Reliability Value of Improved Forecasts

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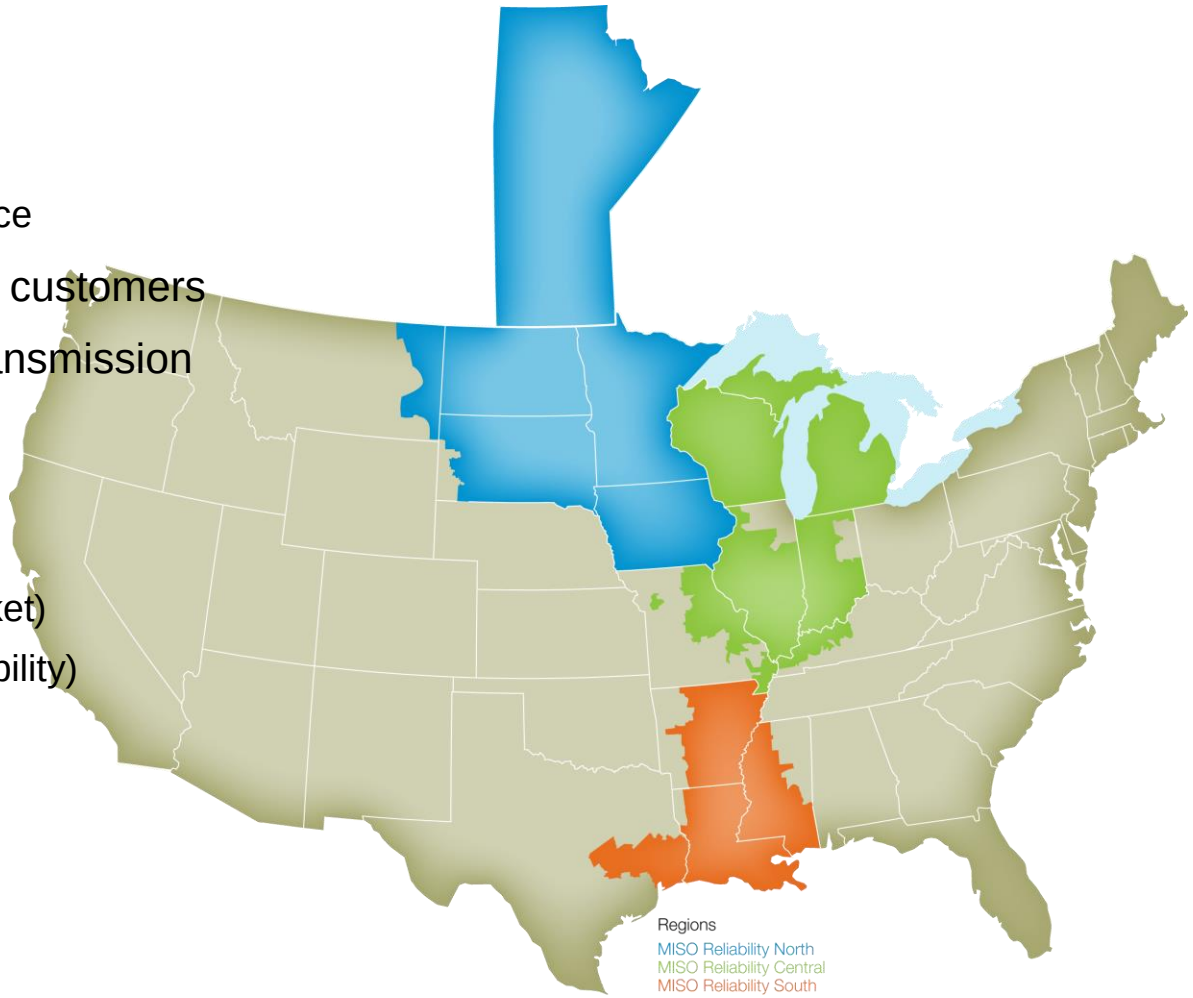
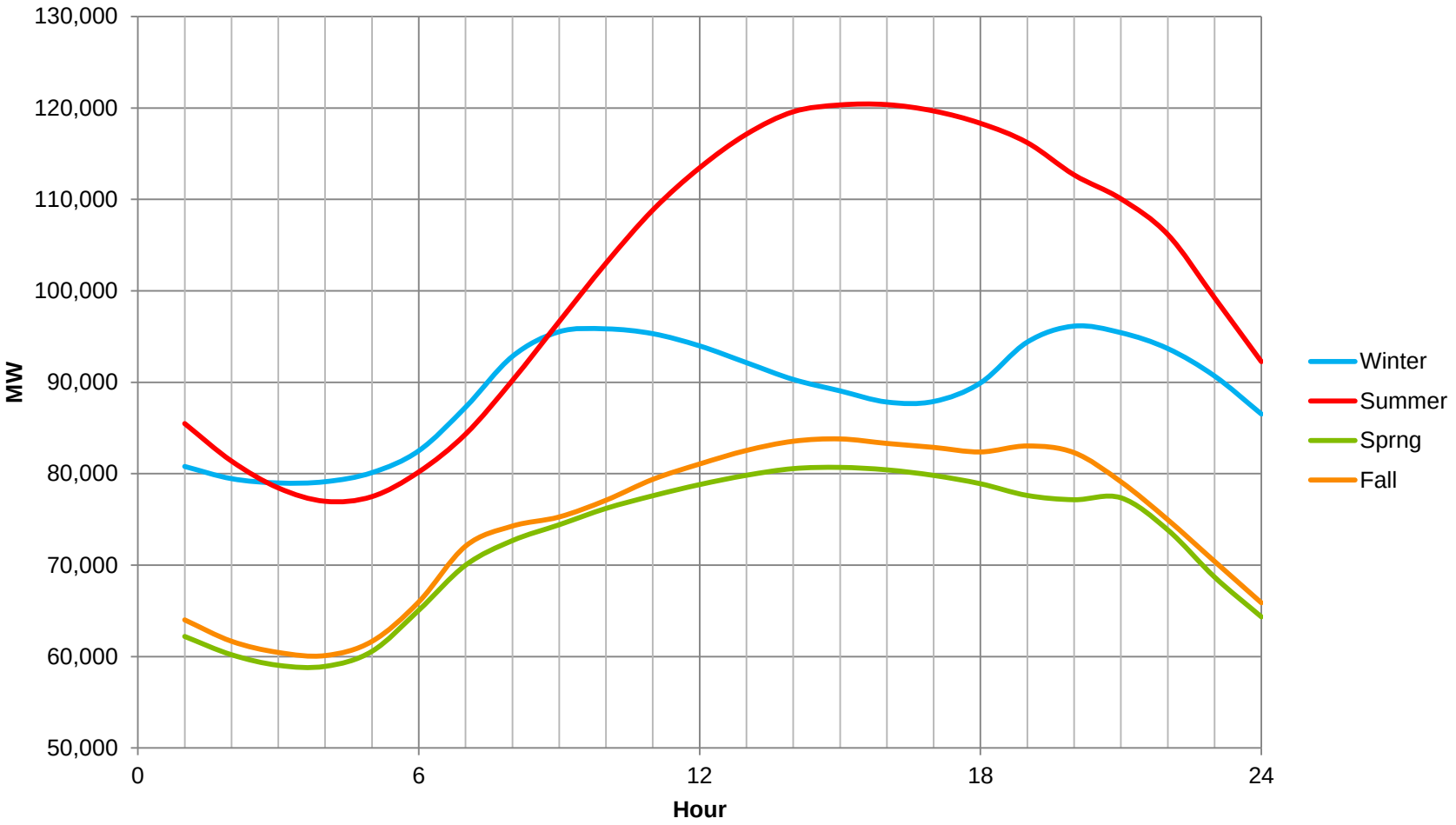
Scope of MISO Operations

- Footprint
  - 15 States
  - 1 Canadian Province
  - 42 million end-use customers
  - 65,800 miles of transmission
- Historic Peak Load
  (July 20, 2011)
  - 127,125 MW (market)
  - 130,917 MW (reliability)
- Historic Wind Peak
  (February 19, 2016)
  - 13,088 MW



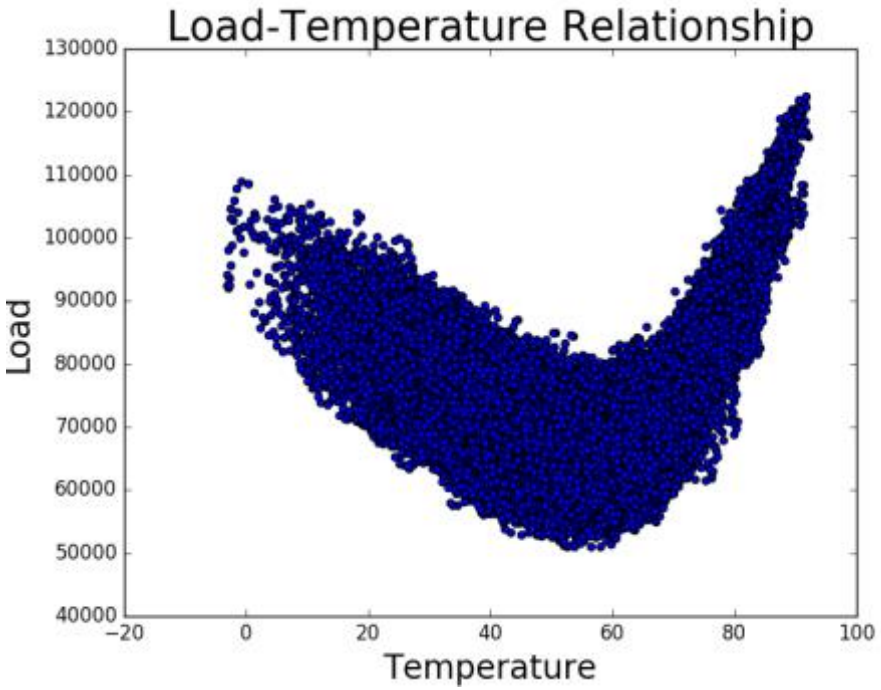
MISO Seasonal Load Profile

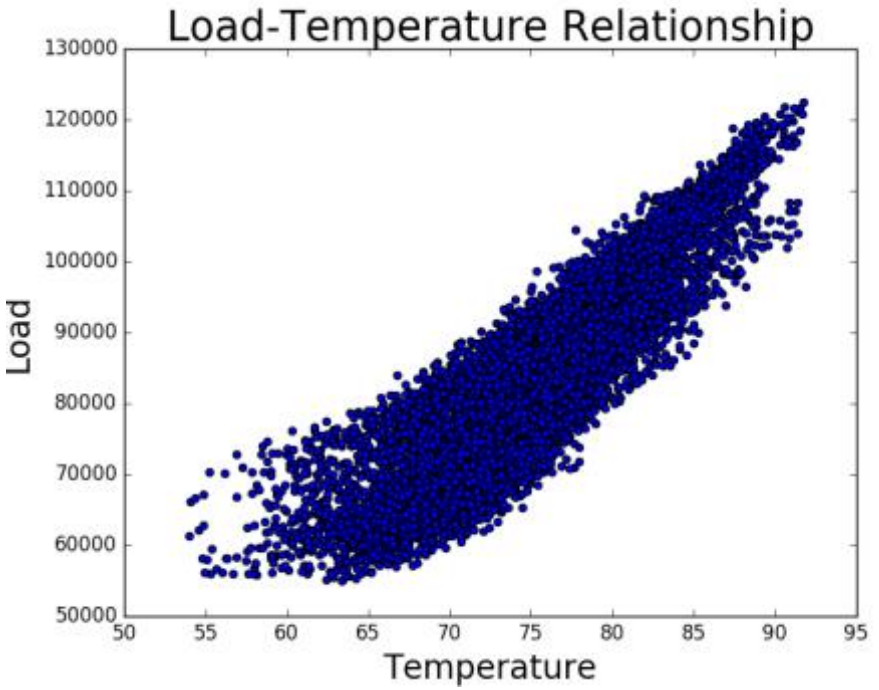


Flexibility in available resources during non-summer months.

Initial Thoughts on Value of Improved Forecasts - Load

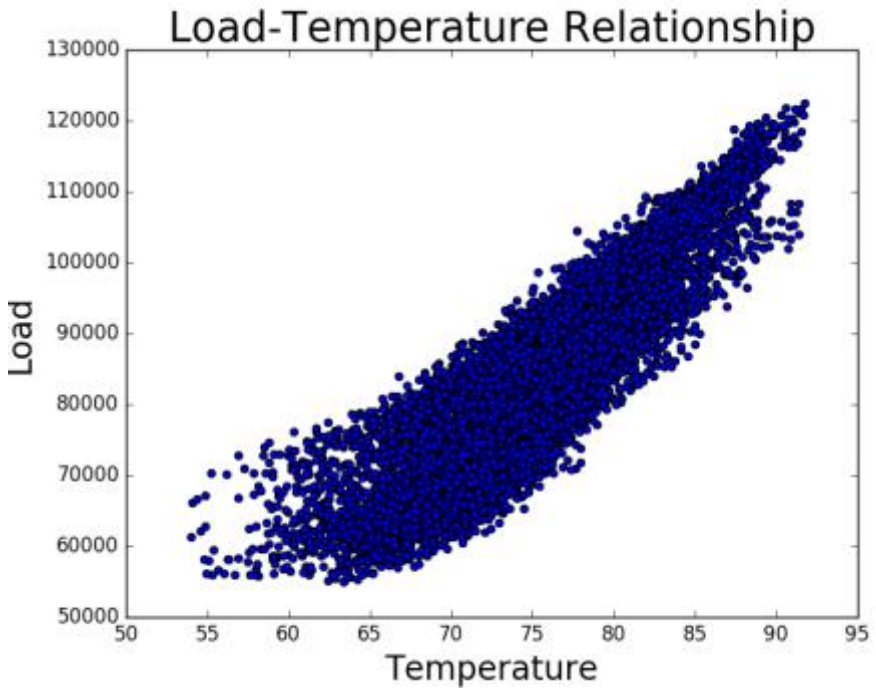
- Temperature Sensitive Load
  - Forecasting in Summer

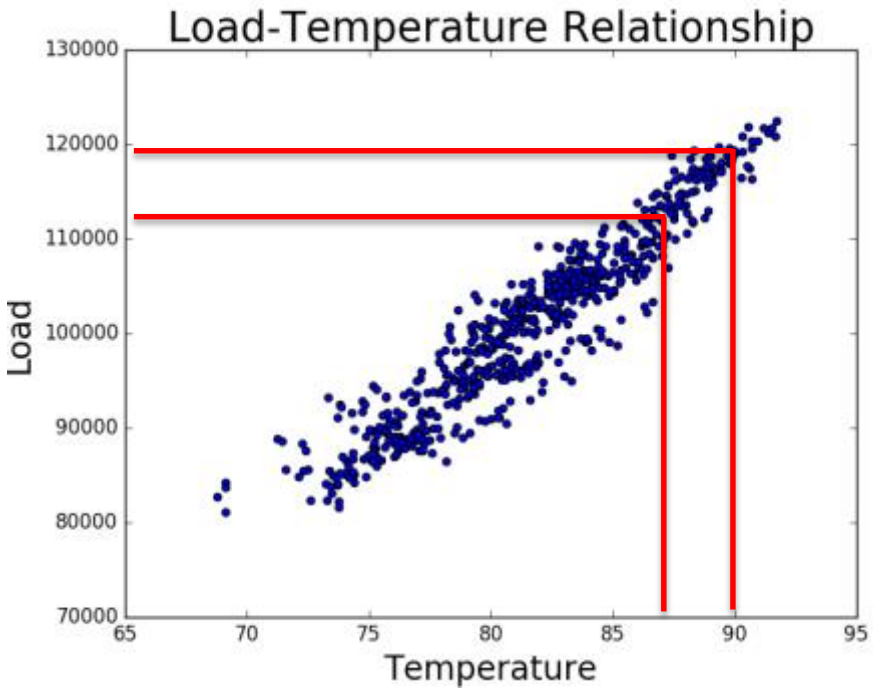




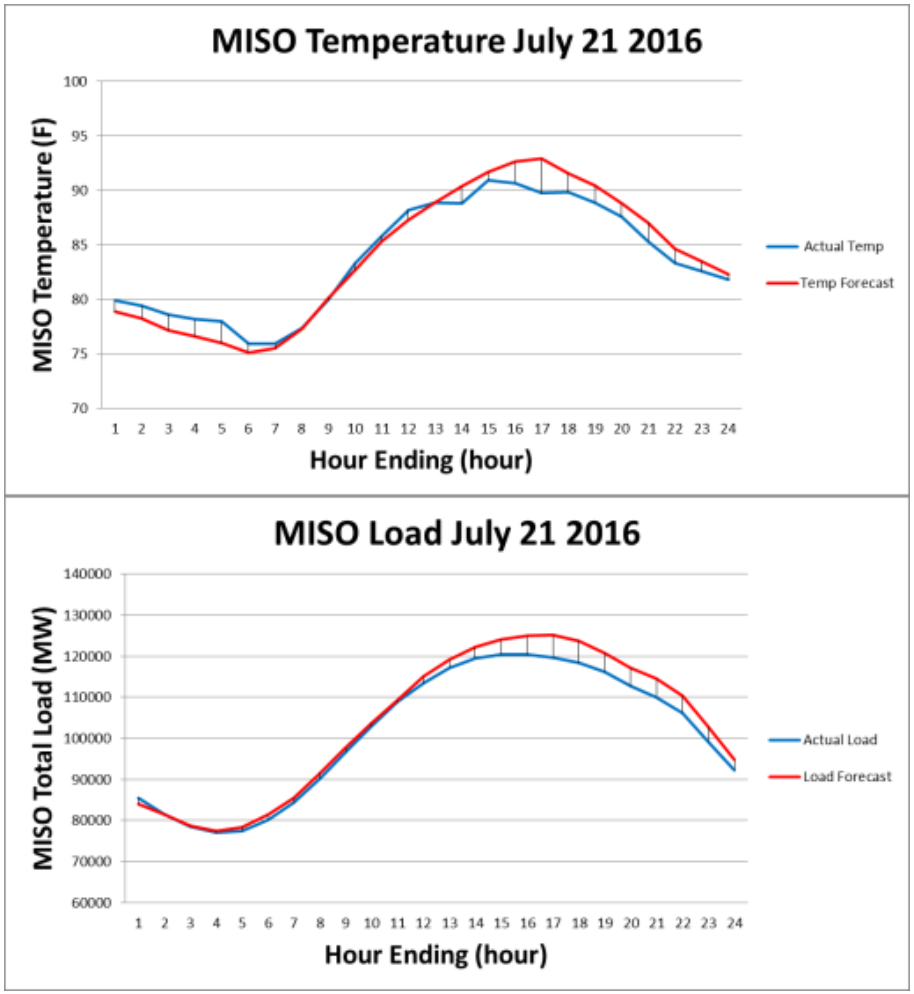
Temperature Impacts on Summer Load

- MISO System Load-Temperature relationship
- Summer weekday afternoon load
  - 87 °F – 112 GW
  - 90 °F – 119 GW



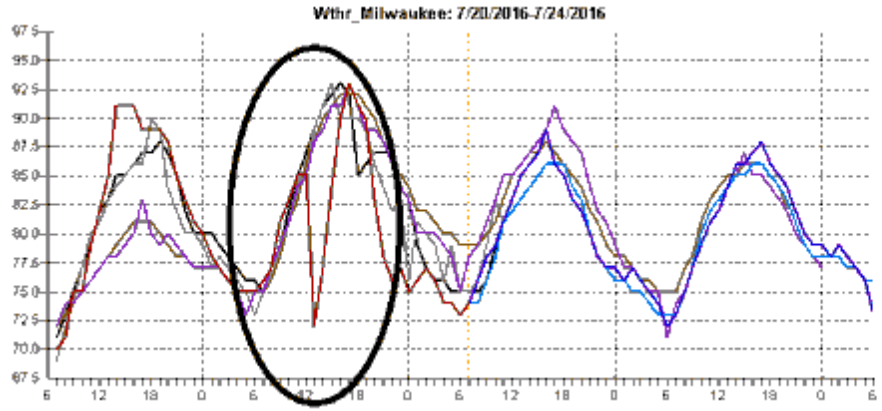


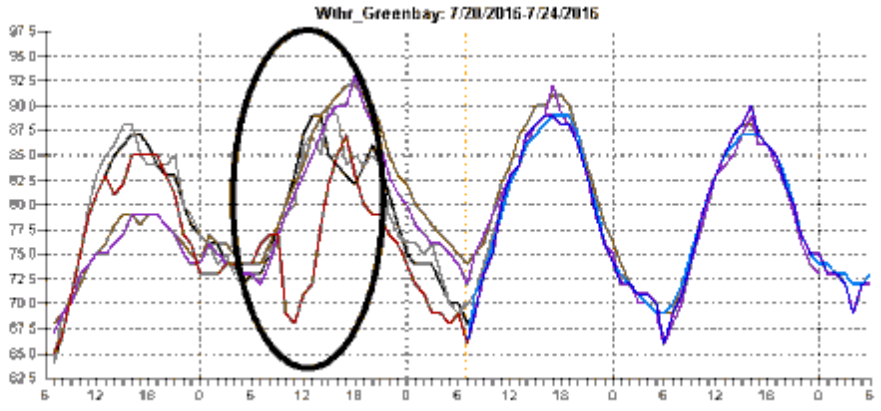
Load Forecasting Common Issue

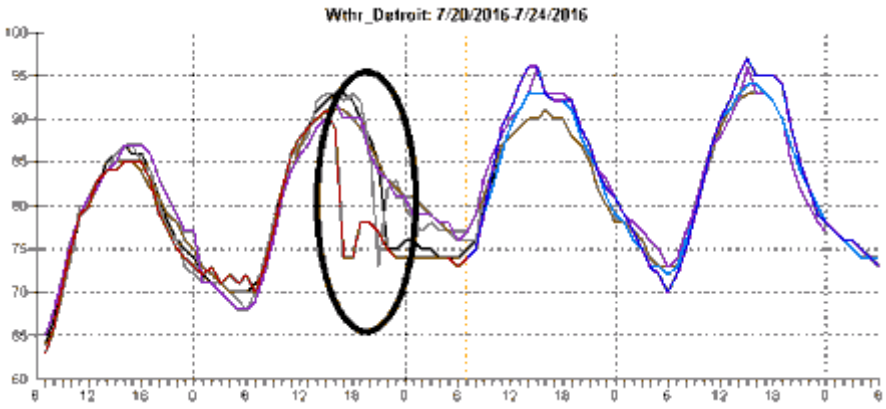


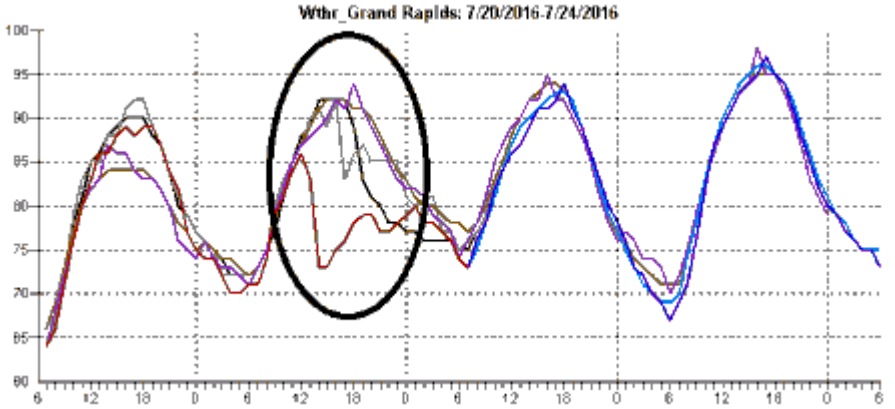
- Hour Ending 17:00
- Temperature forecast error:
  - Temperature forecast: 92.9 °F
  - Actual temp: 89.8 °F
- Load forecast error:
  - Load forecast : 125.1 GW
  - Actual load: 119.7 GW

July 21, 2016 Temperature Details

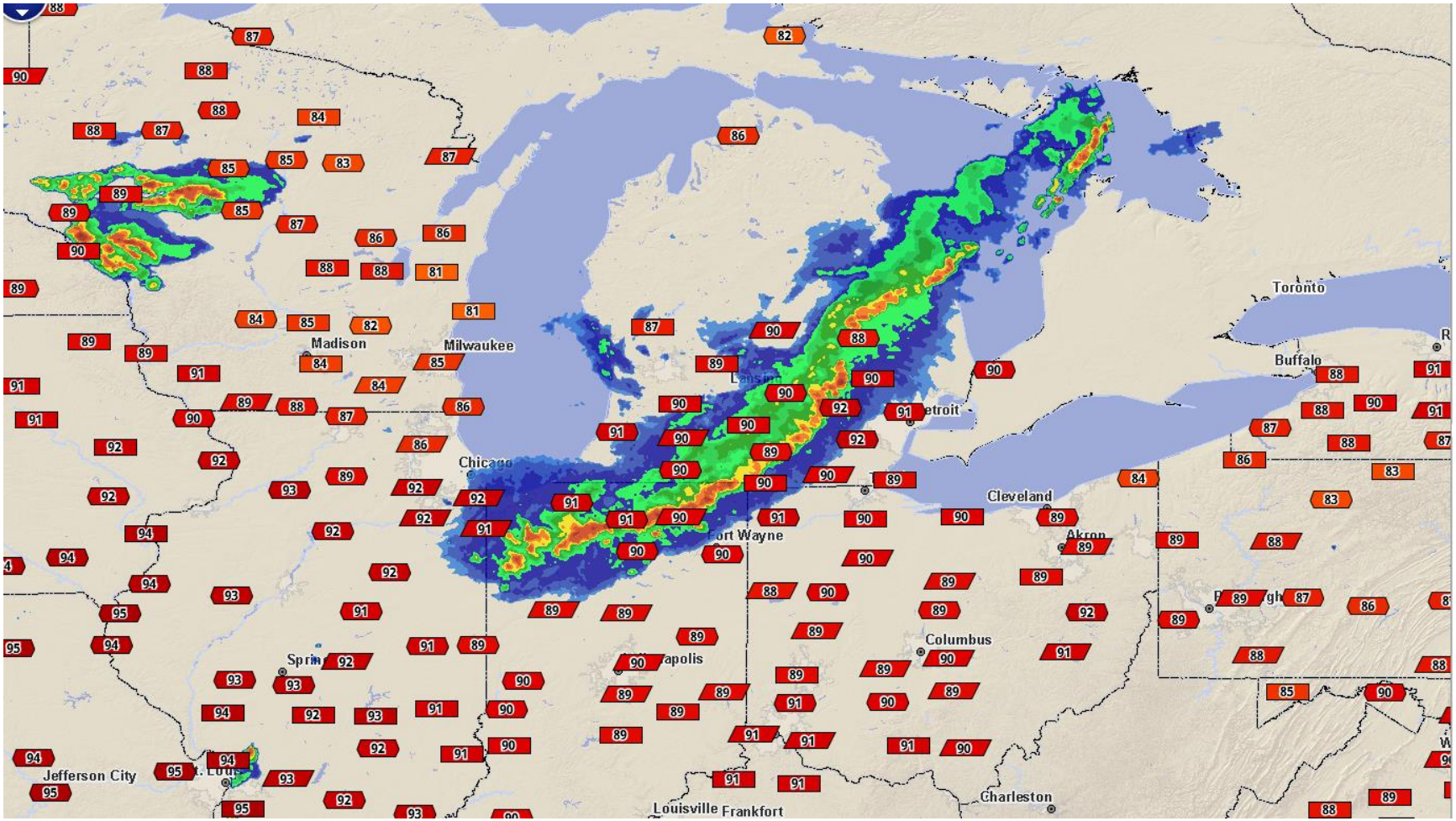




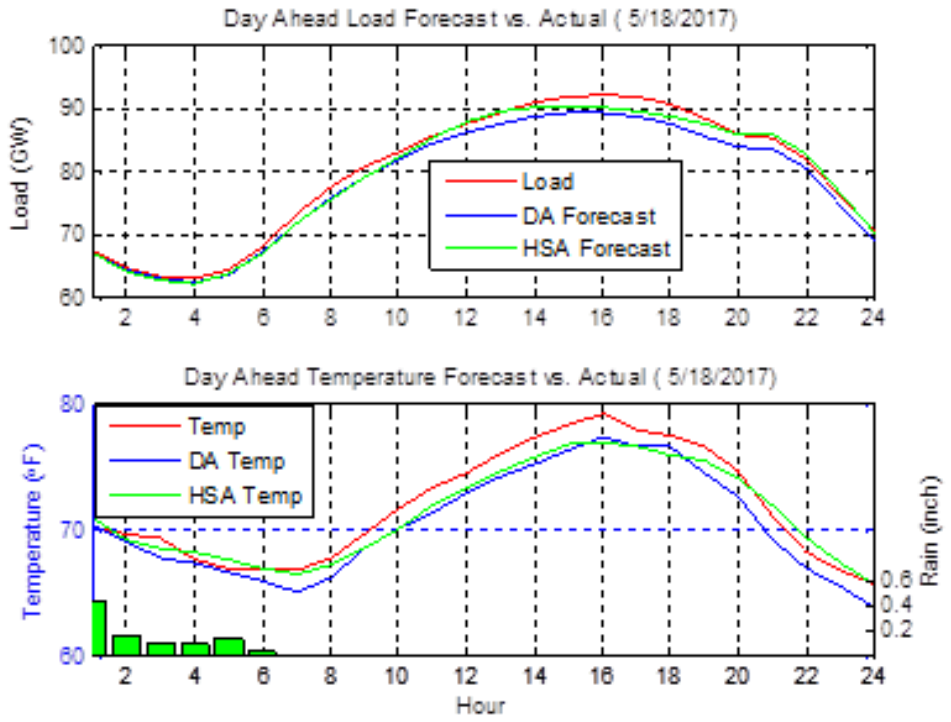




July 21, 2016 Rain Details

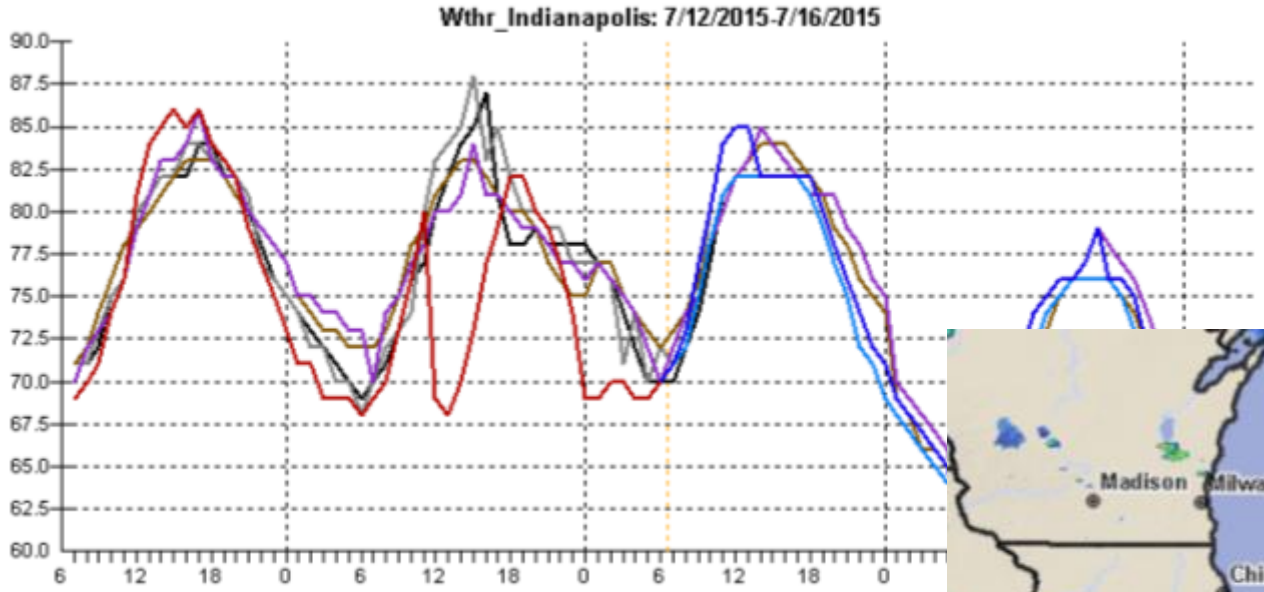


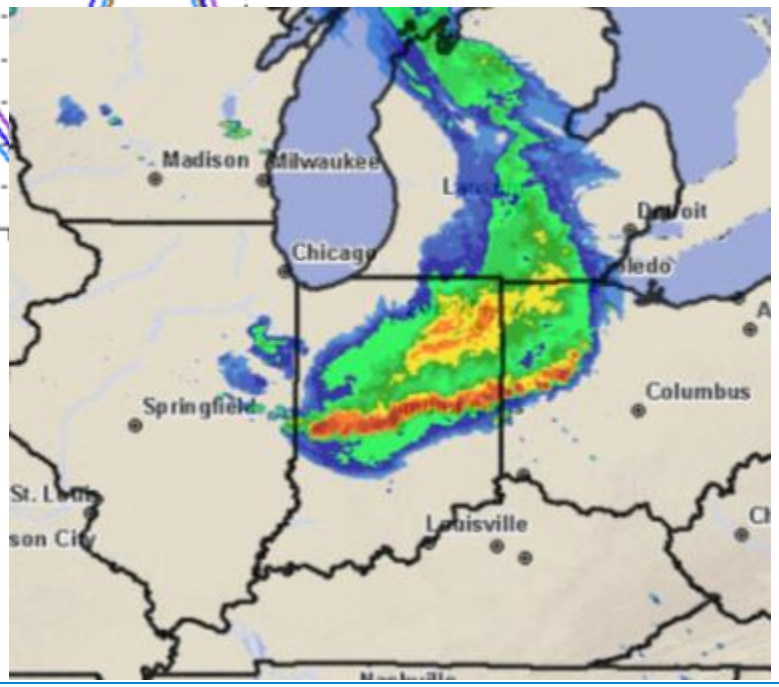
Temperature & Load Under Forecast



- In Central and South Regions, forecasted rain did not materialize
- System temperatures ~2 degrees higher
- Day Ahead load forecast error ~ 3 GW
- Hours Ahead load forecast error ~ 2 GW

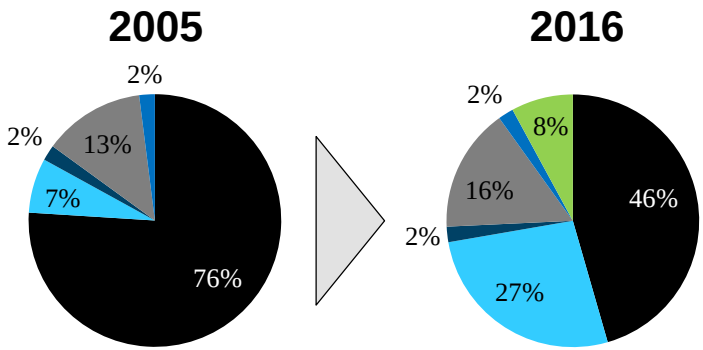
Weather/Temperature Forecast Monitoring



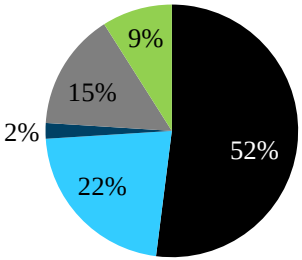


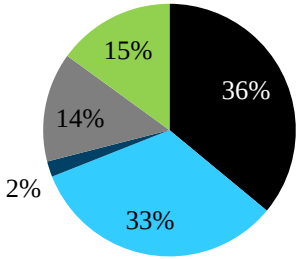
- Control Room monitoring
  - **Load,** Transmission, **Generation**, and Overall System Conditions
- Forecasting team monitoring
  - Load impacts, weather forecasts and measurements, nearby load center cities, load forecast models performance
  - **Override MTLF or Weather forecasts, as needed**

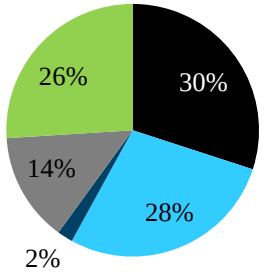
MISO Generation Portfolio Evolution



2031 Future Scenarios





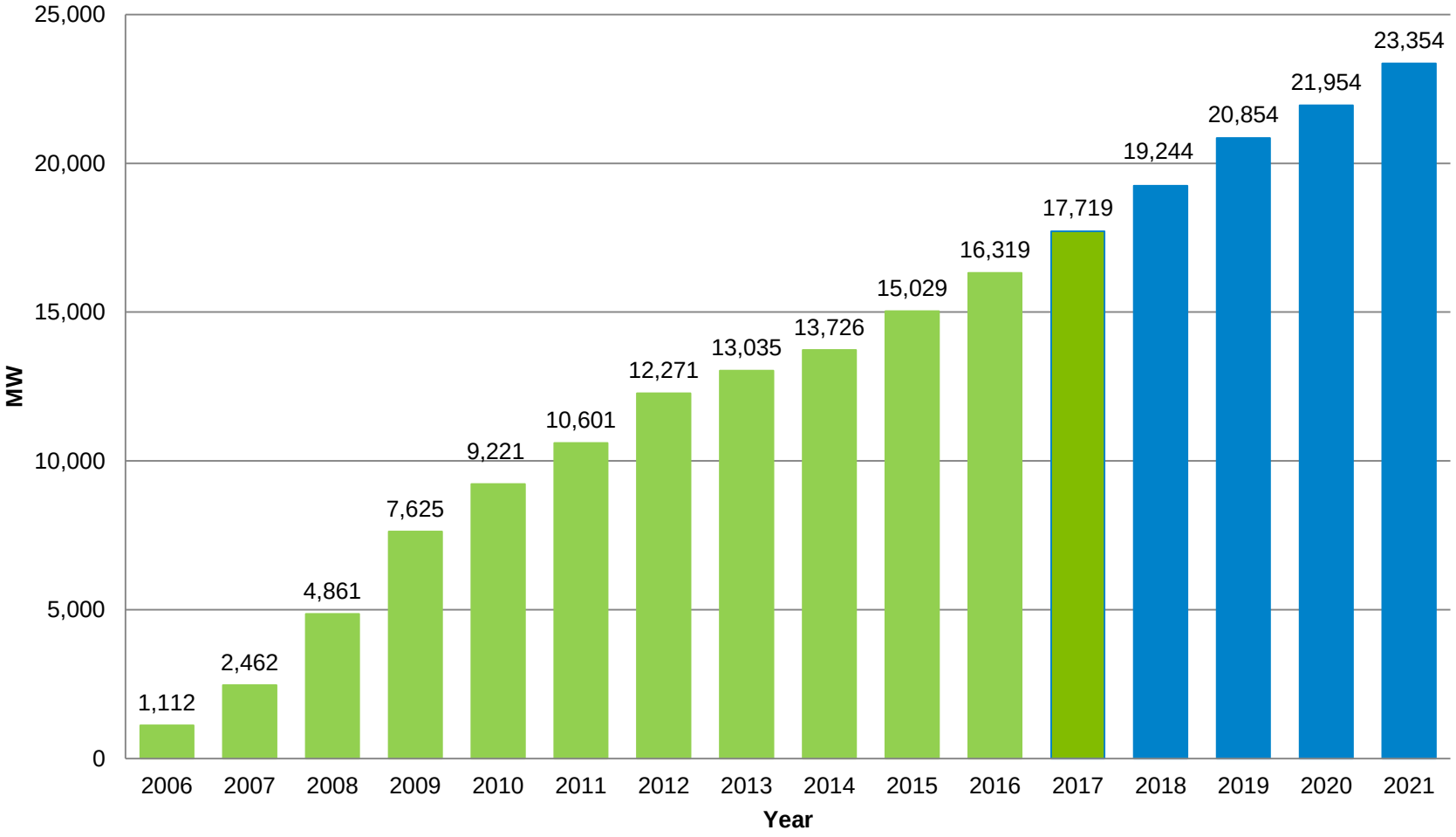


Existing Fleet
No carbon regulations modeled but some reductions expected due to RPS and economics.

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.

Wind Capacity Growth in MISO

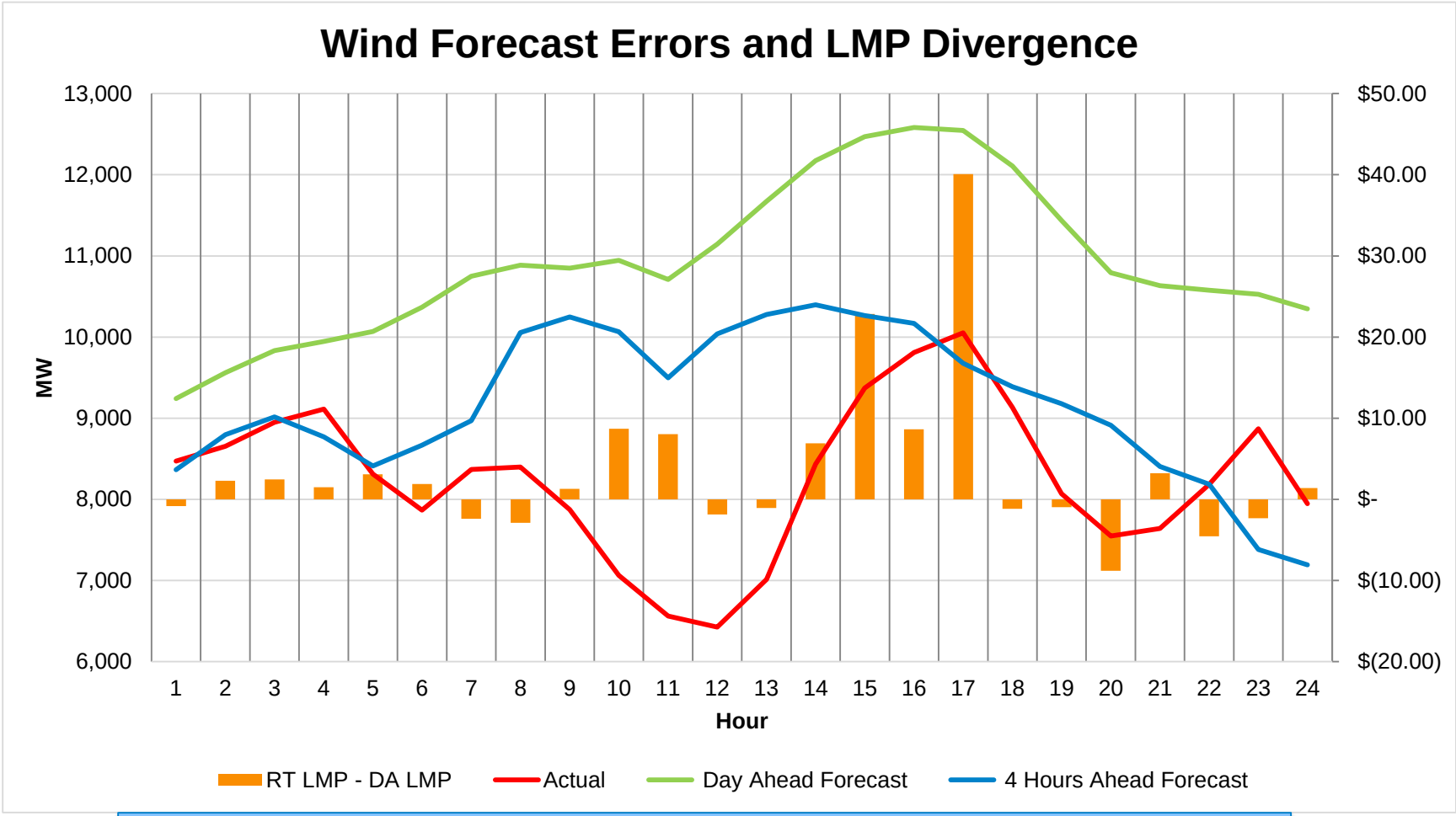


Wind Generation Forecasting Improvements are Needed

- Over forecast errors in Wind Generation
  - Unit commitment (hourly)
    - Increase in RT LMP
  - Dispatch Regulating Reserves
    - Challenges around morning ramp

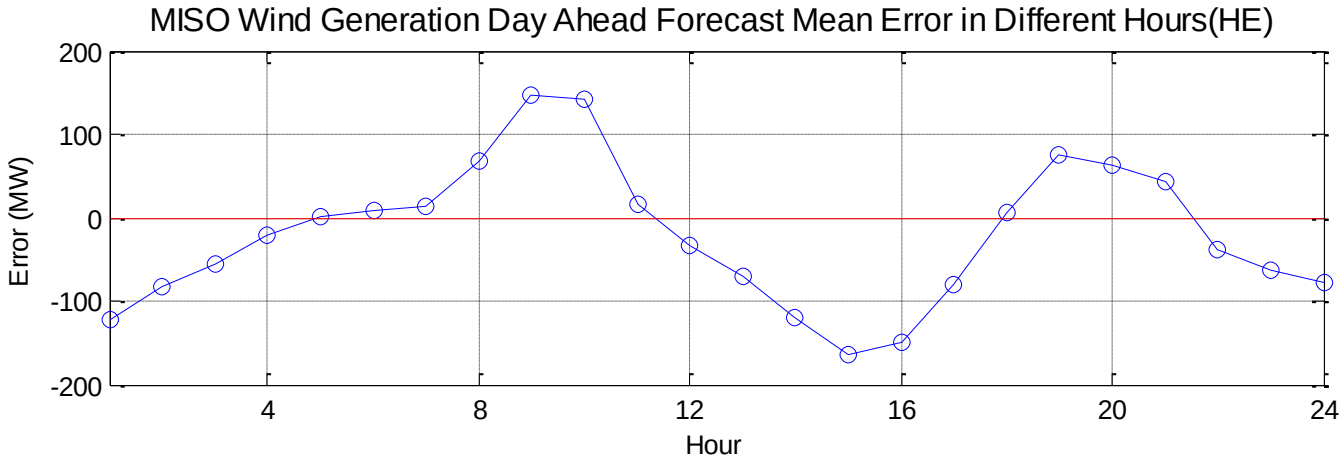
- Under forecast error impacts are managed:
  - Dispatch ability of wind resources
  - State Estimator MW floor (10min ahead)

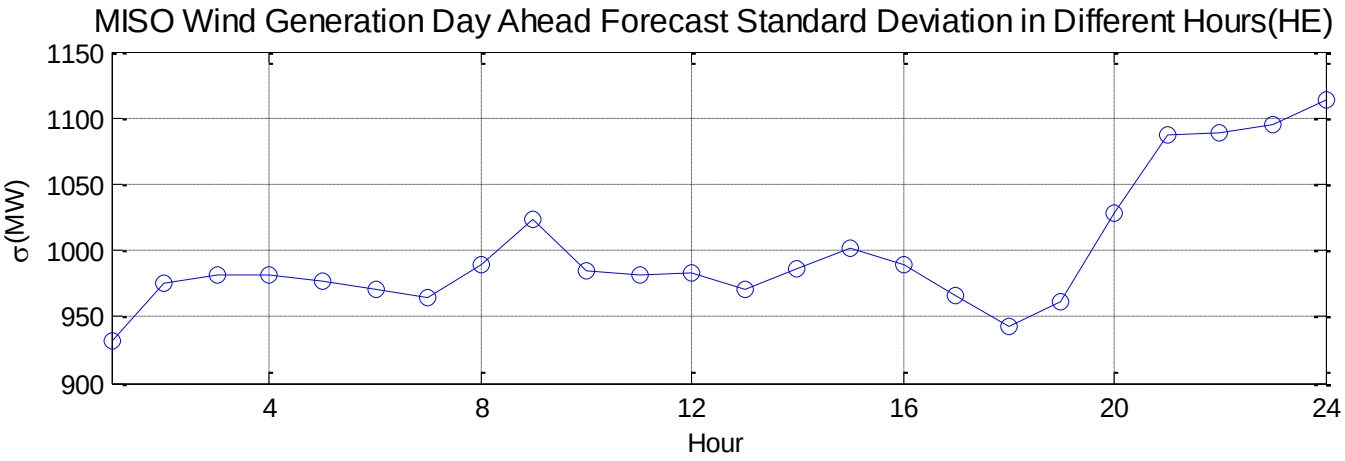
Over Forecast in Day-Ahead and Intra-Day



In Spring, several short lead-time resources are still available

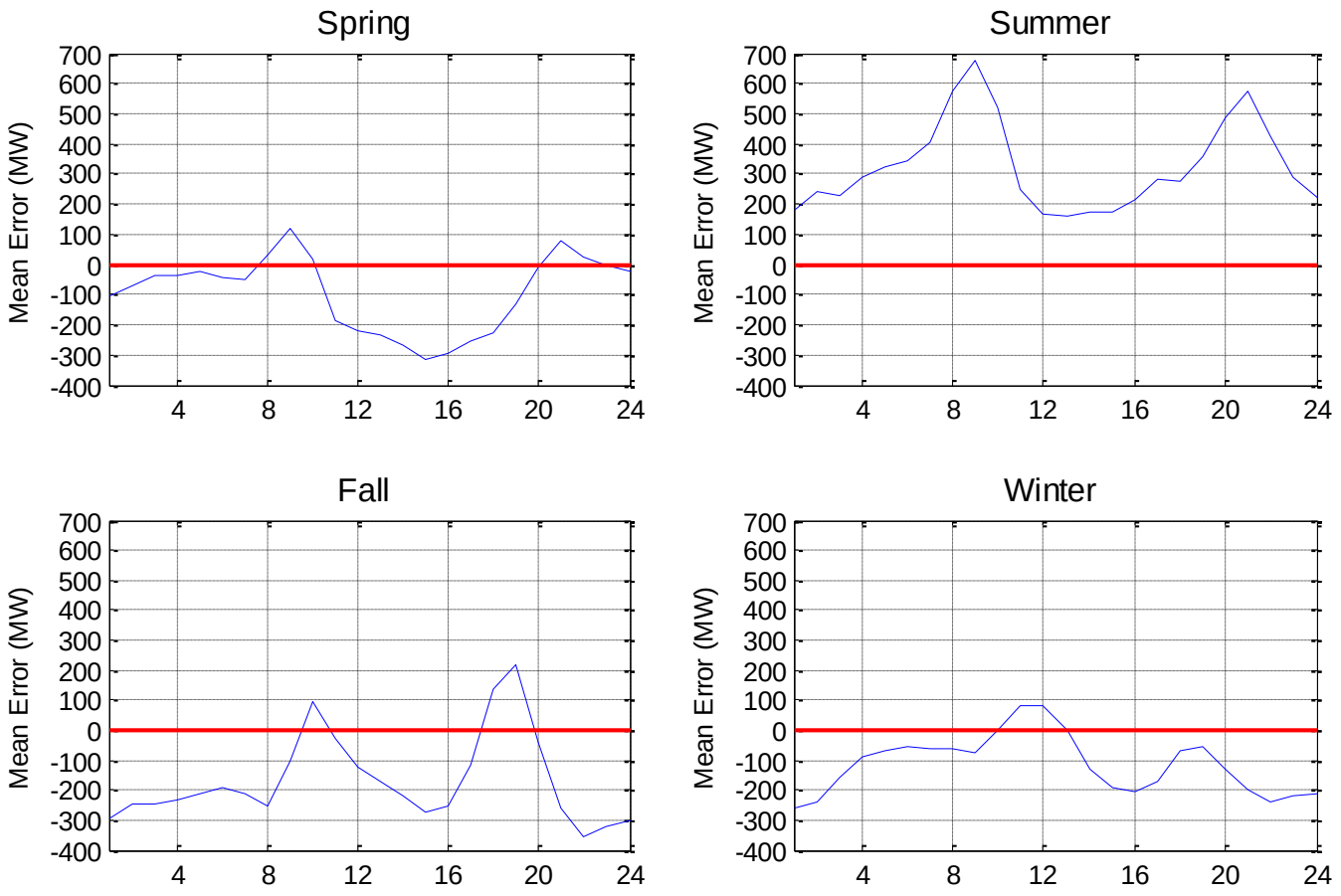
Hourly Average Day Ahead Wind Generation Forecast Error





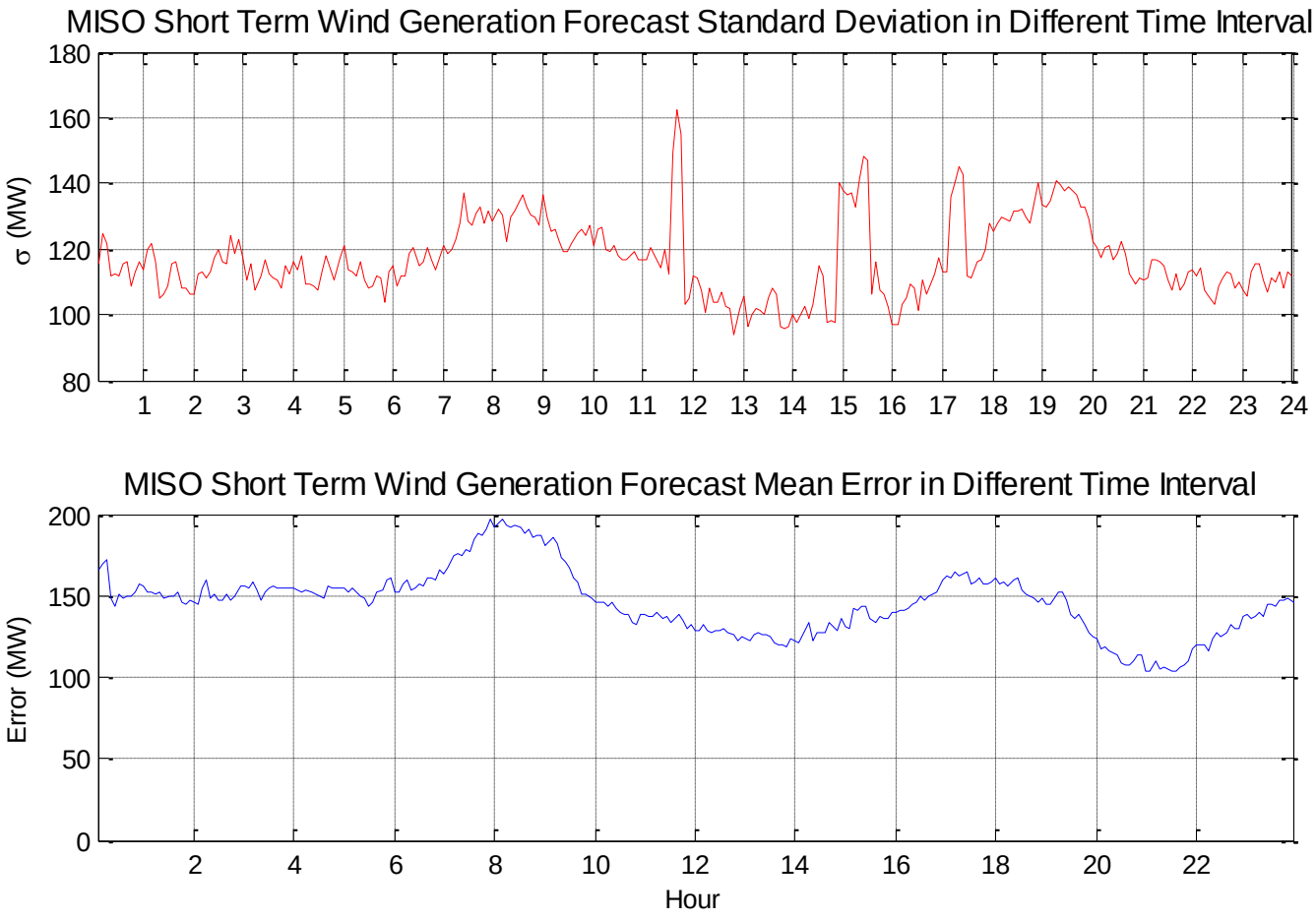
Daily average, forecast error is near zero.
Hourly averages show over/under patterns.

Significant Day Ahead Over Forecast Error in the Summer (Jun-Aug)



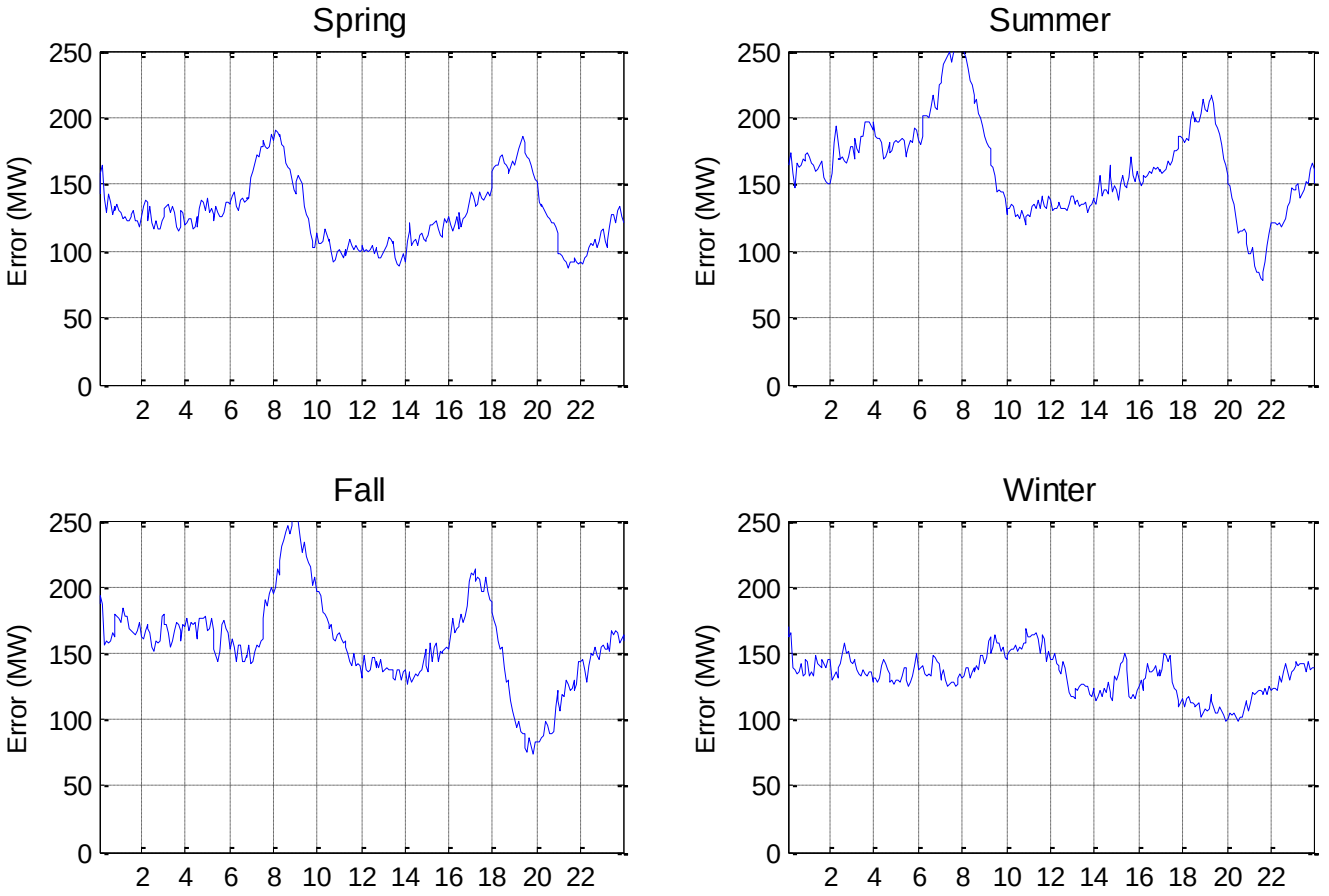
Limited availability of other resources to cover MWs expected.

10-Minute Ahead Wind Generation Forecast Errors



MISO operates with ~ 400 MW of Regulating Reserves

10-Minute Ahead Mean Error



As wind capacity continues to grow, the error will increase. Increasing the need for more Regulating Reserves.

Summary

- Forecasting summer storm systems remain a generation commitment challenge to highly temperature sensitive load
- Growth of wind capacity will introduce more forecasting MW errors
- Forecasting improvements will help minimize energy cost for commitment and dispatch
- Opportunities exist to improve daily patterns of wind forecasting

Thank you!