U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

WIND & WATER POWER PROGRAM

Water Power for a Clean Energy Future




June 2012

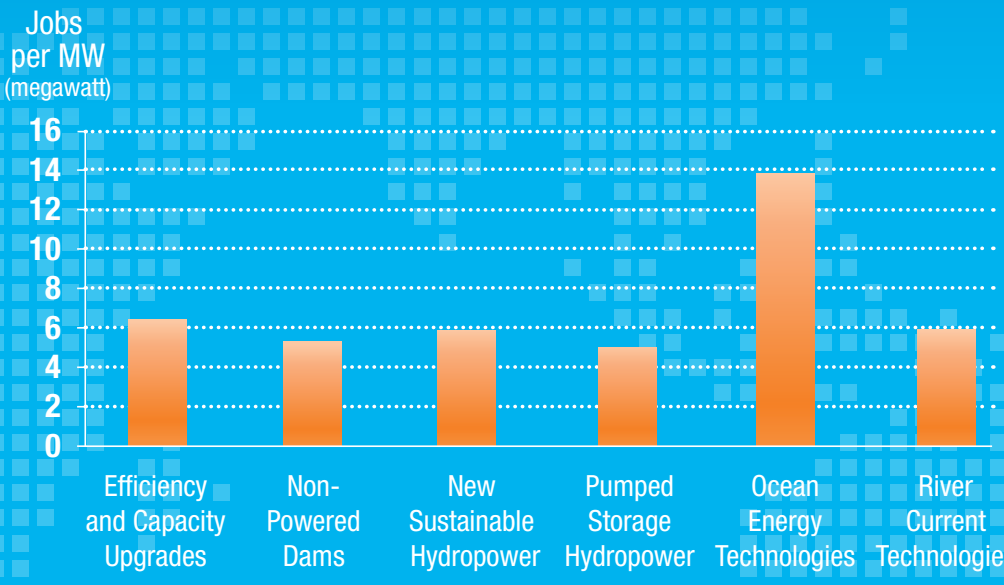
Building a Clean Energy Economy

Leading the world in clean energy is critical to strengthening the American economy. Targeted investments in clean energy research and development jumpstart private sector innovation critical to our long-term economic growth, energy security, and international competitiveness. The U.S. Department of Energy (DOE) Water Power Program (the Program) is growing the nation's global position by funding cutting-edge research to produce the next generation of conventional hydropower and marine and hydrokinetic (MHK) technologies, and by accelerating the development of markets for those technologies.

Currently, the conventional hydropower industry employs more than 300,000 workers in the United States, making it not only the longest-running, but also the largest renewable electricity production workforce in the nation. However, there has been a lack of consistent hydropower education programs in the United States. In an effort to increase our nation's knowledge and skills in this area, the Program has sponsored new graduate research fellowships to train the next generation of hydropower specialists and engineers.

The newly emerging MHK industry holds tremendous potential for job growth as MHK technologies progress towards commercial readiness. The Program invests in fellowships that fund graduate-level training and sends U.S. researchers to advanced European research facilities to establish partnerships, boost innovation, and facilitate knowledge sharing. By capitalizing on water power's significant potential for sustainable growth, the United States can add thousands of clean energy jobs while building a sustainable, renewable energy future.

Water Power Jobs



The U.S. water power industry can create 1.4 million jobs (cumulative) by 2025*

** Job Creation Opportunities in Hydropower.* Navigant Consulting, September 20, 2009.

Department of Energy Water Power Program

Developing and Advancing a Renewable Energy Future

The Water Power Program (the Program) at the U.S. Department of Energy (DOE) is at the forefront of the nation's clean energy frontier. To help the United States meet its growing energy demand, the Program is pioneering research and development efforts in both marine & hydrokinetic (MHK) and conventional hydropower technologies. These water power technology areas hold the promise of clean, affordable electricity that will move our nation towards energy independence.

Hydroelectric power, the largest source of renewable electricity in the United States, allows the nation to avoid 200 million metric tons of carbon emissions each year. Although only a small portion of dams produce electricity, new generation equipment can be added to existing infrastructure to access vast reserves of untapped hydropower capacity in the United States. DOE's Water Power Program leads the critical research and development efforts necessary to develop more efficient technologies that will drive sustainable growth and economic opportunity.

Additionally, DOE's Water Power Program invests in the new and innovative MHK industry. This nascent technology sector is an example of American ingenuity at its best, producing cutting-edge technologies that can contribute to our nation's energy independence. Through research, development, and demonstration efforts, the Program supports the emerging industry in its efforts to capture the energy from oceans and rivers for a new generation of environmentally sustainable and cost-effective electricity.

DOE is currently developing an aggressive strategy to support its vision of providing 15% of our nation's electricity needs from water power by 2030.

Marine and Hydrokinetic Power

The Future of American Clean Energy

Marine and hydrokinetic (MHK) technologies generate energy from highly forecastable waves, currents, and ocean thermal resources. **With more than 50% of the American population living within 50 miles of the coast, a cost-effective MHK industry could provide a substantial amount of electricity for the nation.**

Assessing Resource Potential

There is a vast amount of energy available in waves, tides, ocean and river currents, and ocean thermal resources. The Water Power Program is supporting collaboration between private research institutions and DOE's national laboratories to determine the location and magnitude of electricity generation from MHK resources. The resulting public databases and resource maps will include useful information for federal agencies, Congress, state and federal regulators, research institutions, and developers.

Maps showing the U.S. Tidal and Wave resources can be found on the following pages

Reducing the Cost of Energy

DOE's Water Power Program is developing ten state-of-the-art technology design tools that simulate the behavior and performance of MHK devices. The design tools will identify key cost-reduction pathways and technological innovations. The models will also facilitate rapid design optimization and support a detailed techno-economic assessment of MHK technologies. This will help industry identify research and development gaps and achieve cost-competitive energy rates by 2030.

See Program Highlight: MHK Reference Models (next page)

Advancing Technology Readiness

Because MHK is a nascent industry with hundreds of potentially viable device types, there is currently no singular technology leader. Therefore, the Program is leading the effort to prove functionality, evaluate technical and economic viability, and generate cost, performance, and reliability data for a variety of devices. By cost-sharing some of the initial financial risk for a range of technologies, the Program intends to evaluate device viability, thereby attracting the private sector financing necessary for commercialization.

See Program Highlights: Wave Energy Demonstration and Tidal Energy Demonstration (next page)

Ensuring Environmental Responsibility

MHK technology advancement must preserve the integrity of the marine environment if it is to succeed. To that end, the Water Power Program is supporting a range of environmental studies to ensure that the energy generated from MHK is not only renewable, but also sustainable.

See Program Highlight: Environmental Information Database (next page)

DOE research is helping to address environmental barriers to deployment by demonstrating low injury risk to fish for three types of hydrokinetic turbines.

Program Highlights

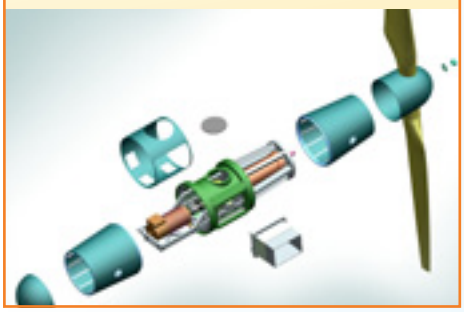
MHK Reference Models

Who: Sandia National Laboratories and National Renewable Energy Laboratory

Where: Albuquerque, New Mexico and Golden, Colorado

What: Develop a representative set of technology device reference models for the MHK industry.

Impact: Gauges existing cost of energy with regard to technology type and evaluates key cost reduction pathways on which future development should be focused.



Wave Energy Demonstration

Who: Ocean Power Technologies

Where: Oregon Territorial Sea, Reedsport, Oregon

What: Build, install, operate, and monitor a 150 kW capacity PowerBuoy—a floating point absorber wave energy conversion technology.

Impact: Obtains critical technical and cost-performance data for a representative wave energy converter in the United States.

Tidal Energy Demonstration

Who: Ocean Renewable Power Company

Where: Cobscook Bay, Eastport, Maine

What: Build, install, operate, and monitor a commercial-scale array of five grid-connected 150 kW TidGen units over three years. This project advances Ocean Renewable Power Company's cross-flow turbine tidal energy technology.

Impact: Advances the technical, operational, and environmental goals of the tidal energy industry.

Environmental Information Database

Who: Pacific Northwest National Laboratory

Website: *mhk.pnl.gov/wiki/index.php/Tethys_Home*

What: Develop a "smart" database of important research on the environmental impacts of MHK technologies.

Impact: Identifies and organizes data on the potential environmental impacts of MHK development to facilitate the classification and evaluation of those impacts by regulators, MHK industry members, and other stakeholders.

TETHYS

Investing in the Future

The Water Power Program is investing in three National Marine Renewable Energy Centers — centers of excellence and education undertaking research, development, demonstration and commercial applications of marine renewable energy technologies. These centers will provide the necessary domestic expertise and infrastructure needed to facilitate comprehensive, standardized testing of MHK devices and to produce certified environmental performance data, ultimately providing the necessary level of confidence to enable the private financing of commercial generation plants.

OSU Oregon State

HNEI Hawai'i Natural Energy Institute

FAU Southeast National Marine Renewable Energy Center College of Engineering and Computer Science Florida Atlantic University

The Northwest National Marine Renewable Energy Center

Partnership between Oregon State University and the University of Washington that focuses on ocean wave and tidal energy and resources.

The Hawaii National Marine Renewable Energy Center

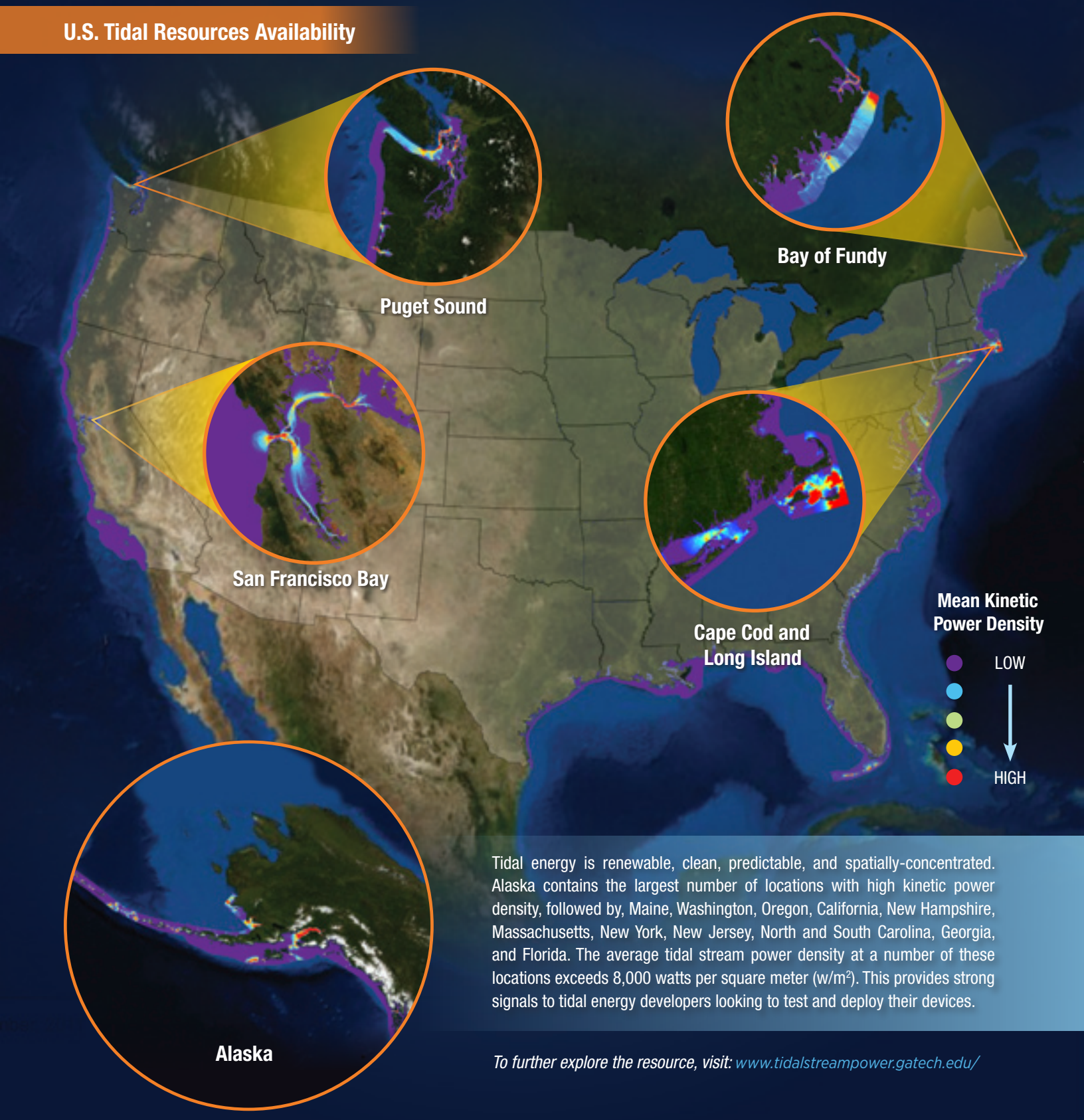
Managed by the University of Hawaii and focuses on ocean wave and ocean thermal energy and resources.

The Southeast National Marine Renewable Energy Center

Managed by Florida Atlantic University and focuses on ocean current and ocean thermal energy and resources.

U.S. WATER POWER RESOURCES

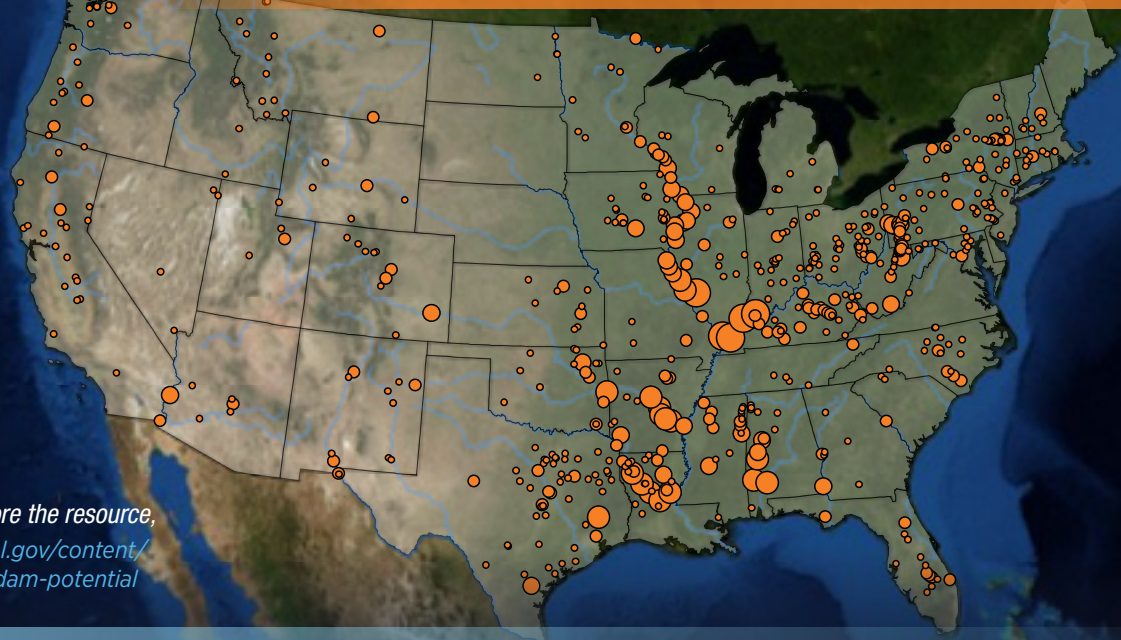
U.S. Tidal Resources Availability



Tidal energy is renewable, clean, predictable, and spatially-concentrated. Alaska contains the largest number of locations with high kinetic power density, followed by, Maine, Washington, Oregon, California, New Hampshire, Massachusetts, New York, New Jersey, North and South Carolina, Georgia, and Florida. The average tidal stream power density at a number of these locations exceeds 8,000 watts per square meter (w/m^2). This provides strong signals to tidal energy developers looking to test and deploy their devices.

To further explore the resource, visit: www.tidalstreampower.gatech.edu/

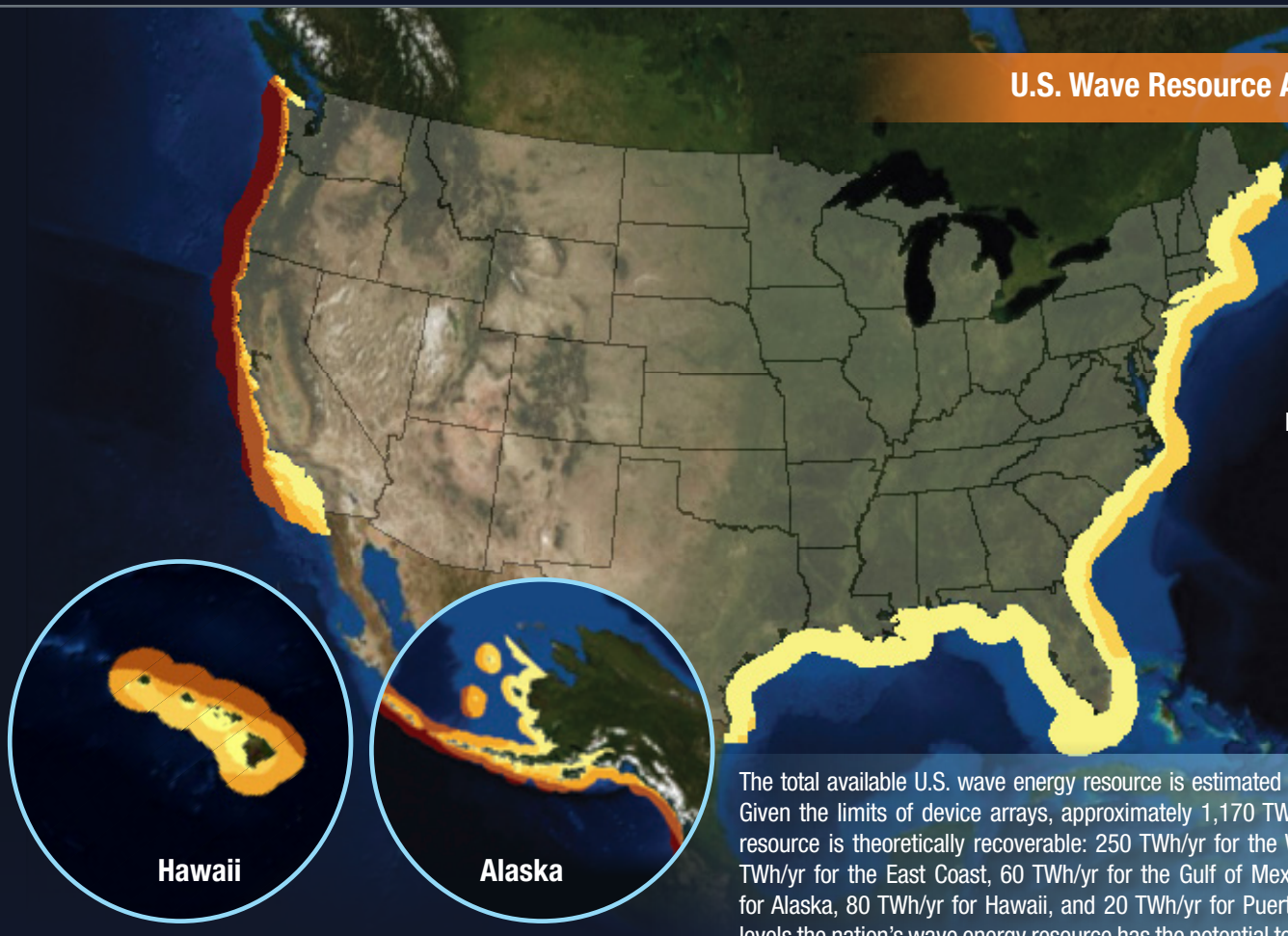
Top 600 U.S. Non-Powered Dams with Potential Capacity Greater than 1MW



To further explore the resource, visit: nhaap.ornl.gov/content/non-powered-dam-potential

The nation has over 50,000 non-powered dams with the potential to add about 12 GW of clean, renewable hydropower capacity. The 100 largest capacity facilities could provide 8 GW of power, the majority of which are locks and dams on the Ohio, Mississippi, Alabama, and Arkansas rivers operated by the U.S. Army Corps of Engineers. Power stations can likely be added to many of these dams without impacting critical habitats, parks or wilderness areas while powering millions of households and avoiding many more million metric tons of carbon dioxide emissions each year.

U.S. Wave Resource Availablility



To further explore the resource, visit: maps.nrel.gov/mhk_atlas

The total available U.S. wave energy resource is estimated at 2,640 TWh/yr. Given the limits of device arrays, approximately 1,170 TWh/yr of the total resource is theoretically recoverable: 250 TWh/yr for the West Coast, 160 TWh/yr for the East Coast, 60 TWh/yr for the Gulf of Mexico, 620 TWh/yr for Alaska, 80 TWh/yr for Hawaii, and 20 TWh/yr for Puerto Rico. At these levels the nation's wave energy resource has the potential to power over 100 million homes each year.

Conventional Hydropower

An American Tradition of Renewable Energy

Over the last decade conventional hydropower has provided on average 6% of the nation's electricity and over 70% of renewable electricity output annually.[1] **Water Power Program studies demonstrate that there are 12 GW of development potential at the country's over 80,000 non-powered dams.** Pumped-storage hydropower is the only existing utility-scale storage technology that can support the integration of variable renewable resources such as wind and solar.

Quantifying Hydropower's Value to the Grid

Conventional and pumped-storage hydropower can increase the flexibility and stability of the U.S. electric grid and support the integration of variable renewable resources like wind and solar. DOE's Water Power Program quantifies the benefits of effective and cost-competitive hydropower technologies and communicates those benefits to stakeholders.

See Program Highlight: Hydropower Grid Services (next page)

Advancing Hydropower Upgrades

The Hydropower Advancement Project, a collaboration of industry experts and DOE's national laboratories, is developing standardized assessment guidelines for upgrades at existing hydropower facilities, and will conduct a number of assessment demonstrations throughout the country. By demonstrating the significant generation gains available from these upgrades and maximizing the diversity and visibility of the demonstration sites, the Hydropower Advancement Project is intended to facilitate widespread upgrades in an otherwise risk-averse industry.

See Program Highlight: American Recovery and Reinvestment Act: Abiquiu Low-Flow Turbine Hydropower Project (next page)

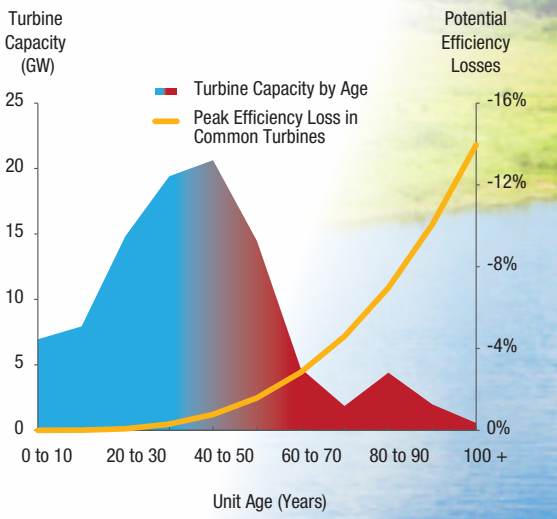
Assessing Resource Potential

Hydropower has an installed generating capacity considerably greater than any other renewable electricity technology. Even so, there are tremendous amounts of untapped hydropower resources within the United States from existing hydropower facilities, non-powered dams, and potential new, sustainable hydropower sites. The Water Power Program's public Water Power GIS tool will enable analyses of the nation's existing and potential hydropower resources at various geographic levels ranging from individual projects to congressional districts to the nation as a whole. It also allows the Water Power Program to identify and focus on specific environmental issues and technologies with the largest potential for expanding clean, low impact hydropower generation.

A map showing the U.S. Non-Powered Dams resources can be found on the previous page

[1] U.S. Energy Information Administration Net Generation by Energy Source: Total (All Sectors Including Pumped Storage), 2000-2010

Modern hydropower turbines are highly efficient compared to older designs, and with half of U.S. turbine capacity at least 40 years or older, updating existing infrastructure is one potential avenue for adding renewable electricity capacity.



Program Highlights

Hydropower Grid Services

Who: Electric Power Research Institute (EPRI)

Where: Nationwide

What: Analyze market structures, hydropower costs and constraints, and the role of hydropower technologies in the operation of the Western U. S. transmission grid.

Impact: Will provide industry stakeholders and investors with the information they need to quantify the value of hydropower technologies to grid stability and renewable resource integration.

Alden Fish Friendly Turbine

Who: An industry team that combines the manufacturing expertise of Voith Hydro with the research abilities of Alden Research Laboratory, led by EPRI.

Where: York, Pennsylvania and Holden, Massachusetts.

What: Provide for the safe passage of downstream-migrating fish through an operating turbine.

Impact: Will provide a more sustainable option for producing electricity at over 1,000 estimated environmentally sensitive hydropower facilities and thousands of new developments.[2]

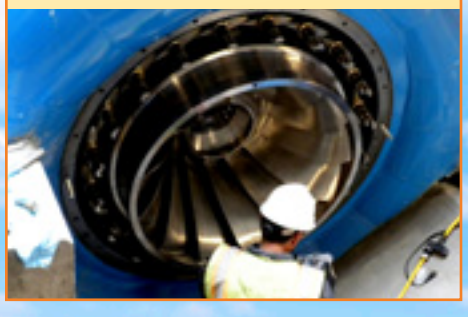
American Recovery and Reinvestment Act: Abiquiu Low-Flow Turbine Hydropower Project

Who: Los Alamos County Department of Public Utilities

Where: Abiquiu Hydroelectric Facility on the Rio Chama River in northern New Mexico.

What: Increase renewable energy generation capacity 22% by installing an efficient, low-flow turbine boosting the facility's output from 13.8 megawatts to 16.8 megawatts.

Impact: Will produce enough energy to power 1,100 homes annually and will supply clean energy to Los Alamos County, including DOE's Los Alamos National Laboratory.



[2] "Fish Friendly" Hydropower Turbine Development and Deployment: Alden Turbine Preliminary Engineering and Model Testing. EPRI, Palo Alto, CA and U.S. Department of Energy,Washington, DC: 2011. 1019890

Investing in the Future

In addition to the broader portfolio of conventional hydropower projects the Water Power Program estimates that the United States can add up to 300 TWh of new, clean hydropower generation per year by 2030, enough to power 30 million American homes. Building on hydropower's current contributions to the nation's energy supply through advanced technology development will allow non-powered dams, new sustainable developments, pumped storage, and the existing conventional hydropower fleet to generate more clean energy and facilitate the integration of variable renewables into the nation's electrical grid. This will cement hydropower's position as the sustainable and reliable base of the nation's renewable energy portfolio.

See Program Highlight: Alden Fish Friendly Turbine

Working Together to Build Our Clean Energy Future

Supporting a Developing Industry

In 2010, DOE's Water Power Program announced a solicitation for the acceleration of technological and commercial readiness of MHK technologies. Twenty-seven cost-shared projects—the single largest investment in the MHK sector in U.S. history—were selected ranging from concept studies and component design to prototype development and in-water device testing. Additionally, a 2011 Water Power Program solicitation for advanced hydropower focused on the development and demonstration of small, innovative hydropower and environmental mitigation technologies in addition to the nation's first advanced pumped storage plant in more than 20 years.

DOE's Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Program has made over 20 advanced water power technology development awards. SBIR/STTR awards contribute to new, innovative technologies that can ultimately help lower the cost of energy. These awards also help remove barriers to commercialization by focusing their research and development efforts on specific industry needs, allowing MHK and conventional hydropower technologies to advance more rapidly.

Collaborating Across Government

The Water Power Program has taken a leading role in convening federal agencies to discuss ongoing MHK resource use and technology development. In 2010, DOE and the Department of Interior signed a memorandum of understanding to prioritize and facilitate the environmentally responsible deployment of commercial-scale offshore wind and MHK energy technologies on the Outer Continental Shelf. Also in 2010, DOE, the U.S. Army Corps of Engineers, and the Department of Interior's Bureau of Reclamation signed a memorandum of understanding to increase U.S. hydropower generation at federal facilities in a sustainable manner and seek solutions to meet the integrated energy and water needs of future generations. Finally, in 2011, DOE and the Department of Commerce's National Atmospheric and Oceanic Administration signed a memorandum of understanding to advance collaborative efforts on the use of weather-dependent and oceanic renewable energy technologies.

MHK Small Business Innovation Research Project

Who: FloDesign, Inc.

Where: Wilbraham, Massachusetts.

What: Advance the Mixer-Ejector Hydrokinetic Turbine to the prototype stage. This new type of shrouded hydrokinetic turbine incorporates proven aerospace propulsion and power technologies into an integrated, tightly coupled system delivering extremely high hydrodynamic efficiency levels.

Impact: Develops and demonstrates an advanced, high efficiency MHK device, which is critical to prove the economic viability of hydrokinetic turbines and deliver competitive costs of electricity.

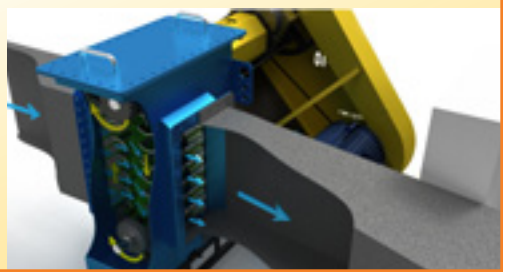
Small, Low-Head Hydropower Small Business Innovation Research Project

Who: Natel Energy

Where: Buckeye Water Conservation and Drainage District, Buckeye, Arizona.

What: Construct and evaluate a 200 kW scale-up of a Schneider Linear Hydroengine, a new low-head turbine.

Impact: Enables the cost-effective generation of reliable, renewable electricity from thousands of existing low head dams, miles of existing irrigation infrastructure, and the significant low head potential in streams.



WATER POWER FAST FACTS

Conventional hydropower and marine and hydrokinetic water power technologies can provide 15% of the nation's electricity needs by 2030.

The water power industry accounts for more than 300,000 jobs in the United States and has the potential to create thousands more by developing new water resources.

Hydroelectricity has been powering America for more than a century and still remains a reliable and dynamic energy resource today.

Over 50% of the American population lives within 50 miles of the coast where close to 500 GW of potential could be captured by MHK technology deployment.

Over the last decade conventional hydropower has provided on average 6% of the nation's electricity and over 70% of clean, renewable electricity output annually.

DOE studies show that the maximum theoretical electric generation that could be produced from U.S. waves and tidal currents is approximately 1,420 TWh/yr--more than a third of the nation's annual electricity usage.

By using hydropower, the United States avoids emitting more than 235 million tons of carbon dioxide pollution into the atmosphere each year.

Hydropower facilities provide a number of benefits in addition to producing electricity, such as flood control, irrigation, water supply, and a range of recreational opportunities.

The International Energy Agency estimates a global opportunity to install 748 GW of MHK technologies by 2050.

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