Summary

• Long Range Transmission Planning (LRTP) addresses the future challenges of the resource fleet evolution
• The LRTP Detailed Business Case summarizes the analysis of the reliability and economic benefits used to demonstrate that the value exceeds the total cost of the projects and supports recommendation of the portfolio
• The LRTP Tranche 1 portfolio provides a total 20-year present value benefit to cost ratio of 2.6
MISO Transmission Planning Objectives

• The goal of MISO Planning is to identify and support development of transmission infrastructure that is sufficiently robust to meet reliability needs and support a competitive energy market, policy goals and competitive transmission development

• MISO Board of Directors Planning Principles
  • Ensure a reliable and resilient transmission system to meet operational needs
  • Make benefits of an economically efficient electricity market available to customers by identifying transmission solutions that enable access to the electricity at the lowest total electric system cost
  • Support federal, state and local energy policy and member goals by planning for access to a changing resource mix
  • Provide an appropriate cost allocation mechanism that ensures that costs are allocated in a manner roughly commensurate with the projected benefits
  • Analyze system scenarios and make results available to energy policy makers and stakeholders to provide context and inform their choices
  • Coordinate planning process with neighbors and work to eliminate barriers to reliable and efficient operations
Long range focus on system planning needed in response to unprecedented industry changes

• The initial 2019 MISO Forward report began to examine industry trends around resource and technology developments that highlighted growing challenges around resource availability, flexibility and visibility of the resource fleet in meeting future energy needs.

• The Renewable Integration Impact Assessment explored challenges of increased renewable penetration and identified significant reliability issues that would need to be addressed through possible reinforcements to maintain robust performance.

• In recognition of the need for more long-term proactive planning to meet the pace of change, Long Range Transmission Planning began with a conceptual roadmap of ideas to help guide development of planning analysis that would be needed to identify possible transmission solutions.
Timeline of LRTP development

- MISO introduced the LRTP conceptual roadmap to stakeholders in June 2020 to begin discussions on the study scope and approach.
- MISO began a series of technical workshops in Aug 2020 to seek input from stakeholders on the study methods and assumptions and to provide regular status updates on the ongoing work and analysis findings.
- MISO initiated discussions on cost allocation mechanisms with the Regional Expansion Cost and Benefits Working Group in Feb 2021 to investigate possible Tariff changes that would be needed before recommendation of projects.
- MISO introduced Business Case development in the Sept 2021 LRTP workshop to begin identifying the benefit components and defining the metrics for quantifying the benefits provided by the initial portfolio of LRTP transmission investments.
Workshops and Stakeholder feedback is an integral element of the LRTP process and success.
LRTP Projects must meet one of three MVP criteria defined in the MISO Tariff

MISO Tariff - Attachment FF, II.C.2...

a. **Criterion 1.** A Multi-Value Project must be developed through the transmission expansion planning process for the purpose of enabling the Transmission System to reliably and economically deliver energy in support of documented energy policy mandates or laws that have been enacted or adopted through state or federal legislation or regulatory requirement that directly or indirectly govern the minimum or maximum amount of energy that can be generated by specific types of generation. The MVP must be shown to enable the transmission system to deliver such energy in a manner that is more reliable and/or more economic than it otherwise would be without the transmission upgrade.

b. **Criterion 2.** A Multi-Value Project must provide multiple types of economic value across multiple pricing zones with a Total MVP Benefit-to-Cost ratio of 1.0 or higher where the Total MVP Benefit-to-Cost ratio is described in Section II.C.7 of this Attachment FF. The reduction of production costs and the associated reduction of LMPs resulting from a transmission congestion relief project are not additive and are considered a single type of economic value.

c. **Criterion 3.** A Multi-Value Project must address at least one Transmission Issue associated with a projected violation of a NERC or Regional Entity standard and at least one economic-based Transmission Issue that provides economic value across multiple pricing zones. The project must generate total financially quantifiable benefits, including quantifiable reliability benefits, in excess of the total project costs based on the definition of financial benefits and Project Costs provided in Section II.C.7 of Attachment FF.
The MISO MVP Tariff further defines the ‘specific types of economic value’ which may be included

MISO Tariff - Attachment FF, II.C.5...

a. Production cost savings where production costs include generator startup, hourly generator no-load, generator energy and generator Operating Reserve costs. Production cost savings can be realized through reductions in both transmission congestion and transmission energy losses. Production cost savings can also be realized through reductions in Operating Reserve requirements within Reserve Zones and, in some cases, reductions in overall Operating Reserve requirements for the Transmission Provider.

b. Capacity losses savings where capacity losses represent the amount of capacity required to serve transmission losses during the system peak hour including associated planning reserve.

c. Capacity savings due to reductions in the overall Planning Reserve Margins resulting from transmission expansion.

d. Long-term cost savings realized by Transmission Customers by accelerating a long-term project start date in lieu of implementing a short-term project in the interim and/or long-term cost savings realized by Transmission Customers by deferring or eliminating the need to perform one or more projects in the future.

e. Any other financially quantifiable benefit to Transmission Customers resulting from an enhancement to the transmission system and related to the provisions of Transmission Service.
The objective of LRTP is to enable reliable and economic delivery of energy in the future with lower-carbon resources.

- Provide a cost-effective solution to allow future resources to serve load throughout the footprint
- Enable access to lower-cost energy production
- Provide more flexibility in fuel mix for customer choice
- Maintain robust and reliable performance in future conditions with greater uncertainty and variability in supply
The scope of LRTP business case analysis includes quantifying the reliability and economic benefits:

A. Congestion and fuel savings
B. Avoided capital costs of local resource investments
C. Avoided transmission investment
D. Reduced resource adequacy requirements
E. Avoided risk of load shedding
F. Decarbonization
G. Reliability issues addressed by LRTP
H. Other qualitative and indirect benefits
LRTP business case analysis uses a range of variables

- LRTP benefits examine value over the 20- to 40-year period from the in-service date (All projects assumed in service by 2030)
  - Benefit/cost calculations are evaluated on a 20-year time horizon
  - Additional benefits are shown for the 40-year horizon to align with assumed life of the assets
- LRTP benefits are evaluated for a range of discount rates from 3.0 – 6.9%
  - The social discount rate of 3.0% represents the value a ratepayer would typically receive on their risk-adjusted investment
  - The Weighted Average Cost of Capital (WACC) of 6.9% is the gross-plant weighted average of the Transmission Owners’ cost of capital and represents the minimum return required on their transmission investments
Tranche 1 Portfolio proposal is the culmination of two years of Futures development, modeling, and engineering and represents the most complex transmission planning study effort in MISO’s history

- Portfolio embodies needed transmission for the ever-changing fleet
- Addresses needs across the entirety of the MISO Midwest subregion
- More work still to do regarding additional Futures and will be addressed in Tranche 2
Preliminary project cost estimates for LRTP Tranche 1 is $10.4 B for projects located across the MISO Midwest subregion

<table>
<thead>
<tr>
<th>Draft LRTP Tranche 1 Portfolio</th>
<th>Location</th>
<th>Estimated Project Cost ($M)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jamestown-Ellendale 345kV</td>
<td>Western MN-Dakotas</td>
<td>$955</td>
</tr>
<tr>
<td>Bigstone-Alexandria 345kV – Cassie's Crossing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wilmarth - North Rochester – Tremval – Eau Claire – Jump River 345kV</td>
<td>MN-WI</td>
<td>$1,194</td>
</tr>
<tr>
<td>Tremval – Rocky Run – Columbia</td>
<td>MN-WI</td>
<td>$673</td>
</tr>
<tr>
<td>Iron Range – Benton – Cassie's Crossing</td>
<td>Western MN-Dakotas</td>
<td>$853</td>
</tr>
<tr>
<td>Webster – Franklin – Morgan Valley 345kV</td>
<td>IA</td>
<td>$894</td>
</tr>
<tr>
<td>Beverly – Sub 92 345kV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orient – Fairport – Zachary – Maywood – Meredosia 345kV</td>
<td>Northern MO</td>
<td>$2,032</td>
</tr>
<tr>
<td>Zachary – Thomas 345kV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Madison – Ottumwa – Skunk River – Ipava – Maple Ridge 345kV</td>
<td>IA-IL-IN-MI</td>
<td>$3,429</td>
</tr>
<tr>
<td>Tazewell – Brokaw - Paxton – Gilman – Morrison – Reynolds – Hiple – Duck Lake 345kV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paxton – Sidney 345kV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oneida – Nelson Road 345kV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Underbuild (facilities to be identified prior to final approval)</td>
<td></td>
<td>$350</td>
</tr>
<tr>
<td><strong>Total Portfolio Project Cost</strong></td>
<td></td>
<td><strong>$10,380</strong></td>
</tr>
</tbody>
</table>

*Final costs under development for MTEP21 Report Appendix
The LRTP Tranche 1 portfolio cost (20-year and 40-year present value at 6.9% and 3.0% discount rate)

The total capital cost of LRTP Tranche 1 portfolio is estimated to be $10.4B

The 20-40yr Present Value (in 2022$) of the portfolio total revenue requirement is expected to be in the range of $14.1B-$16.9B*
Benefit Metrics
The preliminary analysis indicates total economic benefits significantly exceed cost of the Tranche 1 LRTP portfolio.
A. Congestion and Fuel Savings

APC Benefits will be determined by comparing MISO Midwest APC in the LRTP Reference Case with the MISO Midwest APC in the LRTP Change Case.

Make-up of LRTP Reference Case Model

- MTEP Topology
- Future Load Forecast
- Existing Units
- Signed GIA Units
- EGEAS DGPV
- IRP/EGEAS Battery Storage
- IRPs
- Thermal RRFs
- Midwest RRFs < 5% DFAX

Make-up of LRTP Change Case Model

- Reference Case
- Midwest Renewable RRFs ≥5% DFAX
- LRTP Transmission

- The LRTP Reference Case represents necessary generation to serve Futures Load Forecast (on copper sheet).
- The LRTP Change Case includes Renewable RRFs located in MISO Midwest which have ≥5% DFAX on reliability constraints addressed by LRTP projects.
MISO Midwest-focused Reference Case generation determination process and results to meet copper sheet energy requirements in Future 1

- 127.2 GW: Future Load Forecast + Existing Gen + Signed GIA Units + EGEAS DGPV + EGEAS/IRP Battery Storage
- 6.5 GW: Add Thermal IRP Generation
- 8.3 GW: Add Renewable IRP Generation
- 22.8 GW: Add Thermal RRF Generation
- 292 MW: Add MISO Midwest Renewable RRF Generation < 5% DFAX
- 20.1 GW: Add MISO Midwest Renewable RRF Generation ≥ 5% DFAX

A. Congestion and Fuel Savings

LRTP Reference Case Generation Fleet Capacity

LRTP Change Case Generation Fleet Capacity Addition
## LRTP Tranche 1 projects congestion and fuel savings results

### Present Value

<table>
<thead>
<tr>
<th>Present Value</th>
<th>20 year PV (Billions-2022$)</th>
<th>40 year PV (Billions-2022$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discount Rate</td>
<td>6.9% 3.0% 6.9% 3.0%</td>
<td></td>
</tr>
<tr>
<td>CAZ</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>$3.1 $4.4 $4.6 $8.7</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>$1.0 $1.5 $1.6 $3.3</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>$2.1 $2.9 $3.0 $5.6</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>$1.3 $1.9 $2.1 $4.1</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>$1.5 $2.1 $2.2 $4.2</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>$2.9 $4.1 $4.5 $8.9</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>$1.0 $1.5 $1.6 $3.0</td>
<td></td>
</tr>
<tr>
<td>Sum</td>
<td>$13.0 $18.4 $19.7 $37.8</td>
<td></td>
</tr>
</tbody>
</table>

Renewable RRFs ≥ 5% Dfax
Renewable RRFs < 5% Dfax
LRTP Projects
Resource capital investments can be avoided by taking advantage of broader regional renewables instead of purely local resources

- Past experiences with transmission studies like the 2011 Multi-Value Projects indicate that a regional approach will be more cost-effective than a purely local buildout:
  - Magnitude, cost, & locations of resources differ based upon approach used
  - Regional transmission is the bridge between these scenarios
- To determine avoided capital cost of local resource investment savings created by LRTP transmission MISO developed
  - EGEAS LBA (local) granularity expansion models utilizing Future 1 assumptions
  - Calculation to relate the LBA and Regional expansion to LRTP transmission and determine what the avoided capital costs of local resource investments would be
Overview of EGEAS LBA expansion models used to determine what a local build out would be

- Each EGEAS run represents one of the 39 LBAs in MISO, with a Future 1 basis
  - The runs treat each LBA as its own pool.
  - Each LBA then self-constructs resources necessary to meet the simulation constraints such as PRM and emissions.
  - Utilizes the same assumptions as the regional Future 1 analysis and resources are ascribed to LBAs based on resource ownership.
  - Capacity purchases are enabled for the first year to meet each LBA’s PRM and is driven by the construction lead time for new resource alternatives.
  - LBA-specific wind and solar profiles are used instead of the regional profiles which averaged multiple profiles from different locations across MISO.
- The MISO PRM value of 18% is scaled for each LBA based upon its alignment to the MISO coincident peak.
Calculation to relate the LBA and Regional expansion to LRTP transmission to determine cost savings

- **Calculation Overview**
  - Due to Regional and LBA modeling assumptions, the avoided capital costs of local resources investments cannot be determined by subtracting Regional expansion costs from the total LBA expansion costs (doing so would overstate realized benefit).
  - Regional and LBA Regional Resource Forecasting (RRF) expansion reflects Local Resource Zones (LRZ) that make up MISO Midwest (LRZ 1 – LRZ 7).
  - Enabled RRF capacity reflects RRF resources enabled by LRTP transmission, meaning those resources have > 5% Dfax for LRTP transmission resolved reliability issues.
  - Utilizes costs of LRTP transmission enabled capacity to infer avoided capital cost of local resources savings.

\[
\text{Adjusted Capital Cost}_{LBA \text{ Expansion}} = \sum_{\text{Year 2040}}^{\text{Year 2020}} \text{Enabled RRF Capital Cost}_{Region \text{ Expansion}} \times \frac{\sum_{LRZ=1}^{7} (\text{Total RRF Capacity}_{LBA \text{ Expansion}})}{\sum_{LRZ=1}^{7} (\text{Total RRF Capacity}_{Regional \text{ Expansion}})}
\]

\[
\text{Avoided Capital Cost of Local Resource Investments} = \text{Adjusted Capital Cost}_{LBA \text{ Expansion}} - \text{Enabled RRF Capital Cost}_{Region \text{ Expansion}}
\]
Avoided capital costs of local resource investments benefit

\[ \text{Adjusted Capital Cost}_{LBA \text{ Expansion}} = \sum_{\text{Year } 2020}^{\text{Year } 2040} $15.66B \times \frac{90,969 \text{ MW}}{43,431 \text{ MW}} = $34.56B \]

\[ \text{Avoided Capital Cost of Local Resource Investments} = $34.56B - $15.66B = $17.05B \]

- LRTP enables regional resource sharing and reduces local overbuild yielding a 20-year present value benefit of $17.0B*
C. Avoided Transmission Investment

Transmission investment is avoided by developing regional solutions vs incremental fixes

- Captures the avoided cost of reliability upgrades and replacements that will not be required in the future as a result of the addition of LRTP projects
- Includes facilities where thermal loading is approaching the rating but not overloaded
  - Avoided reliability upgrades are determined by using the 10-year and 20-year analysis results to project future loading on facilities loaded near the rating with and without LRTP projects

\[
\text{Flow}_{\text{proj}} = \text{Flow}_{20} + (\text{Flow}_{20} - \text{Flow}_{10})
\]

Example: Facility is included in avoided costs of future transmission investment

<table>
<thead>
<tr>
<th>Line name</th>
<th>kv</th>
<th>RatingMVA</th>
<th>case</th>
<th>Flow10</th>
<th>Flow20</th>
<th>Flowproj</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest - Valley 161kV</td>
<td>161kV</td>
<td>335</td>
<td>w/o LRTP</td>
<td>324</td>
<td>331</td>
<td>338</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>w/ LRTP</td>
<td>315</td>
<td>322</td>
<td>329</td>
</tr>
</tbody>
</table>

- Includes replacement of existing facilities due to age and condition that would not be required because the LRTP projects use existing ROW of aging facilities
Re-use of existing ROW for LRTP projects offsets the costs of age and condition replacement of aging facilities

- The LRTP Tranche 1 portfolio of projects potentially use 750 miles of existing facilities where age and condition of the facilities is expected to require replacement of assets
- Construction of LRTP on the existing right-of-way would include replacement of existing structures and equipment that would avoid the future cost of replacing the existing facilities
Transmission investment is avoided by developing regional solutions vs incremental fixes

- Avoided transmission investment uses exploratory cost estimates based on type of facility improvement required.
- Like in the 2011 MVP business case, an adjustment is applied to avoided reliability upgrades >=345kV to reduce value by 50% to account for potential production cost benefits provided by the upgrades.
- Capital investment for future transmission is assumed to be spread equally over the 5-year period prior to the in-service date (2040) of the avoided reliability upgrades.
- The Annual Transmission Revenue Requirement was calculated to obtain the 20-year net present value discounted to 2022$ values.

### Facility Improvement Type

<table>
<thead>
<tr>
<th>Facility Improvement Type</th>
<th>Unit Cost ($M)</th>
<th>Quantity/Miles</th>
<th>Cost ($M)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bustie Replacement</td>
<td>$1.50</td>
<td>2</td>
<td>$3</td>
</tr>
<tr>
<td>Transformer Replacement 345</td>
<td>$5.00</td>
<td>7</td>
<td>$35</td>
</tr>
<tr>
<td>Transformer Replacement &lt;345</td>
<td>$3.00</td>
<td>5</td>
<td>$15</td>
</tr>
<tr>
<td>Transmission line Rebuild 345kV (per mile)</td>
<td>$2.65</td>
<td>38.2</td>
<td>$78</td>
</tr>
<tr>
<td>Transmission line Rebuild &lt;345kV (per mile)</td>
<td>$1.60</td>
<td>1034.9</td>
<td>$1,656</td>
</tr>
<tr>
<td>Transmission line upgrade 345kV (per mile)</td>
<td>$0.56</td>
<td>301.2</td>
<td>$84</td>
</tr>
<tr>
<td>Transmission line upgrade &lt;345kV (per mile)</td>
<td>$0.34</td>
<td>195.5</td>
<td>$66</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>$1,938</strong></td>
</tr>
</tbody>
</table>

*MISO Estimates
LRTP provides benefits by eliminating the need for other transmission projects

- LRTP avoids the need for transmission investment that yields 20- to 40-year present value benefits from $1.4B to $2.0B*
The resource adequacy benefits are related to an increase in transfer capability and a reduction in the total LCR* 

- As LRTP increases the transfer capability within the footprint, the increase in transfer limit is quantified.
- The potential economic value unlocked by the availability of least-cost resources across the footprint due to increase in transfer capability is estimated.
- A two-step process was developed to quantify the LCR reduction benefits and approximate the monetary value.
Step 1: Perform a transfer analysis to determine the LCR for each local resource zone (LRZ)

1. Calculate the capacity import limit (CIL) for each LRZ and case*  
   - Determine the import limit (e.g., TrLim) for each LRZ and study case  
   - Determine the area interchange for each LRZ and study case

2. Determine the LCR for each LRZ and case*  
   - The LRR UCAP** percentages from the PY22-23 LOLE Study and the 2040 non-coincident peak load forecasts are used to set the LRR for each LRZ

<table>
<thead>
<tr>
<th>Local Resource Zone</th>
<th>CIL (Base)</th>
<th>CIL (With LRTP)</th>
<th>Delta CIL (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LRZ1</td>
<td>5412</td>
<td>6070</td>
<td>658</td>
</tr>
<tr>
<td>LRZ2</td>
<td>4188</td>
<td>5223</td>
<td>1035</td>
</tr>
<tr>
<td>LRZ3</td>
<td>5062</td>
<td>6453</td>
<td>1391</td>
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<tr>
<td>LRZ4</td>
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<td>492</td>
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<tr>
<td>LRZ5</td>
<td>6131</td>
<td>6183</td>
<td>52</td>
</tr>
<tr>
<td>LRZ6</td>
<td>6005</td>
<td>6171</td>
<td>166</td>
</tr>
<tr>
<td>LRZ7</td>
<td>3367</td>
<td>4659</td>
<td>1292</td>
</tr>
</tbody>
</table>

*With and without LRTP projects (14 total cases) | **Unforced capacity
Step 2: Monetize the benefits identified in Step 1

1. The 2040 unforced capacity for each LRZ is determined using forced outage rates (thermal) and ELCC* (non-thermal)

2. The excess capacity within each LRZ is calculated as follows:
   - Excess Capacity = 2040 Unforced Capacity – LCR (without LRTP)

3. The RA benefit is estimated as follows:
   - If Excess Capacity < 0 → Benefit = (CONE**) x (-Excess Capacity)
   - If Excess Capacity > 0 → Benefit = $0/year

<table>
<thead>
<tr>
<th>LRZ</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>PY22-23 CONE ($/MW-yr)</td>
<td>$91,270</td>
<td>$89,490</td>
<td>$86,380</td>
<td>$90,300</td>
<td>$97,190</td>
<td>$89,040</td>
<td>93,770</td>
</tr>
</tbody>
</table>

* Effective Load Carrying Capability | ** Cost of new entry
The annual economic benefits related to resource adequacy are estimated to be $44M per year.

- LRTP reduces the total LCR and yields 20- to 40-year present value benefits from $515-$681M*.

* using a 6.9% Discount Rate
LRTP transmission can reduce risk of load shedding due to unplanned generation events

- Large scale unexpected loss of generation in an area presents a risk of significant load shedding
- Transmission reinforcements provided by LRTP increase transfer capability to allow load to be served from resources located in other areas
- Benefits are associated with avoided risk of load shedding focus on risks of large-scale generation loss caused by severe weather
  - Renewable production is dependent on weather conditions
  - Thermal resources have operational limitations under extreme temperature conditions
- Weather-related events occur in various scales
  - Event scenarios examine generation and load balance after loss of significant resources to determine if import capability is sufficient to cover generation deficiency
  - Risk of load shedding exists where generation deficiency cannot be covered by existing import capability
- Benefits are calculated using Value of Lost Load (VOLL) ranging from $3500-$23,000* /MWh

Severe winter weather events have been occurring at regular intervals over the past 40 years.

More recent extreme winter events (e.g., Uri) have brought operational challenges caused by unplanned generation outages.

Weather conditions affect the availability of resources

- Generation capacity events have become more common in recent years with the existing resource fleet.

- Weather impacts will become more significant with greater dependency on renewable resources and gas-fired dispatchable resources.

- Renewable resources regularly experience periods of low output lasting several hours.

Data Source: MISO Historical Hourly Wind. [https://www.misoenergy.org/markets-and-operations/real-time--market-data/market-reports/#nt=62FMARetReportType%3ASummary&t=10&p=0&sc=MarketReportPublished&sd=desc](https://www.misoenergy.org/markets-and-operations/real-time--market-data/market-reports/#nt=62FMARetReportType%3ASummary&t=10&p=0&sc=MarketReportPublished&sd=desc)
E. Avoided Risk of Load Shedding

LRTP transmission can reduce risk of load shedding due to unplanned loss of generation due to severe winter weather events

### Area/Zonal Event Scenario

Generation Loss:
- Thermal: 40% \(P_{\text{max}}\), Wind: 90% of \(P_{\text{max}}\), Solar 50% of \(P_{\text{max}}\)
- Load Forecast margin: 5% margin

Import Limit: Capacity Import Limit (CIL)

For all LRZ 1-7

### Regional Event Scenario

Generation Loss:
- Thermal: 50% \(P_{\text{max}}\), Wind: 90% of \(P_{\text{max}}\), Solar 50% of \(P_{\text{max}}\)
- Load Forecast margin: 5% margin

Import Limit: Total Transfer Capability

#### Scenario 1:
- Source: MISO Zones 4-7 + PJM
- Sink: MISO Zones 1-3 + SPP

#### Scenario 2:
- Source: MISO Zones 1-3 + SPP
- Sink: MISO Zones 4-7

### Load Loss Calculation

Let
- \(\text{LoadLossMW} \) be the load loss in MW
- \(\text{GenMW}_{\text{cap}}\) be the generation capacity in MW
- \(\text{GenMW}_{\text{loss}}\) be the generation loss in MW
- \(\text{LoadMW}\) be the load in MW
- \(\text{TxLossMW}\) be the transmission loss in MW

\[\text{LoadLossMW} = \text{GenMW}_{\text{net}} - 1.05 \times \text{LoadMW} - \text{TxLossMW} + \text{Capacity Import Limit (MW)}\]

where
- \(\text{GenMW}_{\text{net}} = \text{GenMW}_{\text{cap}} - \text{GenMW}_{\text{loss}}\)
Risk of load shedding is assumed to occur every three years based on the frequency of severe winter weather events.
E. Avoided Risk of Load Shedding

Value of avoided risk of load shedding is determined by applying the Value of Lost Load (VOLL)

\[
\text{Avoided Risk of Load Shed Value($)} = \text{VOLL} \times \text{LoadLossMW} \times \text{duration(hrs)}
\]

where VOLL – Value of Lost Load: $3500- $23,000*

LRTP reduces risk of load shedding and provides 20-40 year net present value benefits of $1.4B to $13.2B**


** using a 6.9% Discount Rate
MISO has developed a carbon price range to capture LRTP’s long-term benefits of reducing CO$_2$ emissions by enabling reliable delivery of low-cost, clean energy.

- Calculate emissions reduced between LRTP Reference Case and LRTP Change Case used for the congestion and fuel cost savings benefit metric.
- Convert to metric tons.
- Using 2.5% annual inflation and discount rates below, apply range of carbon costs to calculate 20- and 40-year NPV of reduced carbon emissions.

20-Year CO$_2$ Emissions Reduced: 400M metric tons
40-Year CO$_2$ Emissions Reduced: 639M metric tons

<table>
<thead>
<tr>
<th>Carbon Cost ($/metric ton)</th>
<th>6.9% Discount Rate</th>
<th>3% Discount Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MN PUC (Min)</td>
<td>Federal (Max)</td>
</tr>
<tr>
<td>2022$</td>
<td>$12.55</td>
<td>$49.51</td>
</tr>
<tr>
<td>20-Year Benefit (2022$, M)</td>
<td>$3,449</td>
<td>$13,608</td>
</tr>
<tr>
<td>40-Year Benefit (2022$, M)</td>
<td>$4,341</td>
<td>$17,125</td>
</tr>
</tbody>
</table>

Prices converted to 2022$. Full range of carbon prices demonstrated in previous workshops. 20-year and 40-year benefits = projects’ in-service value to 2050 and 2070, respectively. Emissions data interpolated between PROMOD model years 2030, 2035, and 2040; and extrapolated post-2040.
F. Decarbonization

LRTP Change Case illustrates the emissions reduced through enabled resources

40-Year Emissions, LRTP Reference & Change Cases

- LRTP Reference Case
- LRTP Change Case

20-Year CO\textsubscript{2} Emissions Reduced: 400M metric tons
40-Year CO\textsubscript{2} Emissions Reduced: 639M metric tons

Emissions data interpolated between PROMOD model years 2030, 2035, and 2040; and extrapolated post-2040.
With the price range considered, Decarbonization benefits range from $3.4B to $29B over 40 years of project life.
LRTP Tranche 1 portfolio allows reliable delivery of energy from future resource portfolio to serve load across the footprint

Reliability analysis was performed to assess the impact of the LRTP projects on steady state system performance

- Thermal and voltage issues were mitigated by the LRTP projects under base conditions reflecting varying load and dispatch patterns
- Additional upgrades were identified to mitigate issues resulting from the addition of LRTP projects

Transfer Analysis

- Improvements in transfer capability allows energy requirements to be met under varying dispatch patterns driven by differences in weather conditions across the Midwest subregion
- LRTP projects provide more robust interconnection to improve system stability during periods of heavy power transfers
MN-Dakotas Reliability Needs Addressed

Jamestown - Ellendale 345kV, Big Stone South – Cassie’s Crossing 345kV
- Assists in transport of energy out of Dakotas toward central MN and Twin Cities area
- Strengthens the existing weak 230kV system to improve connections between 345kV systems to improve long distance movement of power
- Relieves 83 elements with severe overloads observed in the Dakotas and Western MN
- Performs better than other six alternatives removing almost all existing congestion with only minimal new congestion.

Iron Range - Benton County – Cassie’s Crossing 345kV
- Provides low impedance path from Northern to Central Minnesota improving Voltage stability and transfer performance with >10% increase in Manitoba Import limit performing better with higher capacity and lower cost than the four other alternatives
- Relieves 30 elements with excessive overloads in the Dakotas and Northern MN area.
MN-WI Reliability Needs Addressed

Wilmarth - N. Rochester – Tremval - Eau Claire - Jump River
Tremval – Rocky Run – Columbia 345kV
- Provides outlet for renewables located in Minnesota
- Congestion relief and raises stability limit by 250MW to increase transfer capability on the MN-WI interface
- Improves connectivity to serve load centers
- Relieves 40 elements with N-1 heavy loading and severe overloads in MN and WI and 97 elements for N-1-1 contingencies
Central Iowa Reliability Needs Addressed

Webster-Franklin-Marshalltown-Morgan 345kV
Beverly-Sub92 345kV
• Provides outlet for renewables located in IA and SW Minnesota
• Provides corridor for delivery of energy to load centers in central portions of MISO
• Addresses 21 elements with N-1 heavy thermal loading and severe overloads in Iowa and 34 elements for N-1-1 contingencies
Reliability Needs Addressed

Madison – Ottumwa – Skunk River – Ipava – Maple Ridge 345kV
Tazewell – Brokaw - Paxton – Gilman – Morrison – Reynolds – Hiple – Duck Lake 345kV
Paxton – Sidney 345kV
Oneida – Nelson Road 345kV

• Delivers significant increase in transfer capability to support generation deficient areas due to unexpected decrease in renewable output
• Mitigates 28 thermal overloads in Michigan, 16 thermal overload in Indiana, 19 thermal overloads in Missouri and Illinois, 14 thermal overloads in Iowa
• Provides more robust performance under large shifts in dispatch of generation across the region
Missouri Reliability Needs Addressed

Orient – Fairport – Zachary – Maywood – Meredosia 345kV
Zachary – Thomas Hill 345kV

• Provides increased transfer capability of 250MW West-to-East and 438MW MISO-to-Michigan to address voltage collapse conditions in Missouri

• Mitigates heavy loading and severe overloads on 19 elements for N-1 and N-1-1 contingencies

• Provides more robust performance under large shifts in dispatch of generation across the region addressing 14 thermal overloads
Transmission investment provides other qualitative benefits that support the LRTP Tranche 1 business case

- An increasingly connected system is needed to balance generation resource variability across an increasingly heterogeneous footprint.
- Additional transmission reinforcements provided by LRTP increases the ability of the system to manage the increasing different regional flows and operational events without adverse impacts to system performance.

Illustration of flow changes with increasing renewable penetration spread throughout the MISO footprint (MISO Renewable Integration Impact Assessment (RIIA) Summary Report, February 2021 [https://cdn.misoenergy.org/RIIA%20Summary%20Report520051.pdf](https://cdn.misoenergy.org/RIIA%20Summary%20Report520051.pdf))
Transmission investment provides other qualitative benefits that support the LRTP Tranche 1 business case

- Increased transmission capacity better leverages the geographic and fuel diversity of the broader footprint to more effectively manage dispatch variability due to changing weather patterns

Transmission investment provides other qualitative benefits that support the LRTP Tranche 1 business case

- Transmission expansion provides additional operational flexibility and allows more opportunity for planning of transmission and generation outages with less risk of operational issues or rescheduling of outages.
- Transmission expansion allows better use of the transmission network and provides more flexibility to meet changing customer needs and diverse policy goals.
Congestion and Fuel Savings Natural Gas Price Sensitivity
LRTP projects decrease system-wide impacts of natural gas volatility

- Local transmission investment cannot completely insulate electric consumers from the risks associated with fuel price volatility.
- However, LRTP projects offset the risk by providing additional congestion and fuel savings benefits under high natural gas prices by enabling renewable energy.
- Congestion and fuel savings benefits were analyzed through a series of production cost analyses, with higher natural gas cost assumptions.

A. Congestion and Fuel Savings – Natural Gas Price Fuel Sensitivity

Henry Hub Natural Gas Spot Price

- Dollars per million BTU
- Month & Year

MISO Futures used for the LRTP study utilized new natural gas price forecast methodology

- GPCM Natural Gas Market Forecasting System was used to develop forecasts instead of locked-down Henry Hub (HH) and blend of three different forecasts
- Use on base forecast gas price in EGEAS for all Futures
- Using the same assumptions, but referencing PROMOD output, create Future-specific and area-specific gas prices for use in PROMOD models
- A range of gas prices were tested on LRTP Reference and Change Case PROMOD models
Future 1 Natural Gas prices were increased by 20 – 60% for sensitivity evaluation

- When comparing to HH prices, a 20% increase was found to facilitate the best starting point, which ensures year 2040 average price is greater than HH projected price
- A 60% increase was selected as the endpoint, to create a year 2040 value that represented HH highest sale prices historically (2005 and 2008)
LRTP Tranche 1 transmission will provide greater congestion and fuel savings as natural gas price increases

A. Congestion and Fuel Savings – Natural Gas Price Fuel Sensitivity

- 20% price increase generates a $13.2B congestion and fuel savings increase
- 60% price increase generates a $21.1B congestion and fuel savings increase
Distribution of Benefits for Midwest Subregion
The benefits provided by the LRTP Tranche 1 Portfolio are distributed across the Midwest subregion in a manner commensurate with the costs.

<table>
<thead>
<tr>
<th>Cost Allocation Zones</th>
<th>Range of Benefit/Cost Ratio (20-yr Present Value, 6.9% Discount Rate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone 1</td>
<td>2.9 - 4.1</td>
</tr>
<tr>
<td>Zone 2</td>
<td>2.2 - 3.5</td>
</tr>
<tr>
<td>Zone 3</td>
<td>3.2 - 4.5</td>
</tr>
<tr>
<td>Zone 4</td>
<td>2.7 - 3.9</td>
</tr>
<tr>
<td>Zone 5</td>
<td>2.8 - 4.1</td>
</tr>
<tr>
<td>Zone 6</td>
<td>2.7 - 3.9</td>
</tr>
<tr>
<td>Zone 7</td>
<td>2.1 - 3.4</td>
</tr>
<tr>
<td>Total</td>
<td>2.6 - 3.9</td>
</tr>
</tbody>
</table>
The quantifiable benefits are distributed across all zones in the MISO Midwest subregion and aligned with cost allocation of multi-value projects.

Footprint Benefits (minimum) - 20 Year NPV, 6.9%, 2022$

<table>
<thead>
<tr>
<th>Zonal Allocation</th>
<th>Zone 1</th>
<th>Zone 2</th>
<th>Zone 3</th>
<th>Zone 4</th>
<th>Zone 5</th>
<th>Zone 6</th>
<th>Zone 7</th>
<th>Total  ($M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Congestion and Fuel Savings derived directly from PROMOD results</td>
<td>$3,117</td>
<td>$1,035</td>
<td>$2,103</td>
<td>$1,343</td>
<td>$1,477</td>
<td>$2,897</td>
<td>$1,020</td>
<td>$12,991</td>
</tr>
<tr>
<td>Avoided Capital Cost of Local Resource Investment based on load share ratio</td>
<td>$3,137</td>
<td>$2,254</td>
<td>$1,766</td>
<td>$1,762</td>
<td>$1,414</td>
<td>$3,179</td>
<td>$3,533</td>
<td>$17,047</td>
</tr>
<tr>
<td>Avoided Transmission Investment based on the upgrade’s location (80%) and a systemwide spread (20%)</td>
<td>$347</td>
<td>$160</td>
<td>$321</td>
<td>$284</td>
<td>$50</td>
<td>$87</td>
<td>$148</td>
<td>$1,398</td>
</tr>
<tr>
<td>Resource Adequacy Savings based on zonal capacity savings</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
<td>$515</td>
<td>$515</td>
</tr>
<tr>
<td>Avoided Risk of Load Loss* based on load ratio share</td>
<td>$261</td>
<td>$187</td>
<td>$147</td>
<td>$146</td>
<td>$118</td>
<td>$264</td>
<td>$294</td>
<td>$1,417</td>
</tr>
<tr>
<td>Decarbonization** based on load ratio share</td>
<td>$635</td>
<td>$456</td>
<td>$357</td>
<td>$357</td>
<td>$286</td>
<td>$643</td>
<td>$715</td>
<td>$3,449</td>
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<tr>
<td>Total Benefits</td>
<td>$7,497</td>
<td>$4,093</td>
<td>$4,695</td>
<td>$3,892</td>
<td>$3,346</td>
<td>$7,071</td>
<td>$6,224</td>
<td>$36,817</td>
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<tr>
<td>Total Costs</td>
<td>$2,610</td>
<td>$1,876</td>
<td>$1,470</td>
<td>$1,466</td>
<td>$1,177</td>
<td>$2,645</td>
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<td>$14,183</td>
</tr>
<tr>
<td>B/C</td>
<td>2.9</td>
<td>2.2</td>
<td>3.2</td>
<td>2.7</td>
<td>2.8</td>
<td>2.7</td>
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<td>2.6</td>
</tr>
</tbody>
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*VOLL=$3,500
**Carbon Price=$12.55 /metric ton
Conclusion
The LRTP Tranche 1 portfolio provides a regional transmission solution to addressing future energy needs

- For a capital investment of $10.4B, the LRTP portfolio provides $37.0B in financially quantifiable benefits over 20 years
- LRTP transmission projects enhance system performance to maintain reliable operation in future with more variability and uncertainty in energy supply
Conclusions

- The LRTP Tranche 1 portfolio reflects a cost-effective set of solutions that enable delivery of energy to support future energy requirements of the MISO customers.
- The LRTP Tranche 1 portfolio provides economic and reliability benefits that exceed the cost of the investment and are broadly distributed across the MISO Midwest subregion.
Tranche 1 approval will be delayed until July 2022 to facilitate more stakeholder review and engagement.
Questions?
Appendix
The quantifiable benefits are distributed across all zones in the MISO Midwest subregion and aligned with cost allocation of multi-value projects.

<table>
<thead>
<tr>
<th>Benefit Metric</th>
<th>CAZ Distribution Method</th>
<th>Zone 1 ($M)</th>
<th>Zone 2 ($M)</th>
<th>Zone 3 ($M)</th>
<th>Zone 4 ($M)</th>
<th>Zone 5 ($M)</th>
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</tr>
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<td>Avoided Risk of Load Loss*</td>
<td>based on load ratio share</td>
<td>$1,713</td>
<td>$1,231</td>
<td>$965</td>
<td>$962</td>
<td>$772</td>
<td>$1,736</td>
<td>$1,929</td>
<td>$9,310</td>
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<tr>
<td>Decarbonization**</td>
<td>based on load ratio share</td>
<td>$2,504</td>
<td>$1,800</td>
<td>$1,410</td>
<td>$1,407</td>
<td>$1,129</td>
<td>$2,538</td>
<td>$2,820</td>
<td>$13,608</td>
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<tr>
<td>Total Benefits</td>
<td></td>
<td>$10,819</td>
<td>$6,481</td>
<td>$6,566</td>
<td>$5,758</td>
<td>$4,844</td>
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<tr>
<td>Total Costs</td>
<td></td>
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</tr>
</tbody>
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*VOLL=$23,000
**Carbon Price=$49.51/metric ton