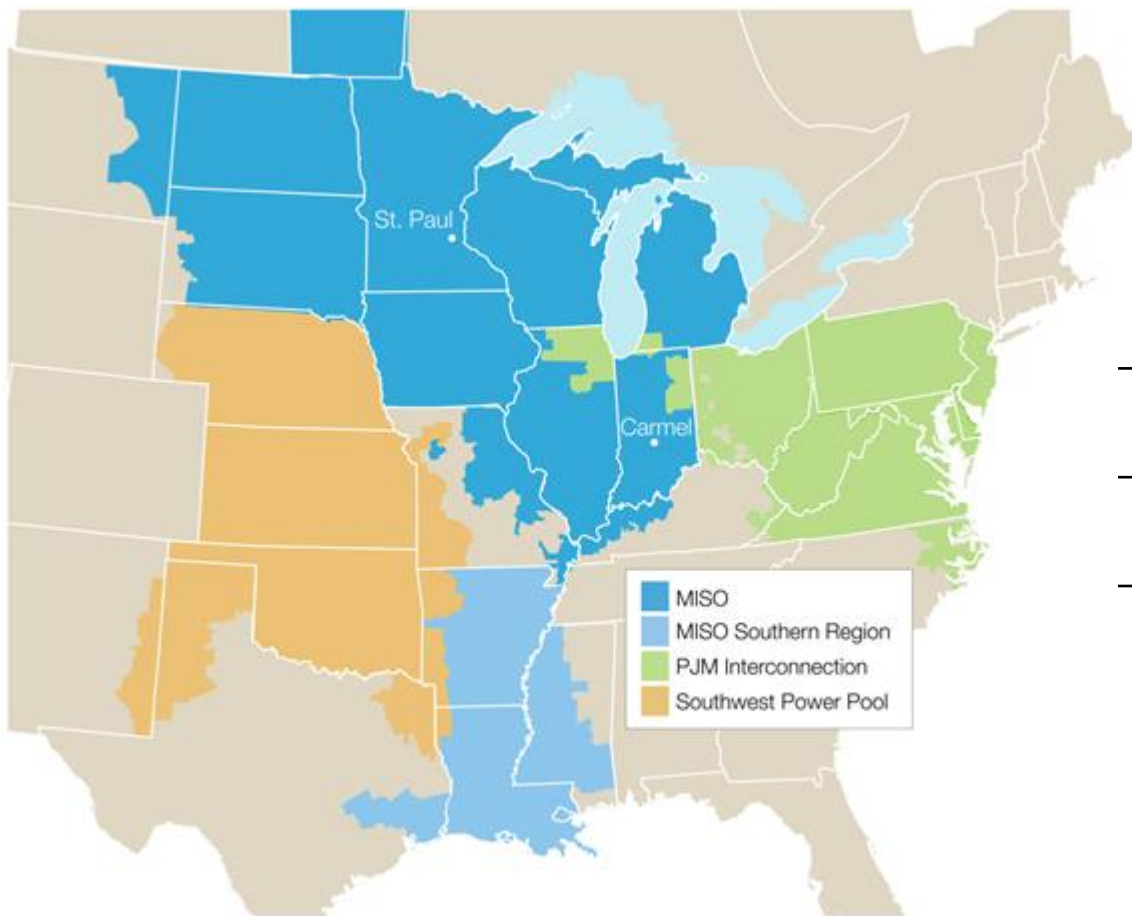


Wind Forecast Integration at MISO

Kris Ruud

Sr. Manager Resource Integration
And Regional Operations Engineering

MISO is one of the largest and most technologically advanced grid operators in the world



	MISO (Inc. South)
High Voltage Transmission - miles	65,170
Installed Generation - MW	162,296
Installed Generation - # of Units	1,431
Peak System Demand - MW	133,576

MISO's role is focused on a few key value-added areas

What We Do

Provide independent transmission system access

Implications

- Equal and non-discriminatory access
- Compliance with FERC requirements

Deliver improved reliability coordination through efficient market operations

- Improved regional coordination
- Enhanced system reliability
- Lowest cost unit commitment, dispatch and congestion management

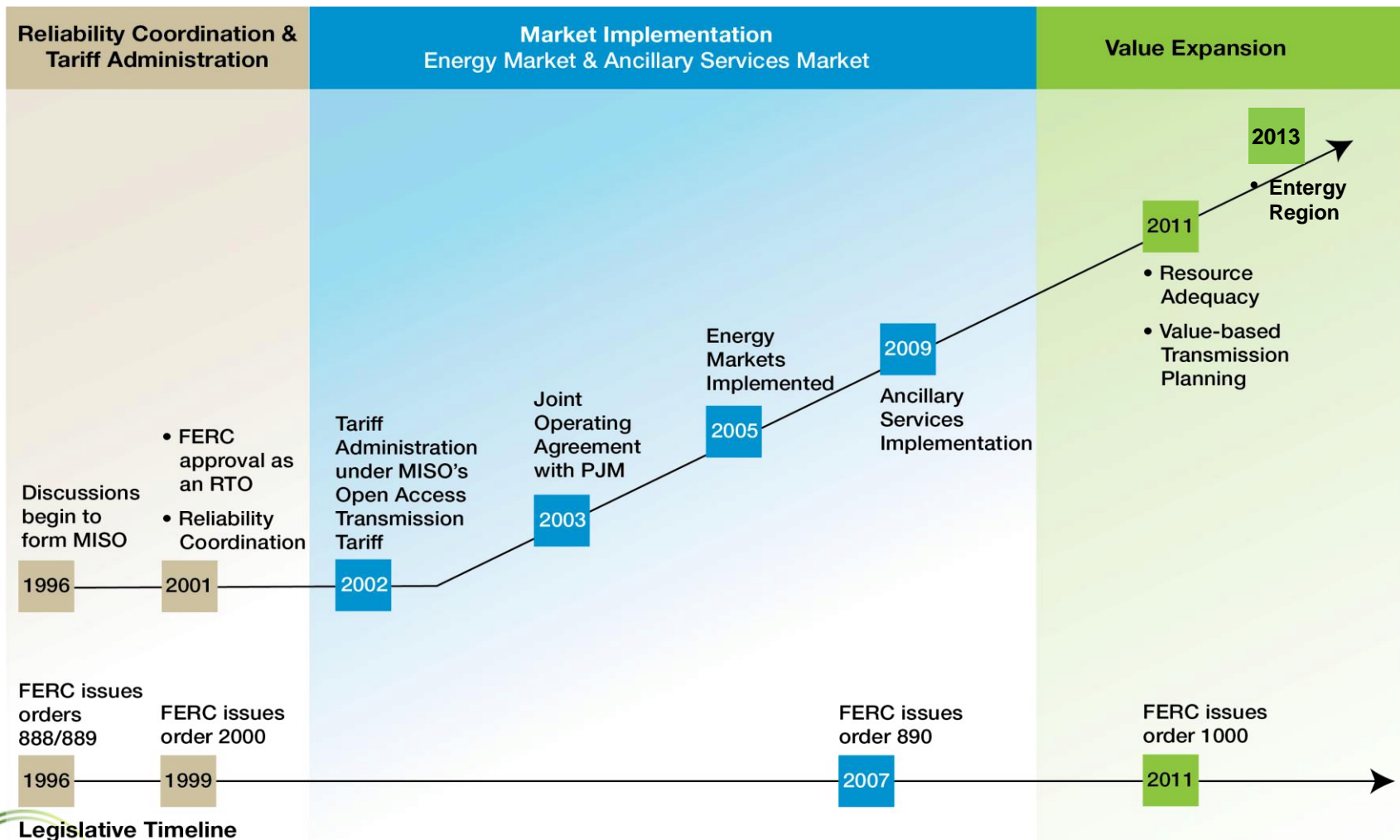
Coordinate regional planning

- Integrated system planning
- Broader incorporation of renewables

Provide price information transparency

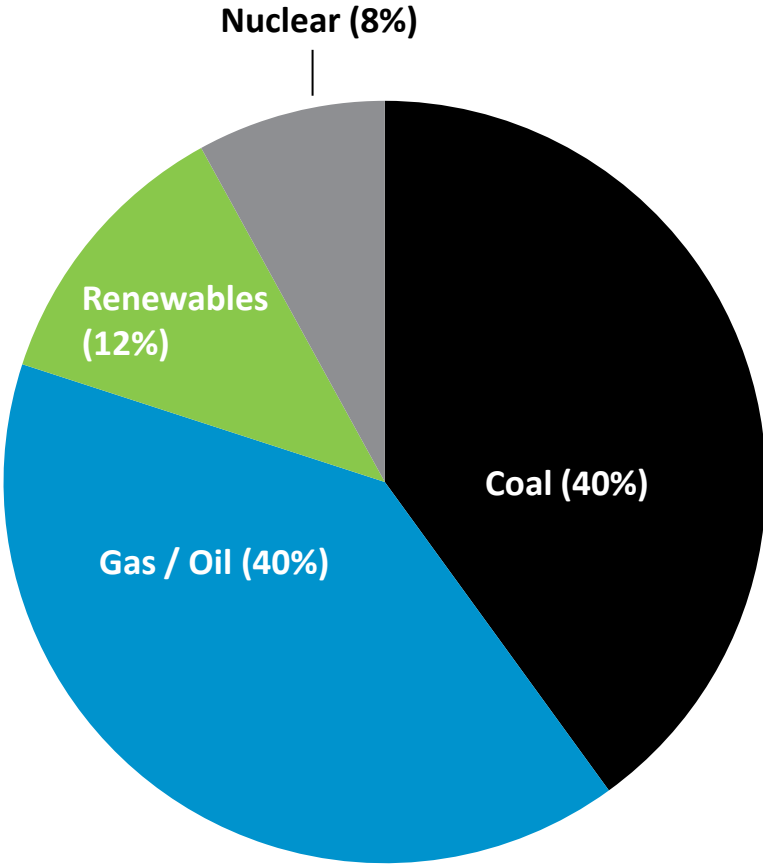
- Market price / value discovery
- Encourage prudent infrastructure investment
- Provide wholesale alignment for retail policy implementation

MISO was formed to address federal requirements, but growth has been based on value creation

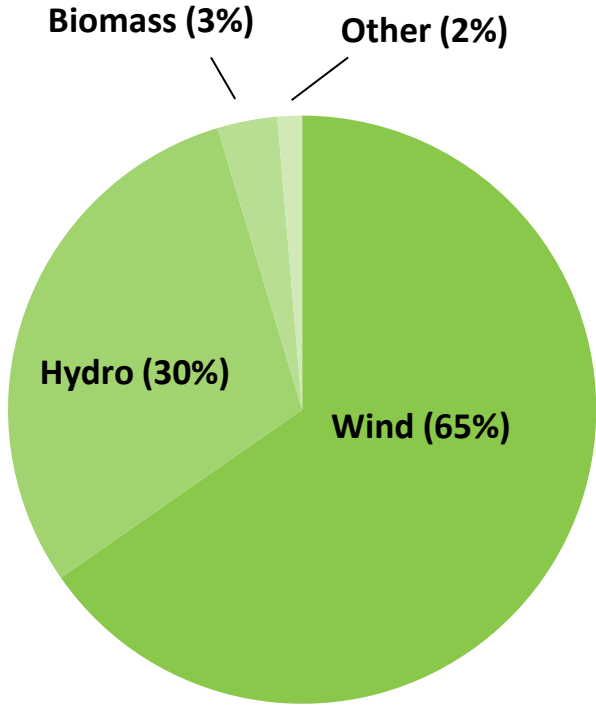


Legislative Timeline

MISO's capacity is comprised primarily of coal and natural gas units...



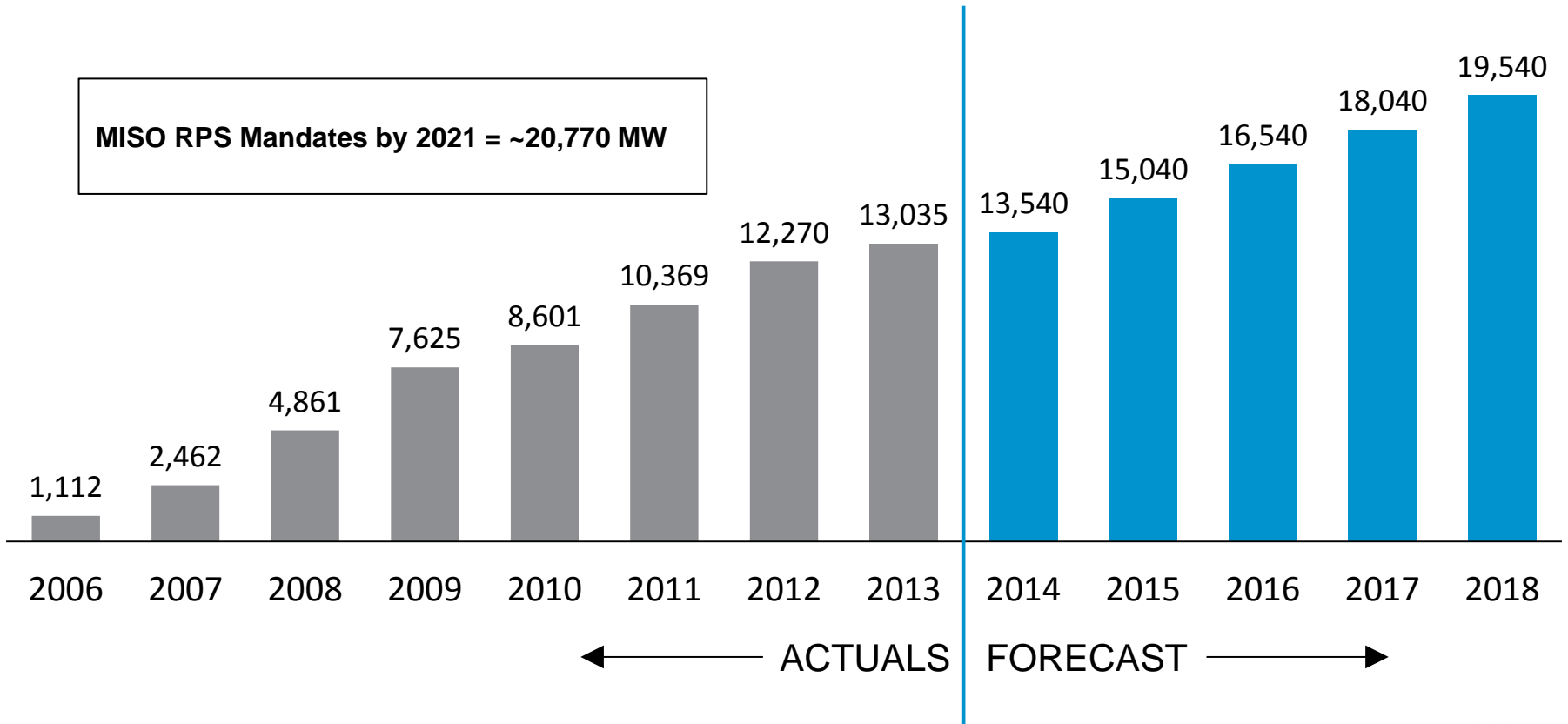
MISO Nameplate Capacity
176,454 MW



MISO Nameplate Capacity – Renewables
21,174 MW

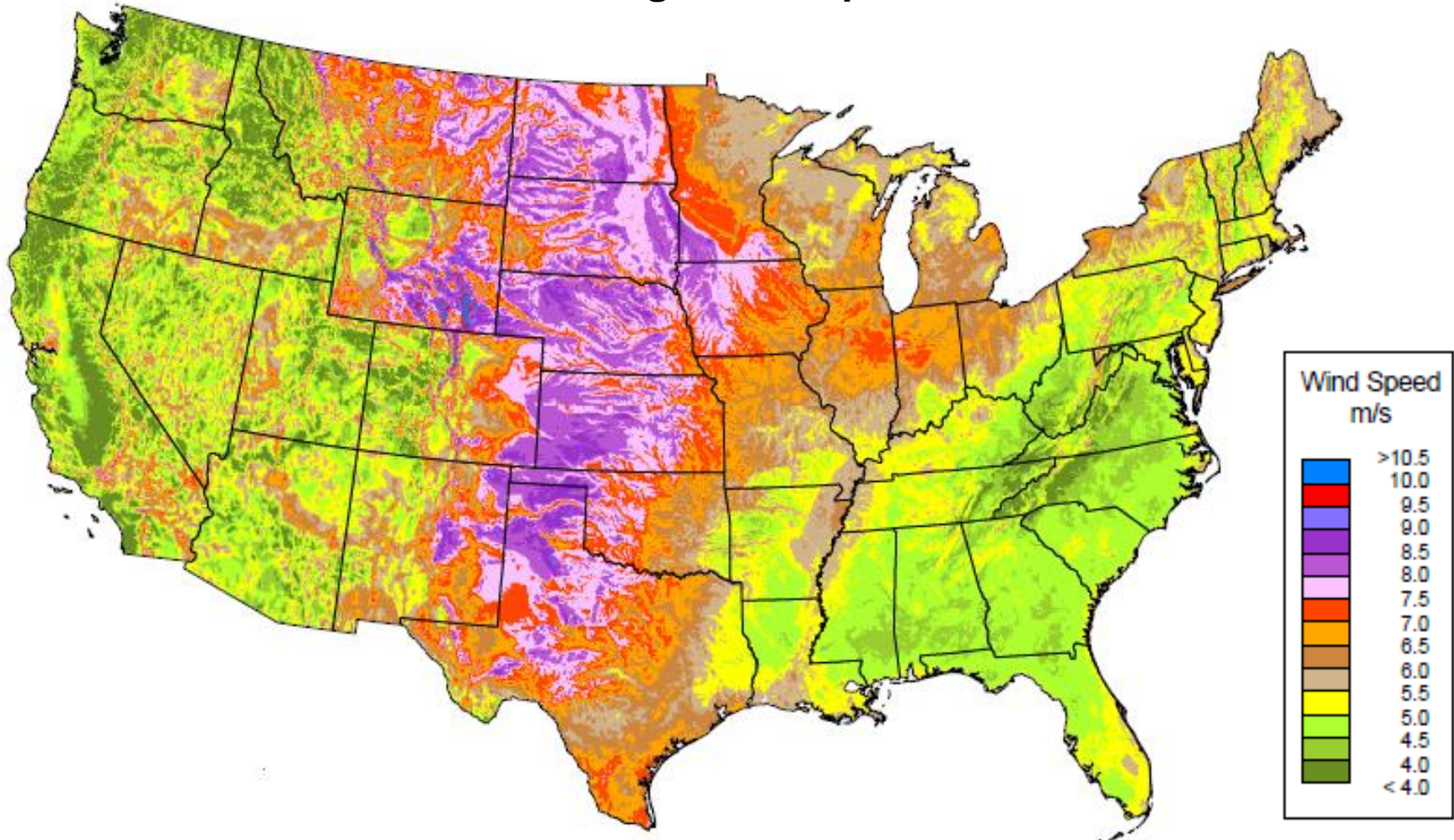
...but wind resources are growing rapidly

Registered nameplate wind capacity in the MISO region (in MWs)

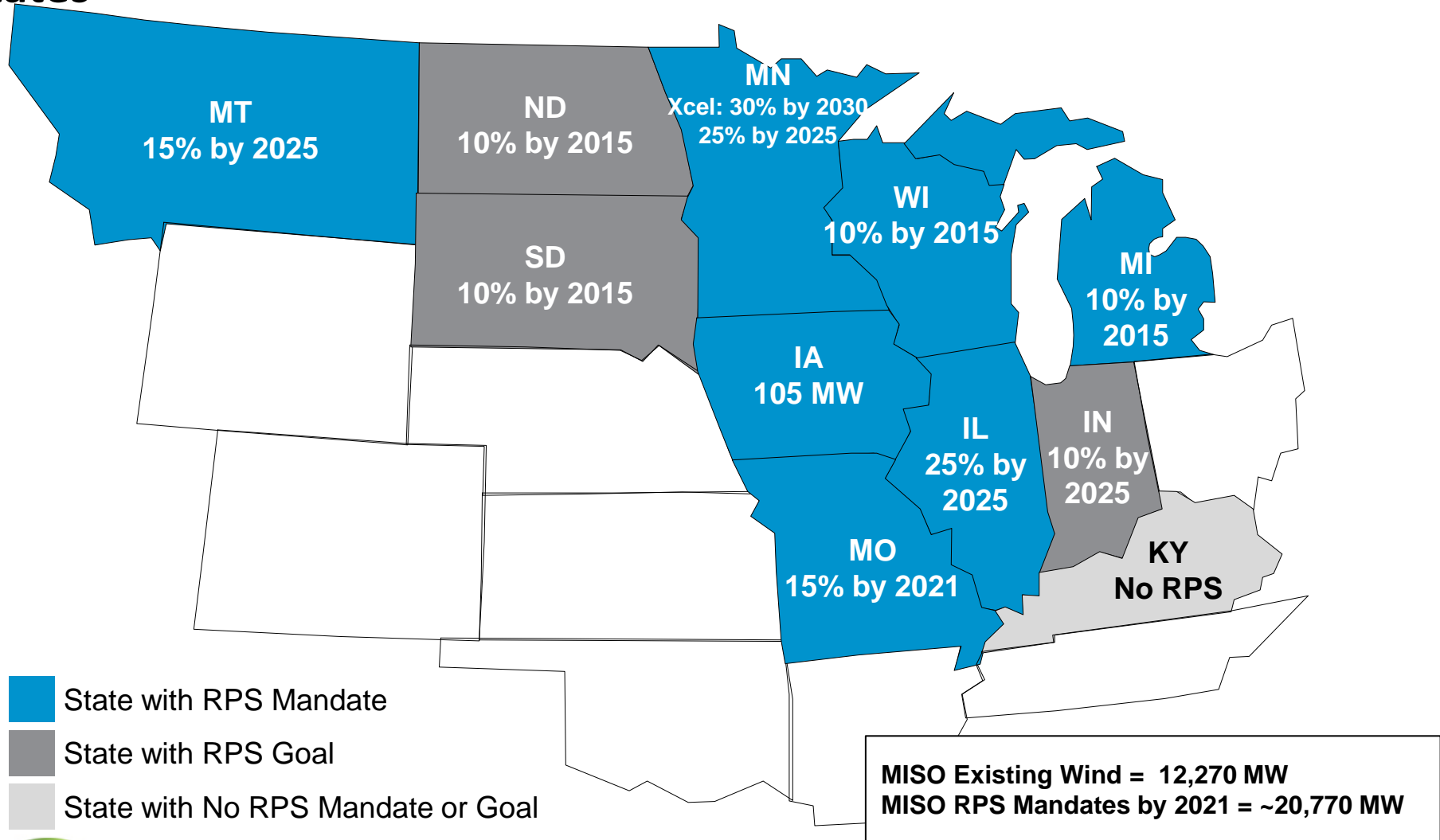


Wind's rapid growth is fueled by MISO's rich wind resource base...

Annual Average Wind Speed at 80 m



...and renewable portfolio standards and goals adopted in MISO states



Inherent characteristics of wind have significant operational impacts on MISO

Driver

- Variability of wind
- Poor correlation of wind and load
- Transmission congestion caused by wind location

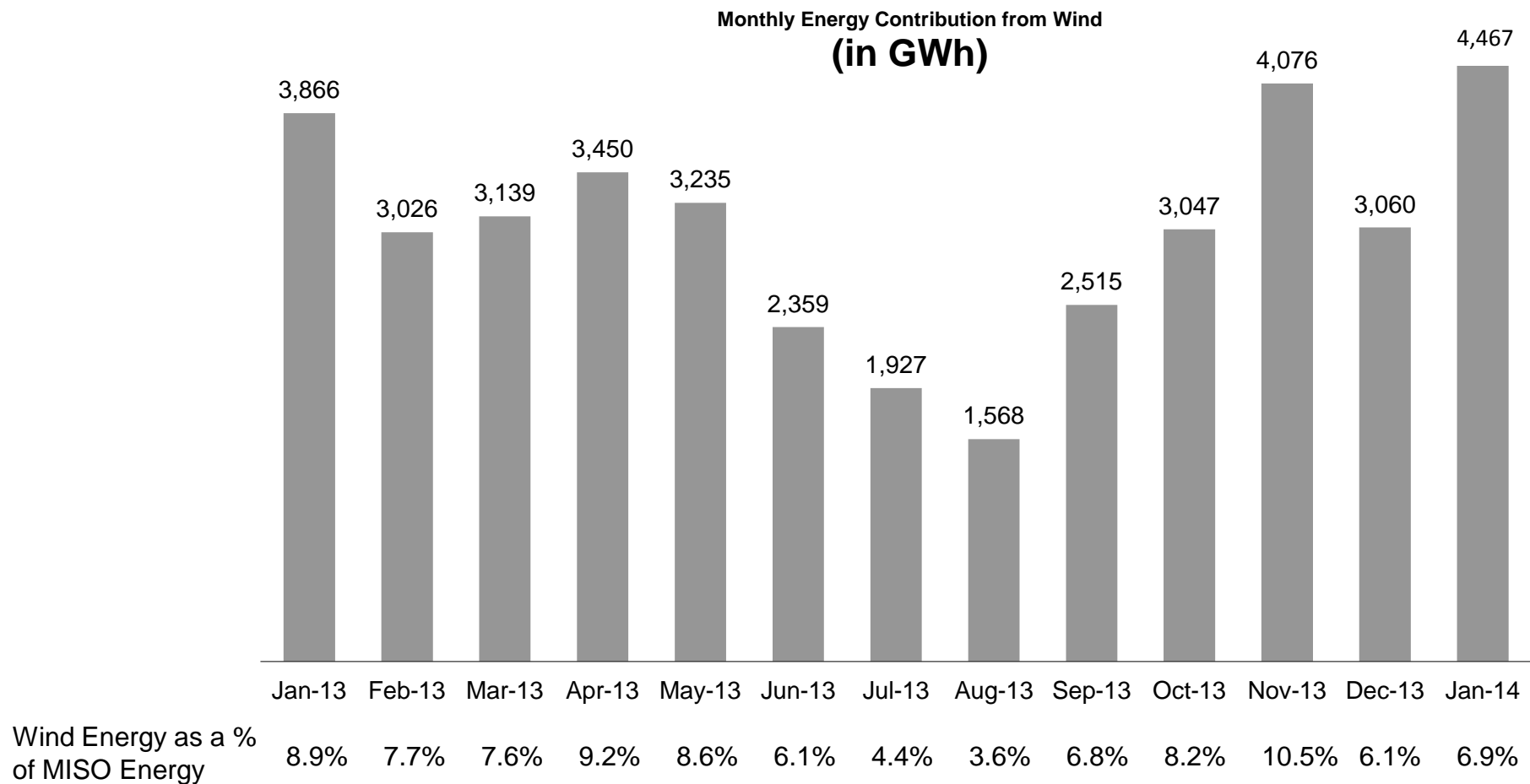
Market Issue

- Congestion management
- Over and under commitment
- Ramp management
- Surplus generation events

Tools

- Market dispatch of intermittent units (DIRs)
- Enhanced wind forecasting
- Future ramp capability enhancement

Wind is variable by month...

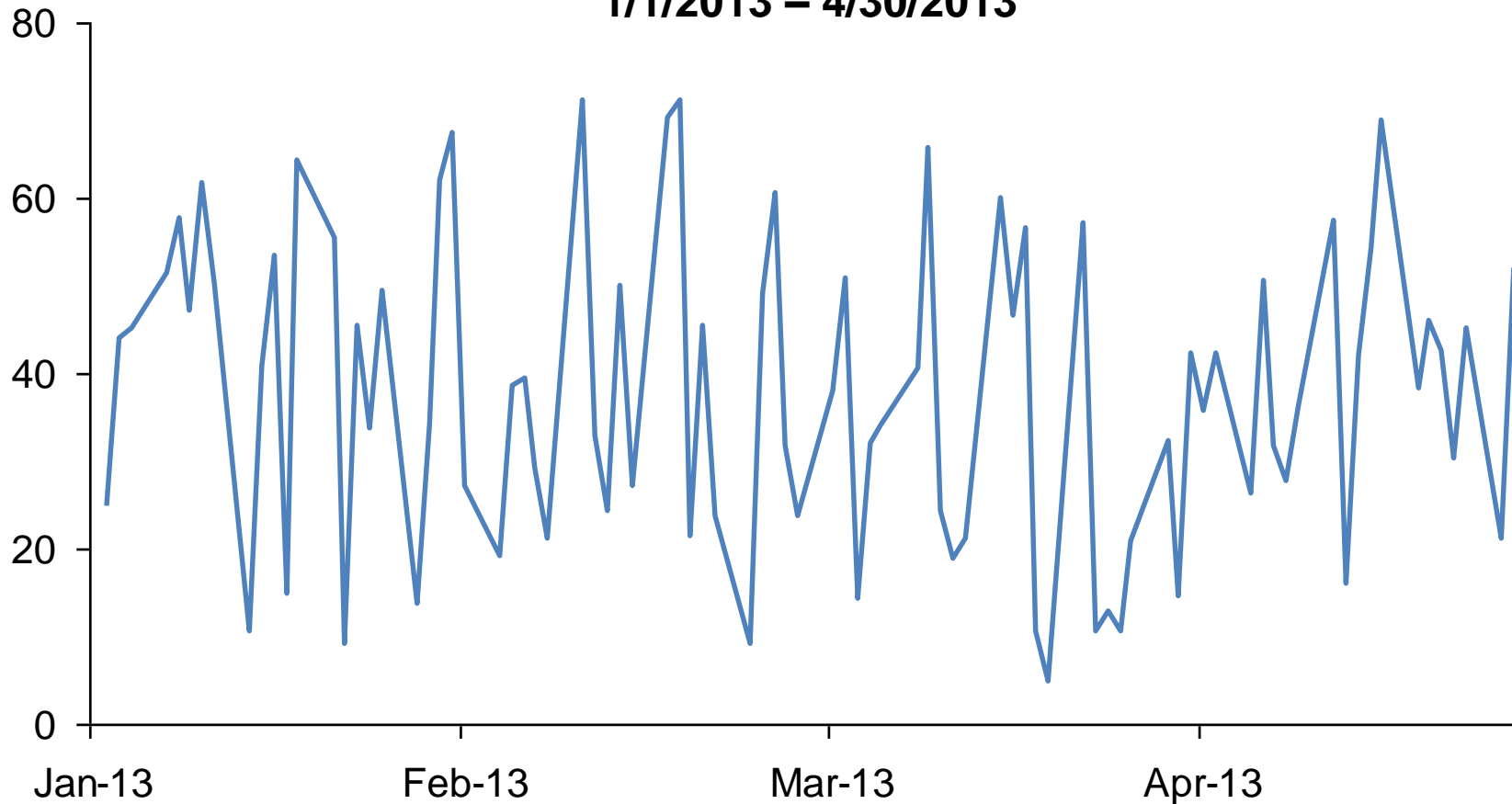


Source: MISO Real-Time Operations and Transmission Asset Management Departments

Source: MISO Monthly Operations Report for the Informational Forum, Feb 2014

...and wind is variable day-to-day and doesn't reliably correlate with load

Daily Wind Capacity Factor % for Peak Hours
1/1/2013 – 4/30/2013



Note: Weekends and holidays are considered off-peak and are excluded from the graph.

Source: MISO Monthly Operations Report for the Informational Forum, January 2013 - April 2013

Wind Forecasts at MISO

- Developed ~2008-2009
- Initially a hourly forecast for the subsequent ~36 hours
 - Assist MISO in making unit commitment decisions
 - Assist MISO in evaluating regional flow patterns
- Short term forecast (5 minute intervals for the next hour) developed as part of DIR deployment (~2010-2011).

Challenges prior to MISO dispatching intermittent resources (DIRs)

- Rapid increase in wind penetration
 - Transmission expansion lagged wind expansion
 - Deployment in areas with little transmission
 - Increasing need for manual curtailments to manage congestion
- Challenges of manual curtailments
 - Highly manual process; time consuming for reliability coordinator
 - Tracking firm vs. non-firm transmission service
 - Manual curtailments not accounted for in security constrained economic dispatch resulting in loss of price transparency
 - Manual curtailments less economic than automated security constrained economic dispatch
 - Adverse settlement impacts on wind participants

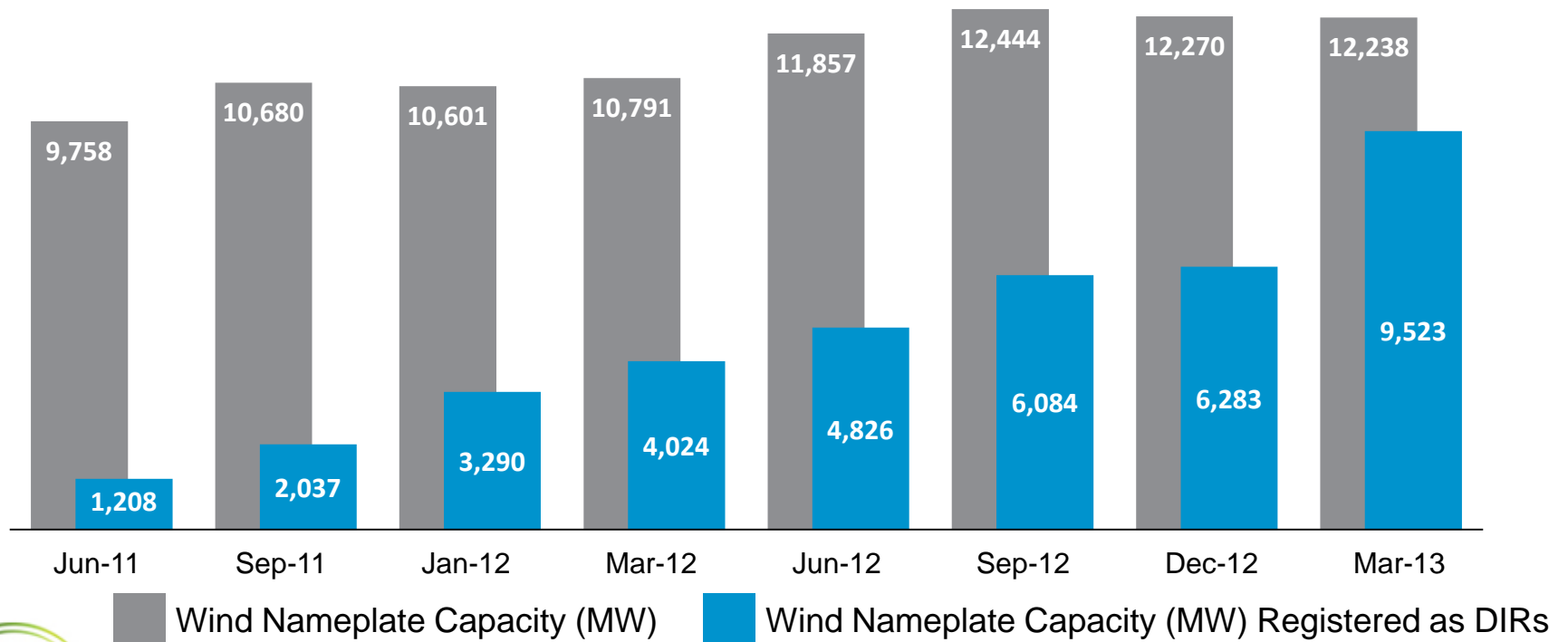
Dispatchable Intermittent Resources (DIRs) design features

- Renewable generation is treated like any other generation resource in the market
- DIRs can participate in the real-time energy market
- DIRs can automatically be dispatched up to a forecasted limit based on an offer price and system conditions.
 - Participants submit a short term wind forecast instead of a hourly economic maximum like other generation resources
 - This enables wind to submit offers and receive dispatch instructions rather than be manually curtailed when transmission constraints limit renewable energy generation to reach the broader market region

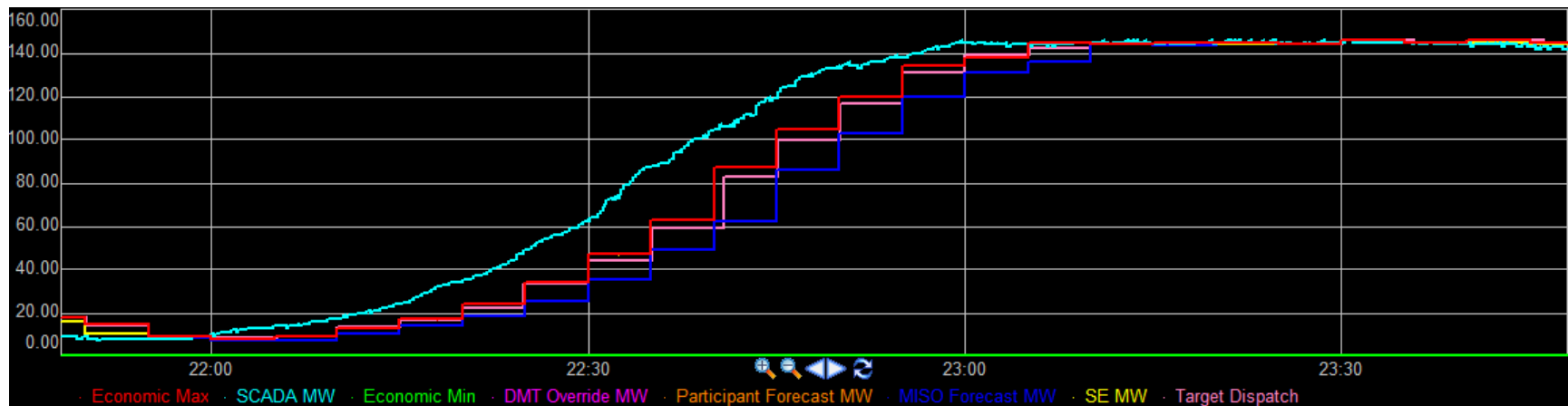
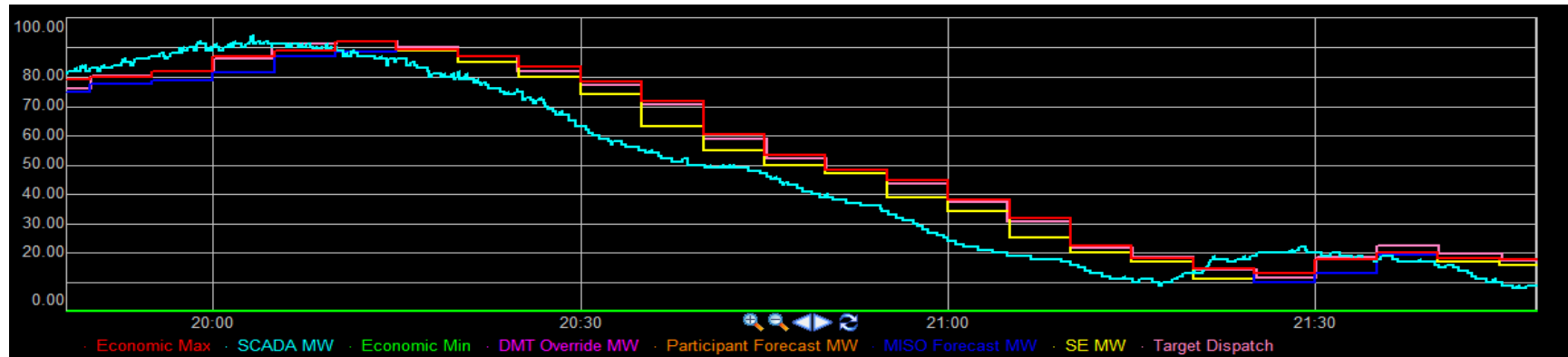
Dispatchable Intermittent Resources enhance system wide operational and market efficiency and improve market transparency

Dispatchable Intermittent Resources (DIRs) registration

- DIRs launched on June 1, 2011
- Registration required as of March, 2013 with limited exceptions



DIRs Heavily Dependent on Short Term Forecast



Improved wind forecasting will allow for improved operations, but wind forecasting is not likely to become an exact science

MISO Forecasting Accuracy: 1/1/2013 – 12/31/2013

	DA		RT	
	Error (MW)	MAPE (%)	Error (MW)	MAPE (%)
w/o dispatch down	593	4.87	463	3.80
w/ dispatch down	596	4.89	504	4.14

Wind variability has the potential to create a ramping challenge which may require improved tools and new market products to manage

- The current wind variability and profile impact ramp requirements as significantly as net scheduled interchange
 - Wind capacity levels expected from the region's Renewable Portfolio Standards will dramatically increase the operational difficulties
 - However, MISO's large balancing area and geographic diversity help minimize the issue at current wind penetration levels
- Current operational methods to manage this ramp include
 - Load and wind forecasting
 - Pre-commitment of units
 - Use of fast-start units and spinning reserves to manage unexpected variability
- Improved operational and market methods under development
 - Improved load and wind forecasting
 - 30-minute reserve products
 - Ramping service product

Questions?

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