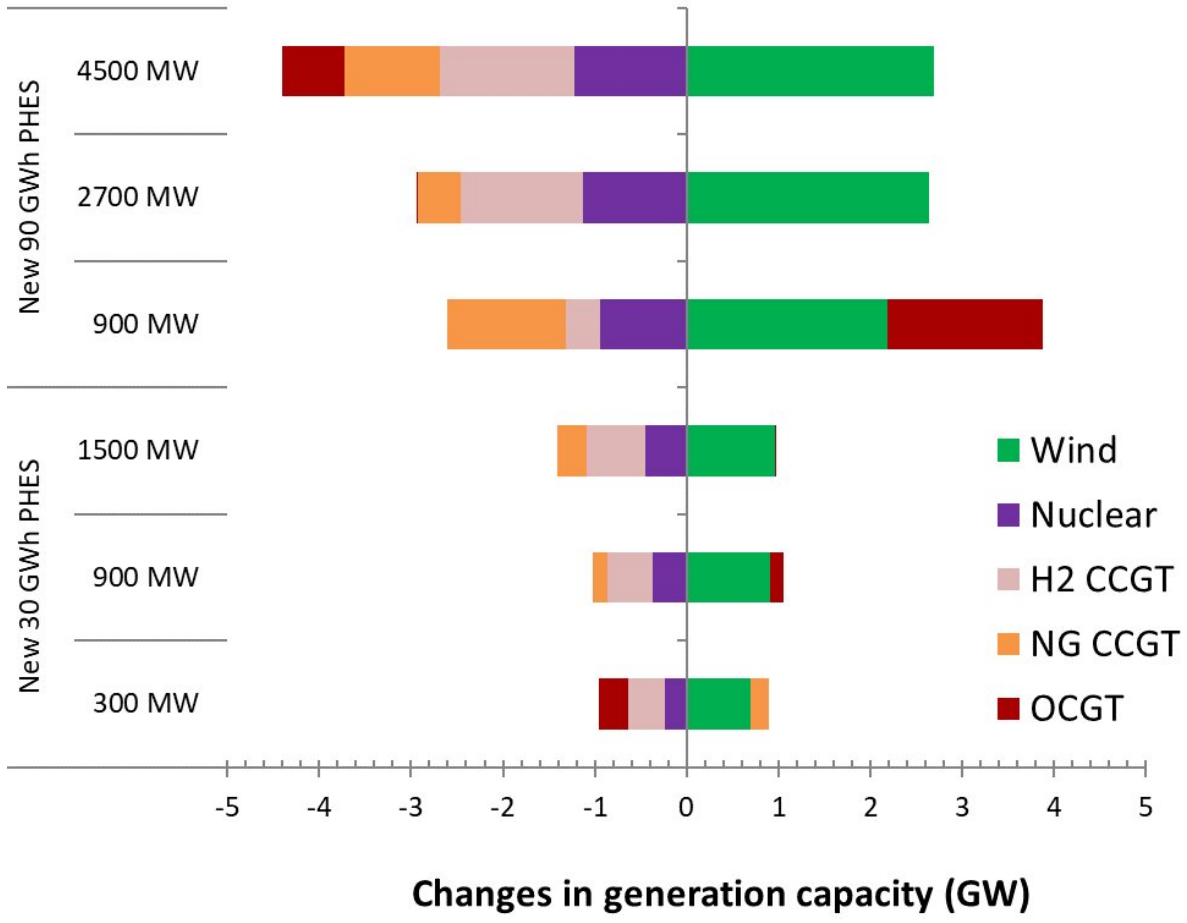
Long-duration energy storage beats the challenge of week-long wind-power lulls

May 24 2022



Changes in the optimal portfolio of power generation due to new energy storage. It demonstrates that long-duration storage facilitates more efficient investment in low-carbon technologies (e.g. wind) and reduces the need for firm but more expensive technologies such as nuclear and hydrogen for power. The storage also helps with providing firm capacity displacing traditional mid-merit and peaking

capacity. Credit: iEnergy, Tsinghua University Press

A novel energy model suggests the overall costs of a net-zero emissions electricity grid are substantially lowered with the integration of long-duration energy storage options, like pumped-storage hydroelectricity that can "firm up" variable renewables such as wind when they struggle through extended week-long lulls.

A paper describing the results appeared in the journal *iEnergy*.

In order to meet globally agreed net-zero greenhouse-gas emission targets, the primary task is to switch to low-carbon sources of electricity generation such as nuclear, hydroelectricity, wind and solar. The main challenge facing the latter two options is that the electricity they produce is variable; when the wind is not blowing or the sun not shining, no electricity is generated.

This means that for a grid to remain reliable, clean sources of electricity that are what is termed "firm" (basically meaning available 24/7) must be deployed to back them up, such as nuclear, hydroelectricity, geothermal and fossil fuels if they are fitted with carbon capture and storage technologies. At other times, the wind can blow too much or solar panels produce too much electricity compared to demand, and generation has to be curtailed—again increasing system costs due to wasted production.

Batteries can help out here too, but, just like your laptop battery, they can only supply their stored energy for a maximum of a few hours, and there are locations—especially in winter—where there can be extended periods of lulls in the wind that last for days or even weeks. Such windless months are projected to occur more frequently as the planet

warms, meaning that climate change not only requires that we decarbonize, it ironically also makes it harder to do so.

Thus in recent years as the proportion of variable renewables making up the electricity mix in some jurisdictions has climbed, researchers have increasingly begun to focus on the feasibility of long-duration energy storage (LDES), meaning storing energy for weeks or even months at a time.

There are several LDES options here, including pumped-storage hydro (in essence, a hydroelectric dam but one where once the water is released, it is pumped back up into the reservoir to be reused later), storing compressed air in caverns, flow batteries, seasonal thermal storage, and even the mechanical stacking of cement blocks.

Feasibility does not only mean technical capability for these options, which has been amply demonstrated but also the cost to the grid of this combination of variable renewables plus LDES compared to the cost of other options. Other possibilities include nuclear, fossil fuels plus CCS, hydroelectricity or geothermal where the geography allows, energy storage in the form of hydrogen, or demand response—using policy or technologies such as smart appliances to encourage people or enterprises to reduce electricity consumption or to shift the times when they use it.

Until now, no analysts had compared the cost to the system of these myriad options while also taking into account growing concern over low wind energy output over extended periods during extremely cold conditions.

"It is the very success with the roll-out of variable renewables in places like Scotland, with its bounty of offshore wind potential, that have placed these challenges front of mind," said Danny Pudjianto, the main author of the paper and a researcher with the Department of Electrical

and Electronic Engineering, Imperial College London. "With high penetration rates for wind and solar in a growing number of jurisdictions, we really need to come to grips with where and how long-duration energy storage fits in."

So the researchers developed a new optimization model that integrates both electricity and hydrogen systems to evaluate the potential value of LDES in a net-zero grid. The model—which assumes an electricity demand equal to that projected for 2050 (the date by which the UK must reach a fully decarbonized economy)—considers different storage designs (although using real-world case studies of pumped-storage hydro in Scotland as a proxy for all other types of LDES), and how they fare depending on the level of demand response built into the system. They then compared this to a system with no LDES at all.

They found that the integration of LDES technologies reduced the overall annual cost of the electricity grid by tens of millions or even hundreds of millions of pounds compared to a system without LDES, depending on the system design. The greater the scale of storage (90 gigawatt-hours [GWh] vs 30 GWh), the greater the system-cost savings.

In the paper, the researchers explained that the presence of LDES acts to "firm up" the variable renewables, thus, in turn, reducing (but not eliminating) the need for other clean and firm options such as nuclear or hydroelectricity that have high upfront capital spending requirements, and in so doing lowering overall system costs.

While using hydrogen for storage of energy works very well to firm up renewables as well, the "round-trip" efficiency of hydrogen is far lower than pumped-storage hydro. This means that because it takes a lot of energy to produce, pressurize, transport and store hydrogen, a lot of the energy that otherwise would be stored is used up. Thus the researchers also found that in a system with high penetration of LDES, the value of

hydrogen storage thus is far lower.

The analysts also discovered that the value of LDES is much lower in a system with a substantial demand response. This is good news, as some consumers may be reluctant to support demand response policies and technologies. A heavy-LDES system with less need for demand response thus potentially reduces the risk of political opposition to decarbonization.

More information: Danny Pudjianto et al, Whole system value of long-duration electricity storage in systems with high penetration of renewables, *iEnergy* (2022). DOI: 10.23919/IEN.2022.0004

Provided by Tsinghua University Press