In the face of drought, hydropower still delivers electricity

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Credit: AI-generated image (disclaimer)

In 2022, a quick internet search for Lake Mead or Lake Powell returns startling images of drying lake beds and parched land.

The megadrought in the Southwestern United States is the driest—and longest—in the last 1,200 years, depleting water reservoir levels to

critically low levels over the past 22 years.

This persistent drought has policymakers and system planners concerned about the reliability of the electric grid under worsening drought conditions and climbing temperatures. Droughts particularly impact hydroelectric power dams as well as some thermoelectric power plants that require large amounts of water for cooling.

But a new report by hydrologists at Pacific Northwest National Laboratory (PNNL) suggests that the relationship between drought and hydroelectric power is more nuanced than it might seem.

To get an accurate picture, PNNL hydrologists combined 20 years' of annual power generation data from more than 600 hydroelectric power plants with historical precipitation data from eight distinct hydropower climate regions of the Western United States. Each hydropower region faces unique climatic conditions. Unique reservoir operating conditions also add complexity. Using these data, the hydrologists extrapolated hydropower generation as far back as 1900.

They found that, even during the most severe droughts being observed over the last two decades, hydropower has sustained 80% of average power generation levels, which equates to about 150 terawatt-hours of renewable electricity—or approximately 20% of electricity demand across the West. This flexible power also helps to balance supply and demand in the western grid.

"That's a noticeable dip—but it's still a lot of renewable energy," said Sean Turner, water resources modeler at PNNL and main author of the report.

The PNNL team used machine learning and statistical analysis to categorize hydroelectric plants according to their yearly generating

patterns. This analysis revealed distinct hydropower climate regions in the West. For example, hydropower plants west of the Cascades experience different climatic conditions than those to the east, which demonstrates that different climate regions exist in a large river basin like the Columbia River.

"When studying and characterizing drought, the instinct is to look at it from a regional or state level, but state boundaries might not be the most relevant for understanding the impacts of drought on hydropower," said Turner. "Grouping them by climate conditions leads to a cleaner assessment of the impact of drought on hydropower."

Focusing on the bigger picture

"When people read stories about one particular dam during a drought, like Glen Canyon Dam, or one particular state, like California, they're left with the impression that hydropower will not be very reliable in the future, but one dam represents just a small portion of overall capacity," said Turner. "This means that total western hydropower will still be a major source of power supply even during the worst drought years."

Hydroelectric dams generate power by releasing reservoir water through turbines. During a drought, with less rain and snowfall, less water flows into reservoirs. With low reservoir levels and less water to release, hydroelectric power production declines.

But drought rarely impairs hydroelectric power across all regions of the Western United States simultaneously, which means that a region unaffected by drought may be able to supplement shortfalls in another.

In fact, in the last 20 years, there has not been a drought that has affected all major hydropower generation regions at once.

For example, river flows and reservoir levels in California and the Southwest today are low due to ongoing drought, which affects hydropower generation in those regions. But the lion's share of hydropower generation in the West is dispatched to the grid from the Northern Cascades and Columbia River Basin, in Washington, Oregon, Idaho, and British Columbia.

"The current drought is severe but it's nowhere close to being the worst hydropower generation year for the West and water resource conditions are actually above average right now in the Northwest," said Turner.

Turner indicates that a backward extrapolation of regional hydropower and the available data on power generation for the 20th century both indicate that a repeat of the historical Western drought of 1976–1977 could be worse for hydropower generation than any other drought this century. Unlike recent events, that period affected all major hydropower generating regions of the Northwest and California.

But it's hard to predict the future.

"The climate models disagree as to whether the droughts will become more severe or frequent in the future, or if the area is going to become drier or wetter in terms of precipitation over the next hundred years," said Turner.

Record-breaking heat waves puts additional strain on hydropower and the grid

In the last week of June 2021, right on the heels of a record-breaking Pacific Northwest heat wave, power systems modeler Konstantinos Oikonomou began investigating how hydropower dams performed during the heat wave and how they were able to meet exceptional load

demand caused by consumers turning up their air conditioning.

He found that the heat wave actually created favorable conditions for hydropower plants.

"Rapid snowpack melt during the heat wave helped reservoirs fill with water, which allowed hydropower plants to meet the increased load demand," said Oikonomou.

But researchers wonder what could happen if multiple heat waves occur consecutively and water from snowpack is no longer abundant.

Hydrologists and power system modelers simulated the impacts of compounded heat waves and droughts on the power grid. They found that regional interconnections are critical to manage extreme events.

This year, Oikonomou's research is focused on creating a new framework for simulating grid behavior under extreme weather conditions, such as compounding droughts and heat waves, and under occurrences like faulty transmission lines. As part of this work, he will run a variety of what-if scenarios for an entire year using the Western Electricity Coordinating Council's large-scale power grid model.

"We use the model to zoom in on particular timestamped events to understand energy shortfalls and what other energy resources in the system had to ramp up to compensate for the loss of hydropower," said Oikonomou. "This information will help power plant operators and system planners explore mitigation strategies to fortify the grid against outages."

More information: Drought Impacts on Hydroelectric Power Generation in the Western United States: www.pnnl.gov/main/publications … ports/PNNL-33212.pdf

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