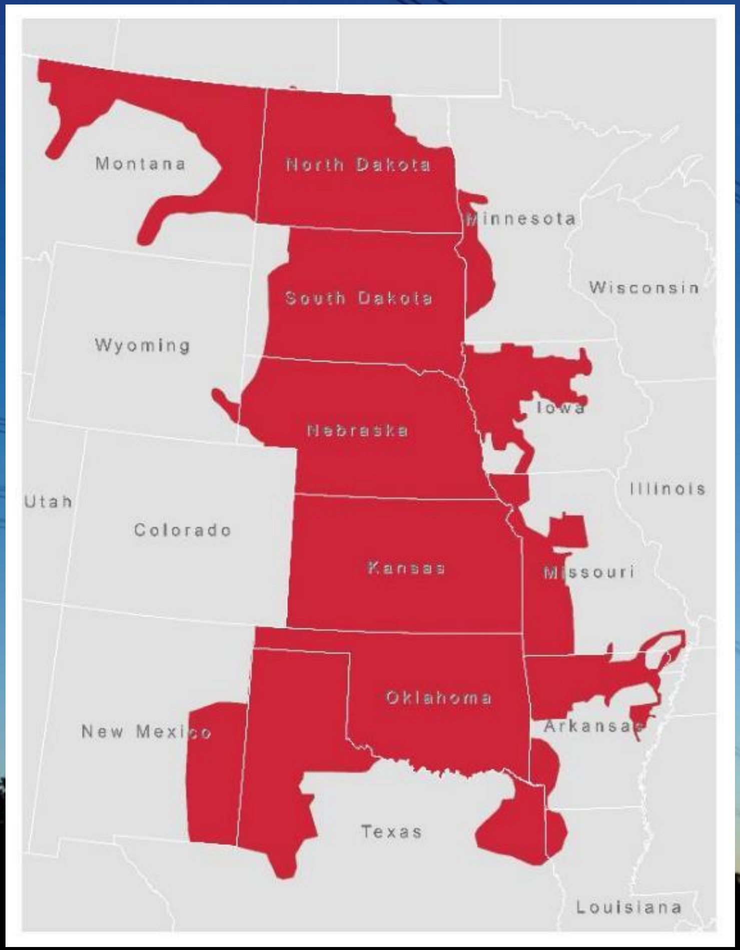
Integration of Probabilistic Forecasts into the EMS and MMS

Status and Prospects for the ESIG 2018 Forecasting Workshop

June 20, 2018

SouthwestPowerPool SPPorg southwest-power-pool

The SPP Footprint: Members in 14 States



- Arkansas
- Kansas
- Iowa
- Louisiana
- Minnesota
- Missouri
- Montana
- Nebraska
- New Mexico
- North Dakota
- Oklahoma
- South Dakota
- Texas
- Wyoming

Our Mission

Helping our members work together to keep the lights on … today and in the future.

GE Grid Software Solutions Portfolio

Providing utility and industrial customers mission-critical IT solutions to modernize and ensure the reliable, efficient and safe delivery of electricity, water and fuels.

GENERATION	TRANSMISSION	DISTRIBUTION	DISTRIBUTED ENERGY	OIL AND GAS	TELCO

Geospatial Information System

Mobile Workforce Automation – Field Force Automation

Market Management

Demand Response Management

Energy Management

Wide Area Management

Distribution Management

Metering Head End

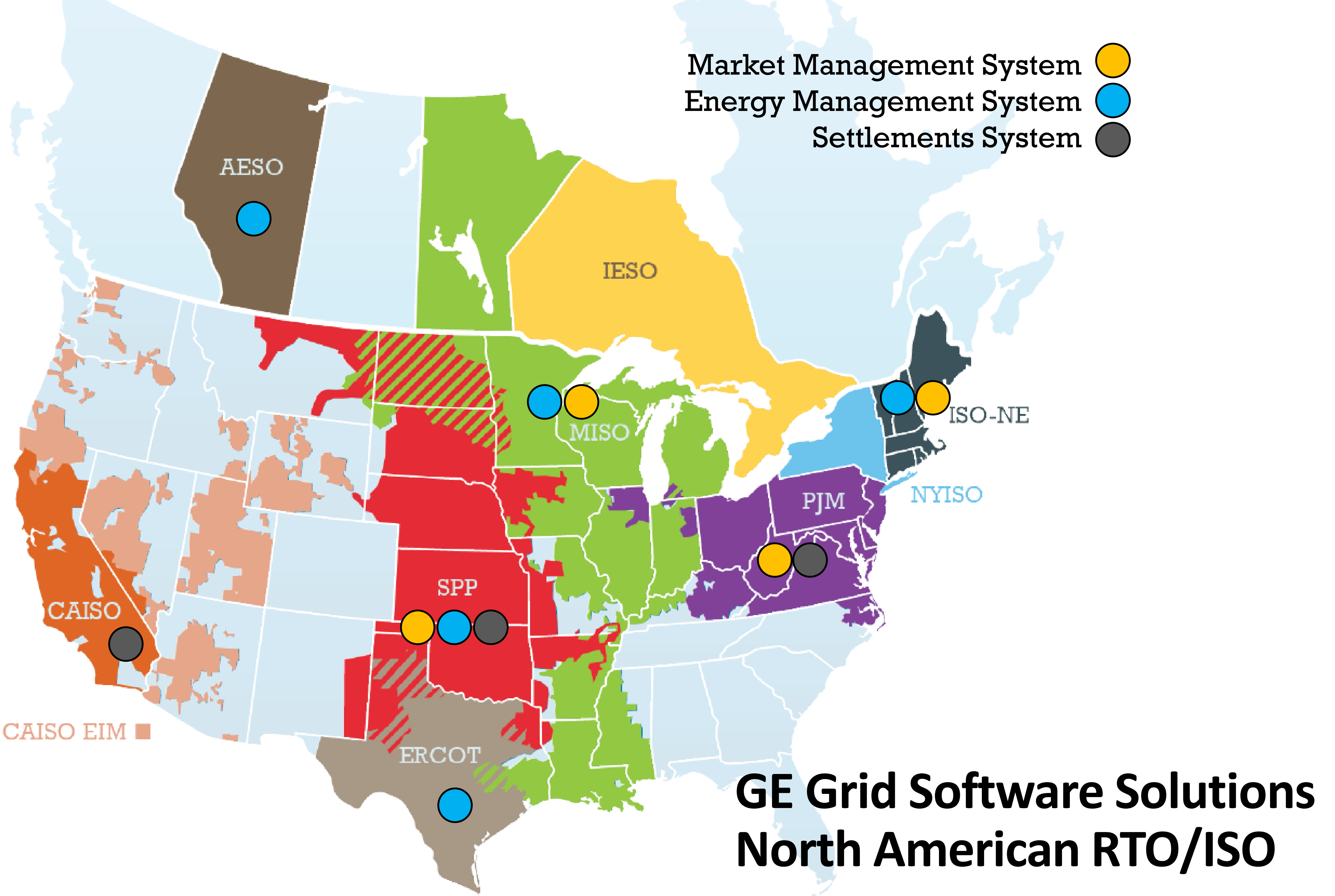
Pipeline

Utilities Communications

Advanced Analytics

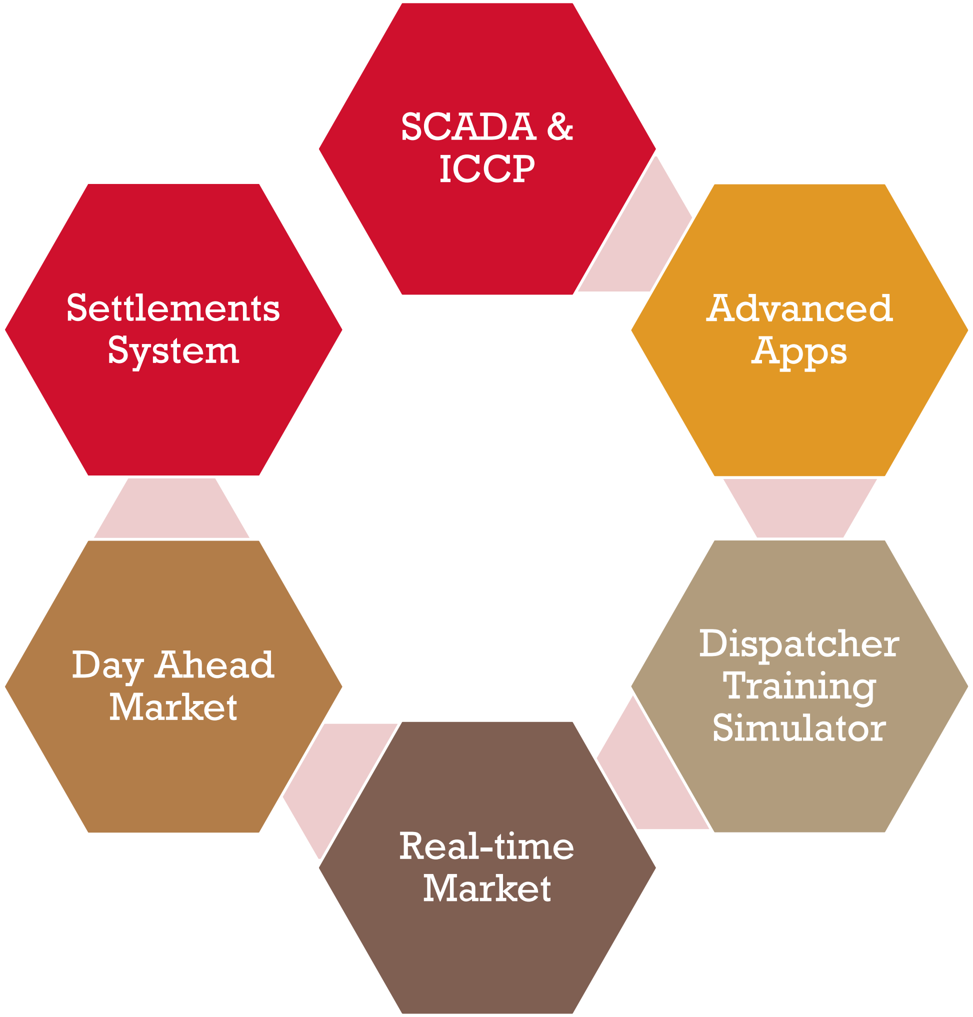
Solution as a Service

Consulting and Integration Services



GE Grid Software Solutions North American RTO/ISO

GE & SPP together since 1997



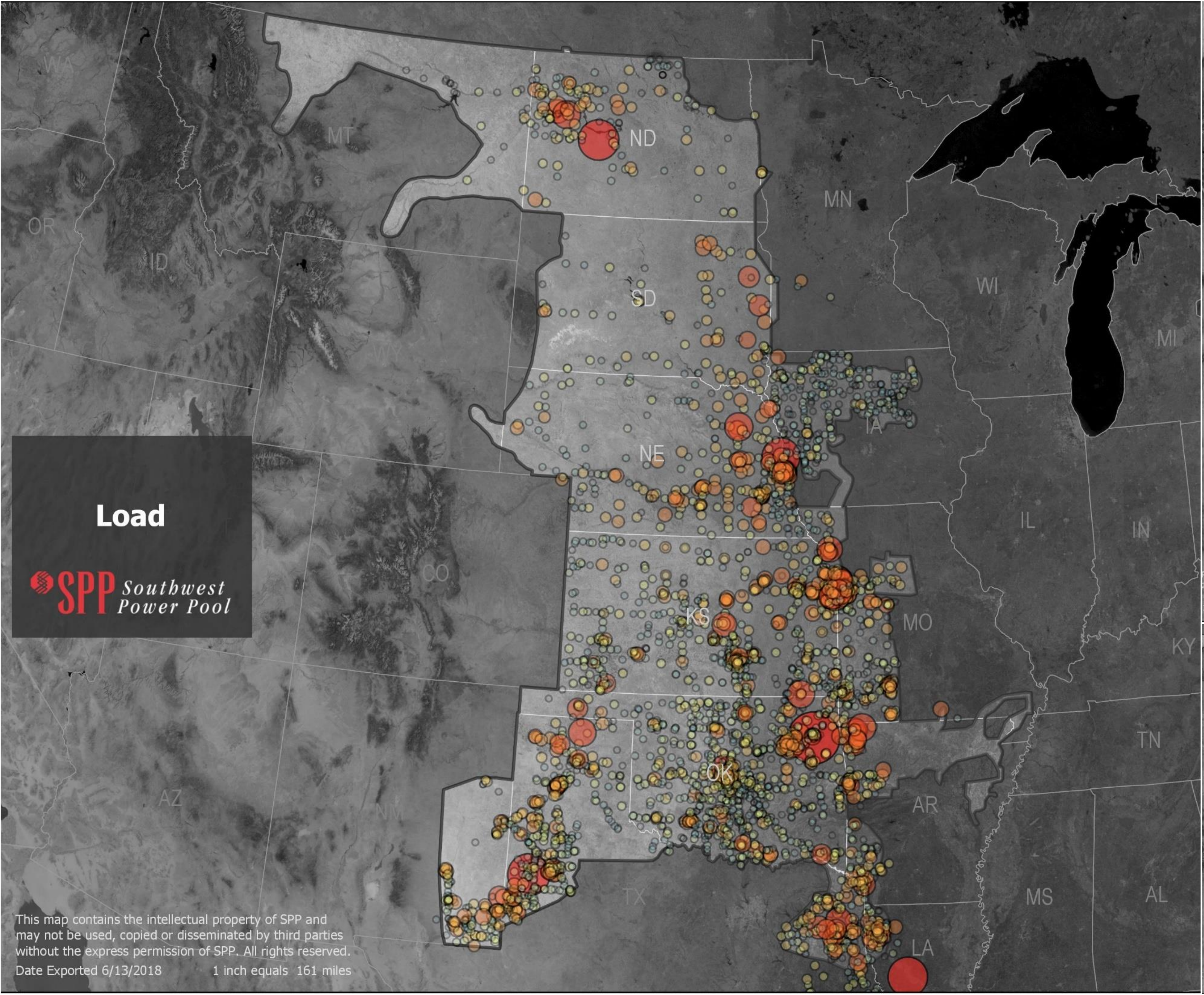
1941	SPP Founded
1968	Became NERC Regional Council
1980	First Telecommunications Network
1991	Implemented Operations Reserve Sharing
1994	Incorporated as non-profit
1997	**Implemented Reliability Coordination**
1998	**Implemented Tariff Administration**
2001	Implemented Regional Scheduling
2004	Became RTO
2006	Implemented Contract Services
2007	**Launched EIS market**
2009	Integrated Nebraska Utilities
2012	Moved to new Corporate Center
2014	**Launched the Integrated Marketplace**
2014	**Became Balancing Authority**
2015	Integrated System joined SPP

SPP Markets & Products

- Integrated Marketplace: Participants buy and sell wholesale electricity in day-ahead and real-time
  - Day-Ahead Market commits the most cost-effective and reliable mix of generation for the region
  - Real-Time Balancing Market economically dispatches generation to balance real-time generation and load, while ensuring system reliability.
  - Transmission Congestion Rights Market allows participants to reduce their exposure to high market prices and potentially receive lower priced deliverable energy

- Products in the Integrated Marketplace are
  - Energy
  - Operating Reserve
    - Regulation Up
    - Regulation Down
    - Spinning
    - Supplemental
  - Congestion Rights

SPP


Load
SPP Southwest Power Pool
ND
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MN
SD
WI
MI
NE
IA
IL
IN
CO
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MO
KY
OK
AR
TN
AZ
NM
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MS
AL
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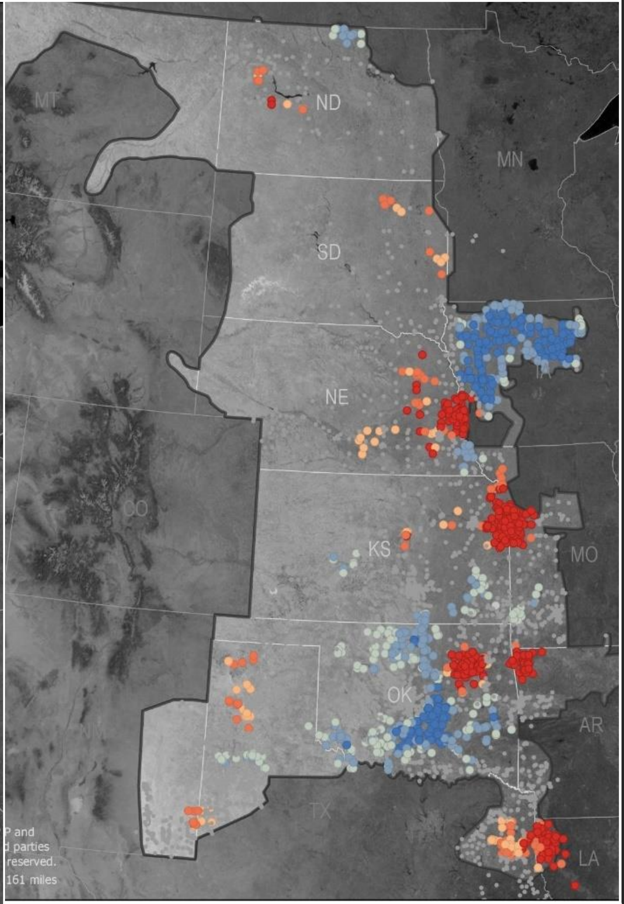
Date Exported 6/13/2018
1 inch equals 161 miles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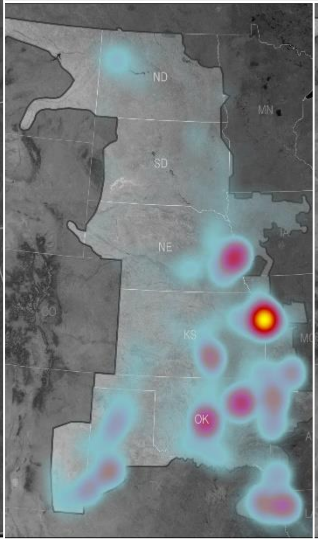
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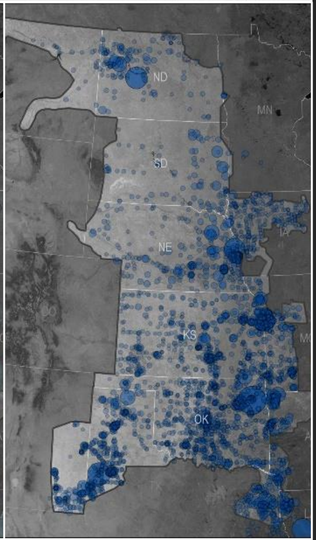
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SPP

SPP’s Load Forecast Approach

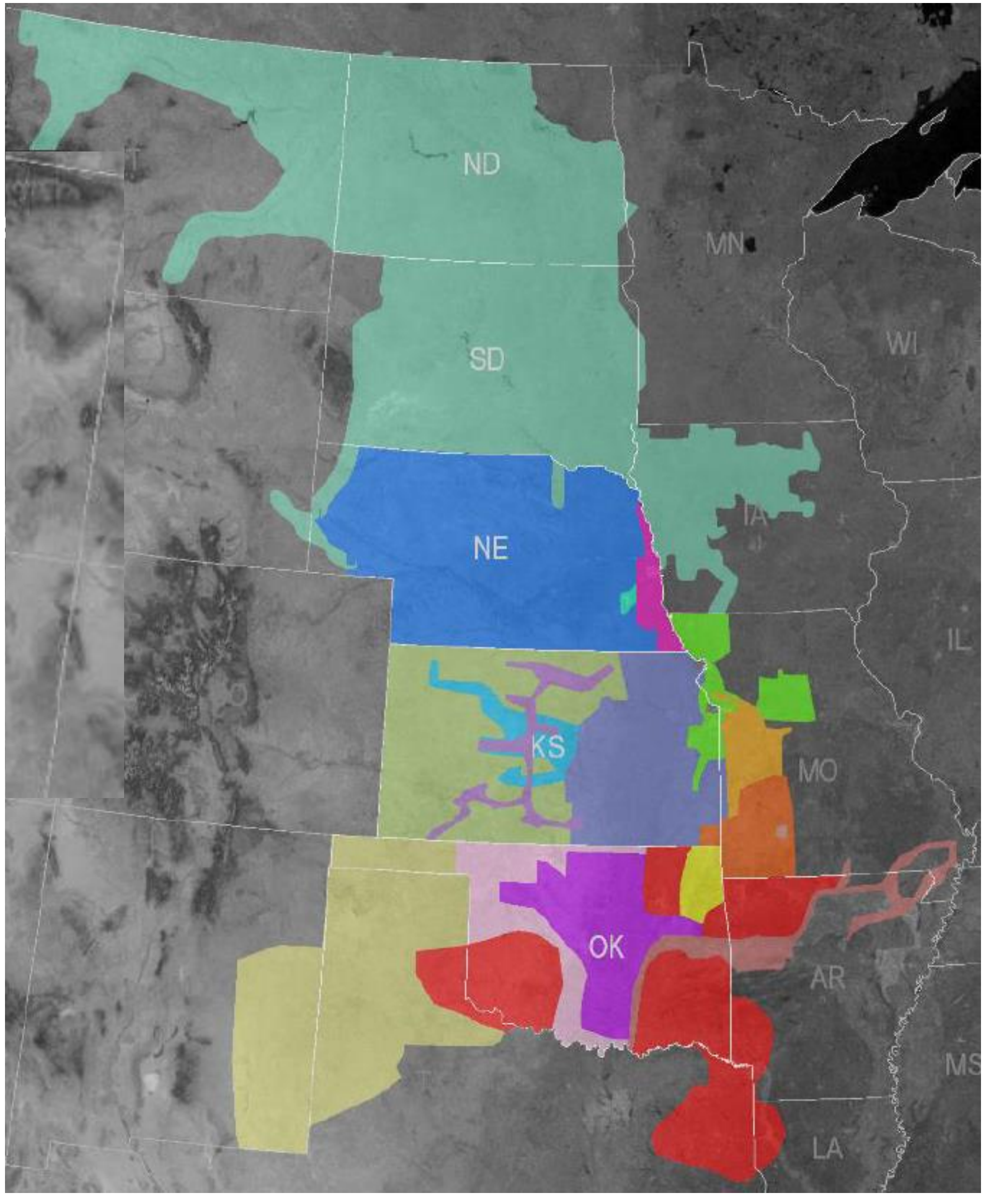
- Load Forecast Areas
  - Historical Balancing Authorities (18)
  - Non-conforming loads (2)
- Primary Inputs
  - Actual load
  - Historical load
  - Actual weather
  - Historical weather
- Horizons
  - Short-term is 0-4 hours ahead with 5-minute granularity
  - Mid-term is 0-10 days ahead with 1-hour granularity

- Forecasts are used in multiple studies
  - State estimator & contingency analysis
  - Current & Next Day Assessments
  - Intra-Day, Day Ahead , and Multi-Day Reliability Unit Commitment
  - Day Ahead Market preparation
- Load forecast applications
  - GE STLF (similar slope)
  - GE MTLF (linear regression)
  - PRT (neural network)
  - SPP Combined Best (metric based)
- Weather forecast vendors
  - Radiant Solutions
  - DTN

Load Forecast Areas

- Load based boundaries historically created by ownership and meter locations.
- Do not coincide with terrain features, climate regions, temperate zones, climate types, or even hardiness zones!

Solution is needed to identify and manage load data at a more granular level. State Estimator is a possible solution. Application flexibility is the roadblock.

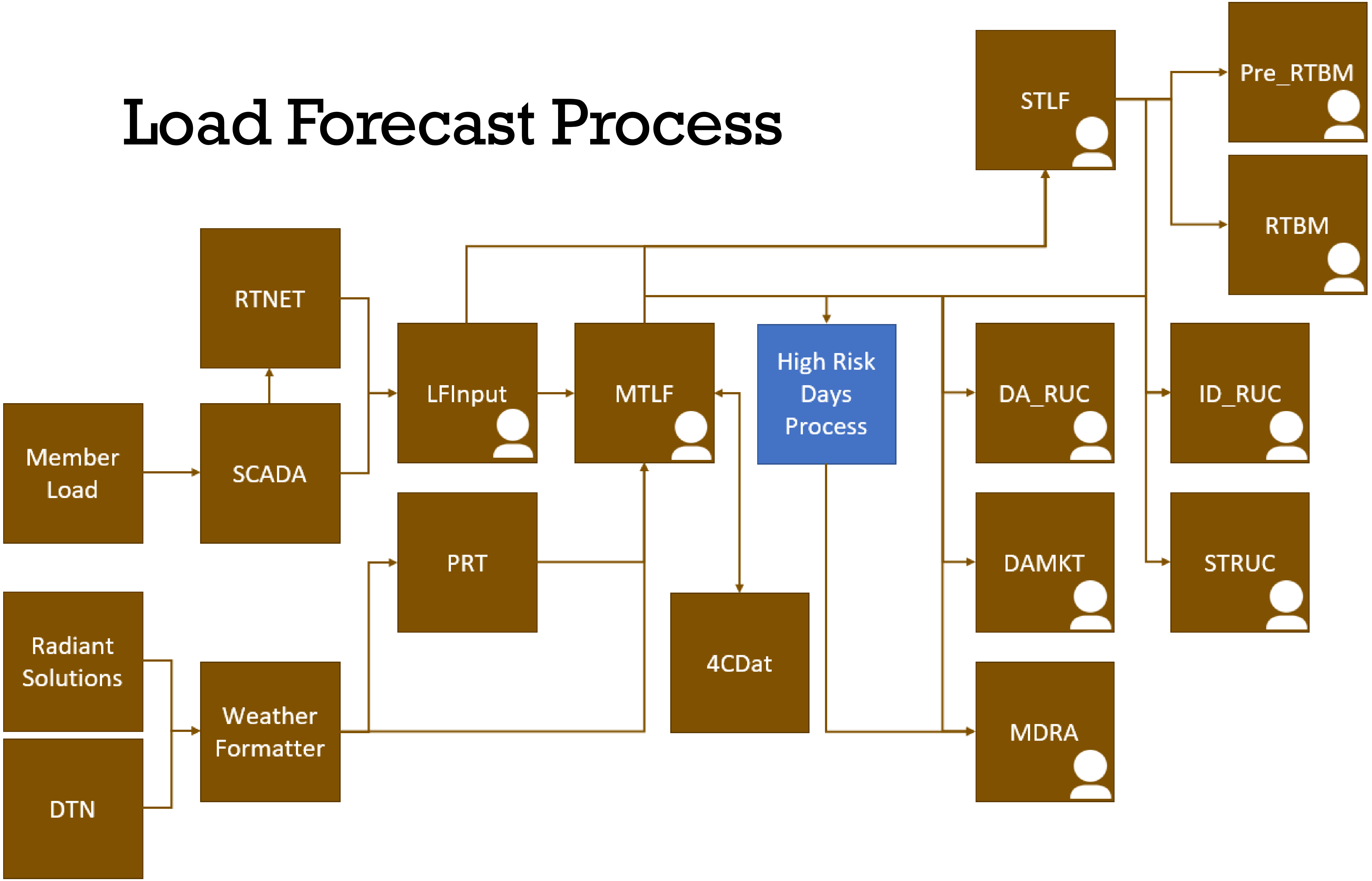


Primary Inputs to Load Forecast

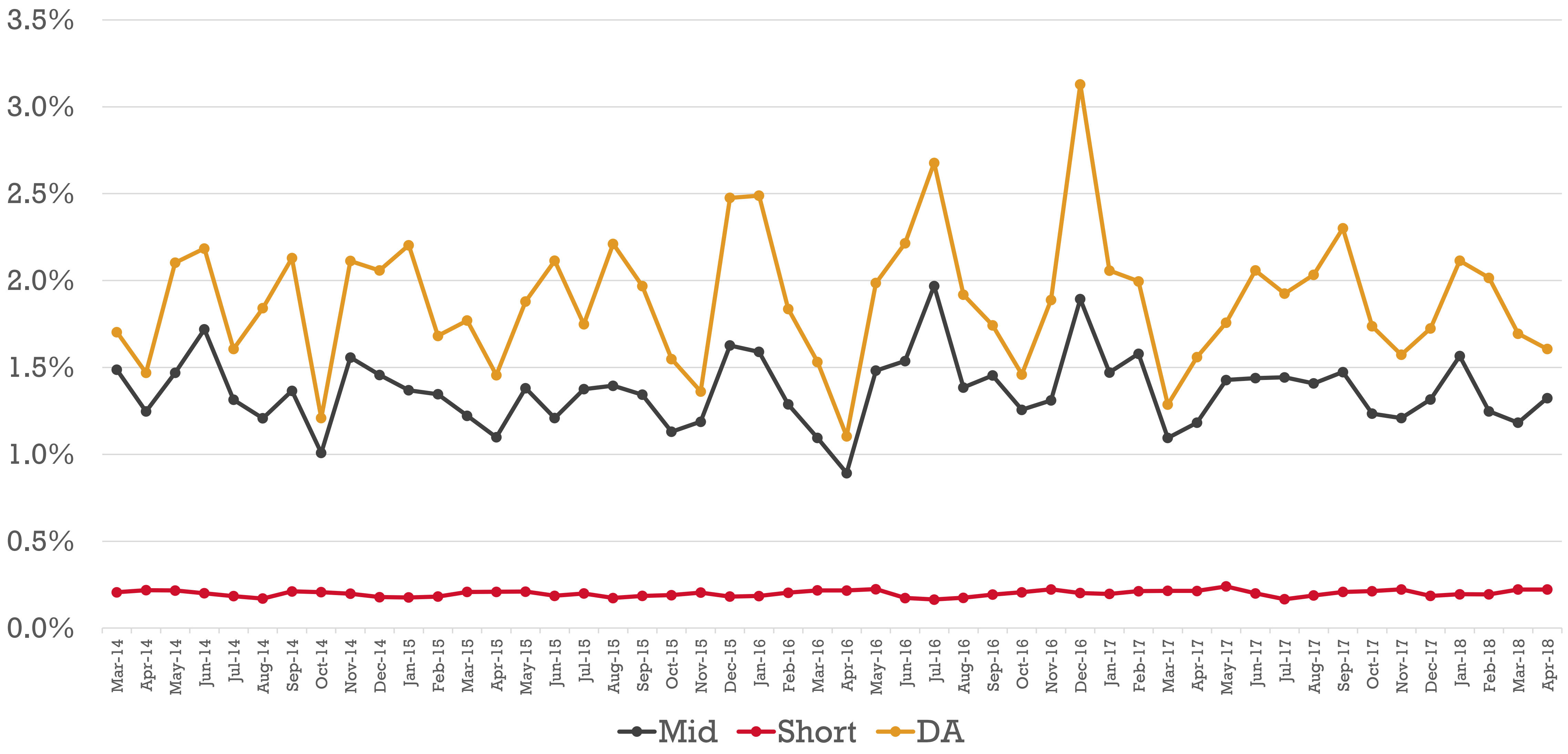
- Actual Load
  - Measured (> 1,500 metering points)
  - Estimated
- Historical Load
  - Actual load is archived
  - Data cleansing requires some manual intervention
- Deterministic
  - Models are trained on actual loads
  - No adjustments are made
  - 3-years of data used

- Actual Weather
  - Dew point
  - Humidity
  - Temperature (dry and wet bulb)
  - Wind chill
- Historical Weather
  - Actuals are archived
  - Data is cleansed by our vendors and checked by SPP staff
- Deterministic
  - Production data is all deterministic
  - Probabilistic temperatures is available from vendor but not in production processes yet

Load Forecast Process

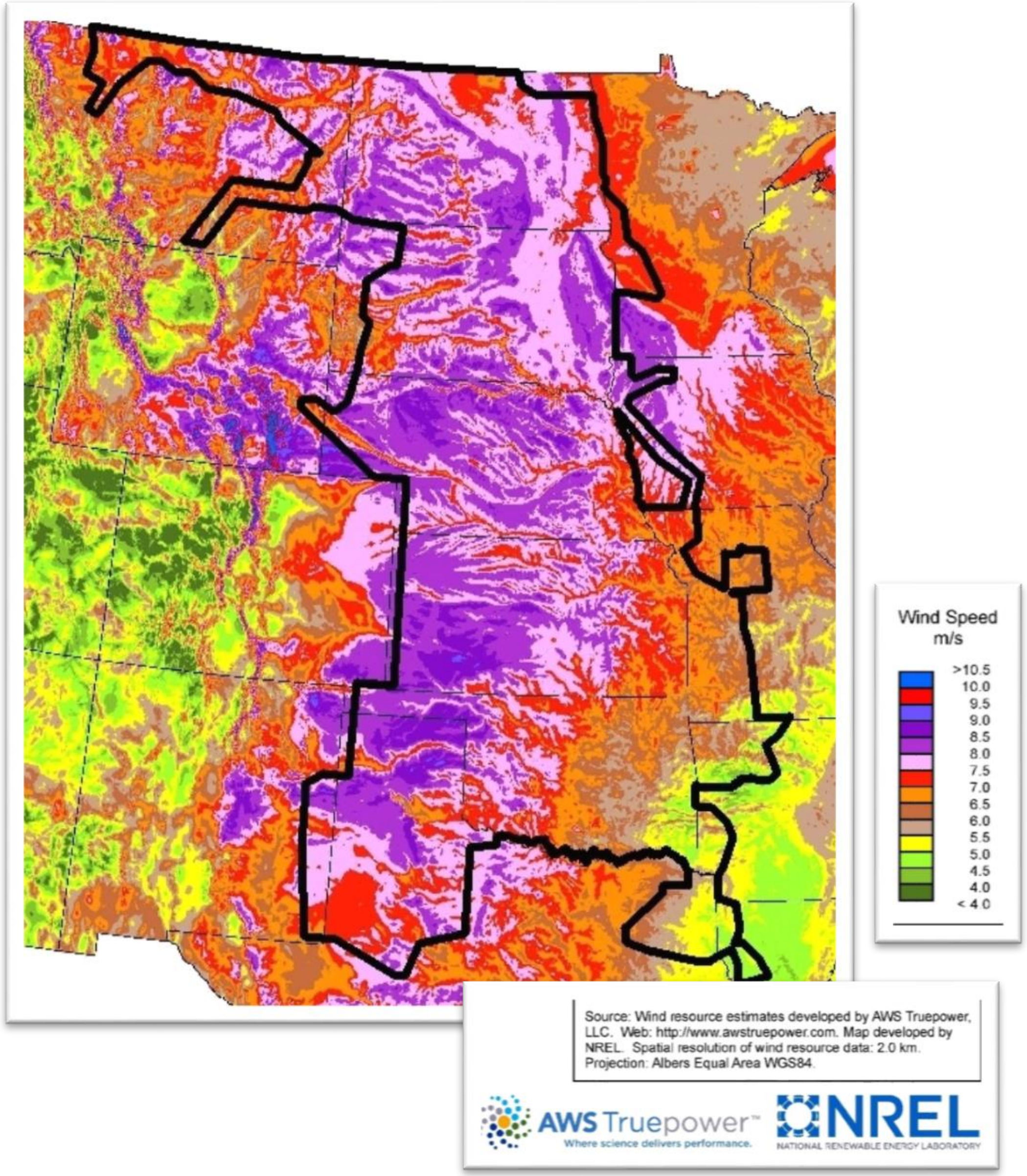


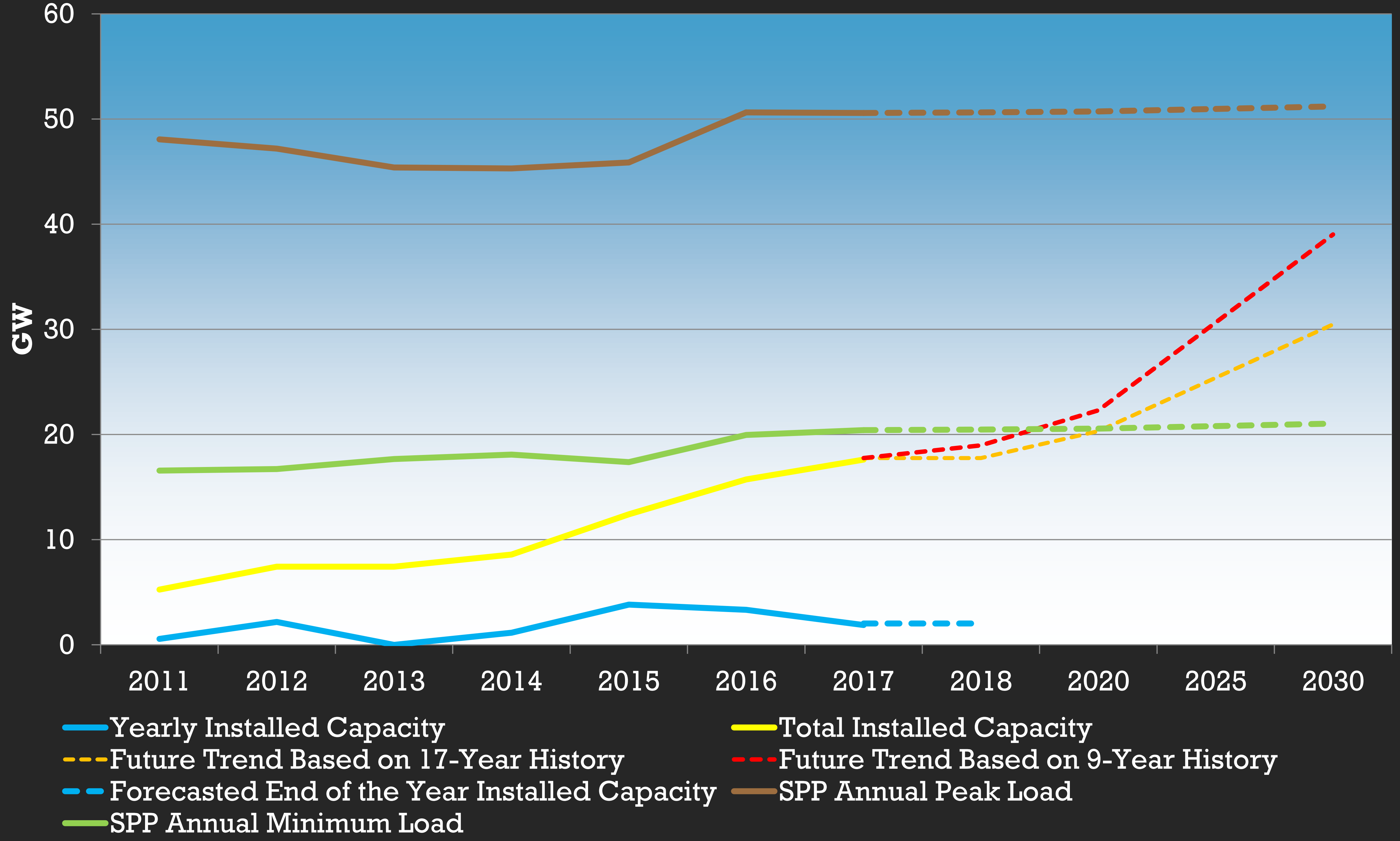
Load % Error
DA [24-hrs out]
Mid [4-hrs out]
Short-term [10-mins out]



Wind Energy in SPP

- Maximum wind penetration:
  - Instantaneous: 63.96% (4/30/18)
  - Hourly Average: 62.89% (4/29/2018)
  - Daily Average: 54.1% (4/29/2018)
  - 2018 up to May 8th:
    - >60%, 6 days
    - >50%, 40days
- Max wind swing in a day: >10 GW (12.5 GW to 2 GW back to 12 GW)
- Max 1-hour ramp: 3,700 MW



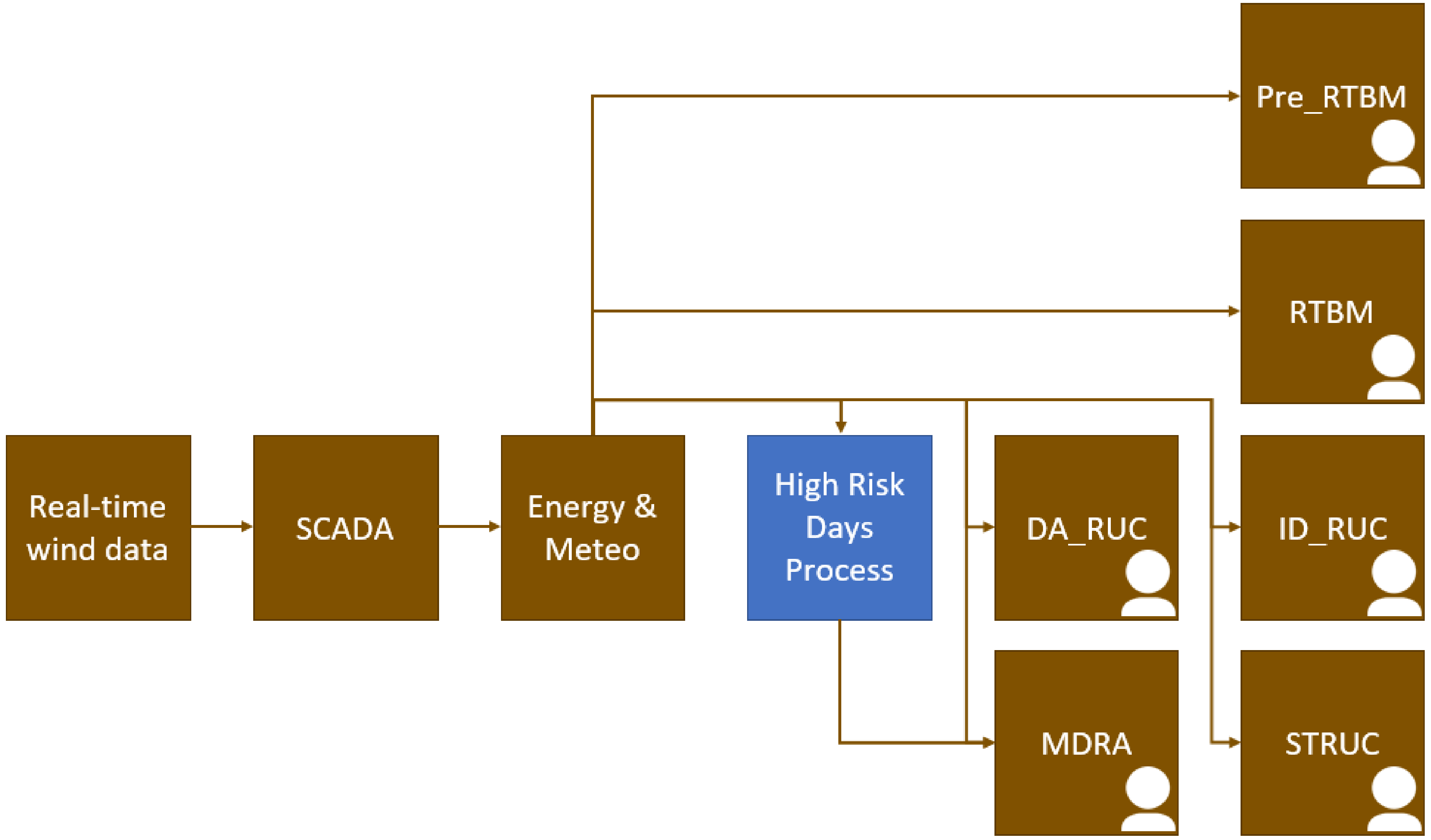


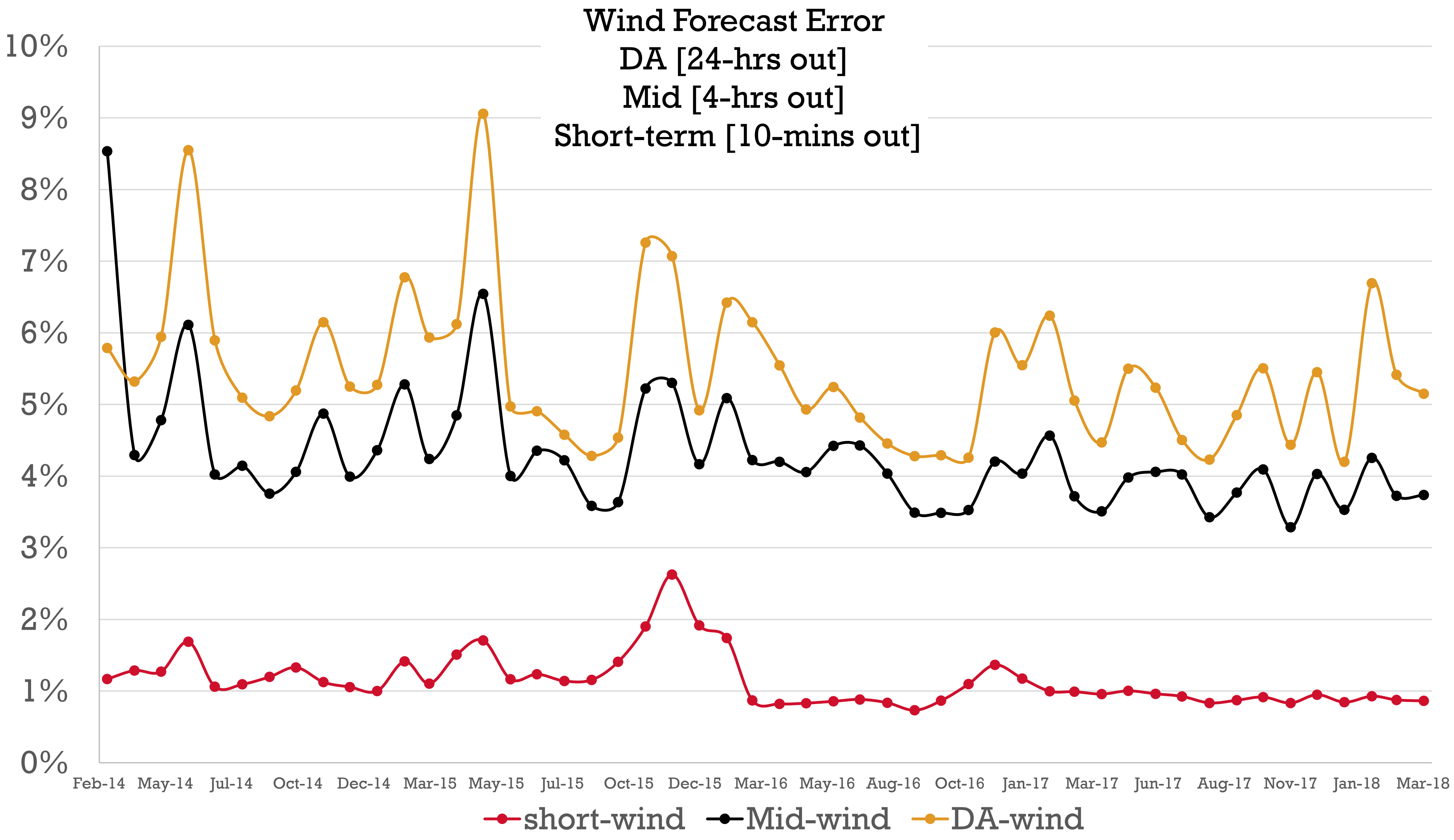
GW
60
50
40
30
20
10
0
2011
2012
2013
2014
2015
2016
2017
2018
2020
2025
2030
Yearly Installed Capacity
Total Installed Capacity
Future Trend Based on 17-Year History
Future Trend Based on 9-Year History
Forecasted End of the Year Installed Capacity
SPP Annual Peak Load
SPP Annual Minimum Load

SPP’s Wind Forecast Approach

- Wind forecasting performed on individual resources (aka wind farms or shares)
- Primary inputs
  - Current generation
  - Total Capability
  - Turbine Availability
  - Actual Weather
  - Historical Weather
- Horizons
  - Short-term is 0-4 hours ahead with 5-minute granularity; updated hourly
  - Mid-term is 0-72 hours ahead with 1-hour granularity; updated hourly
  - Long-term is 48-168 hours ahead with 1-hour granularity; updated 8 times per day
- Forecasts are used in multiple studies
  - Multi-Day Reliability Assessment
  - Day-Ahead Reliability Unit Commitment
  - Intra-Day Reliability Unit Commitment
  - Short-Term Reliability Unit Commitment
  - Pre Real-Time Balancing Market
  - Real-Time Balancing Market
- Wind forecast vendor
  - Energy & Meteo
- Deterministic forecast
- Confidence Band
- Icing forecast

Wind Forecast Process




Wind Forecast Error
DA [24-hrs out]
Mid [4-hrs out]
Short-term [10-mins out]
10%
9%
8%
7%
6%
5%
4%
3%
2%
1%
0%
Feb-14
May-14
Jul-14
Oct-14
Dec-14
Mar-15
May-15
Jul-15
Oct-15
Dec-15
Mar-16
May-16
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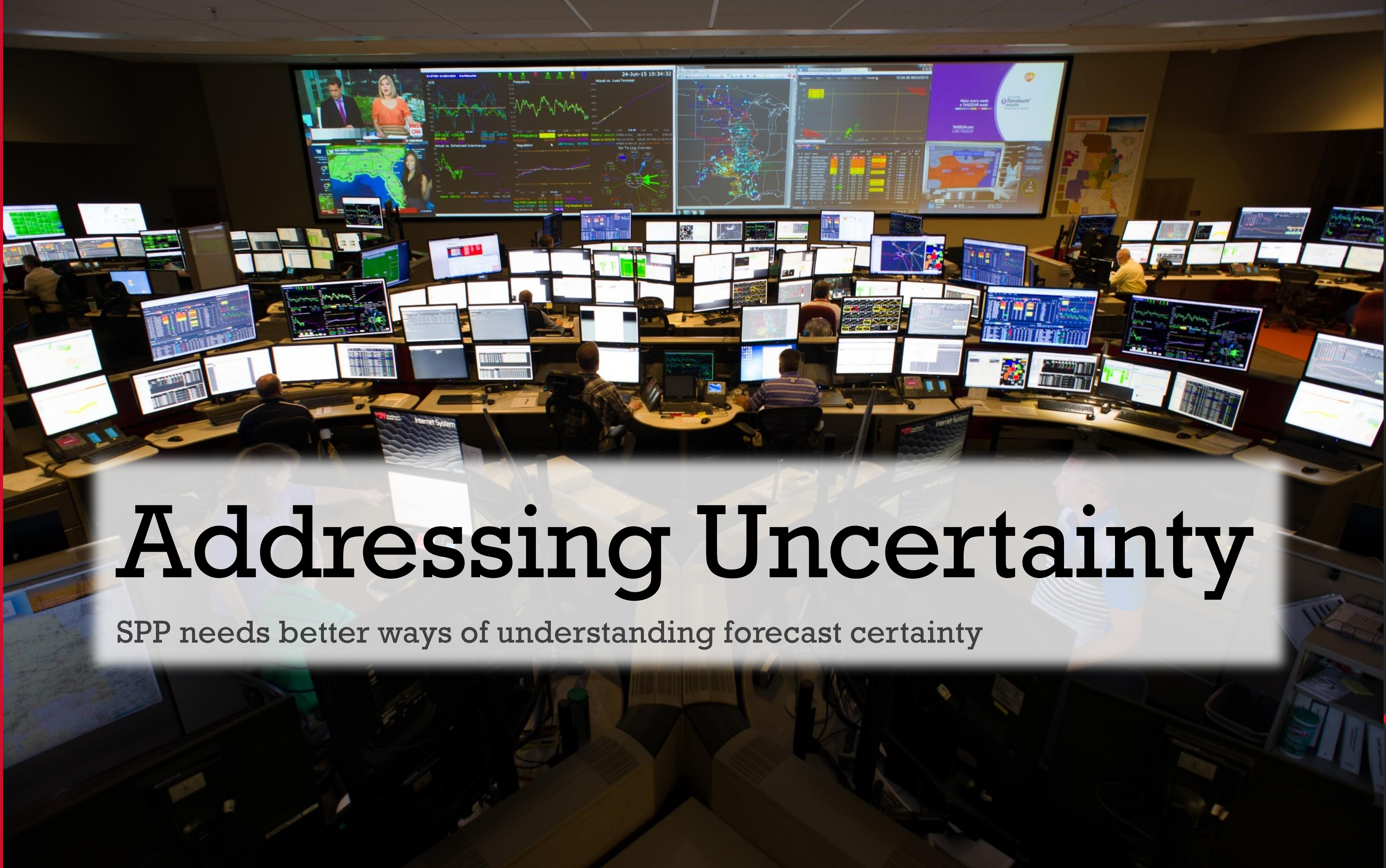
Mar-18
short-wind
Mid-wind
DA-wind



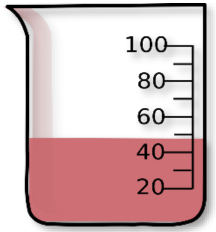
Addressing Uncertainty

SPP needs better ways of understanding forecast certainty

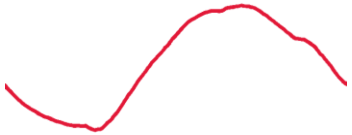
SPP

Risk due to unexpected changes in:

Capacity



Peak Demand

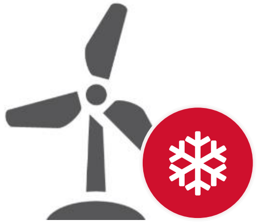


Total Wind

Wind Penetration

Wind Drop

Wind Icing

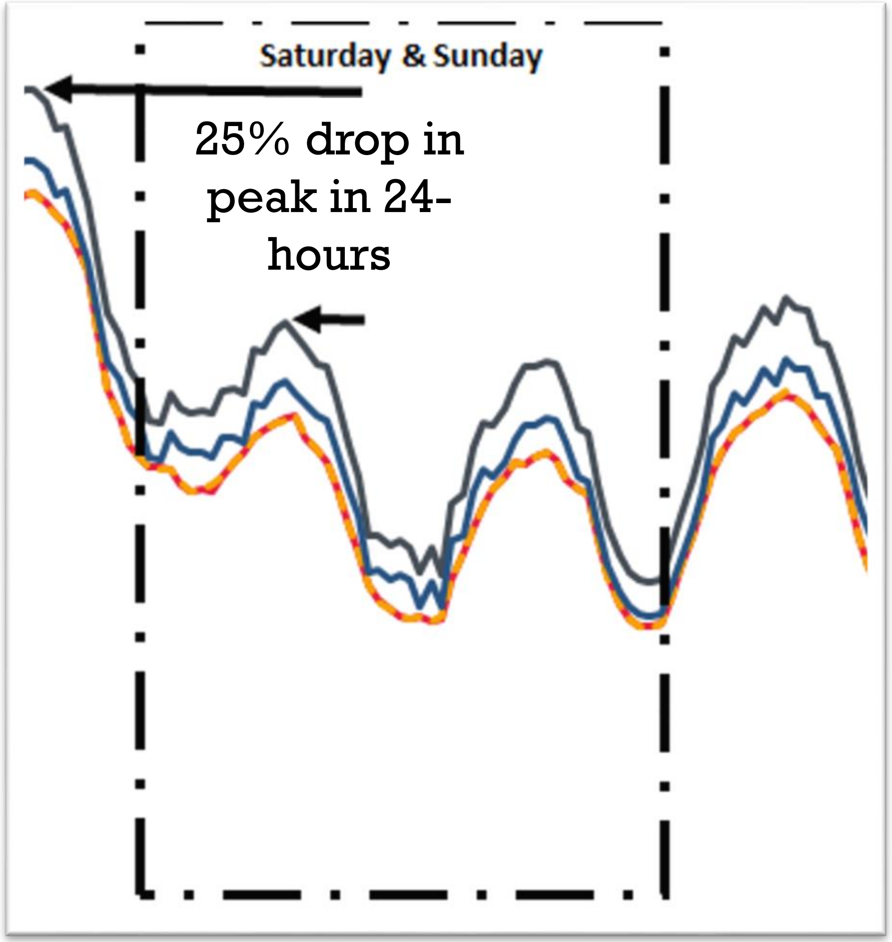


EHV Outages

Weather

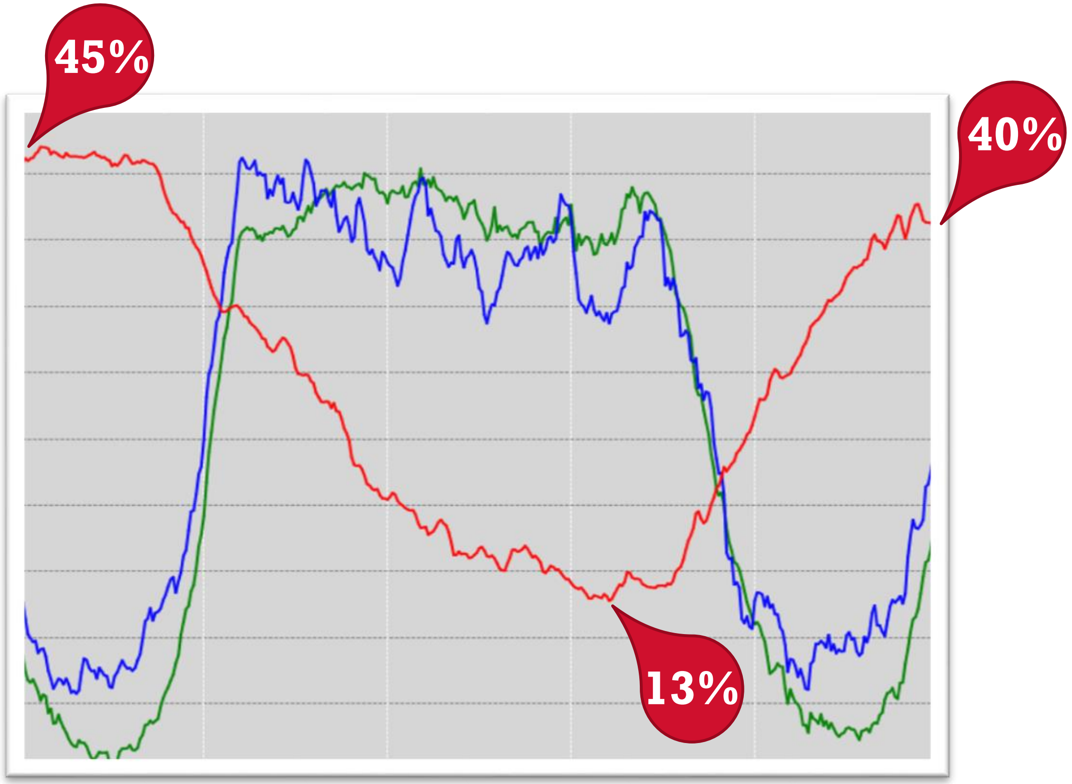
Example: Unexpected Load Drop

- Anticipating drastic changes in weather patterns is needed to ensure forecasts don't hold onto past day's/week's actuals as an input to the forecast for tomorrow
- Thunderstorms are also particularly troublesome in this regard



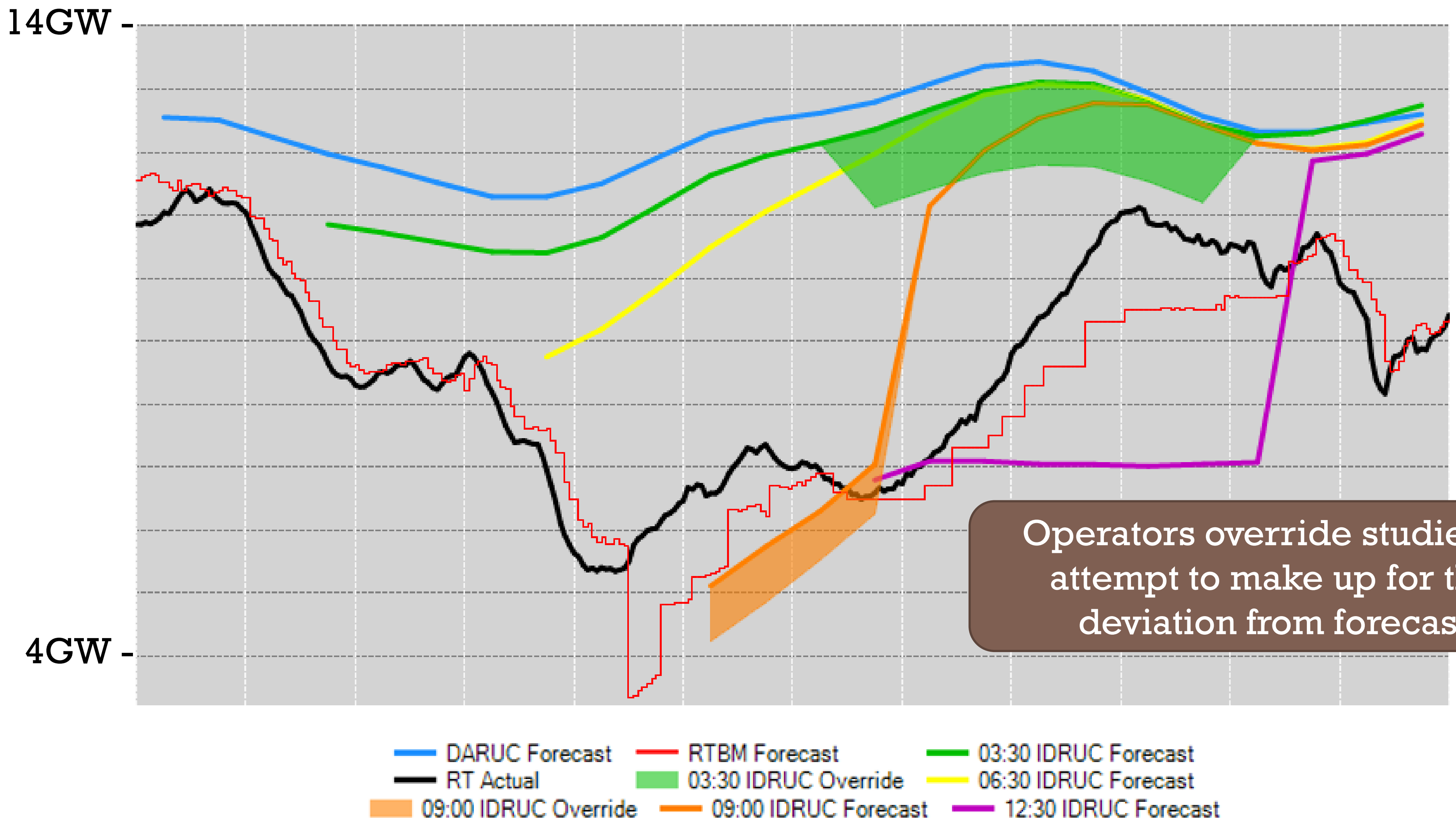
Example: Unexpected Wind Drop

- Maximum difference between actual and forecast wind output of 7 GW
- 54 quick starting resources committed
- Very challenging low pressure system was difficult to forecast
- Drop was significantly outside of forecast confidence bands



Wind Penetration % Generation MW
Load MW

Example: Wind Forecast Overrides



Operators override studies to attempt to make up for the deviation from forecast

High Risk Scenario Days

- Special Studies
  - High wind VSAT
  - DBDA studies with various adjustments to reflect the scenario
  - Wind Drop Study
- Look for
  - High voltage situations
  - Thermal constraints
  - Ramp and Capacity shortages
- Pro-active actions
  - Committing longer lead resources
  - Re-evaluating Approved Outages
  - Setting additional constraint limitations

- Ramp and capacity are primary concerns
- What can our operators do?
  - Employ study offsets
  - Issue commitments & make decisions based on what they think is coming

Help us Continue Improving!

- Uncertainty forecasts for specific sets of load areas and variable resources
- Interaction with vendors when forecasts are outside of confidence bands
- Standardized and automated triggers to run sensitivities
- More granular awareness of load and weather correlations
- Greater flexibility to adjust the relationships between forecast areas and downstream market systems
- More automated methods to cleanse data inputs of errors
- More automated methods to "backcast" and troubleshoot forecast errors and needed model improvements

Looking Ahead

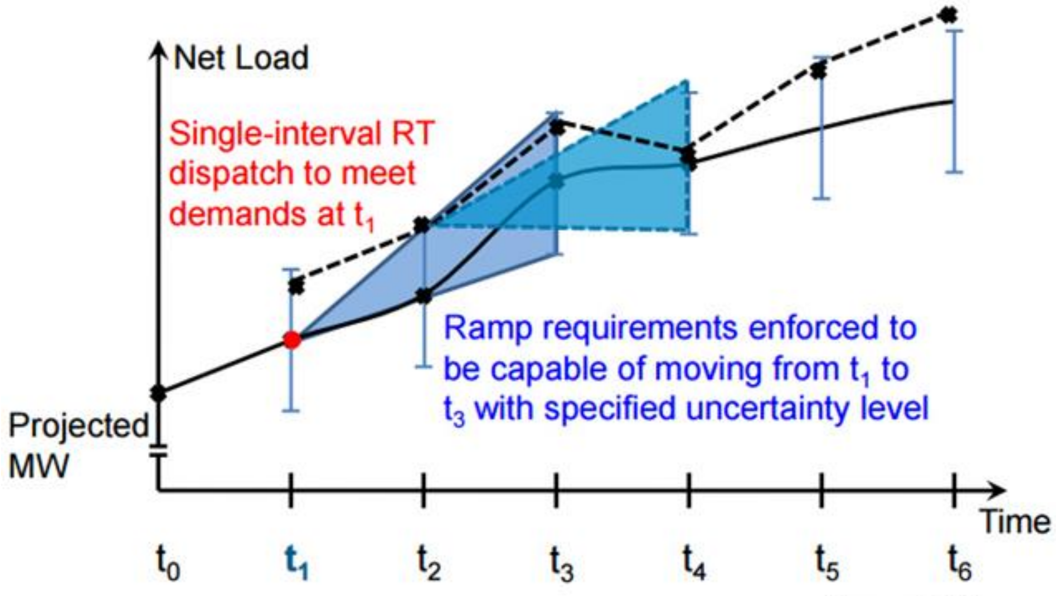
Opportunities for Member Driven Evolution in SPP's Processes

Probabilistic Forecast’s uses in RTO/ISO

- The largest use case is for the setting of high quality requirements for the services required by RTO/ISOs to operate the grid reliably at the least production cost.
- Provide better monitoring and increase understanding by the grid operators of when and where system risk lies.

Ramp Capability Product

- GE has worked with MISO to implement their version of a ramp capability product
- The requirement amount is determined by historical net load error
- Better probabilistic forecasts could inform us of the appropriate amount to procure instead simply relying on past events
- Understanding the value of this ramp is incredibly important and hard to determine. Too much will add to the cost burden while too little will reduce reliability
- Explicitly pricing operational ramp needs in the market will help provide transparent incentives to participants



Source: MISO

Time Coupled Multi-Interval Dispatch

- Provides most optimal dispatch over the study horizon for net load changes that are forecasted accurately
- SPP's PRE-RTBM and ST-RUC studies already incorporate this concept
- Method has issues in determining how to settle appropriately (less price transparency) if prices from all coupled intervals aren't considered

Short Term Capacity Product

- Will help secure reliability over a longer time horizon than current products as it may be necessary to ensure flexible capacity is available further forward in real time (e.g. 30 min)
- Probabilistic net load forecasts would again help provide highest quality determination of the requirement needed by the grid

Multi-Day Economic Unit Commitment

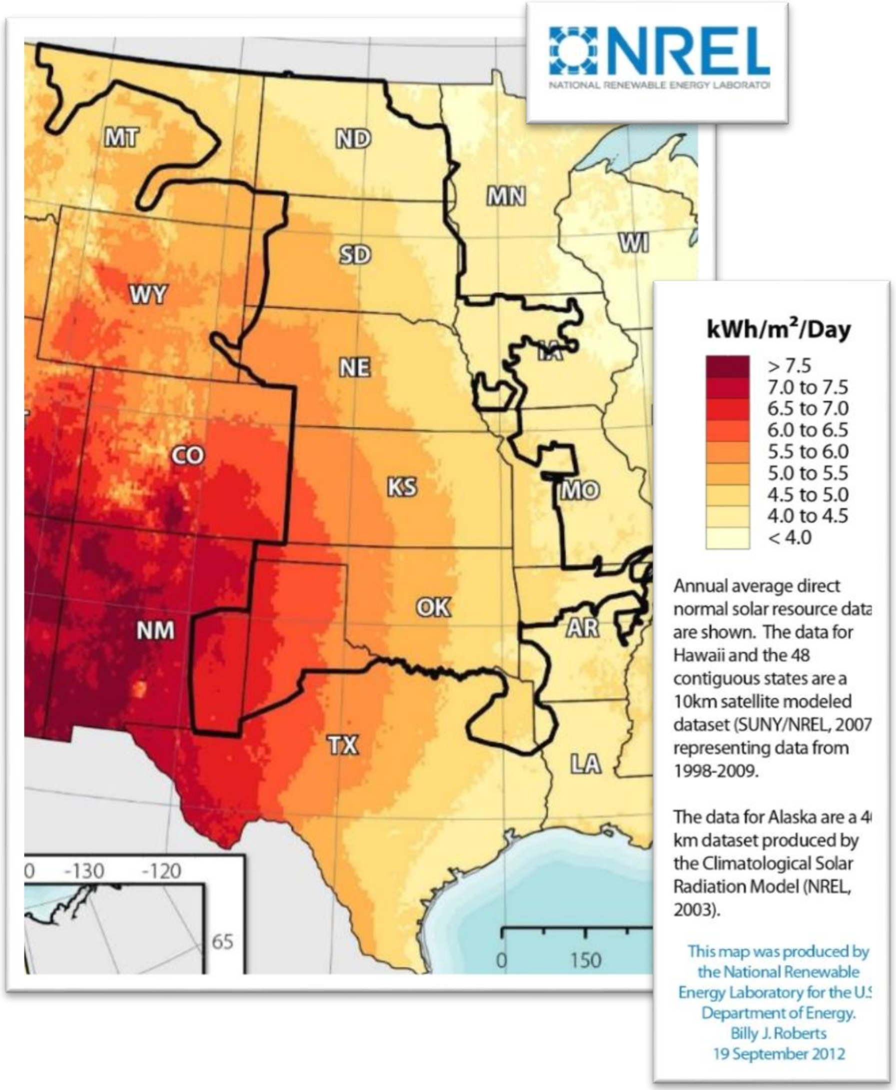
- Resources that need long notification times to prepare to be online or have very long minimum run times need hedging mechanisms that judge their benefits to the system on a longer horizon than the Day Ahead Market
- Forecast error as we go out this far becomes much larger, so our economic analysis of these resources is quite suspect
- Higher quality probabilistic net load forecasts will help to provide more economic validity to call these resources online than we operate with today.

Stochastic Reliability Unit Commitment

- Will internalize the uncertainty into the optimization problem
- Current problem is performance on problems with the size/precision/complexity of these systems
- If the problem is reduced in precision or complexity the quality degrades with it relative to the linear approximation of the ramp product
- Probabilistic forecasts necessary for this approach

SPP Solar Proliferation

- Solar is expected to quickly grow in the footprint
- While SPP currently has forecasts for solar on their system, its size is still quite small (~200MW)
- Nature of solar forecasting is quite different from wind forecasting, but looking to learn from leaders in the industry



Stored Energy Resources

- FERC 841 will ensure all markets have easy access to these resources
- Will help with demand side elasticity problem
- Economics will drive adoption of the electrification of commercial transportation
- Cost of batteries falling fast (Audi - $114/kWh; Tesla - $100/kWh; Power Electronics still ~ $50/kWh and will begin to come into focus)
- Multiple potential benefits: Transmission build out deferment, Voltage/Frequency support, peak shaving, etc.
- Movement away from cobalt heavy chemistries will be important to sustain momentum due to supply issues

Distributed Energy Resources

- Before joining markets or increasing data reporting, they will contribute to additional load forecast error
- TOU pricing by retail utilities will help drive DER market aggregation
- Once integrated will help to reduce error and provide additional flexibility to the grid

Thank You