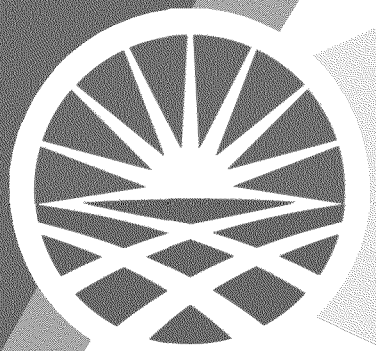

Incentivizing System Reliability and Resilience in the Wholesale Power Market

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Federal Regulatory Affairs

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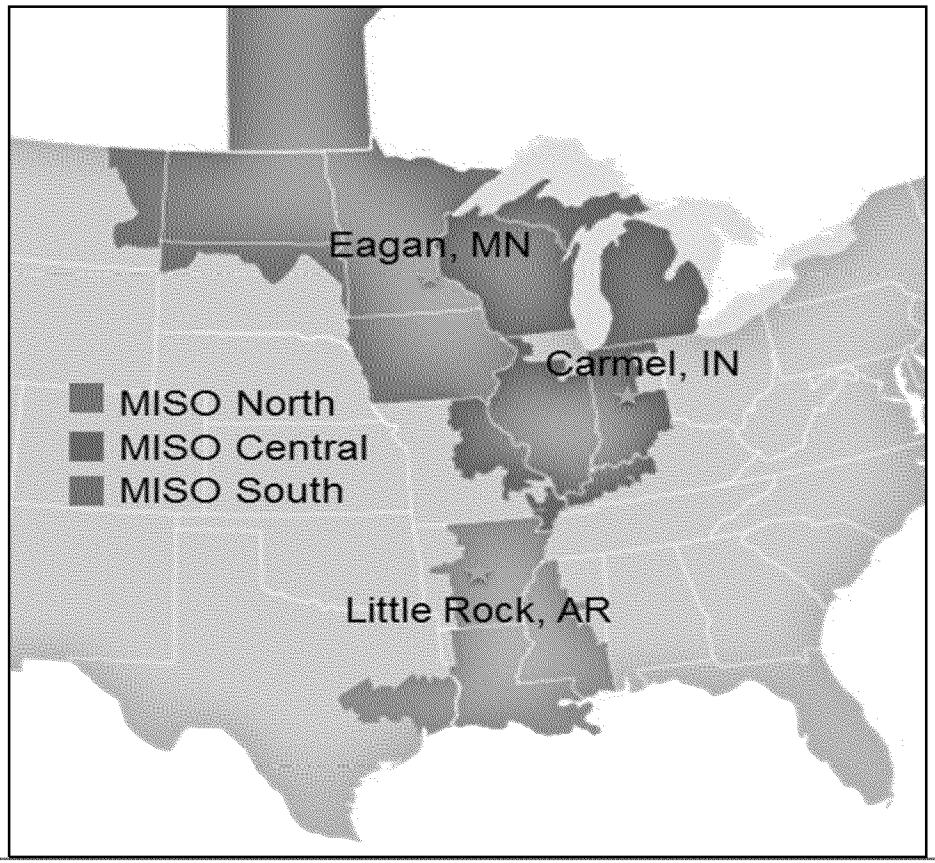
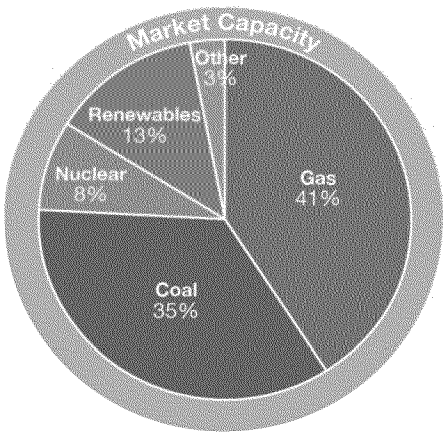
MISO drives value creation through efficient and reliable markets, operations, planning, and innovation

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



https://www.misoenergy.org/AboutUs/LeadershipGovernance/PublishingImages/Corporate%20Fact%20Sheet.jpg

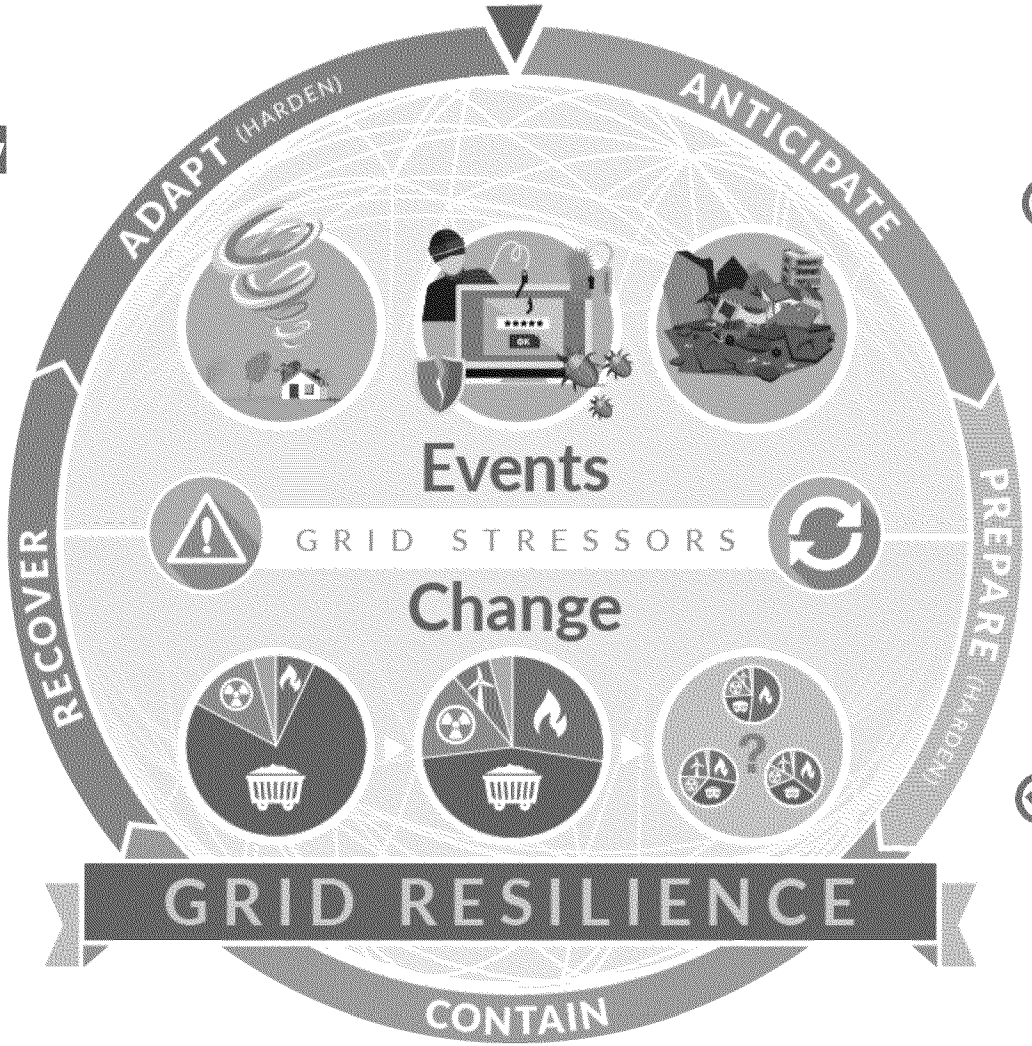
MISO's resilience efforts address all stages of an event, and a variety of grid stressors

Technology and Security

- Maturing identification, protection, detection and response capabilities

Operations

- Improving the ability to anticipate, contain, and recover



Markets

- Operating efficient markets that incent and coordinate resilient outcomes

System Planning

- Enhancing planning criteria to ensure a reliable, flexible transmission system

- Draws upon Department of Energy, North American Electric Reliability Corporation, and National Academy of Engineering efforts related to resilience
- The term "Electric Grid" is the interconnected network for delivering electricity and includes the generation, transmission, and distribution systems, as well as the NERC registered Functional Entities
- Definition expanded to include grid stressors such as change related to portfolio evolution and increasing complexity

MISO is prepared for and managing threats driven by events as well as changes

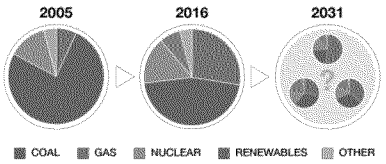
Events

Examples include:

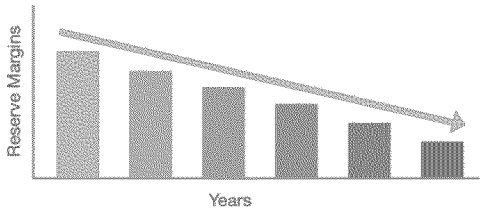
- Natural events and weather events
- Blackouts and major outages
- Cyber and physical attacks / threats
- Disruptions to related infrastructure (communications, fuel supply, transportation, water, waste-water, other)

Change

Changing resource mix



Lower reserve margins



Examples include:

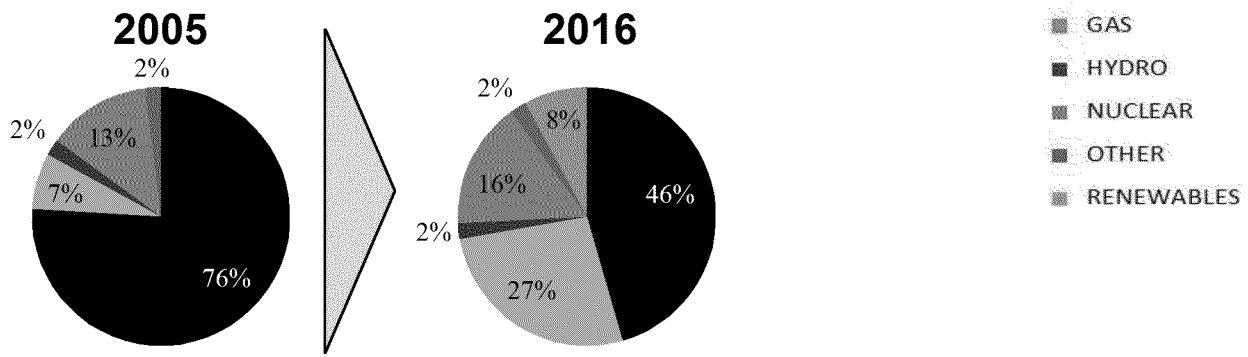
- Changing baseload resources, renewables, and grid topology
- Tightened reserve margins and importance of resource availability and system flexibility
  – Scarcity now seen in shoulder seasons
  – More supply variability with increased renewables
- New resource technologies – DER, storage, etc.
- Fuel supply and delivery vulnerabilities
- Increasing complexity - higher end-to-end interaction and interdependence (generation, transmission, distribution, and consumer)

MISO is working to improve Grid Resilience

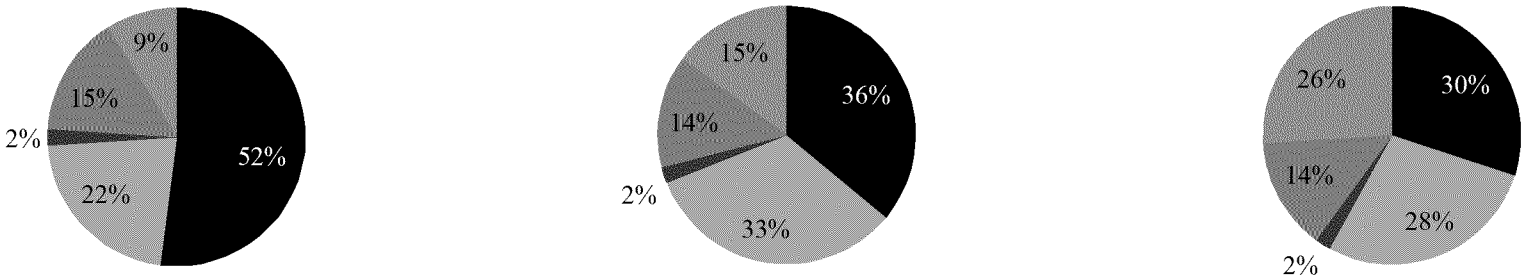
	Technology and Security	Markets	System Planning	Operations
	Maturing identification, protection, detection and response capabilities	Operating efficient markets that incent and coordinate resilient outcomes	Enhancing planning criteria to ensure a reliable, flexible transmission system	Improving the ability to anticipate, withstand, and recover
Implemented	• Vulnerability identification • Communication resiliency evaluation • Risk-based approach appropriate to the critical nature of MISO's technology and security	• Market Roadmap for an evolving portfolio (e.g. ramp product for short-term fluctuations in energy requirements) • Improved scarcity pricing and emergency pricing • Enhancements to market-to-market and coordinated transaction scheduling	• Long-term planning for robustness across multiple future scenarios, incorporating uncertainty • Evaluating system robustness through a Renewable Integration Impact Assessment • Increasing stakeholder awareness of impact of low frequency / high impact events	• Improved situational awareness with disaster preparedness and operating guides • Improved Gas-Electric Coordination (including winterization guidelines) • Drills – cyber-attacks, control room evacuation, system failure, seasonal readiness, restoration plans, Load Modifying Resource (LMR) and Emergency Demand Response (EDR)
Planned	• Mature identification, protection, detection and response capabilities • Focus on resiliency and recovery agility • Collaborate to strengthen security and raise vigilance with our employees, members, and governmental entities • Industry event participation (Grid-EX IV)	• Market System Enhancement - Developing architectural standards with innate resilience • Market Roadmap – Multiday Unit Commitment, Combined Cycle Modeling, Short-term Capacity Reserves, Stored Energy	• Defining planning resiliency metrics and their associated values based upon impact analysis and stakeholder input • Enhanced planning to address reliable portfolio evolution • Enhanced planning to incorporate resiliency metrics	• Implement alternatives for balancing during extended outages • Resource Availability and Need (including Fuel Assurance) • Stakeholder training simulator expansion for extreme events (Loss of multiple units, islanding) • Advances in parallel flow visualization

MISO's generation portfolio changed significantly in the past decade, and MISO is planning for several different future scenarios

MISO Generation Portfolio Evolution



2031 Future Scenarios



Existing Fleet
No carbon regulations modeled but some reductions expected due to RPS and economics.

Policy Regulation
Carbon regulations targeting a 25% reduction across all aggregated unit outputs are enacted.

Accelerated Technology
Increase in carbon emissions results in carbon regulations targeting a 35% reduction across all aggregated unit outputs to be enacted.

MISO's markets changed alongside the generation portfolio to incentivize units capable of supporting resilience and reliability in diverse ways

Ramp Product May 2016	• Provides transparent price signals to help manage ramp constraints that could lead to short-term reserve scarcity events
Extended Locational Marginal Pricing Phase II May 2017	• Expands the criteria of online fast-start resources from 100 minutes start-up/notification to 60 minutes
Scarcity Pricing	• Signals market that MISO is anticipating shortage while procuring the product at an administratively determined price
Emergency Pricing Phase II Jul 2017	• Off-line fast start resources amortized over minimum run time • Available Maximum Emergency units allowed to move down below their Economic Minimum limits

MISO continues to work with stakeholders to develop market enhancements that properly value both new and legacy resources

Market System Enhancement	• The Market System Enhancement program will develop and implement the necessary strategic investments in our market systems to allow us to meet the evolving needs of our customers in the future.
Multiday Unit Commitment	• This project will explore potential improvements in economic scheduling over a longer time horizon than MISO's current Day-Ahead Market.
Combined Cycle Modeling	• This project provides a mechanism to allow combined cycle generator to offer in more than one unit configuration, along with associated costs, on an hourly basis—allowing for the hourly selection of the most economical configuration.
Short-Term Capacity Reserves	• This project explores options that ensure short-term capacity availability to address local and system-wide requirements.
Stored Energy	• Multiple Market Road Map projects would address storage aggregation, and new storage resources.

Conclusion

- MISO's markets achieve economic efficiency, while supporting reliable operations
- MISO is accelerating planned market efforts to improve resilience and address resource portfolio evolution
- Current and planned market enhancements position MISO to continue to support reliable, resilient operations

Questions?