



Challenges and Opportunities for Renewables

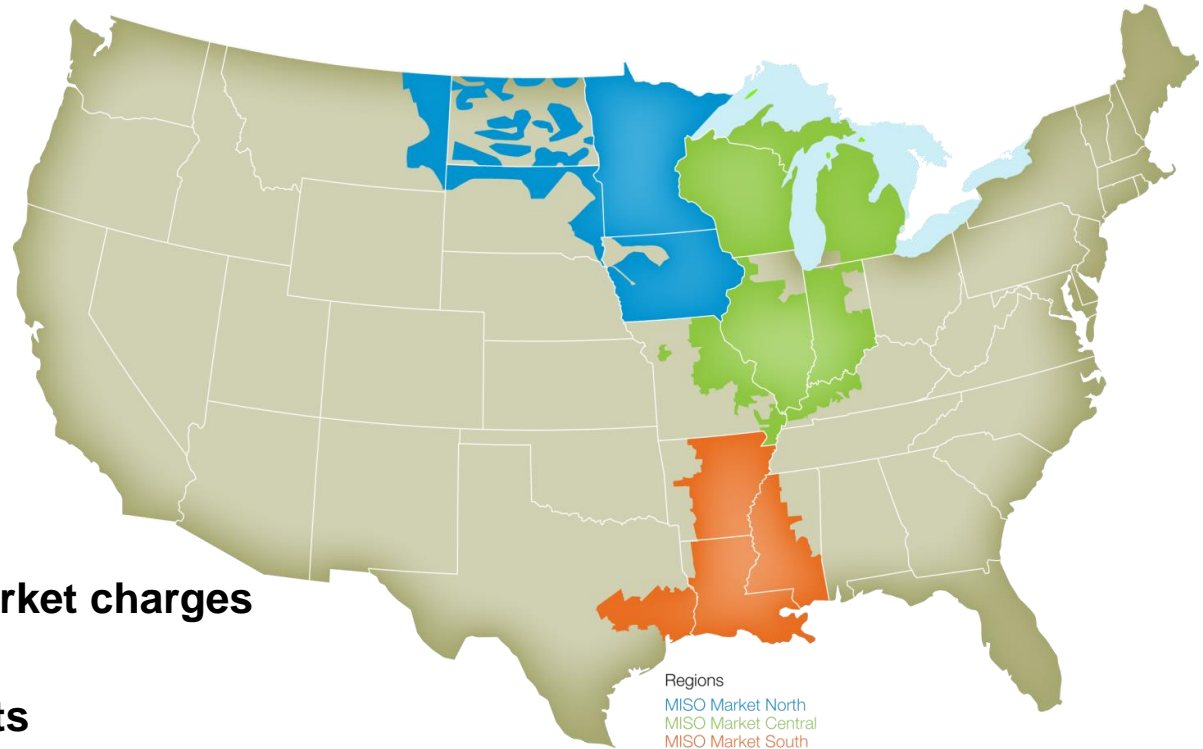
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Current Scope of Operations

- **Generation Capacity**
 - 180,051 MW (market)
 - 194,673 MW (reliability)
- **Historic Peak Load**
(July 20, 2011)
 - 127,125 MW (market)
 - 131,181 MW (reliability)
- **Historic Wind Peak**
(February 19, 2016)
 - 13,088 MW
- **65,800 miles of transmission**
- **5-minute dispatch**
- **2,483 pricing nodes**
- **\$24.7 billion gross market charges (2015)**
- **432 market participants**
- **42 million end-use customers**



Inherent characteristics of wind generation have significant impacts on system operations...

Driver

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

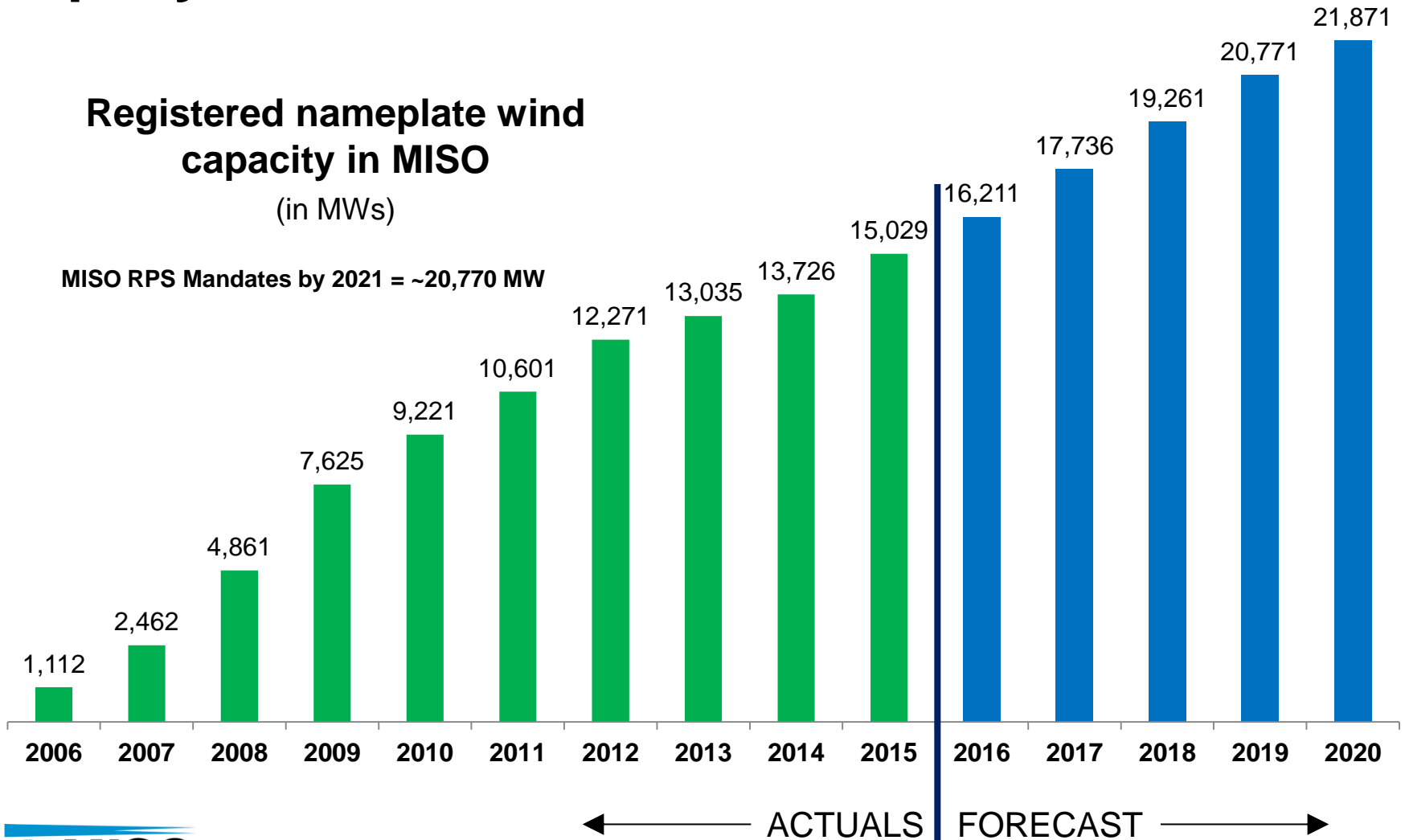
Market Issue

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

Tools

- Forward Planning
- Market dispatch of intermittent units (DIRs)
- Effective wind forecasting
- Ramp capability enhancement

... and wind generation in MISO is growing rapidly

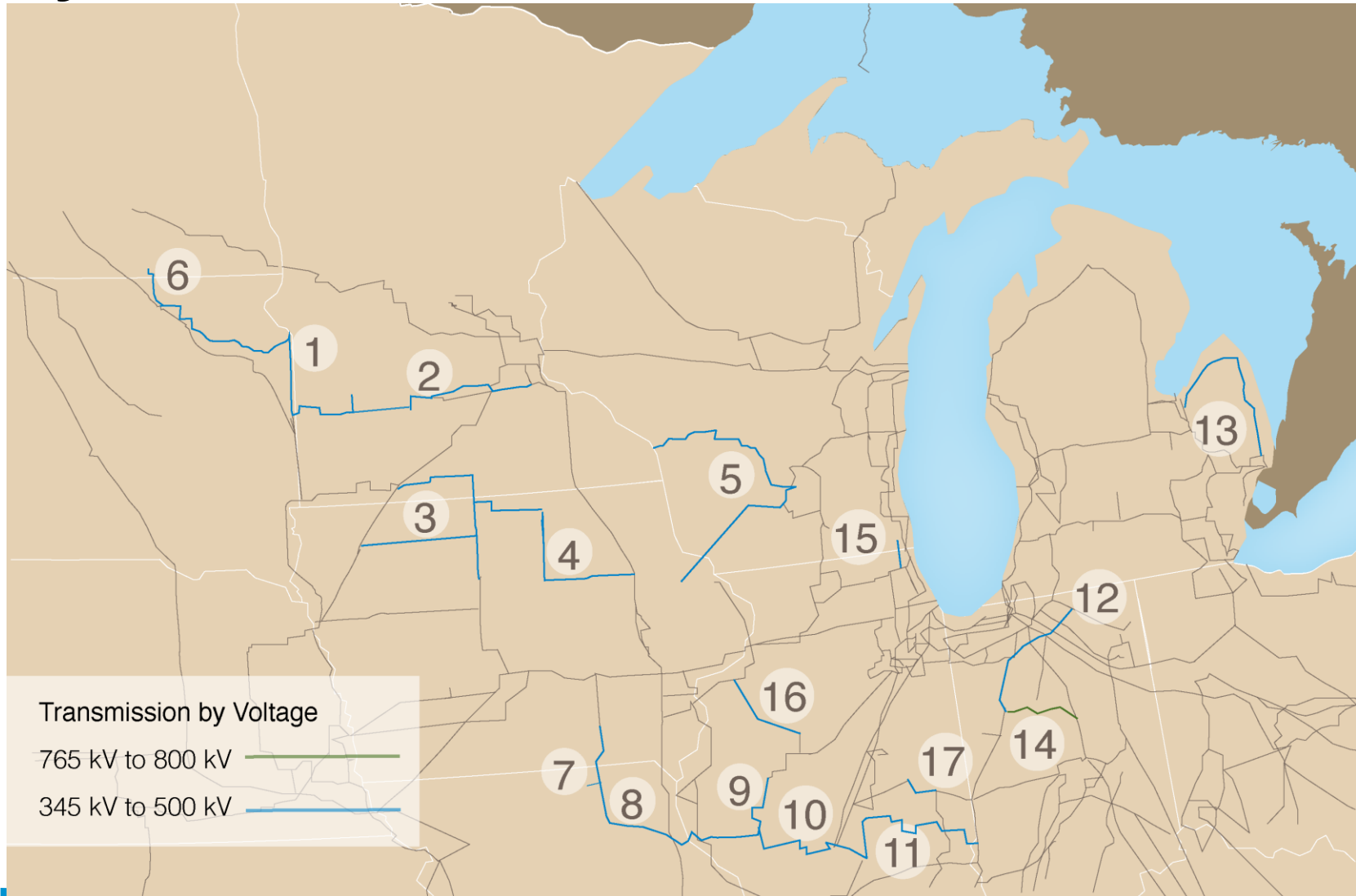


Rapid development of wind generation adversely affected congestion management

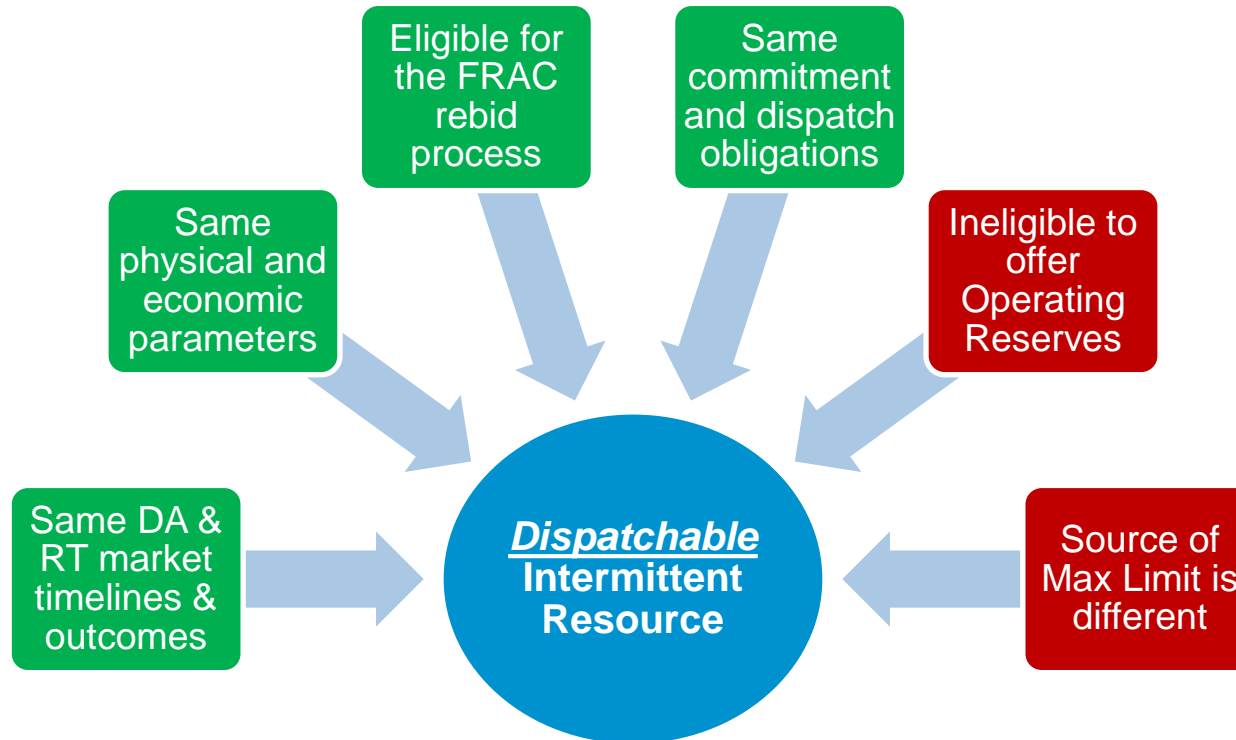
- Wind generation increased 400% between 2007 and 2011, up to 10,000 MW
- High penetration of wind generation in areas that have historically had little generation
- Development of wind generation outpaced the necessary transmission development
- Original market design classified wind as an *'Intermittent Resource'* that could not be economically dispatched
- In areas with high wind penetration, it was difficult for the SCED to manage congestion with limited dispatchable resources

Reliability Coordinators needed to manually curtail wind resources adversely impacting constraints, which was inefficient

The solution was to expand the transmission system...



...and to make wind resources closely mimic traditional generators



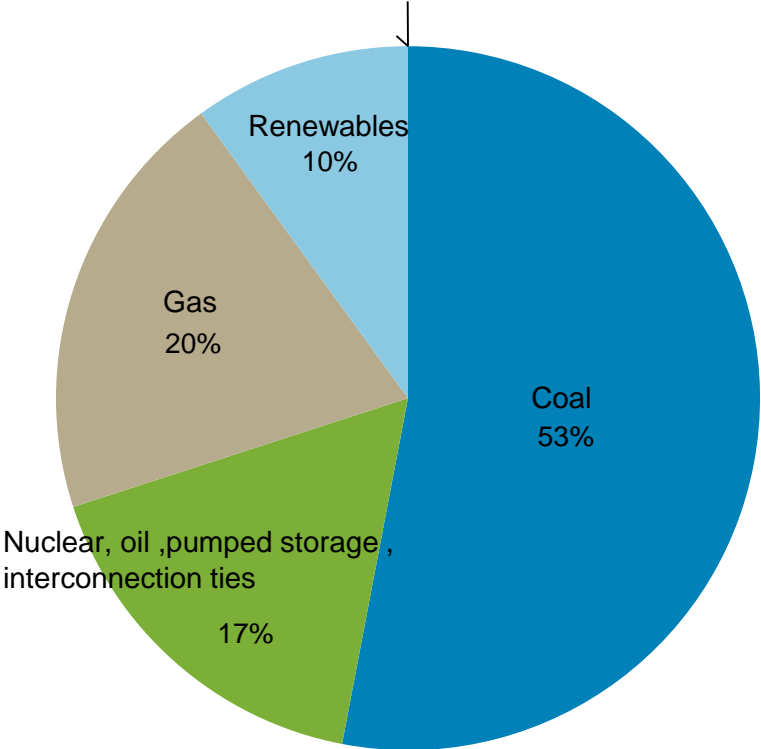
Ability to “dispatch” wind greatly enhanced congestion management and improved utilization of wind generation in the market

Recently, MISO implemented its Ramp Capability Product

- **MISO is the first RTO/ISO to successfully develop and implement a Ramp Capability Product**
- **The Ramp Capability Product increases reliability and decreases the cost of serving load**
 - Provides more transparent price signals, resulting in economic incentives for resource flexibility
 - Manages the ramp capability from controllable resources to better position them to respond to non-controllable variables, such as unexpected or sudden changes in wind generation or in load
 - Mitigates ramp constraints that otherwise could lead to short-term reserve scarcity events and associated price spikes

Current market conditions will not last as public policy and economics will drive portfolio evolution in the footprint

Energy mix in 2016
(Source: MTEP17, Existing Fleet ie Business As Usual)



Energy mix in 2031
(Source: MTEP17 Accelerated Alternative Technologies)

