Evolution of the Grid in MISO Region

Jordan Bakke, David Duebner, Durgesh Manjure, Laura Rauch

MIPSYCON

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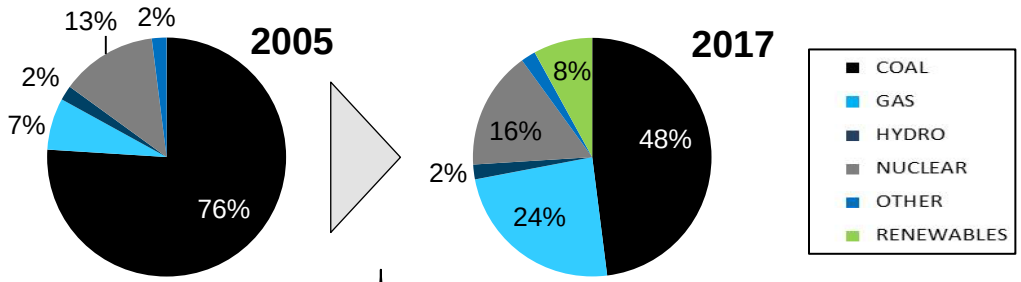
MISO's mission is to ensure reliable delivery of low-cost energy through efficient, innovative operations and planning

- **Footprint**
  - 15 US States, 1 Canadian Province
  - City of New Orleans
- **Scope of Market Operations**
  - $25.3 billion gross market charges
  - 437 Market Participants
  - 42 million end-use customers
  - 65,800 miles of transmission
- **Generation Capacity**
  - 175 GW (market); 191 GW (reliability)
- **Historic Peak load**
  - 127 GW (market); 131 GW (reliability
- **175 Members**

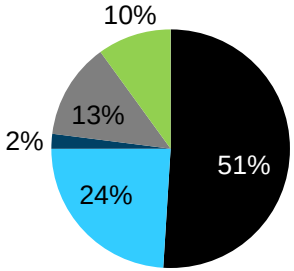
Market Footprint

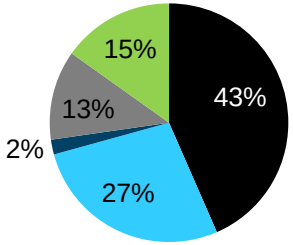
Drivers of Change

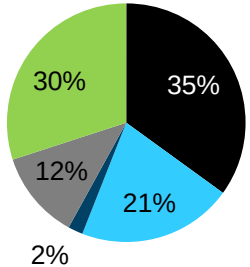
MISO expects significant growth in renewable and gas-fired generation

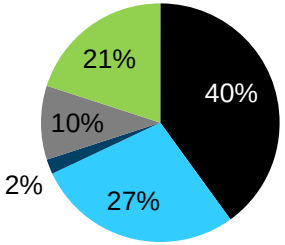


2032 MTEP18 Future Scenarios









Limited Fleet Change
Stalled generation fleet changes. Limited renewables additions driven solely by existing RPS under limited demand growth.

Continued Fleet Change
Continuation of the renewable addition and coal retirement trends of the past decade.

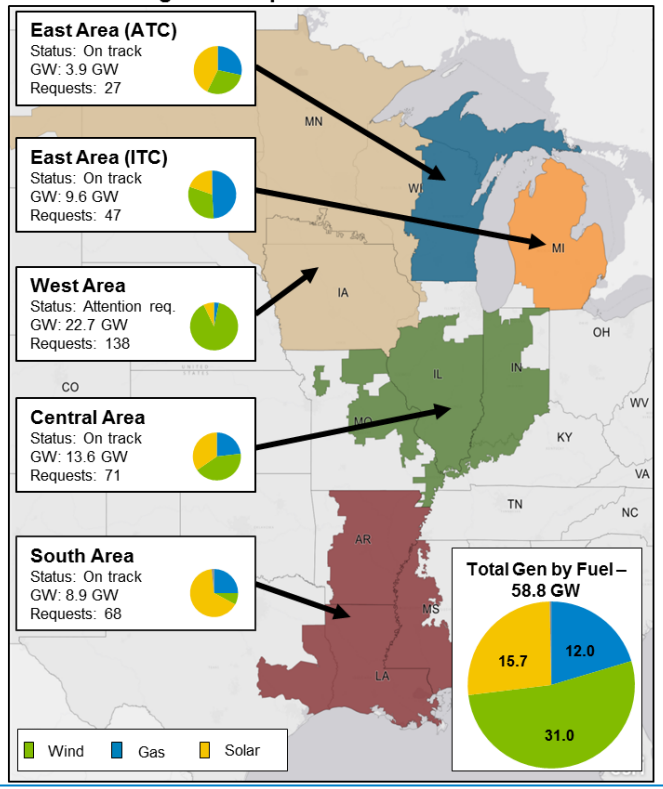
Accelerated Fleet Change
Renewables and demand side technologies added at a rate above historical trends. Fleet changes result in a 20% CO_2 emission reduction[1].

Distributed & Emerging Tech
New renewable additions largely distributed and storage resources co-located with largest sites.

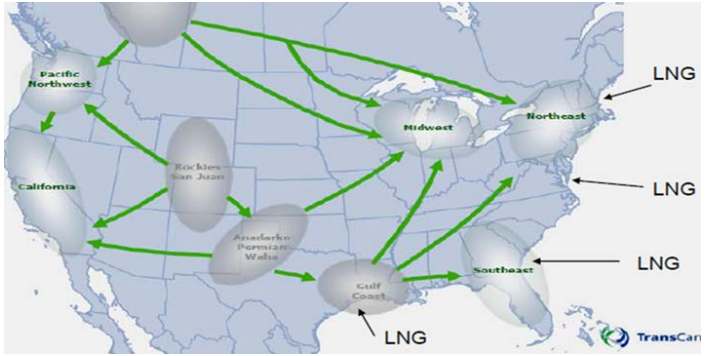
1. Emission reductions from current levels by year 2031

Changing geographic resource deployment drives changes in transmission needs

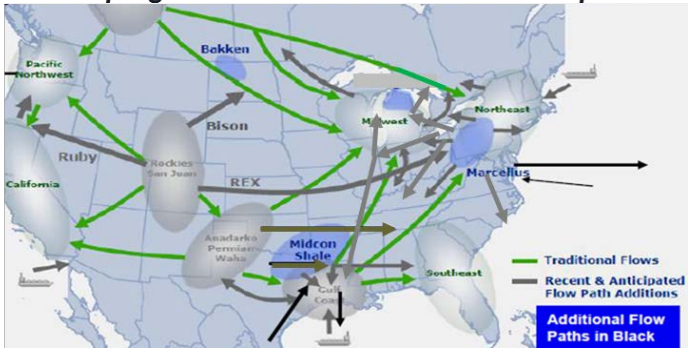
MISO Planning Area Map



Historic Flow Patterns and LNG Imports



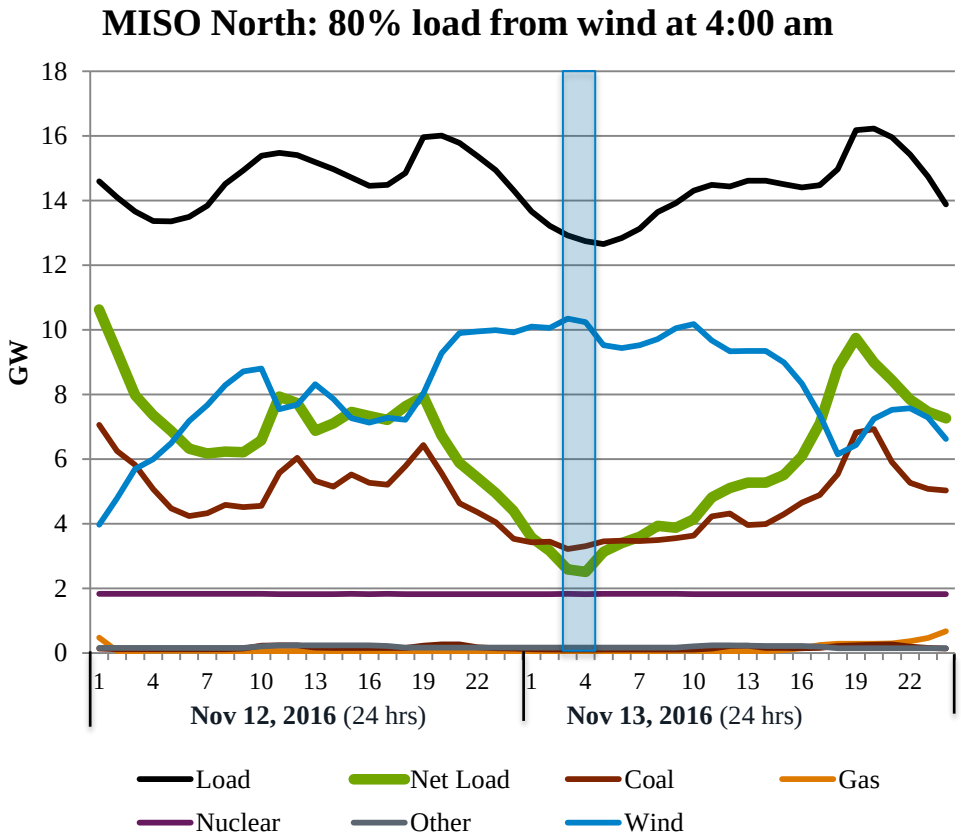
Developing "Grid" Flow Patterns & LNG Exports



MISO is already experiencing high wind generation levels

	MISO Total	MISO North*
2016 wind % of annual energy	8%	27%
2016 hourly wind peak (Dec. 7 @ 11pm)	13.6 GW	11.6 GW
2016 maximum wind as a % of load (Nov. 13 @ 4 am)	22%	80%

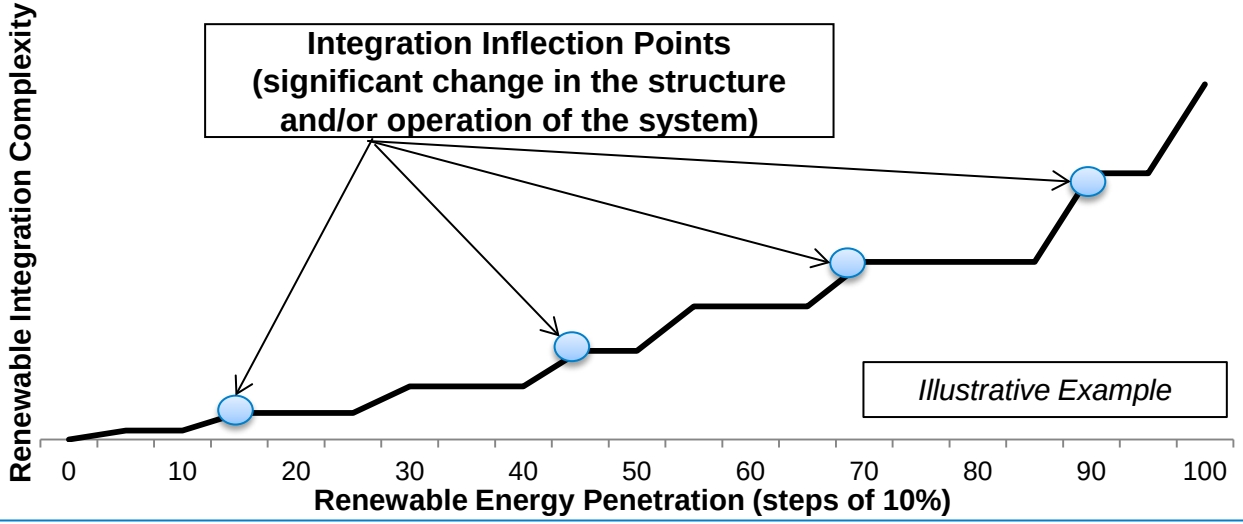
*MISO North has roughly the same annual energy as ISO New England



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

Study Focus Areas:

- RENEWABLE PENETRATION LIMITATIONS
- GEOGRAPHIC DIVERSITY
- INCREASE AWARENESS OF ISSUES
- RELIABILITY (OPERATING & PLANING)
- TIMING AND URGENCY



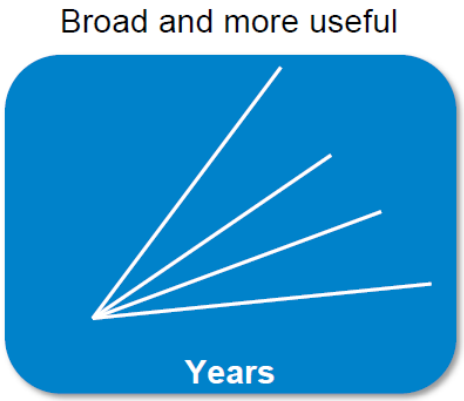
Inflection Point Focus Areas:

- Operational
- Steady State
- System Stability
- Resource Adequacy

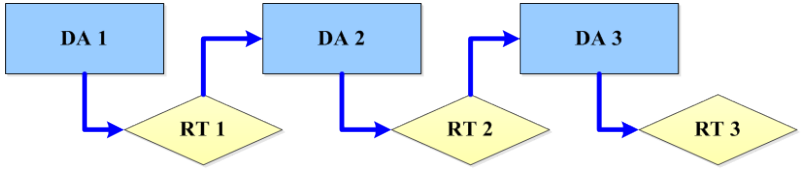
Planning & Modeling

Economic Planning

- Multiple Futures are studied to capture a wide range of possible load growth rates and resource mixes in long-term (15 year) planning horizon



- Economic analysis at hourly (Day-Ahead) and 5-minute (Real Time) levels to capture variability of resources and associated impacts



Reliability Planning

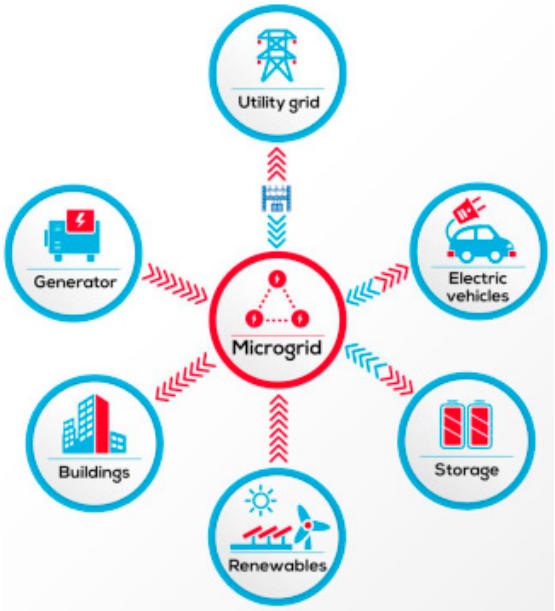
- Additional system conditions are analyzed to capture variable resources:
  - System peak condition: Summer peak in MISO
  - Off-peak conditions: Shoulder peak (70-80% peak load), Light load (minimum load), and Winter peak condition
- Renewable generation study assumptions:
  - System peak models at capacity credit level:
    Wind 15.6% of nameplate, Solar PV 50% of nameplate (est.)
  - Shoulder peak at average or policy design level:
    Wind 40% or 90% of nameplate, Solar PV 50% nameplate
  - Light Load at minimum or design level:
    Wind at 0% or 90% of nameplate. Solar at 0% nameplate at night

Modeling Distributed Energy Resources

- Reliability planning tools need to model DER
- Planning Coordinators and Transmission Planners need DER info at substation levels
  - NERC MOD-032 standard and associated model development processes need updating

Integrating DER

- Changes at distribution level
  - Aggregation of DER, distribution microgrids, Distribution Operators
- Transmission Planners needs to know the load the transmission will serve
  - Net load at transmission bus can work
  - Distribution gross load and DER generation provides more accurate dynamic simulation results



Resource Adequacy

Factors driving reserve margins

External Non-Firm Support

- Diversity of load between MISO and external system allows limited non-firm support
- MISO process reevaluates this value every year
- Increase in Non-firm support (-)

Weather and Economic Uncertainty

- Captures uncertainty due to economics and weather (not forecast error)
- MISO process evaluates variation in this value every year
- Increase in either Weather or Economic Uncertainty (+)

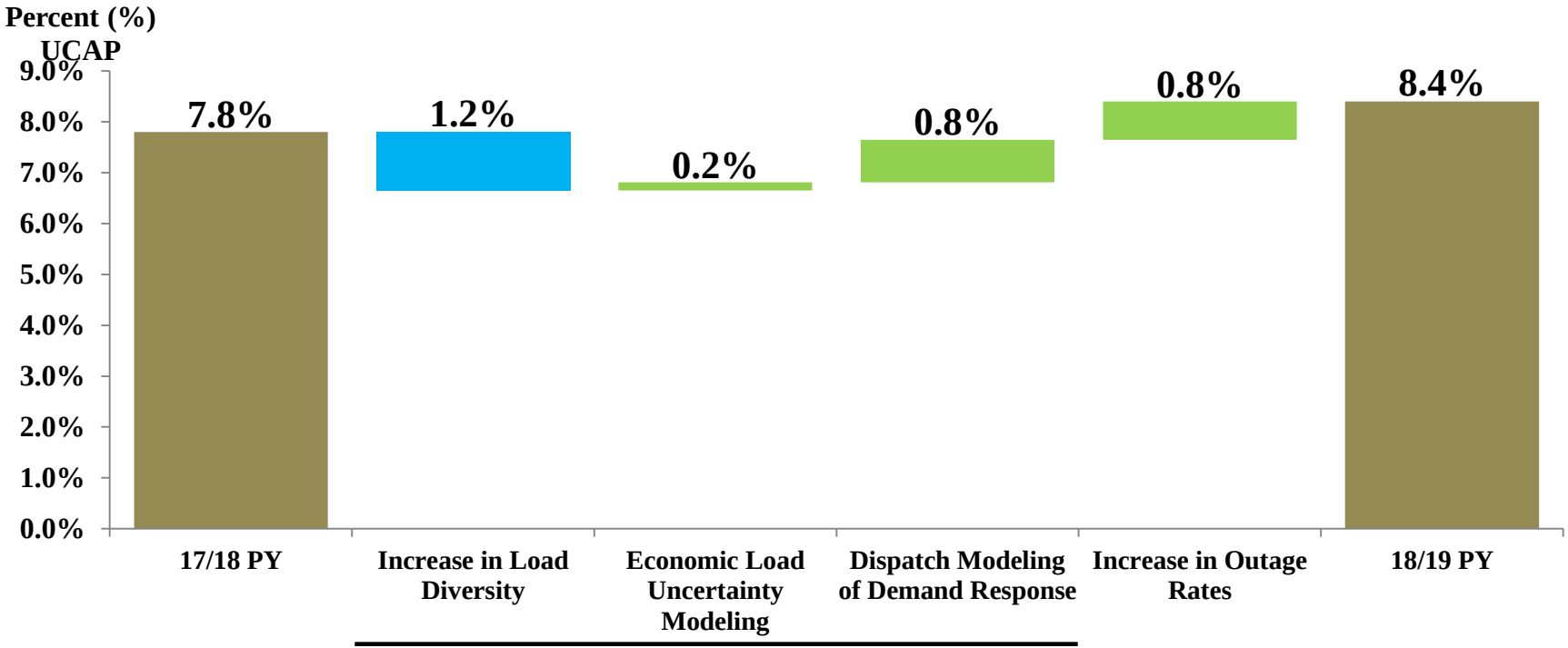
Load

- LBA level forecasts are updated annually and aggregated into regional values
- Increase in forecasted demand (-)
- Flatter load Profile (+)

Generation

- MISO capacity and firm imports included in model
- Increase in Unit size (+)
- Increase in Forced outages (+)

Planning Reserve Margin increase due to increase in outage rates



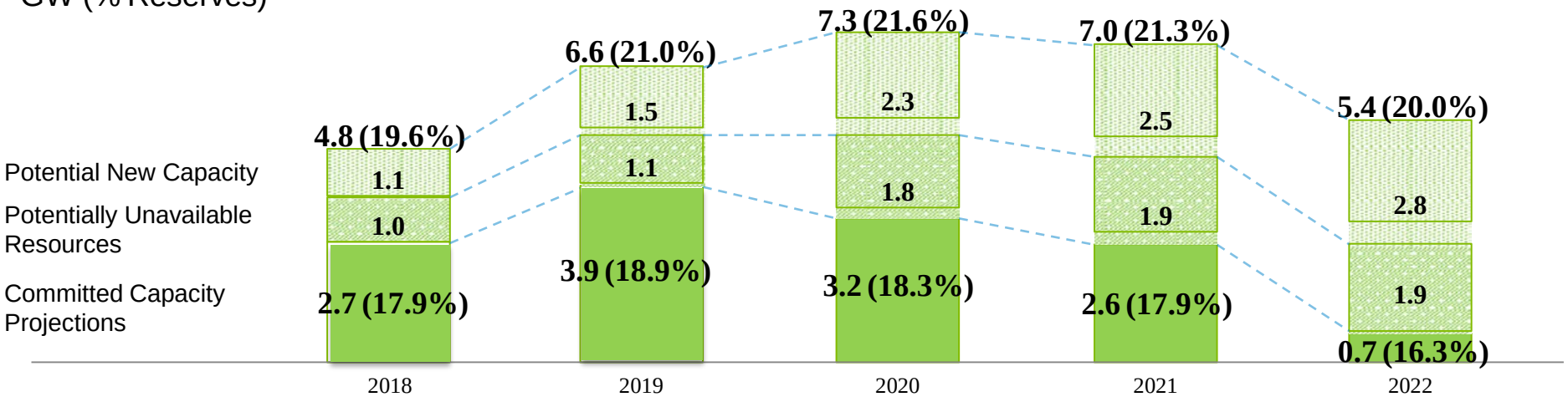
Process changes moving from Multi Area Reliability Simulation (MARS) to Strategic Energy & Risk Valuation Model (SERVM)

The 2017 OMS MISO survey projects sufficient resources to manage resource adequacy risk

Projected Regional Capacity Position in Installed Capacity

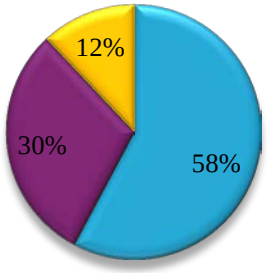
1 Day in 10 Planning Reserve Margin = 15.8%

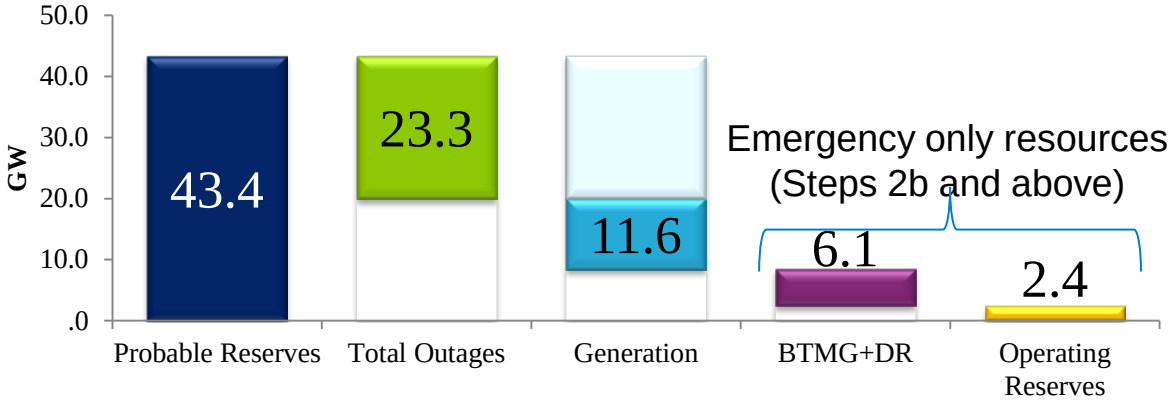
GW (% Reserves)



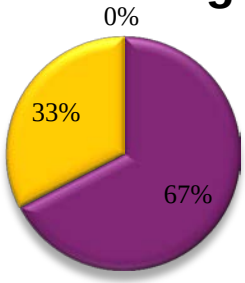
In a high load and extreme outage scenario, MISO is relying on BTMG's and DR to meet peak demand

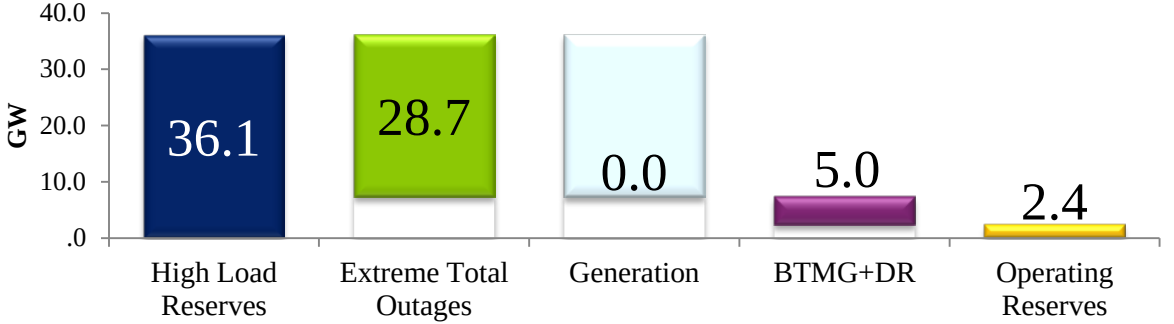
Probable Outage Scenario





Extreme Outage Scenario





Operations

Evolution of DA & RT market operations at MISO

Pre- Energy Market (prior to April 2005)

- Decentralized bi-lateral market and unit-commitment & dispatch
- Sub-optimal dispatch and congestion management
- Individual BAs carried own regulation and spin reserves
- Regulation requirement: ~1600 MW
- Spin requirement: ~1500 MW

Post-Energy market, pre-ASM

- Centralized, optimal unit commitment and dispatch
- Transmission congestion managed through SCED
- Individual BAs still carried their own regulation and spin reserves
- Regulation requirement: ~1600 MW
- Spin requirement: ~1500 MW

Post-ASM (January 2009)

- Centralized, co-optimized energy and operating reserves dispatch
- One centralized regulation target
- Pricing mechanism for regulation moved to market pricing
- Regulation requirement: ~400 MW
- Spin requirement: ~935 MW

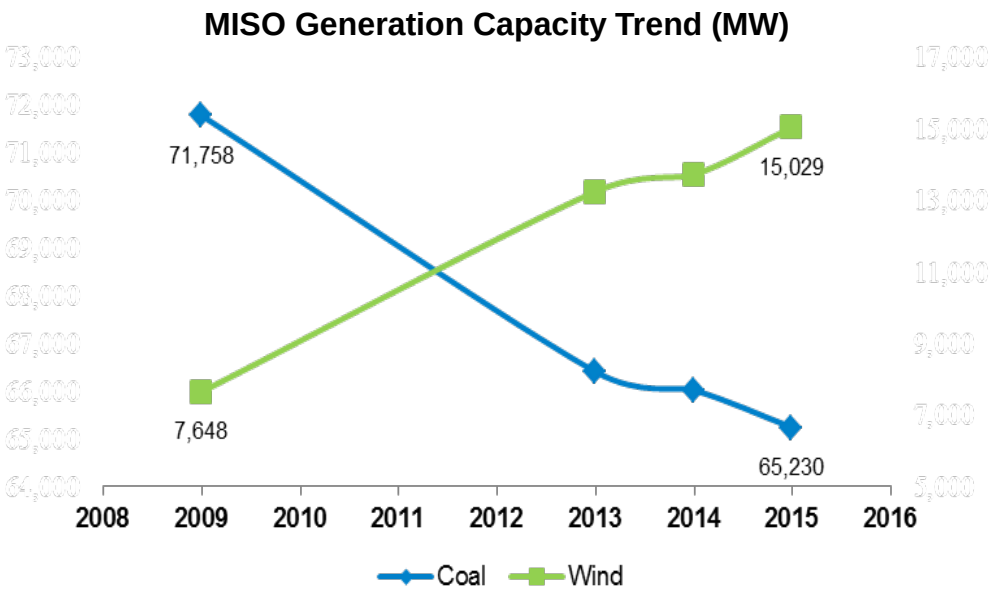
Enhancements for portfolio evolution

- Dispatchable Intermittent Resource product
- Ramping product
- Online transient stability
- **Under consideration**
- Requirements for variable resources to provide ancillary service (efforts through MISO stakeholders, FERC and NERC)
- Market enhancements

DA: Day Ahead RT: Real-time

MISO

Fleet changes, primarily driven by renewables have potential to adversely affect ability to maintain system reliability & economics

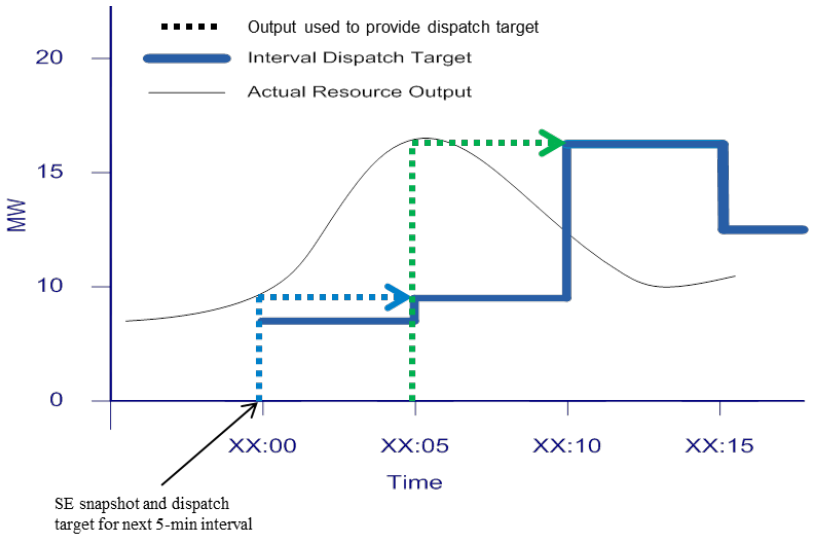


Note the difference in the scale between the coal and wind trends

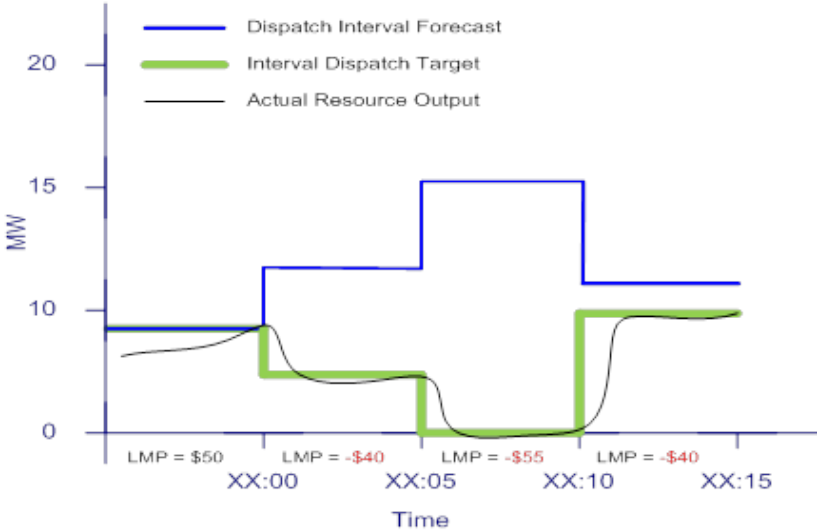
- Efficient dispatch & utilization
  - Uncertainty in output levels and timing
- Congestion management
  - Limited ability to *"dispatch"* wind
- System Ramping needs
  - Potential inability to ensure sufficient controllable generation during times of load ramping
- Adequate frequency response
  - Decreasing levels of frequency responsive generation

Dispatchable Intermittent Resource and Ramping products help manage dispatch, congestion & ramp concerns

Pre-DIR, dispatch target equaled observed output in previous state estimator snapshot – which could be ineffective, as shown below



DIR adjusts dispatch target based on real-time forecast and recognizing transmission limitations, as illustrated below

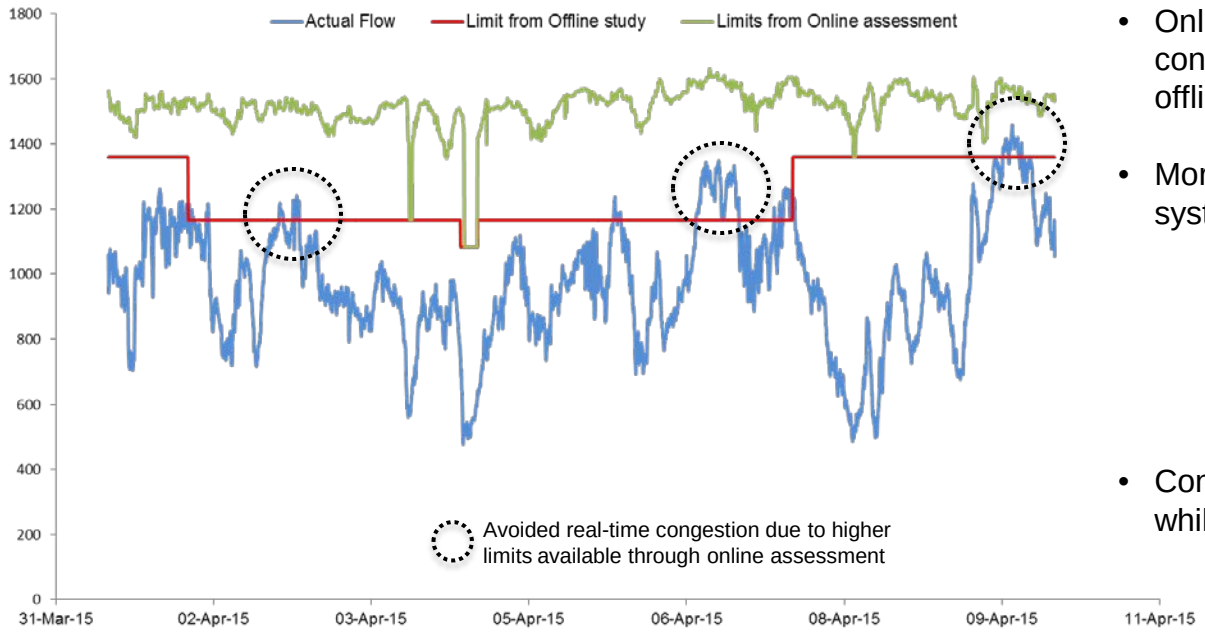


The blue trace is what the wind resource is capable of producing, and the green trace is what the transmission system can accommodate.

DIR: Dispatchable Intermittent Resource

RT: Real-time

Advanced real-time tools allow maximum utilization of renewables while minimizing congestion costs



- Online assessment (green) provides consistently higher limits compared to offline studies (red).
- More efficient utilization of the transmission system by:
  - minimizing real-time congestion and reducing costs
  - accommodating higher wind generation by minimizing curtailments
- Contributes to overall market efficiency while ensuring reliable operations

Online stability assessment reduced congestion costs by ~$31 million in 2016!

In summary, grid operations and planning continue to evolve to meet customer needs

- Planning processes are actively factoring in disruptive drivers to ensure optimal transmission development and resource adequacy
- Large amounts of renewables are being effectively handled in market operations through enhancements such as DIR, ramp-capability product and online stability assessments
- MISO is actively working towards ensuring continued reliability and efficiency in the face of an evolving grid