Technical Appendix

This exhibit provides a summary of the PROMOD V (PROMOD) model, data, and assumptions used in analyzing the Northern Missouri Grid Transformation Program (the Program), and the methodology for estimating the effect of these projects on wholesale electric energy prices, adjusted production costs, and air emissions for Missouri customers.

I. THE PROMOD MODEL

PROMOD is an electric market simulation model marketed by Hitachi Energy.[1] PROMOD provides a geographically and electrically detailed representation of the topology of the electric power system, including generation resources, transmission resources, and load. This detailed representation allows the model to capture the effect of transmission constraints on the ability to flow power from generators to load, and calculate Locational Marginal Prices (LMPs) at individual nodes within the system. PROMOD and similar dispatch modeling programs are used to forecast electricity prices, understand transmission flows and constraints, and predict generation output.

II. DATA AND ASSUMPTIONS

The analysis of the Program relies on data developed by the Midcontinent Independent System Operator, Inc. (MISO). A detailed description of MISO's Long Range Transmission Planning (LRTP) Tranche 1 process and data analysis is provided in the MISO LRTP Tranche 1 Report.[2] To evaluate the LRTP Tranche 1 portfolio reliability metrics and benefits, MISO has performed detailed techno-economic analysis using PROMOD. The analyses herein are based on the same data sets and analyses developed by MISO.

The data and assumptions used by MISO in the LRTP Tranche 1 analysis are based on MISO's Future 1 planning scenario. Additionally, data on the portion of the LRTP Tranche 1 portfolio specific to Missouri were provided by Ameren. The data from MISO includes:

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[1] *See* "PROMOD," Hitachi Energy, available at: https://www.hitachienergy.com/us/en/products-and-solutions/energy-portfolio-management/enterprise/promod.

[2] *See* MISO, "MTEP21 Report Addendum: Long Range Transmission Planning Tranche 1 Portfolio Report with Executive Summary," 2022, available at: https://cdn.misoenergy.org/MTEP21%20Addendum-LRTP%20Tranche%201%20Report%20with%20Executive%20Summary625790.pdf (hereafter MISO LRTP Tranche 1 Report).

1. Load forecasts, including the impact of projected future energy efficiency programs,[3]
2. Transmission system topology, contingencies, and limits, including information on the Program,
3. Generator information (accounting for assumed additions and retirements),[4]
    a. MISO identifies 20.1 GW of renewable resource capacity which is "enabled" by the LRTP Tranche 1 portfolio, based on Powerflow modeling outside of its PROMOD analysis.[5] MISO determined the quantity of renewable resources enabled by LRTP Tranche 1 by identifying resources with a distribution factor (DFAX) $\geq$ 5% on transmission reliability constraints resolved by the LRTP Tranche 1 projects.[6] As described below, my analysis requires estimates of electric generation resource capacity enabled solely by the Program, which were developed by Ameren staff.
4. Fuel and emission prices forecasts.

The system modeled includes individual generator data and complete transmission information for the Eastern Interconnection[7] at the bus-level.[8]

The LRTP Tranche 1 portfolio includes new transmission projects across the MISO Midwest Subregion (see **Appendix Figure 1**).[9] The Program consists of the subset of the LRTP Tranche 1 portfolio that is located within Missouri. My analysis estimates the effects of the Program through a comparison of model outcomes with and without the Program. Apart from the presence of the Program, the only difference between the "with" and "without" cases is the

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[3] *See* MISO, "MISO Futures Report," April 2021, available at: https://cdn.misoenergy.org/MISO%20Futures%20Report538224.pdf.

[4] *See* MISO LRTP Tranche 1 Report, p. 49.

[5] *See* MISO LRTP Tranche 1 Report, p. 49.

[6] *See* MISO LRTP Tranche 1 Report, p. 48.

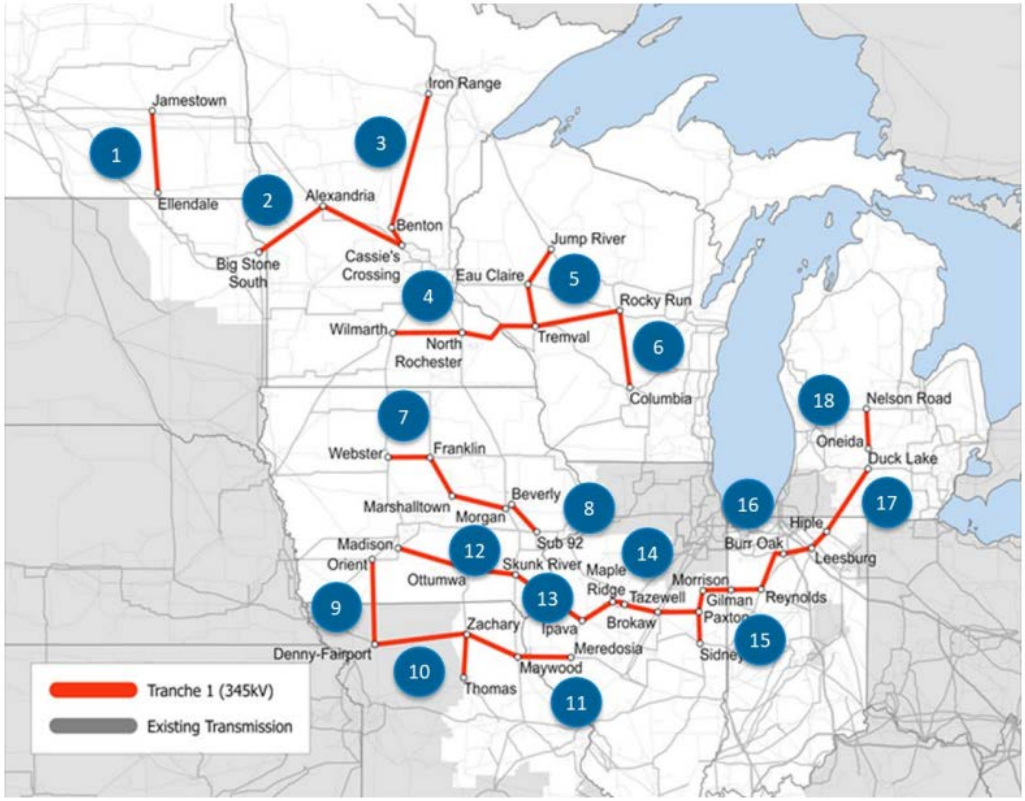
[7] The Eastern Interconnection includes roughly the eastern two-thirds of the "lower 48" states (with the exception of portions of Texas) plus Canadian provinces to the east of Alberta.

[8] A "bus" refers to a specific geographical location in which several high-voltage power lines meet or where a line terminates at a generator or load. A "bus-bar" is a physical piece of electrical equipment used to make connections at an individual bus. *See* Stoft, Steven, Power System Economics: Designing Markets for Electricity, *IEEE Press*, 2002, p. 390.

[9] *See* MISO LRTP Tranche 1 Report, p. 2.

capacity of enabled electricity generation resources. Consistent with MISO's methodology, Ameren Services Company (Ameren Services) Transmission Planning staff identified all enabled Future 1 Regional Resource Forecast (RRF) generators with a DFAX greater than or equal to 5% on transmission reliability constraints resolved by the Program.[10] These identified generators were then removed from all of my modeled scenarios without the Program. **Appendix Table 1** depicts the quantity of capacity enabled by the Program in the MISO Midwest subregion across the study years of 2030, 2035, and 2040.

Appendix Figure 1 – Map of LRTP Tranche 1 Transmission Portfolio



[10] *See* MISO LRTP Tranche 1 Report, p. 48.

Appendix Table 1 – Electricity Generation Capacity Enabled by the Program (MW)

Technology	2030	2035	2040
Combined Cycle	468	468	541
Solar Photovoltaic (PV)	1,345	1,345	1,345
Battery Energy Storage	0	0	35
Solar PV + Battery	0	368	368
Total	**1,813**	**2,181**	**2,289**

III. ANALYTICAL METHOD

Three computations were performed to measure the effect of the Program:

1. A wholesale electric energy price analysis that evaluates the change in Missouri LMPs;
2. A cost analysis that first evaluates changes in production costs needed to meet load in both Missouri and MISO, and second evaluates the net change in costs to Missouri customers from changes in both Missouri production costs and Missouri customers' share of construction costs; and
3. An environmental benefits analysis, which evaluates the reduction in carbon dioxide (CO_2), sulfur dioxide (SO_2), nitrogen oxides (NO_X), and mercury emissions due to the Program.

The analytical methods used for these three computations are described further below.

A. Wholesale Electric Energy Price Comparison

Computation of wholesale electric energy prices is based on outputs from the PROMOD model, including area LMPs and area load. The approach used to develop changes in wholesale energy prices is as follows:

1. Area LMPs are calculated by PROMOD and reflect the load-weighted average LMP of all nodes within a given area.
2. The load-weighted LMP for Missouri, or Missouri LMP, is calculated based on each Missouri area's LMP, weighted by the estimated load for each Missouri area. Some areas, as modeled in PROMOD, include loads in Missouri and one or more neighboring states. In this case, (1) the load-weighted LMP for the Missouri portion of the area is assumed to be the load-weighted LMP for the entire multi-state area, and (2) the load for the Missouri portion of the area reflects the area's total load (in PROMOD) multiplied by the percent of the area's load that is in Missouri, which is estimated using

data from the Energy Information Administration (EIA).[11] **Table 1** of **Schedule TS-D3** depicts average LMP differences across Missouri between cases with the Program and cases without the Program.

B. Adjusted Production Cost and Program Cost Comparison

Computation of adjusted production costs follows the methodology used by MISO.[12] The approach used to develop Missouri Production Costs and MISO Production Costs is as follows:

1. Hourly Adjusted Production Costs (APCs) are calculated for each company. These costs reflect the fuel, variable operations and maintenance, emission allowance, and start-up costs associated with generating energy, adjusted for net sales and purchases (imports or exports) of power with other areas. At the company level, customer loads equal energy output from the company's generation resources net of sales and purchases. Company APCs for 2030, 2035, and 2040 are calculated as the sum of hourly APCs for each company.
2. Missouri Production Costs for 2030, 2035, and 2040 are then calculated as the APC for each company in each year multiplied by the share of each company's load located within Missouri, which was developed from the EIA data as described in Section III.A. These production costs reflect the hourly fuel, variable operations and maintenance, emission allowance, and start-up costs associated with supplying Missouri load, adjusted for net sales and purchases (imports or exports) of power with areas outside of Missouri, including areas within and outside of MISO. **Table 2** of **Schedule TS-D3** provides APC differences across Missouri between cases with the Program and cases without the Program.

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[11] EIA, "Annual Electric Power Industry Report, Form EIA-861 Detailed Data Files," 2022 final data, October 5, 2023, available at: https://www.eia.gov/electricity/data/eia861/.

[12] MISO, "MISO Adjusted Production Cost Calculation White Paper," April 22, 2021, available at: https://cdn.misoenergy.org/20210427%20PSC%20Item%2007%20MISO%20APC%20Calculation%20Methodology%20Whitepaper544059.pdf.

3. In an analogous fashion, MISO Production Costs for 2030, 2035, and 2040 are calculated as the sum of annual APCs for each company in the MISO Midwest Subregion.[13] These production costs reflect the hourly fuel, variable operations and maintenance, emission allowance, and start-up costs associated with supplying MISO load, adjusted for net sales and purchases (imports or exports) of power with areas outside of MISO. **Table 3** of **Schedule TS-D3** provides APC differences across the MISO Midwest Subregion between cases with the Program and cases without the Program.

The approach used to develop Missouri Net Costs is as follows:

1. The present value of total Missouri Production Costs is calculated for the 20-year period, 2030 to 2049, based on the annual Missouri Production Costs for 2030, 2035, and 2040. The year 2030 is chosen to start the flow of changes in production costs because this is the point at which all elements of the Program are expected to be in service.[14] Twenty years of payment reductions are calculated, consistent with the shorter of the two evaluation periods used in MISO's LRTP Tranche 1 economic analysis.[15] Costs over the period 2030 to 2049 are calculated through interpolation and extrapolation from the 2030, 2035, and 2040 results. Annual results are then discounted back to 2024 using both a 3.0 percent and 6.9 percent discount rate to account for a range of possible opportunity costs.[16] **Table 5** of **Schedule TS-D3** provides the present value of Missouri Production Costs for each scenario evaluated.
2. The present value of Missouri Net Costs is calculated as the net of (1) total production costs (as calculated in #1) and (2) Missouri customers' portion of Program costs. Missouri customers' portion of Program costs reflects two components. The first is capital costs for new transmission facilities. For the purposes of the analysis, costs for

[13] States within MISO Midwest include Montana, North Dakota, South Dakota, Iowa, Wisconsin, Michigan, Missouri, Illinois, Indiana, and Kentucky. MISO LRTP Tranche 1 Report, Executive Summary, pp. 1-2.

[14] *See* Direct Testimony of ATXI witness Nick Rudis.

[15] MISO evaluates the MVP Portfolio over 20- and 40-year horizons. *See* MISO LRTP Tranche 1 Report, p. 47.

[16] These discount rates are consistent with those used by MISO in its economic analysis. *See* MISO LRTP Tranche 1 Report, p. 48.

new transmission facilities are incurred in the year in which associated capital expenditures are made. These annual project costs are based on estimates developed by Ameren Services, as outlined by ATXI witness Greg Gudeman,[17] and MISO.[18] The second component is annual expenses. This cost is based on ATXI's May 2024 Attachment O rate formula filing.[19] The portion of operations and maintenance (O&M) expenses and taxes (other than income taxes) allocated to transmission in the formula rate is divided by transmission gross plant in service to calculate an annual transmission expense factor.[20] This factor is then applied to the Program capital cost to estimate ongoing annual expenses for the Program. All future costs are discounted back to 2024. As with all MVPs, transmission costs are then allocated to MISO customers based on their share of MWh load.[21] MISO Missouri customers are assigned 7.7 percent of the total cost of the Project reflecting the MISO Missouri share of load, based on the projections in the MISO dataset.[22] Transmission payments for MISO Missouri customers total $51.1 million on a present value basis using a 3 percent discount rate and $43.7 million using a 6.9 percent discount rate. **Table 4** of **Schedule TS-D3** provides the net cost impact of the Program for each scenario evaluated.

[17] *See* Direct Testimony of ATXI witness Greg Gudeman.

[18] To be conservative, the costs of upgrades of the Associated Electric Cooperative Incorporated (AECI) substations are assumed to be incurred in 2024. Note that these cost estimates projected by MISO are in 2022 dollars and are adjusted for inflation using PJM's Maintenance Adder Escalation Index Numbers from 2022-2024. *See* PJM, "Chronology of Maintenance Adder Escalation Index Numbers," January 3, 2024, available at: https://www.pjm.com/-/media/committees-groups/subcommittees/cds/postings/handy-whitman-index.ashx.

[19] ATXI, Attachment O to MISO Tariff filing, May 2024. Available at: https://misodocs.blob.core.windows.net/transmissionownerratedata/ATXI/2025_ATXI_YE123123TU_AttO_GG_MM_53024.xlsx, accessed June 2024.

[20] Transmission O&M charges are adjusted to exclude EPRI & associated expenditures as detailed in ATXI's Attachment O.

[21] *See* MISO LRTP Tranche 1 Report, p. 14. *See also*, Attachment MM to MISO Tariff, available at: https://misodocs.azureedge.net/miso12-legalcontent/Attachment_MM_-_MVP_Charge.pdf.

[22] 7.7 percent is calculated as the MISO Missouri share of total MISO load based on the LRTP Business Case Analysis. *See* MISO, "LRTP Tranche1 Detailed Business Case Analysis625787.xlsx," available at: https://cdn.misoenergy.org/LRTP%20Tranche1%20Detailed%20Business%20Case%20Analysis625787.xlsx, tab "Assumptions."

These net benefits are conservative because they reflect only reduced production costs but do not include other possible reductions in costs such as those associated with potential reductions in capacity, operating reserve and other ancillary service requirements.[23] The estimate also does not account for other benefits to customers, such as improved reliability, the increased ability to deliver renewable energy, and emission reductions.[24]

C. Environmental Benefits Analysis

The approach used to develop changes in emissions is as follows:

1. MISO CO_2 emissions are calculated from PROMOD output. The estimated CO_2 quantities in each scenario reflects the sum of emissions from all generation sources within the MISO Midwest Subregion. **Table 6** of **Schedule TS-D3** depicts CO_2 differences across the MISO Midwest Subregion between cases with the Program and cases without the Program.
2. Missouri emissions of NO_X, SO_2 and mercury are calculated from PROMOD output. The reported quantities reflect the sum of emissions from all generation facilities located within Missouri. For certain RRF generation facilities in the MISO PROMOD files that are not assigned a specific geographic state but instead are assigned to an area that include portions of both Missouri and one or more neighboring states, Missouri emissions reflect total area emissions of these generation facilities multiplied by the percent of each area's load that is in Missouri, as described in Section III.A. **Table 7**, **Table 8** and **Table 9** of **Schedule TS-D3** provides differences in NO_X, SO_2, and mercury, respectively within Missouri between cases with the Program and cases without the Program.

[23] *See* MISO LRTP Tranche 1 Report, pp. 7-8.

[24] *See* MISO LRTP Tranche 1 Report, p. 47.

IV. SCENARIOS

The results presented in the body of this testimony reflect three scenarios, which differ only with respect to the assumed price of natural gas in the PROMOD modeling. Each scenario was designed by MISO in its LRTP Tranche 1 portfolio analysis, and no additional changes have been made. The definitions are provided by MISO in its LRTP Tranche 1 Report.[25]

- **Base Forecast** – Natural gas price forecast from MISO's Future 1 planning scenario.
- **Base Forecast + 20%** – Assumed 20% increase in the natural gas price forecast, relative to the Base Forecast.
- **Base Forecast + 60%** – Assumed 60% increase in the natural gas price forecast, relative to the Base Forecast.

[25] MISO LRTP Tranche 1 Report, pp. 69-71.