Harnessing the power of water: New study shows the potential of pumped storage hydropower in Alaska

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From rapidly melting glaciers to record-breaking wildfires, Alaska is feeling the impact of global warming more acutely than most of the lower 48 states.

Alaska, the nation's largest state by area, is warming faster than any other U.S. state, according to the U.S. Department of Agriculture. The result is coastal erosion, increased storm effects, sea ice retreat and permafrost melt, among other impacts.

The state's massive size and diverse landscape have created unique energy needs and challenges. Alaska is not connected to a large interstate energy grid like most other states. It consists of two larger transmission systems and more than 150 small, isolated systems serving remote communities.

Alaska is primarily powered by fossil fuel-based power that emits the carbon dioxide that drives climate change. The state gets roughly 30% of its power from renewable energy, including wind, solar and water. To integrate those zero-carbon energy sources into the electric grid on a larger scale, scientists are seeking cost-effective ways to store energy to provide constant power when solar and wind are scarce. In Alaska, the sun might shine 24 hours on some summer days and barely at all in the winter.

Scientists at the U.S. Department of Energy's (DOE) Argonne National Laboratory have led a study to determine the potential of pumped storage hydropower as an efficient way to store large amounts of energy and improve grid resiliency throughout Alaska. Argonne partnered with the DOE's National Renewable Energy Laboratory (NREL) for the project.

Scientists at both labs collaborated on mapping and geospatial analysis to identify Alaska locations feasible for pumped storage hydropower.

Pumped storage hydropower currently provides about 93% of all storage capacity in the U.S. About 1,800 sites in Alaska are suitable for the development of closed-loop pumped storage hydropower projects and many more are suitable for open-loop pumped storage hydropower projects.

Unlike conventional hydroelectric power, pumped storage hydropower technology generates electricity when water is released from an upper reservoir through turbines into a lower reservoir. At night, when electricity is cheaper and abundant, the turbines are reversed to pump water back up into the elevated upper reservoir. Power is stored and released when needed.

"In Alaska, pumped storage hydropower has the potential to integrate more wind and solar into the power grid by storing excess renewable energy to balance intermittent periods of weather," said Vladimir Koritarov, director of the Center for Energy, Environmental and Economic Systems Analysis (CEEESA) in Argonne's Energy Systems and Infrastructure Analysis division. "We are not assuming that projects will be developed on all 1,800 sites, but there are plenty of locations available for potential development."

Along with reducing carbon emissions, renewable energy can lower the cost of electricity driven by the high cost of delivering diesel fuel to Alaska's remote areas. Electricity in Alaska is among the costliest in the nation. Residents in rural areas pay three to four times more than those living in urban areas.

Alaska needs short- and long-term energy storage

Argonne researchers evaluated pumped storage hydropower potential in Alaska's integrated Railbelt system. The transmission grid comprises five regulated public utilities that extend from the cities of Fairbanks to

Anchorage and the Kenai Peninsula. Approximately 80% of the Railbelt's electricity comes from natural gas, which emits carbon dioxide.

Argonne scientists created detailed models using A-LEAF (Argonne Low-Carbon Electricity Analysis Framework), an integrated national-scale simulation framework for power system operations and planning. The scientists studied past and present energy transmission trends, and analyzed overall growth in electricity demand expected in the next 25 years. A-LEAF also considered retiring existing generators as they reach their economic lifetime.

"One of the key findings of the A-LEAF modeling is that the Railbelt system will need both short- and long-duration energy storage in the future. That storage will balance the operational variability of wind and solar generation and provide reliability and backup capacity for longer periods," Koritarov said.

Pumped storage hydropower provides roughly 10 or more hours of energy storage. The study showed that lithium-ion batteries were feasible for short-term (four-hour) energy storage in the Railbelt system.

NREL scientists evaluated Alaska's remote areas that are powered by small isolated electrical grids, or "microgrids." Using the HOMER (Hybrid Optimization Model for Electric Renewables) model, researchers analyzed the viability of small-pumped storage projects in rural communities with at least 250 or more residents. The team identified 18 remote communities with potential for smaller pumped storage projects. The communities met a number of criteria including population size.

Scientists determined that in most cases, pumped storage hydropower may not be economically feasible for remote areas due to the high investment cost of small-size pumped storage projects. Lithium-ion battery storage may be more economically beneficial in rural areas seeking to lower electricity costs but will not provide longer duration storage economically.

"In addition to identifying remote communities with optimal pumped storage hydropower resources and characteristics, the study included a sensitivity analysis of pumped storage hydropower capital costs and the price of diesel fuel," said Rebecca Meadows, an NREL senior engineer.

"The goal was to determine at what point distributed scale-pumped storage hydropower projects could become economically viable. For larger remote communities with higher diesel costs, results showed that pumped storage hydropower could be a cost-effective option depending on site-specific considerations such as renewable resources and constructability."

Putting pumped storage hydropower projects into action

Along with validating the use of pumped storage hydropower as a viable technology for reducing carbon emissions, the Argonne-NREL study offers guidance on developing clean energy policies and regulations and making investment decisions.

Such projects can also pump dollars into the Alaskan economy. Developers are already inquiring about potential pumped storage hydropower developments in the state, Koritarov said.

Argonne, which brought a breadth of expertise to the project, spearheaded a 2021 DOE-sponsored guidebook on how to value pumped storage hydropower projects.

The Argonne-NREL research was conducted under the DOE's HydroWIRES (Water Innovation for a Resilient Electricity System) initiative to understand, enable, and improve hydropower and pumped storage hydropower's contributions to reliability, resilience and integration in the rapidly evolving U.S. electricity system.

More information: Vladimir Koritarov et al, The Prospects for Pumped Storage Hydropower in Alaska, (2023). DOI: 10.2172/1987825. publications.anl.gov/anlpubs/2023/07/183313.pdf

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