Exhibit No. 850

Sierra Club – Exhibit 850
Michael Milligan
Rebuttal Testimony
File No. EA-2023-0017

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Issues:	Project Need & Public Interest (Economic, Reliability, and Resilience Benefits)
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STATE OF MISSOURI

MISSOURI PUBLIC SERVICE COMMISSION

In the Matter of the Application of Grain Belt Express LLC for an Amendment to its Certificate of Convenience and Necessity Authorizing it to Construct, Own, Operate, Control, Manage, and Maintain a High Voltage, Direct Current Transmission Line and Associated Converter Station	)))))))	File No. EA-2023-0017

Rebuttal Testimony

of

Michael Milligan

On Behalf of
Sierra Club

April 19, 2023

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I. Introduction and Qualifications

Q Please state your name, business address, and position.

A My name is Michael Milligan. I am an independent power system consultant, and principal at Milligan Grid Solutions, Inc. My business address is 2875 S York St, Denver, CO 80210.

Q Please summarize your qualifications and experience.

A I retired from the National Renewable Energy Laboratory ("NREL") in 2017 after holding the post of Principal Researcher in the Power Systems Engineering Center. I began at NREL in 1992 as one of two staff members working on grid integration of renewables. During my tenure at NREL, power system integration and related power system research grew tremendously, and now NREL has several divisions with dozens of researchers. I was active in the International Energy Agency Task 25: Design and Operations of Power Systems with Large Amounts of Wind Energy, leading several joint research papers over a 9-year period. I am an internationally recognized expert in grid economics and reliability, and have published more than 225 technical papers, journal articles, and book chapters. My work at NREL set the stage for most of NREL's ongoing research on power system operation and design for efficient, reliable integration of renewable energy.

My work was influential in developing the Western Energy Imbalance Market, which is a real-time energy market serving several states and which has produced more than $3 billion in gross benefits since its implementation in November 2014. I have influenced research and policy throughout the United States, along with most of Western Europe, Scandinavia, China, India, South Africa, Malaysia, and others. During the period of 2009-2016, I led and participated in various North American Electric Reliability Corporation ("NERC") subcommittees on resource adequacy, which led to ground-breaking NERC technical reports on the impact of renewable energy on grid reliability. I was a charter member of the Variable Generation Subcommittee in the Western Electric Coordinating Council ("WECC"), participating until the subcommittee's tasks were later absorbed into other standing committees at WECC, several of which I have continued to participate in. In 2010, I received NREL's Hubbard Award, NREL's highest research award, for "two decades of grid integration analysis and leadership, … and for [my] selfless communication efforts to numerous decision makers, stakeholders, and grid engineers." In 2018, I received one of the first Lifetime Achievement Awards from the Energy Systems Integration Group ("ESIG").

My consulting practice began in 2017 after I left NREL. I am currently a consultant for GridLab, where I am an active participant in the Midcontinent Independent System Operator ("MISO") Resource Adequacy Subcommittee. My other clients have included NERC, the Electric Power Research Institute (both on reliability matters), the International Energy Agency, International Renewable Energy Agency, and many others. My resume is attached.[1]

II. Purpose & Recommendations

Q What is the purpose of your testimony?

A On behalf of Sierra Club, my testimony addresses the need for new transmission and the benefits of increasing transmission capacity related to power system planning, operations, and resilience. Specifically, my testimony focuses on some of the key beneficial aspects of new transmission, including economic benefits through power system operation, reliability improvements, and resilience to extreme weather. Although there are many other benefits,

[1] Schedule MM-1, Resume of Michael Milligan.

my testimony will focus on three main areas: i) economic benefits; ii) reliability benefits, and iii) resiliency benefits. My testimony also addresses how the Grain Belt transmission project will provide these benefits.

Q Have you testified previously before the Missouri Public Service Commission?

A No.

Q What do you recommend in this proceeding?

A I recommend that the Commission approve the revised application for the Grain Belt Express. There is strong evidence that this transmission line will markedly improve the economic operation of the grid, offer significant resilience value, and provide a very high potential to reduce installed capacity with improved joint planning processes.

III. The Need for Additional Transmission, Including Grain Belt Express.

My testimony covers the benefits that additional transmission can provide to grid economics, reliability, and resilience. Although I address each of these topics separately, there are significant linkages between these benefits. For example, a grid that is not reliable cannot hope to be resilient. A grid that is not resilient will impose costs—in many cases significant costs—on consumers. Planning for reliability is a complex mathematical problem that uses various economic and reliability computer models to address the most cost-effective approach to reliability.

In addition, economic structures, such as wholesale electricity markets, can provide greater grid reliability beyond additional transmission, though building additional transmission is necessary for consumers to see these benefits. This increase in reliability results from several of the technical pre-requisites for a market, such as high-resolution visibility on grid conditions, including resource and transmission status in real-time. In 2013, the Federal Energy Regulatory Commission ("FERC") released a staff paper that describes the reliability benefits of real-time energy markets.[2] Building new transmission, such as Grain Belt Express, can unlock these enhanced market benefits for Missouri customers, as I explain in the last section of my testimony.

Q What is the evidence that additional transmission is needed in the region where the Grain Belt Express would be constructed?

A The U.S. Department of Energy ("DOE") recently released a draft report titled *National Transmission Needs Study* in Feb 2023.[3] The DOE report found a "pressing need to expand electric transmission":

> "driven by the need to improve grid reliability, resilience, and resource adequacy, enhance renewable resource integration and access to clean energy, decrease energy burden, support electrification efforts, and reduce congestion and curtailment. Interregional transmission investments will help improve system resilience by enabling access to diverse generation resources across different climatic zones, which is becoming increasingly important as climate change drives more frequent extreme weather events that damage the power system."[4]

According to Adria Brooks, a transmission planning engineer in the Department of Energy's Grid Deployment Office speaking during a webinar on the report, "inter-regional

[2] Schedule MM-2, Federal Energy Regulatory Commission, *Qualitative Assessment of Potential Reliability Benefits from a Western Energy Imbalance Market*, (Feb. 26, 2023), *available at* https://www.caiso.com/Documents/QualitativeAssessment-PotentialReliabilityBenefits-WesternEnergyImbalanceMarket.pdf.

[3] Schedule MM-3, U.S. Department of Energy, *National Transmission Needs Study: Draft for Public Comment,* (Feb. 2023), *available at* https://www.energy.gov/sites/default/files/2023-02/022423-DRAFTNeedsStudyforPublicComment.pdf [hereinafter "Schedule MM-3, DOE, *National Transmission Needs Study*"].

[4] *Id.* at ii-iii.

transmission offers the biggest benefits."[5] A Department of Energy official was quoted as saying "[t]here is also 'significant value' in connecting the Southwest Power Pool with the Mountain region of the Western Interconnection and with the Midcontinent Independent System Operator to the east."[6] A primary feature of the Grain Belt Express is that it proposes to link SPP and MISO, and would provide a part of the "bigger benefits" from interregional transmission benefits, as described by the DOE report.

The DOE report reviewed many transmission studies in the U.S. so that it could draw conclusions supported by broad research and analysis.

Q Does the DOE report have direct relevance for the Grain Belt Express?

A Yes. The report estimates that 7-10 terawatt-miles ("TW-mi") of new transmission needed in 2035 to meet moderate load/high clean futures in the U.S.[7] The regions used in the DOE study are shown in Figure 1 below. The Grain Belt Express connects the Plains with the Midwest, which is one of the highest value pair of regions to connect, according to the DOE study. There are several other points in the DOE study that directly support the Grain Belt Express:

[5] Ethan Howland, *DOE finds 'pressing' transmission needs, with interregional links offering the biggest benefits,* UtilityDive, (Mar. 6, 2023), *available at* https://www.utilitydive.com/news/doe-transmission-needs-report-interregional-webinar/644192/.

[6] *Id.*

[7] One terawatt-mile, or TW-mi, of transmission is a metric that describes transmission capacity in terms of the ability to transmit one terawatt of power, or 1,000 GW of power, for a distance of one mile.

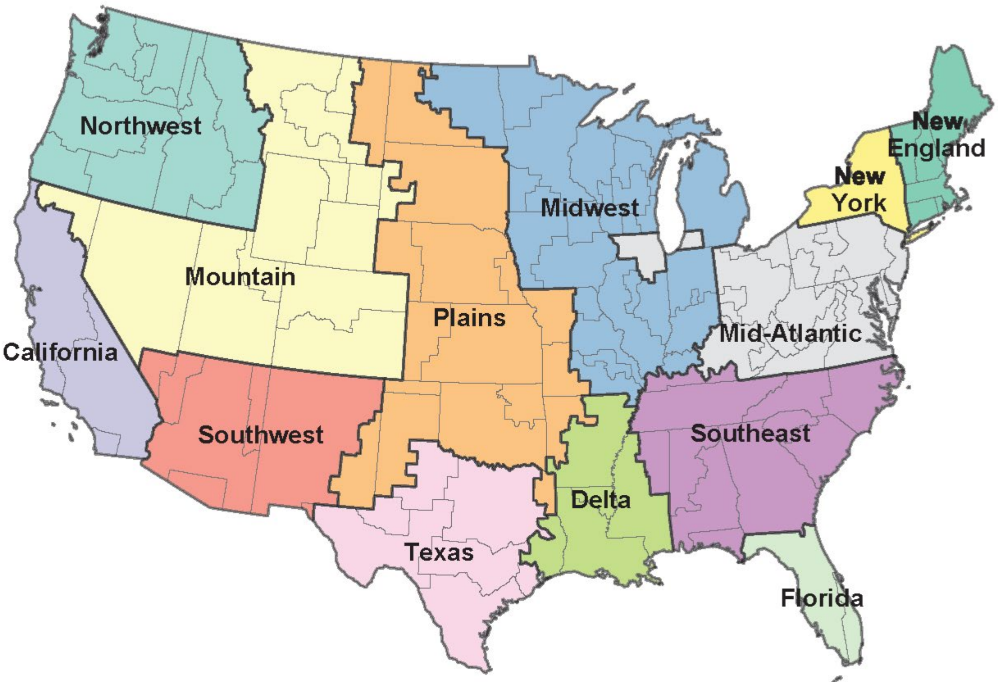

Figure 1. U.S. Department of Energy Transmission Region Definitions
Source: Schedule MM-3, DOE, National Transmission Needs Study

- Southeast Missouri and Southern Oklahoma "have experienced consistently high prices" for the last 2-3 years.[8] Additional transmission would alleviate these high costs to consumers.

- There is a need for increased transfer capacity between the Plains region and neighbors on all sides, which includes the interface between SPP and MISO.[9] This directly relates to the Grain Belt Express because it would link SPP and MISO.

[8] Schedule MM-3, DOE, *National Transmission Needs Study*, at ix.

[9] *Id.* at xi.

- Real-time energy price differentials between Plains and its neighbors, including MISO, have been high and increasing for the last 5 years.[10] The Grain Belt Express would help alleviate these price differentials, promoting economic efficiency.
- The DOE report anticipates that between 15.4 and 25.8 GW of new transfer capacity (median of 21.1 GW, a 175 percent increase relative to the 2020 system) will be needed between the Plains and Midwest by 2035 to meet moderate load and high clean energy futures.[11] The Grain Belt Express, in particular the design upgrade which is the focus of this proceeding, would play a significant role in helping improve this transmission need.
- Connecting MISO with SPP offers "high real-time operational value." This value "has been growing over the past 5 years."[12]

Q Do any MISO assessments support the need for the Grain Belt Express?

A Yes. MISO undertakes an annual assessment of transmission that is needed to better serve demand in its region. The report is known as the MISO Transmission Expansion Plan ("MTEP"). The most recent MTEP report states that more transmission is needed:

> "[a]ll parties in the power industry need to move as fast or faster than the rapid change already taking place in the MISO region. MISO, stakeholders and regulators share responsibility — a Reliability Imperative — to address the immediate and long-term challenges presented by fleet changes and increases in extreme weather in its region."[13]

In this report, MISO shows the wide range of benefits that transmission can provide, as indicated in Figure 2 below. The graph shows cost savings—or benefits—from alleviating transmission congestion, avoided capital cost of resources, resource adequacy (reliability)

[10] *Id.* at x.

[11] *Id.*

[12] *Id.* at xi.

[13] Schedule MM-4, 2022 MISO Transmission Expansion Plan, Executive Summary, at 3, *available at* https://cdn.misoenergy.org//MTEP22%20Executive%20Summary626707.pdf.

savings, and others. I would expect similar benefits for the Grain Belt Express. This MISO report did not specifically address resilience, but I address this later in my testimony.

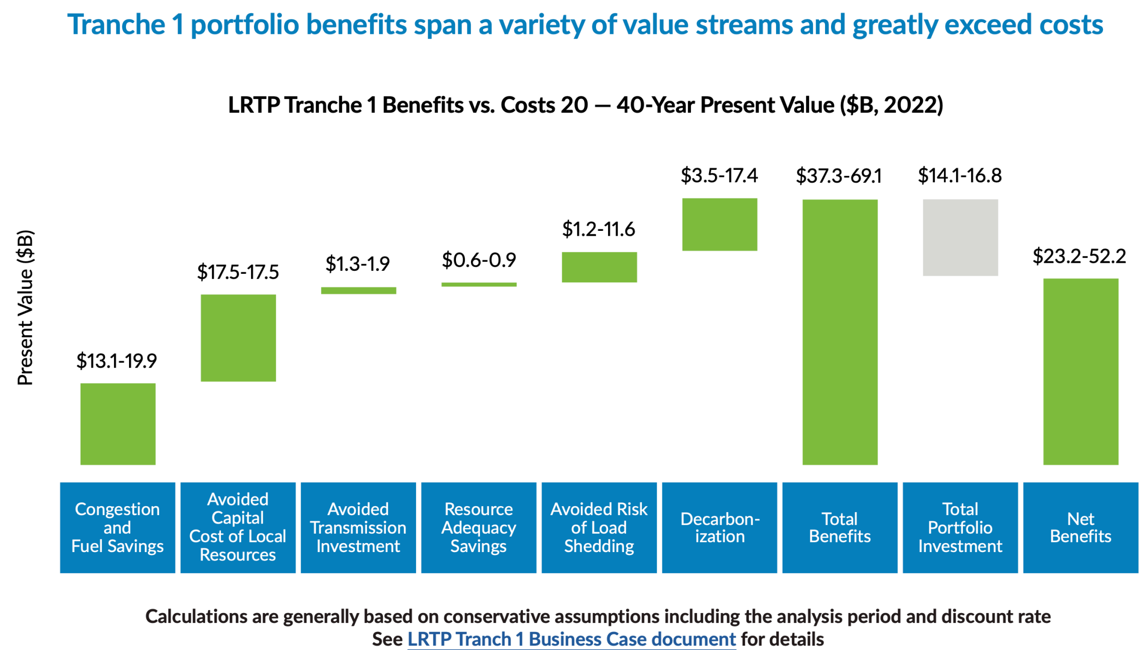

Figure 2. Transmission Benefits from 2022 MISO Transmission Expansion Plan

Source: 2022 MISO Transmission Expansion Plan

IV. Economic Benefits of Transmission, Including Grain Belt Express.

Q What are the economic benefits made possible by high-voltage transmission?

A The operational economic benefits from building transmission primarily result from the reduction in transmission constraints, allowing for access of remote resources that may be more economic, such as wind and solar. "Congestion" on the grid occurs when there is insufficient transmission capacity to deploy a resource (or group of resources) to cost-effectively meet demand. When there is congestion, the path from a cost-effective resource to a demand center is partially, or totally, blocked by the transmission constraint that causes the congestion. Congestion on the grid is similar to congestion on a highway, which limits the flow of vehicles and causes bottlenecks in traffic. Fewer vehicles can pass through, and some drivers might be required to take alternative, longer routes to their destination. Congestion on the grid causes a reduction in power flows from economic resources, causing the grid operator to deploy more expensive resources from an uncongested area to meet demand, similar to a driver taking an alternate, longer, and more expensive route. Removing such congestion will therefore tend to lower overall system costs.

Q How does the grid operator manage this congestion to ensure that demand is served?

A When an economic resource is subject to a transmission constraint and therefore is partially or totally undeliverable, alternative resources are substituted. By definition, the substitute resources are not the most cost-effective; if they were, then they would have been chosen at the outset instead of the economic resource that is behind a transmission constraint.

Q Does this mean that the cost of electricity goes up because of the transmission constraint?

A Yes. For an individual congestion event, the cost increase may not be significant and may not have a material impact on customers' electricity bills, depending on the size of the constraint and the cost of substitute resources. However, over time, the cost of this inefficient dispatch caused by congestion can add up. If a given grid system has multiple constrained interfaces, then costs may increase considerably, even during normal operations.

Q Can new transmission eliminate the extra costs imposed by congestion?

A Yes. If a constraint is partially eliminated, then part of the "penalty" cost of the constraint is eliminated. Further, if a constraint is eliminated altogether, costs will decline accordingly. Cost reductions obtained in this manner represent part of the value of the new transmission.

For example, if adding new transmission reduces operating costs by $1 million/month, that is the gross operational benefit of the new line.

Q Can you provide an example of how congestion interferes with economic dispatch?

A Yes, MISO's Renewable Integration Impact Assessment ("RIIA") study provides some examples.[14] In the RIIA study, MISO finds that wind curtailment can be caused by transmission constraints. This congestion causes the curtailment, or reduction, of wind energy, requiring a substitution of a more expensive resource instead. In general, wind has very low variable costs and would be dispatched by MISO before a generating unit that requires fuel, assuming no congestion. But with congestion, the more cost-effective resource must be (at least partially) curtailed, substituting the energy that would otherwise have been delivered with energy from a more expensive resource. Although this example is of wind energy, the general principle holds whenever a transmission constraint interferes with the most cost-effective dispatch of resources. MISO shows how proposed new transmission lines can be strategically located in weak areas of the grid, thereby alleviating the congestion and eliminating the curtailment of wind energy.

Other studies have confirmed this effect, and several have focused on wind energy. For example, a Union of Concerned Scientists report examines several potential causes of wind curtailments.[15] In a recent study, SPG Global found that "[d]ramatic growth in

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[14] Schedule MM-5, *MISO's Renewable Integration Impact Assessment (RIIA)*, Summary Report, (Feb. 2021), *available at* https://cdn.misoenergy.org/RIIA%20Summary%20Report520051.pdf [hereinafter "Schedule MM-5, *MISO RIIA*"].

[15] Union of Concerned Scientists, *Why Does Wind Energy Get Wasted? The Myth of Wind Energy Oversupply and the True Causes of Wind Curtailment,* (Nov. 2021), *available at* https://www.ucsusa.org/sites/default/files/2021-11/Why-Does-Wind-Energy-Get-Wasted.pdf.

curtailment rates and congestion costs from 2019-2021 indicate a high degree of transmission constraint in the grid, a situation that will only worsen given the current pipeline of renewable generation projects and new government policies promoting further development."[16] Moreover, there is significant wind curtailment in SPP and growing curtailment in MISO:

> "Wind curtailment in the Southwest Power Pool, or SPP, increased over fivefold — from about 1.2 million MWh in 2019 to over 6.3 million MWh in 2021… [In] MISO, curtailment of wind has increased comparatively slowly from roughly 250,000 MWh in 2019 to just over 300,000 MWh in 2021, but totals through July show curtailment of wind is surging. Over 365,000 MWh of wind has been curtailed through the first seven months of the year."[17]

If the price differential between this curtailed wind energy and gas-fired resource (a likely substitute) is $30/MWh, then the cost of this curtailment would have been nearly $11 million for the first 7 months of the year, and could be approximately $18.5 million, extrapolating to the remaining months of the year.

In March 2023, Grid Strategies published a study that confirms that congestion costs are significant and rising. Grid Strategies found that total congestion costs in MISO have reached $2.8 billion in 2021, rising from the already high $1.4 billion in congestion costs in 2016.[18] For SPP, this study found that congestion costs were $1.2 billion in 2021, having

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[16] Adam Wilson, *As IRA drives renewables investment, attention turns to transmission upgrades,* S&P Global Market Intelligence, (Sept. 27, 2022), *available at* https://www.spglobal.com/marketintelligence/en/news-insights/research/as-ira-drives-renewables-investment-attention-turns-to-transmission-upgrades.

[17] *Id*.

[18] Schedule MM-6, Abby Sherman, *Transmission Congestion Costs in The U.S. RTOs*, Grid Strategies, Table 1 at 2, (Mar. 2023).

risen very significantly from $280 million in 2016.[19] These costs are ultimately borne by electricity consumers.

Q Would Grain Belt Express reduce congestion?

A Yes. By providing a new "pathway" connecting resources to demand, existing constraints between Kansas and Missouri will be reduced. This decreases congestion and allows more access to economic resources that may have otherwise been unreachable. The Grain Belt Express would help alleviate the curtailment of renewable energy by providing a new outlet to regions that need cost-effective renewable energy.

Q Are there other sources of potential savings within an RTO or other market area associated with high-voltage transmission?

A Yes. Through its MTEP process, MISO has identified and estimated value (reduction in power costs) that various portfolios of transmission expansion projects would achieve. One such portfolio results in a total benefit/cost ratio ranging from 2.6 – 3.8. These benefit/cost ratios mean than for each dollar of transmission investment, there is a benefit ranging from $2.60 - $3.80. These benefits include (a) congestion and fuel saving, (b) avoided capital cost of local resources (for example building a local combustion turbine or storage device to alleviate congestion), (c) other avoided transmission investments, (d) avoided risk of insufficient local resources, causing dropping some customer loads, and (e) value of reduced carbon pollution.[20]

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[19] *Id*.

[20] Schedule MM-5, *MISO RIIA* at 5 (MISO does not explain how it calculates the value of de-carbonization).

Removal of congestion and fuel savings are the operational benefits that arise from the reduction in transmission congestion, making it possible for the grid operator to schedule and deliver economic energy that was formerly behind a transmission constraint. In MISO's case, part of the fuel saving is caused by the reduction in wind energy curtailment that is made possible by the new transmission. If wind energy is behind a transmission constraint, there may be times that its output must be reduced (curtailed) so as not to exceed transmission path ratings. If new transmission can alleviate that constraint, more wind energy could be delivered to load centers, allowing gas or coal plants to reduce their output and reduce fuel use. The ability to access cheaper resources than would be otherwise available is a key benefit of Grain Belt Express.

This is consistent with work that I did at NREL. NREL's Eastern Wind Integration and Transmission Study ("EWITS")[21] shows transmission reduces wind curtailment. NREL's Renewable Electricity Futures study states, "[a]s renewable electricity generation increases, additional transmission infrastructure is required to deliver generation from cost-effective remote renewable resources to load centers, enable reserve sharing over greater distances, and smooth output profiles of variable resources by enabling greater geospatial diversity."[22]

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[21] Schedule MM-7, National Renewable Energy Laboratory, *Eastern Wind Integration and Transmission Study,* (Rev. Feb. 2011), *available at* https://www.nrel.gov/docs/fy11osti/47078.pdf.

[22] National Renewable Energy Laboratory, *Renewable Electricity Futures Study,* Executive Summary at 3, (2012), *available at* https://www.nrel.gov/docs/fy13osti/52409-ES.pdf.

Q Have other studies confirmed the benefits of transmission for economic operations?

A Yes. There are many such studies. For example, GE recently undertook a study on behalf of PJM and found economic, reliability, and resilience benefits from increased transmission.[23] While at NREL, I was on the technical review committee for the Eastern Wind Integration and Transmission Study (EWITS), which we undertook with MISO as one of our partners.[24] The study developed several transmission overlays for the Eastern Interconnection, building on the Joint Coordinated System Planning ("JCSP") process.[25] The transmission expansion was predicated upon a least-cost planning process so that the overlay would be part of the most cost-effective plan to supply electricity under the various scenarios. More recently, NREL has undertaken the North American Renewable Integration Study ("NARIS") that concludes "[r]egional and international cooperation can provide significant net system benefits through 2050" and that "[o]perational flexibility comes from transmission."[26] In this NREL study, the transmission net benefits of inter-regional expansion and coordination range from nearly $60B to nearly $180B, depending on the future resource mix.[27]

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[23] Schedule MM-8, GE Consulting, *Economic, Reliability, & Resiliency Benefits of Interregional Transmission Capacity,* (Oct. 2022), *available at* https://www.pjm.com/-/media/committees-groups/user-groups/pieoug/2022/20221201/item-02-ge-nrdc-interregional-transmission-study.ashx

[24] Schedule MM-7, National Renewable Energy Laboratory, *Eastern Wind Integration and Transmission Study,* (Rev. Feb. 2011), *available at* https://www.nrel.gov/docs/fy11osti/47078.pdf.

[25] *Id.* at 98-99 (The JCSP included MISO, SPP, PJM, TVA, MAPP, and others.).

[26] National Renewable Energy Laboratory, *North American Integration Study,* (2021), *available at* https://www.nrel.gov/analysis/naris.html.

[27] National Renewable Energy Laboratory, *The North American Renewable Integration Study: A U.S. Perspective,* at 53, (June 2021), *available at* https://www.nrel.gov/docs/fy21osti/79224.pdf.

Q Please summarize your conclusions regarding the operational/economic benefits of the Grain Belt Express.

A The literature regarding the need for new transmission connecting SPP and MISO is compelling. Studies and analyses that have focused on this region of the country offer more specific evidence of value, and are consistent with other similar studies around the U.S. The Grain Belt Express will undoubtably pay for itself, likely as a multiple of its cost.

V. <u>Reliability Benefits of Transmission, Including Grain Belt Express</u>

Q What impact would Grain Belt Express have on planning and reliability?

A Reliability benefits comprise two parts: (1) operational reliability, and (2) long-term reliability/resource adequacy. Operational reliability will be enhanced by the stronger links between regions that would help the grid to respond to disturbances, such as the loss of a large generator. A stronger connection to neighboring areas allows for greater contingency reserve sharing, and for a better, more coordinated economic dispatch response as part of the recovery from the disturbance.

Q How would Grain Belt Express improve long-term reliability/resource adequacy?

A A system has resource adequacy if there are sufficient installed resources (generation, demand response, etc.) to meet demand at some future date or dates. To judge whether a given system is adequate, reliability studies are performed to evaluate the performance of the grid. A typical criterion for adequacy is if the system can achieve a 1 day in 10 years loss of load expectation ("LOLE"). This means that electricity supply would be adequate to serve demand in all but 1 day per decade. If a region does not have sufficient capacity, its loss of load expectation would be higher than the LOLE target. Although more reliability is generally a better outcome for consumers, there is a trade-off between more reliability and cost; too much reliability is expensive, and insufficient reliability has its own costs, as was seen with recent winter storms. Stronger transmission connections would allow for more coordinated resource planning across regions, which would result in the need for less installed resource capacity than if the individual regions would independently plan to their own reliability targets.

LOLE studies have confirmed that installed capacity requirements can be reduced by additional transmission that links different regions together, and can achieve the same long-term reliability target. The addition of transmission must be accompanied by coordinated planning and operations across regions to successfully reduce the level of installed capacity and meet the reliability objective. The reduction in capacity made possible by transmission is sometimes called the "capacity value" of transmission. The EWITS study, referenced above, examined the capacity value of wind energy with and without building a transmission overlay to efficiently deliver wind energy to demand centers. The study found that wind with transmission has a significantly higher capacity value than wind energy by itself, measured by effective load carrying capability ("ELCC"), a common metric used to describe the reliability contribution of a resource or group of resources. Research that I did at NREL with my colleague Eduardo Ibanez explored the larger tradeoffs between building transmission and building additional resources.[28] Using a detailed reliability model of the Western Interconnection, we found that, with a perfectly unconstrained transmission grid, the Western Interconnection could achieve a 1 day/10 years reliability target. Constructing an "ideal"

[28] Eduardo Ibanez and Michael Milligan, *A Probabilistic Approach to Quantifying the Contribution of Variable Generation and Transmission to System Reliability,* (Nov. 2021), https://www.nrel.gov/docs/fy12osti/56219.pdf.

transmission system along with coordinated planning and scheduling could avoid adding approximately 60 GW of capacity under a moderately high renewable energy scenario, a nearly 25% reduction in required capacity. Although a perfectly unconstrained transmission grid is unlikely to be built, this work shows that transmission has a large impact on resource adequacy and can reduce the need for additional resource capacity. Put differently, the reliability target can be achieved with a smaller installed capacity if transmission constraints are reduced or eliminated.

Q Do other studies confirm these results?

A Yes. NREL's Interconnection Seams Study[29] is a rigorous examination of a large DC overlay that would link the 3 U.S. interconnections together. While much larger in scale than the Grain Belt Express, this large overlay would result in benefit-to-cost ratios as high as 2.5, which indicate a significant net value of building new transmission. These cost benefit ratios are significant – a financial investment that yields a 10% return would have a benefit/cost ratio of 1.1/1.0. A benefit/cost ratio of 2.5 would be similar to a 150% return on investment.

Q Are there other resource adequacy benefits that would result from the construction of Grain Belt Express?

A Yes. Utilities in Missouri will have broad access to projects when they issue all-source procurements. Typically, a load-serving entity will require that a generator be capable to deliver power to the LSEs service area or the zone of the regional grid, i.e., MISO Zone 5 for Ameren. When transmission is constrained, the ability of developers to bid for projects is also constrained. When the constraints are removed, competition is fostered, allowing LSEs

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[29] Schedule MM-9, Gregory Brinkman, Joshua Novacheck, Aaron Bloom, and James McCalley, *Interconnections Seam Study,* (Oct. 2020), https://www.nrel.gov/docs/fy21osti/78161.pdf.

to benefit from a broader pool of potential projects. This outcome would improve resource adequacy, reduce costs, or both.

Q Do any Grain Belt witnesses address these economic and reliability benefits? Do you find the points that the Grain Belt witnesses are technically sound and reasonable?

A Grain Belt witness Petti emphasizes several key points that align with my testimony. Petti's testimony discusses several economic benefits that mainly arise in the context of increased resiliency during severe weather. As I point out in my testimony, there is not a firm line between economic, reliability, and resilience benefits because there are interlinkages between them. Specifically, Petti draws attention to the following benefits of the Grain Belt Express:

- Mitigation of high energy prices during extreme weather events;
- Avoided loss of load benefits; and
- Reduced local resource adequacy procurement obligations.

I describe resilience benefits below, consistent with Petti's first two points above. Reduced local resource adequacy obligations are coupled with the larger geographic reach of the grid, once the Grain Belt Express is operational, allowing procurements to cast a wider net of potential resources and fostering competition.

VI. Resilience Benefits of Transmission, Including Grain Belt Express.

Q What is resilience in the context of electric system planning?

A Resilience is generally considered to be the ability of the grid to survive extreme storms and other unusual phenomena, and refers to the ability of the grid to recover quickly from these events.

Q Are there any resilience benefits that Grain Belt would provide?

A Yes. The Grain Belt Express line will link together disparate areas, both in terms of geography and grid regions that include MISO, SPP, and PJM. In effect, that creates a larger geographic/electrical area. This helps make the 'grid larger than the storm,' enabling relatively remote resources not affected by the storm to deliver to load centers within the storm that otherwise might be without power.

Q Is there evidence that transmission can help during extreme events?

A Yes. The Feb. 2023 DOE National Transmission Needs Study report cites many other reports that identify "a pressing need to expand electric transmission—driven by the need to improve grid reliability, resilience, and resource adequacy."[30] According to the report, SPP was not able to import power during Winter Storm Uri in Feb 2021, compromising resource adequacy. During the same storm, MISO also was unable to import additional capacity; some of MISO's inability to import did not coincide with the times of SPP's inability to import. Increased bi-directional transfer capacities can improve system reliability during extreme weather events. Of the several regions affected by Uri, by far the most significant one was Texas, particularly the area operated by ERCOT. ERCOT's grid has extremely limited interconnection with neighboring areas. Consequently, ERCOT was unable to import any significant capacity and experienced lengthy and widespread outages.

A report by Michael Goggin with Grid Strategies shows that even though MISO and SPP had some shortfalls, they were able to mitigate capacity shortages by importing power

[30] Schedule MM-3, DOE, *National Transmission Needs Study*, at ii-iii.

from areas not significantly affected by the storm, mainly to the east. [31] The report cited U.S. Department of Energy data, which showed that MISO's imports were consistently above 13,000 MW during the most severe period of the storm. Much of the power that MISO was importing from the east was used to supply neighboring systems to the west. During that time, ERCOT imported about 800 MW—far less than other, better-connected systems did. The Grid Strategies report is a compelling justification for additional transmission to promote resilience, stating:

> "MISO and SPP also could have benefited from stronger transmission ties to neighboring regions, as well as stronger ties between northern and southern MISO. Power prices in SPP and southern MISO spiked during the event, reaching or exceeding the $1,000/MWh price cap in those markets as prices for natural gas spiked. The need for more transmission capacity was also reflected in the strong west-to-east price gradient across MISO and PJM shown below, with prices in the hundreds of dollars per MWh in MISO versus around $50/MWh in eastern PJM on the morning of February 15."[32]

[31] Schedule MM-10, Michael Goggin, *Transmission Makes the Power System Resilient to Extreme Weather*, at 7, (July 2021), *available at* https://gridprogress.files.wordpress.com/2021/11/transmission-makes-the-power-system-resilient-to-extreme-weather.pdf.

[32] *Id.* at 9.

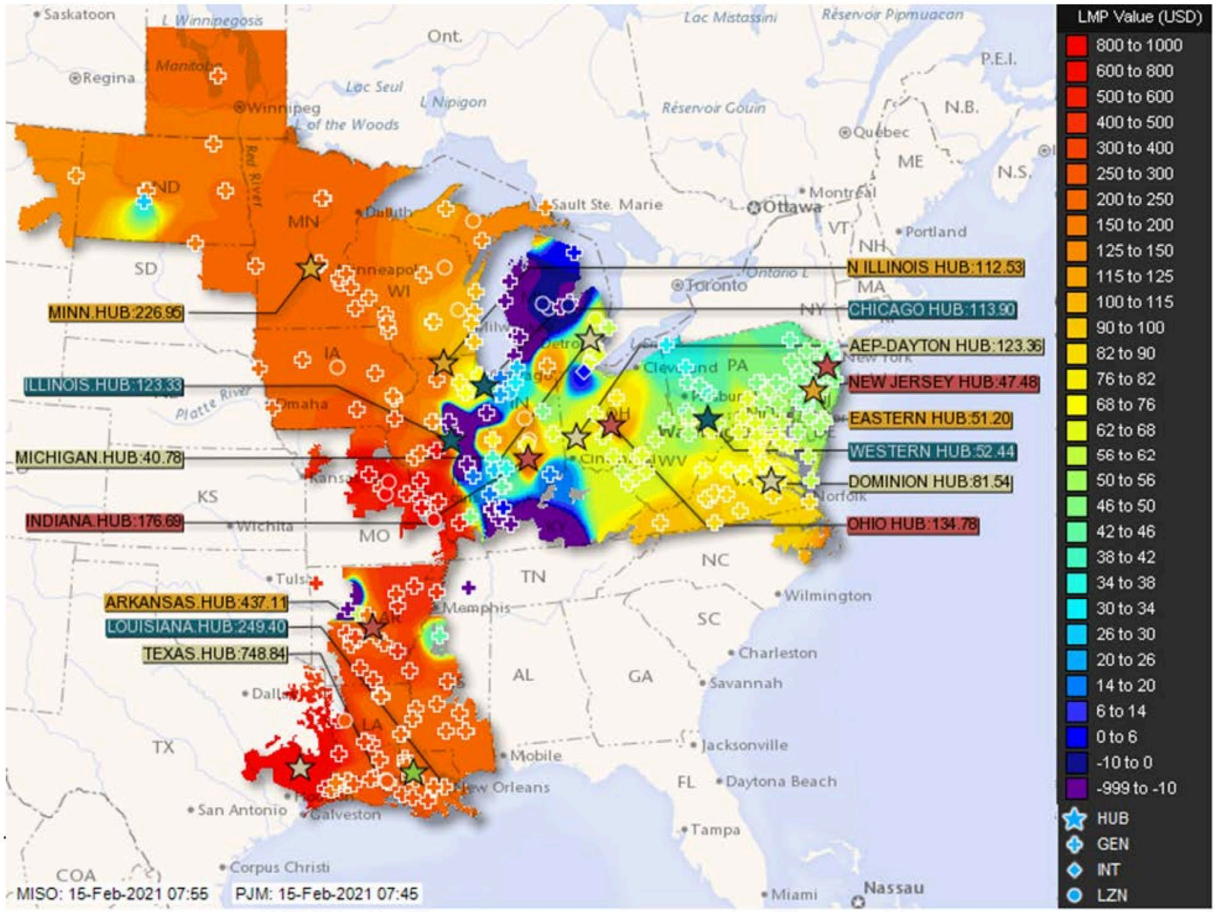

Figure 3. Electric Energy Prices During Winter Storm Uri

Source: Schedule MM-10, Goggin Grid Strategies Report

As shown in Figure 3, the extreme price disparities during Winter Storm Uri demonstrate the need for more transmission to promote resilience. Congestion costs at the MISO-SPP seam nearly reached $2,000/MWh throughout the storm, reflecting a transmission need.[33] These costs are generally passed on to customers.[34]

[33] *Id.*

[34] *Id.*

Q What would be the potential cost impact without such severe transmission congestion during Uri?

A The 2021 Grid Strategies report estimates that $110 million in savings could have been achieved per GW of increase capacity between SPP and MISO during Winter Storm Uri. Examining wholesale power prices and comparing regions affected by Uri with regions outside the storm area shows a striking difference, explaining how the benefit of transmission during Uri would have been so high. Figure 4, below, shows prices during Feb 12-20, 2021, during the height of Storm Uri. ERCOT prices were consistently the highest, reflecting its utter lack of ability to import power. SPP South and MISO South also experienced price spikes, but because they were able to exchange some power during the storm, they were able to mitigate prices somewhat. Even so, those prices exceeded $3,000 MWh at times, reaching nearly $5,000 in SPP South at one point. Grid Strategies estimates that the Grain Belt Express and the proposed Clean Line Plains and Eastern transmission line would have provided hundreds of million dollars in benefits, had they been in service during those few days.[35]

[35] *Id.* at 12.

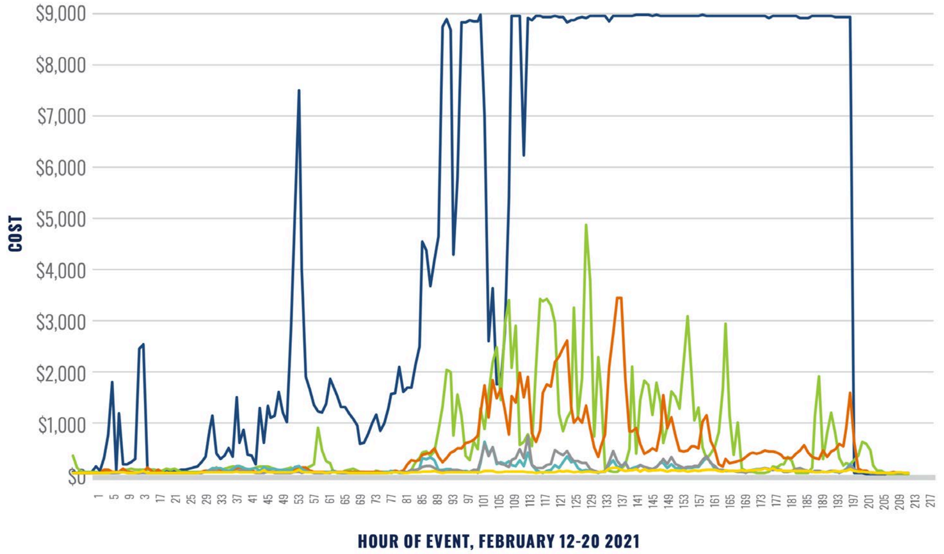

FIGURE 4. *Power prices by region during Winter Storm Uri*

Figure 4. Wholesale Prices During Winter Storm Uri
Source: Schedule MM-10, Goggin Grid Strategies Report

Q Are there other analyses that support transmission resilience benefits?

A Yes. SPP's Uri Outage Report[36] describes key conclusions based upon SPP's experience and data from storm Uri. Key points from the presentation to SPP management states:

a. Relationships & interconnections with neighboring systems facilitated critical helpful assistance.[37]

b. Full use of generation in certain locations was limited by congestion on SPP's system.[38]

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[36] Schedule MM-11, Southwest Power Pool, *SPP's Response to the February 2021 Winter Weather Event,* at 2, *available at* https://www.spp.org/markets-operations/current-grid-conditions/2021-winter-storm-review/ [hereinafter "SPP's Uri Outage Report"].

[37] *Id.*

[38] *Id.*

c. SPP and MISO should include the benefits of enhanced transmission capabilities in addressing systems emergencies like the February 2021 winter weather event in their joint transmission planning process.[39]

d. SPP received thousands of megawatts from PJM and MISO during several critical periods during the event.[40]

e. There was significant congestion in real-time that affected both the SPP and MISO systems. The market-to-market process is designed to help address congestion between the two markets that can be resolved by resources in the other system. Given the supply and demand conditions in both regions as well as the large volume of imports into the SPP region, it would be useful to study the performance of the market-to-market process during this event and to identify areas of effectiveness and of concern.[41]

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[39] Southwest Power Pool, Market Monitoring Unit Executive Summary, *Report on February 2021 Winter Weather Event,* at 6, *available at* https://www.spp.org/documents/66690/spp%20mmu%20winter%20weather%20report%202021.pdf.

[40] Schedule MM-12, Southwest Power Pool, *A Comprehensive Review of Southwest Power Pool's Response to the February 2021 Winter Storm: Analysis and* Recommendations, at 9, (Jul. 19, 2021), *available at* https://spp.org/documents/65037/comprehensive%20review%20of%20spp's%20response%20to%20the%20feb.%202021%20winter%20storm%202021%2007%2019.pdf.

[41] Southwest Power Pool, Market Monitoring Unit Executive Summary, *Report on February 2021 Winter Weather Event,* at 45, *available at* https://www.spp.org/documents/66690/spp%20mmu%20winter%20weather%20report%202021.pdf.

Q What did MISO conclude from its analysis of the event?

A MISO's 2021 Arctic Event Report drew similar conclusions, showing that additional transmission would have been beneficial during Storm Uri. Specifically, the report states:

> "Throughout the extreme conditions MISO utilized numerous tools at its disposal – including operating policies and procedures covering a broad range of operating conditions, long-standing coordination with neighboring regions, like SPP and PJM – and leveraged the value of an expansive geography and diverse generation mix." [42]

MISO also stated that:

> "[t]ransmission is vital to moving electricity from where it is generated to where it is needed most. The MISO region had adequate supply during the Arctic Event, but *transmission constraints, including overloaded lines and the Regional Dispatch Transfer Limits, hindered the ability to move energy to the specific areas where it was needed. MISO's transmission system also supported our neighbors during the Arctic Event*, in particular with substantial power flowing from the east through MISO to support reliable and efficient operations in the Southwest Power Pool (SPP). In addition to new transmission capacity, improved interregional coordination and interconnection will bring significant benefits to facilitate reliability and efficiency."[43]

Q What do you conclude regarding MISO's and SPP's experiences, and how does this information support the expansion/upgrade of Grain Belt Express?

A In essence, all these reports' recommendations and observations support the notion that, to successfully ride through severe weather, *the grid must be larger than the storm*. "Enlarging" the grid is accomplished through strong transmission links to areas that are not affected by the same storm at the same time, or at least not to the same extent, so that unaffected or less affected regions can export into the most-affected regions. Estimates of the resilience value of transmission may be difficult to precisely determine, but the cost of wholesale electricity

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[42] Schedule MM-13, MISO, *The February Arctic Event: February 14-18, 2021,* at 5, *available at* https://cdn.misoenergy.org/2021%20Arctic%20Event%20Report554429.pdf.

[43] *Id.* at 8 (emphasis added).

is but one aspect of the cost of a large outage, such as those that resulted from Uri. According to the Texas State Comptroller's Office, the total cost of Uri to Texans could range from $80 billion to $130 billion, including economic losses from property damage, supply chain disruptions, and agricultural losses.[44]

The expanded capacity of the Grain Belt Express would deliver significant resilience benefits during similar events.

VII. <u>Benefits of Transmission, Including Grain Belt Express, Toward Enhanced Coordination Between MISO and SPP.</u>

Q The proposed Grain Belt Express would cross multiple market regions. Would interconnecting markets, such as SPP and MISO, have any economic benefits?

A Yes. Although there may not be physical congestion between market areas, differences in operational practice and/or balancing authority boundaries impose similar outcomes as physical congestion. MISO and SPP are good examples, as each one is an established wholesale power market with transmission links to the other. With proper coordination between market regions, made possible by transmission, economic resources can be made available to serve demand locally and also in another market region. This benefit is similar to the benefit described above that results in removing transmission constraints, although in this case the benefits span across market boundaries and are not restricted to one RTO region. Another potential benefit of linking two market areas is the potential reduction in ramping (further explained below), which is caused by demand and resource diversity. A third

[44] Jess Donald, *The Economic Impact of the Storm,* Fiscal Notes: A Review of the Texas Economy from the Office of Glenn Hegar, Texas Comptroller of Public Accounts, at 3, (Oct. 2021), *available at* https://comptroller.texas.gov/economy/fiscal-notes/2021/oct/winter-storm-impact.php.

potential benefit is the reduction in operating reserve—extra generation that is kept online in case it is needed. I describe these benefits separately from the core economic benefits of the Grain Belt Express transmission line (Section 3, above) because some of these benefits may require action by SPP and/or MISO to be fully achieved, but nevertheless these benefits could be unlocked if the Grain Belt Express is constructed.

Q What is resource diversity in the context of electric market regions?

A There are several types of diversity. Resource diversity in this context refers to differences in generation behavior in adjacent market areas, which can arise because of different resource types and differences in how these resources are deployed to meet demand. More generally, diversity also refers to the differences in demand behavior in two regions. For example, in a given hour, SPP's demand may be increasing by 1,000 MW at the same time that MISO's demand is falling by 500 MW. Across large geographic regions, that is additional diversity that results from time zone differences and demand patterns. Similarly, wind and solar resources exhibit diversity because different regions may be experiencing different levels of wind or solar generation at the same time caused by differences in local weather, cloud cover, and other weather factors.[45]

Q What is ramping?

A Ramping refers to an increase or decrease in electricity demand, often expressed in terms of the change in MW per hour. It can also refer to similar changes in resource generation that are necessary to keep the system balanced. When a market region has a 1,000 MW hourly

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[45] *See, e.g.*, Michael Milligan, Brendan Kirby, and Stephen Beuning, *Combining Balancing Areas' Variability: Impacts on Wind Integration in the Western Interconnection,* National Renewable Energy Laboratory, (July 2010), *available at* https://www.nrel.gov/docs/fy10osti/48249.pdf.

increase in demand, it is necessary for some combination of resources to also ramp upwards by 1,000 MW/hour to preserve supply-demand balance. Resources generally are constrained by how much they can change output in each time period. For most thermal resources, there is an associated inefficiency with changing output rates that may carry a small economic penalty.

Q Are there any diversity benefits associated with ramping, and how does this relate to long-distance transmission such as the proposed Grain Belt Express?

A Yes, there are benefits. With coordination in operations between market areas, ramp requirements that are shared can reduce the need for ramping in total. For example, if SPP's demand is increasing by 1,000 MW at the same time that MISOs demand is decreasing by 500 MW, there is a "canceling" effect that reduces the overall ramp requirement to a total of +500 MW. This canceling effect benefits customers by reducing overall system costs. My research at NREL established that this cancelling or offsetting impact is significant, especially in systems with significant levels of wind and/or solar energy.[46]

The Grain Belt Express would make possible several coordination approaches to realize ramp reductions, as I discuss below.

Q What type of coordination between markets would be required to enhance the benefits from the Grain Belt Express?

A Potential operating benefits from Grain Belt Express will vary with the degree of coordination between regions. My research on these issues began in 2007, and I have written

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[46] Brendan Kirby and Michael Milligan, *An Examination of Capacity and Ramping Impacts of Wind Energy on Power Systems*, The Electricity Journal Vol. 21(7), (Aug-Sept. 2008), at 30-42, *available at* https://doi.org/10.1016/j.tej.2008.08.002.

more than two dozen papers on these topics.[47] Much of that work was associated with the then-proposed Western Energy Imbalance Market ("WEIM"), which is now operational in the West, and has saved utilities $3.4 Billion since its inception in Nov. 2014.[48] The level of savings from ramping and reserves depends heavily on the size of the regions under consideration, along with the levels and locations of installed wind and solar resources, and other factors unique to each region. There are many different levels of coordination, made possible or enhanced by Grain Belt Express, that would yield progressively larger benefits. Establishing a reserve-sharing group across market boundaries, made possible by the Grain Belt Express, would result in lower contingency reserve requirements[49] among all participants. It would also provide for better response during a contingency event, helping to maintain or improve reliability.

The Grain Belt Express would make it possible to extend the reach of market transactions between resources and load-serving entities, such as the export of wind energy from Kansas to load centers in Missouri, thus allowing broader access to cheap energy in other regions. The most basic level of coordination is a transaction that is made possible by the Grain Belt Express to deliver energy based on terms negotiated between the buyer and the seller.

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[47] Schedule MM-1, Resume of Michael Milligan.

[48] California Independent System Operator, *Western Energy Imbalance Market Benefits Fourth Quarter 2022,* (Jan. 31, 2023), *available at* https://www.westerneim.com/Documents/iso-western-energy-imbalance-market-benefits-report-q4-2022.pdf.

[49] A contingency event could be the loss of a generator or large transmission line, resulting in electrical or mechanical failure. Extra generation is kept online in case of a contingency event. This extra generation is called "contingency reserve."

Q How can these benefits be obtained?

A I've not quantified benefits specifically for the Grain Belt Express. However, my work at NREL and several publications show the impact of alternative levels of coordination that are possible.[50] These include benefits from:

- Additional contingency reserve sharing, resulting in fewer contingency reserves and lower cost.
- Additional flexibility reserve[51] sharing, resulting in less required flexibility reserve and ramping requirements, resulting in lower cost.

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[50] *See*, *e.g.,* Michael Milligan and Brendan Kirby, *Market Characteristics for Efficient Integration of Variable Generation in the Western Interconnection,* National Renewable Energy Laboratory, (Aug. 2011), *available at* https://www.nrel.gov/docs/fy10osti/48192.pdf;

Erik Ela, Michael Milligan, and Brendan Kirby, *Operating Reserves and Variable Generation: A comprehensive review of current strategies, studies, and fundamental research on the impact that increased penetration of variable renewable generation has on power system operating reserves*, National Renewable Energy Laboratory, (Aug. 2011), *available at* https://www.nrel.gov/docs/fy11osti/51978.pdf;

Michael Milligan, Brendan Kirby, Jack King, and Stephen Beuning, *Operating Reserve Implication of Alternative Implementations of an Energy Imbalance Service on Wind Integration in the Western Interconnection: Preprint,* National Renewable Energy Lab, (July 2011), *available at* https://www.nrel.gov/docs/fy11osti/51343.pdf;

Michael Milligan, Debbie Lew, Gary Jordan, Richard Piwko, Brendan Kirby, Jack King, Stephen Beuning, *An Analysis of the Impact of Balancing Area Cooperation on the Operation of the Western Interconnection with Wind and Solar Generation,* National Renewable Energy Laboratory, (May 2011), *available at* https://www.nrel.gov/docs/fy11osti/51546.pdf;

Michael Milligan, Brendan Kirby, Rob Gramlich, and Michael Goggin, *Impact of Electric Industry Structure on High Wind Penetration Potential,* National Renewable Energy Laboratory, (July 2009), *available at* https://www.nrel.gov/docs/fy09osti/46273.pdf.

[51] Flexibility reserve consists of extra generation capability that can respond to unanticipated changes in wind or solar output, and changes in demand.

- Sub-hourly scheduling between market areas, preferably at the five-minute time step. This reduces operating reserves[52] for both the exporting balancing area and the importing balancing area.
- An energy imbalance market ("EIM"), such as the WEIM that has been operating in the Western Interconnection since 2014.

Q Can you describe the impact of continency reserve sharing?

A Contingency reserve sharing involves two or more regions agreeing to share contingency reserve obligations. These obligations are typically based upon the largest MW contingency—loss of a resource or transmission line—in a region. For example, if two regions each have a 500 MW thermal resource that sets their respective contingency level, then each area would ensure an additional 500 MW of generation is available in case of an emergency, totaling 1,000 MW of contingency reserve. Under a reserve-sharing agreement, and subject to transmission constraints, the regions' combined contingency would be 500 MW, and each region would provide a negotiated portion of the 500 MW total reserve. Therefore, the reserve level is reduced by 500 MW in this example.

Q Can you describe flexibility reserve sharing?

A Flexibility reserve is extra generation that is available and online to help manage unforeseen changes in wind and solar generation, along with changes in demand. Because of resource and demand diversity, described above, when two or more regions coordinate, the cancelling

[52] The operating reserve reduction is a combination of ramping/flexibility reserve and regulating reserve. The latter is deployed by automatic generation control, with a computer providing participating resources with an instruction to increase or decrease output every 4-6 seconds.

effect resulting from one region's net demand[53] increasing at the same time its neighbor's net demand is decreasing means that fewer total flexibility reserves are required.

Q How can benefits be obtained from sub-hourly scheduling?

A When one Balancing Area (electrical region which is operated as a single entity and must balance supply and demand in real-time) exports energy to another Balancing Area, the time interval of the delivery can make a large difference in the efficiency of the transaction. Historically, many of these transactions have been scheduled on an hourly basis; i.e. the MW delivery is held constant for one or more hours. In the case of wind or solar energy exports, using an hourly schedule introduces inefficiencies for both the buyer and the seller.[54] My research showed that the exporter must continue to deliver the scheduled level of MW even if the wind (or solar) generation dropped throughout the hour. For example, if wind energy was 100 MW at the top of the hour and is exported on an hourly schedule, the exporter would need to provide that 100 MW for the entire hour. If, however, the wind energy dropped to 50 MW partway through the hour, the exporter would need to provide 50 additional MW so that that export level remains at 100 MW. Meanwhile, the importer would have a -50 MW schedule change at the top of the following hour, and it would be required to hold that level of downward reserve while receiving the 100 MW import. Using Bonneville Power Administration as an example, we found that the reserve obligation required to support

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[53] Net demand = total demand less wind, less solar generation.

[54] *See* Michael Milligan, Brendan Kirby, and Stephen Beuning, *Combining Balancing Areas' Variability: Impacts on Wind Integration in the Western Interconnection,* National Renewable Energy Laboratory, at 9, (July 2010), *available at* https://www.nrel.gov/docs/fy10osti/48249.pdf (Several approaches to improving transactions across different balancing areas are discussed, including dynamic scheduling, faster market-clearing, potential "virtual" balancing area consolidation that uses advanced metering to electrically transfer resources or demand into a different balancing area.).

hourly scheduling dropped from about 400 MW to less than 50 MW by moving to a 10-minute schedule change. Combining all the resources in the Pacific Northwest would have largely eliminated this scheduling "penalty" and resulted in a reduction of the maximum ramping requirement by up to 2,000 MW in some hours.

Moving to 5-minute scheduling would largely mitigate the scheduling penalty, significantly reducing the level of reserve that must be held on both sides of the transaction.

Q What is an Energy Imbalance Market ("EIM")?

A An EIM is a coordinated five-minute energy market. Participating balancing areas send real-time grid data to a central computing system, which then calculates the most cost-effective resource mix to supply electricity demand during the next five-minute period. The computer system then sends signals to the participating generators every 5 minutes to adjust output so that the least-cost resource mix from the combined regions is deployed. If multiple markets are combined using this type of coordinated market structure, all resources would be able to participate so that the lowest-cost mix of resources is always deployed, subject to transmission constraints and resource availability. Transmission constraints within and among the regions reduce the benefit of such a large coordinated system; however, building additional transmission like the Grain Belt Express helps increase benefits from this type of market structure.

Q What evidence is there to show that an EIM would produce significant benefits?

A WEIM, as mentioned above, has been operating in the Western Interconnection since 2014. It is administered by the California Independent System Operator ("CAISO"), which produces a quarterly report showing the actual benefits for that quarter, and cumulative since the market began.[55]

As the number of regions joined the WEIM, benefits increased substantially, reaching approximately $3.5 Billion in cumulative benefits at the end of 2022. Figure 5 below shows the quarterly and cumulative benefits. It is notable that the benefits have been growing nearly exponentially as new entrants began participating in the market.

Q Could the Grain Belt Express enhance a potential EIM in the Midwest?

A Yes. An EIM "overlay" could be placed on SPP, MISO, and potentially other RTOs so that RTO functions would be largely preserved, and yet a very large, coordinated retail energy market would span multiple RTOs, reducing wholesale electricity prices and improving reliability. The WEIM report describes several contributors to the benefits, which include economic transfers between regions, reduced renewable energy curtailment, greenhouse gas reductions, and savings from diversity and its impact on reduced flexibility reserve/ramping requirements. The Grain Belt Express would be a valuable contributor to benefits such as these if SPP and MISO (and perhaps others) were to move towards an EIM-like structure. To be clear, however, although an EIM overlay would provide significant benefits on top of the Grain Belt Express, even without an EIM there would be substantial economic benefits to the proposed increased capacity of the line, as described above.

[55] California Independent System Operator, *Western Energy Imbalance Market Benefits Fourth Quarter 2022,* (Jan. 31, 2023), *available at* https://www.westerneim.com/Documents/iso-western-energy-imbalance-market-benefits-report-q4-2022.pdf.

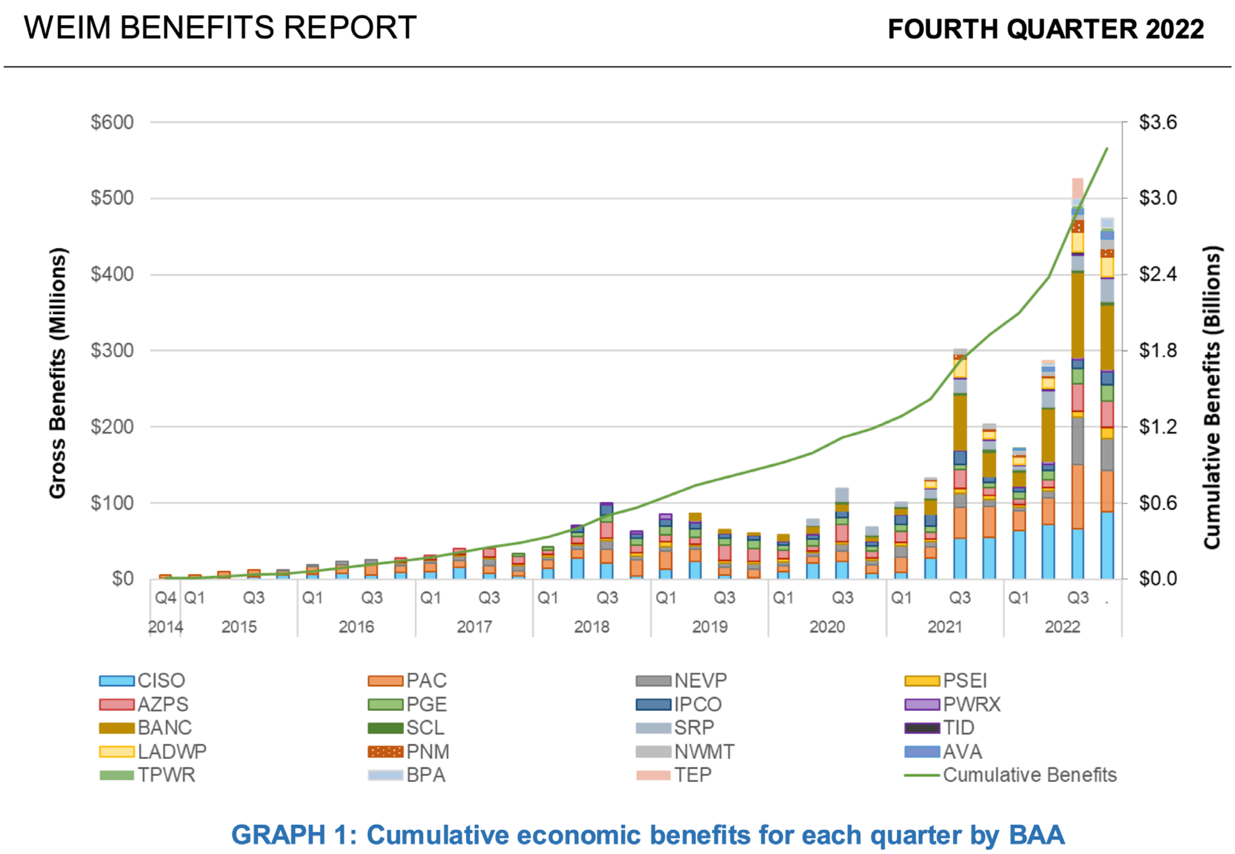

Figure 5. Quarterly Benefits of the Western Energy Imbalance Market
Source: California Independent System Operator, Western Energy Imbalance Market Benefits Fourth Quarter 2022

Q Does this conclude your testimony?

A Yes.

STATE OF MISSOURI

MISSOURI PUBLIC SERVICE COMMISSION

In the Matter of the Application of Grain Belt Express LLC for an Amendment to its Certificate of Convenience and Necessity Authorizing it to Construct, Own, Operate, Control, Manage, and Maintain a High Voltage, Direct Current Transmission Line and Associated Converter Station	)))))))	File No. EA-2023-0017

AFFIDAVIT

Pursuant to Missouri Public Service Commission requirements I, Michael Milligan, hereby state:

1. My name is Michael Milligan. I am an independent power system consultant, and principal at Milligan Grid Solutions, Inc. My business address is 2875 S York St, Denver, CO 80210.
2. Attached hereto and made part hereof for all purposes is my Rebuttal Testimony on behalf of Sierra Club, including schedules, which has been prepared in written form for introduction into evidence in the above-referenced docket.
3. I hereby swear and affirm that based upon my personal knowledge, the facts stated in the Rebuttal Testimony are true. In addition, my judgement is based on my professional experience, and the opinions and conclusions stated in the testimony are true, valid, and accurate.

Under penalty of perjury, I declare that the preceding to be true and correct to the best of my knowledge and belief.

Date: April 19, 2023

Michael Milligan