UNITED STATES OF AMERICA
BEFORE THE
UNITED STATES DEPARTMENT OF ENERGY

Codes, Standards, Specifications, and Other Guidance for Enhancing the Resilience of Electric Infrastructure Systems Against Severe Weather Events	))))	84 Fed. Reg. 32730

COMMENTS OF THE SUSTAINABLE FERC PROJECT, NATURAL RESOURCES DEFENSE COUNCIL, AND UNION OF CONCERNED SCIENTISTS

The Sustainable FERC Project, Natural Resources Defense Council, and Union of Concerned Scientists appreciate the opportunity to respond to the Department of Energy's (DOE) Request for Information (RFI) regarding regional standards and practices to increase resilience. First, we explain how many regions, as well as the Federal Energy Regulatory Commission (FERC or Commission), have adopted standards and operating practices that extensively use renewable resources to stabilize power system voltage and frequency, including following grid disturbances. Next, we highlight the important contributions of renewable resources to power system resilience during extreme weather, particularly during recent cold snap events. Finally, as has been known for at least 50 years, we note the critical role of transmission expansion in increasing power system resilience to extreme weather and other unexpected events.

I. Renewable resources increase resilience

As an initial matter, to ensure fairness and economic efficiency, it is important that any standards and policies targeted at resilience are technology neutral and do not discriminate against newer technologies. Given that all generation resources are susceptible to weather-related outages, resilience is best viewed as an attribute of a power system rather than of individual generators. Wind and solar resources have demonstrated that they make the power system more resilient to many types of disturbances. Wind and solar meet or exceed the reliability and resilience services provided by conventional resources,[1] as they are required to offer comparable reliability services while simultaneously offering distinct resilience advantages.

For example, FERC already requires renewable plants to match or exceed conventional power plants on several key resilience elements. FERC Order 827 requires wind and solar plants to provide a comparable level of reactive power service as conventional power plants.[2] Reactive power is a key element of resilience, as it is essential for controlling power system voltage after a grid disturbance. Additionally, FERC Order 842 requires that wind and solar plants, as well as conventional power plants (except for nuclear power plants), have the capability to provide primary frequency response.[3] Frequency response enhances resilience, as it prevents the grid from collapsing when a large conventional generator fails. Further, FERC Order 661-A requires wind plants to be able to ride through voltage and frequency disturbances.[4] FERC Order 661-A demands more for wind plants than the standard for conventional generators; in fact, many conventional generators would be unable to meet FERC Order 661-A if it were applied to them. Ride-through capability improves resilience, as it prevents power system collapse.

Moreover, thanks to their power electronics and advanced control systems, renewable plants can respond more quickly and accurately than conventional plants to stabilize frequency

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[1] Milligan (2018), "Sources of Grid Reliability," The Electricity Journal, Volume 31, Issue 9, November 2018, https://www.sciencedirect.com/science/article/pii/S104061901830215X?via%3Dihub.

[2] FERC (2016), *Reactive Power Requirements for Non-Synchronous Generation*, 155 FERC ¶ 61,277, Docket No. RM16-1-000; Order No. 827, June 16, 2016, https://www.ferc.gov/whats-new/comm-meet/2016/061616/E-1.pdf.

[3] FERC (2018), *Essential Reliability Services and the Evolving Bulk-Power System - Primary Frequency Response*, 162 FERC ¶ 61,128, Docket No. RM16-6-000; Order No. 842, February 15, 2018, https://www.ferc.gov/whats-new/comm-meet/2018/021518/E-2.pdf.

[4] FERC (2005), *Interconnection for Wind Energy,* Docket No. RM05-4-001; Order No. 661-A, December 12, 2005, https://www.ferc.gov/EventCalendar/Files/20051212171744-RM05-4-001.pdf.

and voltage, both of which are key to ensuring grid resilience.[5] Because of this, the Electric Reliability Council of Texas, Inc. (ERCOT) regularly uses its wind plants to stabilize power system frequency and voltage.[6] As noted by the North American Electric Reliability Corporation (NERC), primary frequency response in ERCOT is much better when wind output is high, at least in part because wind plants provide the service faster and more accurately than conventional generators.[7] Additionally, Xcel Energy regularly uses wind to provide frequency regulation, and both Southwest Power Pool, Inc. (SPP) and Midcontinent Independent System Operator, Inc. (MISO) incorporate wind into their markets as a fully dispatchable resource.[8] Further, in assessing the resilience of possible future energy mixes, both PJM Interconnection, L.L.C. (PJM) and ISO New England Inc. (ISO-NE) found that portfolios with large amounts of renewable energy are some of the more resilient to severe weather.[9]

Recent resilience discussions often have included proposals to compensate particular fuel sources regardless of their resilience attributes. There are better ways to reward resilience, including through markets. For example, a market for primary frequency response service could identify which resources across an entire interconnection can most cost-effectively provide the service at any point in time. In the case of reactive power and voltage control, compensation

[5] See, for example, Ela et al. (2014), *Active Power Controls from Wind Power: Bridging the Gaps,* January 2014, https://www.nrel.gov/docs/fy14osti/60574.pdf; Loutan (2017), *Demonstration of Essential Reliability Services by a 300-MW Solar Photovoltaic Power Plant,* March 2017, https://www.nrel.gov/docs/fy17osti/67799.pdf.

[6] Milligan et al. (2015), "Alternatives No More," IEEE Power & Energy Magazine, October 20, 2015, http://iiesi.org/assets/pdfs/ieee-power-energy-mag-2015.pdf.

[7] NERC (2018a), *State of Reliability 2018,* June 2018, p. 139, https://www.nerc.com/pa/RAPA/PA/Performance%20Analysis%20DL/NERC_2018_SOR_06202018_Final.pdf.

[8] Milligan et al. (2015), *supra* note 1.

[9] PJM (2017), *PJM's Evolving Resource Mix and System Reliability,* March 30, 2017, https://www.pjm.com/~/media/library/reports-notices/special-reports/20170330-pjms-evolving-resource-mix-and-system-reliability.ashx; ISO-NE (2018), *Operational Fuel-Security Analysis,* January 17, 2018, https://www.iso-ne.com/static-assets/documents/2018/01/20180117_operational_fuel-security_analysis.pdf.

should not be market-based because the need for the service can be highly localized, which inherently introduces market power concerns if only a small number of resources can provide the service. However, there are methods to compensate for reactive power service based on cost.

II. Renewable resources have performed well during extreme weather

Several recent extreme weather events demonstrate the contributions that renewables make to meeting peak demand, as the high renewable output made up for lower than expected output from fossil generators that experienced equipment failures. For example, during late January 2019, portions of PJM and MISO experienced record cold weather with temperatures as low as -30°F.[10] On January 31, 2019, temperatures forced coal and gas outages totaling approximately 18 GW and 20 GW in PJM and MISO, respectively. Over the course of the event, high wind output in PJM provided needed power to both PJM and MISO, as generators of all types, including some MISO wind plants, experienced temperature-related outages. Figure 1 below shows that during periods of high electricity demand, wind output, as represented by the orange line, was consistently above the level of output that was planned by grid operators, as represented by the gray line.

[10] MISO (2019), *MISO January 30-31 Maximum Generation Event Overview,* February 27, 2019, slide 2, https://cdn.misoenergy.org/20190227%20RSC%20Item%2004%20Jan%2030%2031%20Max%20Gen%20Event322139.pdf; PJM (2019a), *Cold Weather Operations Summary January 2-31, 2019,* February 5, 2019, p. 2, https://www.pjm.com/-/media/committees-groups/committees/oc/20190205/20190205-oc-cold-weather-ops-january-28-31-info-only.ashx.

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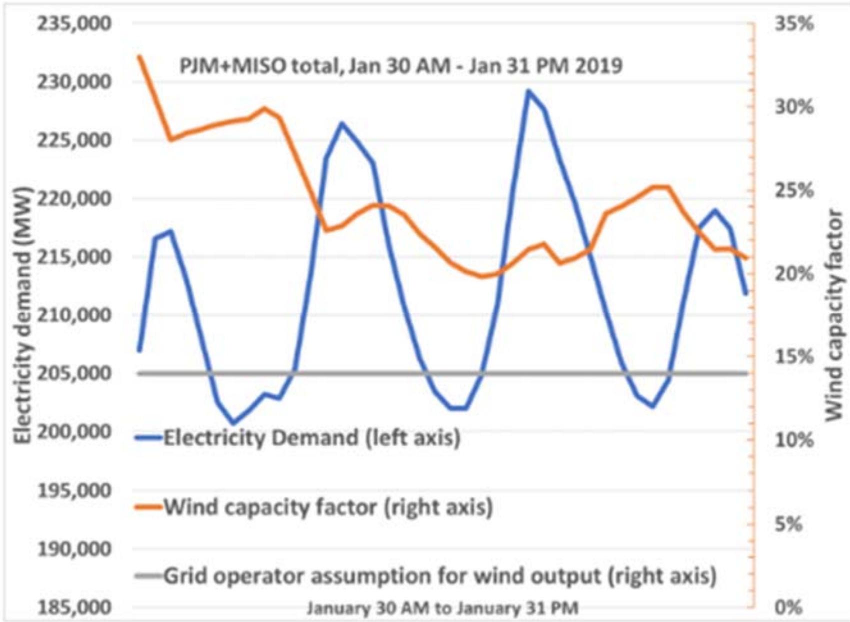
Figure 1: Wind Output in PJM and MISO during January 2019 Cold Snap[11]



Additionally, during the "Bomb Cyclone" cold snap in early January 2018, wind output was consistently high across PJM and the northeast. Despite temperatures dropping as low as -8.4°F on two separate occasions between January 1 and January 7, 2018,[12] PJM wind output was an estimated 55% higher than average wind output in 2017.[13] As shown in Figure 2 below, even during the highest periods of demand, wind output was three to five times higher than levels planned for and compensated for by PJM. Additionally, during its most challenging time periods, ISO-NE saw wind output levels that were twice the average.[14]

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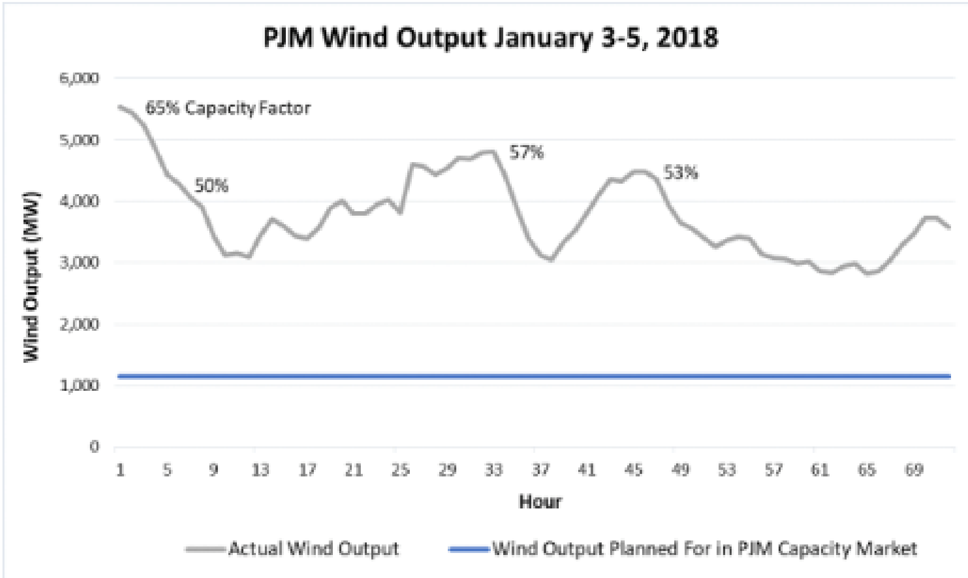
[11] Goggin (2019), "How Transmission Helped Keep the Lights on During the Polar Vortex," February 14, 2019, https://www.aweablog.org/transmission-helped-keep-lights-polar-vortex/.

[12] PJM (2018a), *PJM Cold Snap Performance Dec. 28, 2017 to Jan. 7, 2018,* February 26, 2018, p. 3, https://www.pjm.com/-/media/library/reports-notices/weather-related/20180226-january-2018-cold-weather-event-report.ashx.

[13] Hunt (2018), "How Did Wind Energy Perform During the Bomb Cyclone?," March 30, 2018, https://www.aweablog.org/wind-energy-perform-bomb-cyclone/.

[14] *Id.*

Figure 2: Wind Output in PJM During 2018 Bomb Cyclone[15]



Wind plants in PJM also played an important role in keeping the lights on during the Polar Vortex event in 2014. On January 6 and 7, 2014, when around 22% of PJM's generation fleet was unavailable mainly due to fossil generator forced outages,[16] wind output significantly exceeded the capacity value counted on by PJM. As shown in Figure 3 below, economic analysis indicates that wind saved PJM consumers over $1 billion over those two days by reducing electricity price spikes.[17]

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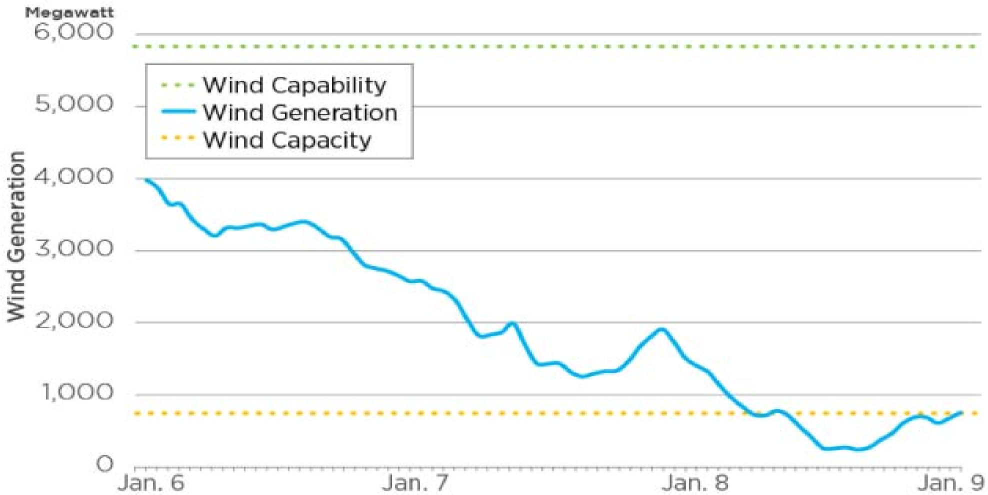
[15] *Id.*

[16] PJM (2014), *Analysis of Operational Events and Market Impacts During the January 2014 Cold Weather Events*, May 8, 2014, p. 4, https://www.pjm.com/~/media/library/reports-notices/weather-related/20140509-analysis-of-operational-events-and-market-impacts-during-the-jan-2014-cold-weather-events.ashx.

[17] Hresko and Goggin (2015), *Wind Energy Saves Consumers Money During the Polar Vortex*, January 2015, p. 2, https://www.awea.org/Awea/media/Resources/Publications%20and%20Reports/White%20Papers/AWEA-Cold-Snap-Report-Final-January-2015.pdf.

Figure 3: Polar Vortex Wind Generation in PJM[18]



Additionally, in ERCOT in February 2011, over 8,000 MW of generation unexpectedly went offline (of which 99% was fossil capacity and only 1% wind capacity), causing rolling blackouts.[19] Wind energy provided upwards of 3,500 MW of wind generation during the morning load peak during the cold event, and the President and CEO of ERCOT offered a special thanks to the wind community for their contribution.[20] In all four events, many coal and gas generators failed, largely due to equipment freezing in the cold.

Renewables also have performed well during other extreme weather events like hurricanes, high temperatures, and droughts. Texas wind plants, for example, generally performed well above their expected capacity values during Hurricane Harvey in 2018, while some coal and gas generators were taken offline or de-rated due to wet or flooded coal piles and

[18] PJM (2014), p. 22, *supra* note 16.

[19] Doggett (2011), ERCOT, *Review of February 2, 2011 Energy Emergency Alert (EEA) Event,* February 14, 2011, slides 11 & 29, http://www.ercot.com/content/meetings/board/keydocs/2011/0214/Review_of_February_2,_2011_EEA_Event.pdf.

[20] Galbraith (2011), "Trip Doggett: The TT Interview," February 4, 2011, https://www.texastribune.org/2011/02/04/an-interview-with-the-ceo-of-the-texas-grid/.

low gas system pressure.[21] High temperatures and droughts can also force fossil and nuclear plants to reduce their output due to water shortages or high cooling water temperatures, while the output of many thermal plants is reduced at high ambient air temperatures.[22]

III. **Transmission investment increases resilience**

The electricity transmission and distribution systems, rather than the generation system, should be the primary focus of efforts to improve electric reliability and resilience. DOE data confirm that the vast majority of customer outages result from failures on the transmission and distribution systems, while very few are caused by generation shortfalls or fuel supply issues. As highlighted by Rhodium Group (Rhodium), generation inadequacy accounts for less than 1/10,000th of all customer-hours of outages, with fuel supply emergencies equaling an even smaller share at fewer than 1 in 1.4 million.[23] Similarly, a Public Utilities Fortnightly analysis found that "distribution system outages appear to impose roughly two orders of magnitude more minutes of outage on customers than does resource adequacy … 146 compared to 1.2 minutes a year."[24] That analysis further states that this is likely an overestimate of outages caused by generation shortfalls, as balancing authorities typically can resort to steps such as leaning on neighboring power systems or reducing system voltage in the event of a generation shortfall and avoid resorting to customer outages.

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[21] NERC (2018b), *Hurricane Harvey Event Analysis Report,* March 2018, p. 16, https://www.nerc.com/pa/rrm/ea/Hurricane_Harvey_EAR_DL/NERC_Hurricane_Harvey_EAR_20180309.pdf.

[22] Climate Central (2012), "Heat and Drought Pose Risks for Nuclear Power Plants," July 18, 2012, https://www.climatecentral.org/blogs/heat-and-drought-pose-risks-for-nuclear-power-plants.

[23] Houser, Larsen, and Marsters (2017a), "The Real Electricity Reliability Crisis," October 3, 2017, https://rhg.com/research/the-real-electricity-reliability-crisis-doe-nopr/.

[24] Wilson (2010), "Reconsidering Resource Adequacy, Part 1," Public Utilities Fortnightly, April 2010, https://www.fortnightly.com/fortnightly/2010/04/reconsidering-resource-adequacy-part-1.

Using another U.S. Energy Information Administration (EIA) dataset, Rhodium also found that between 2012 and 2016, only 8.6% of outage minutes were due to "loss of electricity supply" to the distribution utility; this includes those caused by transmission failures, generation failures, fuel emergencies, generation shortfalls, and weather impacts to transmission and generation assets, while the other 91.4% of outage minutes were due to events affecting the distribution system.[25]

Further, as documented in a recent report, of the 27 U.S. blackouts that have caused outages to more than 1 million customers since 2002, only four were due to non-weather problems – three started on the transmission system (the 2003 Northeast Blackout, the 2008 Turkey Point Blackout, and the 2011 Southwest Blackout) and one from a power plant fire (Puerto Rico 2016).[26] Only the ERCOT 2011 rolling blackouts were related to a generation shortfall (mostly due to inadequate equipment weatherization for extremely cold weather).[27] Due to their larger size and geographic diversity, the Eastern and Western Interconnections (which are subject to FERC jurisdiction) tend to be more resistant to generation shortfalls than ERCOT. Taken together, these data indicate that over 90% of customer outage minutes are

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[25] Houser, Larsen, and Marsters (2017b), "Electric System Reliability: No Clear Link to Coal and Nuclear," October 23, 2017, available at https://rhg.com/research/electric-system-reliability-no-clear-link-to-coal-and-nuclear/.

[26] Silverstein, Gramlich, and Goggin (2018), *A Customer-Focused Framework for Electric System Resilience,* May 2018, p. 74, https://gridprogress.files.wordpress.com/2018/05/customer-focused-resilience-final-050118.pdf.

[27] As described in the FERC-NERC investigation report, a five-day stretch of extremely cold weather caused the loss (outage, de-rate, or failure to start) of 210 individual generating units within ERCOT, leading to controlled load-shedding of 4,000 MW affecting 3.2 million customers. Local transmission constraints and loss of local generation caused load shedding for another 180,000 customers in South Texas. Outside ERCOT, El Paso Electric lost 646 MW of local generation, and two Arizona utilities lost 1,050 MW of generation. Some of these losses were due to frozen generation equipment and others were due to the loss of gas supply due in part to frozen pipeline equipment. See FERC and NERC (2011), *Outages and Curtailments During the Southwest Cold Weather Event of February 1-5, 2011,* August 2011, https://www.ferc.gov/legal/staff-reports/08-16-11-report.pdf.

caused by distribution system failures, while the vast majority of the remainder are caused by transmission system failures.

A. RTOs agree that the focus should be on transmission, not generation

In their comments in FERC's resilience docket last year,[28] the regional transmission organizations and independent system operators (collectively, RTOs) unanimously and strongly agreed that transmission should be a primary focus of any efforts to increase resilience. For example, MISO highlighted "Transmission Planning" and "Inter-regional Operations" as two of the three areas FERC should focus for improving resilience (the other being "Information Technology Tools"). As MISO explained, "[c]ontinued industry dialogue on more effectively identifying, valuing, and incorporating resilience attributes in transmission planning processes will help the Commission identify further opportunities to support and advance grid resilience."[29]

Similarly, PJM argued that "resilience efforts will require changes to transmission and infrastructure planning," explaining that "the Commission could provide assistance to RTOs by requiring them to plan for and address resilience, and confirm that resilience is a component of regional transmission system planning," and that "[r]obust long-term planning, including developing and incorporating resilience criteria into the [Regional Transmission Expansion Plan], can also help to protect the transmission system from threats to resilience."[30]

New York Independent System Operator, Inc. (NYISO) explained that the Commission "must also recognize the critical importance of maintaining and enhancing grid interconnections. These interconnections support and bolster reliability and resilience by creating a larger and

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[28] FERC Docket No. AD18-7-000.

[29] MISO (2018), *Responses of the Midcontinent Independent System Operator, Inc.*, Docket No. AD18-7-000, March 9, 2018, p. 2, https://elibrary.ferc.gov/IDMWS/common/opennat.asp?fileID=14837872.

[30] PJM (2018b), *Comments and Responses of PJM Interconnection, L.L.C.*, Docket No. AD18-7-000, March 9, 2018, pp. 11, 69, & 50, https://elibrary.ferc.gov/IDMWS/common/opennat.asp?fileID=14838232.

more diverse resource pool available to meet needs and address unexpected and/or disruptive events throughout an interconnected region."[31] NYISO provided a detailed explanation of how "[t]he resiliency value of an interconnected grid has been clearly demonstrated during recent periods of system stress," and explained that "[m]aintaining and protecting existing interconnections between neighboring regions and continually assessing opportunities to improve inter-regional transaction coordination can bolster the resiliency of the grid throughout an interconnected region. These interconnections foster the opportunity for the Northeast and Mid-Atlantic markets to rely on a broader, more diverse set of resources to meet the overall needs of the region."[32]

ISO-NE discussed the consumer savings and resilience benefits of its recent transmission investments, noting that "[a]s a result of these investments, the region has a robust transmission system that has the ability to operate reliably under myriad operating conditions."[33] SPP also noted how "[t]his additional transmission has enabled resources of all fuel types to help meet customer demand during a range of potential threats to reliability and resilience," and that "[t]he construction of new transmission facilities pursuant to modern design standards enhance the robustness of the system."[34] The California Independent System Operator Corporation (CAISO)

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[31] NYISO (2018), *Response of the New York Independent System Operator, Inc.,* Docket No. AD18-7-000, March 9, 2018, pp. 10-12, https://elibrary.ferc.gov/IDMWS/common/opennat.asp?fileID=14838205.

[32] *Id.* at pp. 11-12.

[33] ISO-NE (2018), *Response of ISO New England Inc.,* Docket No. AD18-7-000, March 9, 2018, p. 15, https://elibrary.ferc.gov/IDMWS/common/opennat.asp?fileID=14837909.

[34] SPP (2018), *Comments of Southwest Power Pool, Inc. on Grid Resilience Issues,* Docket No. AD18-7-000, March 9, 2018, pp. 3 & 5, https://elibrary.ferc.gov/IDMWS/common/opennat.asp?fileID=14838087.

further explained that a key function of its transmission planning process is "maintaining reliability through a resilient electric system."[35]

Finally, in their comments, ERCOT and the Public Utility Council of Texas (PUCT) explained that "[o]ne of the most critical elements of system resilience is ensuring that the transmission system is planned in such a way as to ensure continued operations following an unexpected outage of one or more generators or transmission elements."[36]

Additionally, in the predecessor to the resilience docket,[37] NERC explained the central role of transmission for reliability and resilience and the importance of improved transmission planning methods, noting repeatedly that "[t]he right combination and amount of resources and transmission together maintain adequacy of the system."[38]

B. Transmission can greatly improve reliability and resilience

It is widely understood that a more robust transmission system improves electric reliability and resilience, though most transmission planning studies do not quantify that benefit. It is intuitive that a stronger transmission system with more network paths to deliver power will be more reliable. Just as most commuters have a backup route in case their primary road to work is blocked by a traffic accident, grid operators are required to have at least one backup path to get

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[35] CAISO (2018), *Comments of the California Independent System Operator Corporation in Response to the Commission's Request for Comments About System Resiliency and Threats to Resilience,* Docket No. AD18-7-000, March 9, 2018, p. 148, https://elibrary.ferc.gov/IDMWS/common/opennat.asp?fileID=14838234.

[36] ERCOT and PUCT (2018), *Joint Comments of the Electric Reliability Council of Texas, Inc. and the Public Utility Commission of Texas,* Docket No. AD18-7-000, March 9, 2018, p. 7, https://elibrary.ferc.gov/IDMWS/common/opennat.asp?fileID=14837920.

[37] FERC Docket No. RM18-1-000.

[38] NERC (2017), *Comments of the North American Electric Reliability Corporation in Response to Notice of Proposed Rulemaking,* Docket No. RM18-1-000, October 23, 2017, p. 2, https://www.nerc.com/FilingsOrders/us/NERC%20Filings%20to%20FERC%20DL/Comments%20of%20NERC%20re%20Proposed%20Grid%20Reliability%20and%20Resilience%20Pricing.pdf.

electricity to homes, businesses, and hospitals. However, having multiple backup paths becomes particularly valuable when a disaster takes out multiple power lines simultaneously.

As utilities Xcel and ITC explained in a recent application to build a new transmission line in Minnesota, "the Project will improve the robustness of the regional backbone transmission system by improving the efficient delivery of energy and enabling the system to better withstand contingencies under multiple future scenarios. A robust transmission system is better positioned to deal with unplanned system outages."[39]

Analysis confirms that investing in transmission expansion improves electric reliability and resilience. Kansas utility Westar has reported that transmission expansion has been associated with a 40% reduction in transmission-related customer outages.[40] Additionally, a London Economics analysis evaluated the value of transmission for making the power system more resilient to extreme events. It found that "[o]ver a single year period, under constrained system operating conditions, electric consumers are projected to save as much as $1.3 billion in PJM and $740 million in MISO with the 1,300 MW Eastern Interconnect project. This is equal to savings of about $20 (in MISO) to $40 (PJM) on a typical household's annual electricity utility bill in the affected regions."[41] The project in the Western U.S. was estimated to save over $100 million per year by making the power system more resilient. The study found additional economic savings of $500 million annually in each of MISO, PJM, and the Western U.S., for

[39] Northern States Power Company and ITC Midwest LLC (2018), *Application to the Minnesota Public Utilities Commission for a Certificate of Need for the Huntley-Wilmarth 345 KV Transmission Line Project,* MPUC Docket No. E-002, ET6675/CN-17-184, January 17, 2018, p. 8, https://www.huntleywilmarth.com/staticfiles/microsites/hw/HW-Certificate-of-Need-Application.pdf.

[40] SPP (2016), *The Value of Transmission,* January 26, 2016, p. 15, https://www.spp.org/documents/35297/the%20value%20of%20transmission%20report.pdf.

[41] Frayer et al. (2018), *How Does Electric Transmission Benefit You? Identifying and Measuring the Life-Cycle Benefits of Infrastructure Investment,* January 8, 2018, p. 40, http://www.wiresgroup.com/docs/reports/WIRES_LEI_TransmissionBenefits_Jan2018.pdf.

total annual savings of $1.5 billion, from the two transmission projects reducing occurrences of widespread blackouts and regional power outages.

Researchers also have modeled theoretical power systems and demonstrated that strengthening the grid by adding network paths significantly increases the system's resilience to damage and prevents power outages.[42] That study also found power flow control devices are highly effective at preventing outages. Similar modeling of the United Kingdom's power system has demonstrated that investing in stronger transmission infrastructure, as well as additional backup paths for power, significantly reduces the risk of power outages due to windstorms.[43] If anything, that study likely understates the value of additional backup transmission paths because it only looks at wind storm events. With a wind storm, there is a very high correlation between the failure of the first circuit and backup circuits because the storm affects a large area. With other events that account for most transmission line outages (equipment failure, human error, wildfire, lightning strike, tower collapse, tree damage, tornado), there would be a much lower correlation for the loss of the two circuits, making additional backup paths much more valuable.

By enabling the delivery of electricity from other regions, transmission plays a particularly important role in keeping electricity reliable and affordable when unexpected events, such as extreme weather, affect part of the system. Weather and other extreme events tend to be geographically limited in scope so one region is almost never experiencing an extreme supply shortfall at the same time as all neighboring regions.

[42] Nagarajan et al. (2016), "Optimal Resilient Transmission Grid Design," 2016 Power Systems Computation Conference (PSCC), June 20-24 2016, http://public.lanl.gov/rbent/pscc_resilience.pdf.

[43] Panteli et al. (2017), " Power System Resilience to Extreme Weather: Fragility Modeling, Probabilistic Impact Assessment, and Adaptation Measures," IEEE Transactions on Power Systems, Vol. 32, No. 5, September 2017, https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7801854.

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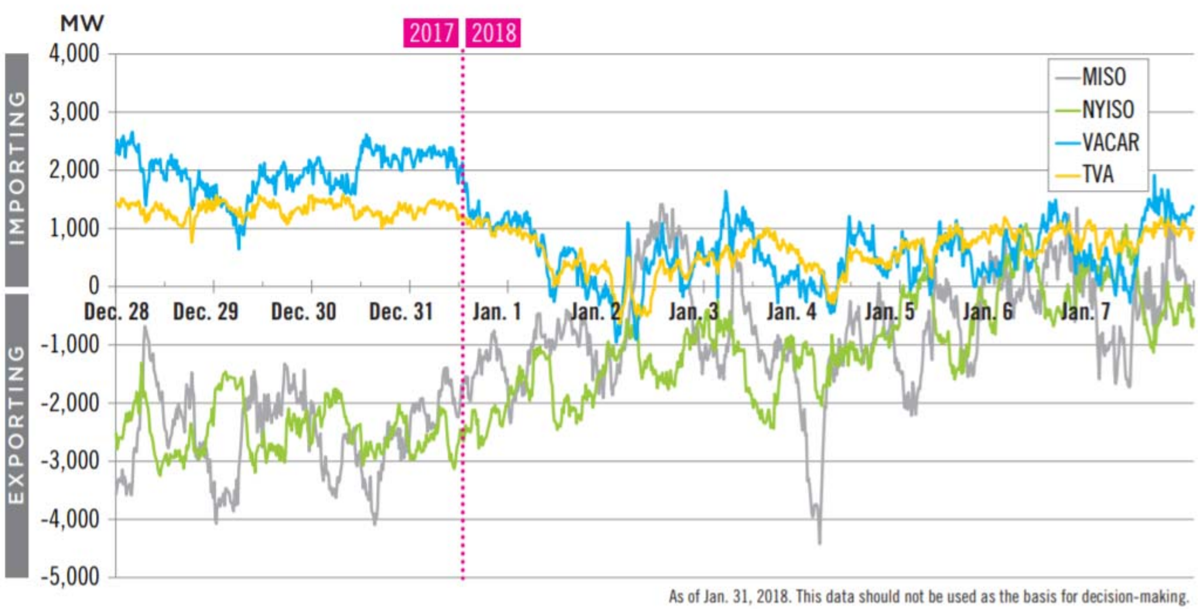
For example, during the Bomb Cyclone event in early January 2018, temperatures were far more extreme in eastern PJM than in western PJM, causing wholesale electricity prices in eastern PJM to be about three times higher than in western PJM. Specifically, power prices in Virginia averaged about $222/MWh versus $76/MWh in Northern Illinois. Largely as a result, PJM congestion costs in the first half of 2018 tripled to nearly $900 million relative to a year earlier. Greater west-to-east transmission capacity in PJM, and an ability to import more power from MISO, would have saved PJM consumers hundreds of millions of additional dollars during the Bomb Cyclone event alone.

Figure 4: PJM imports and exports during Bomb Cyclone[44]



In Figure 4 above, PJM documented how its transmission ties with its neighbors were heavily utilized during the Bomb Cyclone.[45] On January 1-7, 2018, PJM was able to export power to its southern neighbors VACAR (Virginia-Carolina) and TVA (Tennessee Valley

[44] PJM (2018a), p. 9, *supra* note 12.

[45] PJM (2019b), *The Benefits of the PJM Transmission System,* April 16, 2019, p. 37, https://pjm.com/-/media/library/reports-notices/special-reports/2019/the-benefits-of-the-pjm-transmission-system.ashx?la=en.

Authority) as they dealt with record cold, while PJM saw large swings in transfers with MISO and NYISO as those regions experienced high demand at different times.

Similarly, in 2019, a polar vortex-related cold snap caused extreme electricity demand and power plant failures in northern MISO. MISO was able to import nearly 12,000 MW over its transmission ties with neighboring power systems. Over half of those imports came from PJM, which was experiencing near-record wind output. The next extreme event might more strongly affect western PJM, causing greater demand and price spikes and generator unavailability there; over time transmission expansion will ultimately benefit all.

The reliability cost of an inadequate transmission system also can be quite high. The 2003 blackout in the northeast U.S. and Canada, which largely resulted from a congested transmission system and inadequate transmission maintenance, caused an estimated $7-10 billion in economic losses. A congested transmission system with poor coordination in transmission system planning and operations was also a contributing factor to the 2011 blackout that affected parts of southern California and Arizona.[46] The costs to consumers and the economy from these transmission-related outages are a significant share of America's total annual spending on transmission, indicating that additional spending to increase transmission system resilience – in addition to transmission's other benefits – would be worthwhile.[47]

The reliability benefits of a more interconnected power system have been apparent for over 50 years. The official report to President Johnson regarding the large-scale 1965 Northeast blackout concluded that "[i]solated systems are not well adapted to modern needs either for

[46] FERC and NERC (2012), *Arizona-Southern California Outages on September 8, 2011,* April 2012, https://www.ferc.gov/legal/staff-reports/04-27-2012-ferc-nerc-report.pdf.

[47] EEI (2018), "Historical and Projected Transmission Investment," October 2018, http://www.eei.org/issuesandpolicy/transmission/Documents/bar_Transmission_Investment.pdf.

purposes of economy or service" and recommended "an acceleration of the present trend toward stronger transmission networks within each system and stronger interconnections between systems in order to achieve more reliable service at the lowest possible cost."[48]

Another reliability concern is that much of America's transmission infrastructure, including transmission lines, towers, transformers, and other substation equipment, is reaching the end of its useful life. Like most infrastructure, this equipment will likely see a higher outage and failure rate as it nears the end of its life, putting reliability at risk. In part due to its obsolescence, the American Society of Civil Engineers recently gave America's power grid infrastructure a "D+."[49]

Grid operators confirm that their transmission infrastructure is reaching the end of its life and must be replaced.[50] PJM recently noted that "[t]wo-thirds of all system assets in PJM are more than 40 years old; over one-third are more than 50 years old. Some local, lower-voltage transmission facilities, especially below 230 kV, are approaching 90 years old."[51] Nationally, most of our transmission infrastructure was built between 1960 and 1980; according to one estimate, just replacing that infrastructure alone will cost around $8-14 billion per year over the next 25 years.[52] A similar estimate states that the grid will need $57 billion in investment over

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[48] Federal Power Commission (1965), "Report to the President on the Power Failure in the Northeastern United States and the Province of Ontario on November 9-10, 1965," December 6, 1965. p. 43, http://blackout.gmu.edu/archive/pdf/fpc_65.pdf.

[49] American Society of Civil Engineers (2017), *Infrastructure Report Card,* 2017, http://www.infrastructurereportcard.org/cat-item/energy/.

[50] NYISO (2016), *Power Trends 2016 The Changing Energy Landscape,* 2016, p. 2, https://www.nyiso.com/documents/20142/2223020/2016-Power-Trends.pdf/1bec79c7-ffda-1476-1aaf-1bf27ef8b67b.

[51] PJM (2019b), p. 5, *supra* note 44.

[52] Pfeifenberger, Chang, and Tsoukalis (2015), *Investment Trends and Fundamentals in US Transmission and Electricity Infrastructure,* July 17, 2015, slides 6-7, https://brattlefiles.blob.core.windows.net/system/publications/pdfs/000/005/190/original/investment_trends_and_fundamentals_in_us_transmission_and_electricity_infrastructure.pdf?1437147799.

the next five years alone.[53] And any investment must not only remedy current shortfalls, but also account for future transmission needs to maximize benefits.

Higher-voltage transmission lines tend to experience fewer outages, suggesting that investment in these higher-capacity lines will improve system reliability. Higher-voltage lines tend to have multiple circuits and multiple AC power phases, which protects against the loss of a single phase or circuit. As American Electric Power explains, "765 kV [kilovolt] circuits experience, on average, 1.0 forced outages per 100 mile-years. A comparable statistic for 500 kV is 1.4 forced outages per 100 mile-years. While single-phase faults are the dominant type of failures for both voltage classes, no multi-phase faults have been recorded at 765 kV in normal operation, short of tower failure."[54] NERC data confirm that higher-voltage transmission lines and infrastructure have a lower outage rate than lower-voltage lines.[55]

As outlined in Figure 5 below, recent analysis identifies transmission improvements as some of the lowest-hanging fruit for improving system resilience.[56] A stronger transmission system provides other benefits that increase reliability and resilience and keep electricity costs low for consumers. Transmission allows the grid to operate equally reliably with fewer power plants, by allowing the sharing of planning and operating reserves across the power system and with neighboring power systems. Grid operators keep power plant capacity in reserve to ensure there is sufficient power supply to handle fluctuations in electricity supply and demand over the

[53] Freedman et al. (2017), *Maximizing the Job Creation Impact of $1 Trillion in Infrastructure Investment,* March 2017, http://www.cg-la.com//documents/Maximizing-the-Job-Creation-Impact-of-%241-Trillion-in-Infrastructure-Investment.pdf.

[54] AEP (2006), *AEP Interstate Project: I-765,* April 6, 2006, p. 2, https://www.aep.com/newsroom/resources/docs/AEP_Interstate_Project-Technologies.pdf.

[55] NERC (2018), "Dashboard Data Detail-TADS," August 8, 2018, https://www.nerc.com/pa/RAPA/tads/Key_TADS_Documents/TADS%20Dashboard%20RAW%20Data.xlsx.

[56] Silverstein, Gramlich, and Goggin (2018), p. 63, *supra* note 26.

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course of a day (operating reserves) and from year-to-year (planning reserves). On large power systems and over larger geographic areas, those fluctuations in supply and demand tend to cancel each other out, allowing grid operators to keep a smaller share of plants in reserve. The geographic diversity benefit is particularly large for inter-regional transmission and as renewable resources provide an increasing share of generation, due to the diversity in weather and climate across large areas.

Figure 5: High and Low Value Resilience Investments[57]

	High Value		Low Value
Grid operator, reliability coordinator	Interconnection rules Schedule coordination Fuel coordination Emergency planning and drills System & asset models Situational awareness		Generation capacity payments
T&D, Genco Capital	Distribution pole hardening Additional transmission paths and loops Back-up communications Transmission automation Distribution automation	T&D undergrounding Generator weatherization	Coal & nuclear subsidies
T&D, Genco O&M	Tree trimming Cyber security & secure communications networks Physical security Mutual assistance Strategic spare equipment & mobile substations Situational awareness, system monitoring, PMUs Emergency planning and drills Outage management system		Fuel supply guarantees
Customer	Distributed generation, back-up generators Emergency supplies More efficient building shells Community critical infrastructure hardening	Insurance Distributed storage	

SPP found $1.354 billion in net present value benefits, around 8% of the total benefits of its transmission upgrades, were due to transmission enabling a 2% reduction in the need for planning reserves.[58] The aggregation of power plants into MISO and PJM, enabled by existing

[57] *Id.* at p. 6.

[58] SPP (2016), p. 16, *supra* note 40.

transmission, respectively saves $2.2 billion to $2.7 billion and $1.2 billion to $1.8 billion annually on planning reserves.[59] An Xcel Colorado analysis found that 200 MW of transmission ties with neighboring balancing authorities enabled a reserve margin reduction from 19.2% to 16.3% while meeting the same loss of load probability standard.[60]

IV. Transmission infrastructure makes the power system resilient to uncertainty

As utilities and grid operators confront growing uncertainty due to an increased reliance on volatilely-priced fuels, uncertain policy changes, rapid technology improvements, and large changes in the generation mix, transmission provides valuable flexibility to respond to unexpected changes.

Transmission is an important mechanism to protect consumers against the inherent but unpredictable volatility in the price of fuels used to produce electricity. Transmission can alleviate the negative impact of fuel price fluctuations on consumers by making it possible to buy power from other generators and regions and move it efficiently on the grid. This increased flexibility helps to modulate swings in fuel price, as it makes demand for fuels more responsive to price as utilities can respond to price signals by decreasing use of an expensive fuel and instead importing cheaper power produced from other sources.

A Johns Hopkins University study highlighted the large optionality value of transmission and found that standard deterministic transmission planning greatly underestimates the value of transmission. Specifically, the study argued that current transmission planning methods, which at best use several deterministic scenarios to highlight ranges of future outcomes for the power

[59] MISO (2019), "Value Proposition," https://www.misoenergy.org/about/miso-strategy-and-value-proposition/miso-value-proposition/; PJM (2019c), "PJM Value Proposition," 2019, p. 1, https://www.pjm.com/about-pjm/~/media/about-pjm/pjm-value-proposition.ashx.

[60] Xcel Energy (2016), *2016 Electric Resource Plan Volume 2,* CPUC Proceeding No. 16A-0396E, May 27, 2016, p. 391, https://www.xcelenergy.com/staticfiles/xe/PDF/Attachment%20AKJ-2.pdf.

system, are "a weak tool for decisions under uncertainty" and "don't account for flexibility."[61] Probabilistic methods that quantitatively account for uncertainty in the transmission planning process result in a larger and more optimal transmission build, saving consumers tens of billions of dollars relative to deterministic methods that fail to account for the value of transmission in providing flexibility. Moreover, the probabilistic method saved hundreds of billions of dollars relative to some deterministic planning methods that greatly underbuilt transmission.[62]

Focusing on the transmission system also would have other benefits, such as ensuring rates are just and reasonable by promoting market competition. As the Commission explained in FERC Order 890, some power plant owners "can have a disincentive to remedy transmission congestion when doing so reduces the value of their generation or otherwise stimulates new entry or greater competition in their area. For example, a transmission provider does not have an incentive to relieve local congestion that restricts the output of a competing merchant generator if doing so will make the transmission provider's own generation less competitive."[63] A large body of studies have confirmed that investments in transmission more than pay for themselves by promoting competition and providing consumers with access to lower-cost energy.[64]

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[61] Muñoz, Watson, and Hobbs (2015), "Optimizing Your Options: Extracting the Full Economic Value of Transmission When Planning Under Uncertainty," The Electricity Journal, Volume 28, Issue 5, June 2016, pp. 26-38, https://www.sciencedirect.com/science/article/pii/S1040619015001025; Hobbs et al. (2013), *Assessing Transmission Investments Under Uncertainty,* August 6-7, 2013, slide 31, http://energy.gov/sites/prod/files/2013/09/f2/1-2013RMReview-Hobbs.pdf.

[62] Espinoza (2014), *Engineering-Economic Methods for Power Transmission Planning Under Uncertainty and Renewable Resource Policies,* January 2014, p. 102, http://hobbsgroup.johnshopkins.edu/docs/FD_Munoz_Dissertation.pdf.

[63] FERC (2007), *Preventing Undue Discrimination and Preference in Transmission Service,* 118 FERC ¶ 61,119, Docket Nos. RM05-17-000 and RM05-25-000; Order No. 890, February 16, 2007, http://www.nerc.com/files/order_890.pdf.

[64] For example, see SPP (2016), *supra* note 40; MISO (2017), *A 2017 Review of the Public Policy, Economic, and Qualitative Benefits of the Multi-Value Project Portfolio,* September 2017,https://cdn.misoenergy.org/MTEP17%20MVP%20Triennial%20Review%20Report117065.pdf; Chang et al. (2013), *Recommendations for Enhancing ERCOT's Long-Term Transmission Planning Process,* October 2013,

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V. Conclusion

We appreciate the opportunity to provide these comments regarding effective approaches to resilience. We hope that as DOE considers opportunities to increase power system resilience, it focuses its efforts on the use of new technologies and transmission expansion.

Respectfully submitted this 23rd day of August, 2019,

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