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Q&A: Stanford energy experts discuss whether batteries can replace natural gas in backing up wind and solar power

Storing energy produced by wind or solar for later use has a challenge competing with existing natural gas-fired generation units. But batteries designed for the job could ease the way.

BY JOSIE GARTHWAITE

As the mix of energy sources feeding power-hungry homes, businesses and industry comes to incorporate more renewables like wind and solar, society faces a reckoning with where to turn when wind and sunshine die down. What will it take for greener sources not only to join fossil fuels on the American power grid, but eventually to displace them?

In February 2019, Los Angeles **announced (https://www.latimes.com/business/la-fi-garcetti-los-angeles-gas-plants-20190211-story.html)** plans to phase out three natural gas power plants by 2029 and to replace them with a combination of renewable energy and battery storage. A few months earlier, the California utility Pacific Gas & Electric won regulatory approval for similar plans. It hoped to replace a trio of natural gas plants with industrial scale battery storage systems, including a 730 megawatt-hour project to be designed and built by electric car company Tesla Motors. For comparison, the two small plants slated for retirement in PG&E's plan can generate up to 47.6 megawatts of electricity when needed, while a larger natural gas plant in the project can produce up to 606 megawatts.

(https://news-media.stanford.edu/wp-content/uploads/2019/03/12124638/GridStorage1.jpeg)

The Scattergood Generating Station in El Segundo, California, is one of three natural gas power plants that Los Angeles plans to replace with a combination of renewable energy and battery storage in the coming decade. *(Image credit: iStock)*

The idea behind both plans is that the capricious nature of energy from sunshine and wind creates a problem for operators who need to match the amount of energy supply at all times to the amount of demand. Storage technologies including batteries offer a way to maintain the supply-demand balance by drawing electricity from the grid when renewables are abundant and sending it back when demand picks up or renewables' output falls short.

Both the Los Angeles and PG&E plans have some unusual factors. But even so, they may offer glimpses of a future in which large-scale battery storage helps ease the way for the kind of energy mix that growing numbers of states demand. California mandated last year that all of its electricity come from zero-emission sources by 2045. And clean electricity legislation is **on the table (https://www.eenews.net/stories/1060120293)** this year in states including Minnesota, New Mexico, New York, and Washington state. In California, **regulators are also requiring (http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M079/K171/79171502.PDF)** PG&E and the two other investor-owned utilities to procure at least 1.3 gigawatts of energy storage capacity for the state's grid by 2020.

Yet batteries face significant hurdles if they are to help renewables displace fossil fuels. Here, **Simona Onori (https://profiles.stanford.edu/simona-onori)**, an assistant professor of energy resources engineering in the **School of Earth, Energy & Environmental Sciences (http://earth.stanford.edu/)** (Stanford Earth), and **Frank Wolak (https://profiles.stanford.edu/frank-wolak)**, who directs the Freeman Spogli Institute's Program on Energy and Sustainable Development, discuss some of the promises and pitfalls of deploying batteries for grid storage, as well as viable alternatives.

From a performance standpoint, which types of batteries are best suited to the job of providing energy storage for the grid?

Simona Onori: Compared to other battery technologies, lithium-ion batteries are lightweight and compact with high storage capacity for their size. They're more resilient to damage from excessive discharging and extreme temperatures, they have a longer useful life and they can cycle more times without significant loss of capacity. Lithium-ion energy storage systems require little maintenance and few replacement parts and the batteries have a modular structure that lends itself to large-scale applications on the grid.

Looking ahead, improvements in redox or flow batteries are making them an increasingly promising option for stationary applications. An electrical energy storage technology known as supercapacitors or double-layer capacitors may also provide high benefits for the grid, especially if used in a hybrid configuration with other devices like lithium-ion batteries. With this setup, supercapacitors would be used to regulate frequency, thanks to their fast response times, while batteries would provide energy when demand peaks. The feasibility of this solution hasn't been fully explored yet, but it's something we're researching in our lab.

How much is known about how lithium-ion batteries will endure the stress and demands of storage for the grid?

Onori: The performance and useful life of any battery will strictly depend on how the battery is used. The more a battery is stressed – under extreme temperatures, for example – the worse it will perform and the shorter its life will be. They need a robust battery management system that keeps them operating within their temperature sweet spot.

Battery stress factors are usually summarized in what we call a duty cycle. We have very solid knowledge about duty cycles in cars, but not much is known about battery duty cycles for the grid, mostly due to the lack of field data. As more and more batteries are used in grid applications, more data will be collected that can eventually help to build accurate models.

What are the most viable alternatives to batteries when it comes to storing energy for the grid?

Frank Wolak: Historically, the most cost-effective form of grid-scale storage has been a pumped storage hydroelectric facility, where water is pumped uphill when prices are low and then run downhill through a turbine to produce electricity when prices are high.

Concerns from environmental groups and a lack of reliable revenue sources have prevented new pumped storage units from being developed at many attractive sites in California. In addition, because pumped storage relies on certain geographic features, such as reservoirs that are close in distance but far apart in elevation, it cannot necessarily be located where it might be most helpful to maintaining a reliable supply of electricity.

Can battery storage offer a cheaper alternative to gas-fired power plants?

Wolak: Investments in storage have a steep hill to climb relative to existing natural gas-fired generation units, which often produce electricity at a market price that is above the marginal cost of production of the generation unit, which provides net revenues to recover the fixed cost of these generation units.

The economics of storage might change in the future in favor of batteries, but the best hope for storage in the near term is a high price of greenhouse gas emissions which makes it more expensive to operate natural gas plants when renewable energy is not available.

Energy storage isn't the only way to deal with dips in renewable energy production. What are some promising alternatives?

Wolak: We could shift energy use to periods with significant renewable energy production. In the standard form of these programs, participants decide how much electricity to consume each hour based on retail prices that vary along with the hourly wholesale price.

In California, it's more common for providers to sell demand reductions. Under these schemes, if participants are able to reduce their demand below a certain baseline, a utility will pay them for that reduction at the same rate as if they were supplying additional energy.

Wolak is also a senior fellow at Stanford's Precourt Institute for Energy.
