Can the electricity grid be carbon-free by 2035?

The nation's electricity grid—comprised of power plants, high voltage transmission lines, and local distribution systems—is undergoing many changes and facing many challenges. One of those changes is a shift away from conventional sources of electricity, such as coal, and an increasing dependence on lower-carbon and carbon-free sources of electricity, especially wind and solar power. Adding further momentum to this shift, newly-elected President Biden announced the goal of achieving a carbon-free electricity grid by 2035. (Decarbonizing the grid is estimated by EPA to reduce global average temperature increase in the year 2100 by 0.049 degree C.[i]) Absent major technology breakthroughs, this goal means the elimination of coal and natural gas to produce electricity within the next 15 years, even though fossil fuels provide more than 60 percent of the nation's electricity (2.5 trillion kilowatt-hours last year), and some states rely on fossil fuels for more than 90 percent of their electricity.[ii]

Achieving President Biden's goal will require considerable work and an enormous investment to add new sources of electricity to replace fossil fuels, improve energy efficiency, build new transmission lines and other infrastructure, speed the development and deployment of new technologies, and upgrade the operation of the nation's grid. As just one example, we estimate the U.S. would have to add, on average, roughly 49,000 megawatts (MW) of new carbon-free electric generating capacity every year between now and 2035 to decarbonize the grid.[iii] Conceptually, that is like adding Pennsylvania's entire electricity supply to the grid each year for 15 years.[iv]

In short, making the grid carbon-free grid by 2035—while well intentioned—is likely to be an overly ambitious challenge. As evidence, several large utilities and other experts have questioned the feasibility of this 15-year time frame because of the magnitude of the challenges that must be overcome.[v] Several of the significant challenges facing a transitioning power grid are summarized below.

Transmission Critical to any plan that reduces carbon emissions from the power sector is a significant increase in the use of wind and solar power. There is a growing consensus that extensive investment in new electric transmission capacity will be required to deliver this power.[vi] A recent study from the MIT Energy Initiative found that transmission infrastructure would need to be nearly doubled in order to fully decarbonize the power sector in the most cost-effective manner,[vii] while The Brattle Group estimated additional transmission investment up to $25 billion per year would be needed for a grid that is 75 percent renewables,[viii] more than doubling the industry's $21.4 billion average annual transmission investment.[ix]

Cost concerns aside, completing the necessary transmission projects by 2035 will be challenging because the process of identifying, permitting, and building new transmission lines is lengthy. Regional transmission planning typically follows a 10-year planning horizon,[x] and projects between electricity regions of the kind that will be required to decarbonize the grid take longer to approve and build, since there is currently no framework for allocating the costs and benefits of such projects between regions.[xi] This challenge is illustrated by the Transwest Express Transmission Line, a 700-mile, 3,000-MW capacity line intended to deliver wind power from Wyoming to Nevada and California. Development of the project began in earnest in 2005, but final permits were not received until 2020, with construction finally scheduled to run from 2022 to 2024, nearly 20 years after the project began.[xii]

Even with federal and state support and approval, new transmission projects can be delayed or abandoned due to local opposition. For example, the Plains & Eastern Clean Line transmission project was a 700-mile, $2.5-billion project begun in 2010 to bring wind power from Texas and Oklahoma to serve eastern power demand. Despite federal and state approvals and support from the Department of Energy, the project was essentially abandoned 8 years later due to local opposition along the construction route.[xiii] Other transmission projects are taking 17 years or more to complete.[xiv]

Resource adequacy and reliability Wind and solar generation present challenges to power system planning and operation because their power output is variable and cannot be scheduled to coincide with electricity demand. This challenge will grow as more renewables come online, as several examples illustrate. In ERCOT, the grid operator covering most of Texas, wind provided 20 percent of electricity in 2019 (up from 8 percent in 2010).[xv] A sudden drop in wind production during a 2019 heat wave caused ERCOT to initiate emergency procedures in order to avoid blackouts.[xvi] MISO also had to initiate emergency procedures during the winter of 2019 when wind output dropped by two-thirds when it was needed most.[xvii] California, where almost one-third of the generating capacity is renewable,[xviii] was not as lucky this past summer, when a drop in solar power output contributed to rolling blackouts and other emergency measures that were necessary to avoid a collapse of the grid.[xix]

The North American Electric Reliability Corporation (NERC), the entity responsible for ensuring the reliability of the North American power grid, has noted that old methods for measuring resource adequacy and reliability no longer work. NERC stated that, "Resource planners must consider greater uncertainty across the resource fleet as well as uncertainty in electricity demand that is increasingly being effected by demand-side resources."[xx] There are currently no standards identifying which new analyses should be performed, nor what new criteria should be used to determine whether an electricity region's power supply is adequate and reliable.

Technology At any point in time, the gap between electricity demand and wind and solar output must be filled by other sources of electricity. To avoid using carbon-emitting resources for gap filling, energy storage technology must be deployed that can store renewable generation when it exceeds power demand and produce electricity when power demand exceeds renewable generation. The most commonly proposed energy storage systems are large-scale battery installations, though only 1,300 MW of battery capacity are currently installed on the grid.[xxi] Battery cost and performance have been continually improving but remain high, with current cost estimates ranging from $132-$245/MWh of power provided to the grid.[xxii] This makes battery storage cost prohibitive for widespread use in supporting renewable generation. For example, using battery technology alone to support a nationwide generating mix that is 80 percent wind and solar generation would require 450,000 MW of 12-hour batteries (or 900,000 MW of 6-hour batteries) and could cost $2.5 *trillion*.[xxiii]

Similarly, carbon capture, utilization, and storage (CCUS) technology could significantly reduce the carbon emissions of dispatchable fossil fuel power plants, but the technology lacks a track record showing it can be cost-effective for widespread deployment. Efforts to improve both CCUS and battery storage continue to show promise, but it is risky to assume they can be proven cost-effective and widely deployed within 15 years.

Other challenges Many other challenges need to be addressed in the course of transitioning the electricity grid to a carbon-free framework. Among these are the following:

- **Market design** The nation's power markets are not well-suited for high levels of renewable generation as they are currently designed.[xxiv] Prices in these markets are based on the cost of generating power when needed, but wind and solar power output are driven by weather and not price signals or power demand. By generating power whether needed or not, they tend to artificially depress market prices below a level conventional generators need to break even, even when conventional generators are essential to grid reliability. New market structures and rules will need to be developed to ensure power generators are adequately and fairly compensated.[xxv]

- **Stranded costs** More than 30 percent (334,000 MW) of the 1,107,000 MW of operating electric generating capacity in the U.S. is comprised of fossil fuel generators less than 20 years old.[xxvi] Dealing with these stranded assets poses a significant challenge as power plant owners seek to be made whole for their undepreciated investment—either through regulatory ratemaking (utilities) or legal action (non-utility generators).

- **Fuel security and fuel diversity** NERC has found fuel security—a power plant's immediate access to fuel when needed—to be important enough to develop guidelines to help regional planners assess their exposure to fuel risk.[xxvii] Fuel diversity can reduce the cost of electricity by allowing system operators to rely on different power plants with different fuels as the relative costs of fuels change.[xxviii] Both of these important attributes will be reduced as the power sector transitions, but the impact on reliability and electricity cost are not well-understood.

- **Jobs** Remaking the electricity system will end the employment of many workers in affected industries. A recent report by the Energy Futures Initiative found that more than 185,000 jobs are supported by coal-fired electric power generation.[xxix] All would be at risk, as would a portion of the 686,000 jobs supported by the natural gas industry. Many of these jobs are in rural communities that would be disproportionately harmed by their loss.

Conclusion There are considerable economic and technical challenges associated with the transition of the electric power grid. These challenges must be overcome, not only to reduce carbon emissions, but also to maintain a reliable and affordable supply of electricity. Ensuring that a decarbonized grid, electric reliability, and affordable electricity prices can all co-exist could take longer than 15 years.

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[i] U.S. EPA, "Pollutant-Specific Significant Contribution Finding for Greenhouse Gas Emissions From New, Modified, and Reconstructed Stationary Sources: Electric Utility Generating Units, and Process for Determining Significance of Other New Source Performance Standards Source Categories," *Federal Register*, January 13, 2021, p. 2553. EPA determined that hypothetically eliminating all CO2 emissions from the U.S. electric power sector "corresponds to a hypothetical global mean temperature reduction of 0.049 degrees (sic) Celsius (°C) (approximately 0.1 degree Fahrenheit, the calculated effect in 2100) of removing 1,780 million metric tons (MMT) of CO2 emissions each year from 2020 through 2100) from source categories above that threshold (i.e., just EGUs)."

[ii] U.S. Energy Information Administration, *Electric Power Monthly*, February 2020.

[iii] According to *AEO 2020*, fossil fuels are projected to total 737,200 MW of electric generating capacity in 2035. Therefore, 737,200 MW of fossil fuels would have to be replaced by non-carbon-emitting electricity resources (e.g., renewables, battery storage, nuclear) by 2035. This averages 49, 147 MW per year over a 15-year period. For purposes of simplification, we assume that (1) electricity demand is the same in 2035 as that projected by AEO 2020 and (2) each MW of fossil generation is replaced by one MW of non-carbon-emitting generation.

[iv] Pennsylvania's total electric generating capacity was 47,812 MW in 2019. U.S. Energy Information Administration, *State Electricity Profiles, Data for 2019*, November 2, 2020.

[v] For example, Xcel Energy and American Electric Power. See Wilson, A., "Biden's Energy Goals Draw Skepticism Despite Bright Outlook for Renewables," S&P Global Market Intelligence, January 22, 2021.

[vi] Scott Madden Management Consultants, *Informing the Transmission Discussion: A Look at Renewables Integration and Resilience Issues for Power Transmission in Selected Regions of the United States*, study commissioned by WIRES, January 2020.

[vii] Brown, P.R., and A. Botterud, "The Value of Inter-Regional Coordination and Transmission in Decarbonizing the US Electricity System," *Joule* 5:1-20, January 20, 2021. The report found that a 90 percent increase in transmission capacity would lower the cost of electricity on a carbon-free grid by 46 percent when compared to approaches that lack transmission expansion ($73/MWh vs. $135/MWh, on average). Note that $73/MWh is still roughly twice the cost of electric power today.

[viii] The Brattle Group, *The Coming Electrification of the North American Economy Why We Need a Robust Transmission Grid*, study commissioned by WIRES, March 2019.

[ix] Edison Electric Institute, *Historic and Projected Transmission Investment*, November 2020.

[x] NERC, *2020 Long-Term Reliability Assessment*, Figure 35, December 2020.

[xi] Scott Madden Management Consultants, *Informing the Transmission Discussion: A Look at Renewables Integration and Resilience Issues for Power Transmission in Selected Regions of the United States*, study commissioned by WIRES, January 2020.

[xii] http://www.transwestexpress.net/about/timeline.shtml.

[xiii] Scott Madden Management Consultants, *Informing the Transmission Discussion: A Look at Renewables Integration and Resilience Issues for Power Transmission in Selected Regions of the United States*, study commissioned by WIRES, January 2020.

[xiv] For example, Gateway West started in 2007 and has a scheduled in-service target date of 2024 (17 years to complete). The SunZia Southwest Transmission Line began in 2006 and has an in-service target date of 2024 (18 years to complete).

[xv] http://www.ercot.com/content/wcm/lists/181766/FuelMixReport_PreviousYears.zip.

[xvi] https://www.americaspower.org/coal-retirements-have-ercot-power-prices-soaring/.

[xvii] *Energy Wire*, "Turbine shutdowns in polar vortex stoke Midwest debate," Jeffrey Tomich, February 27, 2019.

[xviii] S&P Global Insight database, queried December 22, 2020.

[xix] FERC, *Preliminary Observations on the August 2020 California Heat Storm*, December 2020.

[xx] NERC, *2020 Long-Term Reliability Assessment*, p. 6, December 2020.

[xxi] EIA, *Monthly Generator Inventory*, October 2020.

[xxii] Lazard, *Lazard's Levelized Cost of Storage Analysis Version 6.0*, October 2020.

[xxiii] Temple, James, "Relying on renewables alone significantly inflates the cost of overhauling energy," *MIT Technology Review*, February 26, 2018.

[xxiv] See, e.g., Ela, E., et al., "Future Electricity Markets: Designing for Massive Amounts of Zero-Variable-Cost Renewable Resources," *IEEE Power and Energy Magazine*, Nov./Dec. 2019, pp. 58-66.

[xxv] Perchman, C., *Whither the FERC? Overcoming the Existential Threat to its Magic Pricing Formula Through Prudent Regulation*, National Regulatory Research Institute, January 2021.

[xxvi] EIA, *Monthly Generator Inventory*, October 2020.

[xxvii] NERC, *Reliability Guideline: Fuel Assurance and Fuel-Related Reliability Risk Analysis for the Bulk Power System*, March 2020.

[xxviii] NETL, *Reliability, Resilience and the Oncoming Wave of Retiring Baseload Units, Volume I: The Critical Role of Thermal Units During Extreme Weather Events*, National Energy Technology Laboratory, March 13, 2018.

[xxix] Energy Futures Initiative, "2020 U.S. Energy and Employment Report," https://www.usenergyjobs.org/.