Power and storage

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"The overall question for me is how to decarbonize society in the most affordable way," says Nestor Sepulveda SM "16, PhD "20. As a postdoc at MIT and a researcher with the MIT Energy Initiative (MITEI), he worked with a team over several years to investigate what mix of energy sources might best accomplish this goal. The group"s initial studies suggested the "need to develop energy storage technologies that can be cost-effectively deployed for much longer durations than lithium-ion batteries," says Dharik Mallapragada, a research scientist with MITEI.

In a new paper published in Nature Energy, Sepulveda, Mallapragada, and colleagues from MIT and Princeton University offer a comprehensive cost and performance evaluation of the role of long-duration energy storage (LDES) technologies in transforming energy systems. LDES, a term that covers a class of diverse, emerging technologies, can respond to the variable output of renewables, discharging electrons for days and even weeks, providing resilience to an electric grid poised to deploy solar and wind power on a large scale.

"If we want to rely overwhelmingly on wind and solar power for electricity -- increasingly the most affordable way to decrease carbon emissions -- we have to deal with their intermittency," says Jesse Jenkins SM "14, PhD "18, an assistant professor of mechanical and aerospace engineering and the Andlinger Center for Energy and the Environment at Princeton University and former researcher at MITEI.

In their paper, the researchers analyzed whether LDES paired with renewable energy sources and short-duration energy storage options like lithium-ion batteries could indeed power a massive and cost-effective transition to a decarbonized grid. They also investigated whether LDES might even eliminate the need for available-on-demand, or firm, low-carbon energy sources such as nuclear power and natural gas with carbon capture and sequestration.

"The message here is that innovative and low-cost LDES technologies could potentially have a big impact, making a deeply decarbonized electricity system more affordable and reliable," says lead author Sepulveda, who now works as a consultant with McKinsey and Company. But, he notes, "We will still be better off retaining firm low-carbon energy sources among our options."

In addition to Jenkins and Mallapragada, the paper"s coauthors include Aurora Edington SM "19, a MITEI research assistant at the time of this research and now a consultant at The Cadmus Group; and Richard K. Lester, the Japan Steel Industry Professor and associate provost at MIT, and former head of the Department of Nuclear Science and Engineering.

"As the world begins to focus more seriously on how to achieve deep decarbonization goals in the coming decades, the insights from these system-level studies are essential," says Lester. "Researchers, innovators, investors, and policymakers will all benefit from knowledge of the cost and technical performance targets that are suggested by this work."

The team set out to assess the impacts of LDES solutions in hypothetical electric systems that reflect real-world conditions, where technologies are scrutinized not merely by their standalone attributes, but by their relative value when matched against other energy sources.

"We need to decarbonize at an affordable cost to society, and we wanted to know if LDES can increase our probability of success while also reducing overall system cost, given the other technologies competing in the space," says Sepulveda.

For their study, the researchers surveyed a range of long-duration technologies -- some backed by the U.S. Department of Energy"s Advanced Research Projects Agency-Energy (ARPA-E) program -- to define the plausible cost and performance attributes of future LDES systems based on five key parameters that encompass a range of mechanical, chemical, electrochemical, and thermal approaches. These include pumped hydropower storage, vanadium redox flow batteries, aqueous sulfur flow batteries, and firebrick resistance-heated thermal storage, among others.

"Think of a bathtub, where the parameter of energy storage capacity is analogous to the volume of the tub," explains Jenkins. Continuing the analogy, another important parameter, charge power capacity, is the size of the faucet filling the tub, and discharge power capacity, the size of the drain. In the most generalized version of an LDES technology, each attribute of the system can be independently sized. In optimizing an energy system where LDES technology functions as "an economically attractive contributor to a lower-cost, carbon-free grid," says Jenkins, the researchers found that the parameter that matters the most is energy storage capacity cost.