The Evolving MISO Grid and Multi-State Transmission

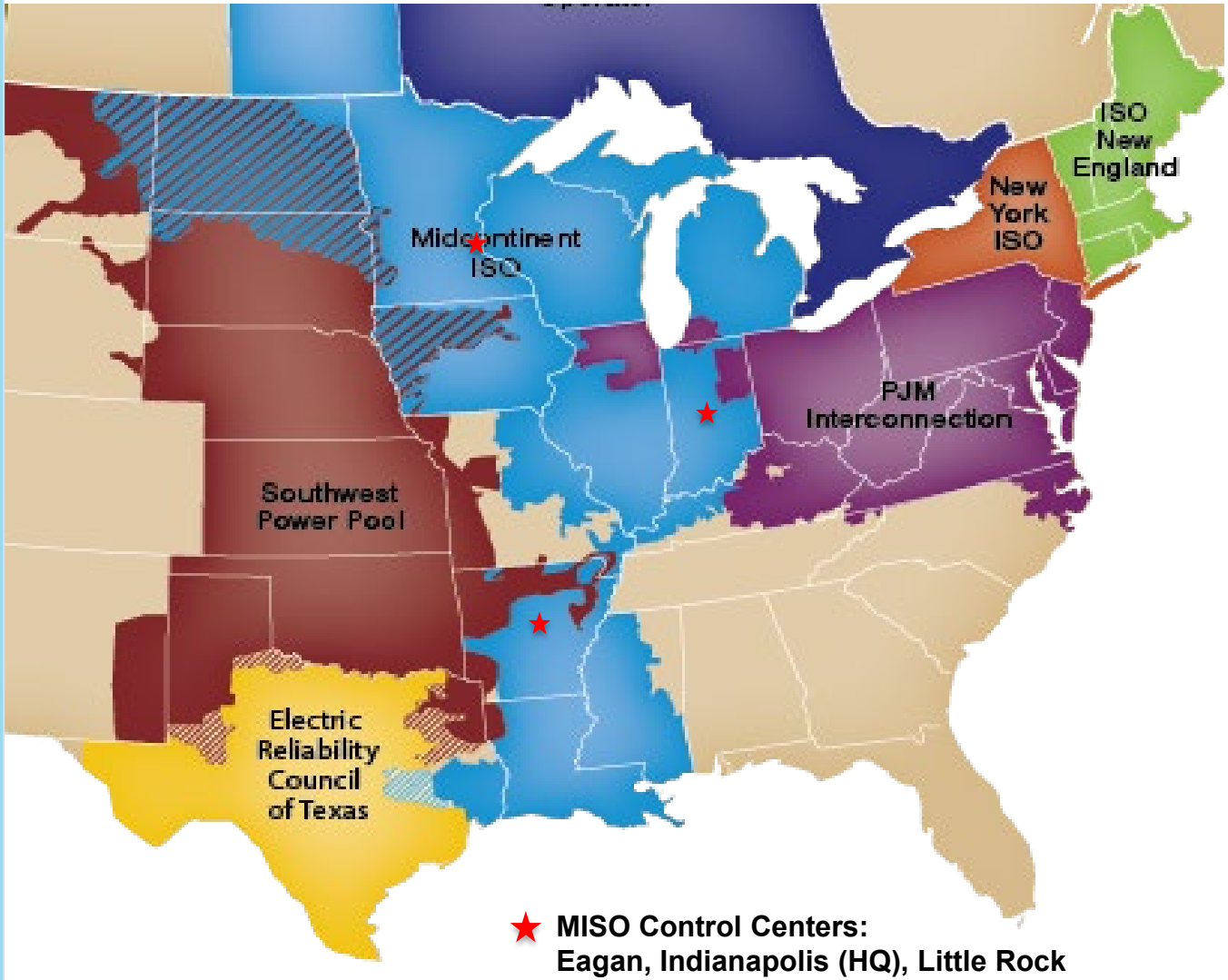
MN Legislative Energy Commission (LEC)

February 3, 2020

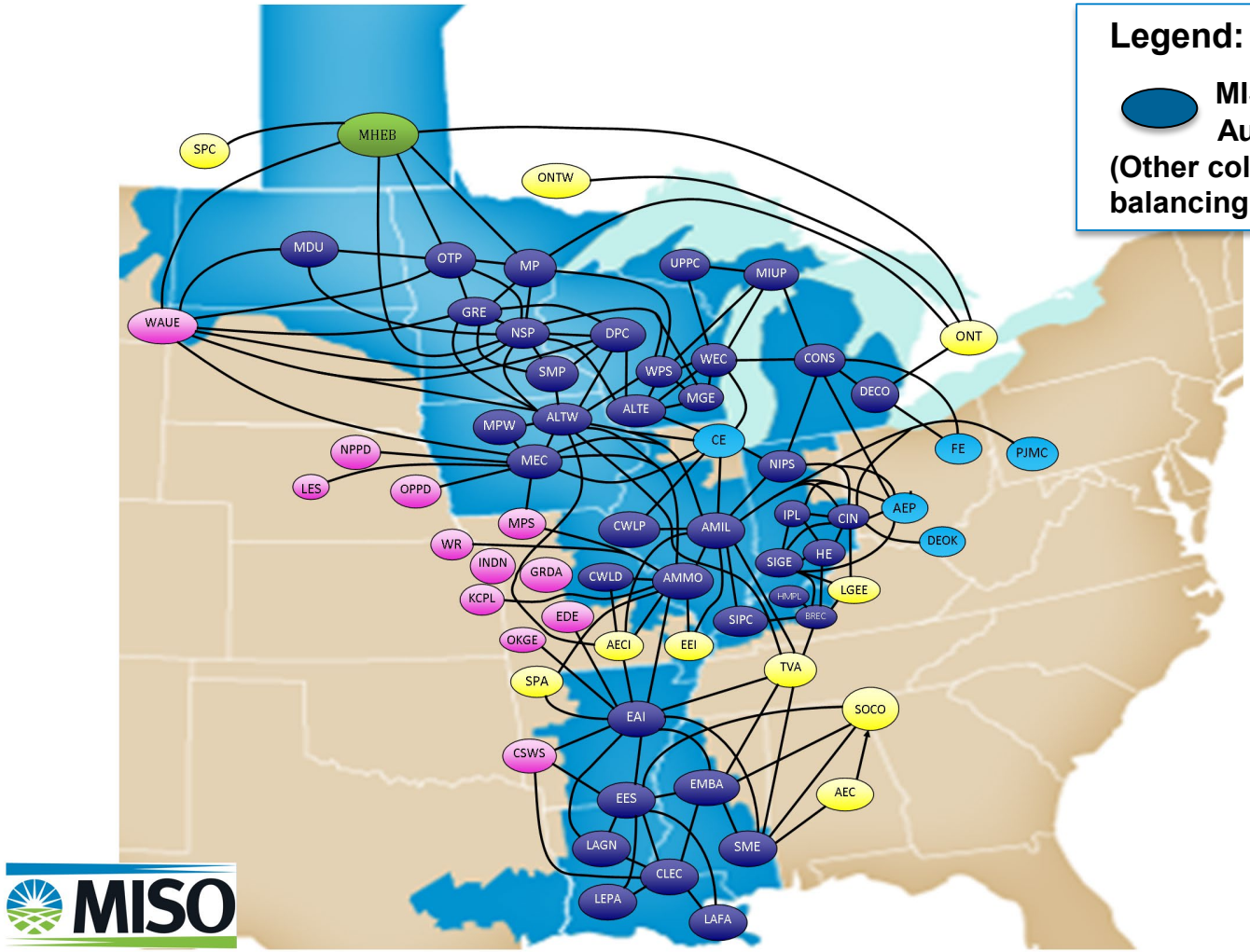
MISO & neighboring U.S. electric grid operators

MISO

- 15 states + Manitoba
- 42 million customers
- $30 billion market
- > 6,600 generation units with 175,000 MW capacity
- 72,000 miles of high voltage transmission lines
- ~ 190 member utilities
- > 460 market participants



MISO integrates dozens of 'Balancing Authorities' within MISO and coordinates with neighboring regions



Legend:

MISO utility "Balancing Authorities"

(Other colors are neighboring balancing authorities)

Illustrative of the complexity and the multi-state, interconnected nature of the grid

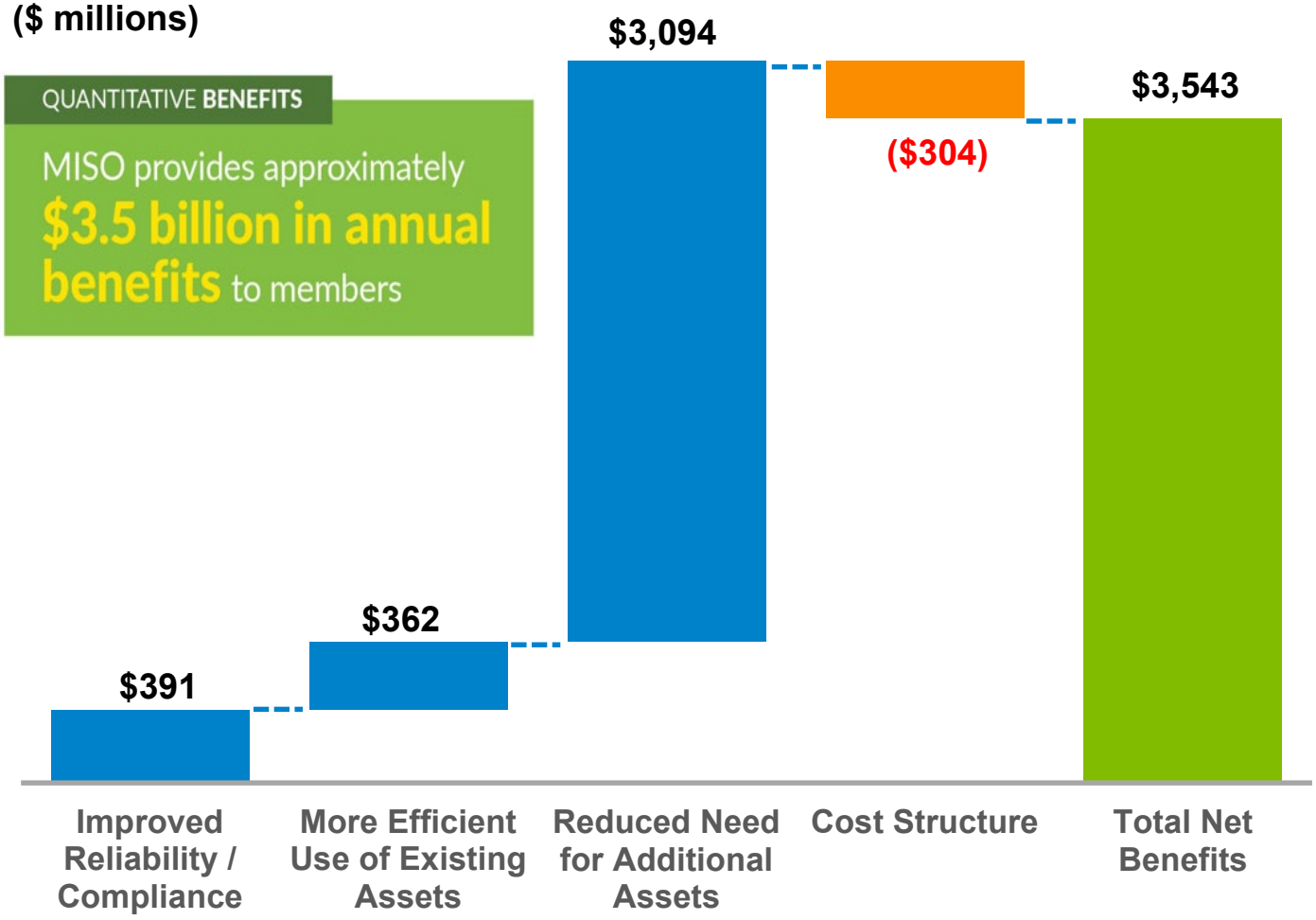
MISO Value Proposition: $3.5 billion in benefits annually, and over $23 billion since 2009

2018 Benefit by Value Driver

($ millions)

QUANTITATIVE **BENEFITS**

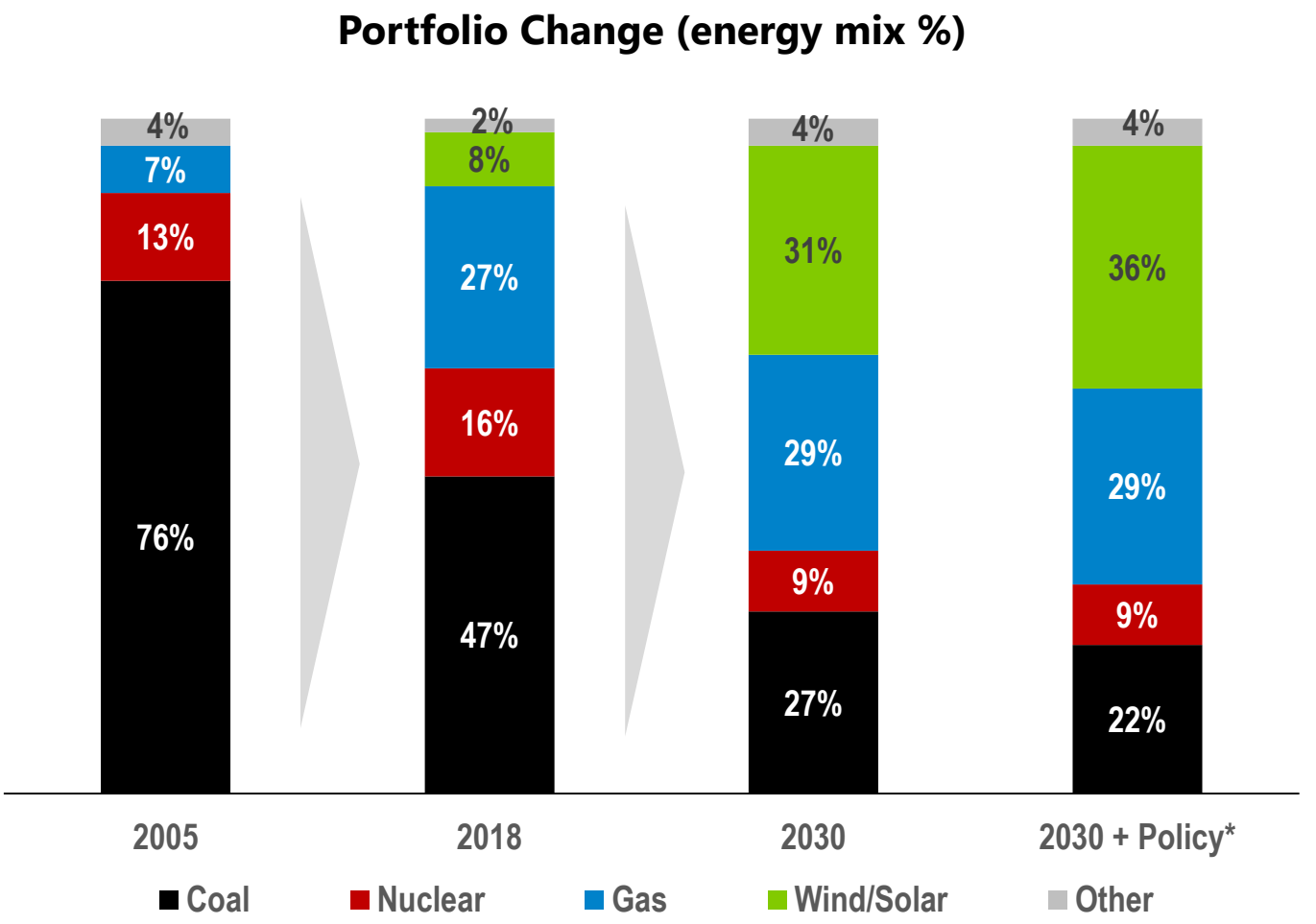
MISO provides approximately **$3.5 billion in annual benefits** to members



Cumulative Annual Benefits

$23,300 million

MISO's changing resource portfolio will remain a key influencer of the way value is created moving forward

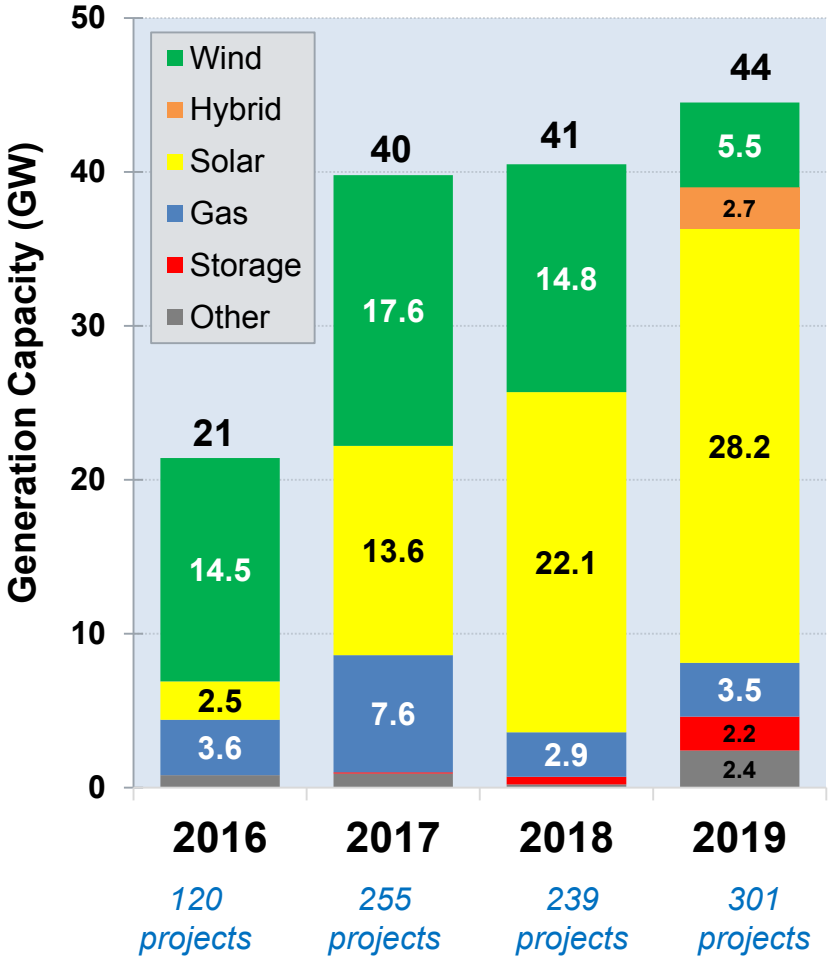


(Based on utility and state announcements)

More aggressive utility de-carbonization goals and proposed policy changes in Illinois, Minnesota and Wisconsin may further accelerate renewables penetration

The rapid increase in generator interconnection requests create system transmission capacity challenges

Projects entering MISO's Generator Interconnection Queue over the past 4 yrs

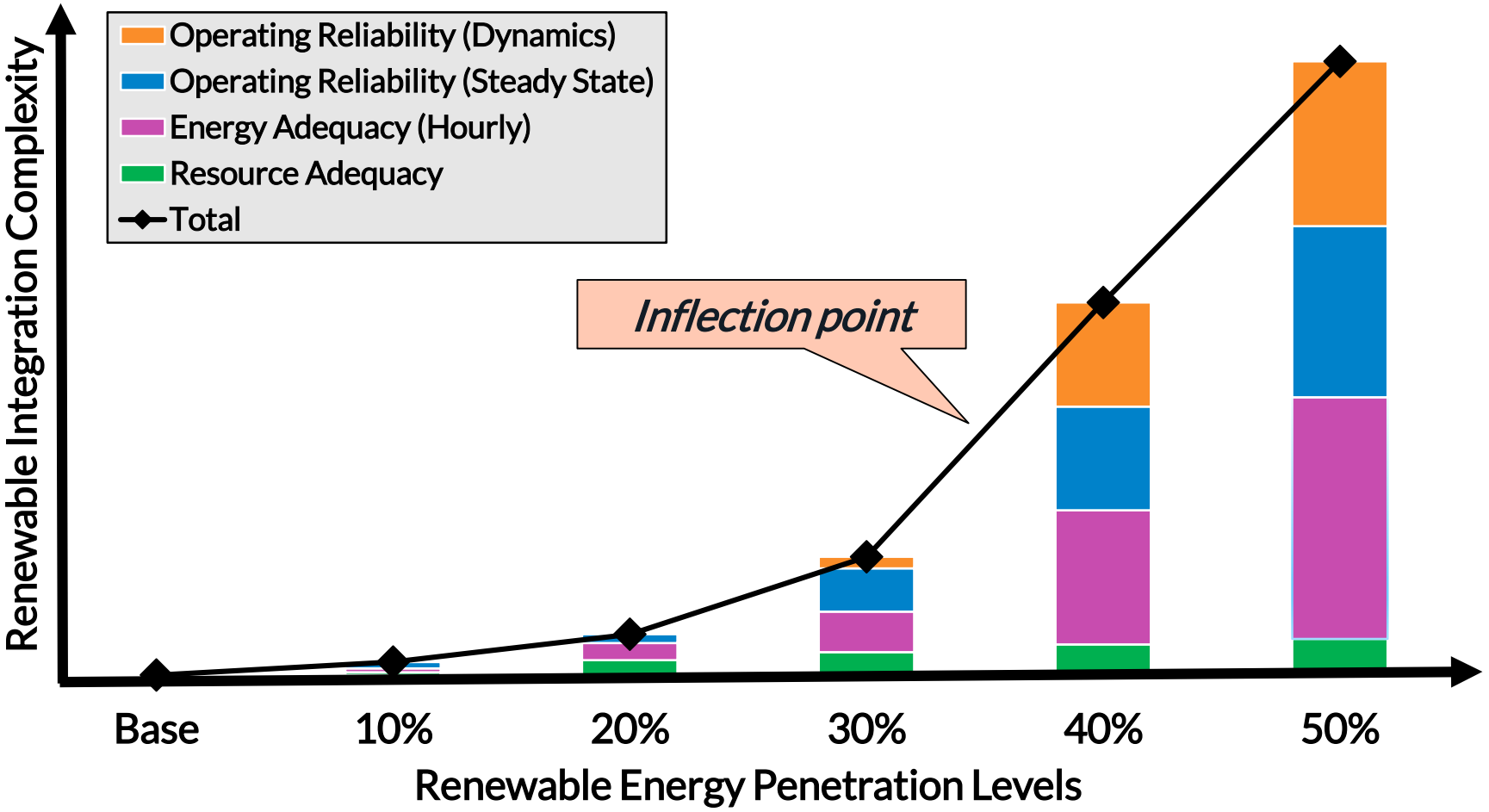


Recent experience in 'Western' MISO
(last 3 completed queue cycles)

Cycle -> *(date applied)*	Feb 2016	Aug 2016	Feb 2017
Initial upgrade costs ID'd *(Thousand $/MW)*	460	610	1,000
Capacity "In" *(GW entering)*	5.7	5.6	3.4
Capacity "Out" *(GW exiting)*	4.7	2.3	0.2
% Out *(GW exiting/ GW entering)*	80%	40%	5%

➢ ***System capacity is fully committed; new requests are 'hitting a wall'***

MISO's Renewable Integration Impact Assessment (RIIA) indicates integration complexity increasing sharply beyond 30% renewable penetration



(from RIIA Phase 1&2 Wrap-up Workshop - 11/13/2019)

The regional transmission planning process provides a comprehensive, value-based approach

Economic Planning

Scenario-based planning to provide economic and market efficiency benefits

Interconnection Planning

Evaluate long-term interconnection queue requests; identify upgrades to integrate into base expansion model

Planning Horizons
Reliability: 5 to 10 years
Economic: 15 to 20 years

Policy Planning

Long-term policy focused planning to analyze the impacts of changes in state or federal policy and industry trends; determine the transmission required to support those policies and industry trends

Reliability Planning

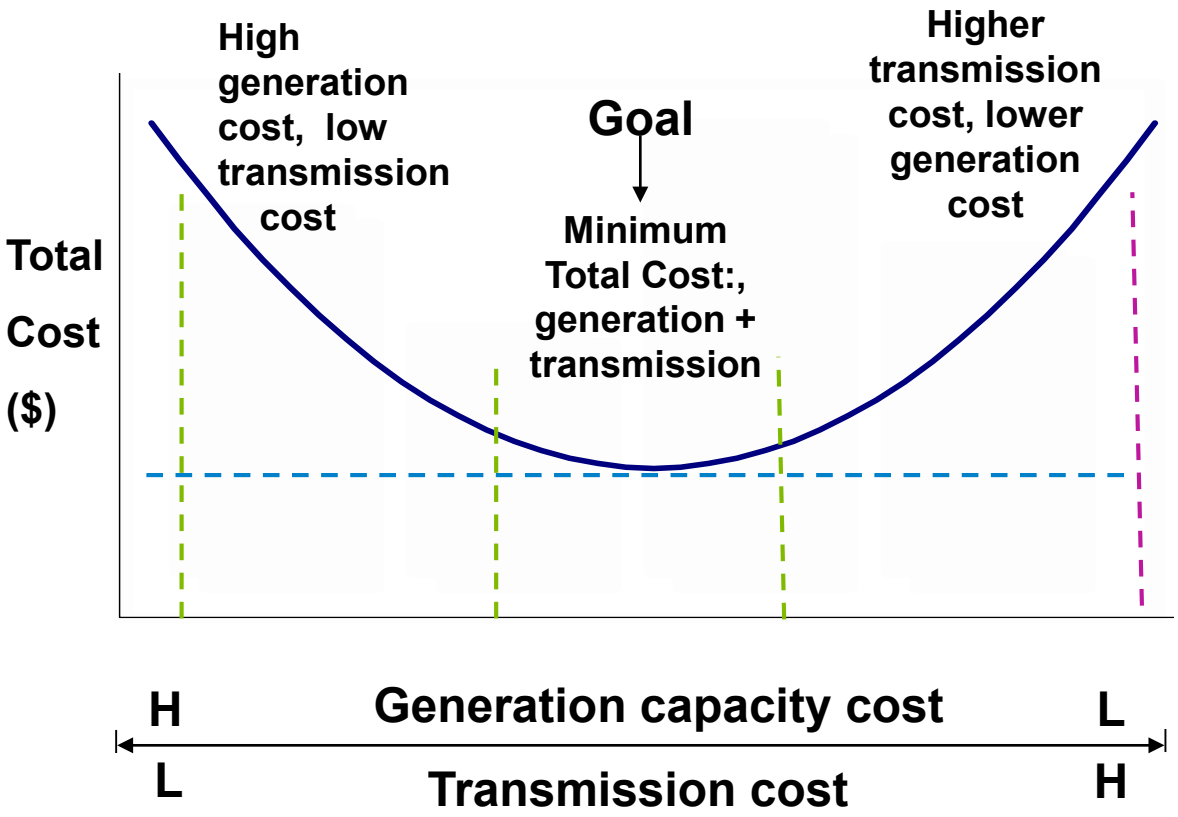
Validate needs for plans identified by the member Transmission Owners; seek efficiencies by combining plans, if possible; evaluate system against reliability standards

MISO is expanding futures to ensure wide range of possible solutions

Future #1	**Announced Plans:** The footprint develops in line with utility announcements/plans, along with State mandates, goals, or preferences.
Future #2	**Advanced Fleet Change 2.0** Changing federal & state policies reduce emissions to 50%. EV adoption increase & electrification begins and drives a 40% increase in energy demand.
Future #3	**Advanced Electrification** Changing federal & state policies will support carbon emissions reduction of 80% or more. Increased electrification occurs increasing energy demand by 70%.

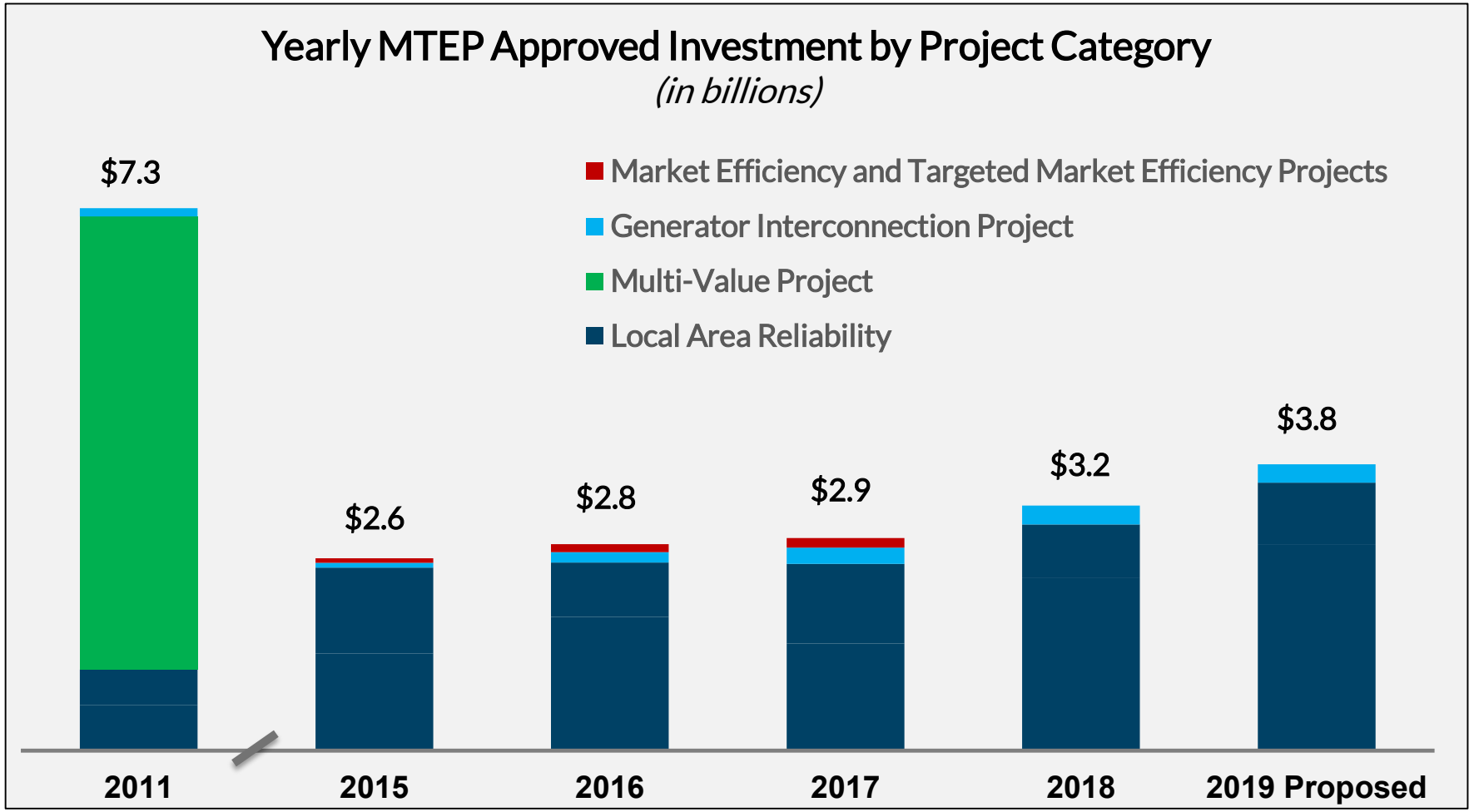
- **Futures "bookend" a range of economic, political and technological possibilities**
- **They help ensure that any new recommended transmission provides benefits and value, regardless of specific future developments**

MISO plans transmission, not generation, but minimizing total costs requires balancing generation and transmission investment



MISO's transmission planning process is focused on minimizing the total cost of delivered power to consumers: energy, capacity and transmission – to meet a given objective

Since the MVP portfolio, investment trend has been focused on shorter term reliability needs



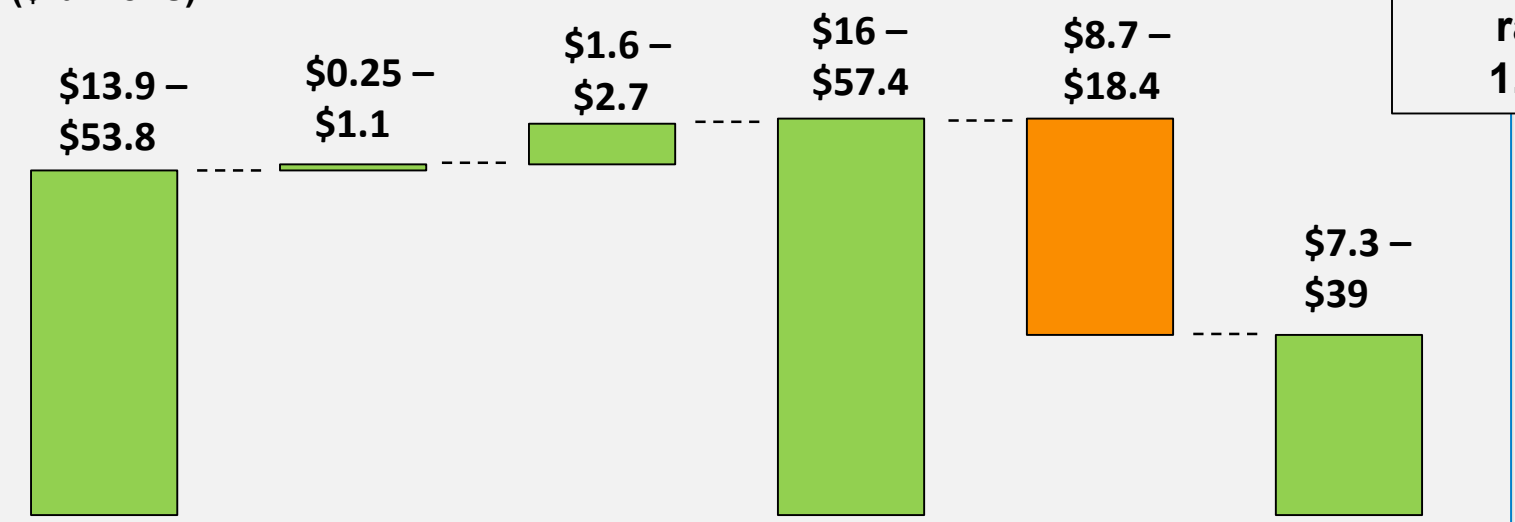
Numbers provided are as approved by the Board of Directors Dec. 2019

Local Area Reliability = MISO categories of "Other" and Baseline Reliability projects, including those based on local Transmission Owner needs for reliability, economics, equipment age and condition, environmental, etc.

MVPs continue to show value, over eight years after their approval, and are being highly utilized

MVP Benefits by Value Driver

($ billions)



- Congestion and fuel savings
- Operating reserves*

- Planning Reserve Margin
- Transmission Line Losses*

- Wind turbine investment
- Future transmission investment*

Benefit-to-cost ratios of 1.8 to 3.1

** Values were calculated in MTEP17 Triennial Review and converted to 2019$*

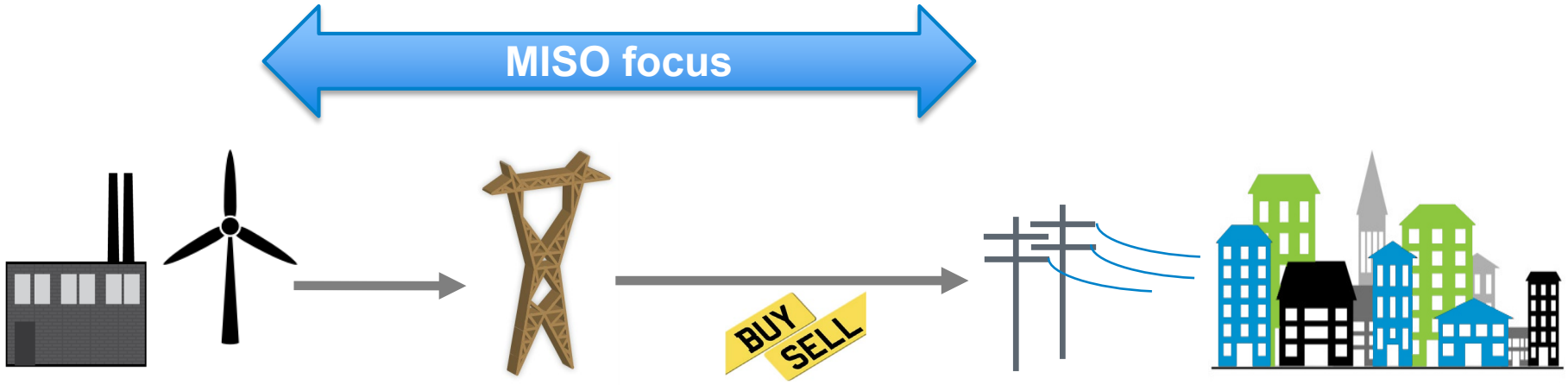
The Evolving MISO Grid

Additional pages from MISO tour and overview presented to:

MN Legislative Energy Commission

November 20, 2019

MISO members participate across the electricity value chain



Independent Power Producers (29)
- *Allete Clean Energy*
- *Apex Clean Energy*
- *Geronimo*
- *NextEra*

Competitive Transmission Developers (30)
- *ITC-Midcontinent Development*
- *LS Power*
- *Xcel Energy Transmission Development*

Transmission Owners (51)
- *Dairyland Power*
- *Great River Energy*
- *Minnesota Power*
- *MN Municipal Power Agency*
- *Otter Tail Power*
- *SMMPA**
- *Xcel Energy*

Power Marketers/ Brokers (36)
- *EDF*
- *The Energy Authority (for SMMPA*)*

Muni/Coop/ Transmission Dependent (31)
- *City of Rochester*
- *Wilmar Municipal Utilities*

Eligible End-User Customers (9)
- *ArcelorMittal USA*
- *Midwest Industrial Customers group*

MISO Members by Sector (#); *Minnesota examples*

*Southern Minnesota Municipal Power Agency

What does MISO do?

Efficient Wholesale Market Management & Operations to Ensure Reliability

- Conduct day-ahead and real-time energy and operating reserves markets
- Manage least cost economic dispatch of generation units
- Monitor and schedule energy transfers on the high voltage transmission system

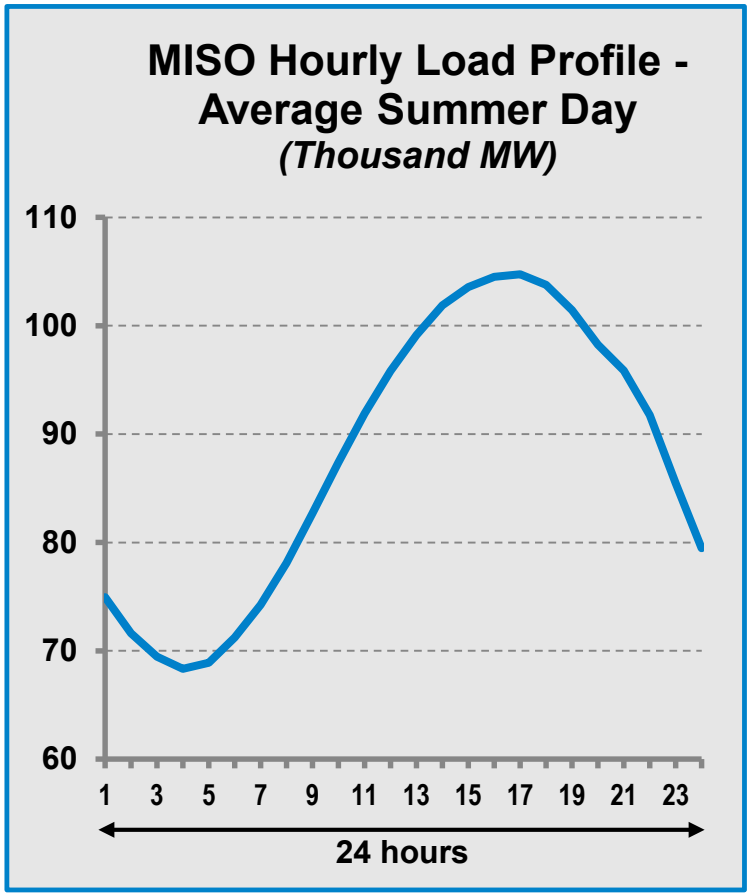
Comprehensive Regional Transmission Planning

- Long-range transmission planning
- New generator interconnection and retirement
- Long-range studies, such as Renewable Integration Impact Assessment (RIIA)

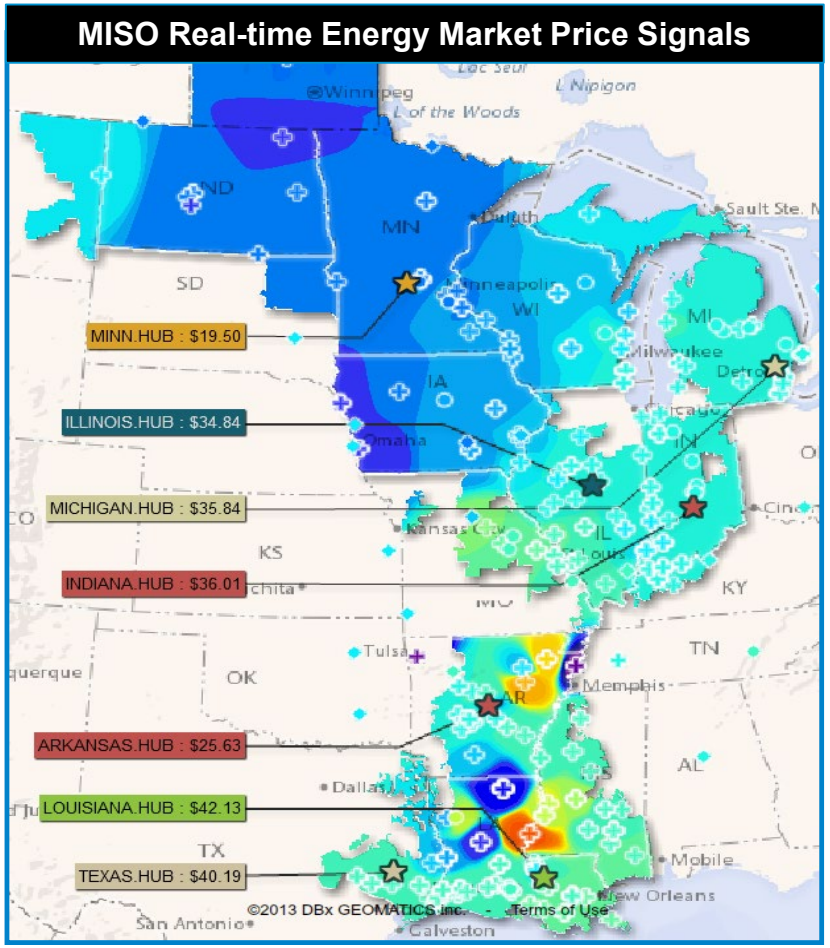
MISO's Vision: Be the most reliable, value-creating RTO

MISO conducts wholesale markets to ensure lowest costs and reliable operations

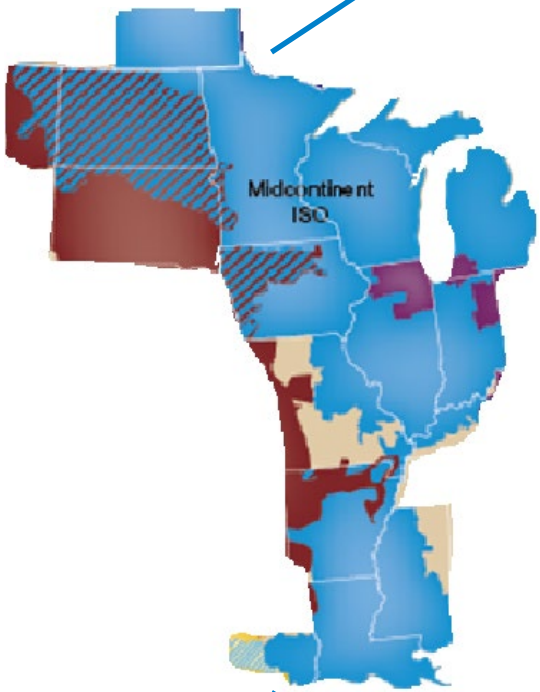
The requirement to balance demand (load) with supply (generation) instantaneously at all points on the grid…



…results in wholesale prices that can fluctuate rapidly to send timely signals to market participants.



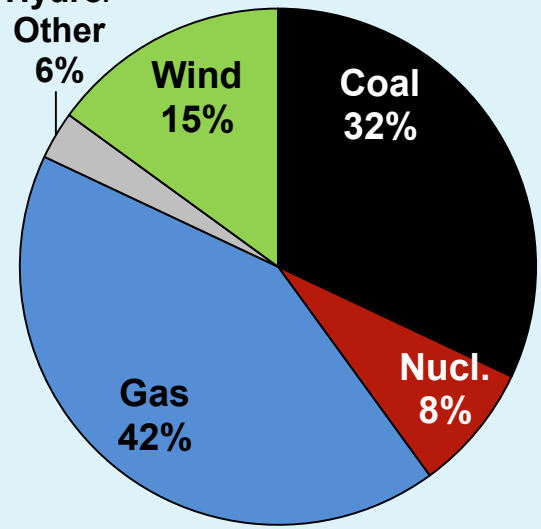
MISO connects a large, diverse generation fleet…



Total MISO, 2018

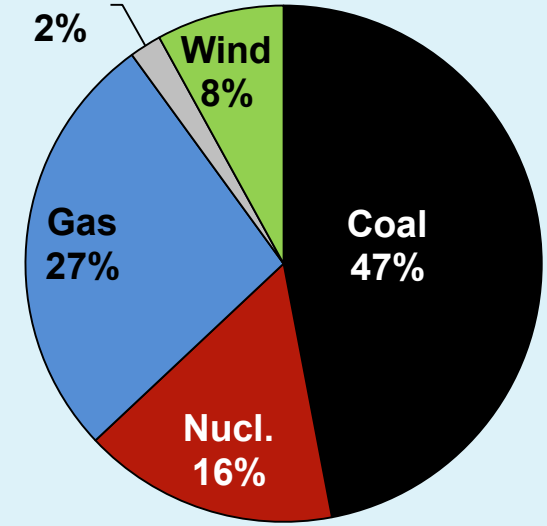
Generating Capacity

175
Thousand MW



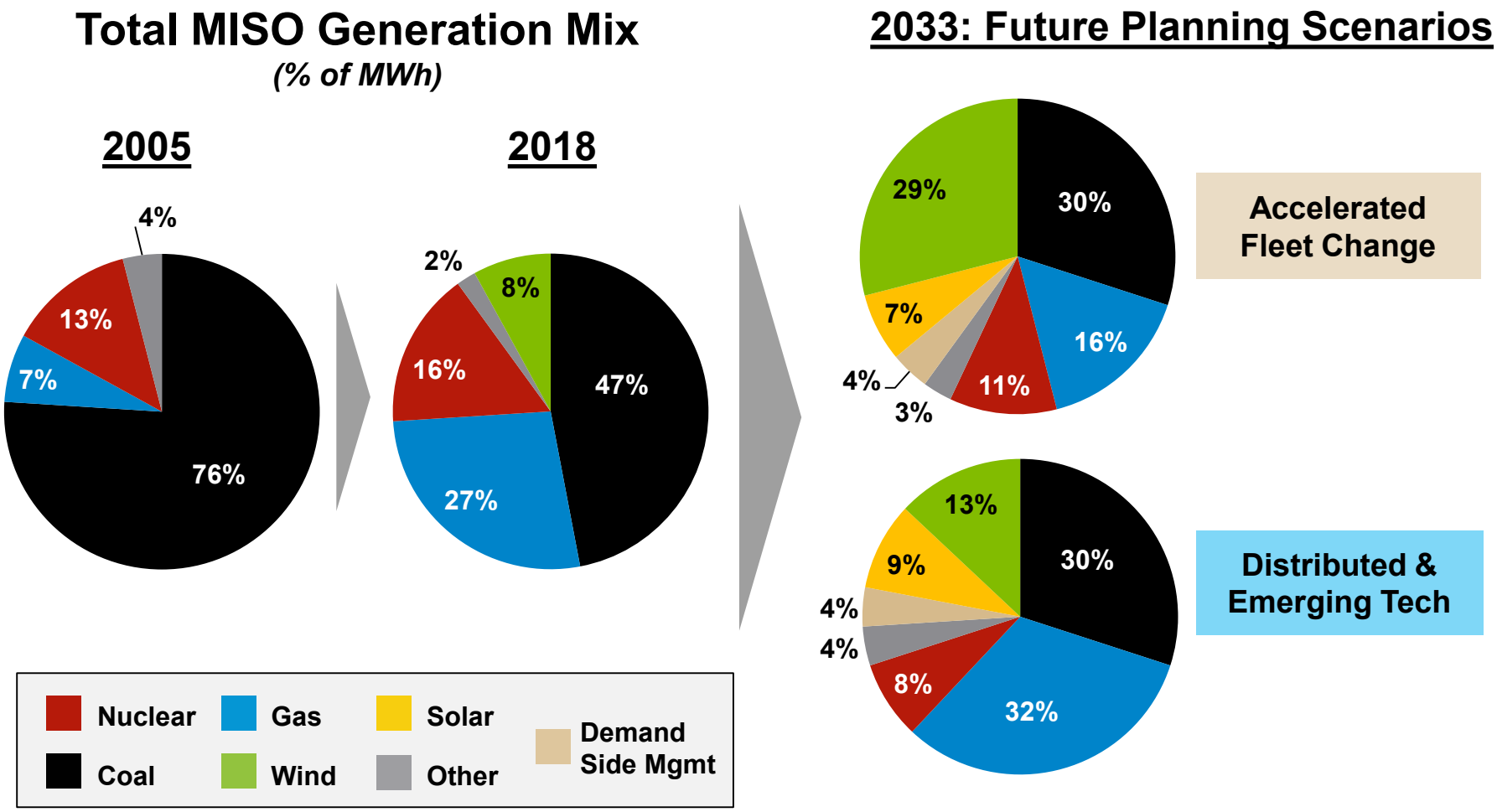
Electricity Generated

640
Million MWh



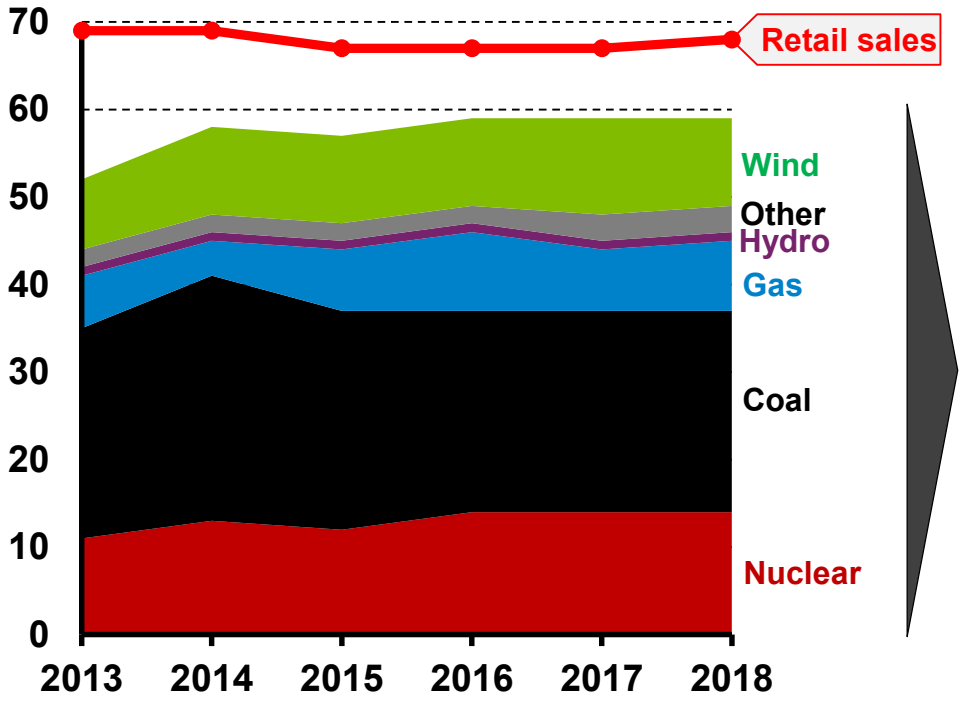
Source: Misoenergy.org website

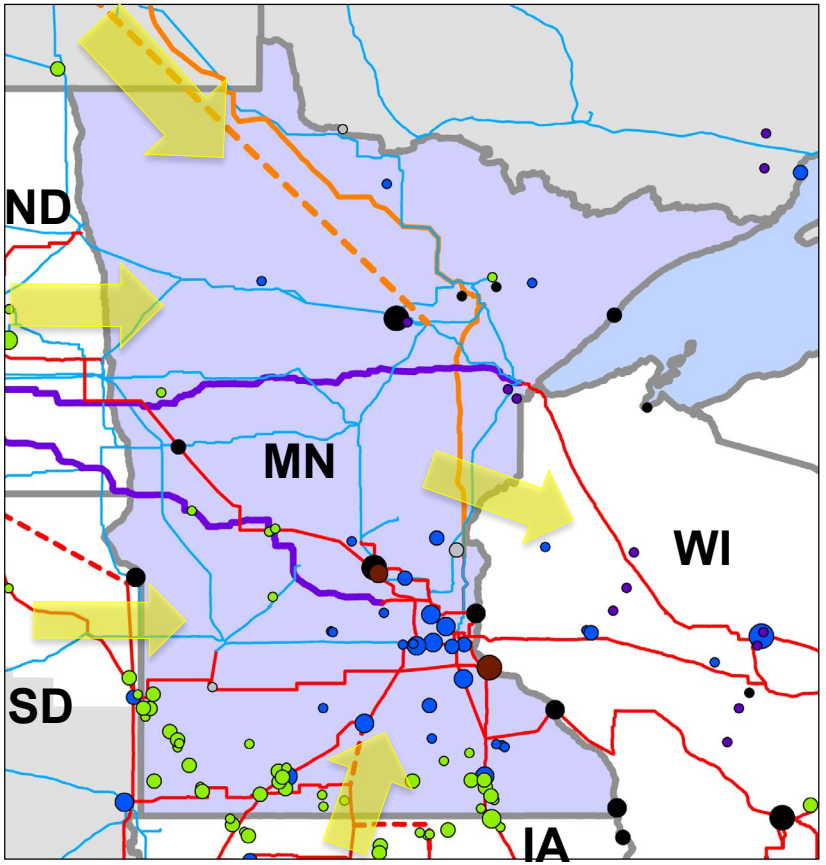
…a generation fleet which has shifted, with the pace accelerating toward more renewables and conventional unit retirement



Within MISO, the state of Minnesota is a net importer of electricity, and a "crossroads"

Minnesota "In State" Retail Sales vs. Generation ***(million MWh/yr)***



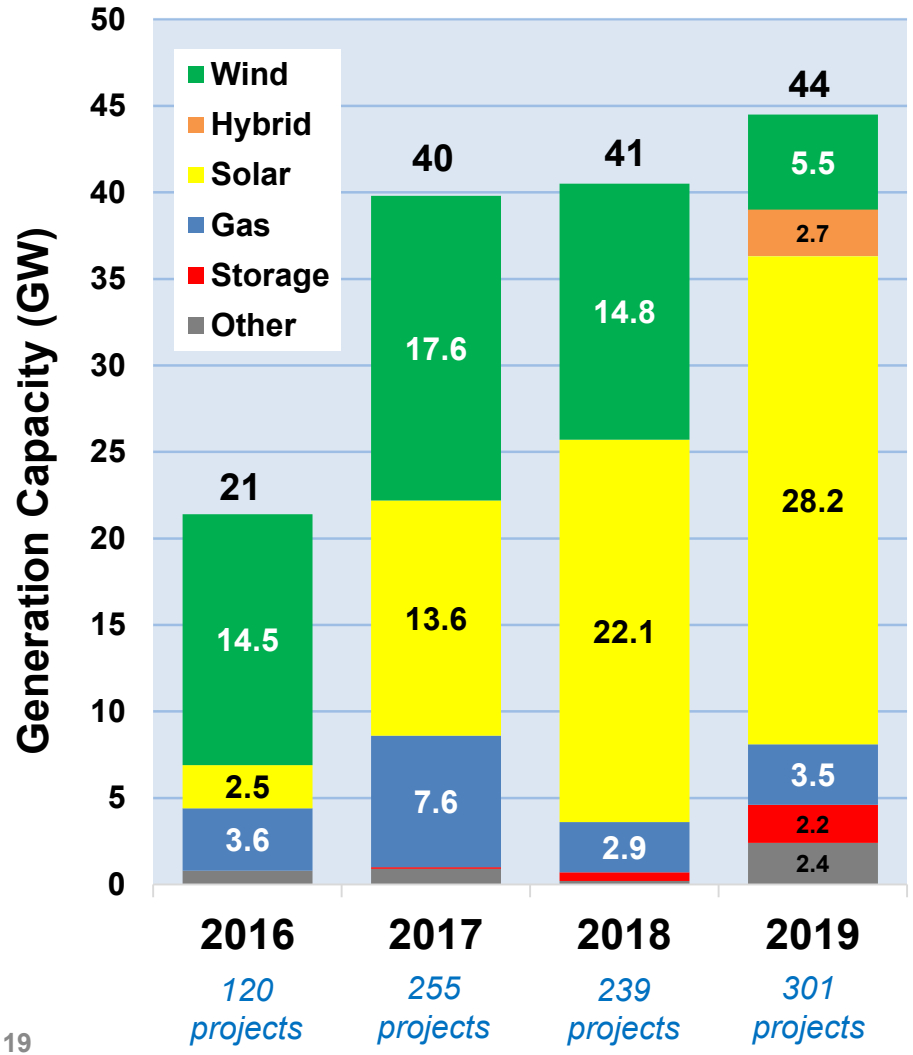


As a state, MN consumes more electricity than it generates within state borders; it is a net importer in the MISO system

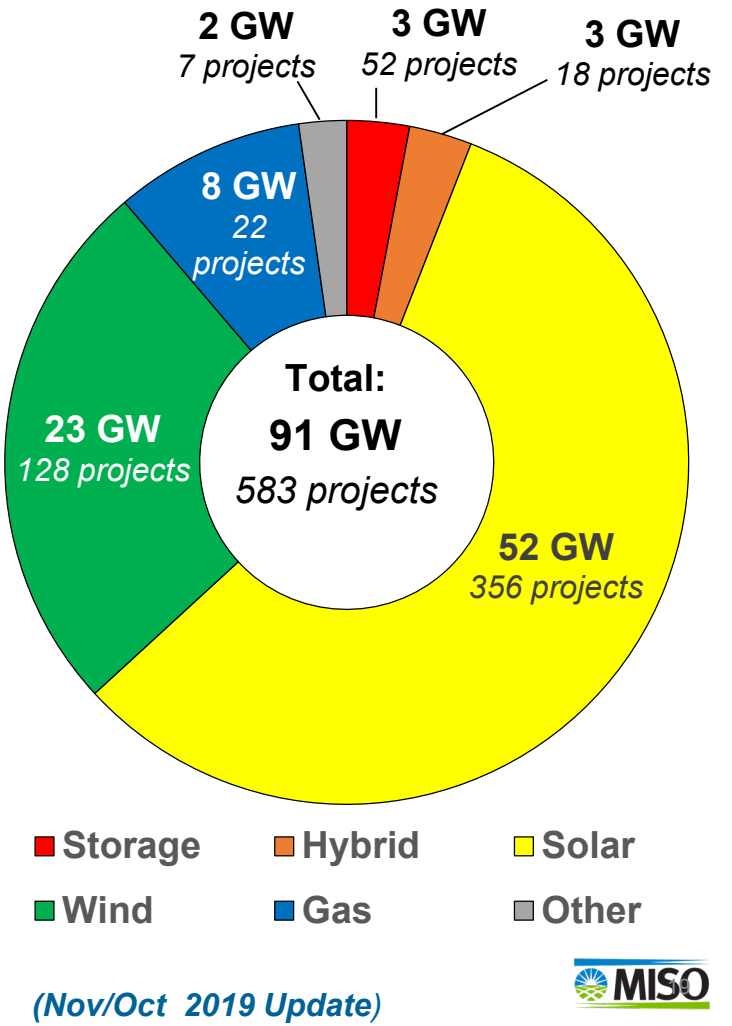
Source: US Energy Information Administration (EIA)

Renewables account for over 85% of MISO's current active generator interconnection request 'queue'

Projects entering MISO's Generator Interconnection Queue over the past 4 yrs



MISO's Current Generator Interconnection Queue (currently active projects)



(Nov/Oct 2019 Update)

Overview of MISO's Renewable Integration Impact Assessment (RIIA)

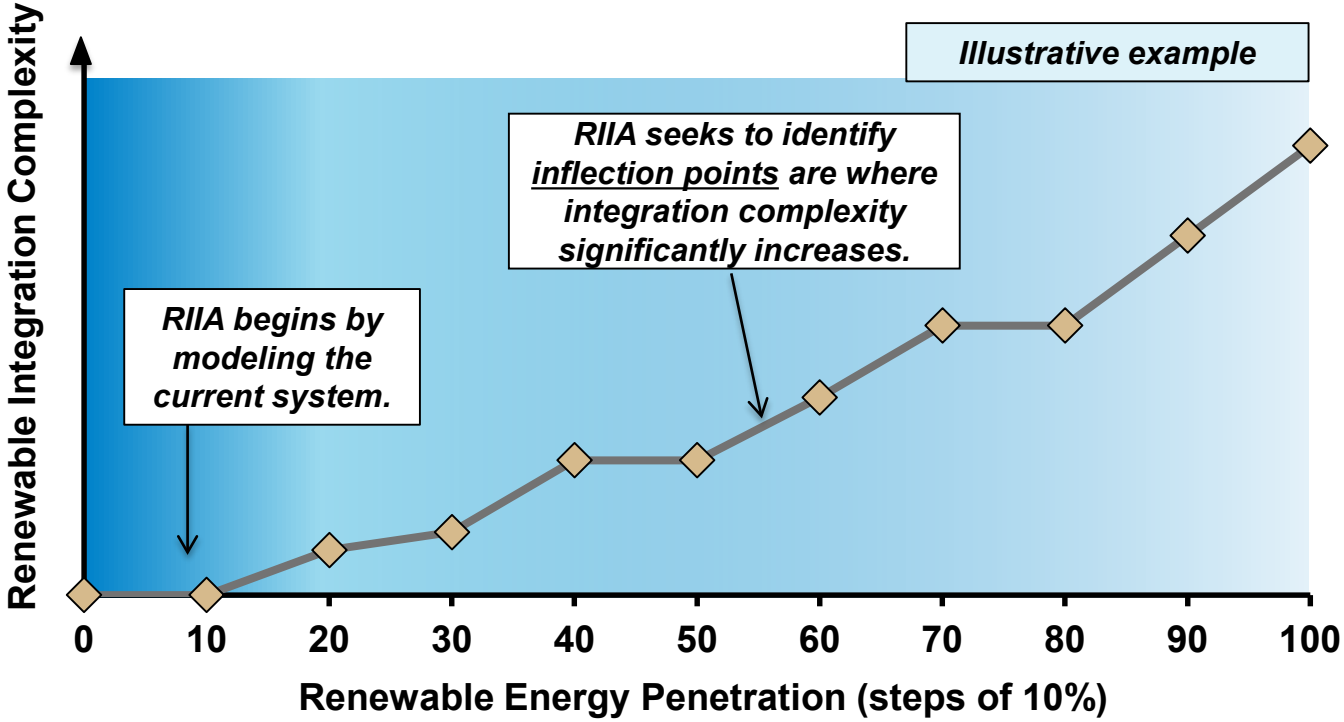
Context:

RIIA is an ongoing study conducted collaboratively with MISO members to identify MISO-wide renewable penetration levels at which integration complexity significantly increases.

Emerging Themes:

- **Up to 30% renewables, challenges appear manageable with regular, incremental transmission expansion**
- **By 40%, significant challenges begin**
  - **40% MISO-wide equates to 70-100% local penetration in wind-rich Iowa, Minnesota, North Dakota, South Dakota**
  - **Tradeoffs required between renewable curtailment & transmission investment**
  - **Increased flexibility requirements (ramping from conventional generation)**
  - **Increased system stability concerns**
- **Challenges can be addressed; however, least cost solutions require careful study and regional coordination across the MISO footprint**
- **The value of MISO-wide diversity and 'interconnectedness' are key**

Renewable Integration Impact Assessment (RIIA) seeks to find inflection points of renewable integration complexity



Focus Areas

Resource Adequacy

Having the sufficient capacity of resources to reliably serve peak demand

Energy Adequacy

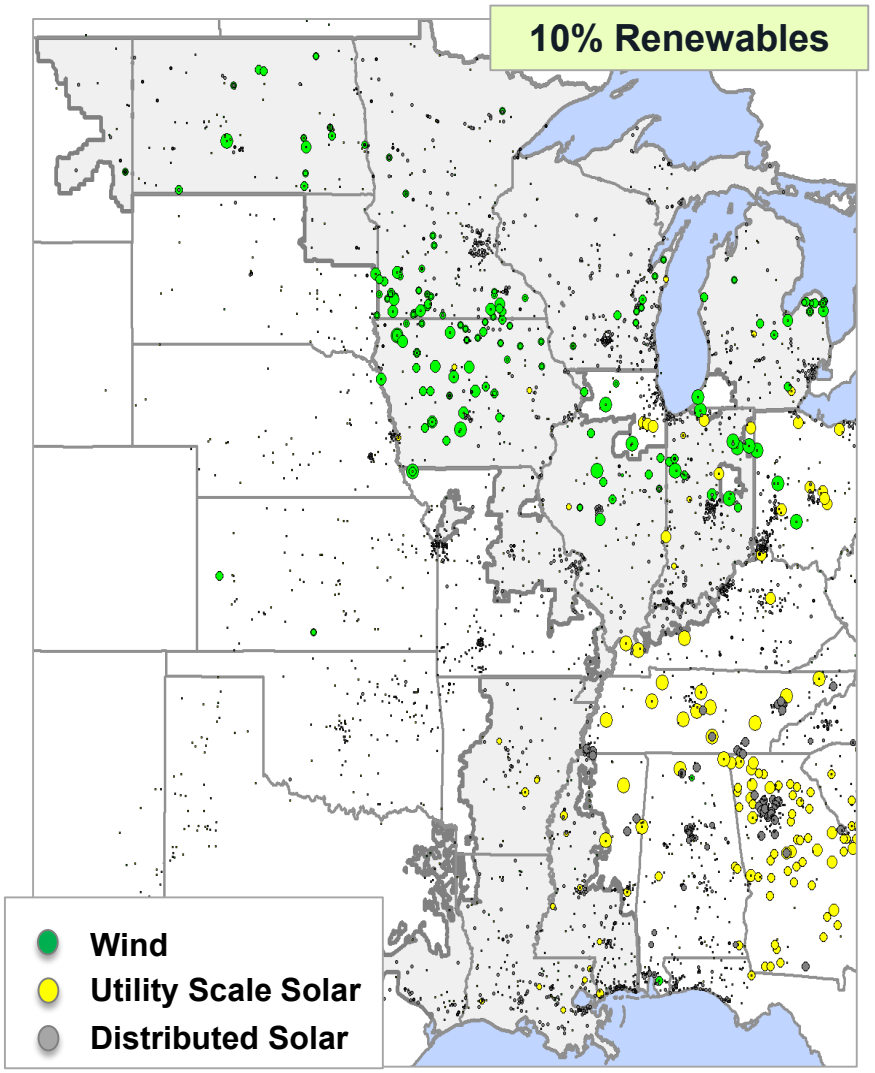
Ability to provide energy in all operating hours throughout the year

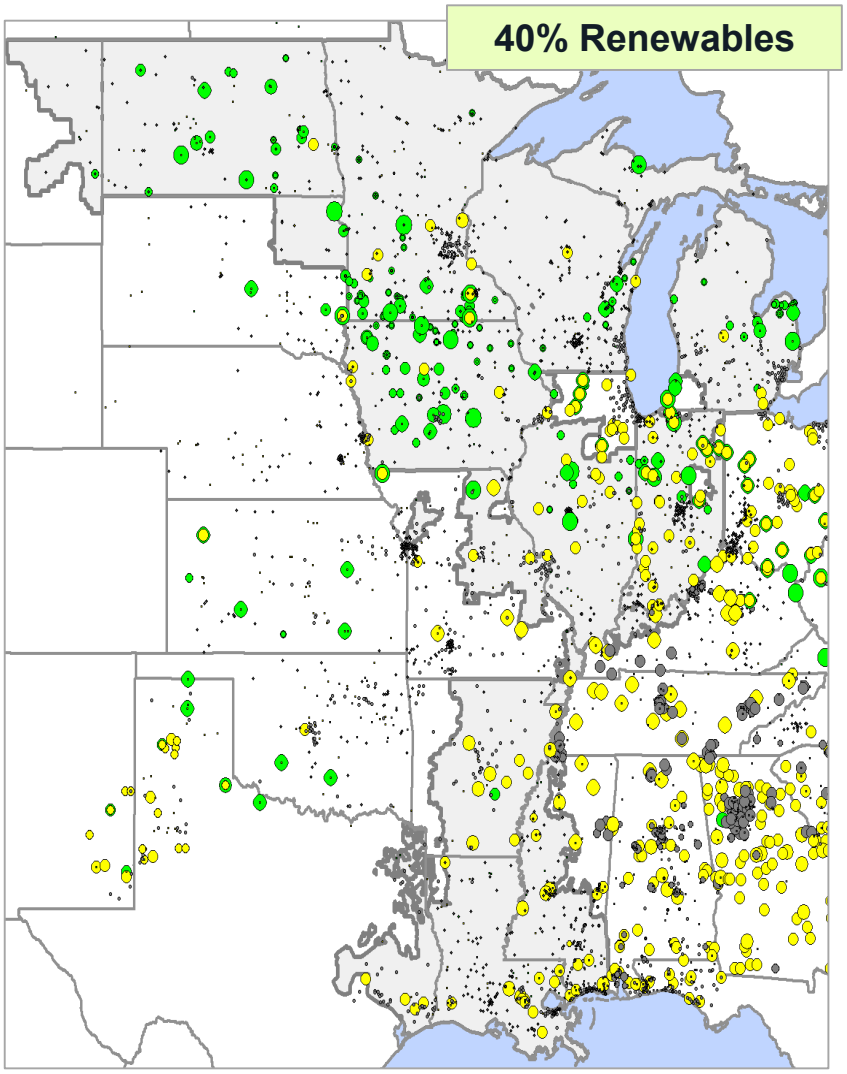
Operating Reliability

Ability to withstand unanticipated component losses or disturbances

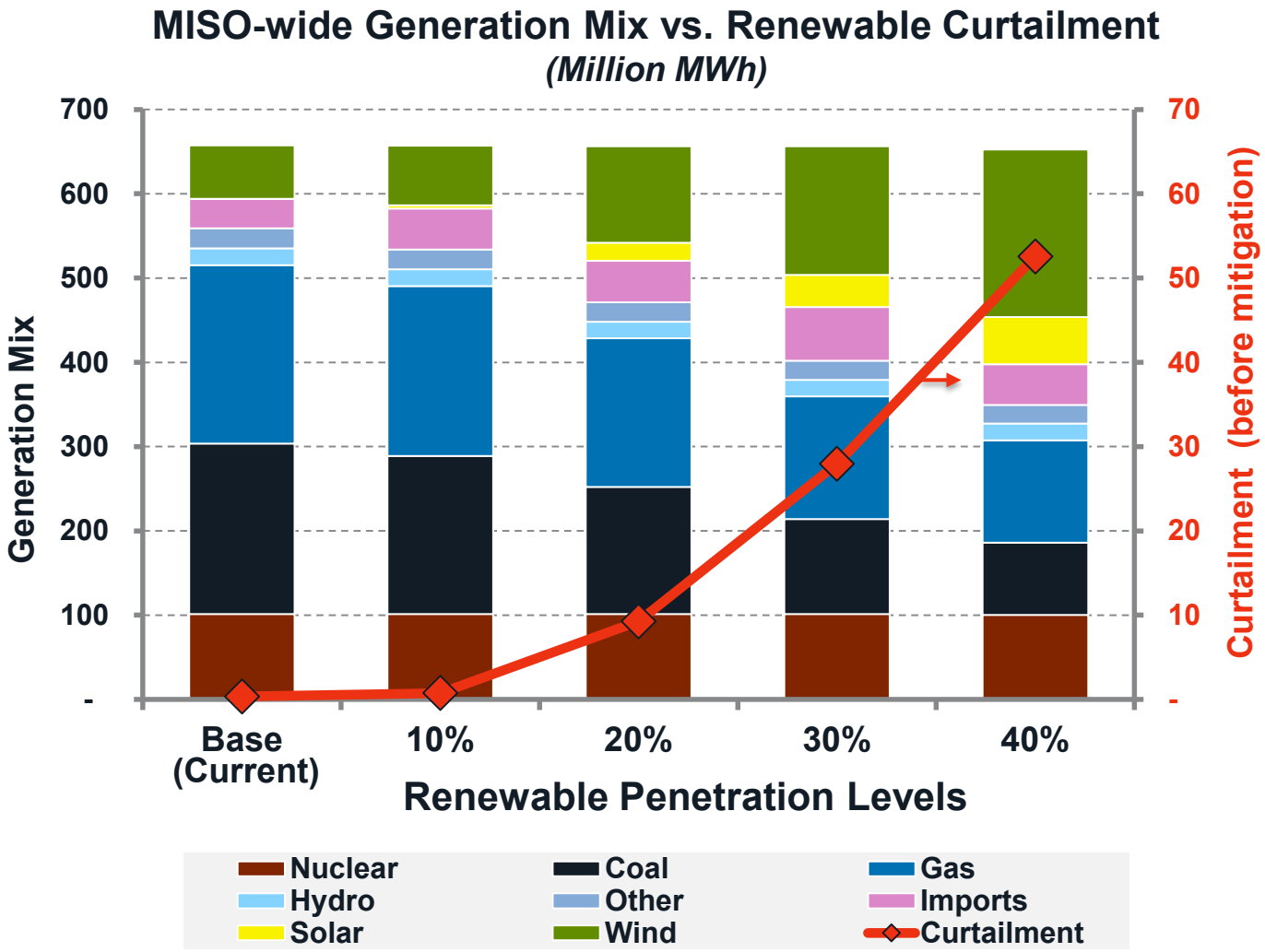
MISO

RIIA assumes a logical distribution for location and type of increasing levels of renewable generation across MISO





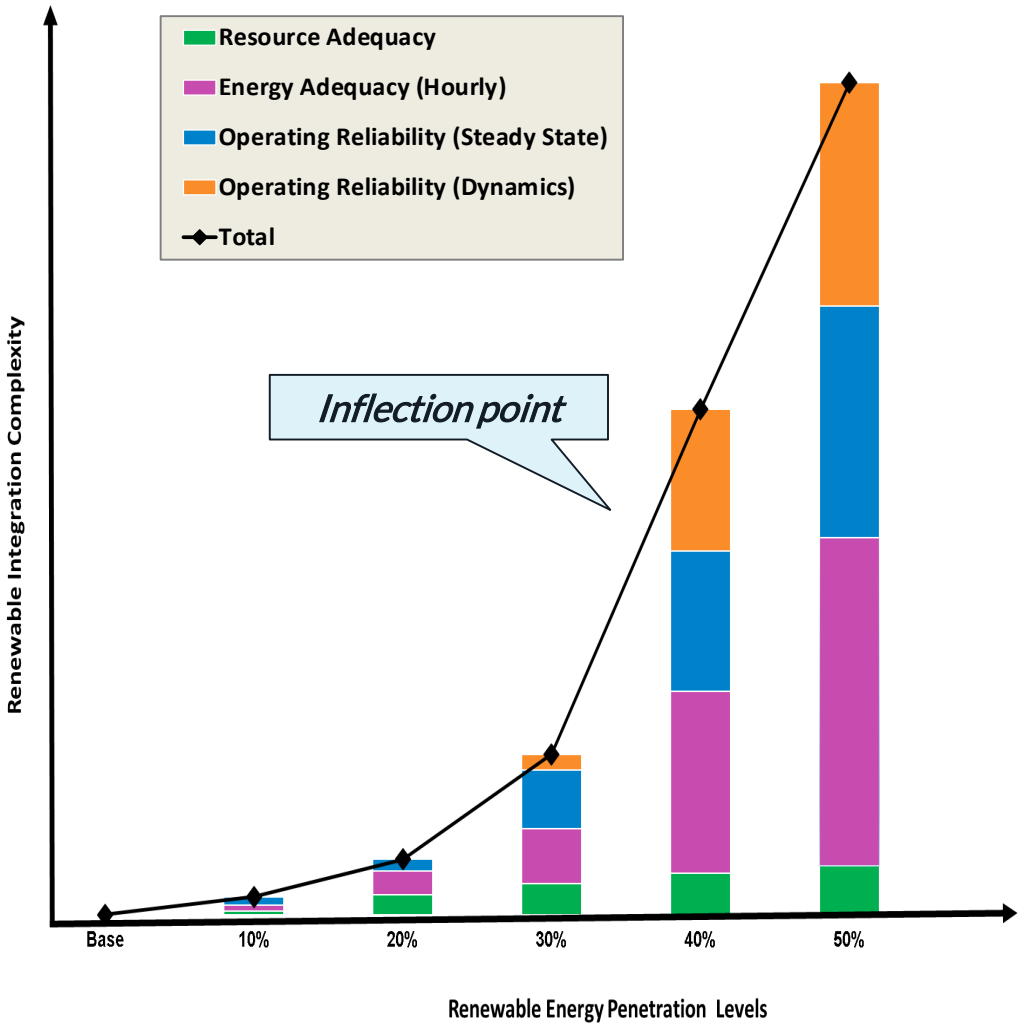
As renewable penetration increases, so do the integration challenges…



Increasing curtailment of renewables is an integration challenge that calls for mitigation, such as transmission investment

Note: Curtailment is undispatched renewable energy. Generation mix shown is after mitigation.

MISO's Renewable Integration Impact Assessment (RIIA) indicates integration complexity increasing sharply beyond 30% renewable penetration



1. Risk of losing load compresses into a small number of hours and shifts into the evening
2. Existing infrastructure becomes inadequate for fully accessing the diverse resources across the MISO footprint
3. Regional energy transfer increases in magnitude and becomes more variable leading to a need for increased extra- high-voltage line thermal capabilities
4. Power delivery from low short circuit areas may need transmission technologies equipped with dynamic support capabilities
5. Frequency response is stable up to 60% instantaneous renewable penetration, but may require additional planned headroom beyond
6. Grid-technology-needs evolve as renewable penetration increases, leading to an increased need for integrated planning
7. Diversity of technologies and geography improves the ability of renewables to serve load

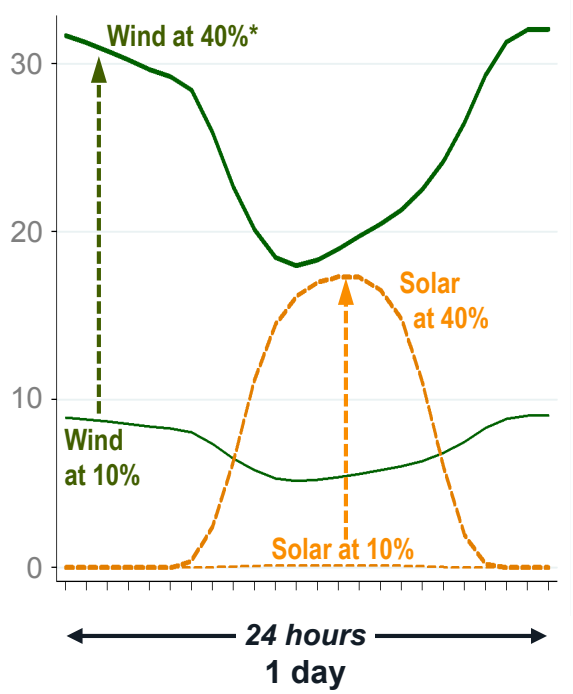
*(**Nov 2019 Update:** from RIIA Phase 1&2 Wrap-up Workshop - 11/13/2019)*

Increasing variability due to renewable generation will require generators to perform differently than today

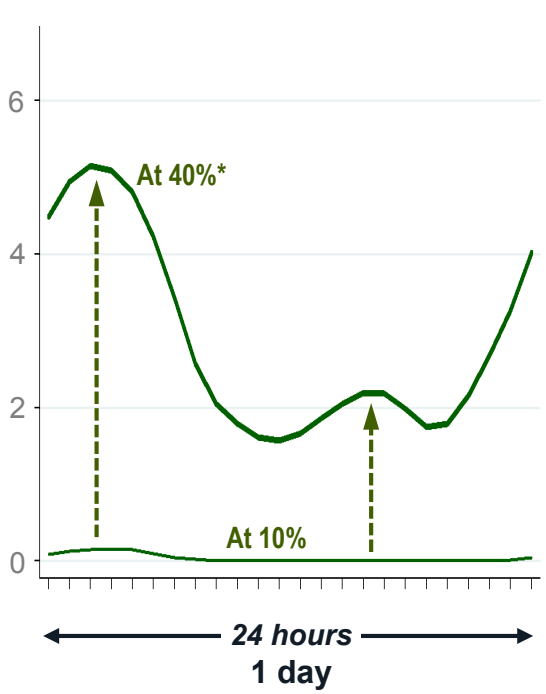
More hourly variability from renewables…

…requires increased flexibility (curtailments and ramp capability)

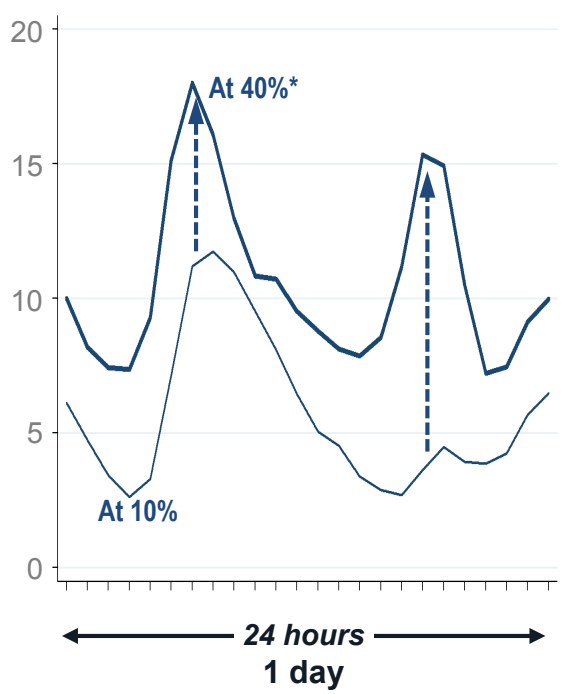
Renewable Output
(Thousands of MW)



Wind Curtailment
(Thousands of MW)

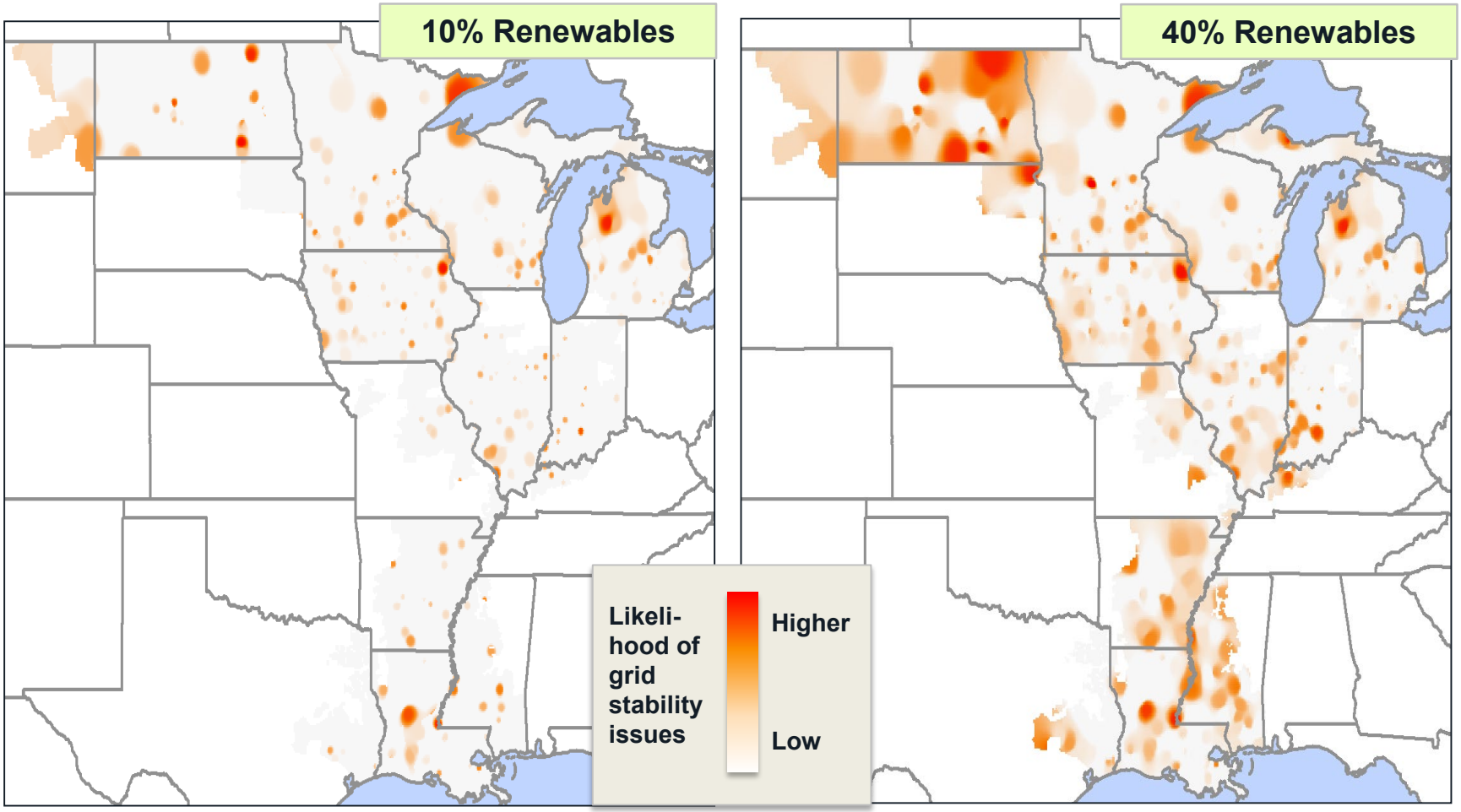


Coal and Gas Ramp
(% of capacity)



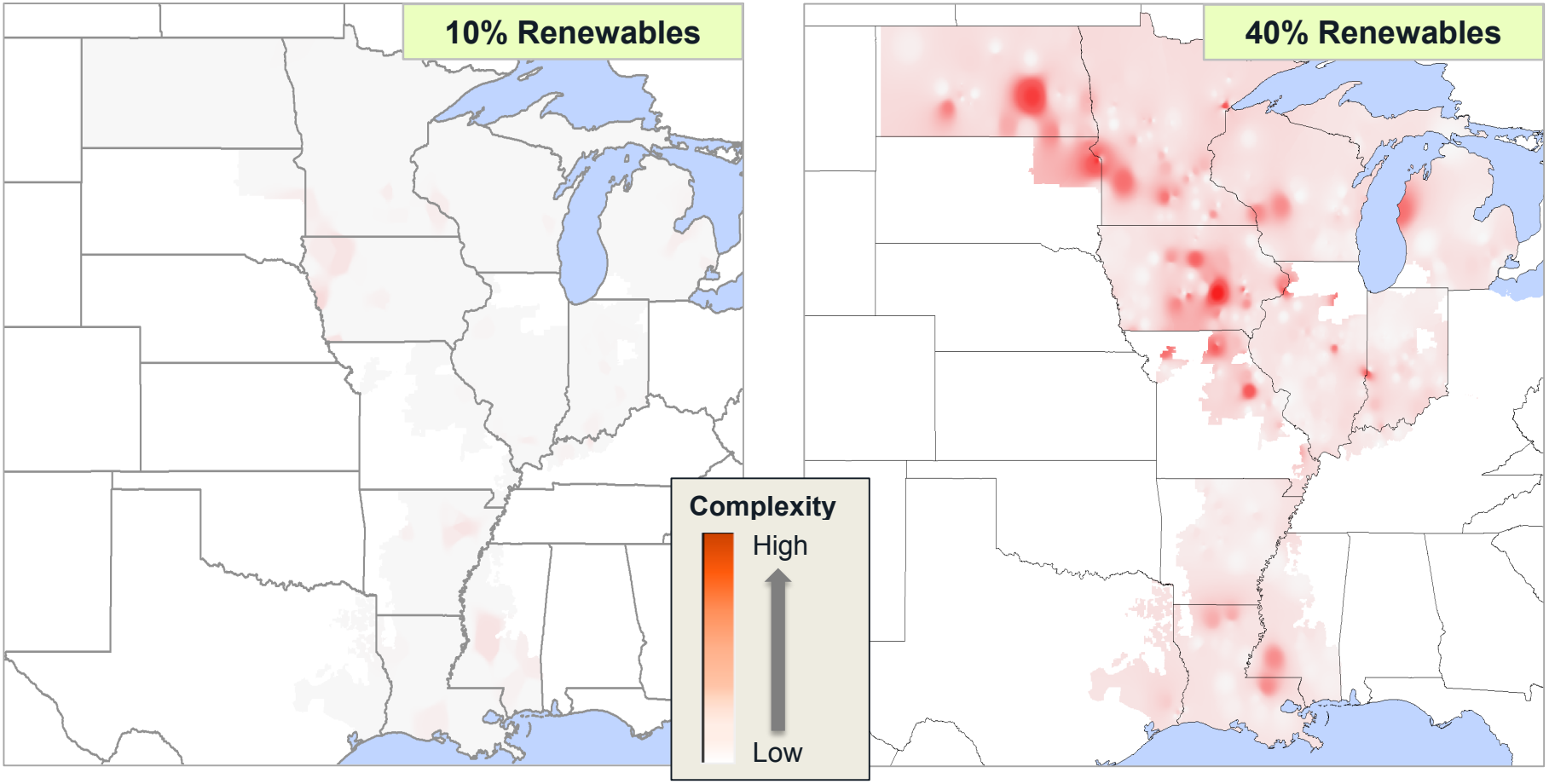
* All %'s in labels refer to MISO-wide renewable penetrations levels

Power system stability concerns significantly increase by 40% renewable penetration



- Stability concerns are driven by the reduction in conventional generation and the increase in inverter based (i.e., wind/solar/battery) generation
- Additional system reinforcement is needed (e.g., more transmission, keeping more conventional generation online)

Renewable integration complexity increases sharply by 40%, illustrating need for transmission expansion



- Integration complexity is measured as the approximate cost of the transmission fixes needed
- At the 40% penetration, transmission fixes could reduce curtailments from 18% to 9%

Summary

- The generation fleet within MISO is evolving
- By 40% renewable penetration, significant integration challenges begin
- Challenges can be addressed; however, least cost solutions require careful study and regional coordination…diversity and interconnectedness are key

Questions?

Brian Tulloh btulloh@misoenergy.org (External Affairs)
Jordan Bakke jbakke@misoenergy.org (RIIA*)
Alison Archer aarcher@misoenergy.org (External Affairs - Regulatory)

*Renewable Integration Impact Assessment (RIIA)

All RIIA-related documents can be found on MISO's web page (MISOenergy.org)

Home > Planning > Transmission Planning Studies and Reports > Renewable Integration Impact Assessment