



Testimony before the United States House of Representatives Committee on Energy and Commerce

For a hearing on “Power Struggle: Examining the 2021 Texas Grid Failure”

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Good morning Chairman Pallone, Ranking Member Rodgers, Chairperson DeGette of the Subcommittee on Oversight and Investigations DeGette, and members of the Committee. I am grateful to the Committee for inviting my testimony.

Advocates of renewable energy have argued since the 1970s that the variable, weather-dependent nature of sunlight and wind is a modest obstacle at best to relying on 100 percent renewables. Some have argued that weather-dependent energies would, paradoxically, make electricity even more reliable. This argument was that the distributed and localized production of renewable energy, the buildout of additional required transmission networks, and increased storage to smooth out fluctuating production, would all make electricity service more reliable than depending on a small number of large, centralized power plants connected by a few major transmission lines.¹

But recent power outages in Texas and California have poured cold water on these arguments. Adding more variable energy sources to electricity grids, all else being equal, might not in itself make electricity less reliable. But all else is not equal. The significant integration of variable energies leads to the loss of traditional power plants and the construction of new transmission lines to weather-dependent energy projects that are unreliable in extreme weather events. The policy interventions required to ensure friendly investment conditions for renewables, including the lowering of acceptable reserve margins or the counting of “average” contributions, even if reduced, from variable renewables, are interfering with grid resiliency.

I. Why We Need Weather-Resilient Energy

It is not the case that all energy sources have pluses and minuses when it comes to building resilient systems. Weather dependency matters. When a continent-sized mass of freezing air moved all the way into Texas in February and remained there for several days, different energy sources performed differently, both absolutely and against expectations. Where performance for a given resource was lower than expected, we must ask: can we change rules and spend money that will increase its performance? In other words, was the limitation merely our own preparedness? Or was poor performance intrinsic to the fuel type?

Consider the average performance for the different fuel types over all four days of the blackouts in Texas. During the four days of emergency operations during the cold snap, from early February 15th to midnight February 18th, output levels of nuclear, natural gas, coal, and wind to the grid were 79.3 percent, 47.4 percent, 51.5 percent, and 13.7 percent, respectively, of winter-rated total installed capacity.²

The Texas grid operator, ERCOT, in its pre-winter 2020 report on winter power plant availability for the winter of 2020/2021, expected some of the gas and coal fleet to experience winter outages, along with the loss of some capacity in normal winter high-demand periods, with further losses in extreme weather.

ERCOT also expected, during peak demand events in winter, to have power from wind represent about 27% of installed wind capacity. In its most severe appraisal of the loss of wind capacity, ERCOT expected 8% of wind power compared to capacity.

Therefore, here is the performance of nuclear, gas, coal, and wind, over the four days of the emergency, as compared to “normal” expected winter peak conditions: nuclear, 79.1%; gas, 54.4%; coal, 57.5%; and wind, 50.2%.

When examined this way, the issue of low wind and solar output during many hours of the emergency becomes much more severe than previously reported. If ERCOT actually modeled simultaneous extreme loss of thermal generation along with extreme low wind, it did not add the scenario to its winter adequacy report.³

To see this, it is necessary to look at the lowest instantaneous performance during the four days of blackouts, compared to total installed capacity. Because electricity grids must operate in exact balance between supply and demand, every single second, continuously, averages over the four-day event do not adequately represent the severity of the emergency nor allow an understanding of the impact of adding more variable energy sources in the future.

For nuclear, the lowest hourly value of production was 73% of output compared to installed capacity, which was 73% of expected based on winter adequacy reporting. For coal, it was 41% of total, or 46% of winter adequacy expectations. For natural gas it was 40%, or 46% based on winter adequacy expectations. For wind, it was 2%, or 9% of winter adequacy expectations. Even if comparing based on the extreme low wind speeds scenario, which again, was not stacked on top of a severe outages scenario for thermal generation, the worst hour of wind was only a third of the expected production.

The single hour of greatest probable load-shedding, with the maximum difference between the demand that ERCOT expected to see versus the supply of electricity it actually provided, was the single hour of lowest wind output. On February 15th, in the hour from 7pm to 8pm central time, ERCOT's fleet of 27.9 GW of wind produced at a rate of 0.65 GW. This hour saw a difference of 28.9 GW between expected demand and delivered generation.⁴

Some energy experts and reporters have contended that Texas regulators did not expect to rely on wind to provide much electricity during the cold snap, and rather had relied on natural gas and other thermal power plants. They point out that conventional energy sources underperformed ERCOT's risk accounting more than wind energy had.⁵

But that's precisely the issue: regulators like ERCOT do not account for the availability of variable renewable energy sources because they are neither always on, like nuclear, nor easily dispatchable, like gas. The main implication of this reality has been left unsaid: *efforts to expand transmission for the purpose of increasing the use of variable renewable energy cannot be justified as a means of preventing power outages like the ones that occurred in Texas and California.*

What both states needed to avoid blackouts was more power from reliable, firm, "baseload" power plants, not weather-dependent ones. California's chief grid operator made this point in a conference call to reporters during that state's crisis in August 2020, but it went mostly unreported, perhaps because it contradicted the widespread and longstanding assumption that the weather-dependent nature of renewables was a trivial, well-understood concern.⁶

Adding variable energy sources can only make grids more resilient if significantly more money is spent maintaining reliable power sources, namely nuclear, natural gas, and coal plants, to make up for their lost revenue and lost operation hours.

Consider again the situation in Texas. Variable wind energy provided 21 percent of the state's total electricity over the course of last year.⁷ But during the power supply shortage, wind produced only 8 percent of the state grid's electricity.

But this figure of 8 percent occurred during severe load-shedding, intentional blackouts designed to save the entire grid from catastrophic collapse. If, instead, load-shedding had not

occurred, with all expected demand being fulfilled by better operation of gas, coal, and nuclear plants, the wind output observed would have been only 5.9 percent of the grid's power.

In his recent testimony to the House Committee on Science, Space, and Technology, the coauthor of Princeton University's Net-Zero America study noted that just because an energy technology is not reliable does not mean that it has no role in a reliable system.⁸ If we accept this view, we must acknowledge that the increased use of unreliable energy sources will, necessarily, for inherently physical reasons, result in higher electricity costs, stemming from the additional equipment and personnel required to operate a system with more unreliable electricity sources.

This fundamental reality has been obscured by the high complexity of wholesale electricity "markets," which were created by government policies and regulations and mask the high cost of integrating variable renewable energy sources — until, that is, disaster strikes.

Texas regulators appeared to be controlling the cost of electricity until they could no longer do so during the February crisis. Now the state faces high costs for the failure, with the ERCOT wholesale market alone clearing \$50 billion of electricity costs over four days, as well as further high costs if they act to correct the problem through investments in winterization and larger capacity reserve margins.⁹

That \$50 billion, and future money, is money that could have gone to making the grid more resilient to extreme weather events, whether from climate change or not, but instead went into subsidizing the integration of variable renewable energy sources.

We can see the same impact of variable energies in Germany. Few people realize that Germany has actually increased its fossil fuel combustion capacity over the 20 years of its landmark renewable energy program from 2001 to the present. It did so precisely in order to protect against the kinds of disasters that befell Texas and California. While it decreased the use of such plants some, they are likely to be used significantly more if Germany follows through on its pledge to shutter all of its nuclear plants by the end of 2022.

Another reason Germany is maintaining its coal plants is so that it does not become overly dependent on natural gas, about half of which is imported from Russia even before completion of a massive new pipeline directly connecting Russia to Germany. Germany only operated its hard coal plants in 2020 at a 17.1 percent capacity factor, compared to the 40 percent in the U.S.¹⁰ In the United States, coal plants are closing rapidly due to this low utilization, but in Germany with only a fraction of the operation hours they are not closing.

Maintaining this additional power plant capacity while significantly expanding transmission and personnel to handle the integration of variable energies has come at a high cost.

In California, costs to the public have not been contained as they were in Texas before the February crisis. As a result, California's retail electricity prices rose eight times faster than the nationwide average in the 10 years between January 2011 and December 2020, due to its increased use of variable energy sources. This occurred despite falling prices for natural gas, which provides the biggest share of the state's electricity production. Today, California households pay 55 percent more than the national average per kilowatt-hour of electricity. In 2020, California's electricity prices rose 7.5 percent, compared to just 0.25 percent in the other 49 states.¹¹

None of this is unique to the U.S. Germany, which has deployed more variable renewable energy than any other nation in Europe, has used various regulatory mechanisms and subsidies to prevent utilities from going bankrupt,¹² and its electricity prices rose 50 percent in the 15 years after

2007. In the first half of 2020, German electricity prices were 43 percent higher than the European average.¹³

II. Why Variable Energies Externalize Risk

Part of the reason California and Texas failed to do what Germany is doing in protecting its fossil fuel capacity stemmed from overconfidence in variable renewable energy sources and the functioning of their wholesale electricity markets. These markets were created by government policy and regulation, as California's grid operator noted during the crisis of August 2020.

These "deregulated" or "restructured" electricity markets are an experiment that is only twenty years old, while the average age of a unit of firm capacity in the U.S. is 32 years, as of January 2021.¹⁴ The average age of a unit of wind or solar is 6.3 years. Hence, the grid's firm capacity is on average much older than the markets themselves, while the significant influx of variable wind and solar is much younger, and in fact is enabled by the experiment of restructuring electricity markets.¹⁵ Indeed, while 76 percent of utility-scale wind and solar is located in restructured electricity markets, only 62 percent of firm capacity is located there.

The increasing complexity of restructured electricity systems such as those in Texas and California means that nobody is sure who is responsible when things go wrong. In both California and Texas elected officials and regulators pointed fingers at each other, and rightly so, since they were all, to some extent, responsible. By contrast, if there is a power shortfall in Georgia, which has stuck with the older model of utility generation, blame falls on just a handful of individuals: the CEO of the vertically-integrated monopoly utility and the five public service commissioners elected by the public which oversee that monopoly.

A significant share of the subsidies for the expansion of variable renewables came from outside the Texas and California electricity systems, through federal tax incentives. Money that could have gone to making those systems more reliable and resilient instead helped pay for the equipment that made them more fragile. Texas power plants fight for what had been, before the blackouts, a declining pool of revenue to pay for operations, but solar and wind are assured of survival through tax dollars from around the U.S. Prices plunge to negative values regularly in Texas and California. As solar and wind farms receive layers of subsidies making negative prices survivable, the baseload power plants that the grid relies on during crisis events lose significant revenue.

It is not the case that energy storage would have helped in Texas. Energy usage was so extreme above available capacity that even a large amount of batteries would have been drained only hours into an event lasting for four days. Instead, batteries would've had to be saved for weeks or even months only to dump their power in single-use discharge, a business model that cannot justify the cost of building and charging the batteries in the first place. Batteries must operate a very large number of times to pay for themselves.

Some compare the extra costs of winterizing or weatherizing equipment to an insurance policy that Texas should now pay for,¹⁶ but insurance policies are not designed to stop earthquakes, floods, and fires. Weatherization is more like installing emergency equipment to prevent disasters than like financial arrangements to compensate for disasters after the fact. But if these "safety system" weatherization upgrades actually succeed in preventing blackouts, in a restructured electricity market with frequent negative prices they may never be able to recover their costs, as by

design restructured markets like California and Texas attempt to use extreme shortfall events to incentivize new investment and reliability.

Under its current system, a requirement to weatherize would have significantly stressed Texas power plant owners because they are losing much of their revenue to variable renewable energy generators that weren't available in the crisis. Ironically, extra expenditures required to weatherize may have pushed power plants into early retirement as their revenues collapse -- unless more money is found to pay them regardless of their actual operation hours in a year. This dynamic is a result of both the restructured market logic and the increasing penetration of variable renewables.

Today, the risks of integrating variable renewable energy sources onto electric grids are being socialized. Part of the problem in Texas was that wind and solar farms set the price for the rest of the system. The total number of negative price hours, whereby power plants had to pay people to take unneeded electricity, grew dramatically between 2019 and 2020, just as they did in California during the same period, and have grown since. Some analysts claim those negative prices are a good thing because they are a market signal to buy batteries. But batteries help with minutes of electricity not days and would thus not have helped prevent the outages in Texas.

Investors developing solar and wind energy could only do so because they assumed few, if any, of the risks of blackouts caused by extreme weather events, instead handing off these projects to new owners or the risk of energy shortfalls onto middlemen. In contrast, when a regulated vertically-integrated monopoly utility in Georgia builds a power plant of any kind, it expects to assume the full system costs and risks over the life of the facility, as part of a rationally planned total fleet.

Although our ability to predict the weather a few days out continues to grow, the downside of getting predictions wrong jumps rapidly as the percentage of electricity coming from the weather jumps. With larger numbers of smaller entities, the risk of getting it wrong and leading to bankruptcies increases, with the burden of continuing to provide and pay for the grid always falling back on the citizens themselves. Indeed, as one entity after another files for bankruptcy following the Texas blackouts, their unmet financial commitments fall on a decreasing number of surviving entities which then must pass the costs on to consumers to stay solvent.

III. Variability and Complexity Increase Costs

And all of that complexity has been created by a grid with just 25 percent of electrical generation coming from variable wind and solar energy. This is far from the widely touted goal of 100 percent electricity from renewables, and much further from the goal of 100 percent of *energy*, which includes fuels used for transportation, heating and cooling, and would amount to two to three times more electricity than required today.¹⁷

It is sometimes claimed that the wind is always blowing or the sun is always shining somewhere in the U.S., and thus we just need a grid large enough to bring that solar or wind energy to places that don't have it. But if the sun is not shining and the wind is not blowing in most of the country, which is often the case in large-scale heat waves and cold snaps, then the burden on the places where they are would be far too high for high-demand low-supply states to rely upon.

Few understand that significantly increasing variable renewable energy requires both greatly over-building the amount of electricity capacity that is required, and also cutting off increasing amounts of electricity from variable renewables when it is not needed. For instance, last weekend, March 20th and 21st, 2021, California shut off, or curtailed, 70 GWh of wind and solar electricity,¹⁸

which may be the most in any two-day period in its history. It has been paying surrounding states for years to take excess power. But increasingly it must cut off the power coming from its solar farms when it is too sunny and demand for electricity too low.

The cost of this excess electricity is high and growing, and must be overcome by continued subsidies, as wind and solar are indeed continuing to request and receive. It is no longer typical to hear renewable energy experts talk about “grid parity”, a very popular concept in prior years, of wind and solar being so cheap that, unsubsidized, they can compete with reliable generation. Instead, subsidies remain, and if payments are not made to high-reliability power plants the risk of blackouts soars, and if payments are not made from consumers to build extensive transmission serving remote wind and solar projects, development slows to a crawl. Thus, maintaining high reliability in the presence of variable renewables increases costs not just in managing shortages but also in managing surpluses.

The impact of variable renewable energy sources on electricity prices can be seen in the more than two-dozen states that have had in place renewable energy mandates. University of Chicago economists found that state policies promoting variable renewables led consumers to pay \$125 billion more for electricity. And those costs did not include the cost to taxpayers in the form of the separate federal production and investment credit subsidies for renewables.¹⁹

Most experts and regulators now agree that the older, simpler model of regulated electric utilities with a few large power plants, less transmission, and little storage, is more resilient.²⁰ Significantly expanding variable renewables requires significantly expanding the size and complexity of the grid to make up for both variable energy supply and low power density. The National Academies of Sciences has clearly and repeatedly said that complexity will make electricity grids less resilient, all else being equal, than simpler grids.²¹

IV. Fuel Diversity Reduces Risk

Since even renewable advocates emphasize that we cannot rely on variable renewable energy sources, we can all agree that phasing out coal and nuclear would lead us to almost total dependency on a single energy source, natural gas. Relying entirely on a single energy source, especially one used both inside and outside the electricity system, and in fact often requiring the electricity system to stay on to remain flowing, is counter to historical evidence on how to make electricity affordable, reliable, and resilient. With gas burned in situ as the dominant alternative to electrification for heating, cooking, and industry, we can no longer turn to coal, or any other fuel independent of the gas supply, as a practical alternative.

Coal energy has the highest carbon intensity of fossil fuels, but the electricity that coal provided during the cold snap saved Texas from more widespread blackouts, and possibly more fatalities.²² The coal and natural gas plants that failed did so because the Texas regulator failed to respond adequately to the cold snaps of 2011 and 1983, and they did not enforce any additional requirements to winterize their systems. I believe the U.S. should maintain and expand its fleet of highly-reliable, carbon-free, and 94 percent efficient nuclear power plants. But if the U.S. does decide to shut down its nuclear plants, as many plants across the country are scheduled to do shortly, it will need to maintain its coal plants to prevent catastrophic collapses of the electric grid and higher energy prices due to reliance on a single fuel.

Nuclear energy means we can have electricity that is affordable, but some people want to get rid of nuclear energy for reasons that appear to have little to do with energy and the environment and more to do with lingering Cold War national security concerns. For America to give up on nuclear energy would have, I believe, potentially catastrophic outcomes for our national security and for the world. But if Congress and the American people choose to phase out nuclear, they should be aware that coal plants would be necessary to maintain the resilience of the grid.

As such, we can have an electricity that is affordable, carbon-free, and/or nuclear-free, but we can't have all three. You can swap in the word "reliable" or "resilient" for "affordable" in the prior sentence and it remains equally true.

In the past, we referred, properly, to electricity as a service, not a commodity. A commodity is a basic good that is interchangeable with goods of the same type. Coal, natural gas, and uranium are commodities. Electricity is a natural monopoly service and not interchangeable. The amount of electricity California curtailed on that single day would have totaled \$315 million during the Texas blackouts.²³ As a service, electricity is not transferable after the point at which its value is realized.²⁴

Congress and state legislatures asked grid engineers to figure out how to integrate variable renewable energies onto electric grids without properly considering the consequence of making electricity less reliable, resilient, and affordable. I do not think we can label such consequences as "unanticipated." They have been widely anticipated for decades but largely ignored by policymakers and the public in their enthusiasm for a vision of harmonizing electricity consumption with natural energy flows of sunlight, water and wind.

In the end, variable renewable energy sources must be subsidized by the society and so the question is who will pay. California's renewable energy policies have implicitly redistributed wealth from the poor to the rich, as the state's wealthy have flocked to subsidized rooftop solar and battery systems, leaving most of the state's poor and middle class with higher utility bills.²⁵

If affordability was all that was at stake, then perhaps Congress should not be so alarmed. But the outages in Texas and California showed that resiliency, reliability, and affordability are related. Wealth and resources that go to accommodating the electricity grid for variable renewable energy sources, in the form of transmission, storage, and overall management, are resources not available to keep electricity grids clear of the vegetation that causes fires and led to the bankruptcy of Pacific Gas and Electricity in 2019; not available to keep reliable power plants on-line in case we need them during extreme weather events; and not available for weatherizing and winterizing equipment.

V. The Sanctity of Electricity

The system in Texas in the end was based on the idea that a greater number of unreliable energy sources would add up to greater reliability. The idea in Texas was that electricity price spikes would somehow result in electricity generators, but there was a collective action problem. The monies and the costs were divided up into thousands of different parties, none with sufficient interest to guarantee the whole system's reliability.

Electricity experts and renewable energy advocates criticize the older electricity model as followed in Georgia by utilities like Southern Company because the utilities ended up maintaining so much supposedly unnecessary capacity. The CEO of Southern was viewed as unnecessarily

conservative for becoming concerned about electricity supply in his territory with just 10 gigawatts of electricity to spare. And yet the shortfalls in Texas exceeded 28 gigawatts in some hours, and in California the shortfall was about 2 gigawatts.

We need an electricity system that cares for the people and that means it must be affordable, reliable, and resilient. We need a system that's fair. That means that we're not raising electricity prices on the poor, and we're not transferring wealth from the poor to the rich. We must treat our electricity system as sacrosanct. It is the basis for our high-energy civilization. When we confront major electricity system failures, like the ones in Texas and California, we must take a clear-eyed look at what went wrong, and consider, first and foremost, whether we might be making it worse in pursuit of lower goals.

We need to respect our grid authorities. In both Texas and in California, the expert authority, the grid operators, the scientists and engineers who knew what was needed, were overridden by political appointees. The difference between the older regulated system and the new restructured wholesale market system is that policymakers were able to hold people accountable in the old system and are unable to do so in the new system.

The externalization of hidden transmission, storage, and personnel costs from variable renewable projects onto the grid as a whole is both unfair and dangerous. For additional electrical transmission to benefit society, it would need to be paid for by variable renewable developers and not externalized onto the grid's regular consumers.

While a significant amount of electricity policy is determined by the states, Congress can play a constructive role in maintaining the reliability, resiliency, affordability, as well as the diversity and sustainability, of our grid by taking policy action now to keep operating the nuclear plants that have been critical to preventing power outages in recent years.

Bad policies have unfairly and counterproductively undermined the economics of nuclear power plants, including those that prevented wider power outages during the recent cold weather crisis. Those plants are Byron and Dresden in Illinois, Palisades in Michigan, Davis-Besse and Perry in Ohio, and Beaver Valley in Pennsylvania. If those nuclear plants are lost, our grids may suffer from more energy shortages during future heat waves or cold snaps.

We should be grateful to Texas and California for dramatically reminding us that less reliable elements of a system make the system, all else being equal, less reliable. Adding transmission and storage to systems that rely increasingly on variable energy sources will raise electricity's costs, and those higher costs threaten, in turn, the grid investments we need to ensure resilience to extreme weather.

Thank you again for the opportunity to testify and I look forward to your questions.

¹ Amory Lovins, "Energy Strategy: The Road Not Taken," *Foreign Affairs*, October 20, 1976. Stabilizing grid with 100% renewables 2050

Mark Z. Jacobson, Mark A. Delucchi, Mary A. Cameron, Bethany A. Frew, "Low-Cost solution to the grid reliability problem with 100% penetration of renewables," *Proceedings of the National Academy of Sciences* 112, no. 49 (2015): 15060-15065; DOI:10.1073/pnas.15110028112

² EIA, "EIA-930", EIA.gov, accessed March 22, 2021, https://www.eia.gov/beta/electricity/gridmonitor/dashboard/electric_overview/US48/US48. Installed capacity from: EIA, "EIA-860M", EIA.gov, accessed March 22, 2021, <https://www.eia.gov/electricity/data/eia860M>

³ ERCOT, "Final Seasonal Assessment of Resource Adequacy for the ERCOT Region (SARA); Winter 2020/2021," <http://www.ercot.com/content/wcm/lists/197378/SARA-FinalWinter2020-2021.pdf>

⁴ Solar power, which performed well during the crisis during daytime hours compared to the low expectations of the grid operator, put out 0.0 GW from its 4.9 GW of capacity during this crucial hour of need.

⁵ Jesse Jenkins, "A Plan to Future-Proof the Texas Power Grid," *New York Times*, February 18, 2021.

⁶ "The situation could have been avoided," said the CEO of CAISO. "For many years we have pointed out that there was inadequate supply after electricity from solar has left the peak. We have indicated in filing after filing after filing that procurement needed to be fixed. We have told regulators over and over that more should be contracted for. That was rebuffed. And here we are." CAISO. August 17, 2021. Audio recording of call. <http://www.caiso.com>.

In their final Root Cause Analysis, CAISO, the California Public Utilities Commission, and California Energy Commission contextualized and softened the remarks of the CEO, who had by then departed the position, but nonetheless concluded that regulators had indeed overestimated what could be expected of solar, wind, and demand response, and that solar was still over-valued by the CPUC. CEC, "Root Cause Analysis: Mid-August 2020 Extreme Heat Wave," January 13, 2021, p. 6, 49.

⁷ "Electricity Data Browser: Retail Sales of Electricity Annual," United States Energy Information Administration, accessed March 8, 2021, <https://www.eia.gov/electricity/data/browser>.

⁸ Dr. Jesse Jenkins, "Lessons Learned from the Texas Blackouts: Research Needs for a Secure and Resilient Grid," March 18, 2021.

⁹ Mark Chediak, "Texans Will Pay for Decades as Crisis Tacks Billions onto Bills," *Bloomberg*, February 22, 2021.

¹⁰ Fraunhofer Institute for Solar Energy Systems ISE, "Net installed electricity generation capacity in Germany" and "Electricity Price Statistics," Eurostat. Accessed March 7, 2021.

¹¹ "California," *Environmental Progress*, accessed March 8, 2021, <https://environmentalprogress.org/california>.

Calculations based on data from "Electricity Data Browser: Retail Sales of Electricity Annual," United States Energy Information Administration, accessed March 8, 2021, <https://www.eia.gov/electricity/data/browser>.

¹² Freja Eriksen, "German Electricity Supply Security to Stay Very High Even with Coal Exit – Economy Ministry," *Clean Energy Wire*, last modified July 4, 2019

¹³ "Electricity prices for household consumers-bi-annual data (from 2007 onwards)," Eurostat, March 11, 2021,

https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nrg_pc_204&lang=en;

¹⁴ Generator capacity, first service date, and type from: EIA, "EIA-860M", EIA.gov, accessed March 22, 2021, <https://www.eia.gov/electricity/data/eia860M>

¹⁵ Generator capacity, first service date, and type from: EIA, "EIA-860M", EIA.gov, accessed March 22, 2021, <https://www.eia.gov/electricity/data/eia860M>

¹⁶ Erin Douglas, "Gov. Greg Abbott Wants Power Companies to "Winterize." Texas' Track Record Won't Make That Easy," *The Texas Tribune*, last modified February 20, 2021, <https://www.texastribune.org/2021/02/20/texas-power-grid-winterize/>.

¹⁷ British Petroleum Company. 2020. BP statistical review of world energy. London: British Petroleum Co.

¹⁸ CAISO, "Wind and Solar Curtailment March 21, 2021", [caiso.com](http://www.caiso.com/Documents/Wind_SolarReal-TimeDispatchCurtailmentReportMar21_2021.pdf), accessed 3/22/2021. http://www.caiso.com/Documents/Wind_SolarReal-TimeDispatchCurtailmentReportMar21_2021.pdf

¹⁹ Michael Greenstone et al., *Do Renewable Portfolio Standards Deliver?* (Chicago: Energy Policy Institute at the University of Chicago, 2019); "Renewable Portfolio Standards Reduce Carbon Emissions—But, at a High Cost," Energy Policy Institute at the University of Chicago, April 22, 2019, <https://epic.uchicago.edu/insights/renewable-portfolio-standards-reduce-carbon-emissions-but-at-a-high-cost/>.

²⁰ National Academies of Sciences, Engineering, and Medicine. 2012. *Terrorism and the Electric Power Delivery System*. Washington, DC: The National Academies Press.

National Academies of Sciences, Engineering, and Medicine. 2017. *Enhancing the Resilience of the Nation's Electricity System*. Washington, DC: The National Academies Press.
<https://doi.org/10.17226/24836>

National Academies of Sciences, Engineering, and Medicine. 2021. *The Future of Electric Power in the United States*. Washington, DC: The National Academies Press.

²¹ National Academies of Sciences, Engineering, and Medicine. 2017. *Enhancing the Resilience of the Nation's Electricity System*. Washington, DC: The National Academies Press.
<https://doi.org/10.17226/24836>, p. vi.

²² Giulia McDonnell Nieto del Rio, "Extreme Cold Killed Texans in Their Bedrooms, Vehicles and Backyards," *The New York Times*, February 19, 2021.

²³ CAISO, "Wind and Solar Curtailment March 21, 2021", [caiso.com](http://www.caiso.com), accessed 3/22/2021.
http://www.caiso.com/Documents/Wind_SolarReal-TimeDispatchCurtailmentReportMar21_2021.pdf

²⁴ *In re Erving Industries, Inc.*, 432 B.R. 354 (Bankr. D. Mass. 2010).

²⁵ Severin Borenstein, Meredith Fowlie, and James Sallee, "Designing Electricity Rates for An Equitable Energy Transition", (Berkeley: Energy Institute at Haas, 2021), <https://haas.berkeley.edu/energy-institute/research/abstracts/wp-314/>.