Turning wild water into white coal: Using hydropower when wind and solar are interrupted

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Researchers examine the underside of a Francis turbine at the Norwegian University of Science and Technology's Waterpower Laboratory. Credit: Thor Nielsen/NTNU

In early April, the Intergovernmental Panel on Climate Change, the IPCC, issued its Working Group III report describing options for what the nations of the world can do to keep global warming from reaching catastrophic levels.

The options are many, and the need to act is urgent—the Working Group concluded that the world has just 30 months—to 2025—for greenhouse gas emissions to peak before they must be brought down.

The sobering report was not without its bright spots, however. One important finding is that renewable energy costs have plummeted in recent years, making it more and more feasible to power the world's demand for energy with non-fossil fuel sources.

Exploiting renewable energy like wind and solar power requires different ways of thinking about what to do when the sun doesn't shine and the wind doesn't blow, however.

And a one-hundred-year old laboratory on the Norwegian University of Science and Technology's (NTNU) Gløshaugen campus is helping to come up with solutions. You can hear about the laboratory and the research being done there in the latest episode of 63 Degrees North, NTNU's English-language podcast.

Battery or backup

The laboratory—the Waterpower Laboratory—is a five-story high structure filled with 600 millimeter stainless steel pipes and tanks with 450,000 liters of water that allow researchers to test turbines at scale model.

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Turbines, combined with generators, are the key structure that turns the kinetic energy of falling water into electric energy.

Hydropower itself is a renewable resource, but it's getting much more attention now with the buildout of more and more renewable energy, says Ole Gunnar Dahlhaug, a professor at NTNU's Department of Energy and Process Engineering and head of the Waterpower Lab.

What's key is that a hydroelectric plant can be used to back up solar or wind power when they can't generate electricity.

"The Norwegian system has more than 1,000 dams. And in that dam, we have a lot of water. And that water when it is in the dam, it's a battery. And that battery is 87 terawatt hours. That is approximately I would say 60 to 70% of the Norwegian annual utilization of energy," he said in the 63 Degrees North podcast episode on the laboratory. "So that's quite a big battery."

The way this works is to use the excess electricity from renewable sources to pump water from a lower reservoir up to an upper reservoir. That's the "battery." The water can be stored in that upper reservoir until the electricity is needed. Then the water from the upper reservoir can be run back down through the hydropower plant to generate electricity.

"So when the wind stops blowing or the storm is coming, we could utilize that water in a shorter time when we need it. And then we stop the hydropower plants when we have enough wind," Dahlhaug said.

And here's where the Waterpower Lab is making a difference: most of the turbines in today's hydropower plants aren't designed to take the stresses and strain of starting and stopping suddenly, much less pumping water up and down through the system.

Flexible operation, degassing water

Johannes Kverno is in the middle of his Ph.D. research, studying stresses on a type of hydropower turbine called a Francis turbine. For part of his research, he's using sensors on a scale model of a Francis turbine to measure just how much stress different kinds of operation will have on the turbine when he runs high pressure water through it in the lab.

"Since hydropower is a really fast acting type of power source, it's very useful and usable to quickly adjust according to the both the demand and the supply. But of course, most of the turbines in Norway at least were designed for more stable operation at close to their design points," he explained in the podcast episode. "So with more flexible operation, there will be more fatigue, which will reduce the lifetime of the runners and increase the cost of operating the plants."

Vera Gütle, who recently completed her master's degree on her research at the Waterpower Lab, used the facilities to study ways to reduce the environmental impact of high water flows around hydropower facilities.

The problem is that if the water around hydropower plants becomes supersaturated with air—which can happen during high flow periods, like during the spring snowmelt—it can make fish sick in the same way that divers who have been breathing pressurized air and who come up to the surface too quickly can get "the bends," where gas bubbles form in their bloodstream.

The Waterpower Laboratory enabled Vera to simulate these conditions and test ways to actually remove the extra air—in this case, using ultrasound. They pressurize an 18,000 liter tank of water with air, and run it through a channel.

"So we let water from the tank run through the through the channel. And then we apply the ultrasound and measure the amount of air which is dissolved in the water. And then we are testing if we can reduce the amount of air that's in the channel," she said on the podcast.

A hydropower supercomputer

Hydropower has played a crucial role in the history of Norway as a country, and the story behind the Waterpower Laboratory is inextricably linked to how the nation built a modern economy.

The engineer behind its construction was a man named Gudmund Sundby. He'd been hired by the two-year-old Norwegian Institute of Technology in 1912 to help the university develop its hydropower program. It was a huge responsibility, because Norway was counting on hydropower to be the economic engine that would bring it into the global economy.

In 1912, Norway was a still a young country—it had dissolved its union with Sweden in 1905—and needed to exploit the few natural resources it had to build its economy. With its steep-sided mountains and ample rainfall, hydropower was an obvious motor for Norway's economic development.

And if Norway didn't build out its hydropower potential, other countries would. Its undeveloped capacity to generate cheap electricity from falling water had already made Norway a magnet for energy-intensive industries—like aluminum. In the early 1900s, Western countries were flocking to Norway to buy up rights to waterfalls—so much so that the young Norwegian government had to pass what came to be called the "Panic Law," to get the situation under control.

Somebody had to build the expertise to harness these wild waters. That man was Gudmund Sundby.

But Sundby needed help. In an age where all calculations had to be done by hand, Sundby really needed the 1912 equivalent of a supercomputer—a high tech laboratory where future engineers could test and refine their designs at scale, with enough water power to really see if their calculations were right.

By 1915, Sundby had made his case. Tucked in the government's 1915 national budget was a NOK 150 000 earmark to construct a Waterpower Laboratory at the Norwegian Institute of Technology. That earmark represented 0.1 percent of the national budget at the time. It may not sound like much until you realize that in the 1940s, the American government spent "just" 1 percent of its national budget on the Manhattan Project to develop the atomic bomb.

More information: Filip Stojkovski et al, Constraints of Parametrically Defined Guide Vanes for a High-Head Francis Turbine, *Energies* (2021). DOI: 10.3390/en14092667

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