Wind Update

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Contents

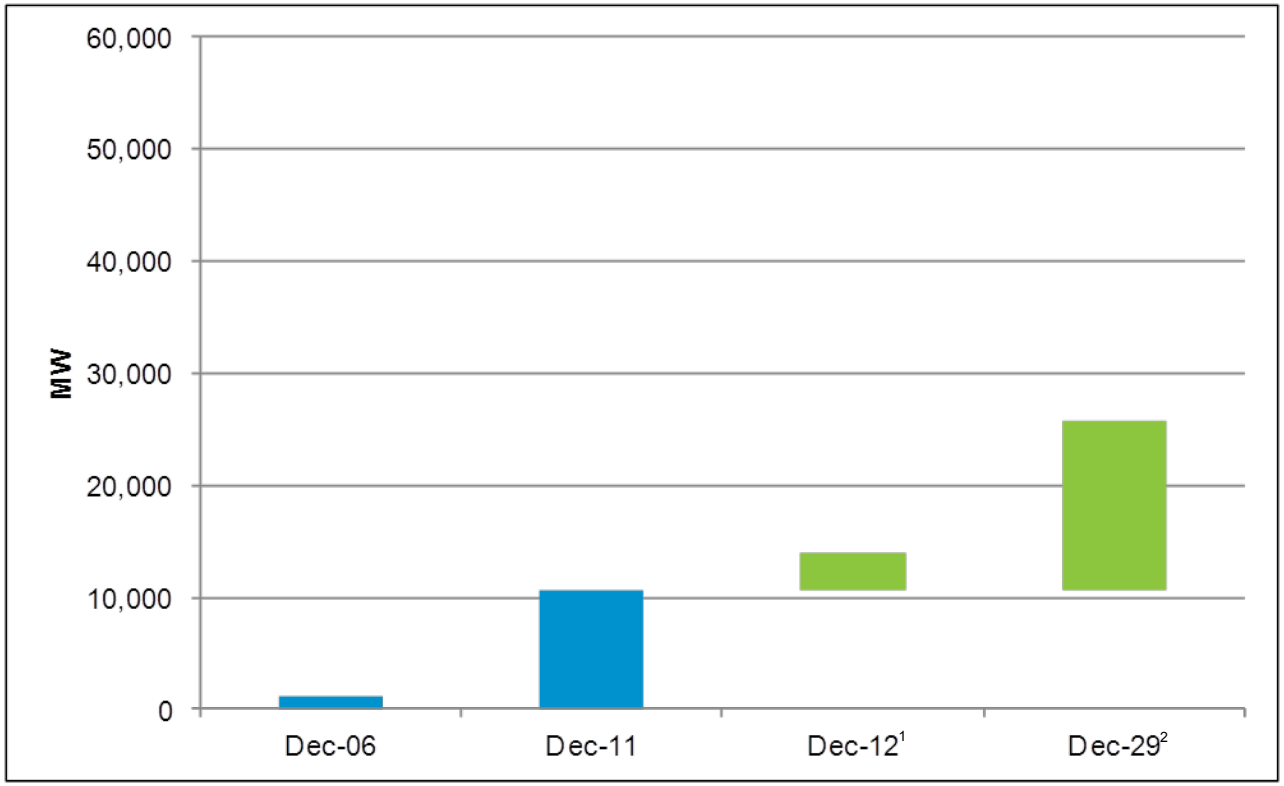
- Summary
- Review of Historical Wind Growth and Output
- Impact of Wind on Operations
  - Wind Curtailments
  - Dispatchable Intermittent Resources (DIRs) and Their Impact
- Future Wind Growth and Potential Impacts

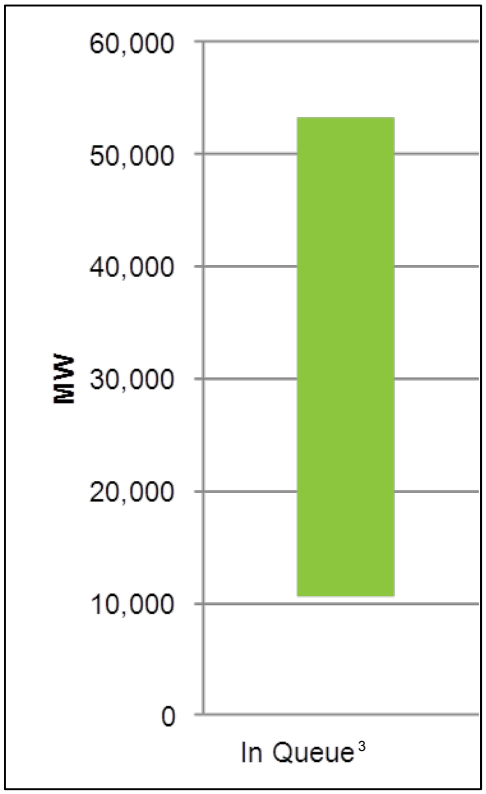
Summary

- Wind capacity and output continues to grow and that trend is expected to continue.
  - Congestion will continue as more wind is added.
  - Multi-Value Projects will mitigate this congestion over time.
- Output variability is being mitigated by geographic diversity of the wind resources, which will influence our ability to manage it operationally.
- Processes and tools to reliably and efficiently manage wind output continue to be enhanced:
  - Dispatchable Intermittent Resources have been successful to date and will continue to be used as a tool to manage wind output and its effects on market operations.
  - Wind forecasting has improved and is expected to continue to improve.
- MISO does not currently anticipate significant operational management issues in the next several years.
- MISO continues to move forward with future analysis, tools, plans, and education to manage the increase of this important resource in the future.

Growth of Wind

Registered wind capacity in the MISO footprint has increased consistently over the last several years, and is expected to continue on that trend. Iowa and Illinois were ranked 2nd and 3rd in the country respectively for the amount of wind capacity installed in 2011.

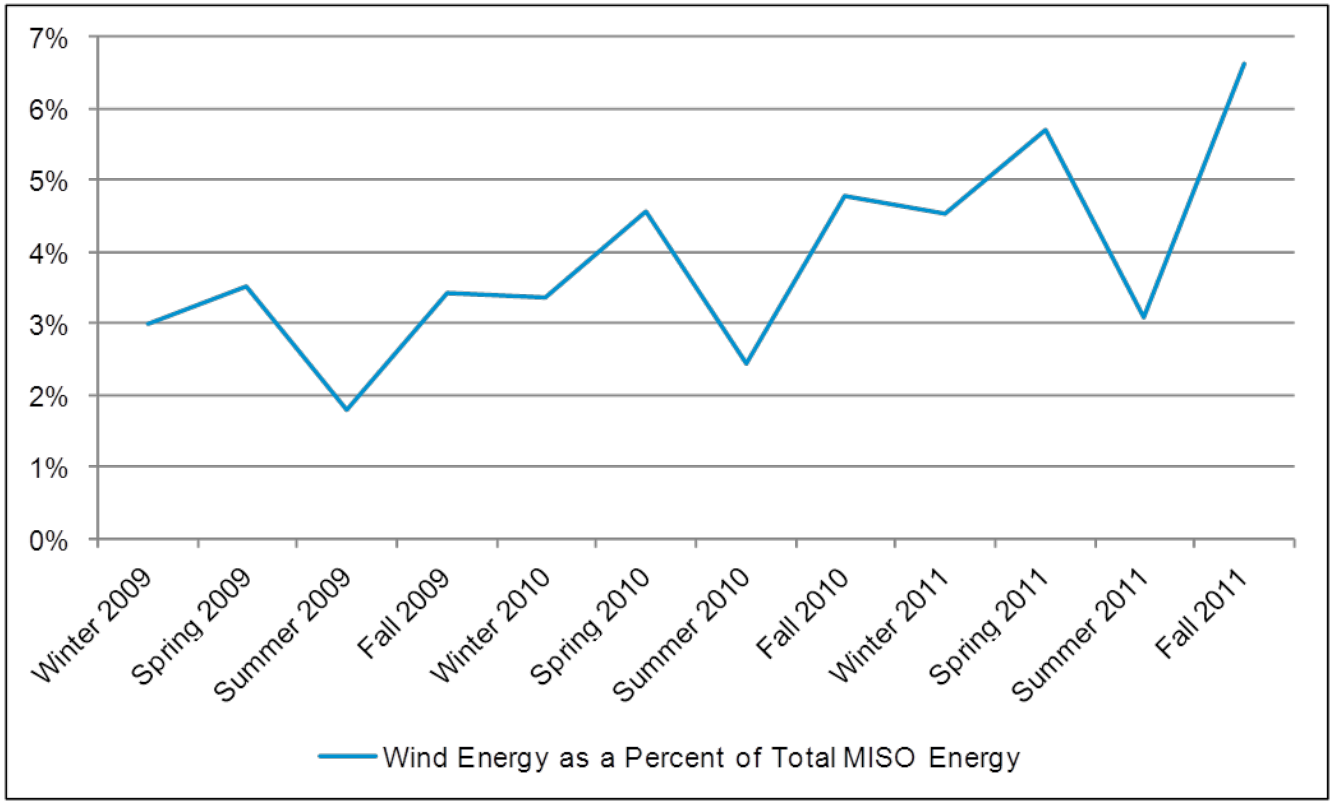




1 – Capacity projected to be added in MISO Footprint during 2012 (3,000 MW).
2 – Capacity estimated to be added in MISO Footprint by the end of 2029, based on the amount of additional wind generation needed to meet current Renewable Portfolio Standards (RPS) in the MISO region (15,000 MW).
3 – Interconnection Queue as of October 1st, 2011 (42,500 MW).

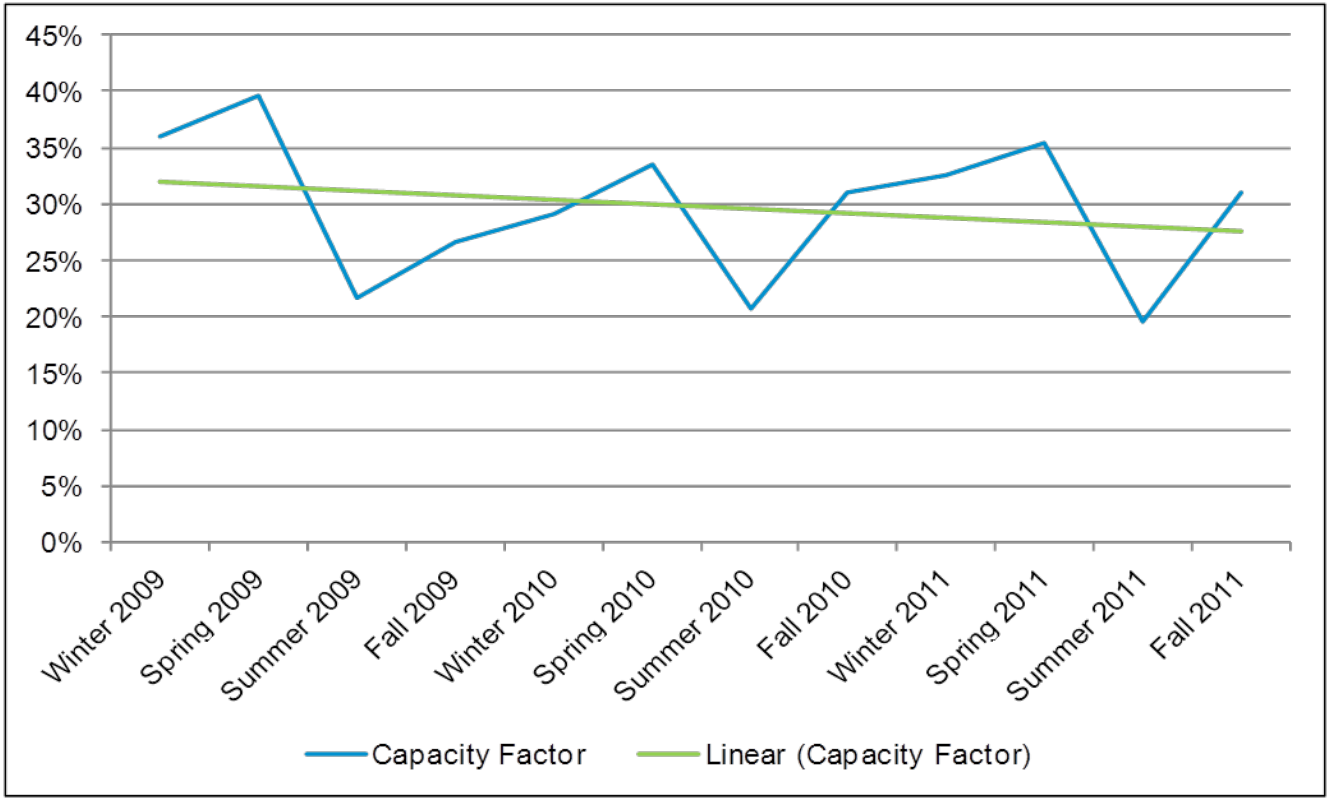
Wind Generation

Consistent with registered wind capacity, the contribution of wind to total MISO energy has also trended upward over the last 3 years. Also note the seasonal nature of the wind output.



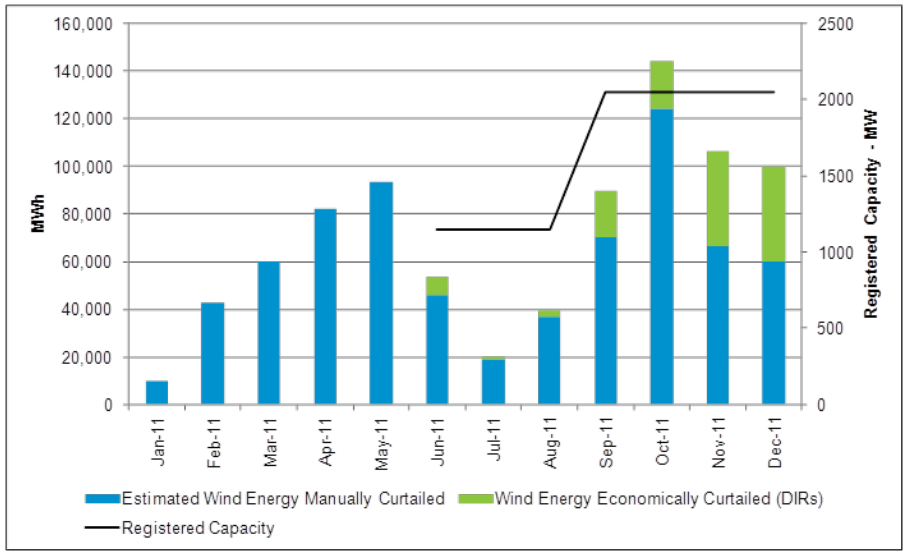
Wind Generation

The capacity factor of wind also has followed a consistent seasonal pattern over that same period, and has declined slightly overall. The decline is expected since more of the new wind resources are in less windy areas of the footprint.

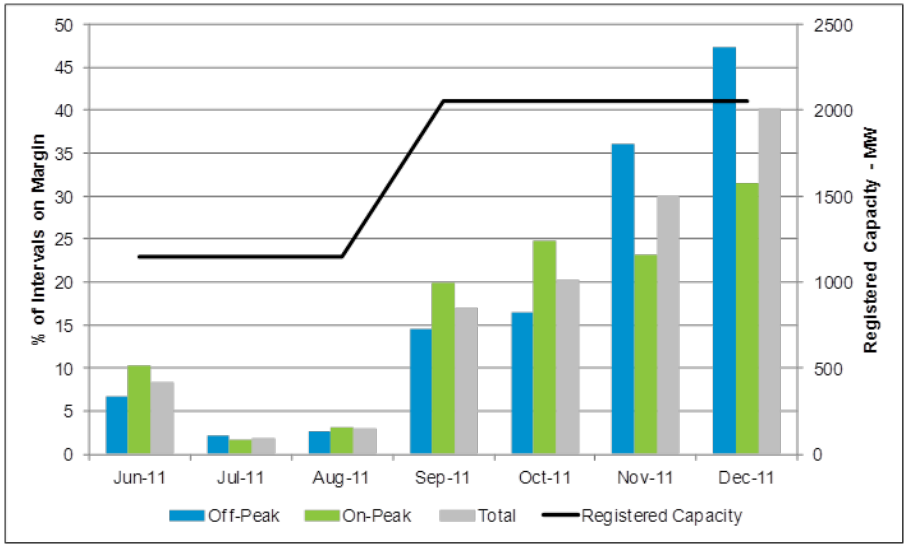


Dispatchable Intermittent Resource Impacts

Since Dispatchable Intermittent Resources went into effect on June 1, 2011, economic curtailments (dispatch of these resources below their forecast maximum output) have become a larger share of total wind curtailments...



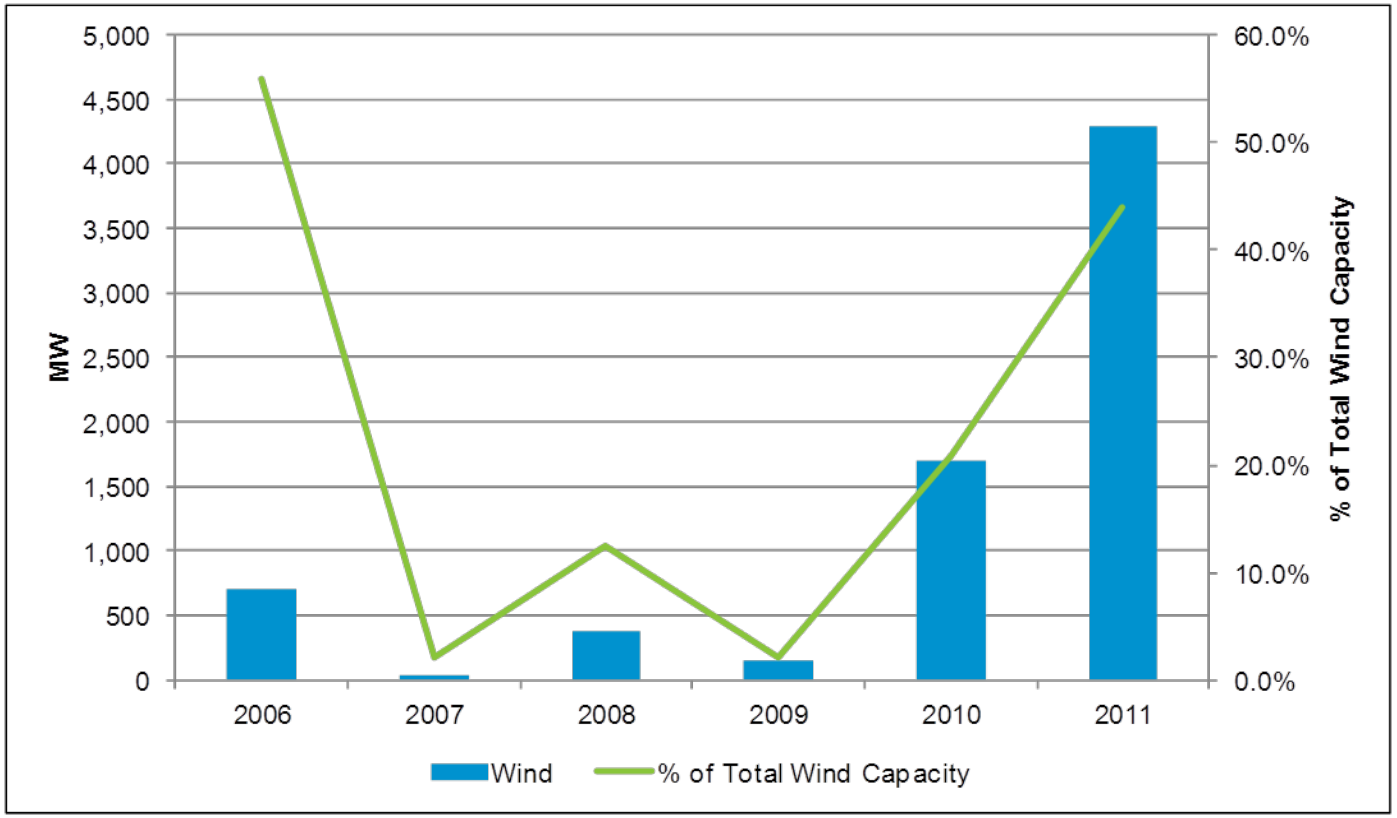
…providing more precise and timely congestion relief than the manual curtailments that they replace…



…and resulting in Dispatchable Intermittent Resources setting price more frequently through energy offer-based economic dispatch.

Wind Output at Time of Peak Load

Wind output at the time of the annual peak load has not been consistent – nor do we expect it to be.



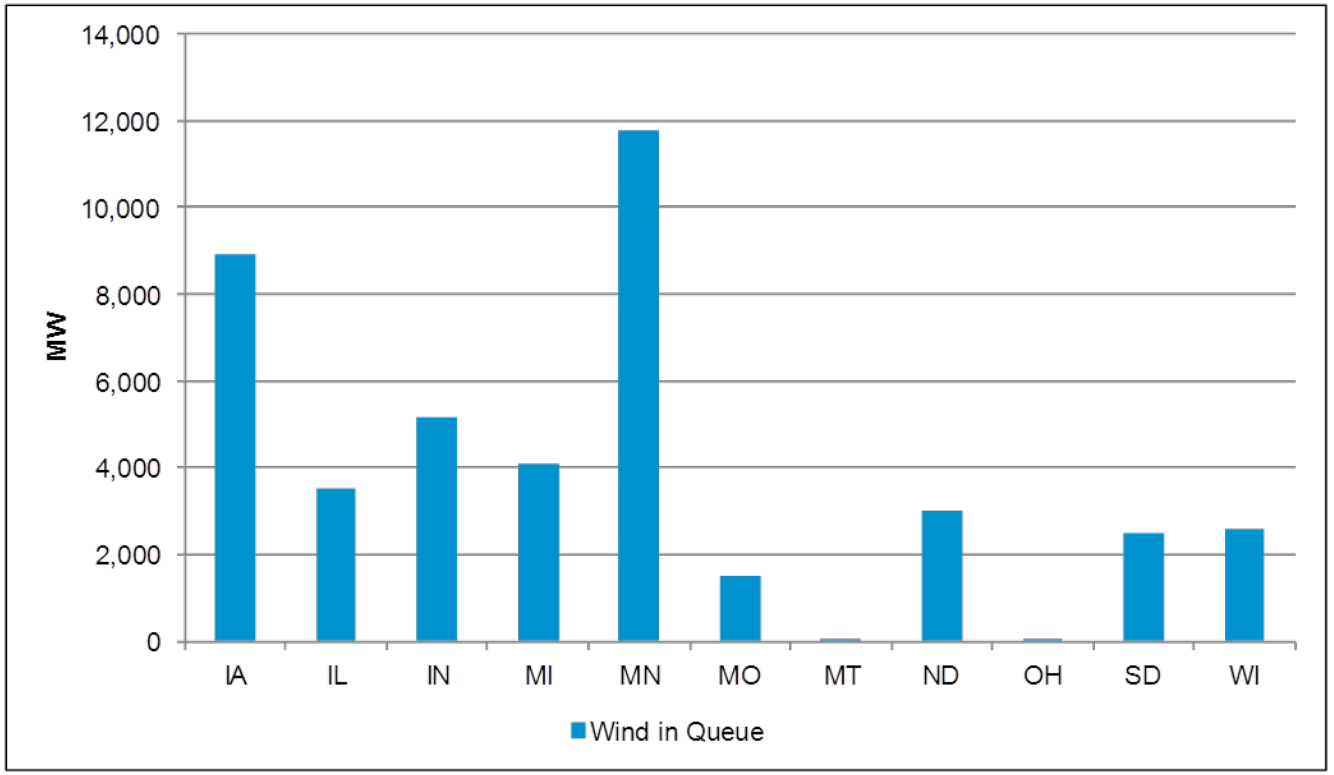
Such variation in output creates a challenge for determining capacity credits.

Looking Forward - Continued Wind Growth

- Wind growth is expected to increase to support Renewable Portfolio Standards (RPS).
  - Production tax credit extension is contentious and uncertain.
- Dispatchable Intermittent Resources will become the primary wind resource type. This resource type was developed to improve reliability and market efficiency:
  - Through economic dispatch.
  - With more accurate price signals.
  - With more cost-effective congestion management.
  - With expected lower levels of manual wind curtailments.
  - With expected mitigation of minimum generation conditions.
- Operational challenges associated with wind:
  - Output variability.
  - Lack of correlation between wind output and load.
  - Use of System Ramp.

Impacts of Growth Mitigated by Locational Diversity

In the near to mid-term, significant operational impacts from wind's continued expansion will be influenced by increasing geographical dispersion…

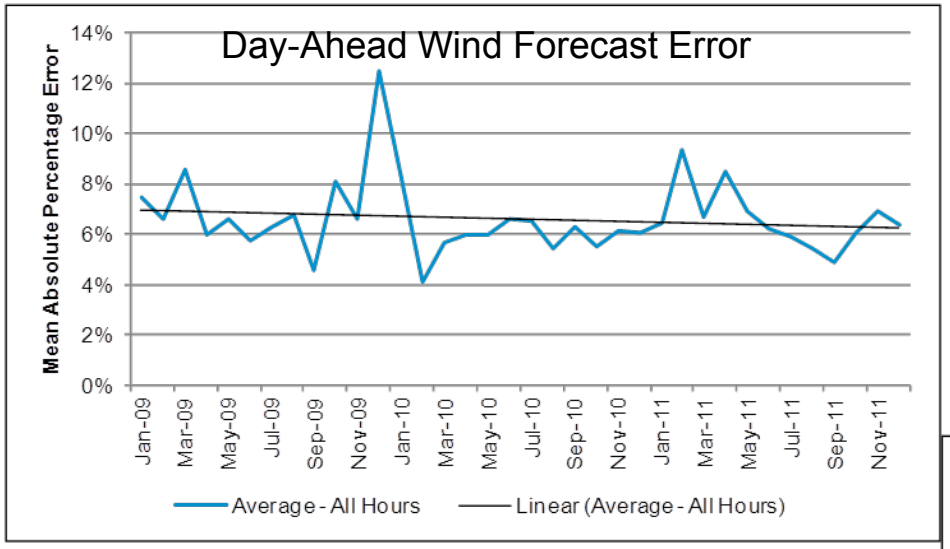


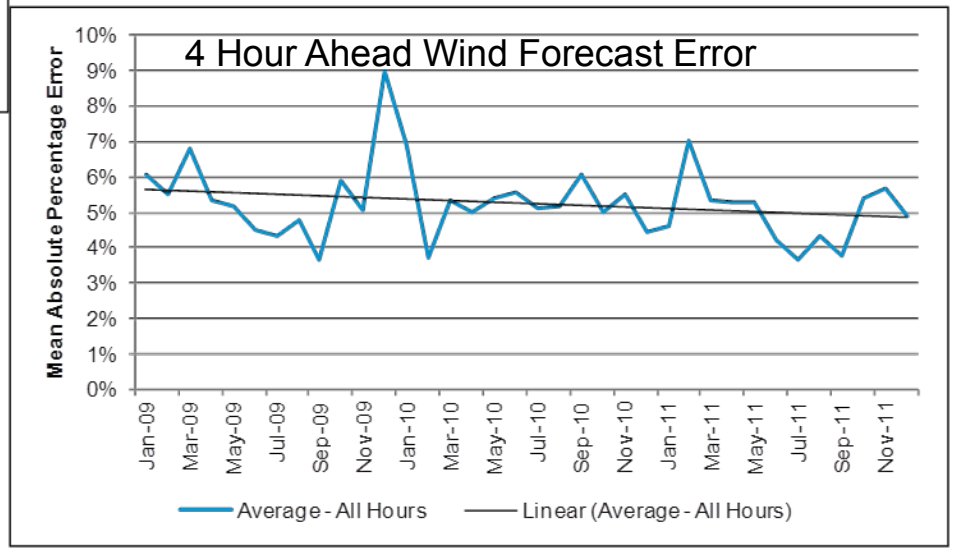
Operational Considerations

- Operations response to increases in wind output:
  - Rapid increases in wind output mitigated by Dispatchable Intermittent Resources, which can be dispatched down.
- Operations response to decreases in wind output:
  - Rapid decreases in wind output managed through:
    - Wind forecasts which lead to unit commitments.
    - 5 minute Energy Dispatch if possible.
      - Note that operating reserve shortages will tend to increase if ramp is insufficient.
    - Use of fast-start units to manage forecast error if no on-line capacity available or insufficient ramp.
    - Operating reserve deployment when necessary.
  - Growth in the magnitude of average changes in wind output has been mitigated by Increased geographical diversity and dispatchable intermittent implementation (less price chasing).
- To date, wind has not been a significant contributor to operating reserve deployments.
  - Wind has had a small impact on regulation reserves.
  - Contingency reserves have never been deployed due to a drop in wind output. Such deployments would be an indicator of need for further market products.

Mitigating Near-Term Impacts

Improvements in wind forecast accuracy should continue to be realized and allow for more effective, proactive management of output variability.





Addressing Increasing Wind Capacity

(Initiatives and Process Improvements)

- Completed wind integration initiatives:
  - Wind forecasting enhancements.
  - Addition of Dispatchable Intermittent Resources as a market resource (June 2011).
- Continuing wind forecasting improvements:
  - Process and data improvements.
  - Work to improve forecasts during icing conditions.
  - Expand use of additional wind speed prediction data.
- Continuing work on potential ramp management products:
  - Preparing to hold another ramp management workshop in 2012.
  - Continuing to monitor both 5 minute operating reserve shortages and contingency reserve deployments.
  - Continuing work to study intermittent resource variability and its operational impact.

Addressing Increasing Wind Capacity

(Other Factors)

- Portfolio changes
  - MISO resource portfolio may also mitigate effects of growth.
  - EPA rule changes – Coal unit retirements replaced by more gas unit capacity will likely increase system ramp ability.
    - Gas units tend to have faster ramp and shorter start-up times.
    - May be restricted by other environmental impacts.
- Evaluate lessons learned from systems with similar or larger wind portfolios:
  - National Grid (UK).
  - Red Electrica (Spain).

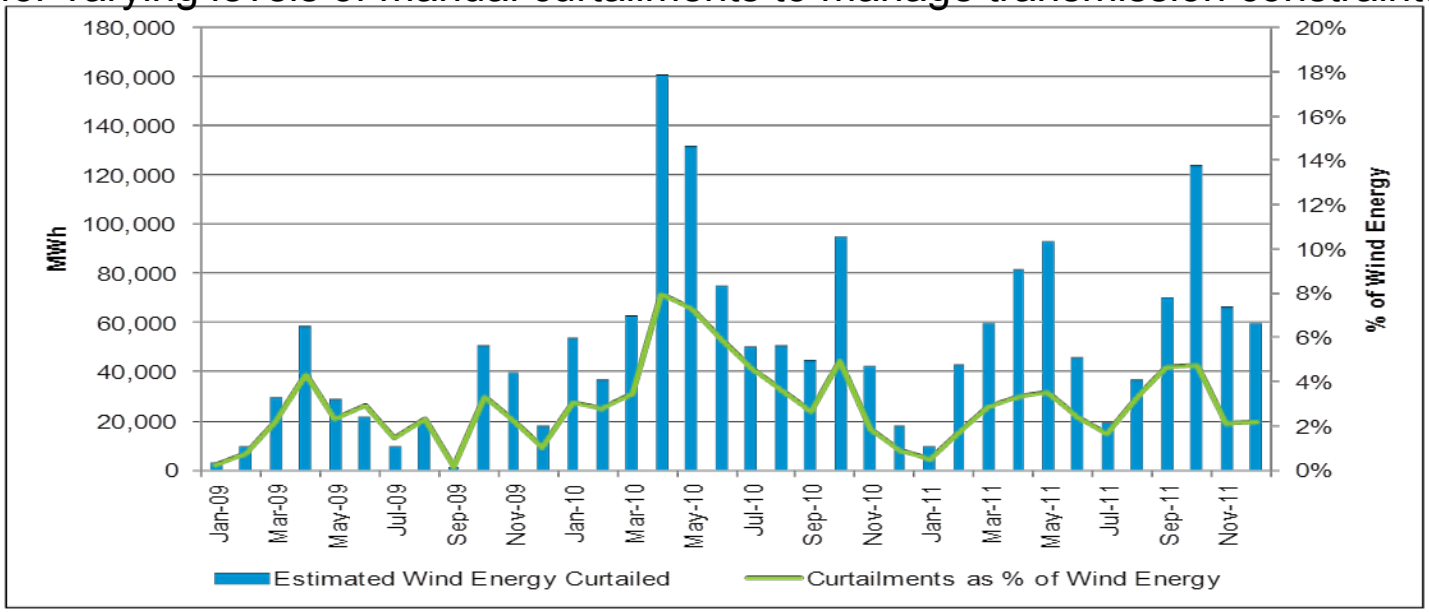
Summary

- Significant operational issues are not expected in the next several years given:
  - Operational experience gained over time.
  - Geographic (locational) diversity effects.
  - Completed and continuing efforts to improve tools.
  - Market incentives.
  - Experience from other system operators that have faced similar challenges.
  - Transmission improvements.

APPENDIX

Manual Wind Curtailments

As wind output has increased, its impact on local congestion has driven the need for varying levels of manual curtailments to manage transmission constraints.

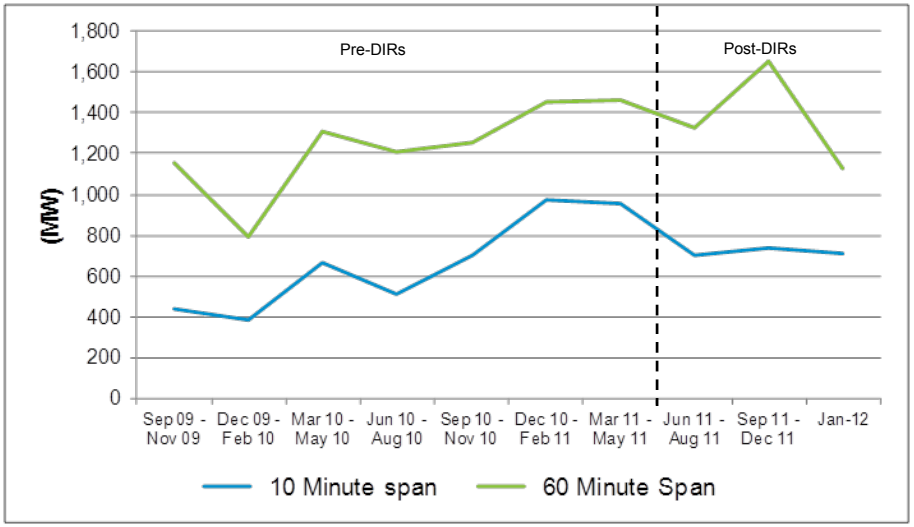


Dispatchable Intermittent Resources were developed by MISO to:

- Improve reliability and market efficiency
  - Through economic dispatch
  - With more accurate price signals
  - With more cost effective congestion management
  - With expected lower levels of manual wind curtailments

Historical Wind Changes

Average of 5 Largest Wind Drops



The magnitude of average changes in wind output over 10 and 60 minutes spans has been influenced by:

- Increased geographical diversity
- DIR implementation (less price chasing)

…trends which will also contribute to our ability to effectively manage the variable nature of wind output for the next several years.

Average of 5 Largest Wind Drops as a % of Registered Capacity