The Power of Water: New Hydropower Technologies for the 21st Century

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DOE invests in early-stage research to accelerate the development of innovative water power technologies while ensuring that environmental issues are addressed.

DOE analyzes technology to support industry efforts in optimizing the performance and reliability of current and future water power turbines, plants, and other assets.

DOE researches markets and listens to stakeholders to provide policy makers with accurate and actionable information about challenges facing water power.
Priorities for EERE

Increasing energy affordability
Improving grid resiliency and reliability
Reducing regulatory burdens
FY19 President’s Budget Request

• $45M for Water Power in FY19, including hydropower and marine energy
• EERE proposed “Beyond Batteries” initiative to explore storage alternatives includes $20M for Water Power

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<tbody>
<tr>
<td>Sustainable Transportation</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Vehicle Technologies</td>
<td>306,959</td>
<td>304,874</td>
<td>68,500</td>
<td>-238,459</td>
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<tr>
<td>Bioenergy Technologies</td>
<td>205,000</td>
<td>203,608</td>
<td>37,000</td>
<td>-168,000</td>
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<tr>
<td>Hydrogen and Fuel Cell Technologies</td>
<td>101,000</td>
<td>100,315</td>
<td>58,000</td>
<td>-43,000</td>
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<tr>
<td>Total, Sustainable Transportation</td>
<td>612,959</td>
<td>608,797</td>
<td>163,500</td>
<td>-449,459</td>
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<tr>
<td>Renewable Energy</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Solar Energy</td>
<td>207,600</td>
<td>206,190</td>
<td>67,000</td>
<td>-140,600</td>
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<tr>
<td>Wind Energy</td>
<td>90,000</td>
<td>89,388</td>
<td>33,000</td>
<td>-57,000</td>
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<tr>
<td>Water Power</td>
<td>84,000</td>
<td>83,429</td>
<td>45,000</td>
<td>-39,000</td>
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<tr>
<td>Geothermal Technologies</td>
<td>69,500</td>
<td>69,028</td>
<td>30,000</td>
<td>-39,500</td>
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<tr>
<td>Total, Renewable Energy</td>
<td>451,100</td>
<td>448,035</td>
<td>175,000</td>
<td>-276,100</td>
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</table>
DOE and hydropower

Why is DOE interested in hydropower?

- Critical infrastructure
- High-skilled jobs
- Cost-effective clean power
Policy Recommendation:
Valuation of Essential Reliability Services (ERS): FERC should study and make recommendations regarding efforts to require valuation of new and existing ERS by creating fuel-neutral markets and/or regulatory mechanisms that compensate grid participants for services that are necessary to support reliable grid operations.

Area for Further Research:
Study mechanisms for enabling equitable, value-based remuneration for desired grid attributes—such as ERS, fuel availability, high resilience, low emissions, flexibility, etc.—with alternative market and non-market structures. This research could assess potentially underrecognized contributions from baseload power plants, using fuel-neutral metrics and values relevant to analyze all resource options.
Hydropower is extremely responsive and important for grid reliability/flexibility

Hydropower’s flexibility is an important asset...

<table>
<thead>
<tr>
<th>Resource Type</th>
<th>Frequency Response (Inertia &amp; Primary)</th>
<th>Voltage Control</th>
<th>Ramp</th>
<th>Essential Reliability Services (Frequency, Voltage, Ramp Capability)</th>
<th>Fuel Assurance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Regulation</td>
<td>Contingency Reserve</td>
<td>Load Following</td>
<td>Cycle</td>
</tr>
<tr>
<td>Hydro</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Coal - Steam</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Natural Gas - Steam</td>
<td></td>
<td></td>
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Source PJM 2017
Preliminary Analysis of Hydro Flexibility Value as part of ongoing NARIS Study

...which can create substantial value

<table>
<thead>
<tr>
<th></th>
<th>Total cost</th>
<th>PLEXOS (million $)</th>
<th>RiverWare (million $)</th>
<th>Reduction (million $, %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAU</td>
<td>223.0</td>
<td>218.9</td>
<td></td>
<td>4.17 (1.9%)</td>
</tr>
<tr>
<td>HiWind</td>
<td>155.2</td>
<td>154.2</td>
<td></td>
<td>0.98 (0.6%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Avg. price</th>
<th>PLEXOS ($/MWh)</th>
<th>RiverWare ($/MWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAU</td>
<td>40.5</td>
<td>38.3</td>
</tr>
<tr>
<td>HiWind</td>
<td>30.0</td>
<td>27.0</td>
</tr>
</tbody>
</table>

which can create substantial value
Hydropower’s role in renewable integration

In 2017 Costa Rica ran on 100% renewables for **300 days**

Hydropower provided 78% of this electricity

The Arenal Dam in Lake Arenal
157 MW of installed capacity

In May 2016 Portugal ran on 100% renewables for **4 uninterrupted days**

Hydropower provided 32% of this electricity

The Alto Lindoso Dam on the Lima River
630 MW of installed capacity

- Current worldwide PSH capacity is 150 GW.
- 31.5 GW of new hydropower capacity was installed worldwide in 2016.
- 6.4 GW of that was PSH—nearly twice the amount of what was installed in 2015.
Pumped storage is also critical and often overlooked.
More flexibly-utilized hydro of the future will have to adapt

Bagnell Dam, Osage Power Plant, and Lake of the Ozarks, Missouri

Strain gauge amplitude spectrum from tests at Vattenfall’s Stornorrfors hydro plant [2016]


Osage plant loads for 1/6/2009 – 1/16/2009
Data from soon-to-be-released U.S. Hydro Market Report show rising O&M costs

Since 2007, growth in O&M cost has outstripped inflation.

- Data from 189 Large (100-500 MW) and Medium (10-100 MW) capacity projects (representative set of whole U.S. fleet)
- +35% cost increase for Medium and Large projects; only +14% increase in consumer price index
Flexibility constrained by license obligations and competing water uses
• Primary findings
  – Benefits for base case ($39.6 million) exceed its associated costs ($29.0 million) – ROI of 1.36
  – Primary frequency response and capacity provide tremendous value despite the fact that those services are concentrated in a very small number of hours each year—17 and 19, respectively.
How can DOE help?

• Early-stage R&D in **technologies and systems** to reduce costs and unlock new resources

• Research to **improve environmental sustainability** of existing and future hydropower technologies

• Supply objective **data, information and analysis** to identify market opportunities, and **reduce permitting and deployment barriers**

• Research to evaluate and improve the ability of hydro and pumped storage to provide **essential flexibility and reliability services** for the rapidly evolving electric grid
New Hydropower Valuation Research Initiative

• Launch a new national research initiative in 2018 to understand and drive utilization of the full potential of hydroelectric resources to contribute to electric reliability and resiliency, now and into the future.

• Completed:
  – New collaborative of hydropower national laboratories
  – Foundational multi-laboratory projects
  – RFI to solicit feedback on priorities and strategic direction

• Coming shortly:
  – Direct industry engagement and opportunities, including Water Power Week in DC
Foundational Initial Projects

• Development of an advanced valuation methodology for pumped storage, tested through techno-economic analysis of pumped storage at two sites with high-levels of variable generation.

• Report on current operational landscape, research roadmaps for future grid scenarios and technology innovation
Request for Information

https://eere-exchange.energy.gov/default.aspx#Foaldc7e629f0-7127-43df-a13b-6a5da7a38b3a

DE-FOA-0001886: RFI: Expanding Hydropower and Pumped Storage’s Contribution to Grid Resiliency and Reliability

Topics:
• Hydropower Capability, Operational Impacts, and Costs
• Current Operations Landscape
• Role and Value of Hydropower in Future Power Systems
• Additional Research Needs

Deadline for Comments: April 6
How can organizations get funds for their R&D priorities?

**Competitively Selected Awards**
- Competitive award of discretionary grants or cooperative agreements with industry, academic, or national laboratory partners through funding opportunity announcements (FOAs)
- May include cost-share requirements

**Small Business Innovative Research (SBIR)**
- Enables small businesses to explore their technological potential and provides the incentive to **profit from its commercialization**

**National Laboratory Funding**
- **Direct funding** for R&D at national labs is selectively competed
New website for all DOE water power-related resources, all in one location

Information is sourced from industry and five national laboratories: Argonne National Laboratory, Idaho National Laboratory, National Renewable Energy Laboratory, Oak Ridge National Laboratory, and Pacific Northwest National Laboratory

Four main categories for fast data access:
- Infrastructure
- Environmental, Sustainability, Regulatory
- Technology Development
- Markets and Values

For More Information: hydrowise.ornl.gov
Chilean company Valhalla’s Espejo de Tarapacá project, which is comprised of a 300 MW pump hydro plant that operates with seawater.
Opportunities for new hydro, and to use existing hydro in new ways

New Approaches to Designing and Developing New Hydro

Humpback Creek
Hydroelectric Plant 1250kW

Power Creek Plant
6278kW (2 x 3124 kW)

Using Existing Hydro to Improve Resiliency & Reliability

City of Cordova, AK
1,566 customers, 18MW
1 Substation, 78mi UG distribution lines
WHOOSH Innovations
Fish Transport System

• Novel solution to safely and rapidly transport fish over and around barriers
• Modular and quickly reconfigurable in order to provide options for a variety of dam designs and river systems
• Originally based on innovative technology from a non-energy industry

Both reduce the costs of licensing

Biologically-Based Design and Evaluation (BioDE) of Hydro Turbines

• New open-source computer-driven design tools to improve fish survival
• Maintains efficiency and generation for new turbines, reduce design and regulatory review time, and increases sustainable hydro development
• Already demonstrated in turbine procurement and evaluation processes by Grant County Public Utility District and USACE
PNNL released a study showing new ability to project seasonal hydropower generation rather than annual for individually simulated hydropower plants.

Building regulatory constraints into simulations can improve seasonal projections of hydropower and reduce uncertainty in projections and can also demonstrate the impact of regulatory constraints on hydro flexibility.

Water use and regulatory constraints to hydropower flexibility

[Map showing regions and hydro projects]