. PHES fleet consists of single-speed pumps, which are less efficient than variable speed pumps.
- 33 State of California, Assembly Bill No. 2514 Chapter 469 (September 29, 2010), [http://www.leginfo.ca.gov/pub/09-10/bill/asm/ab\\_2501-2550/ab\\_2514\\_bill\\_20100929\\_chaptered.pdf](http://www.leginfo.ca.gov/pub/09-10/bill/asm/ab_2501-2550/ab_2514_bill_20100929_chaptered.pdf).
- 34 The legislation meant to encourage a variety of storage technologies, whereas a single large PHES procurement could have fulfilled a utility's storage obligation.
- 35 In its final Rulemaking, the CPUC acknowledged that they were sympathetic to arguments that PHES meets the storage definitions in AB 2514, but given that the majority of PHES projects are at least 500 MW, a single project within a utility's territory could meet the target without achieving the state's market transformation goals. The CPUC stated that it would hold a workshop to further explore uses for pumped storage projects and encourages utilities to consider large-scale pumped storage projects where it makes sense without other general procurements. California Public Utilities Commission, "Decision Adopting Energy Storage Procurement Framework And Design Program," Rulemaking 10-12-007 (December 16, 2010), [http://assets.fiercemarkets.net/public/sites/energy/reports/20131021\\_78912194.PDF](http://assets.fiercemarkets.net/public/sites/energy/reports/20131021_78912194.PDF).
- 36 State of California, Senate Bill No. 801 Chapter 814 (October 14, 2017), [https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill\\_id=201720180SB801](https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201720180SB801).
- 37 At the conclusion of its study, LADWP determined and received permission to pursue the procurement of a 100 MW, four-hour battery energy storage system paired with solar with an anticipated operation date of 2022. Board Of Water And Power Commissioners of The City of Los Angeles, "Minutes Of Regular Meeting", (Los Angeles, April 24, 2018), [http://ladwp.granicus.com/DocumentViewer.php?file=ladwp\\_57cfe8e49576f7aea3de183899c83970.pdf&view=1](http://ladwp.granicus.com/DocumentViewer.php?file=ladwp_57cfe8e49576f7aea3de183899c83970.pdf&view=1).
- 38 See Section 3: State of Oregon, House Bill 2193 (2015), <https://olis.leg.state.or.us/liz/2015R1/Downloads/MeasureDocument/HB2193>.
- 39 State of Oregon Public Utilities Commission, "Order: Implementing Energy Storage Program Guidelines Pursuant to House Bill 2193" (July 27, 2017), <https://apps.puc.state.or.us/orders/2017ords/17-291.pdf>.
- 40 State of Oregon, "Enrolled: Senate Concurrent Resolution 1" (2019), <https://olis.leg.state.or.us/liz/2019R1/Downloads/MeasureDocument/SCR1/Enrolled>.
- 41 General Court of the Commonwealth of Massachusetts, "An Act To Promote Energy Diversity" Bill H.4568 189th (2015 - 2016), <https://malegislature.gov/Bills/189/House/H4568>.
- 42 Massachusetts Energy Storage Initiative, *State of Charge* (July 2017), page v., <https://www.mass.gov/files/2017-07/state-of-charge-report.pdf>.
- 43 Massachusetts is a deregulated state in which utilities cannot own generation. Under this new legislation, utilities are now allowed to own storage resources.
- 44 Rutgers, The State University of New Jersey, "New Jersey Energy Storage Analysis (ESA): Final Report Responses to the ESA Elements of the Clean Energy Act of 2018" (May 23, 2019), <https://www.bpu.state.nj.us/bpu/pdf/commercial/New%20Jersey%20ESA%20Final%20Report%2005-23-2019.pdf>.
- 45 Ibid, at v. Rutgers found that PHES would have the lowest lifetime cost and has massive scalability, despite geographic constraint concerns.
- 46 State of New Jersey, "Draft 2019 New Jersey Energy Master Plan: Policy Vision to 2050" (June 10, 2019), at page 57, <https://nj.gov/emp/pdf/Draft%202019%20EMP%20Final.pdf>.
- 47 State of New York Public Service Commission, "Order Establishing Energy Storage Goal And Deployment Policy" CASE 18-E-0130, Bill No. A11099/S8602-A, PSL §74 (enacted Nov. 29, 2017 and amended Nov. 5, 2018 and Dec. 11, 2018), <http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7BFDE2C318-277F-4701-B7D6-C70FCE0C6266%7D>.
- 48 New York State Department of Public Service, "New York State Energy Storage Roadmap and Department of Public Service/ New York State Energy Research and Development Authority Staff Recommendations (Roadmap)" Case 18-E-0130, In the Matter of Energy Storage Deployment Program (June 21, 2018), <http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7b2A1BFBC9-85B4-4DAE-BCAE-164B21B0DC3D%7d>.



- 49 The Order runs through the Roadmap’s recommendations in seven general categories: 1) procurement approaches, 2) IOU roles, 3) retail rate actions, 4) market acceleration, 5) soft costs, 6) clean peak actions, and 7) wholesale market actions. New York State Department of Public Service, “In the Matter of Energy Storage Deployment Program, Case No. 18-E-0130,” <http://documents.dps.ny.gov/public/MatterManagement/CaseMaster.aspx?MatterSeq=55960> (accessed April 16, 2020).
- 50 Ibid, 48. One of the Roadmap’s numerous recommendations is investment in a \$350 million statewide bridge incentive to accelerate the deployment of customer-sited storage and storage sited on the distribution or bulk systems. In the Order, the PSC authorizes NYSEDA to fund the bridge incentive at \$310 million to accelerate energy storage deployment at customer sites and at the distribution and bulk-system level, including when paired with on-site renewable generation.
- 51 Per PSL §74, a “qualified energy storage system” dispatches energy using mechanical, chemical, or thermal processes to store energy. However, the procurement requirements include operability by December 31, 2022; 7-year contracts; and operational local reliability services.
- 52 New York State Department of Public Service, “In the Matter of Energy Storage Deployment Program, Case No. 18-E-0130”, at page 9, <http://documents.dps.ny.gov/public/MatterManagement/CaseMaster.aspx?MatterSeq=55960> (accessed April 16, 2020).
- 53 Each IOU is directed to procure dispatch rights for bulk energy storage systems within their territory that provide a combination of: local reliability services; local load relief; local environmental benefits as a result of less reliance on peaker units; and wholesale services.
- 54 Note that O&R and ConEd procurement schedule is accelerated they issued an RFP for energy storage systems in July 2019. Additionally, in the Order, the PSC directs NYSEDA to continue refining renewable energy credit procurements that recognize the operational flexibility of pairing storage with renewable energy resources; the two resources do not have to be co-located.
- 55 The proposed Mineville PHES project, if approved, could take up to three years to construct. The proposed project would use abandoned iron mine chambers to store, pump, and release water. Poindexter, Gregory. “240-MW pumped storage project proposed for Mineville, N.Y.” *Hydro Review*, December 21, 2016, <https://www.hydroreview.com/2016/12/21/240-mw-pumped-storage-project-proposed-for-mineville-n-y/#gref>.
- 56 Clean Peak refers to approaches that compensate CO<sub>2</sub> reductions by shifting peak and reducing combustion turbine peaking units.
- 57 NYSEDA and stakeholders had to file the study results with the PSC by July 1, 2019, including how many megawatts of peaking units could be replaced or repowered economically with energy storage.
- 58 In the Order, the PSC recognized storage’s dual distribution benefits and services to the wholesale market and directs the DPS and NYSEDA to work with the IOUs and NY-ISO to establish a Market Design and Integration Working Group to enable dual market participation.
- 59 Nevada Legislature, SB 204 (2017), <https://www.leg.state.nv.us/App/NELIS/REL/79th2017/Bill/5078/Overview>.
- 60 Public Utilities Commission of Nevada, Docket 17-07014 Order (March 12, 2020), Section 10, [http://pucweb1.state.nv.us/PDF/AxImages/DOCKETS\\_2015\\_THRU\\_PRESENT/2017-7/44671.pdf](http://pucweb1.state.nv.us/PDF/AxImages/DOCKETS_2015_THRU_PRESENT/2017-7/44671.pdf).
- 61 Ibid., Section 12.
- 62 FERC Order 841 (Feb. 2018) addresses storage resources’ participation in the capacity, energy, and ancillary service markets in organized wholesale markets. Federal Energy Regulatory Commission, 18 CFR Part 35 [Docket Nos. RM16-23-000; AD16-20-000; Order No. 841]: “Electric Storage Participation In Markets Operated By Regional Transmission Organizations And Independent System Operators” (Issued February 15, 2018), <https://www.ferc.gov/whats-new/comm-meet/2018/021518/E-1.pdf>.
- 63 Massachusetts, for example, has adopted the nation’s first Clean Peak Standard, for which storage will qualify. In addition, the state has amended its SMART solar incentive to require that any solar installation over 500kW include storage. PHES should seek to be included in this and other state clean peak standards.
- 64 US Department of Energy - EERE Water Technologies Office, *2017 Hydropower Market Report* (April 2018), <https://www.energy.gov/sites/prod/files/2018/04/f51/Hydropower%20Market%20Report.pdf>.



**Clean Energy States Alliance**

50 State Street, Suite 1

Montpelier, VT 05602

802.223.2554

[cesa@cleanegroup.org](mailto:cesa@cleanegroup.org)

[www.cesa.org](http://www.cesa.org)

Clean Energy States Alliance (CESA) is a national, nonprofit coalition of public agencies and organizations working together to advance clean energy. CESA members—mostly state agencies—include many of the most innovative, successful, and influential public funders of clean energy initiatives in the country.

CESA works with state leaders, federal agencies, industry representatives, and other stakeholders to develop and promote clean energy technologies and markets. It supports effective state and local policies, programs, and innovation in the clean energy sector, with an emphasis on renewable energy, power generation, financing strategies, and economic development. CESA facilitates information sharing, provides technical assistance, coordinates multi-state collaborative projects, and communicates the views and achievements of its members.

© 2020 Clean Energy States Alliance

