**The Grid of the Future (The Grid, part two)**

The Grid, part one, was about challenges to the American electricity grid – severe storms and weather impacting reliability; load growth from the energy demands of data centers, industry, and electrification; and adding clean energy. Part two is about strategies to meet those challenges. While utilities will tend to default to building more natural gas plants, there are better solutions!

It takes 10 years to build new transmission lines. Maximizing the use of existing infrastructure can meet demands sooner. Grid enhancing technologies (GETs) are hardware and software systems that better sense, calculate, and control electricity flow in real time, allowing lines to carry larger loads. GETs can be installed quickly with minimal transmission upgrades, enabling wind and solar projects to interconnect faster. "Reconductoring," or replacing existing wires with advanced wires, can double power capacity. Belgium and the Netherlands are reconductoring nearly their entire networks. Making use of interconnection points from retired coal plants and building on existing rights of way are other shortcuts. Grid hardening is also needed to protect aging grid infrastructure from hazards such as wildfire, floods, and storms, for example by burying wires or replacing wood poles with concrete or steel.

Decarbonization means shifting away from fossil fuels and adding more renewable energy, but solar and wind resources vary in availability. Their intermittency makes it more difficult for the grid to match electricity supply to demand in real time. The sun may shine all day, but folks come home from work and start cooking and using appliances, just as the sun is setting. Adding a battery allows stored solar power to be used later, when it is needed. Batteries are increasingly part of solar projects, driven by a 90% drop in the price of lithium batteries since 2010 and by their enhanced energy density. Batteries are going to be big! All kinds of batteries, EVs with vehicle-to-grid connections, long duration storage, and battery recycling are getting attention. Regional interconnections are another way to shift electricity, in this case to where it is needed. On one end, then, the *supply* of electricity can be shifted over time by storing it or over space through interconnections. The cheapest approach, though, may be to better manage *demand*, at the other end. At home, this might mean not running the clothes dryer when air conditioning is critically needed for a heat wave or scheduling EV charging for 2 am.

For a century or so, the grid has transmitted electricity from centralized power plants and distributed it to users. Now, rooftop solar panels, batteries, EVs, and other distributed energy resources (DER) are proliferating. These smaller scale energy sources bring energy production closer to where it's used (at the grid edge or distribution end) and electricity no longer flows only one-way. Microgrids range from photovoltaic solar plus a battery powering a single building to mini-grids powering multiple buildings or homes at once, such as neighborhoods, campuses, islands, or military outposts. A virtual power plant (VPP) is a connected aggregate of DER technologies. Appliances and buildings are becoming "smarter," digitalized for communication and coordination.

One path forward involves expanding the grid we know. New transmission lines are needed to connect up utility-scale solar and wind and to stitch together the Eastern, Western, and Texas Interconnections, ideally with streamlined but equitable permitting and siting. While those are under construction, GETs and reconductoring can increase grid capacity cheaper and quicker. Another path sees the grid becoming more decentralized and digitized, to make use of DERs and manage demand. Home solar and battery and EV installations can contribute to easing the load. Adding VPP to optimize the use of electricity so that peak demand is not exceeded can help constrain costs. Utilities, especially, but also ratepayers (that's us), industry, and government, will have to adjust to new systems. All pathways are needed to modernize the grid and make it bigger, smarter, and more reliable. Now that I know how important, but fragile, the grid is, I will check out what's happening to the grid near me, look more closely at PUC candidates on the ballot, and follow grid developments. I'm keen to see the American grid evolve into the grid of the future!

**REFERENCES** ***(my comments in italics)***


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**Energy Storage and Batteries**


>> *For pumped storage hydropower (PSH), water is pumped uphill to a reservoir when extra power is available, then released to flow through turbines to produce electricity when needed. In 2022, the 22 GW of PSH represented 70% of US utility-scale electrical storage capacity and utility-scale battery storage was at 9 GW. Battery storage grew to 16 GW in 2023 (led by California with 7.3 GW and Texas with 3.2 GW), and is expected to top 30 GW by the end of 2024. Moss Landing, California, is the largest operating facility in the country (750 MW).* (https://www.energy.gov/eere/water/pumped-storage-hydropower) *and* (https://www.eia.gov/todayinenergy/detail.php?id=61202). *A battery story: Back in 2017, Elon Musk wagered that he could build the then largest lithium-ion battery in the world (100 MW) within 100 days from contract signing or that the battery would be free; the Hornsdale Power Reserve in Australia was completed in 63 days.* (https://en.wikipedia.org/wiki/Hornsdale_Power_Reserve)
>> (https://www.energyvsclimate.com/episode-fully-charged/) Fully charged: battery storage & how to make it better, Energy vs Climate podcast, May 2024. *No transcript. Dr. Y. Shirley Meng is enthusiastic!*


**The Grid Where You Live**


>> *Try state or municipal government, local news, or utility websites, or area conservation organizations.*
>> Utility Dive (https://www.utilitydive.com) - *news and industry sponsored news; search on your state*
>> Energy News Network (https://energynews.us) - *nonprofit news, clean energy focus*
>> Clean energy investing in America (https://cleanpower.org/investing-in-america/) – *slick, interactive*
>> Grid Deployment Office, *home page for links and news* (https://www.energy.gov/gdo/grid-deployment-office). National transmission needs study. *Scroll down to regional fact sheets to see transmission in your area.* (https://www.energy.gov/gdo/national-transmission-needs-study)
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