Grid Modernization

Evaluating system needs in light of an evolving resource mix

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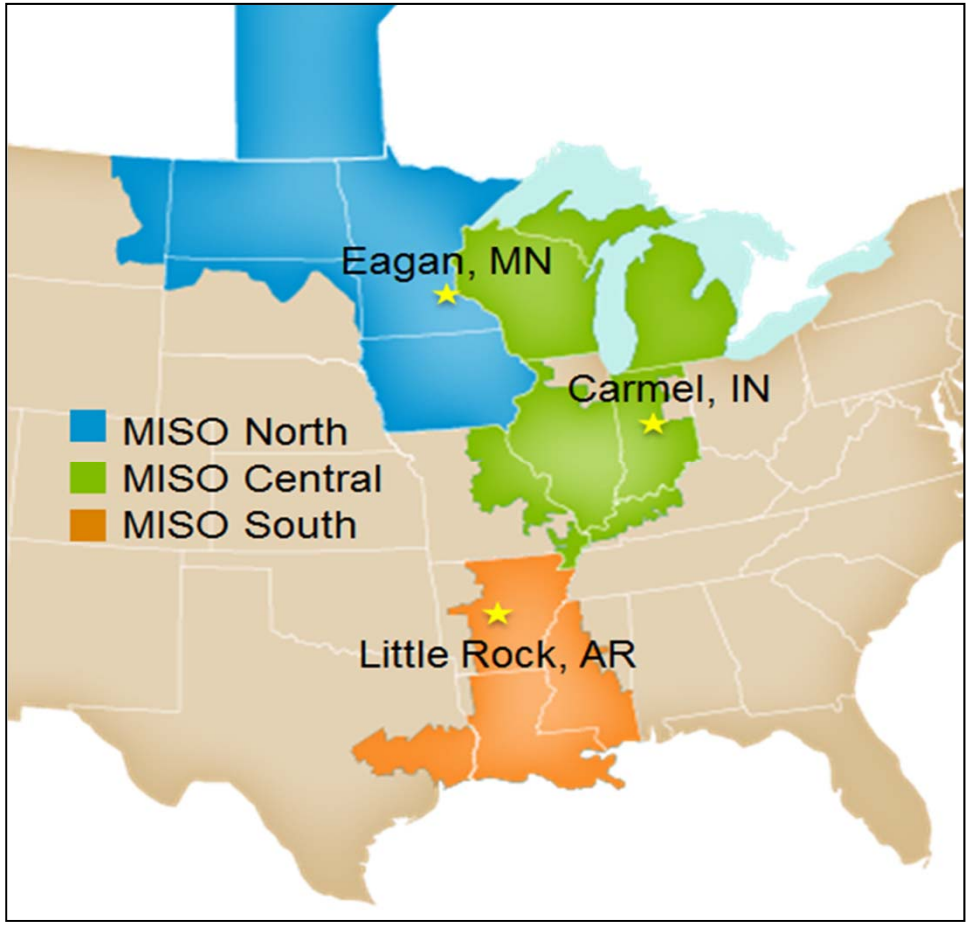
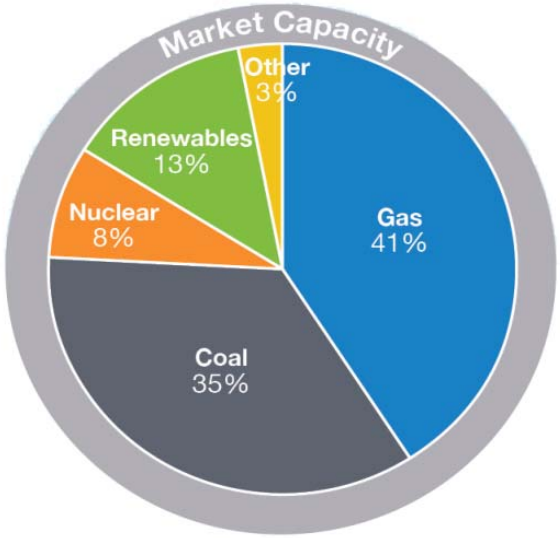
MISO drives value creation through efficient and reliable markets, operations, planning, and innovation

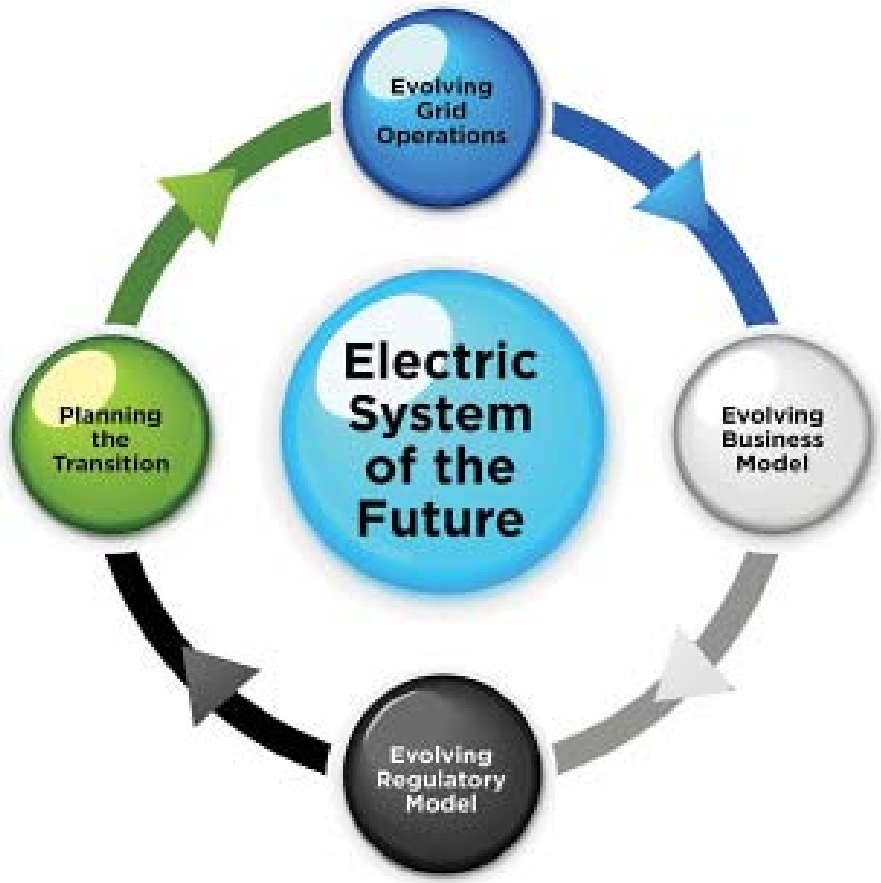
The most reliable, value-creating RTO



MISO by-the-numbers	
High Voltage Transmission	65,800 miles
Generation Capacity	174,000 MW
Peak Summer System Demand	127,125 MW
Customers Served	42 Million



There are many considerations in discussing the grid of the future, with implications to operations, planning, business models and regulatory models



" The goal of the "Future of the Grid: Evolving to Meet America's Needs" initiative was to determine - through a holistic approach that considers the system's many interdependencies - a path forward that will ensure resilience, mitigate vulnerabilities, and incorporate innovation, while continuing to provide affordable, safe, reliable, and ubiquitous power."

-- "The Future of the Grid" by GridWise Alliance for DOE (2014)

Recently, MISO and stakeholders discussed the future of the grid, with five potential focus areas

- ***The Grid*** will be a two-way delivery system
- ***Generation*** will become more distributed and intermittent
- ***Additional technologies*** will be incorporated into the grid at an increasing pace
- ***Markets*** will compensate necessary resource attributes and services
- ***Consumers*** are starting to use the grid differently

The Grid will be a two-way delivery system

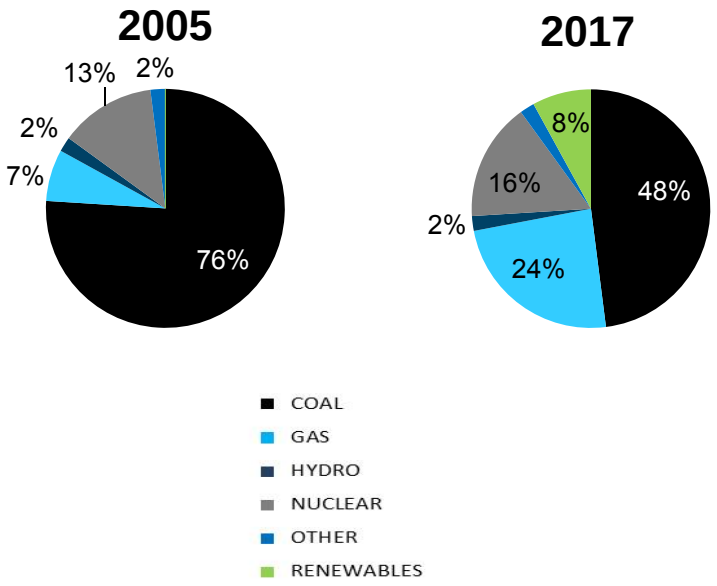
- The grid (T&D) serves as a “central nervous system” for an increasingly dynamic, complex system
- Will no longer be a one-way “delivery pipe” for electrons
- Interdependencies between transmission and distribution infrastructures will increase
- Distribution providers will shift from energy delivery to the facilitation of broader services

As lines blur between transmission and distribution, continued adaptation and execution will be important

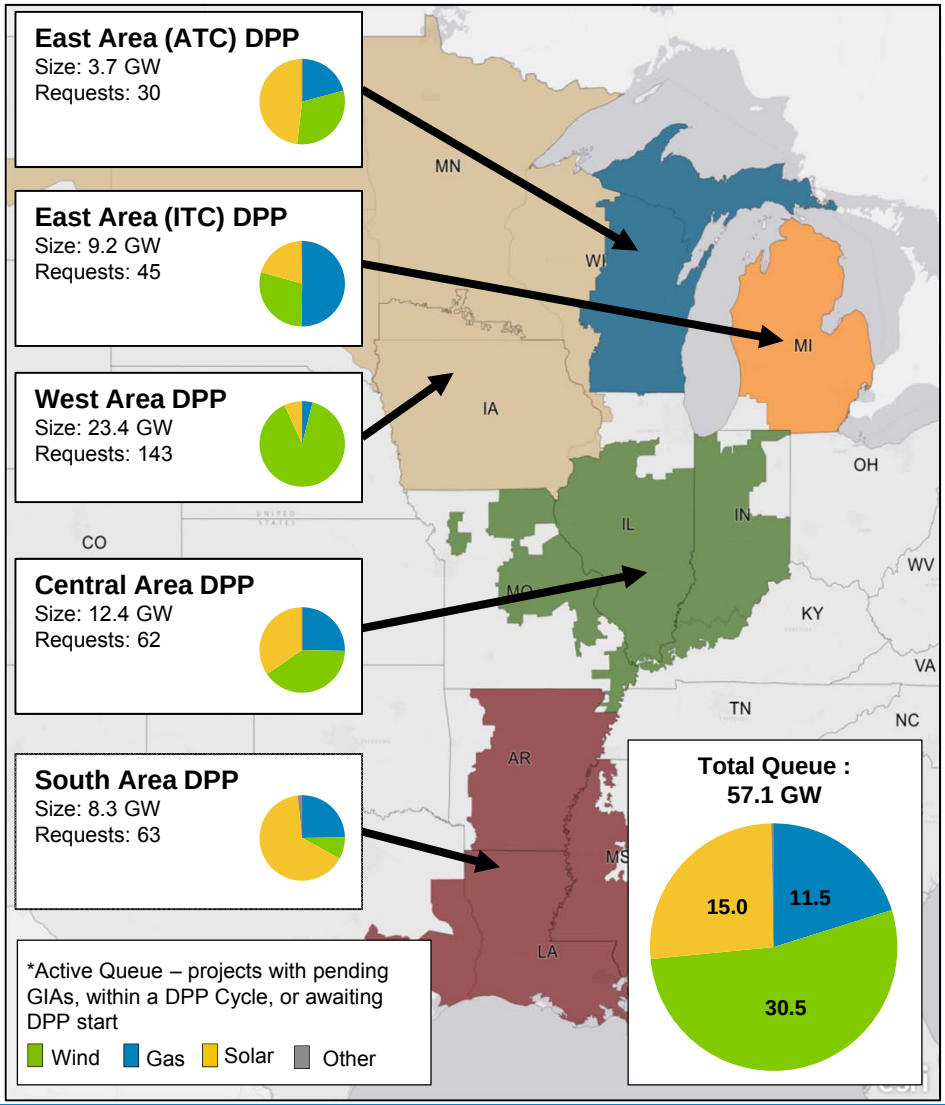
Category	2000		Future
Predictability of Flows for Planning	Highly predictable	Moderately predictable	Less predictable to unpredictable
Balancing Generation and Load	Generation is built and expected to serve local load obligations	Generation is built and dispatched to serve regional load obligations	Generation and load work together to serve load obligations
Security	Physical security prioritized, cyber threat minimal	Physical security important, cyber threat significant	Increased complexity and likelihood of threats
Grid Intelligence	Primitive	Facilitative	Transformative, machine learning, artificial intelligence

Generation will become more distributed and intermittent

MISO Generation Portfolio Evolution



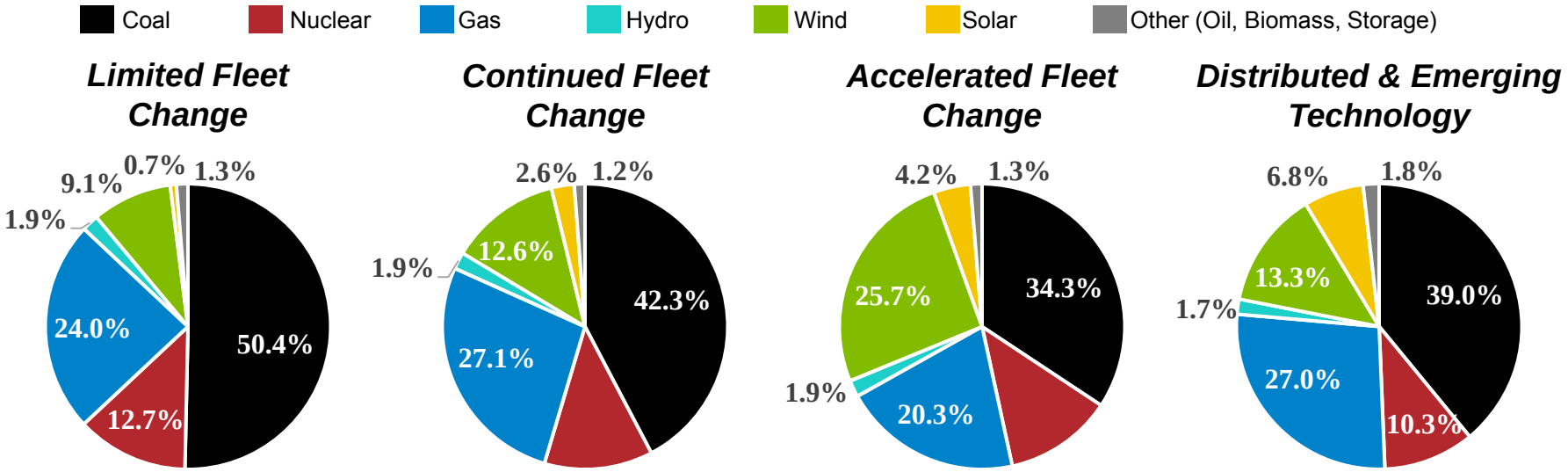
MISO Active Queue by Study Area



The MISO region must prepare for the continued fleet transition indicated by the interconnection queue

- Traditional baseload resources will remain under pressure
- New generation will be central and distributed, with a mix of dispatchable and non-dispatchable resources. Economics favor utility-scale renewables over customer-owned, but policies may support both
- Increased intermittency will necessitate more flexibility from other resources and changes to MISO planning, markets, and operations

2032 MISO MTEP Future Scenarios – Energy Mix



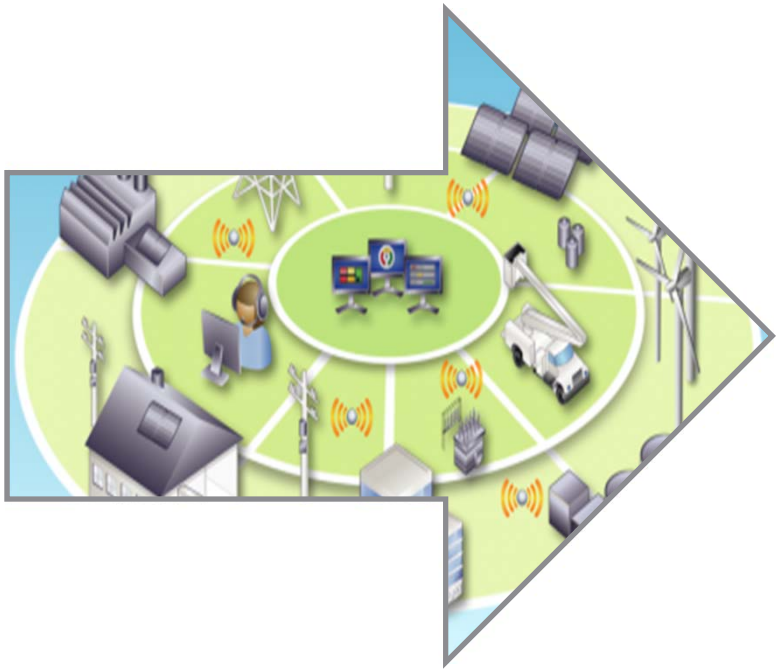
Additional technologies with new and different operating characteristics – including enabling technologies – are incorporated at an increasing pace

- Example: Storage
  - Growing component of the system with multiple uses
  - Active projects include pumped hydro and battery storage; 140 MW of capacity in the generation queue
  - Accelerated growth in high cost areas (Hawaii, California, overseas)
  - The grid, itself, functions as an energy storage system in some regards

Storage Applications by User:

Wholesale	Utility	Retail
• Energy Arbitrage • Black Start • Ramp • Spin / Non-Spin Reserves • Frequency Regulation • Voltage Support	• Resource Adequacy • Transmission Congestion Relief • Transmission Deferral • Distribution Deferral • Microgrid Islanding	• Time-of-Use Bill Management • Demand Charge Reduction • Increased PV Self-Consumption • Backup Power

Markets will provide price signals that compensate necessary resource attributes and services -- will help to integrate the overall system



- Increased variability in supply requires more flexibility from other generating assets
  - Adaptable and responsive supply and load will compensate for less flexible and non-dispatchable resources
  - Increased zero marginal cost resources will place pressures on energy prices but the value of flexibility will increase
  - Market design evolves to compensate for value provided or charging for new costs/burdens incurred
- As load and supply characteristics evolve at both the wholesale and retail levels, the seamless flow of services between levels increases
  - Importance of alignment in pricing between wholesale and retail

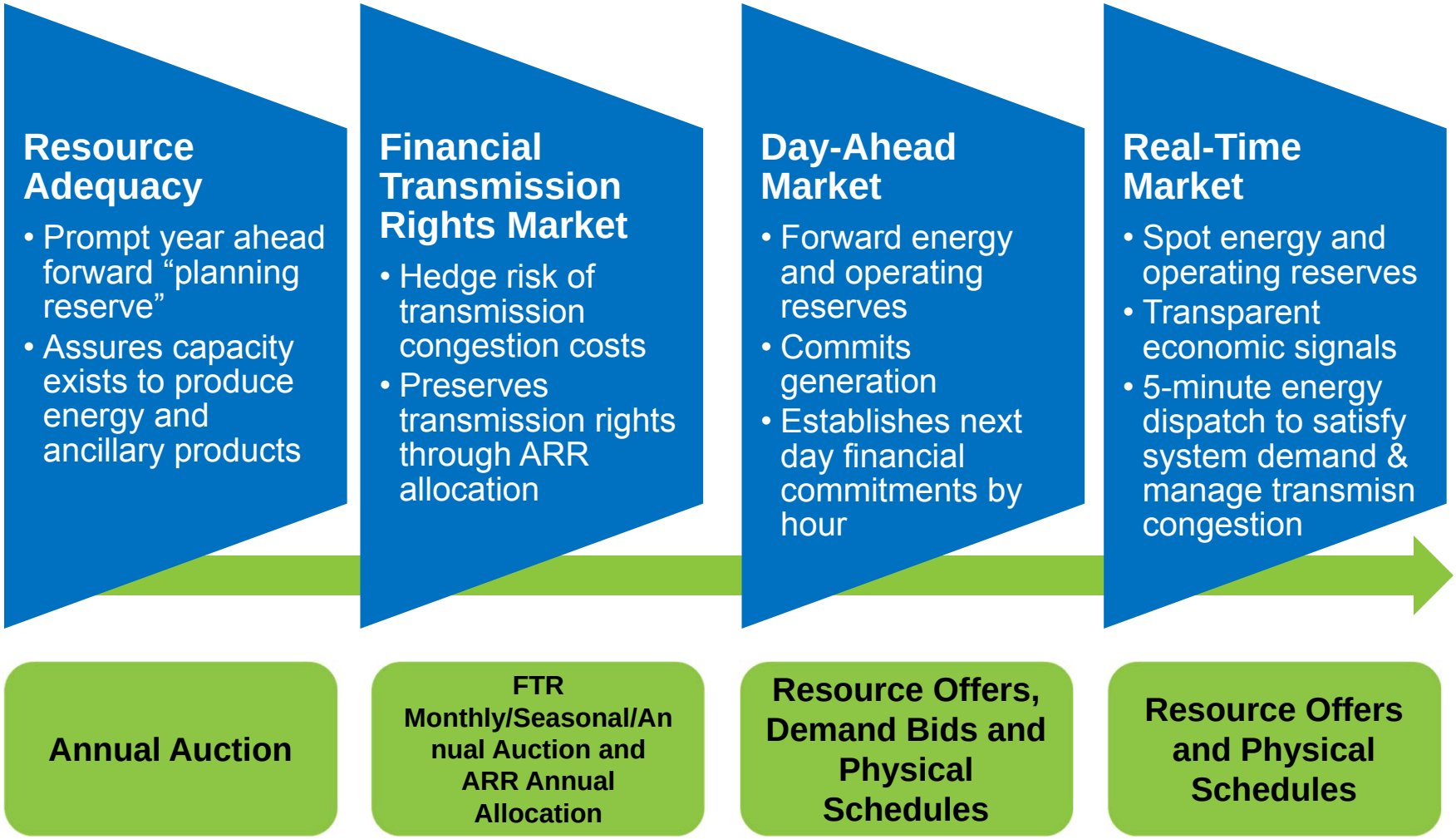
Consumers are starting to use the grid differently, wanting more control over their energy choices while still valuing reliability and low price

- Emergence of the “prosumer” - consumers and producers of energy
  - Disaggregated and transparent costs are identified to understand the true cost of electricity services
  - Possible emergence of new business models
  - Customers compensated for energy and ancillary services
- The trend is accelerated in high cost regions with supporting policies / subsidies
- Customers stay connected to the grid to ensure reliability

In summary…

- ***The Grid*** will be a two-way delivery system
- ***Generation*** will become more distributed and intermittent
- ***Additional technologies*** will be incorporated into the grid at an increasing pace
- ***Markets*** will compensate necessary resource attributes and services
- ***Consumers*** are starting to use the grid differently

Four primary markets are MISO's tools to manage generation and transmission…

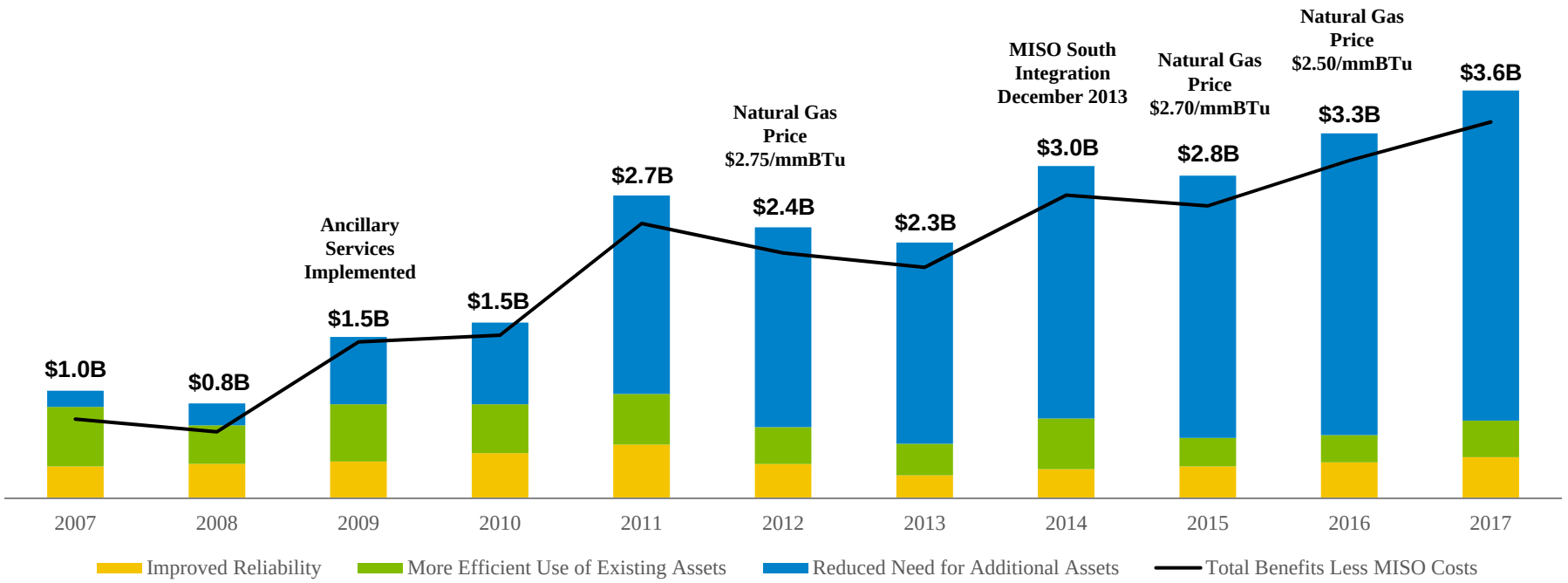


. . . Paired with a strong transmission planning process

MISO Transmission Expansion Plan (MTEP) identifies issues and opportunities, develops alternatives for consideration, and evaluates those options to determine effective transmission solutions.

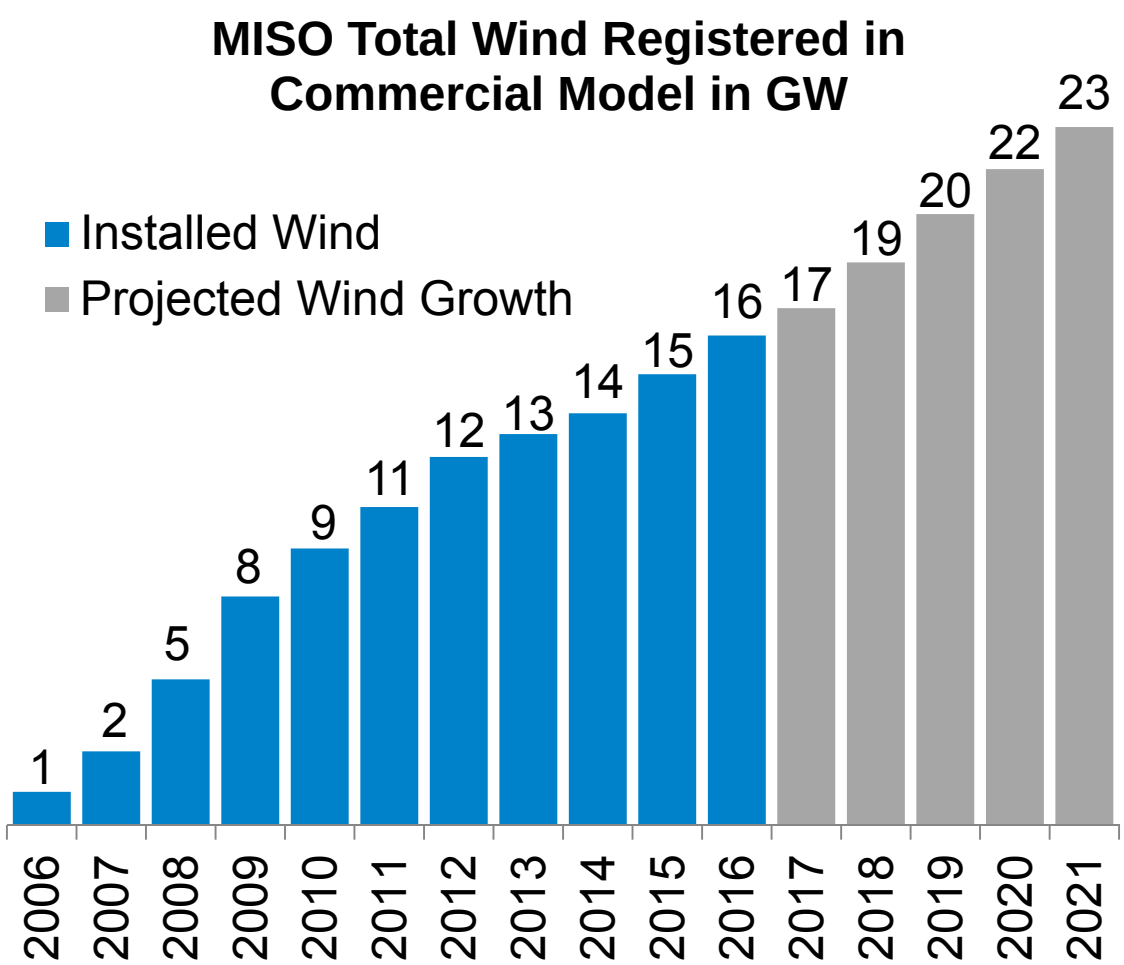
- Ensure the reliability of the transmission system
- Provide economic benefits such as increased market efficiency
- Facilitate public policy objectives such as integrating renewable energy
- Address other issues or goals identified through the stakeholder process

The region continues to successfully navigate the dynamic environment to expand value



Improved Reliability	Reduced Need for Additional Assets	More Efficient Use of Existing Assets
• Value of additional energy served based on RTO transmission performance versus non-RTO regions • MISO has outperformed total RTO region reliability every year since 2012 • Economies of scale in Compliance work	• Footprint diversity allows the pool to share resources reducing capacity need for reserves • Generator availability improves with market reducing need for additional resources • Demand response growth delays need for generation	• Security constrained energy dispatch ensures least cost generation is deployed first • Ancillary Service Market frees cheaper capacity for energy and secures regulation service and reserves at competitive cost

Fast growth in wind drove development of new products and services

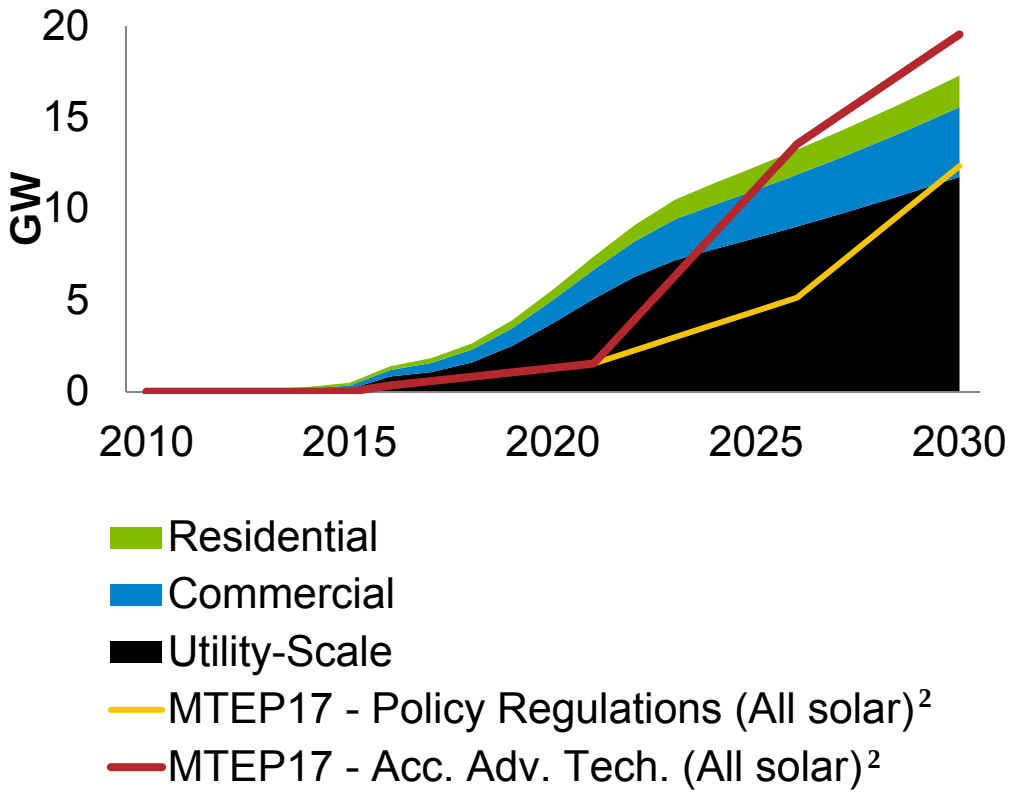


Major Milestones:

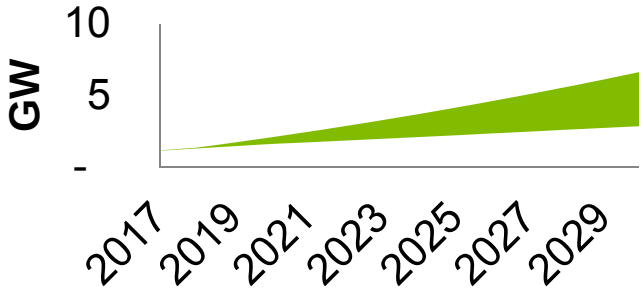
- **2008** Interconnection Queue Reform
- **2009** Wind Forecasts in Operations
- **2009** Launched Ancillary Services
- **2010** Dispatchable Intermittent Resources
- **2011** Multi-Value Transmission Projects
- **2012** Interconnection Queue Reform
- **2016** Solar Forecasts in Operations
- **2017** Interconnection Queue Reform

Significant new DERs is forecasted in MISO – external forces could accelerate pace of change

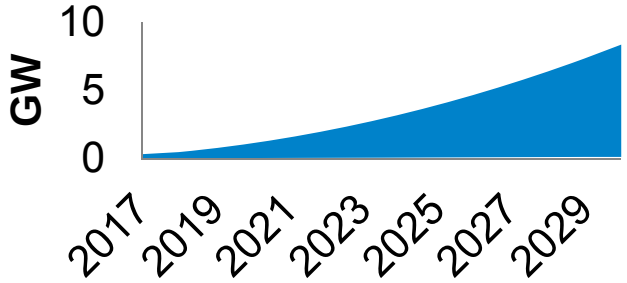
Installed PV in MISO by Segment[1]



Possible Range of DR Deployment[2]



Possible Range of EE Deployment[2]

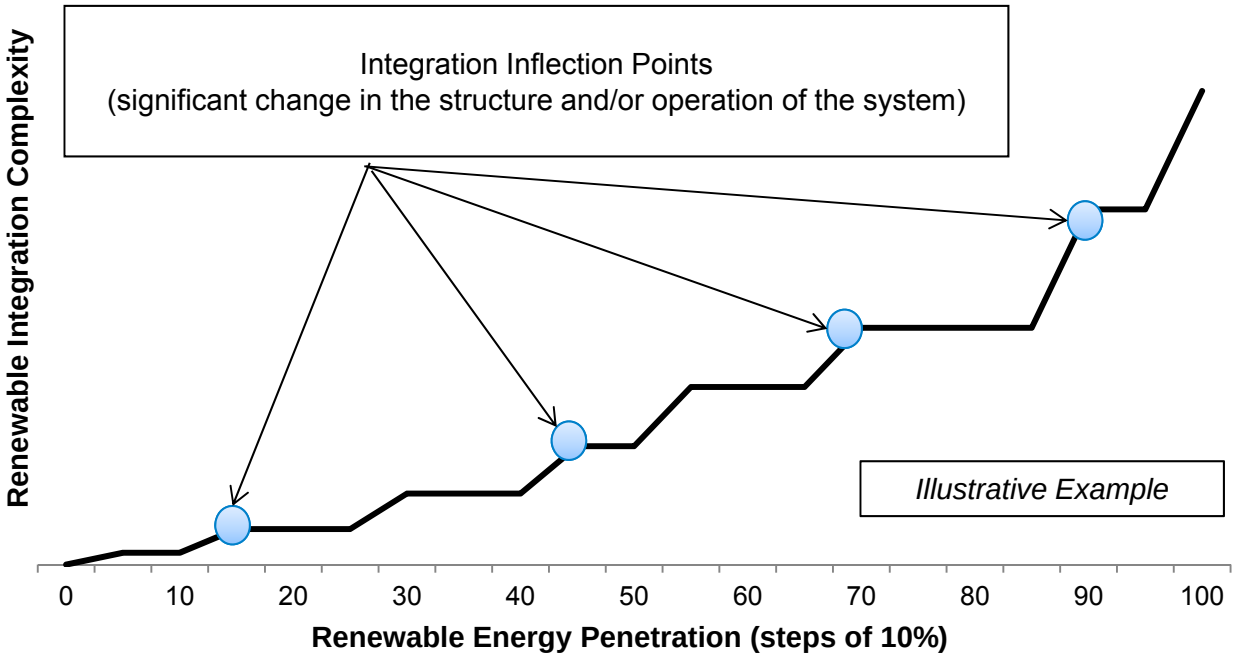


Smart thermostats are resulting in measurable reductions in load – according to Nest, as of March 2017 their smart thermostats have saved roughly 193,000 MWh per month. "That's the same amount of energy created by 27 thousand wind turbines in a month.

[1]IHS reference case forecast [2]MISO planning futures

Assessment will seek to find inflection points of renewable integration complexity

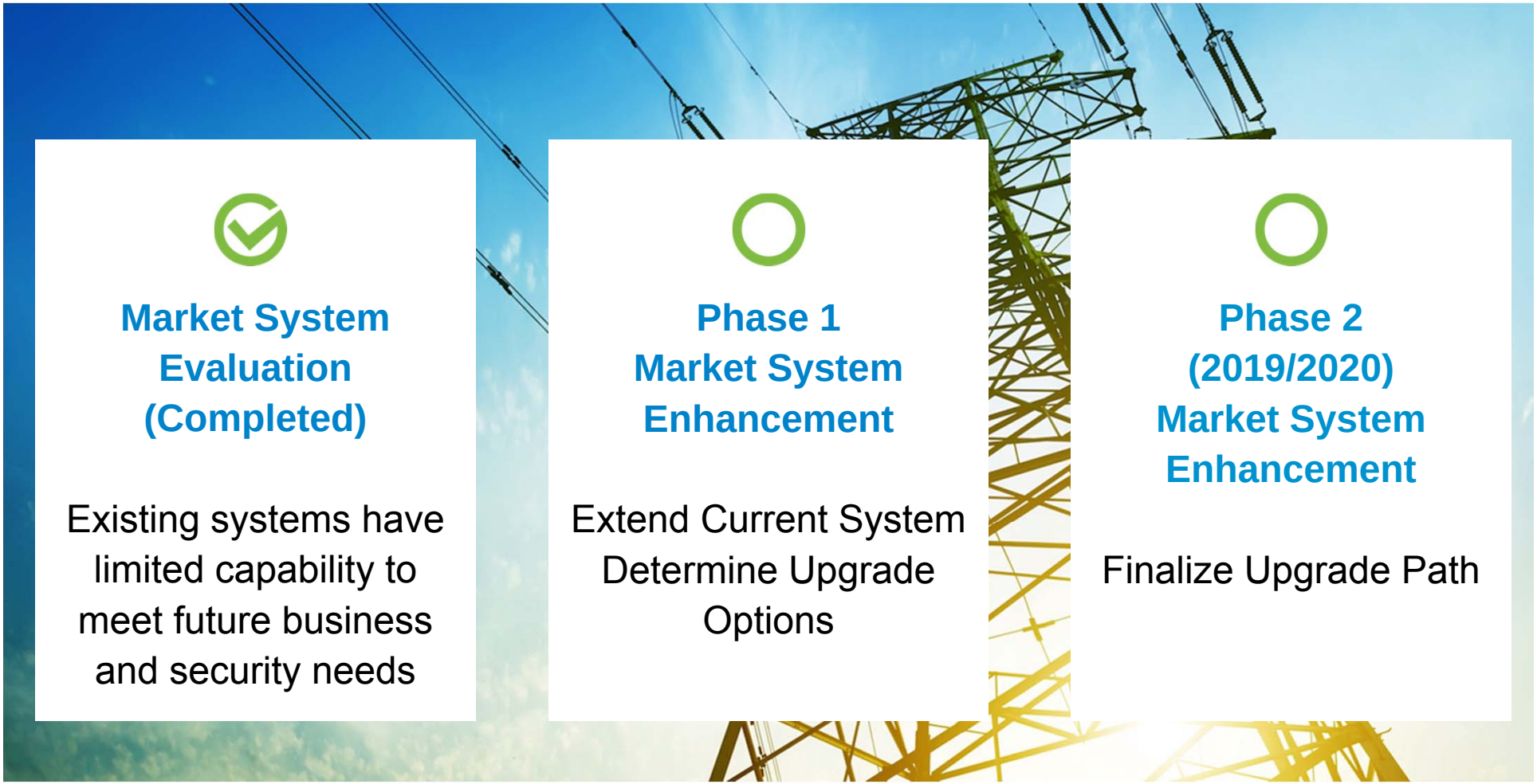
Study Focus Areas:



Inflection Point Focus Areas:

- Operational
- Steady State
- System Stability
- Resource Adequacy

The execution of MISO's strategy relies on secure systems with the tools and information necessary to ensure reliability



Market System Evaluation (Completed)

Existing systems have limited capability to meet future business and security needs

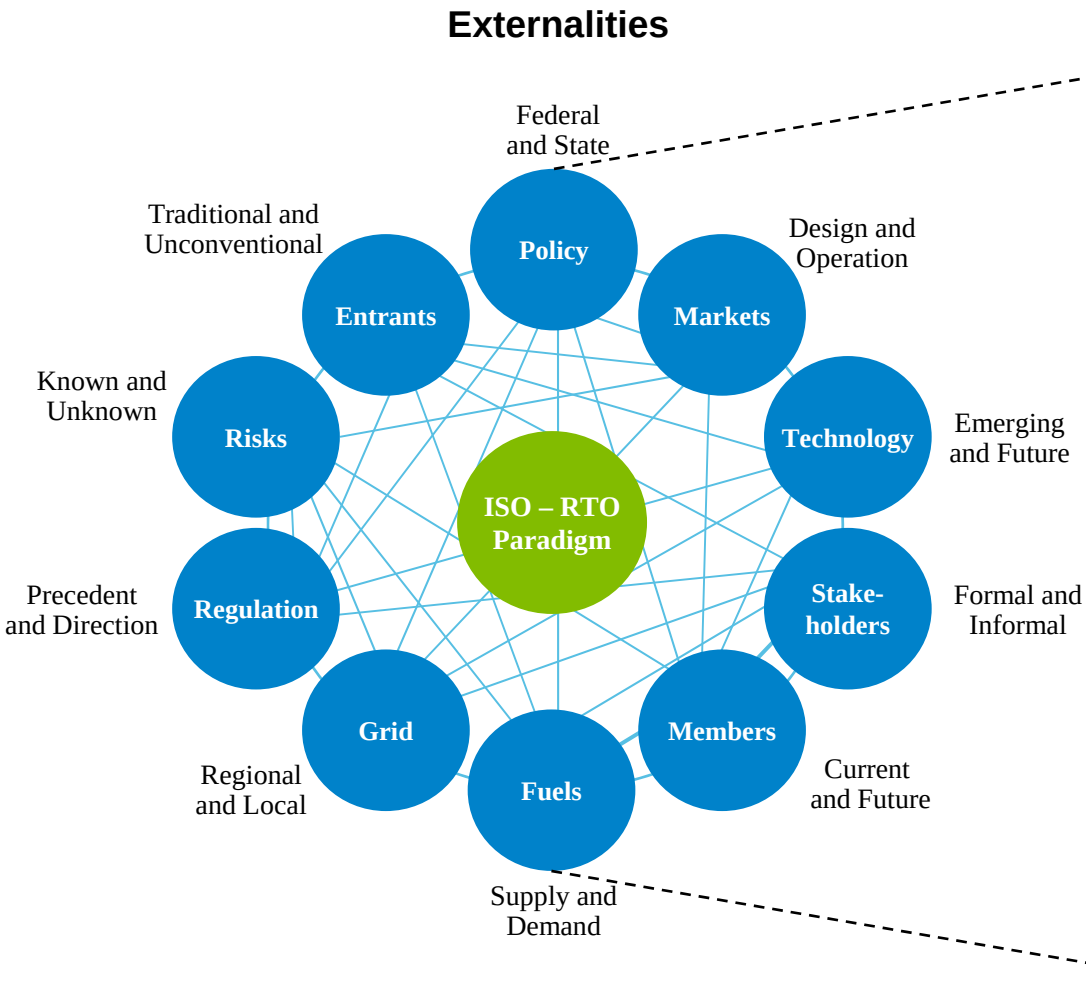
Phase 1 Market System Enhancement

Extend Current System Determine Upgrade Options

Phase 2 (2019/2020) Market System Enhancement

Finalize Upgrade Path

MISO's role continues to evolve as the industry's requirements change



Future MISO Role

- **Ensure reliability**
- **Create value for members and consumers**
- **Create and operate efficient markets**
- **Enable efficient infrastructure investment**
- **Maintain unbiased analytic foresight for future markets**
- **Educate stakeholders on future market possibilities**

Thank you

Links for more information

- MTEP (Transmission Planning):
  - https://www.misoenergy.org/Library/Repository/Meeting%20Material/Stakeholder/PAC/2017/20170719/20170719%20PAC%20Item%2002b%20MTEP19%20Futures%20Siting%20Process.pdf
- Dispatchable Intermittent Resources:
  - https://www.google.com/amp/s/www.greentechmedia.com/amp/article/renewables-curtailment-in-california-and-the-midwest-what-can-we-learn-from
  - (From 2013, focused on rules): https://www.misoenergy.org/Library/Repository/Meeting%20Material/Stakeholder/Workshops%20and%20Special%20Meetings/2013/20130802%20Wind%20Integration%20Workshop/20130802%20Wind%20Integration%20Workshop%20Presentation.pdfWind forecasting (from 2015):
  - https://www.misoenergy.org/Library/Repository/Meeting%20Material/Stakeholder/BOD/Markets%20Committee/2015/20150826/20150826%20Markets%20Committee%20of%20the%20BOD%20Item%2006%20Wind%20Forecasting.pdf
- Wind capacity credit:
  - https://www.misoenergy.org/Library/Repository/Study/LOLE/2017%20Wind%20Capacity%20Report.pdf
- Demand Response:
  - https://www.misoenergy.org/Library/Repository/Meeting%20Material/Stakeholder/Training%20Materials/MP%20100/Demand%20Response%20Primer.pdf
- Ramp capability product:
  - https://www.misoenergy.org/Library/Repository/Meeting%20Material/Stakeholder/Workshops%20and%20Special%20Meetings/2016/20160115%20Ramp%20Capability%20Integration%20Technical%20Workshop/20160115%20Ramp%20Workshop%20Presentation.pdf
- Market Management System Enhancement effort:
  - https://www.misoenergy.org/Library/Repository/Meeting%20Material/Stakeholder/BOD/BOD/2017/20170622/20170622%20BOD%20Item%2006c%20MSE%20and%20Summary.pdf
- DER projections:
  - https://www.misoenergy.org/Library/Repository/Meeting%20Material/Stakeholder/Workshops%20and%20Special%20Meetings/2017/20170627%20Applied%20Energy%20Group/20170627%20AEG%20%20DR%20EE%20DG%20Assessment%20Data%20v3.pdf
  - https://www.misoenergy.org/Library/Repository/Meeting%20Material/Stakeholder/Workshops%20and%20Special%20Meetings/2017/20170627%20Applied%20Energy%20Group/20170627%20AEG%20DR%20EE%20DG%20Assessment%20Data%20Appendix.pdf
- AGC:
  - https://www.misoenergy.org/Library/Repository/Meeting%20Material/Stakeholder/MSC/2017/20170810/20170810%20MSC%20Item%2005%20Fast%20AGC%20Enhancement%20Study.pdf
- ELMP ex-post pricing formulations:
  - https://www.misoenergy.org/_layouts/MISO/ECM/Download.aspx?ID=169056
- Storage (see links in the meeting materials section):
  - https://www.misoenergy.org/Events/Pages/CIWenergystorage20170724.aspx