TRANSMISSION CONGESTION COSTS IN THE U.S. RTOS

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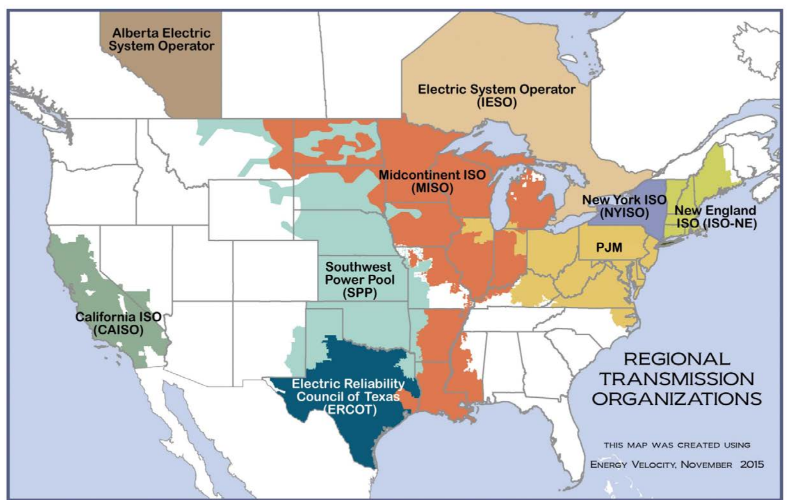
Congestion costs are incurred on the U.S. electric transmission grid when there is inadequate capacity to deliver the lowest-cost generation to load (consumers). Higher cost generation is dispatched instead, raising prices. Various financial products exist to manage congestion and the associated risk, but the cost of congestion is ultimately paid by the electricity customers.

Congestion costs rise sharply in 2021

Yearly internal market congestion costs doubled from 2020 to 2021 across the Regional Transmission Organizations/Independent System Operators (RTOs/ISOs) that serve around 58% of U.S. electricity load[1]. Costs in RTO regions, apart from CAISO, were about $7.7 billion. Extrapolated to the rest of the U.S., including CAISO, congestion costs totalled around $13.4 billion.

Of the seven operators of wholesale electricity markets in the country, all except California Independent System Operator (CAISO) publicly post congestion data. All analysis not directly cited is based on the market monitor reports, linked in the appendix.

FIGURE 1. *FERC — RTO/ISO Regions*



As shown in Table 1, total reported congestion costs increased year-over-year by approximately 5% from 2019 to 2020, and by about 100% from 2020 to 2021. Reduced electricity demand in business and industry as a result of the COVID-19 pandemic, only partially offset by increased residential demand, contributed to lower congestion costs throughout 2020. This trend reversed from 2020 to 2021, and many other factors contributed to unprecedented congestion costs.

1 Peak loads for U.S. RTO/ISOs in 2021 (GW): ERCOT–74.3, ISO-NE–26, MISO-120, NYISO–31.3, PJM–187, SPP–51; peak load for the entire U.S.: 844 GW.

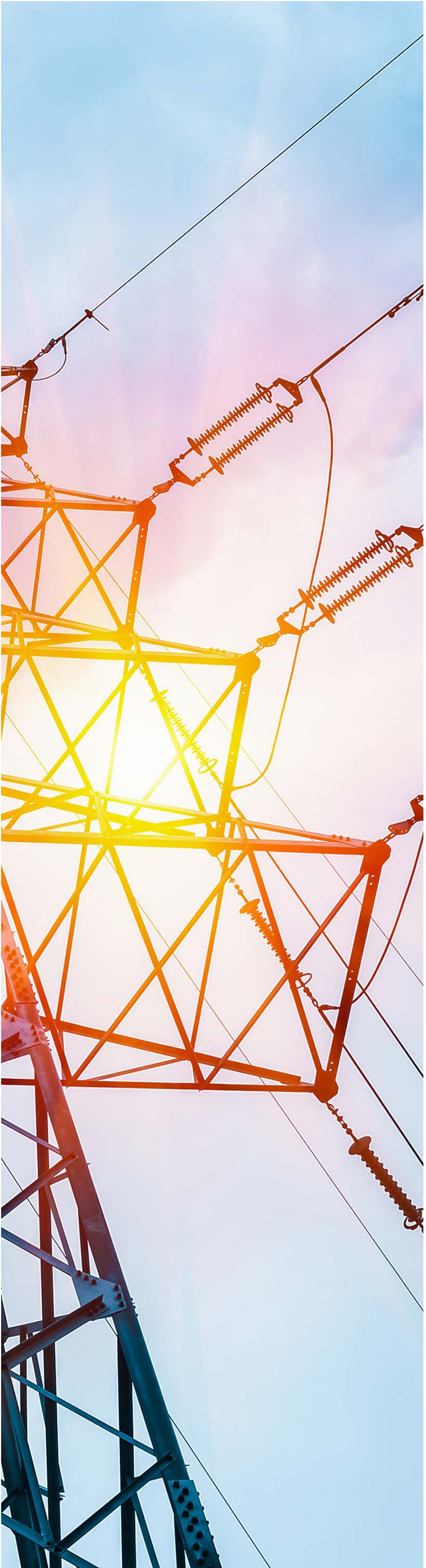


TABLE 1. *Total Transmission Congestion Costs ($ millions) for RTOs from 2016–2021*

RTO	2016	2017	2018	2019	2020	2021
ERCOT	497	976	1,260	1,260	1,400	2,100
ISO-NE	39	41	65	33	29	50
MISO	1,402	1,518	1,409	934	1,181	2,849
NYISO[2]	529	481	596	433	297	551
PJM	1,024	698	1,310	583	529	995
SPP	280	500	450	457	442	1,200
TOTAL	3,771	4,214	5,090	3,700	3,878	7,745

Non-RTO regions do not have transparent congestion data, but it can be assumed that congestion outside of these transparent markets is similar to congestion within them. The price transparency and generally more favorable transmission expansion policies in the RTO regions tend to reduce congestion in those areas relative to non-RTO regions. However, RTO regions have experienced more renewable deployment in recent years than non-RTO areas, which may somewhat offset those factors as renewable expansion tends to increase transmission congestion when it outpaces transmission expansion. Scaling the annual congestion costs totals from Table 1 approximates the nation-wide values shown below:

TABLE 2. *Estimated Congestion Costs Nationwide[3] ($ millions)*

2016	$6,501
2017	$7,266
2018	$8,776
2019	$6,379
2020	$6,686
2021	$13,353

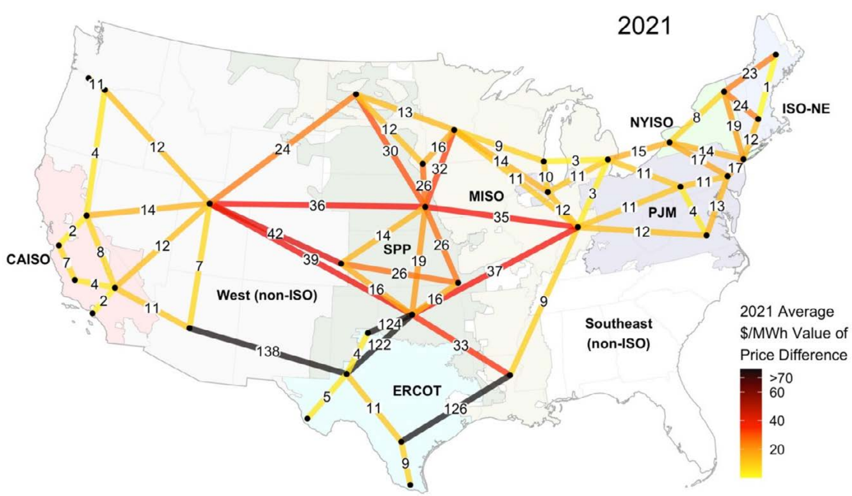
2 NYISO does not report both real-time and day-ahead congestion values in their market monitor report. These numbers are based on day-ahead market congestion.

3 This includes CAISO, who does not publicly release transmission congestion cost data.

The best way to reduce transmission congestion is to increase transmission capacity. One forward-looking PJM analysis finds that transmission enhancements approved between 2014 and 2023 will reduce costs to customers by over $280 million annually by alleviating congestion, in addition to the estimated congestion savings of approximately $100 million from the first four years of operation of five interregional projects. MISO has also estimated that the transmission upgrades currently underway in the region are expected to yield $12 to $53 billion in net benefits over the next 20 to 40 years, with congestion and fuel savings estimated to total between $20 and $71 billion.

While we do not have comprehensive congestion costs or value of transmission for interregional links, a study by the Lawrence Berkeley National Laboratory (LBNL) maintains that there is significant value in transmission expansion between regions (see figure below). LBNL found that interregional links have just as much, if not more, value than intraregional links. Expanding transmission capacity across regions can help reduce congestion within regions, particularly for ERCOT and SPP.

FIGURE 2. *LBNL — Marginal Value of Transmission in Relieving Congestion*



Analysis

A closer look at the changes in congestion costs over the years identifies a few key drivers in congestion trends. ERCOT and MISO were the only two RTO territories to have congestion cost increases in 2020, while the rest of the RTO territories saw decreases–largely due to the effects of the COVID-19 pandemic. However, in 2021, every RTO territory saw increases in congestion costs–even compared to pre-2020 levels. In 2020, ISO-NE reported congestion costs were mainly related to constraints with exporting wind energy in the north; inadequate infrastructure to manage power flows from areas of high generation to the load centers; constraints in power flows between NY and NE, where there can be large differences in energy prices; constraints surrounding energy imports from other regions on low-voltage lines; and more expensive generation needing dispatching.

Northeast US: ISO-NE and NYISO

Congestion rose 72% in 2021 from 2020 levels in ISO-NE, part of which, as mentioned earlier, is attributed to reduced effects of the COVID-19 pandemic. However, in addition to the issues listed for 2020 above, transmission development is not keeping pace with renewable energy growth. A new wind generator in coastal Maine went online in late 2020, and along with other abundant wind generation, and in the absence of proactive transmission additions, congestion increased. As of 2021, Maine placed fifth in the nation for the highest amount of wind energy produced; and, as of mid-2022, Maine had over 1,000 MW of generating capacity. Finally, there was unusually warm weather in the summer months and unusually cold weather in Q1– contributing to higher electricity usage.

In 2020 NYISO congestion costs decreased to the lowest they have been since before 2016; not only because of the pandemic, but unusually low natural gas prices and reductions in demand/consumption decreased the cost of redispatch in relieving congestion. However, prices picked back up in 2021 as lockdowns ended and the price of natural gas surpassed its historic peak prices in 2008. Additionally, NYISO reported spikes in congestion on colder winter days because of higher natural gas prices; as well as unusually severe transmission outages in the summer months.

Midwest - MISO and SPP

Congestion in the MISO territory dropped in 2019, but soared in 2020. MISO's state of the market report attributes much of this congestion to the significant increase in wind output, without the added transmission capacity to support it. A severe weather event in May of

2020 caused a high-voltage transmission outage that, in just one day, produced $13 million in congestion costs. An estimated **$90 million** accrued in congestion due to Hurricane Laura; as well as $45 million attributable to low generation availability in Michigan. Other extreme weather events in 2020 that likely impacted all or parts of the MISO territory include: the tornado, storm, and flooding event in January; the Midwest and Ohio Valley severe weather event in March; the north, central, and Ohio Valley severe weather event in April; Hurricane Sally in September; Hurricane Delta in October; and the central derecho in August.

In 2021, congestion costs in MISO nearly tripled to **$2.8 billion**. Roughly $730 million was due to Winter Storm Uri–accounting for 26% of all congestion for the entire year. This is consistent with the general pattern nationally that much of the congestion (and value of transmission) occurs in a relatively small percentage of the hours. An additional **$1 billion** in congestion costs can be attributed to insufficient transmission capacity in the Upper Midwest.

In addition to Winter Storm Uri, all or parts of the MISO footprint likely experienced effects from other extreme weather events, including flooding in Louisiana, severe weather (unusual heat or cold), tornado outbreaks, as well as Hurricanes Ida and Nicholas. The PJM territory had also been subject to the effects of Winter Storm Uri, along with other extreme weather events, that likely contributed to a similar share of total congestion costs as in MISO.

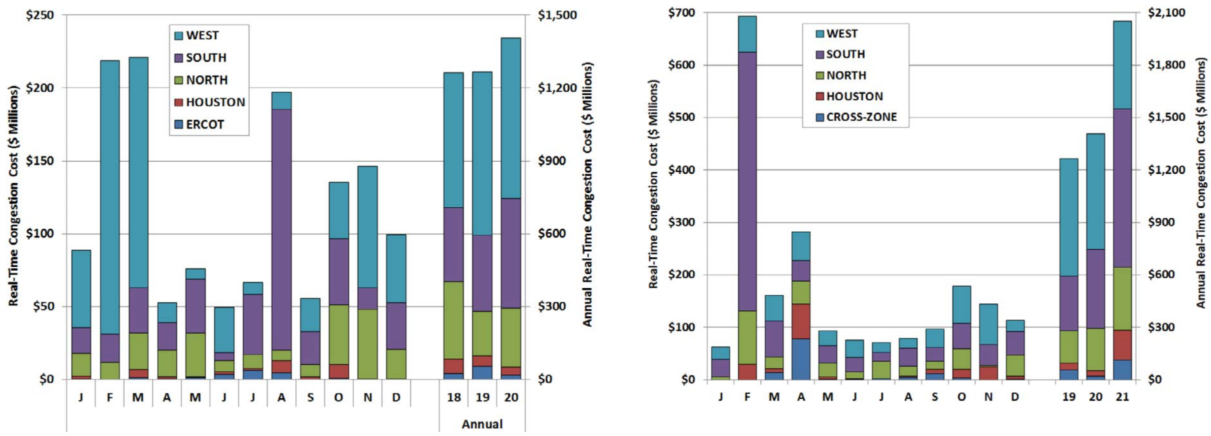
SPP's congestion costs were nearly **$1.2 billion** in 2021, more than doubling from 2020 levels and increasing 114% from 2017 levels (the highest cost congestion year prior to 2021). Market monitor analysts attribute most of this increase from the distance of generation to load centers, outage of key transmission facilities, volatile fuel prices, and the effects of Winter Storm Uri. Areas in SPP where inexpensive wind resources are abundant (and where new generation outpaces transmission expansion) have continued to see higher congestion prices.

Texas

ERCOT saw a dip in congestion costs in 2019, but increased in both 2020 and 2021. ERCOT, along with MISO, was one of the two RTO regions to have seen increases in congestion costs in 2020, rather than decreases. The market monitor report for 2020 attributes the majority of congestion costs to high loads caused by gas and oil projects in the Permian Basin. ERCOT also saw significant outages caused by Hurricane Hanna in July. The south Texas hail storms in May, Hurricane Delta in October, and a severe weather event in April also likely contributed to 2020 congestion costs.

In 2021, ERCOT 3 GW of wind output and 3.6 GW of solar came online, without concomitant transmission development which contributed to a real-time congestion cost increase of 46%. Texas was also heavily impacted by Winter Storm Uri in February. Costs in February and March are usually higher because of planned outages for maintenance and repairs, as well as seasonal conditions affecting some energy sources. However, as shown in the figures below, February congestion costs were significantly higher in 2021 than in 2020 as a result of the storm. Congestion costs in February accounted for about 15% of total costs in 2020; but, in 2021, that percentage increased to **33%**.

FIGURES 3 & 4. *ERCOT — Real-Time Congestion Costs by Zone, 2020 vs. 2021*

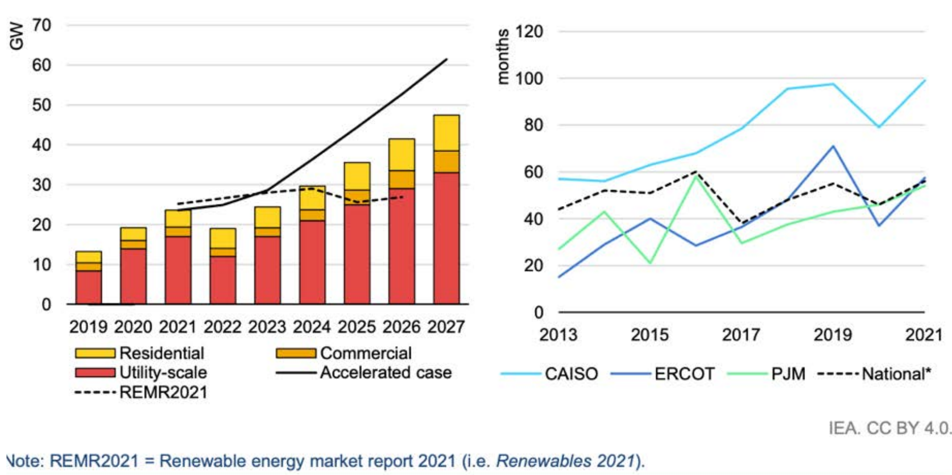


The Energy Transition

Forecasting long-term congestion has proven to be a difficult task; however, there are a handful of signals that suggest congestion costs may continue to rise without any intervention. The Inflation Reduction Act (IRA), officially signed into law in August of 2022, is expected to expand the development of renewable generation capacity by 75% in five years–a more than 25% increase from non-IRA projections. Interconnection is a slow process with ever-growing backlogs, lagging far behind generation–a process that can take 4-7 years from interconnection approval to completion. To facilitate the energy transition and reduce customer costs, all U.S. regions must expand their transmission capacity.

Already, lack of proactive investment in the transmission system is slowing the energy transition. In spite of this, RTOs have seen significant growth in wind resources with New wind resources from MISO (2 GW in 2021; up 14% from 2020 and 61% since 2018), SPP (3.2 GW in 2021; up 12% from 2020 and 48% from 2018), and PJM (0.4 GW in 2021, up 14% from 2020 and 132% since 2018) leading the way. The transmission system is overdue for billions of dollars of investment to enable even greater renewable energy interconnection.

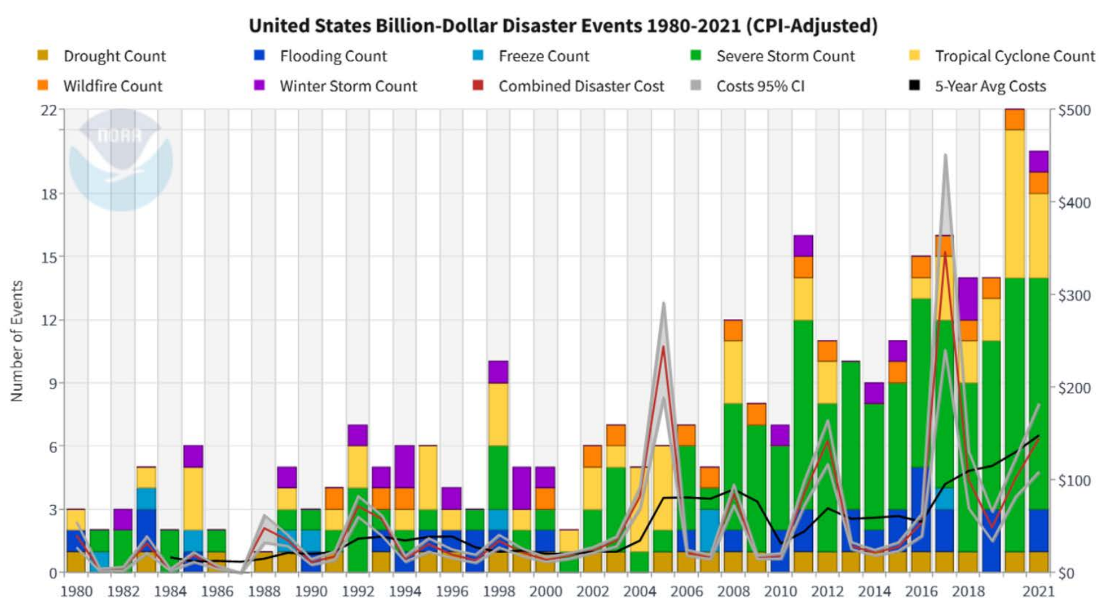
FIGURE 5. *IEA — U.S. Solar PV Capacity Additions Forecast to 2027 (*left*), median time between solar PV interconnection request and plant commissioning, 2013-2021 (*right*)*



In Princeton's Net Zero America Study, researchers estimated that, in order to meet Biden's 2050 climate goals, it is likely the U.S. will need to more than triple transmission capacity. The IRA designated almost $2.9 billion for transmission expansion projects, but siting and permitting obstacles remain salient for all transmission projects.

Along with regulatory, economic, and technology constraints; the issue of extreme weather events remains forefront to reliability, resilience, and decarbonization concerns. According to the National Centers for Environmental Information (NOAA NCEI), the frequency and cost of environmental disaster events has increased since the 1980s. Extreme weather events, such as Winter Storm Uri, will likely increase in cost, frequency, and magnitude. Major power system failures and instances of congestion are likely to increase without transmission expansion. Climate change is linked to higher frequency and intensity of severe weather events, heat waves, wildfires, and large storms. Even polar vortexes, such as Winter Storm Uri, are attributed to a warming climate, despite the event of unusually cold weather. Similarly, although we do not have data for CAISO, we can assume that the wildfire outbreaks in the past two years likely contributed to congestion costs. As we saw in the market monitor reports, extreme weather events have a significant impact on congestion costs. Further, it stresses the importance of transmission expansion and upgrades to ensure the energy transition takes place to mitigate the effects of climate change.

FIGURE 6. *NOAA — Environmental Disaster Events from 1980-2021*



The history of billion-dollar disasters in the United States each year from 1980 to 2021, showing event type (colors), frequency (left-hand vertical axis), and cost (right-hand vertical axis.) The number and cost of weather and climate disasters is rising due to a combination of population growth and development along with the influence of human-caused climate change on some type of extreme events that lead to billion-dollar disasters. NOAA NCEI.

APPENDIX A | Sources for Table 1 – Transmission Congestion Costs ($ millions) for RTOs from 2016-2021

ISO-NE (2017), *2016 Annual Markets Report*, May 30, 2017, https://www.iso-ne.com/static-assets/documents/2017/05/annual_markets_report_2016.pdf, p. 90.

ISO-NE (2018), *2017 Annual Markets Report*, May 17, 2018, https://www.iso-ne.com/static-assets/documents/2018/05/2017-annual-markets-report.pdf, p. 84.

ISO-NE (2019), *2018 Annual Markets Report*, May 23, 2018, https://www.iso-ne.com/static-assets/documents/2019/05/2018-annual-markets-report.pdf, p. 91.

ISO-NE (2020), *2019 Annual Markets Report*, May 2020, https://www.iso-ne.com/static-assets/documents/2020/06/a6_2019_annual_markets_report.pdf, p. 96.

Monitoring Analytics (2018), *State of the Market Report for PJM*, March 8, 2018, https://www.monitoringanalytics.com/reports/PJM_State_of_the_Market/2017/2017-som- pjm-volume2.pdf, p. 503.

Monitoring Analytics (2019), *State of the Market Report for PJM*, March 14, 2019, https://www.monitoringanalytics.com/reports/PJM_State_of_the_Market/2018/2018-som- pjm-volume2.pdf, p. 512.

Monitoring Analytics (2020), *State of the Market Report for PJM*, March 13, 2020, https://www.monitoringanalytics.com/reports/PJM_State_of_the_Market/2019/2019-som-pjm-volume2.pdf, p. 518

Potomac Economics (2017a), *2016 State of the Market Report for the ERCOT Electricity Markets*, May 2017, https://www.potomaceconomics.com/wp-content/uploads/2017/06/2016-ERCOT-State-of-the-Market-Report.pdf, p. i.

Potomac Economics (2017b), *2016 State of the Market Report for the MISO Electricity Markets*, June 2017, https://www.potomaceconomics.com/wp-content/uploads/2017/06/2016- SOM_Report_Final_6-30-17.pdf, p. x.

Potomac Economics (2017c), *2016 State of the Market Report for the New York ISO Electricity Markets*, May 2018, https://www.potomaceconomics.com/wp- content/uploads/2018/06/NYISO-2017-SOM-Report-5-07-2018_final.pdf, p. 9.

Potomac Economics (2018a), *2016 State of the Market Report for the ERCOT Electricity Markets*, May 2018, https://www.potomaceconomics.com/wp-content/uploads/2018/05/2017-State-of-the-Market-Report.pdf, p. i.

Potomac Economics (2018b), *2017 State of the Market Report for the MISO Electricity Markets*, June 2018, https://www.potomaceconomics.com/wp-content/uploads/2018/07/2017-MISO-SOM_Report_6-26_Final.pdf, p. vi.

Potomac Economics (2018c), *2017 State of the Market Report for the New York ISO Electricity*

Markets, May 2019, https://www.potomaceconomics.com/wp- content/uploads/2019/05/NYISO-2018-SOM-Report Full-Report 5-8-2019_Final.pdf, p. 8.

Potomac Economics (2019a), *2016 State of the Market Report for the ERCOT Electricity Markets*, June 2018, https://www.potomaceconomics.com/wp-content/uploads/2019/06/2018-State-of-the-Market-Report.pdf, p. i.

Potomac Economics (2019b), *2016 State of the Market Report for the MISO Electricity Markets*, June 2019, https://www.potomaceconomics.com/wp-content/uploads/2019/06/2018-MISO-SOM_Report_Final2.pdf, p. vi.

Potomac Economics (2020a), *2019 State of the Market Report for the ERCOT Electricity Markets*, May 2020, https://www.potomaceconomics.com/wp-content/uploads/2020/06/2019-State-of-the-Market-Report.pdf, p. 47.

Potomac Economics (2020b), *2019 State of the Market Report for the MISO Electricity Markets*, June 2020, https://www.potomaceconomics.com/wp-content/uploads/2019/06/2018-MISO-SOM_Report_Final2.pdf, p. xii.

Potomac Economics (2020c), *2017 State of the Market Report for the New York ISO Electricity Markets*, May 2020, https://www.nyiso.com/documents/20142/2223763/NYISO-2019-SOM-Report-Full-Report-5-19-2020-final.pdf/bbe0a779-a2a8-4bf6-37bc-6a748b2d148e?t=1589915508638, p. 9.

SPP (2017), *State of the Market 2016*, August 10, 2017, https://www.spp.org/documents/53549/spp_mmu_asom_2016.pdf, p. 6.

SPP (2018), *State of the Market 2017*, May 8, 2018, https://www.spp.org/documents/57928/spp_mmu_asom_2017.pdf, p. 1.

SPP (2019), *State of the Market 2018*, May 15, 2019, https://www.spp.org/documents/59861/2018%20annual%20state%20of%20the%20market%2 0report.pdf, p. 2.

SPP (2020), *State of the Market 2019*, May 11, 2020, https://www.spp.org/documents/62150/2019%20annual%20state%20of%20the%20market%20report.pdf, p. 2.

ISO-NE (2021), *2020 Annual Markets Report*, June 9, 2021, https://www.iso-ne.com/static-assets/documents/2021/06/2020-annual-markets-report.pdf, p. 119.

ISO-NE (2022), *2021 Annual Markets Report*, May 26, 2022, https://www.iso-ne.com/static-assets/documents/2022/05/2021-annual-markets-report.pdf, p. 116.

Potomac Economics (2021), *2020 State of the Market Report for the MISO Electricity Markets*, May 7, 2021, https://www.potomaceconomics.com/wp-content/uploads/2021/05/2020-MISO-SOM_Report_Body_Compiled_Final_rev-6-1-21.pdf, p. 57.

Potomac Economics (2022), *2021 State of the Market Report for the MISO Electricity Markets*, June, 2022, https://cdn.misoenergy.org/20220622%20Markets%20Committee%20of%20the%20BOD%20Item%2004%20IMM%20State%20of%20the%20Market%20Report625261.pdf, p. 58.

Monitoring Analytics (2021), *State of the Market Report for PJM*, March 11, 2021, https://www.monitoringanalytics.com/reports/PJM_State_of_the_Market/2020/2020-som-pjm-vol2.pdf, vol 2, p. 530.

Monitoring Analytics (2022), *State of the Market Report for PJM*, March 10, 2022, https://www.monitoringanalytics.com/reports/PJM_State_of_the_Market/2021/2021-som-pjm-vol2.pdf, vol 2, p. 564.

Potomac Economics (2021), *2020 State of the Market Report for the New York ISO Markets*, May 2021, https://www.nyiso.com/documents/20142/2223763/NYISO-2020-SOM-Report-final-5-18-2021.pdf/c540fdc7-c45b-f93b-f165-12530be925c7, p. 25.

Potomac Economics (2022), *2021 State of the Market Report for the New York ISO Markets*, May 2022, https://www.nyiso.com/documents/20142/2223763/NYISO-2021-SOM-Full-Report-5-11-2022-final.pdf/5307870c-9b62-1720-1708-6b9c157211bb, p. 61.

Potomac Economics (2021), *2020 State of the Market Report for the ERCOT Electricity Markets*, May 2021, https://www.potomaceconomics.com/wp-content/uploads/2021/06/2020-ERCOT-State-of-the-Market-Report.pdf, p. 47.

Potomac Economics (2022), *2021 State of the Market Report for the ERCOT Electricity Markets*, May 2022, https://www.potomaceconomics.com/wp-content/uploads/2022/05/2021-State-of-the-Market-Report.pdf, p. 61.

SPP (2021), *State of the Market 2020*, August 12, 2021, https://www.spp.org/documents/65161/2020%20annual%20state%20of%20the%20market%20report.pdf, p. 6.

SPP (2022), *State of the Market 2021*, May 10, 2022, https://www.spp.org/documents/67104/2021%20annual%20state%20of%20the%20market%20report.pdf, p. 9.

APPENDIX B | Sources for Table 3 – Transparent Market Size in Relation to Entire U.S.

ERCOT (2020), *2020 ERCOT System Planning Long-Term Hourly Peak Demand and Energy Forecast*, December 31, 2016, http://www.ercot.com/content/wcm/lists/196030/2020_LTLF_Report.pdf, p. 2.

ISO-NE (2019), "Net Energy and Peak Load by Source," September 20, 2019, https://www.iso-ne.com/static-assets/documents/2019/02/2019_energy_peak_by_source.xlsx.

NYISO (2020), *2020 Load and Capacity Data "Gold Book,"* April 2020, https://www.nyiso.com/documents/20142/2226333/2020-Gold-Book-Final-Public.pdf, p. 13.

PJM (2019), *PJM Load Forecast Report*, January 2019, https://www.pjm.com/-/media/library/reports-notices/load-forecast/2019-load-report.ashx, p. 4.

Potomac Economics (2020), *2019 State of the Market Report for the MISO Electricity Markets*, June 2020, https://www.potomaceconomics.com/wp-content/uploads/2019/06/2018-MISO-SOM_Report_Final2.pdf, p. 8.

SPP (2020), *State of the Market 2019*, May 11, 2020, https://www.spp.org/documents/62150/2019%20annual%20state%20of%20the%20market%20report.pdf, p. 26.

ISO-NE (2021), *2020 Annual Markets Report*, June 9, 2021, https://www.iso-ne.com/static-assets/documents/2021/06/2020-annual-markets-report.pdf, p. 97.

ISO-NE (2022), *2021 Annual Markets Report*, May 26, 2022, https://www.iso-ne.com/static-assets/documents/2022/05/2021-annual-markets-report.pdf, p.97.

Potomac Economics (2021), *2020 State of the Market Report for the MISO Electricity Markets*, May 7, 2021, https://www.potomaceconomics.com/wp-content/uploads/2021/05/2020-MISO-SOM_Report_Body_Compiled_Final_rev-6-1-21.pdf, p. 8.

Potomac Economics (2022), *2021 State of the Market Report for the MISO Electricity Markets*, June, 2022, https://cdn.misoenergy.org/20220622%20Markets%20Committee%20of%20the%20BOD%20Item%2004%20IMM%20State%20of%20the%20Market%20Report625261.pdf, p. 8.

Monitoring Analytics (2021), *State of the Market Report for PJM*, March 11, 2021, https://www.monitoringanalytics.com/reports/PJM_State_of_the_Market/2020/2020-som-pjm-vol2.pdf, vol 2, p. 4.

Monitoring Analytics (2022), *State of the Market Report for PJM*, March 10, 2022, https://www.monitoringanalytics.com/reports/PJM_State_of_the_Market/2021/2021-som-pjm-vol2.pdf, vol 2, p. 5.

Potomac Economics (2021), *2020 State of the Market Report for the New York ISO Markets*, May 2021, https://www.nyiso.com/documents/20142/2223763/NYISO-2020-SOM-Report-final-5-18-2021.pdf/c540fdc7-c45b-f93b-f165-12530be925c7, p. 7.

Potomac Economics (2022), *2021 State of the Market Report for the New York ISO Markets*, May 2022, https://www.nyiso.com/documents/20142/2223763/NYISO-2021-SOM-Full-Report-5-11-2022-final.pdf/5307870c-9b62-1720-1708-6b9c157211bb, p. 8.

Potomac Economics (2021), *2020 State of the Market Report for the ERCOT Electricity Markets*, May 2021, https://www.potomaceconomics.com/wp-content/uploads/2021/06/2020-ERCOT-State-of-the-Market-Report.pdf, p. 21.

Potomac Economics (2022), *2021 State of the Market Report for the ERCOT Electricity Markets*, May 2022, https://www.potomaceconomics.com/wp-content/uploads/2022/05/2021-State-of-the-Market-Report.pdf, p. 31.

SPP (2021), *State of the Market 2020*, August 12, 2021, https://www.spp.org/documents/65161/2020%20annual%20state%20of%20the%20market%20report.pdf, p. 1.

SPP (2022), *State of the Market 2021*, May 10, 2022, https://www.spp.org/documents/67104/2021%20annual%20state%20of%20the%20market%20report.pdf, p. 1.

APPENDIX C | Sources for Analysis not linked to Market Monitor Reports

MISO (2017), MTEP17 MVP Triennial Review, September 2017, https://cdn.misoenergy.org/MTEP17%20MVP%20Triennial%20Review%20Report117065. pdf, pp. 4-6.

Cohen, Judah, Laurie Agel, Matthew Barlow, Chaim I. Garfinkel, and Ian White.(2021). "Linking Arctic variability and change with extreme winter weather in the United States", Science vol. 373, no. 6559 (Sep 1, 2021): pp. 1116-1121. https://www.science.org/doi/10.1126/science.abi9167.

Iea. (2022). *Rep. Renewables 2022: Analysis and Forecast to 2027*. International Energy Agency (IEA), December 2022. https://iea.blob.core.windows.net/assets/ada7af90-e280-46c4-a577-df2e4fb44254/Renewables2022.pdf.

Iea. "Covid-19 Impact on Electricity – Analysis." IEA. Accessed January 27, 2023. https://www.iea.org/reports/covid-19-impact-on-electricity.

Millstein, Dev, Ryan H. Wiser, Will Gorman, Seongeun Jeong, James Hyungkwan Kim, and Amos Ancell. (2022). "Empirical Estimates of Transmission Value using Locational Marginal Prices". Lawrence Berkeley National Laboratory, September 1, 2022. https://eta-publications.lbl.gov/sites/default/files/lbnl-empirical_transmission_value_study-august_2022.pdf.

U.S. Energy Information Administration - "EIA - Independent Statistics and Analysis". EIA. Accessed January 27, 2023. https://www.eia.gov/state/?sid=ME#:~:text=In%202021%2C%20Maine%20ranked%20fifth,Maine%27s%20in%2Dstate%20net%20generation.

U.S. Energy Information Administration - "EIA - Independent Statistics and Analysis". EIA. Accessed January 27, 2023. https://www.eia.gov/state/analysis.php?sid=ME#:~:text=As%20of%20mid%2D2022%2C%20Maine,of%20wind%2Dpowered%20generating%20capacity.&text=The%20state%27s%20largest%20wind%20facility,came%20online%20in%20November%202021.

"In 2020, U.S. Natural Gas Prices Were the Lowest in Decades." U.S. Energy Information Administration (EIA). Last Modified January 7, 2021. https://www.eia.gov/todayinenergy/detail.php?id=46376.

"Natural Gas", U.S. Energy Information Administration. Accessed January 27 2023. https://www.eia.gov/dnav/ng/hist/rngwhhdm.htm.

E. Larson, C. Greig, J. Jenkins, E. Mayfield, A. Pascale, C. Zhang, J. Drossman, R. Williams, S. Pacala, R. Socolow, EJ Baik, R. Birdsey, R. Duke, R. Jones, B. Haley, E. Leslie, K. Paustian, and A. Swan, (2021), "Net-Zero America: Potential Pathways, Infrastructure, and Impacts", Final Report Summary, Princeton University, Princeton, NJ, 29 October 2021. https://netzeroamerica.princeton.edu/img/Princeton%20NZA%20FINAL%20REPORT%20SUMMARY%20(29Oct2021).pdf.

"Electricity Transmission Provisions in the Inflation Act." Congressional Research Service. Accessed January 27, 2023. https://crsreports.congress.gov/product/pdf/IN/IN11981.

"Climate Change Indicators: Weather and Climate". U.S. Environmental Protection Agency. Accessed January 27 2023. https://www.epa.gov/climate-indicators/weather-climate#:~:text=Rising%20global%20average%20temperature%20is,with%20human%2Dinduced%20climate%20change.

"Wildfire Climate Connection". National Oceanic and Atmospheric Administration (NOAA). Accessed January 27 2023. https://www.noaa.gov/noaa-wildfire/wildfire-climate-connection.

"2021 U.S. billion-dollar weather and climate disasters in historical context". National Oceanic and Atmospheric Administration (NOAA). Updated January 24 2022. https://www.climate.gov/news-features/blogs/beyond-data/2021-us-billion-dollar-weather-and-climate-disasters-historical.