
A Voith Hydro turbine is prepped for installation at Washington State's Wanapum Dam. Grant Public Utility District replaced all of the dam's 10 aging turbines with more efficient, fish-friendly models. Photo courtesy: Grant County Public Utility District

# Hydropower's Untapped Potential

BY ROBERT SPRINGER

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At first glance, the potential for hydropower in the U.S. seems limited.

Of the country's 84,000 dams, only a small fraction produce hydropower, and the country seems to have an appetite for tearing down dams, not building new ones.

But a look under the hood of the hydropower industry reveals a bullish view on the technology and growth of the industry. Powering non-powered dams, upgrading existing turbines to increase efficiency, and embracing small-scale hydro could give an old and established industry new life.

## NON-POWERED DAMS: AN UNTAPPED RESOURCE

Dams are created for many reasons, including irrigation, recreation and creating a stable water supply. Now, some of these non-powered dams (NPD) have been targeted by power producers as possible sources of additional power.

While the practice of retrofitting dams for hydropower has been around for a while, a 2012 report, "An Assessment of Energy Potential at Non-Powered Dams in the United States," by the Oak Ridge National Laboratory (ORNL) for the Department of Energy caught the industry's attention about the potential of NPDs as a power source.

The report looked at all U.S. dams to gauge their suitability for hydropower. Most don't have the flow to generate meaningful electricity, according to Boualem Hadjerioua, Deputy Water Power Manager and Senior Research Engineer at Oak Ridge and the lead author of the report.

He found that the top 597 NPD sites had a potential capacity greater than 1 MW each, with the top 25 accounting for 40 percent of the U.S. total. Fortunately, many of the best sites are near population centers in the East, the report said.

The Ohio River is a good example of a river that has NPDs and enough flow to generate electricity, according to Hadjerioua. "That's where this big potential is, where there is a lot of water," he says. "So, you have a lot of water and you have a lot of those locks and dams. And if you could put a couple of turbines or some turbines you can generate a lot of hydropower." Six NPDs owned by the U.S. Army Corps of Engineers (USACE) are being developed on the Ohio with a total capacity of 400 MW.

On the Ohio, Hadjerioua says that power companies are constructing the turbines on the sides of the locks and dams and diverting some of the water for electricity generation before discharging it back into the river.

The report caused other agencies to do their own analyses, which they did in greater detail than ORNL did in its nationwide report. An agency like the Tennessee Valley Authority or Bureau of Reclamation might only have from 70 or 80 to 200 dams to analyze, Hadjerioua says, so doing another assessment made sense.

Determining if an NPD is a good site for hydropower is complicated. "So, you look at the hydraulics and you look at the hydrology," Hadjerioua says. "And then you look at the environment – do you have any environmental issues? Then you go into a financial analysis. So, basically the viability of any particular site is based on the economic indicators."

Turning an NPD into a power-producing facility needs to make sense for the government agency that owns and manages the dam and for the investors who put up the money to retrofit it for power generation, Hadjerioua says.

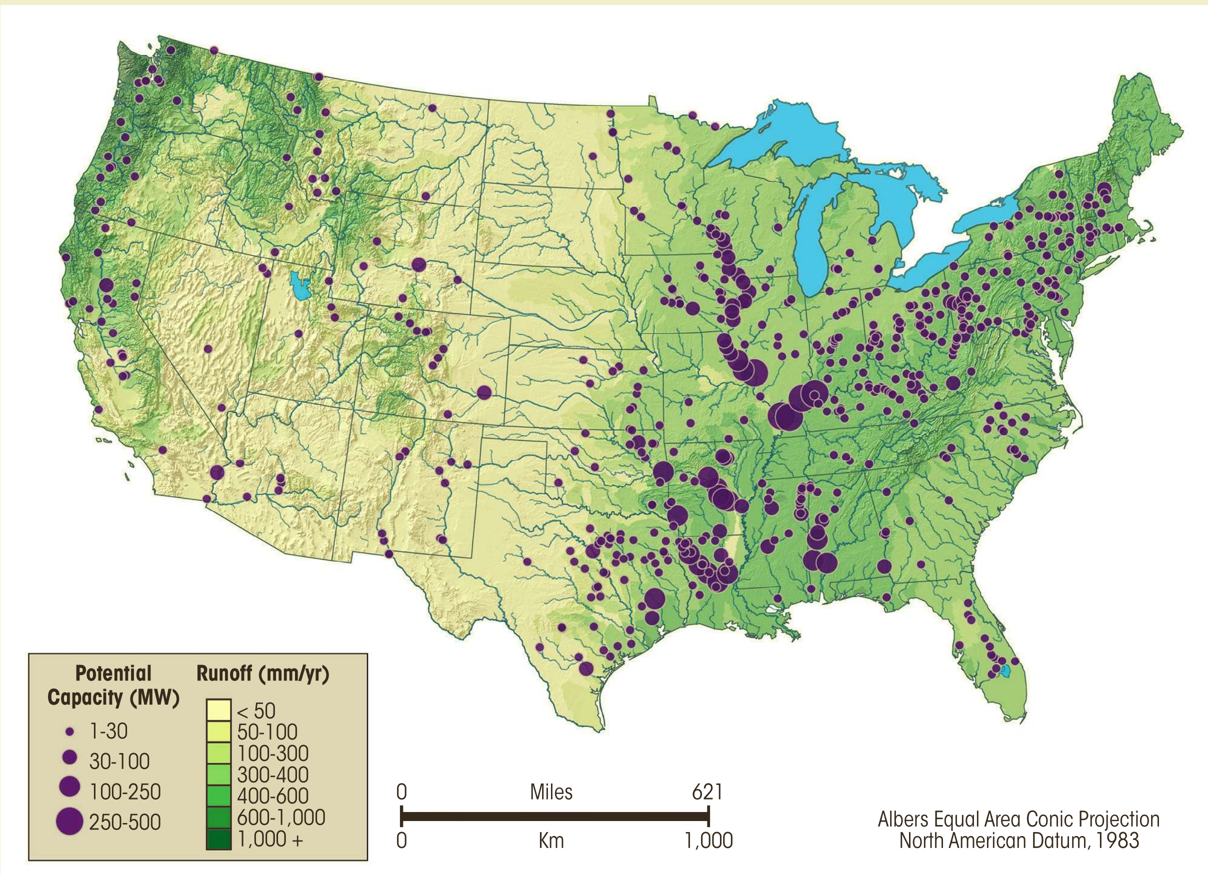
Hadjerioua thinks about 25 projects with a total capacity of more than 250 MW were a direct result of the ORNL report.NEEDS CLARITY RR Some of the applicants for permits called and talked to ORNL staff, which he found hopeful. "We are encouraged that our report has contributed to this kind of awareness," he says.

## RED ROCK: ADDING HYDROPOWER CAPACITY TO A NON-POWERED DAM

The Red Rock Hydroelectric Project (RRHP) is a good example of how and why some NPDs are being retrofitted for hydropower.

The Red Rock Dam, about 45 miles

### U.S. Non-powered Dams with Potential Capacity Greater than One Megawatt 1




Most of the nation's non-powered dams with generating capacity greater than 1 MW are located in the populous eastern half of the U.S. NPDs are increasingly being viewed as potential sources of clean, renewable electricity.

*Source: Oak Ridge National Laboratory*

southeast of Des Moines, Iowa, was completed in 1969 by USACE for flood control and recreational use.

Electricity wholesaler Missouri River Energy Services (MRES) purchased the Federal Energy Regulatory Commission (FERC) permit from another company that worked to develop a hydropower project at the site. MRES had been looking to get into the hydropower market as it "provides base load reliability, which many other renewable resources are not able to provide since they are intermittent," said Joni Livingston, MRES director of member services and communications.

It's "almost impossible" to build a coal or nuclear plant now due to regulatory restrictions, Livingston said. And even though the initial capital costs are high for a hydropower project of this size, it will have a lifespan of about 80 to 100 years. The plant will produce enough electricity to power 18,000 homes.

The $379 million project is expected to be completed in 2018. "The plant is rated for 36.44 MW, but during the summer, when there are high water levels, it will likely produce as much as 55 MW," says Livingston.

MRES selected Ames Construction to build the project. Key factors in Ames receiving the contract included its experience with similar projects and the ability to self-perform more than 75 percent of the work, said to David Gatto, business development manager at Ames.

"The advantage to performing the work with your own forces is to maintain control over all aspects of construction, from the leadership, management, materials, sequences and most importantly to be able to react to issues that will arise during construction," Gatto says.

RRHP will include "some of the most advanced civil engineering structures designed worldwide today," according to Ames' website. The diaphragm wall is designed to hold back the earthen dam in front of the intake structure, Gatto said. The wall must be constructed with zero defects to protect the dam during construction and operation.

"The diaphragm wall is constructed by making a series of 5 feet by 11 feet rectangle shafts into the ground up to 130 feet deep to form a T element," Gatto said. "Twenty-six elements form the diaphragm wall. The complexity is to keep the excavation from caving in while placing the necessary reinforcement steel and concrete in the T elements to form the wall."

MRES will use two Kaplan turbines. Each turbine is rated at 18 MW but will have a peak capacity of 55 MW during peak flow conditions. Voith Hydro will provide the turbines. There aren't standard turbines for a project like Red Rock, Gatto said, so Voith will custom design and manufacture them to fit the site conditions.

Not only is RRHP one of the largest projects that Ames has worked on, it's also one of the most unique. "This project is one of the first examples of the retrofit of an existing dam and is receiving increasing focus on green energy and power production for other power distribution companies," he said.

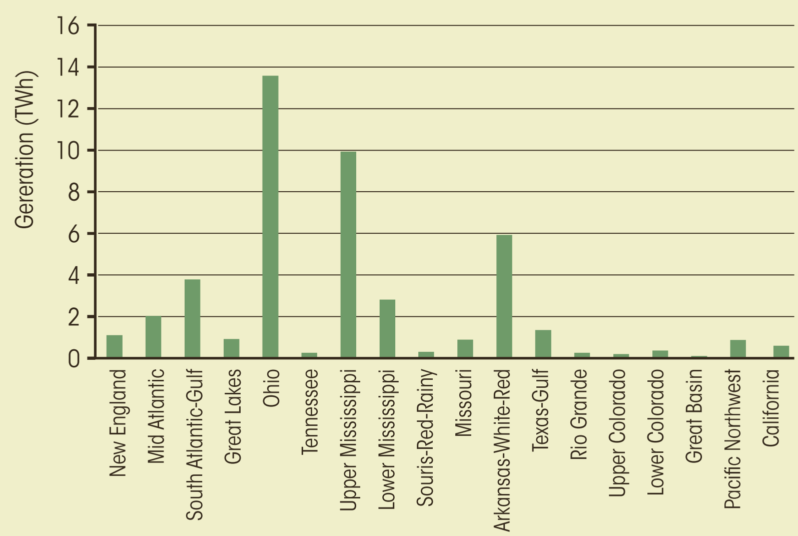
## AN UPGRADE AT WANAPUM DAM

Unlike Red Rock, Washington State's Wanapum Dam was built as a hydropower project and started producing power in 1964. By the 1980s, the turbines started to experience mechanical failures, said Stuart Hammond, hydro engineering supervisor at Grant Public Utility District, the dam's operator.

"Those had resulted in some significant outages or repairs and those failures were related primarily to the blade design," Hammond said. "The blades were large and heavy, and that resulted in the blades drooping and when the blades drooped then the seals at the hub, which are called trunnion seals, started to leak and those can leak oil out into the river."

In addition, the blade material was prone to cavitation damage. "Cavitation is a hydraulic phenomenon," Hammond said. "An extremely low pressure zone is

**Potential Non-powered Dam Generation** 2




Non-powered dams on the Ohio River have more than 13 terawatt hours of potential generation, the greatest of any U.S. river. Many NPDs are located near population centers, and could provide energy to areas that not as suited to wind or solar.

*Source: Oak Ridge National Laboratory*

formed very locally; essentially a vapor bubble forms in the water, and when it dissolves there's a lot of energy and over time as that occurs repeatedly and continuously, it causes pitting in the metal of the blade. It eats away the metal, which given enough time will completely eat away the metal and you can have a hole clear through your blade."

Hammond says the problems that Wanapum experienced are pretty common to any hydraulic system, including pumps and motor boat propellers.

Grant PUD had to decide whether to fix the turbines or replace them. They compared options. They found that new turbines could increase efficiency and eliminate failures, Hammond said.

A "very unique requirement" in the contract for the manufacturing of the turbines specified that they be free from cavitation damage.

"When the manufacturers of the turbines saw that requirement in our contract they said, 'Well, look, you can't do that. Nobody has done that.' But we required it and they did it," Hammond said.

Voith Hydro was surprised to see that requirement, said Richard Donelson, manager of hydraulic engineering design for Voith Hydro. Undaunted, "Voith Hydro took up the challenge – which was beyond our previous level of technology – by making the turbine as large as possible. The guide vane circle was increased and the new design replaced the existing 20 wicket gates with 32 much shorter gates. The runner was lowered in elevation to accommodate the larger runner and fully spherical discharge ring.

"This provided some additional submergence for the turbine which resulted in improved cavitation performance. Even with all these changes it was still a challenge to develop a runner that could meet the requirements of the specification," Donelson said.

Initially, blade designs were assessed with computational fluid dynamics. The winning designs were then developed using physical model testing, according to Donelson. "The final design was then witnessed by PUD in an independent laboratory and selected for the prototype contract," he said.

## HELPING FISH PASS SAFELY

Grant PUD has a dual mandate at Wanapum dam – produce power and help fish survive the passage through the turbines.

Voith engineered the new Kaplan turbines to solve both problems.

"The redesigned Wanapum turbine runner was one of the first to make use of Voith Hydro's patented Minimum Gap turbine runner technology, which was developed by taking a scientific approach to reduce hydraulic losses, fish strike and mortality, cavitation, and large pressure gradients," Donelson says.

Adjustable blades like Wanapum Dam have large gaps "at the inlet and outlet of the blade-hub and blade-periphery junctions," said Donelson. "These gaps can cause strong secondary flows, low pressures and high shear areas known to cause fish mortality."

It turned out eliminating the cavitation resulted in "higher minimum pressures in the turbine water passage which also improves fish survival," Donelson said. "The technology has been applied to other projects across the country."

Hammond said fish survival rates are 97 percent with the new turbines. (The utility's license specifies a minimum 95 percent survival rate.)

It took 10 years to replace all of the 10 turbines. They started replacing the turbines in 2004 and finished in 2014. The old turbines were rated at 89.5 MW each while the new ones are rated at 104 MW. The new turbines' efficiency is 3 percent higher than the old turbines.

Hammond has been pleased with the new turbines. "Performance has been excellent," he said. "They operate and run quietly. They are reliable. And so far, we haven't found any indications of cavitation damage or any other signs of any type of mechanical failures, such as leaking trunnion seals."

## A LOOK INTO HYDROPOWER'S FUTURE IN THE U.S.

Kristina Johnson, CEO of Enduring Energy and former undersecretary for energy in President Obama's first term, is upbeat on hydropower's future in the U.S.

"I'm very bullish," she said. "I'd like to see us increase our hydropower by four percent, a net four percent increase so that we go from like 8 to maybe 12 percent on the electric grid in the country."

Financing is a major challenge to hydropower's adoption, Johnson said. How do you value a resource that is very expensive to build yet lasts 100 years and provides clean, renewable energy?

Industry and government have yet to square that circle.

The government could help in another way, she said.

"I think that it would be helpful to have a national policy that we should power every unpowered dam that shouldn't be removed; it's very simple," Johnson said. "So you look at 81 of the top 100 dams that can be powered in the U.S. are run by the Army Corps. Why not have an executive order that says, 'Thou shalt power those?' I think it's a great infrastructure plan."

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> - Kristina Johnson, Enduring Energy

She thinks the energy produced should go to green the government.

Hadjerioua, the author on Oak Ridge's NPD assessment, is working on a taskforce that will produce another report, Hydropower Vision Report. More than 200 experts from various disciplines and agencies, including federal agencies, industry and developers, are involved.

"Basically, we are working on that to state, 'Where is hydropower today and where are we going?'" Hadjerioua said. "So, where is the potential, how are we going to develop this, what's the technology needed and so forth? And that is being developed right as we speak and probably will be published next year or so."

The future of hydropower seems to be in smaller projects ranging from 4-to-5 MW in size that benefit a single community, said Hadjerioua.

It's not just existing dams that are attracting attention.

Irrigation canals are naturals for hydropower, Johnson said, since fish passage issues are virtually nonexistent.

"Of course, the devil's in the details, but imagine you had multiple drops along the same canal," she said. "You could probably put in cookie cutter, smaller but similar powerhouses, along the way or just drop in some more units eventually. So then you start to get economies of scale, and that would help drive the industry."

Voith Hydro's StreamDiver is suitable for irrigation canals and other small scale hydro projects.

"The fact that the units are easy to install and require almost no maintenance opens the market beyond conventional utilities to local developers or municipalities who have water rights but are not currently utilizing its power potential," said Carl Atkinson, director of sales and marketing at Voith Hydro.

StreamDriver is being used in Europe but not yet in the U.S.

Johnson said the U.S. needs to take a balanced, regional approach, as not all renewable technologies make sense everywhere.

Wind and solar don't pencil out everywhere, and neither does hydropower.

"We're going to have hydro in areas where the resources are," she said. "We're going to have nuclear in areas where you don't have the natural resources, and we're still going to have natural gas and coal where we need carbon, and apply some way of reusing the $CO_2$ so that it doesn't go into the atmosphere. So it's that balance." pe