Solar Uncertainty Management and Mitigation for Exceptional Reliability in Grid Operations (SUMMER-GO)

Bri-Mathias Hodge, Ph.D.

July 12, 2018

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

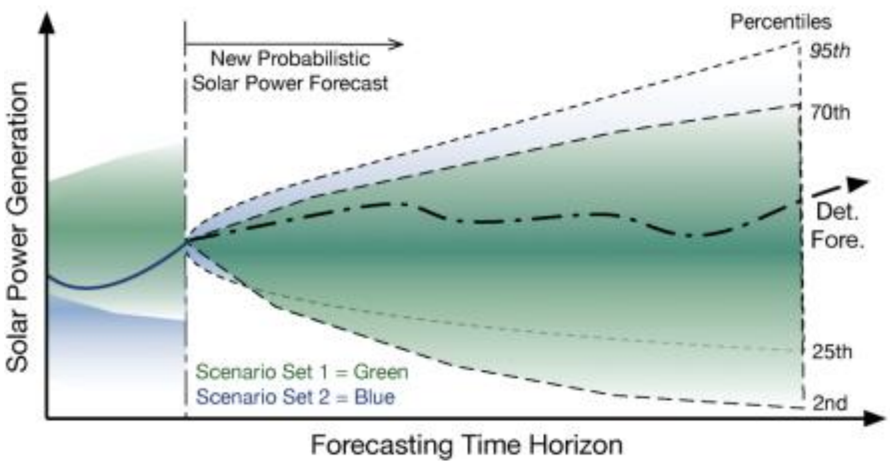
Solar Uncertainty Management and Mitigation for Exceptional Reliability in Grid Operations (SUMMER-GO)

Prime: NREL, PI: Bri-Mathias Hodge, Ph.D.

Technology Summary: The SUMMER-GO Team will design novel algorithms to create probabilistic solar power forecasts and automate their integration into power system operations. Adaptive reserves will dynamically adjust reserve levels conditional on meteorological and power system states. Risk-parity dispatch produces optimal dispatch strategies under uncertainty by cost-weighting solar generation scenarios.

Team: NREL (National Renewable Energy Laboratory), radiant SOLUTIONS, ercot, UT DALLAS

Technology Outcomes: Adaptive reserves and risk-parity dispatch will reduce system operating costs while increasing system reliability. A situational awareness tool will help system operators understand the uncertainty in the solar power forecasts, and the impacts on operations.

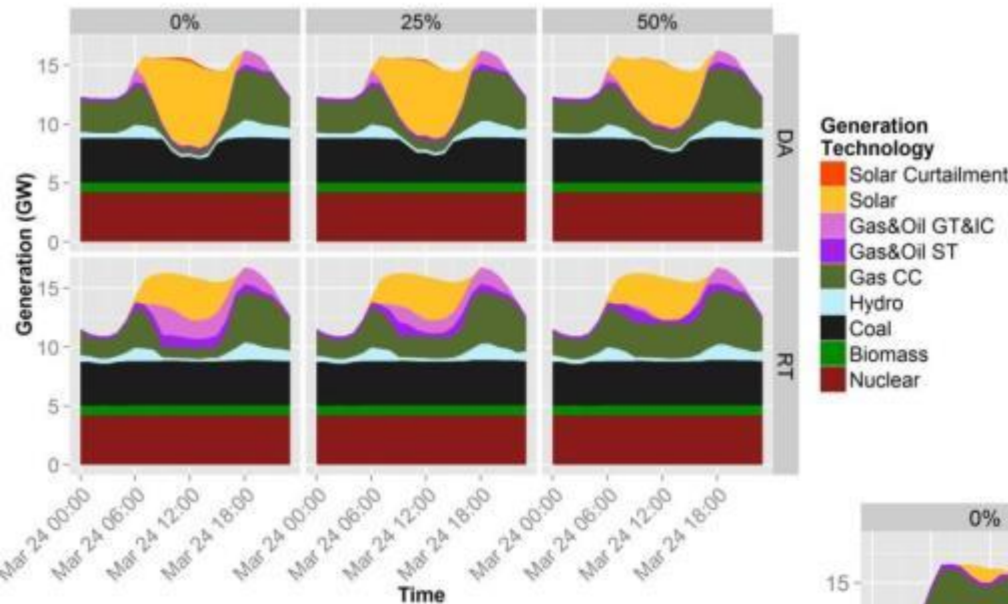


Project Objectives and Approach: This project will bring probabilistic solar forecasts into ERCOT's real-time operation environment through automated reserve and dispatch tools that increase economic efficiency and improve system reliability. The adaptive reserves aim to reduce overall reserve levels by 25% while maintaining or improving system reliability. The risk-parity dispatch will automate the use of probabilistic forecast information in a 5-minute dispatch window. The situational awareness tool will present forecast uncertainty information that is relevant, timely, and allows for better decision making.

SUMMER-GO is a suite of tools that enable the incorporation of probabilistic solar forecasts into operations to improve system reliability and will be validated in ERCOT's real-time operational test system.

Project Background and Motivation

Examples: Large deterministic over and under-forecasting events in ISO-NE 18% solar power scenario

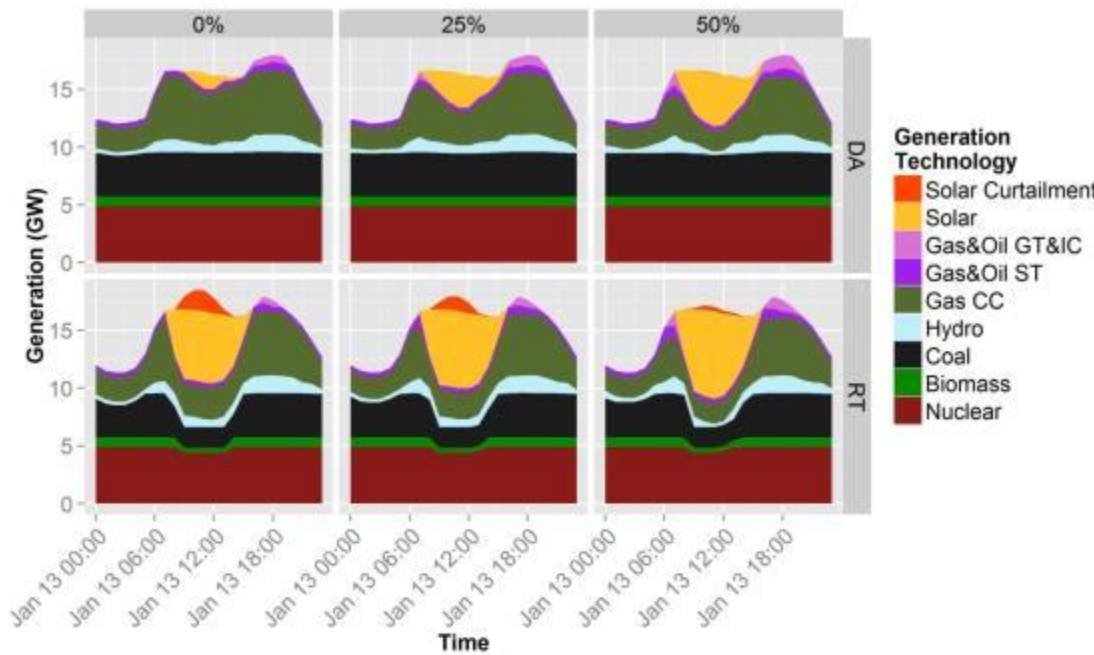


Consequences:

- Excess generation a mid-day; shortage of ramping capability in the evening
- High solar curtailment
- Higher system costs
- Reliability concerns from thermal ramping availability

Consequences:

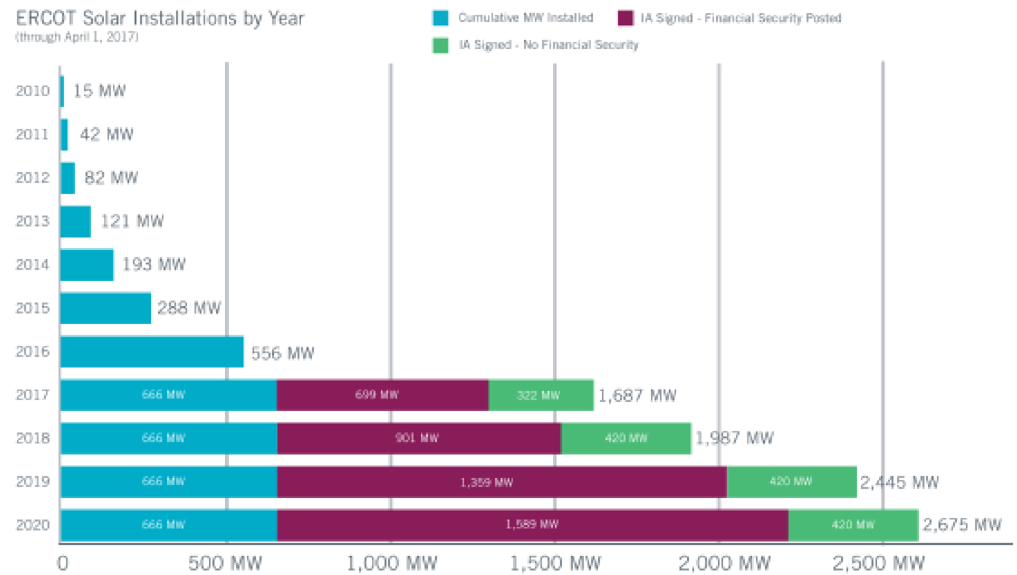
- Shortage of generation in RT
- Need quick-start units
- Reliability concerns if enough ramping capacity not available
- High marginal costs of these units translate to high system costs

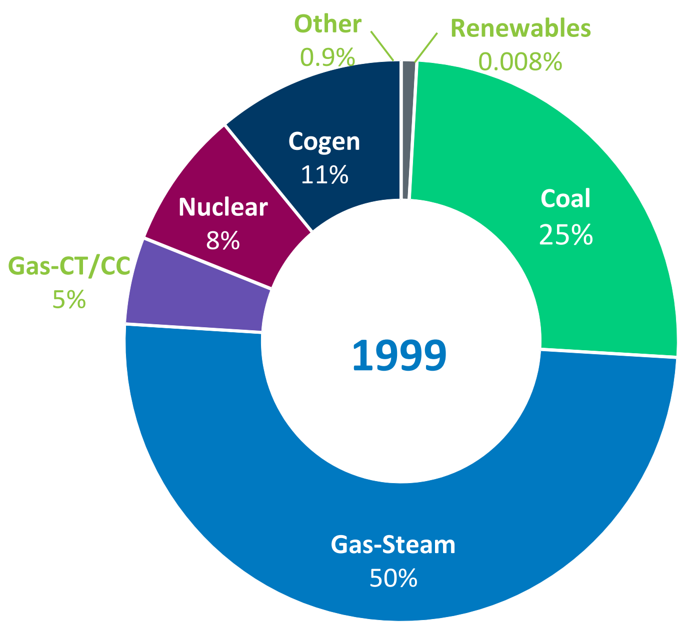


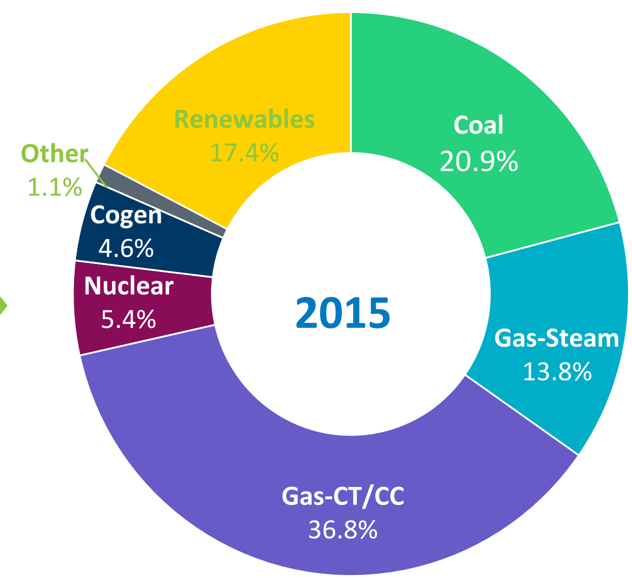
Project Background and Motivation

ERCOT:

- Largest single-state energy market in US
- Recent increase in renewable (wind) and flexible gas capacity
- Rapid increase in solar installations







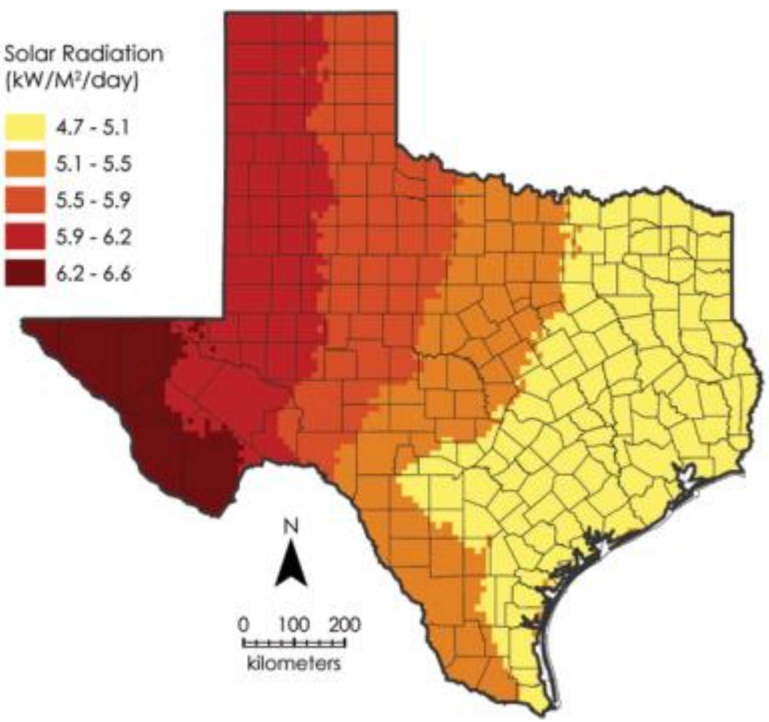
Project Background and Motivation

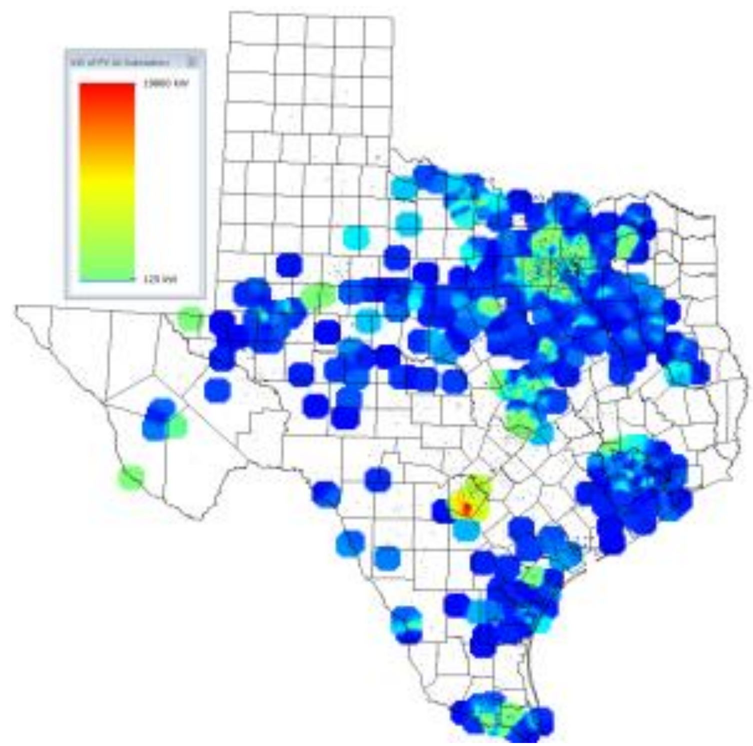
Texas has:

- Largest solar resource in US
- Peak energy needs in summer
- Sustained drought periods
- Land availability
- Transmission availability (CREZ)

Distributed PV in ERCOT (2015)

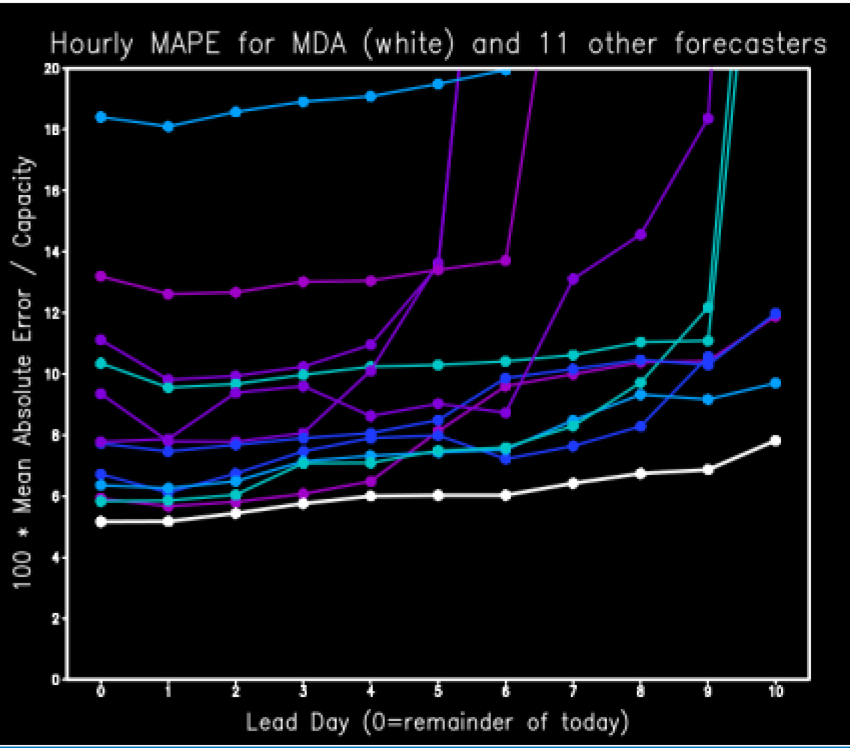
Registered: 57.12 MW
(Incl. registered NOIE : 55.12 MW)
Unregistered: 50.10 MW
Total: 107.22 MW

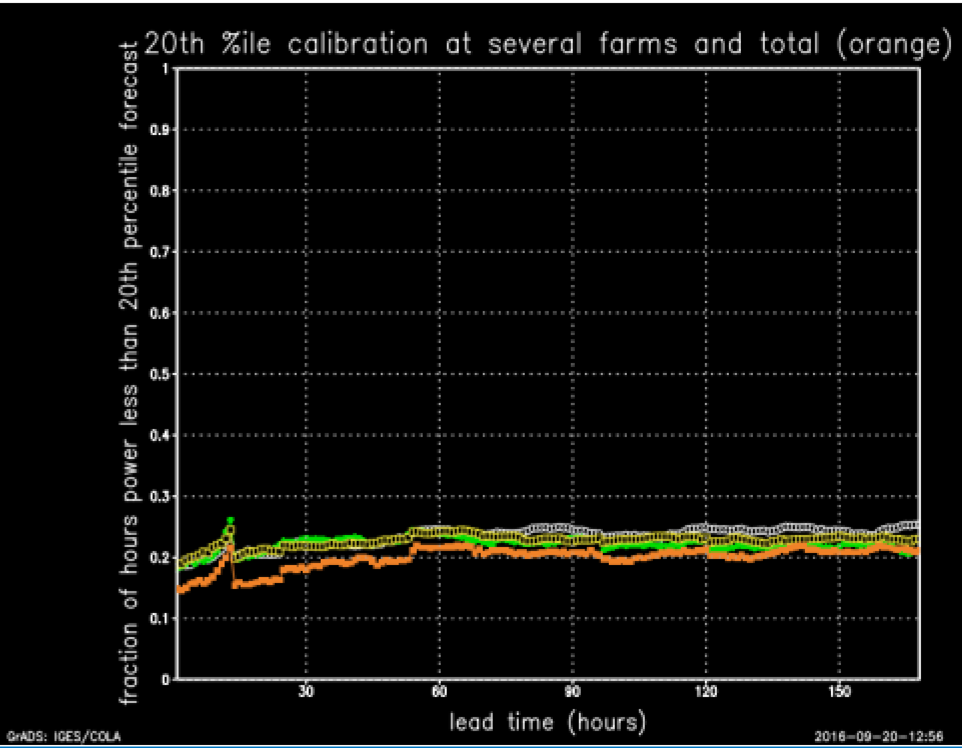




Project Background and Motivation

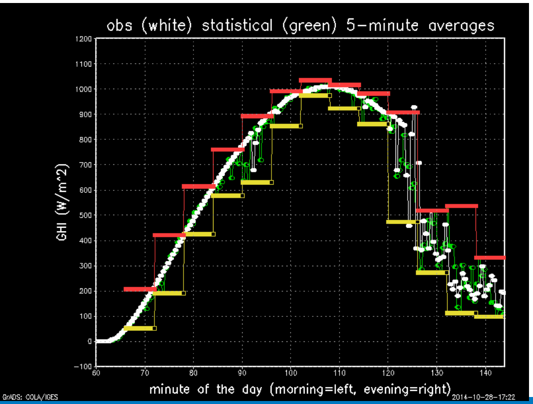
- Radiant Solutions and ERCOT have an existing collaboration, with Radiant Solutions having provided ERCOT's operational solar power forecast for over a year already.
- Radiant Solutions' deterministic forecasting system is top-of-the-industry (see recent trial results for multiple locations in the bottom left figure).
- Already produce well-calibrated probabilistic solar power forecasts (see bottom right), and currently deliver the 80% exceedance value to ERCOT operationally.

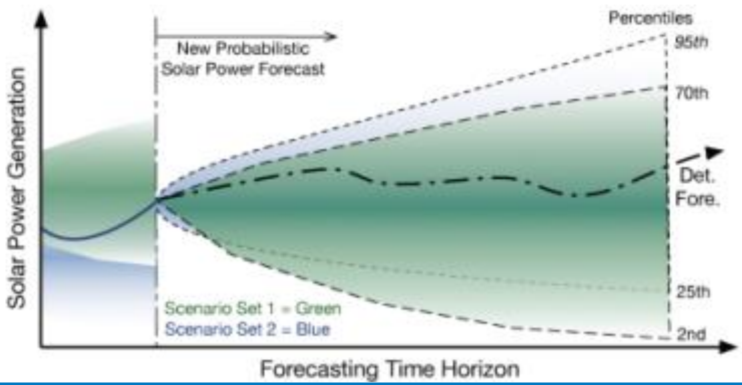


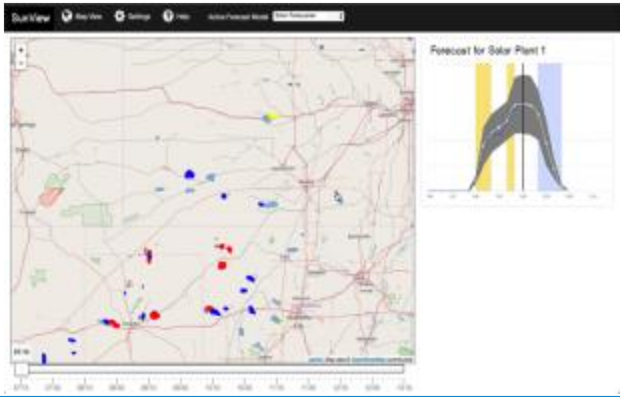


Project Objectives

- Produce and deliver operationally accurate, sharp, and well-calibrated probabilistic solar power forecasts.
- Reduce system operating reserves through dynamically adaptive reserve setting algorithms.
- Reduce system operating costs and increase reliability scores through risk-parity economic dispatch.
- Provide an open-source solar power forecasting visualization tool for industry adoption.



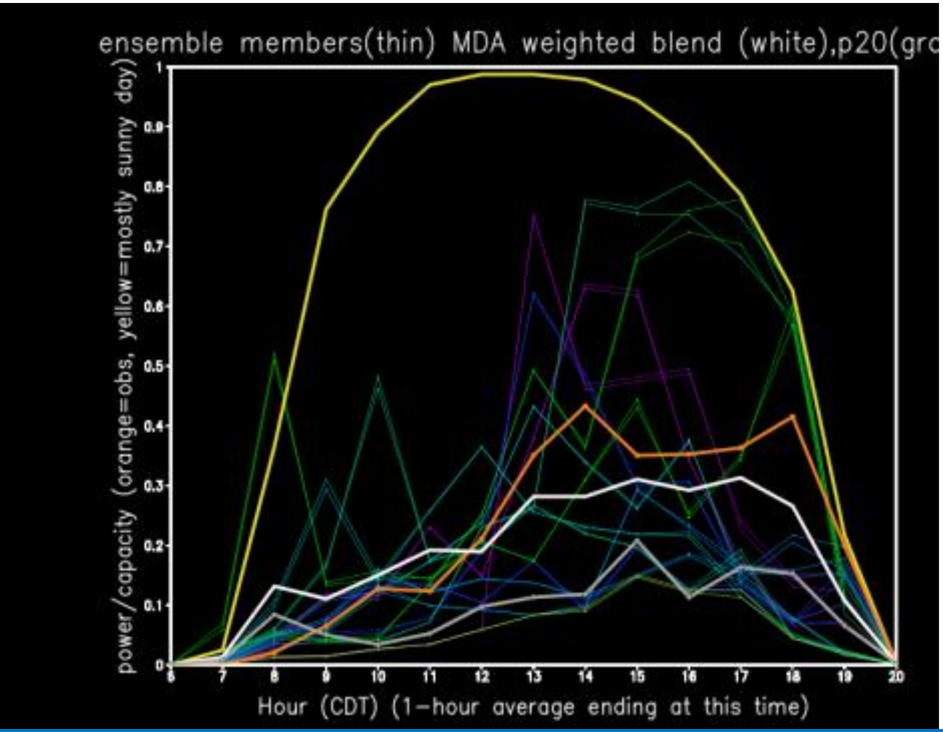


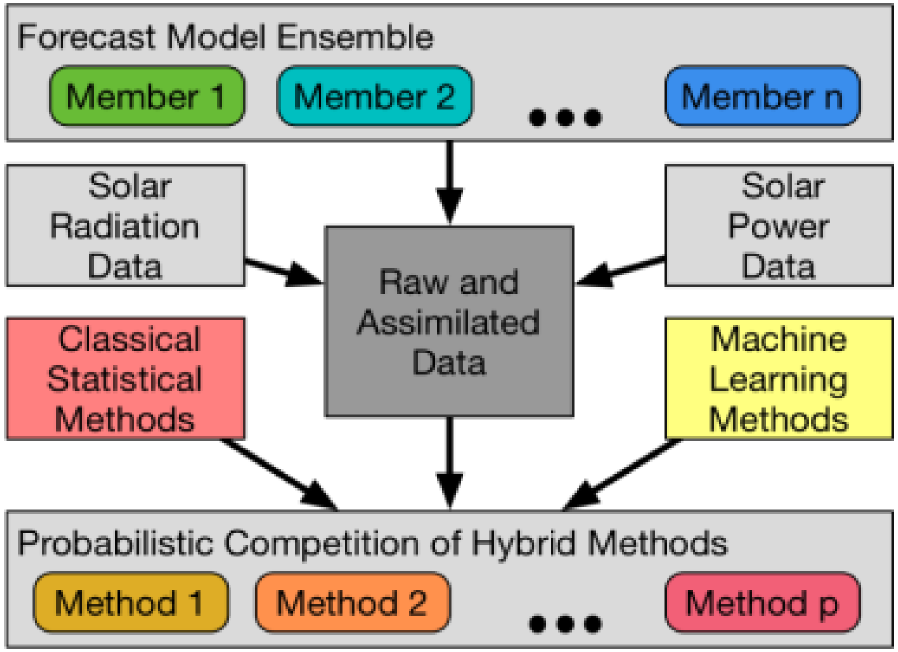


Probabilistic Solar Forecasts

Planned Improvements:

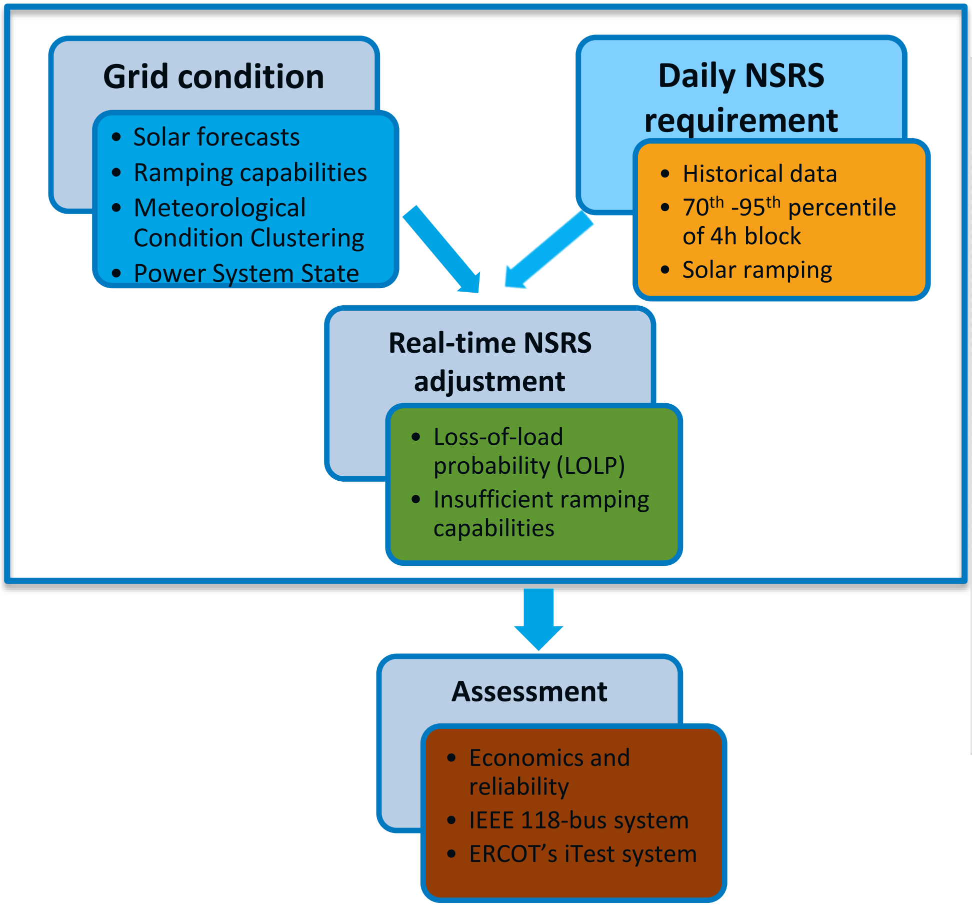
- Increase the Radiant Solutions ensemble to greater than 75 members from 6 distinct NWP systems, from 13 members from 4 distinct NWP systems.
  - Adding in the European Centre for Medium-Range Weather Forecasts (ECMWF) 50 ensemble members and High Resolution Rapid Refresh (HRRR) model.
- Utilize an ensemble of hybrid machine learning-statistical techniques to improve probabilistic forecast accuracy, sharpness, and calibration through situational dependent blending.

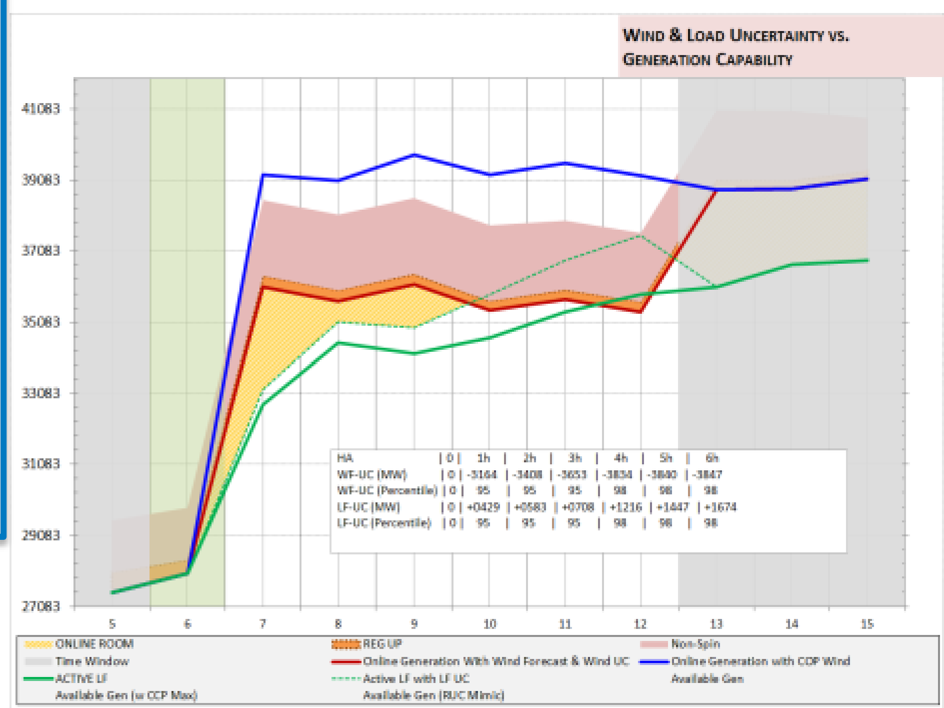




Adaptive Reserves

- Update Non-Spinning Reserve Service (NSRS) on a daily basis based on historical data, solar forecast, and power system state forecast.
- Values assessed using online tool for determining loss-of-load-probability (LOLP) and ramping capabilities.





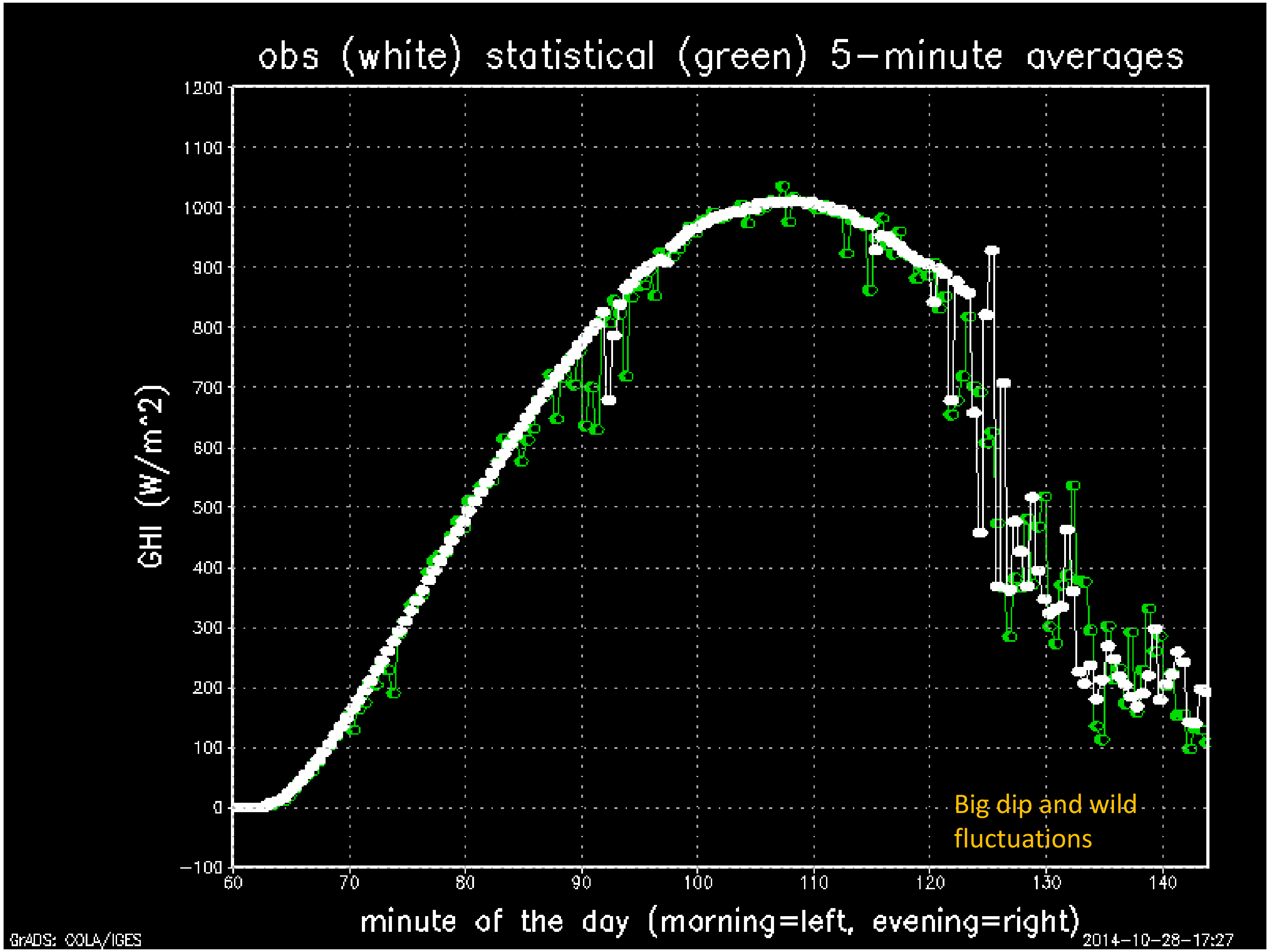
Sub-hourly variability – 5 minute averages

Radiant Solutions predicts sub-hourly variability

White curve=measured

Green curve uses statistics to generate variability knowing only

1-hour average



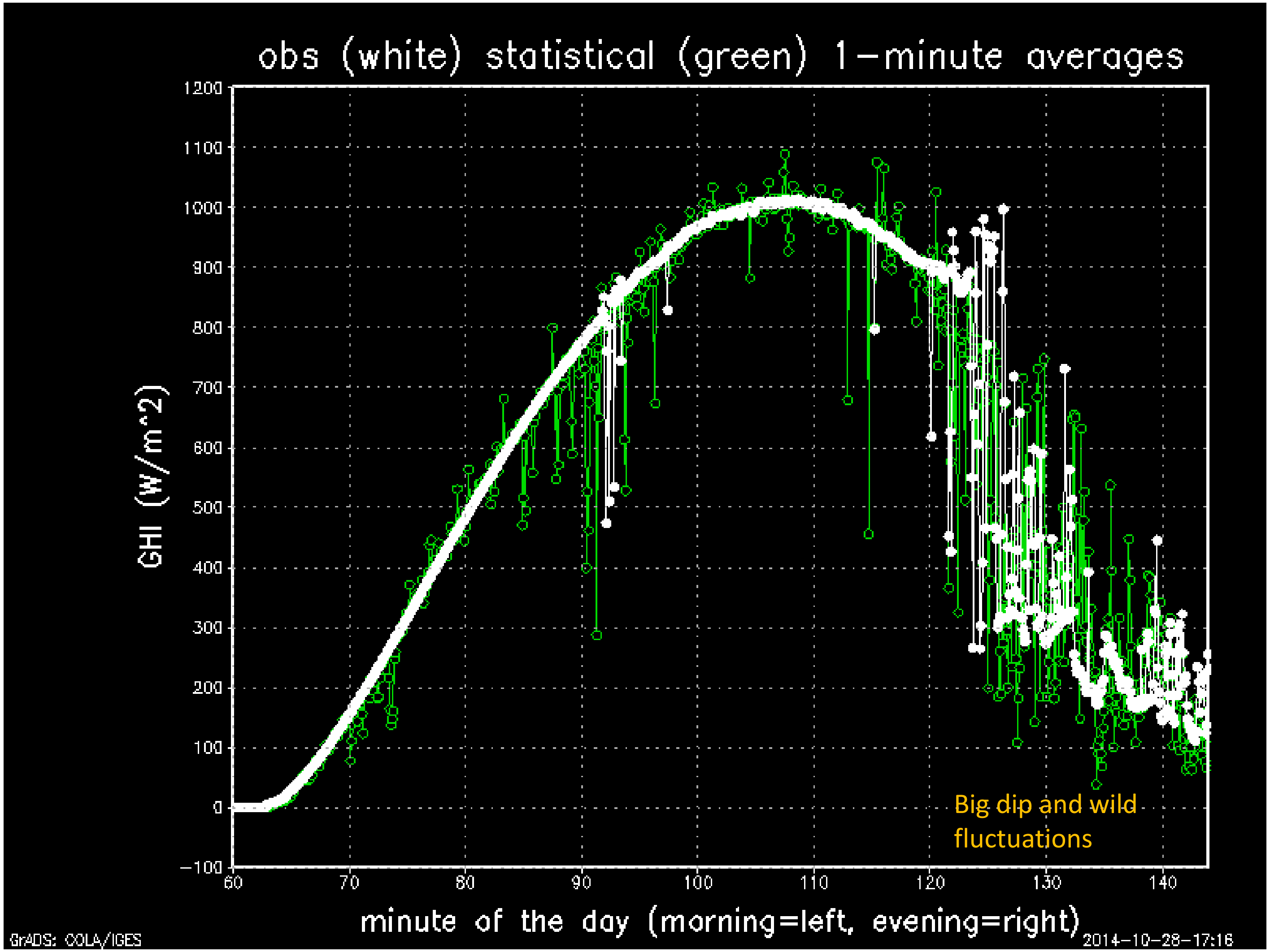
Sub-hourly variability – 1 minute averages

Radiant Solutions predicts sub-hourly variability

White curve=measured

Green curve uses statistics to generate variability knowing only

1-hour average



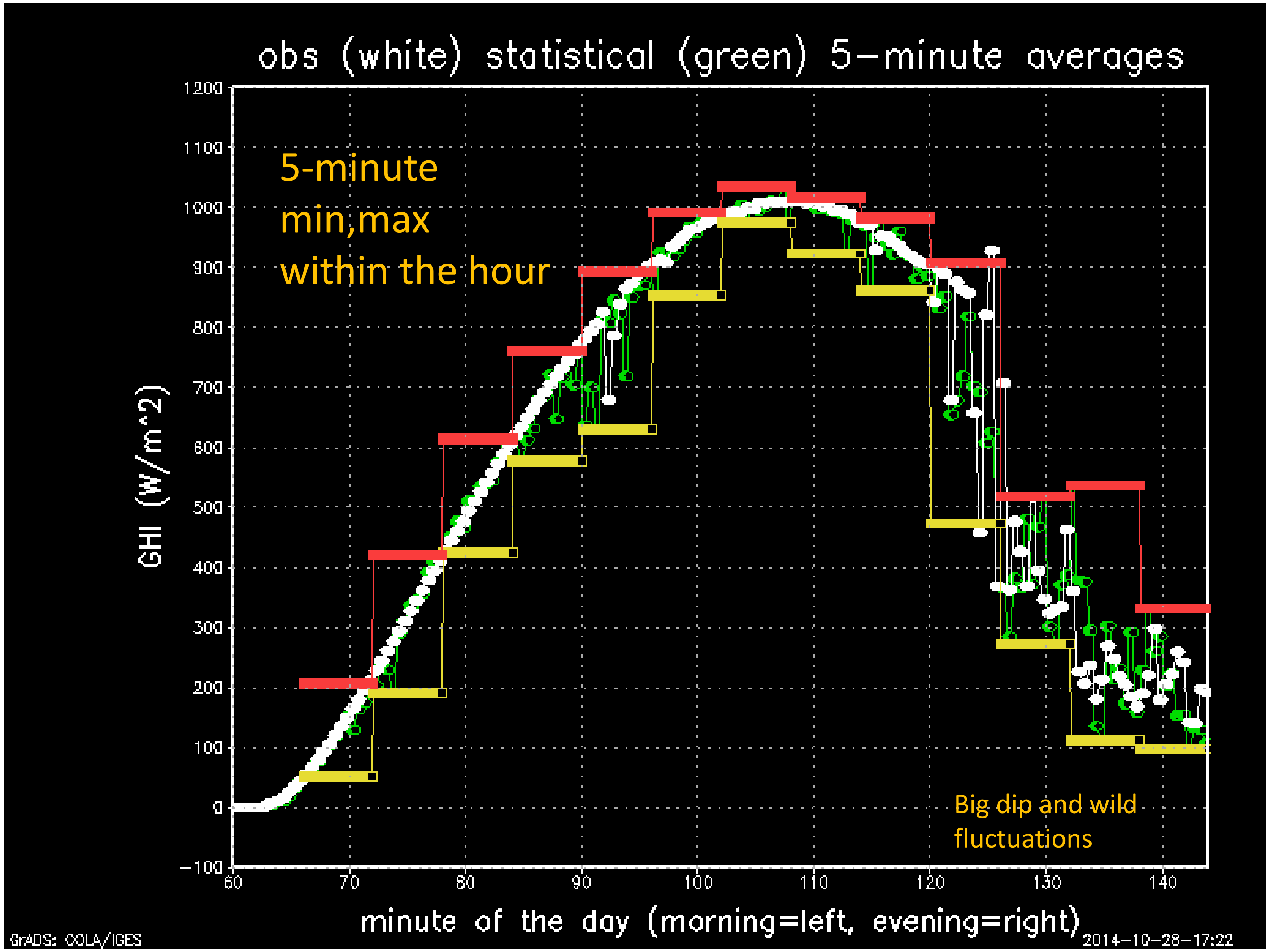
Sub-hourly variability – 5 minute min/max

Radiant Solutions predicts sub-hourly variability

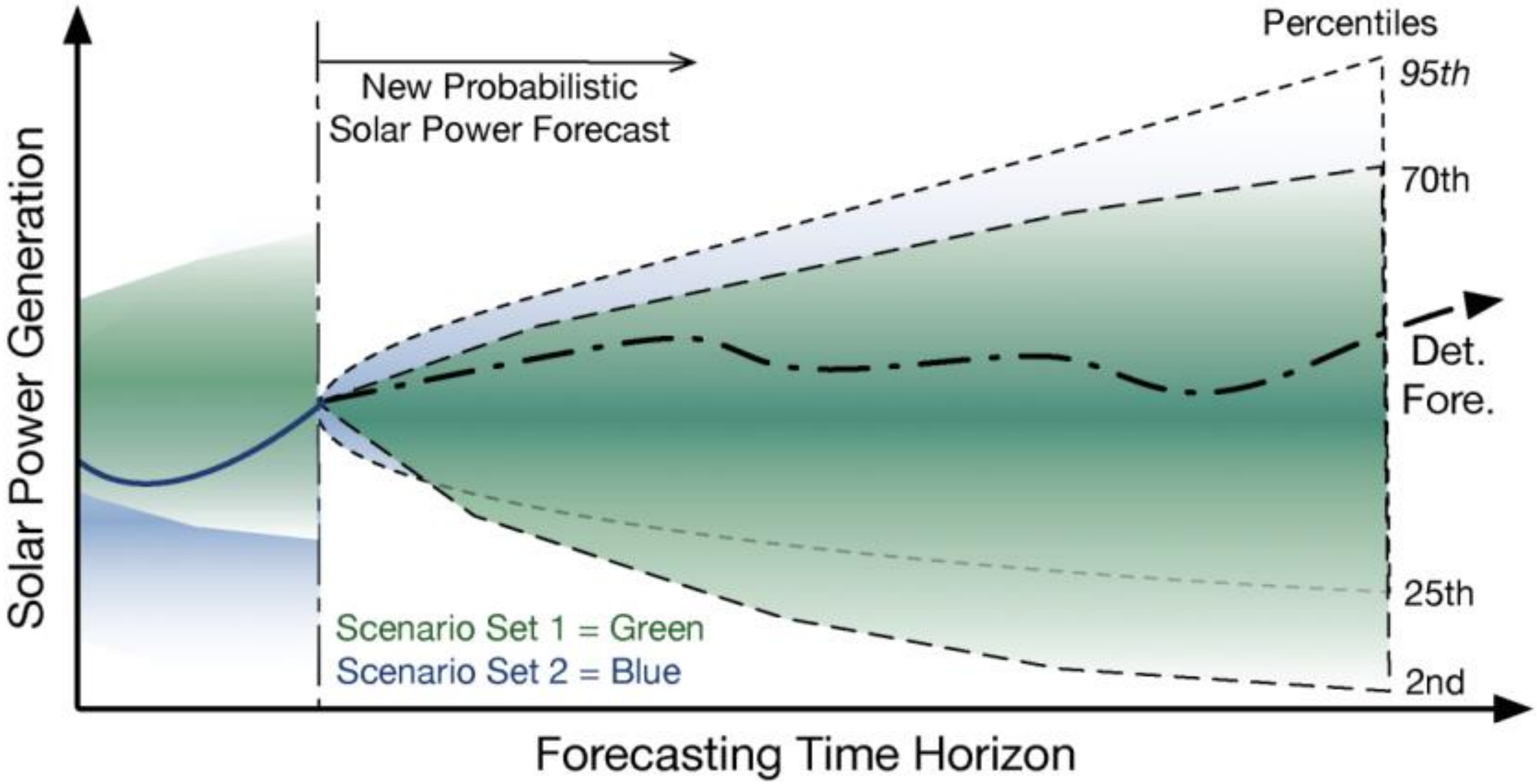
White curve=measured

Green curve uses statistics to generate variability knowing only

1-hour average



Risk-Parity Dispatch



Advantages:

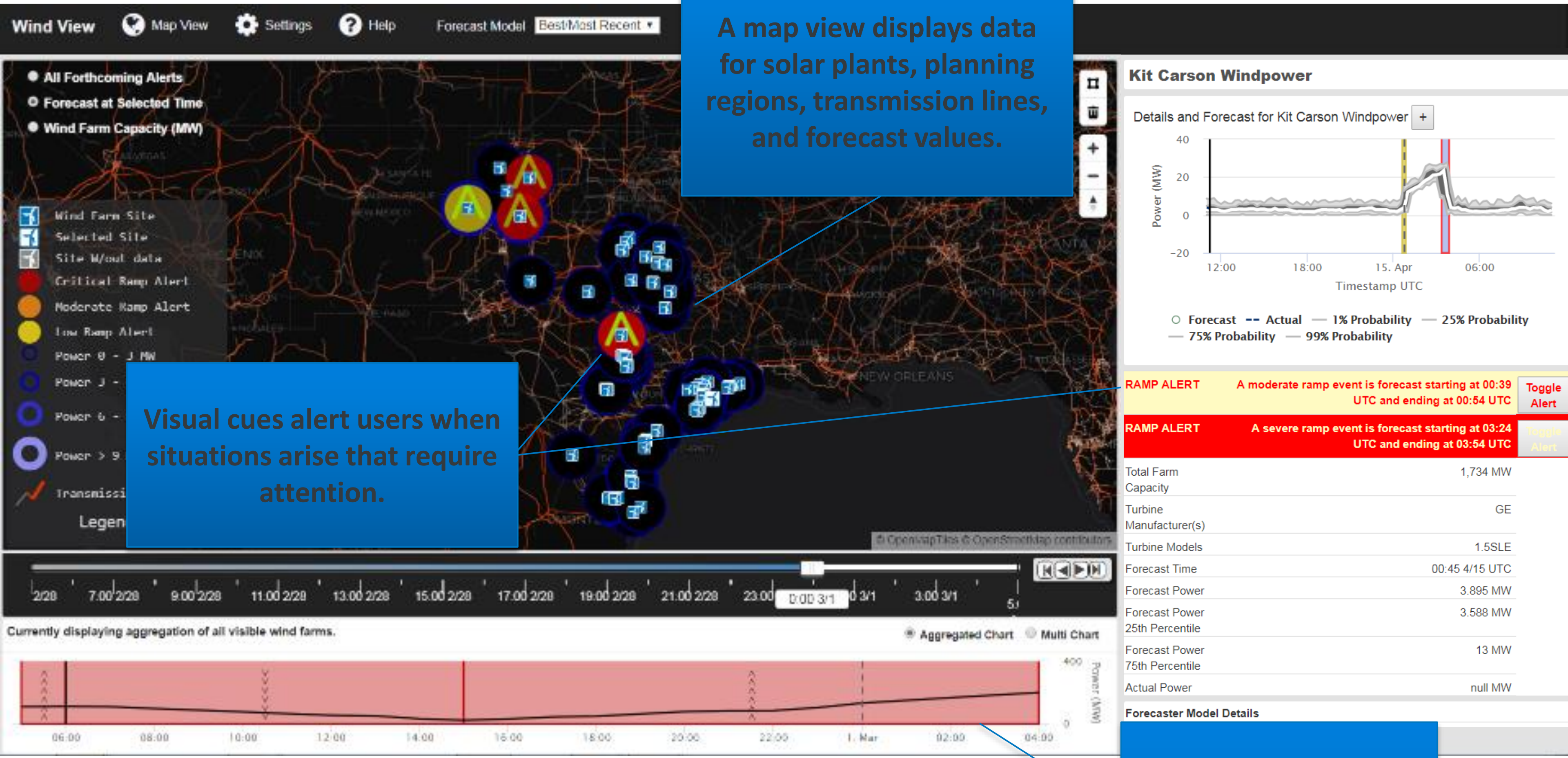
- Explicitly incorporates probabilistic information into dispatch process.
- Reduced solve time compared to full stochastic dispatch.
- Takes into account both the meteorological and power system states.
- Does not produce overly conservative solutions such as robust dispatch.

SolarView

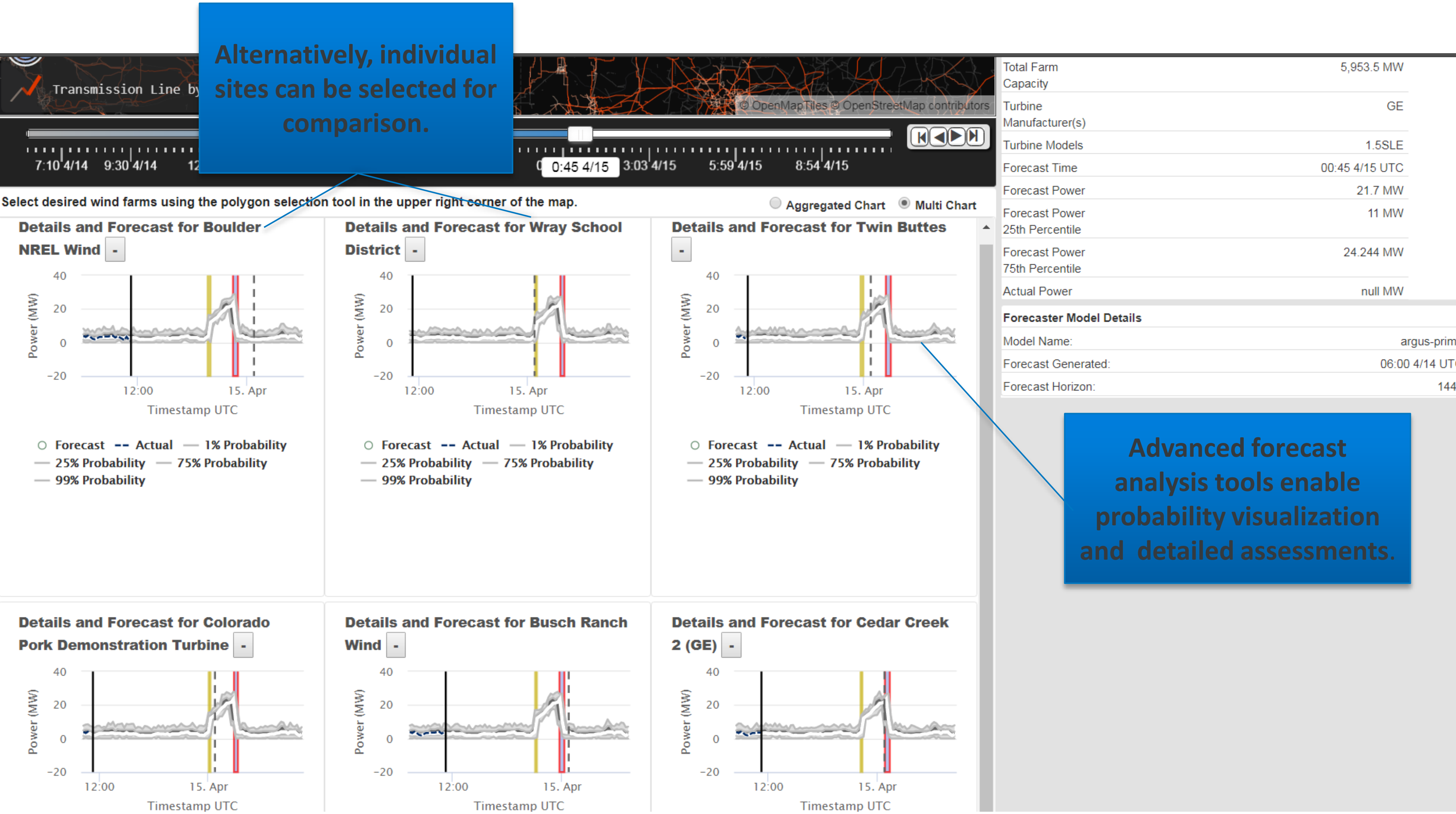
A map view displays data for solar plants, planning regions, transmission lines, and forecast values.

Visual cues alert users when situations arise that require attention.

Aggregated regions can be selected to view details.

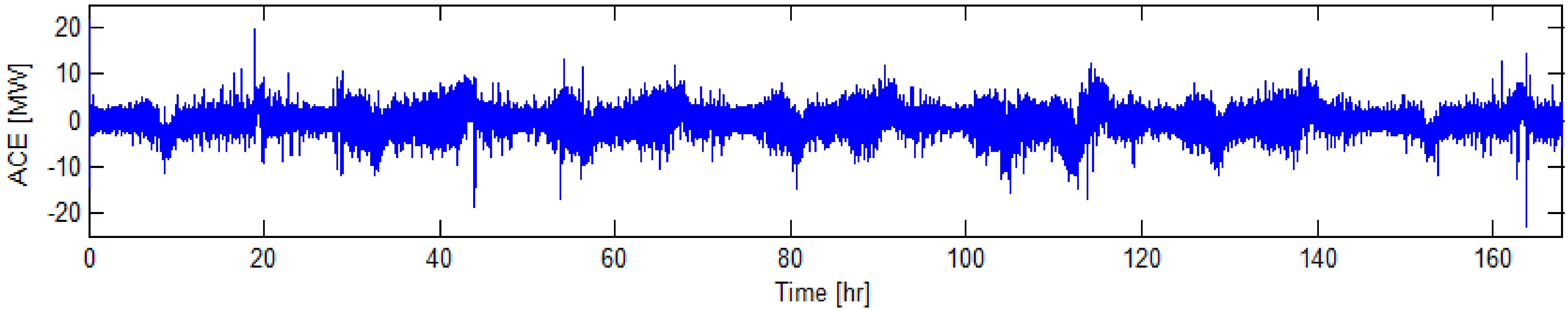


SolarView


Alternatively, individual sites can be selected for comparison.
Transmission Line by
© OpenMapTiles © OpenStreetMap contributors
7:10 4/14
9:30 4/14
0:45 4/15
3:03 4/15
5:59 4/15
8:54 4/15
Select desired wind farms using the polygon selection tool in the upper right corner of the map.
Aggregated Chart
Multi Chart
Details and Forecast for Boulder NREL Wind
Details and Forecast for Wray School District
Details and Forecast for Twin Buttes
Details and Forecast for Colorado Pork Demonstration Turbine
Details and Forecast for Busch Ranch Wind
Details and Forecast for Cedar Creek 2 (GE)
Power (MW)
Timestamp UTC
12:00
15. Apr
Forecast
Actual
1% Probability
25% Probability
75% Probability
99% Probability
Total Farm Capacity 5,953.5 MW
Turbine Manufacturer(s) GE
Turbine Models 1.5SLE
Forecast Time 00:45 4/15 UTC
Forecast Power 21.7 MW
Forecast Power 25th Percentile 11 MW
Forecast Power 75th Percentile 24.244 MW
Actual Power null MW
Forecaster Model Details
Model Name: argus-prima
Forecast Generated: 06:00 4/14 UTC
Forecast Horizon: 1440
Advanced forecast analysis tools enable probability visualization and detailed assessments.

Validation - FESTIV Capabilities

- Steady-State power system operations simulator (i.e. UCED + AGC).
- Simulates all temporal resolutions of the scheduling process:
  - DA, HA, RT, AGC
- All models are interconnected (output of one serves as input to next):
  - Interconnected nature allows FESTIV to capture the real nature of forecasts.
  - Allows for impact of forecast accuracy to be studied.
- Simulates scheduling <u>*AND*</u> deployment of reserves.
- Provides <u>*BOTH*</u> economic metrics (production costs, LMPs, etc.) and reliability metrics (ACE, CPS2, etc.).



Validation and Implementation - ERCOT iTest System

- Probabilistic forecasts will be ingested into the iTest system operationally
- Adaptive reserves and risk parity dispatch will be implemented in the iTest system
- iTest System:
  - Replica of ERCOT's production environment, including hardware, software, and interfaces
  - Last stop for changes to be implemented in operations
  - Utilizes real system data in real-time

Source: GE Grid Solutions

Project Timeline and Interconnections

Algorithm Development
[15 months]

1. Probabilistic Solar Power Forecasts
2. Adaptive Reserves
3. Risk-Parity Dispatch
4. SolarView

University of Arizona

	Metric Definition (From Measurement)	Success Value	Assessment Tool
Milestone 5	Complete successful validation of the probabilistic forecasts according to the standards adopted by the Topic Area 1 awardee.	To be determined by Topic Area 1 team.	Forecasts provided to Topic Area 1 team.

Johns Hopkins

?

EPRI

Validation and Verification
[12 months]

Implementation and Demonstration
[9 months]

Thank you!
Questions?

www.nrel.gov

Consideration of Key FOA Topics

Important Topic	**Proposed Solution**
Partnership with at least one balancing authority	ERCOT is a committed project partner receiving more than 20% of project funding, and they will be heavily involved in all phases of the project.
Probabilistic format of numerical and visualized output	MDA is committed to providing probabilistic solar power forecasts, and the SolarView platform will be developed for visualization and situational awareness.
Development of decision-making process for unit commitment and economic dispatch using probabilistic forecast as input	The adaptive reserves will be utilized at multiple timescales, including unit commitment and economic dispatch, and the risk-parity dispatch will be used in the dispatch time frame.
Demonstration of solar power forecasts integrated in development environment	The project team will utilize two development environments to demonstrate the value and robustness of the forecasts and tools developed: NREL's FESTIV model and ERCOT's iTest environment.
Compliance with validation guidelines of test framework	The project team will work closely with the awardee in Topic Area 1 to meet the validation guidelines.

Going above and beyond the FOA topics:

- This project spans the full range of technology readiness levels and upon completion will be able to see the solutions put into practice with the flip of a switch.
- Open source nature of the tools will create benefits beyond the ERCOT area.

Work Breakdown Structure and Task Description

Budget Period 1. Algorithm Development —15 months

- **Task 1.1:** Develop Probabilistic Solar Power Forecasts (M1–M15)
  - **Subtask 1.1.1:** Create Probabilistic Solar Power Forecasting Algorithms for Utility-Scale PV Plants and Balancing Area-Level Solar Generation (M1–M12)
  - **Subtask 1.1.2:** Create Probabilistic Behind-the-Meter Solar Power Forecasts (M3–M15)
- **Task 1.2:** Develop Adaptive Reserve Algorithms (M1–M15)
  - **Subtask 1.2.1**: Grid Condition Clustering (M1–M6)
  - **Subtask 1.2.2**: Grid Condition Forecasting (M5–M12)
  - **Subtask 1.2.3**: Develop Adaptive Reserve Algorithm (M3–M15)
- **Task 1.3:** Develop Risk-Parity Dispatch Algorithm (M1–M15)
  - **Subtask 1.3.1**: Determine Dynamic Costs (M1–M9)
  - **Subtask 1.3.2**: Develop Risk-Parity Algorithm (M1–M15)
- **Task 1.4:** Develop Situational Awareness Tool, SolarView (M9–M15)

Budget Period 1 Milestones

- **Milestone 1.1:** Demonstrate ability to produce the full spectrum of forecast probabilities at multiple timescales, including day-ahead and sub-hourly.
- **Milestone 1.2:** Demonstrate that the adaptive reserve algorithms can reduce total reserves by more than 25%.
- **Milestone 1.3:** Demonstrate that the risk-parity algorithm consistently converges to the optimal solution in less than 4 minutes for a small utility system.
- **Milestone 1.4:** Complete solar-specific features in the software, and successfully demonstrate the SolarView capabilities to the solar program manager.
- **Budget Period 1 Go/No-Go Decision Point: A**ll Year 1 milestones completed. (15 months)

Work Breakdown Structure and Task Description (2)

Budget Period 2. Verification and Validation — 12 Months

- **Task 2.1:** Validate Probabilistic Solar Power Forecasts (M16–M27)
  - **Subtask 2.1.1:** Ground Truth Collection & Produce Operational Utility-Scale Probabilistic Forecasts (M16–M27)
  - **Subtask 2.1.2:** Provide Probabilistic Behind-the-Meter Solar Power Forecasts Operationally (M16 – M27)
  - **Subtask 2.1.3:** Coordinate with Validation Team (M16–M27)
- **Task 2.2:** Ingest Probabilistic Forecasts into ISO Energy Management System (M16–M27)
- **Task 2.3:** Estimate Adaptive Reserve Economic and Reliability Impacts (M16–M27)
  - **Subtask 2.3.1**: Create Adaptive Reserve Time-Series Data (M16–M19)
  - **Subtask 2.3.2**: FESTIV 118-Bus Simulations of Adaptive Reserve Impacts (M18–M23)
  - **Subtask 2.3.3**: FESTIV ISO Simulations of Adaptive Reserve Impacts (M20–M27)
- **Task 2.4:** Estimate Risk-Parity Dispatch Economic and Reliability Impacts (M16–M27)
  - **Subtask 2.4.1**: Incorporate Risk-Parity Algorithm into FESTIV (M16–M21)
  - **Subtask 2.4.2**: FESTIV Simulations of Risk-Parity Dispatch Impacts (M20–M27)

Budget Period 2 Milestones

- **Milestone 2.1:** Complete successful validation of the probabilistic forecasts according to the standards adopted by the Topic Area 1 awardee.
- **Milestone 2.2:** Successfully ingest probabilistic solar power forecasts into the ISO's system with more than 95% reliability during a 1-month period.
- **Milestone 2.3:** Reduce total production costs when compared to the case without adaptive reserves. This will be assessed using case study simulations of the IEEE 118-bus and the ISO's realistic test system with FESTIV.
- **Milestone 2.4:** Increase reliability scores when compared to the case with standard economic dispatch and deterministic forecast. This will be assessed using case study simulations of the IEEE 118-bus test system and the ISO's realistic test system with FESTIV.

- **Budget Period 2 Go/No-Go Decision Point:** All Year 2 milestones completed. (27 months)

Work Breakdown Structure and Task Description (3)

Budget Period 3. Implementation and Demonstration—9 Months

- **Task 3.1:** Provide Operational Probabilistic Forecasts (M28–M36)
  - **Subtask 3.1.1:** Provide and Ingest Operational Forecasts (M28–M36)
- **Task 3.2:** Incorporate Adaptive Reserves into ISO Test Environment (M28–M36)
  - **Subtask 3.2.1**: Implement Adaptive Reserves (M28–M36)
- **Task 3.3:** Incorporate Risk-Parity Dispatch into ISO Test Environment (M28–M36)
  - **Subtask 3.3.1**: Analyze Historical Data to Determine Risk Parameters (M28–M33)
  - **Subtask 3.3.2**: Demonstrate Risk-Parity Implementation (M32–M36)
- **Task 3.4:** Provide the ISO Operator Training on Situational Awareness Tool (M33–M36)
  - **Subtask 3.4.1**: Develop SolarView Training (M28–M30)
  - **Subtask 3.4.2**: Deliver SolarView Training (M30–M33)

Project Management Plan

- The PI has extensive experience with similarly sized projects with external collaborators
- Extensive ongoing joint work between team members
- Dedicated project manager and NREL's project milestone tracking system

NREL

PI: Bri-Mathias Hodge (Manager, PSDS)

PM: Tessa Greco (Project Manager) 5%

TECHNICAL SUPPORT

National Renewable Energy Lab (NREL)

Probabilistic Solar Power Forecasting
Bri-Mathias Hodge 10%
Anthony Florita 5%

Dynamic Reserves
Bri-Mathias Hodge 10%
Qin Wang 15%

Risk-Parity Dispatch
Qin Wang 35%
Bri-Mathias Hodge 10%
Anthony Florita 5%

Situational Awareness Tool
Jonathan Duckworth 10%
Bri-Mathias Hodge 2%

University of Texas at Dallas (UTD)

Dynamic Reserves/ Risk-Parity Dispatch
Jie Zhang 5%
Graduate Student TBD 85%

ISOs

Electric Reliability Council of Texas (ERCOT)

Dynamic Reserves/ Risk-Parity Dispatch
Pengwei Du 15%
Nitika Mago 10%
Sandip Sharma 5%
Nick Steffan 15%

INDUSTRY PARTNERS

MDA Systems, Inc. (MDA)

Probabilistic Solar Power Forecasting
Stephen Jascourt 20%
Chris Cassidy 12%

- Bi-weekly team meetings to gauge progress and coordinate joint tasks
- Deep dive meetings held as necessary on particular technical topics
- Asynchronous collaboration tools, i.e. GitHub and Slack, for coordination
- Biannual in-person team meetings

Project Team, Experience, and Qualifications

Key Participant	Organization	Background and Expertise
Bri-Mathias Hodge, Ph.D., PI	NREL	• Manager of the Power System Design and Studies group. • Expertise in the area of grid planning and operations with high levels of renewable energy, particularly the impact of renewable energy (RE) forecasting on power system planning and operations. • Published more than 100 peer-reviewed papers on RE integration. • Served as PI on projects totaling $11.5M+ in the last five years. • Work package leader for Advanced Usage of Probabilistic Forecasts in the IEA Task 36 on Forecasting for Wind Energy.
Sandip Sharma, Co-PI	ERCOT	• Manager of the Operations Planning group. • Focus on RE integration, frequency response, and ancillary services. • Member of the NERC Resources subcommittee and previously of the NERC Frequency Response Standard drafting team.
Stephen Jascourt, Ph.D., Co-PI	MDA	• Senior scientist who created the MDA solar forecasting system based on first principles, including a large volume of research-quality observations worldwide. • Works on product development and improvement projects bridging between scientific research and operational applications. • Worked for the University Corporation for Atmospheric Research's COMET Program, and trained weather forecasters on complex calculations behind numerical weather prediction models.
Jie Zhang, Ph.D., Co-PI	University of Texas at Dallas (UTD)	• Assistant professor with expertise in the forecasting of wind power, solar power, and load; grid integration of renewable energy; and the modeling, design, and optimization of complex energy systems. • PI or co-PI on several wind, solar, and electricity projects funded by the DOE Grid Modernization Initiative and SunShot Initiative. • Published 80+ peer-reviewed journal and conference publications.

Budget

Performer	Federal vs. Cost Share	Budget Period 1 (8/1/2017-10/31/2018)	Budget Period 2 (11/1/2018-10/31/2019)	Budget Period 3 (11/1/2019-7/31/2020)	TOTALS
NREL	Federal	$525,063	$296,828	$178,181	$1,000,072
	Cost Share	$0	$0	$0	$0
ERCOT	Federal	$118,200	$150,575	$117,075	$385,850
	Cost Share	$50,000	$30,000	$20,000	$100,000
MDA Information Systems	Federal	$164,522	$124,485	$56,724	$345,731
	Cost Share	$0	$120,000	$90,000	$210,000
University of Texas at Dallas	Federal	$46,510	$47,403	$46,088	$140,001
	Cost Share	$7,310	$7,310	$7,310	$21,930
PROJECT TOTALS	Federal	$854,295	$619,291	$398,068	$1,871,654
	Cost Share	$57,310	$157,310	$117,310	$331,930
	Total Costs (Federal + Cost Share)	$911,605	$776,601	$515,378	$2,203,584
	Cost Share	**6.29%**	**20.26%**	**22.76%**	**15.06%**

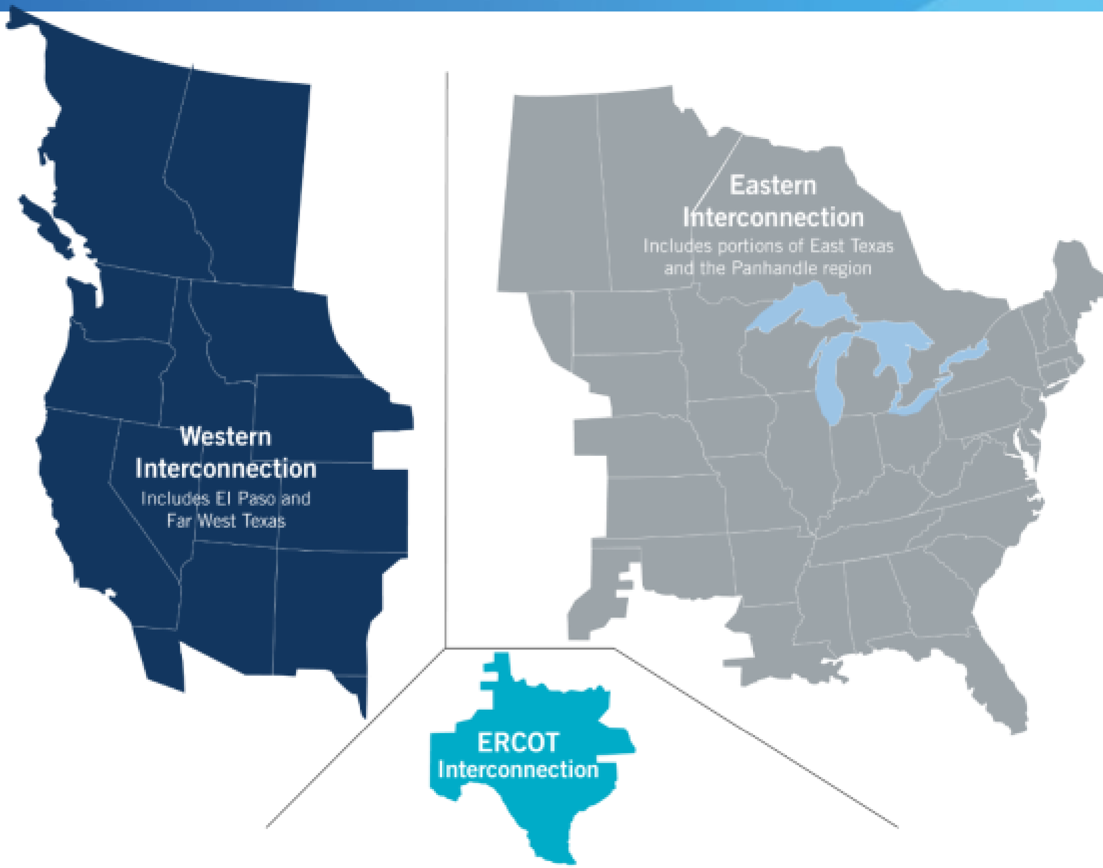
Budget Period 3 Milestones

- **Milestone 3.1:** Successfully deliver probabilistic solar power forecasts to the ISO's system with more than 98% reliability during the demonstration period.
- **Milestone 3.2:** Demonstrate robust utilization of the adaptive reserve algorithms in the iTest system for a continuous period of 1 month.
- **Milestone 3.3:** Demonstrate robust utilization of the risk-parity dispatch in the iTest system for a continuous period of 1 month.
- **Milestone 3.4:** Conduct a minimum of two training sessions for the ISO's operators.

What is ERCOT?

The Texas Legislature restructured the Texas electric market in 1999 and assigned ERCOT four primary responsibilities:

- **System Reliability**
- **Competitive Wholesale Market**
- **Open Access to Transmission**
- **Competitive Retail Market**



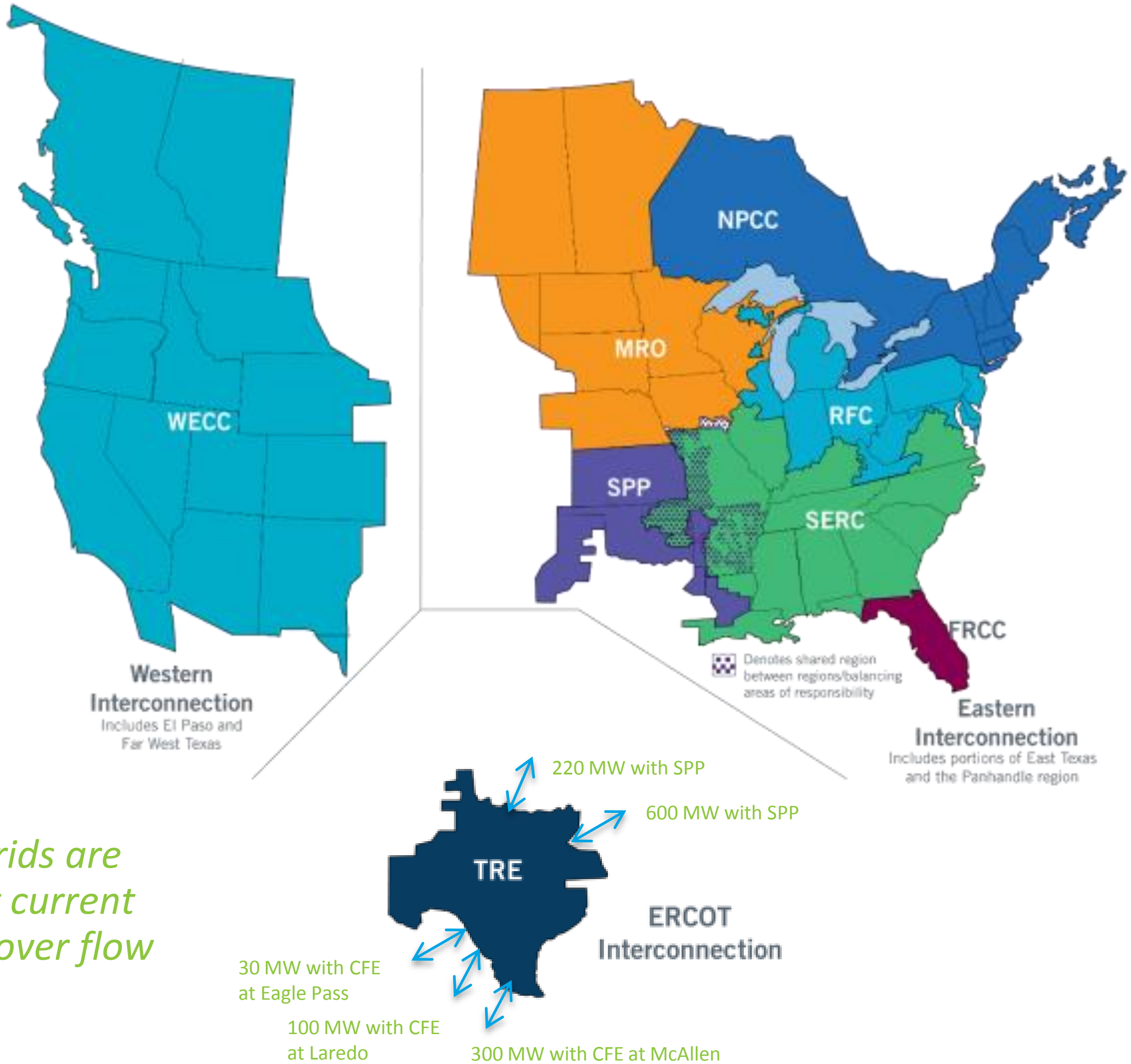
ERCOT is a nonprofit organization and regulated by the Public Utility Commission of Texas, with oversight by the Texas Legislature.

ERCOT is not a market participant and does not own generation or transmission/distribution wires.

The ERCOT Region

The interconnected electrical system serving most of Texas, with limited external connections

- 90% of Texas electric load; 75% of Texas land
- 71,110 MW peak, August 11, 2016
- More than 46,500 miles of transmission lines
- 570+ generation units



ERCOT connections to other grids are limited to ~1250 MW of direct current (DC) ties, which allow control over flow of electricity

ERCOT Current Records

Peak Demand Record: 71,110 megawatts (MW)

- Aug. 11, 2016, 4-5 p.m.

Weekend Record: 66,921 MW

- Sunday, Aug. 7, 2016, 5-6 p.m.

Winter Peak Record: 59,650 MW

- Jan. 6, 2017, 6-7 p.m.

Wind Generation Records (instantaneous)

- Output: 16,141 MW
  - March 31, 2017, 8:56 p.m.
- Penetration (load served): 50%
  - March 23, 2017, 3:50 a.m.
  - Total Load = 28,780 MW

Recent Monthly Peak Demand Records

2017

- January: 59,650 MW (Jan. 6, 6-7 p.m.)

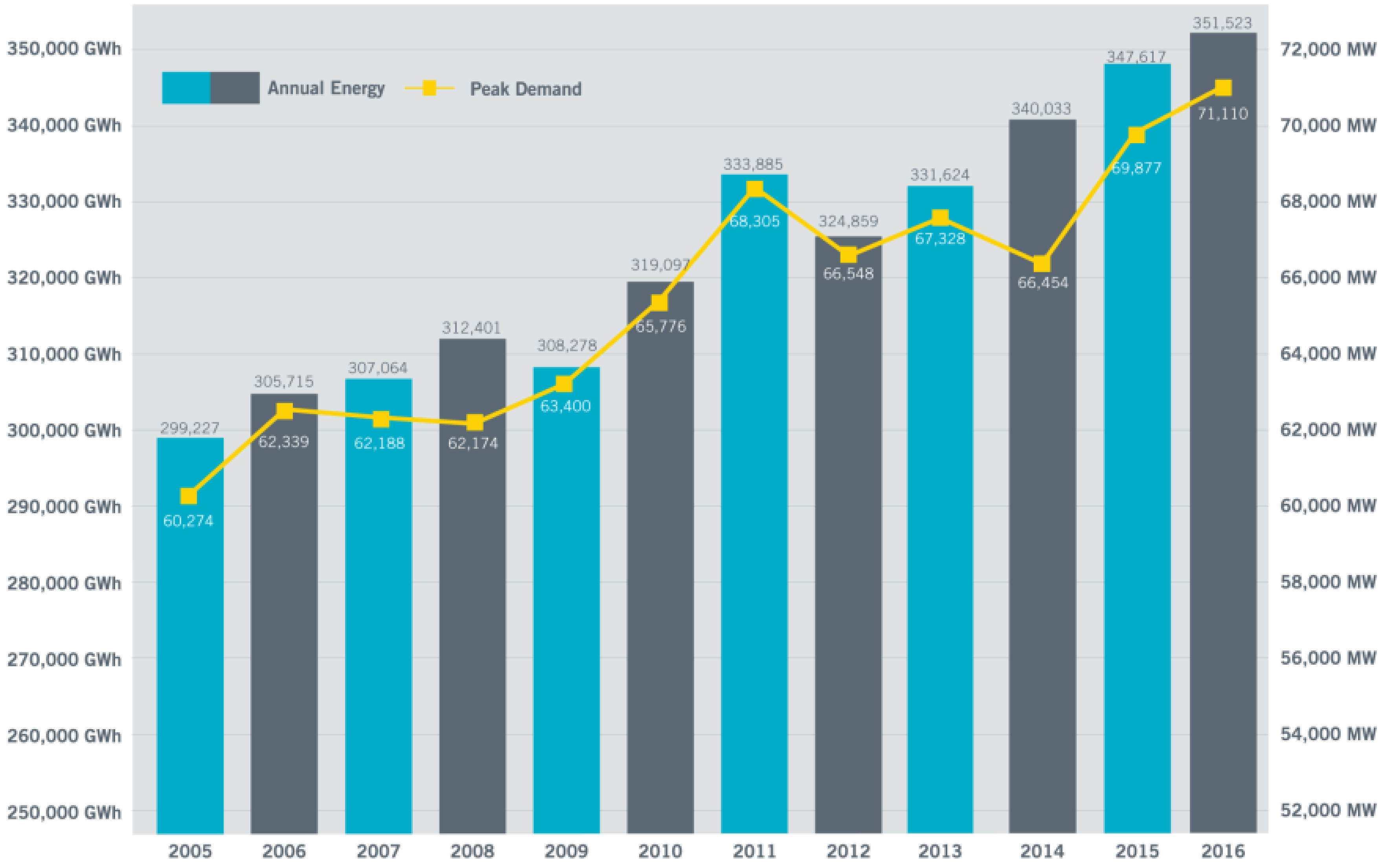
2016

- August: 71,110 MW
  (All-time record)
- September: 66,949 MW (Sept. 19, 4-5 p.m.)
- October: 59,864 MW (Oct. 5, 4-5 p.m.)
- December: 57,932 MW (Dec. 19, 7-8 a.m.)

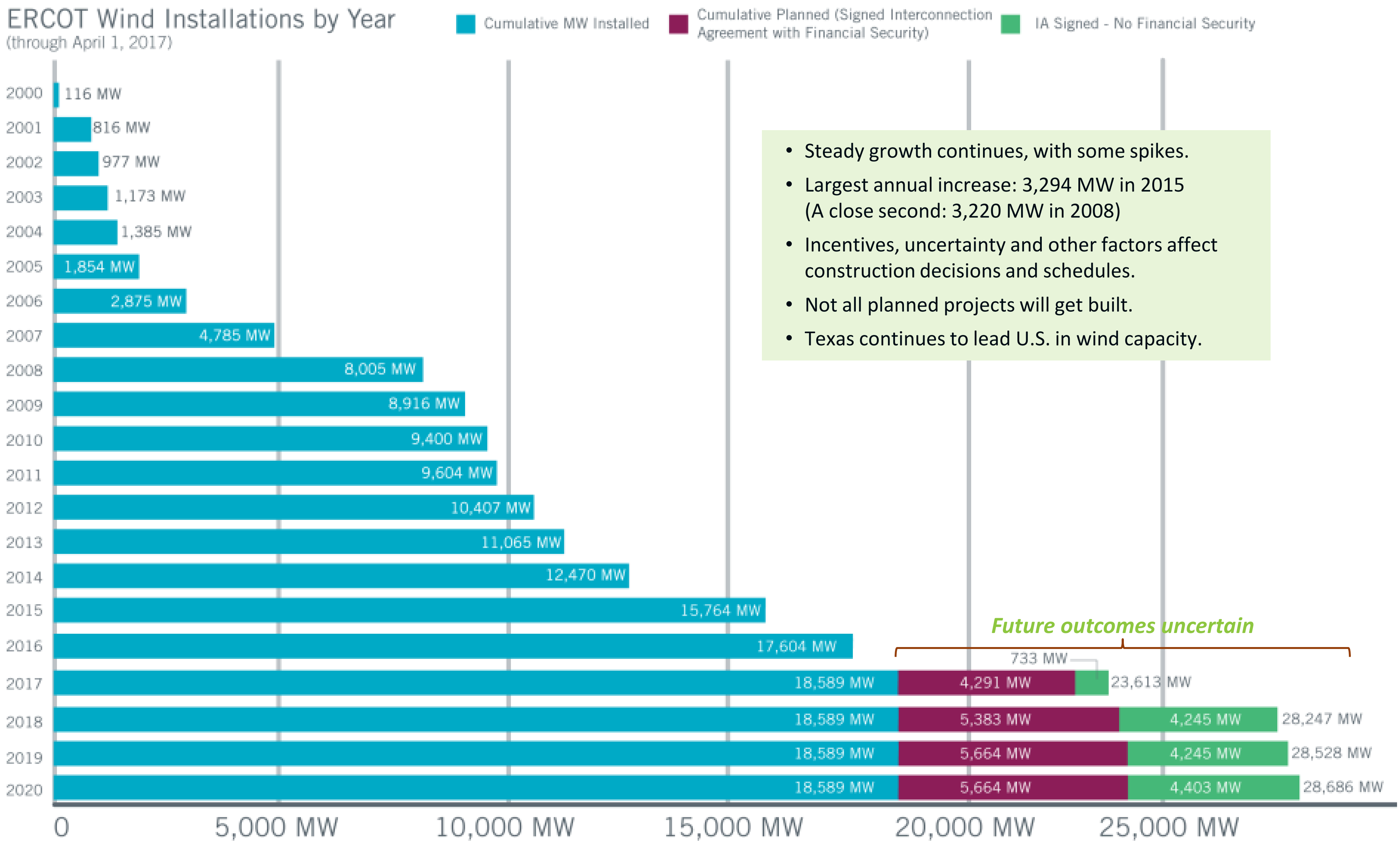
2015

- July: 67,650 MW (July 30, 4-5 p.m.)

ERCOT Annual Energy and Peak Demand (2005-2016)

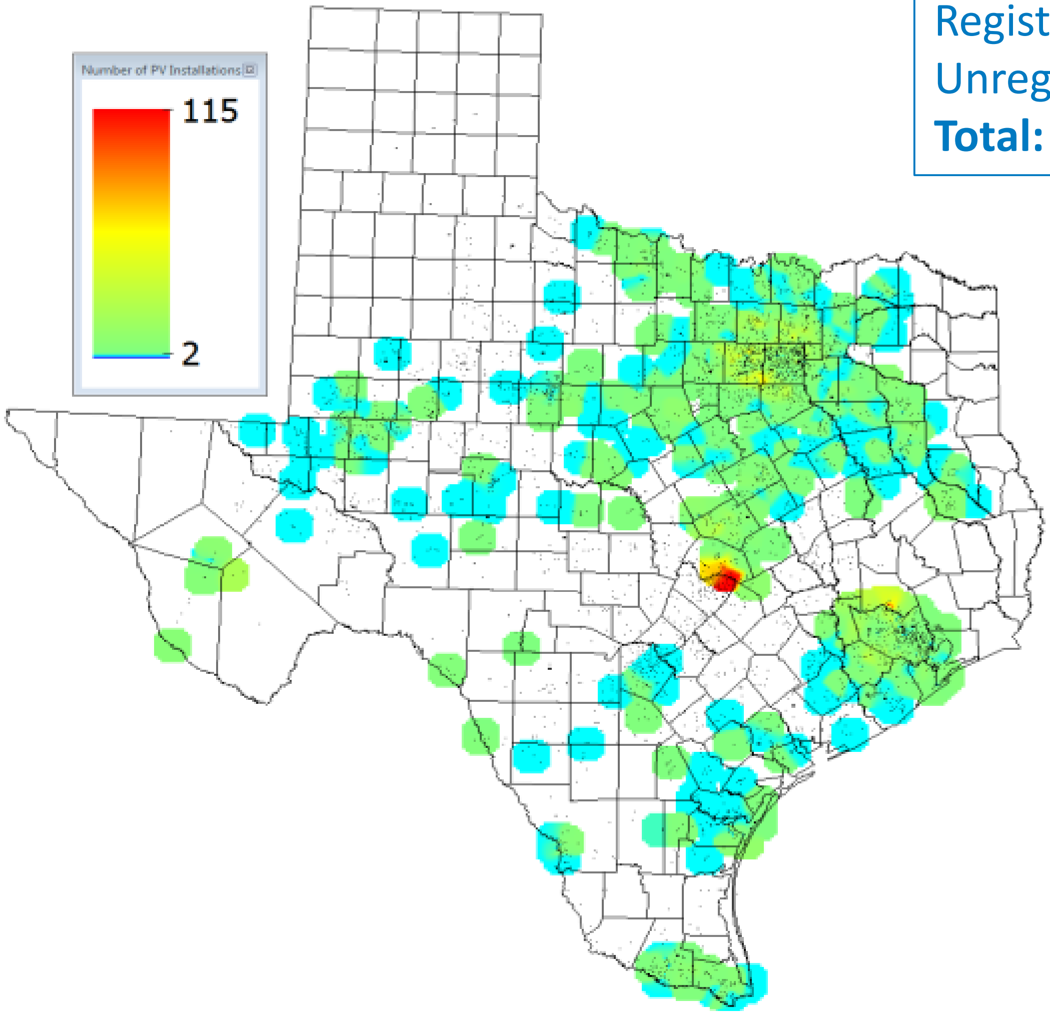


ERCOT Wind Generation Capacity – March 2017



- Steady growth continues, with some spikes.
- Largest annual increase: 3,294 MW in 2015
  (A close second: 3,220 MW in 2008)
- Incentives, uncertainty and other factors affect construction decisions and schedules.
- Not all planned projects will get built.
- Texas continues to lead U.S. in wind capacity.

Registered and Unregistered Distributed PV: Number of Installations (6702 total)



Registered: 9
Unregistered: 6693
Total: 6,702

Source: DREAM TF Dec 14, 2015

ERCOT Solar Forecasting

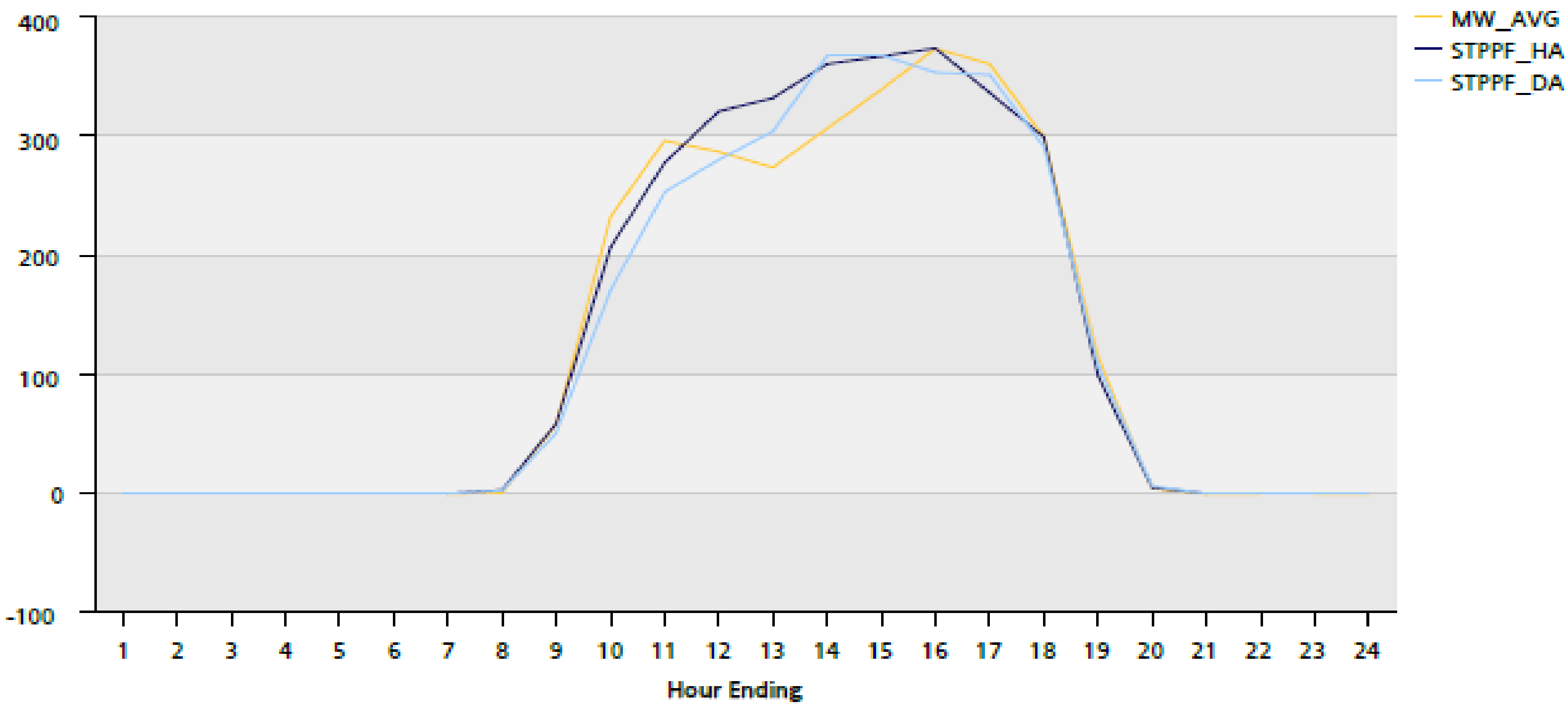
Daily Solar Report for: October 4, 2016

Hour Ahead MAPE: 4.21% Day Ahead MAPE: 4.62%

Hours counted:13

(Only hours above 1 MW are counted) Current Installed Capacity: 484MW*

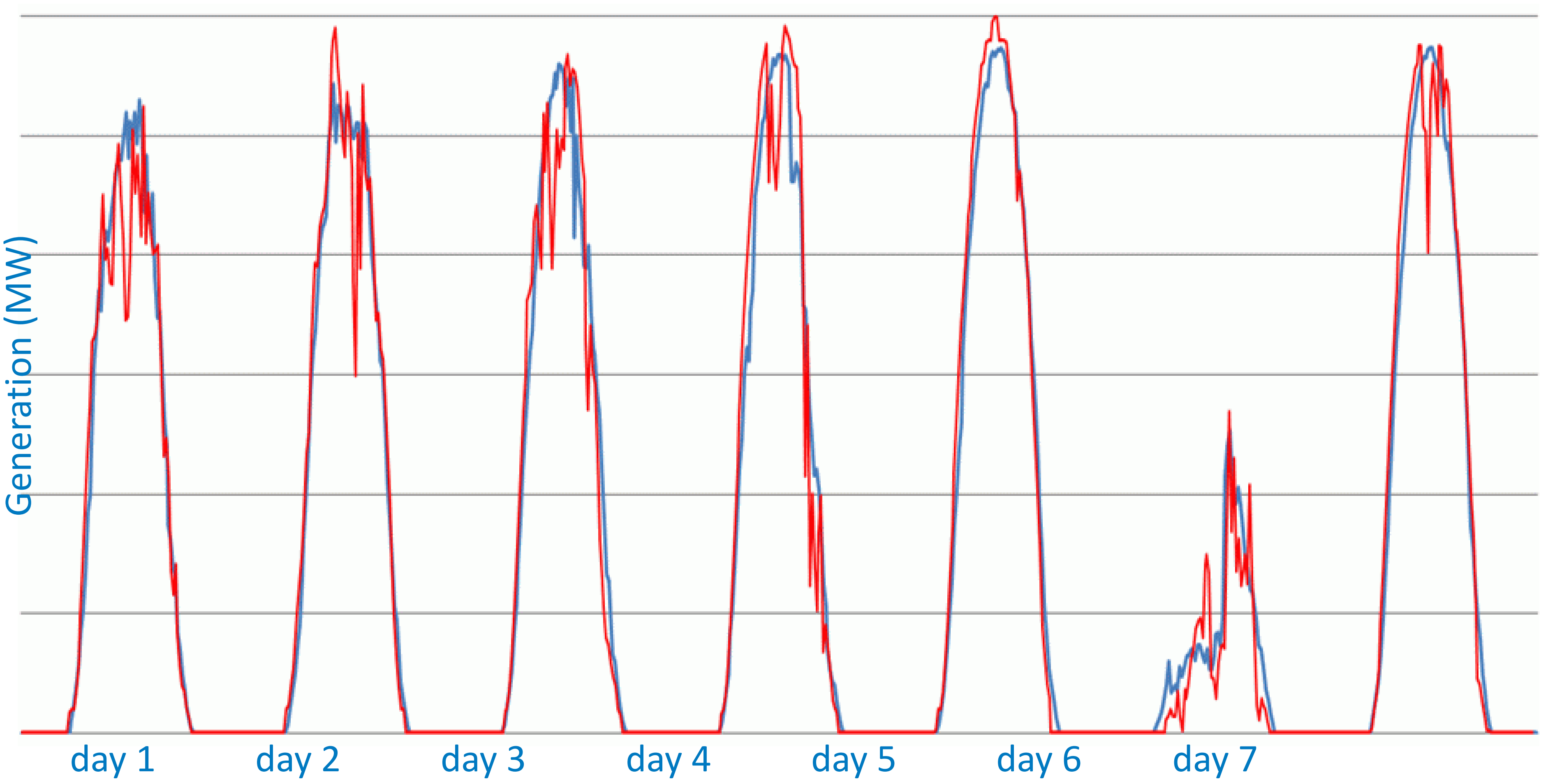
Solar Output vs. Forecasts



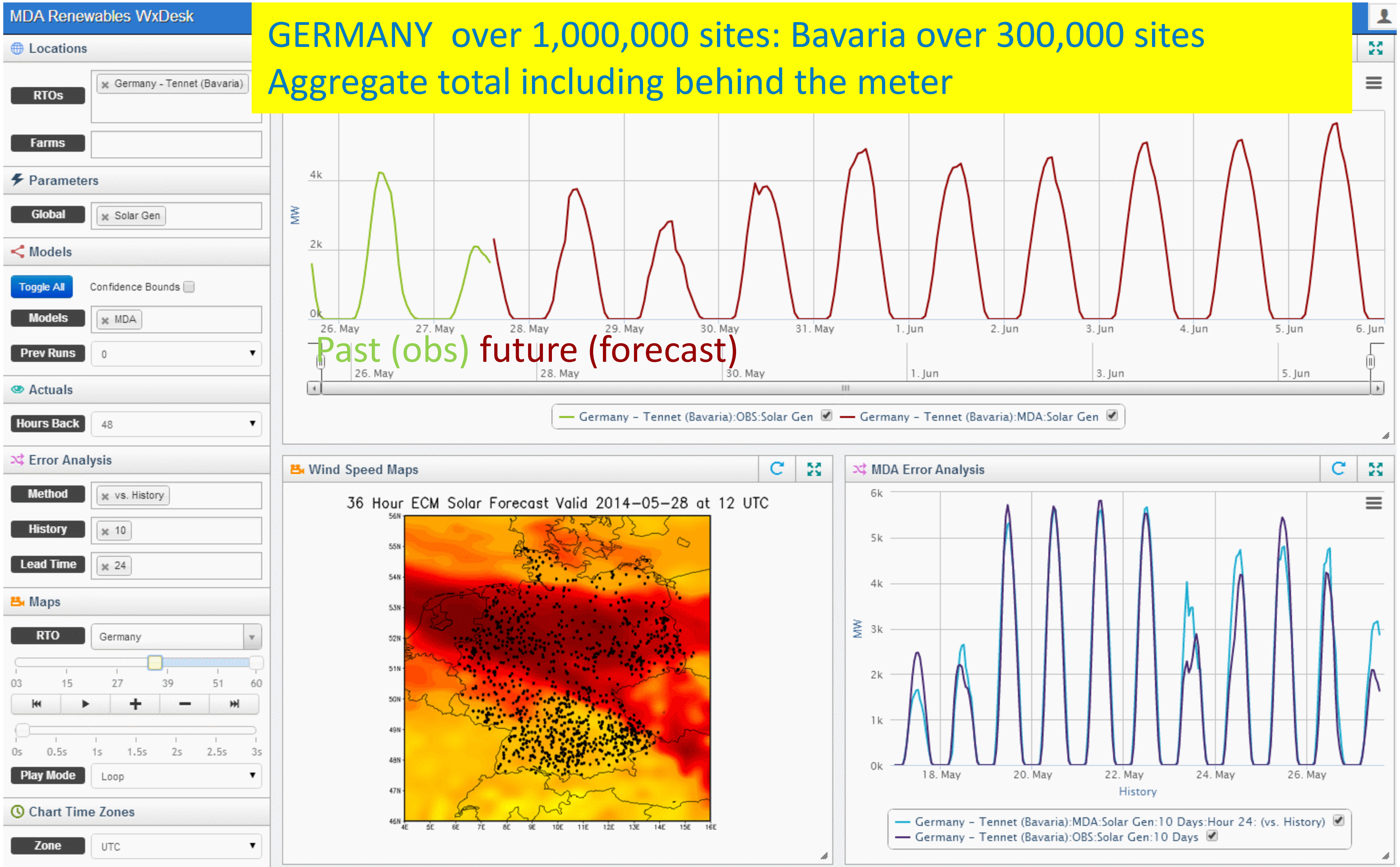
Solar Forecast Example: East Coast Solar Farm

Solar farm power (MW) measured (red) vs. estimated (blue) every 15 minutes

MDA estimate is based on short-range forecast. No site data available for previous 5 weeks!



Solar Forecasting Web Display



Map of regional variation vs locations

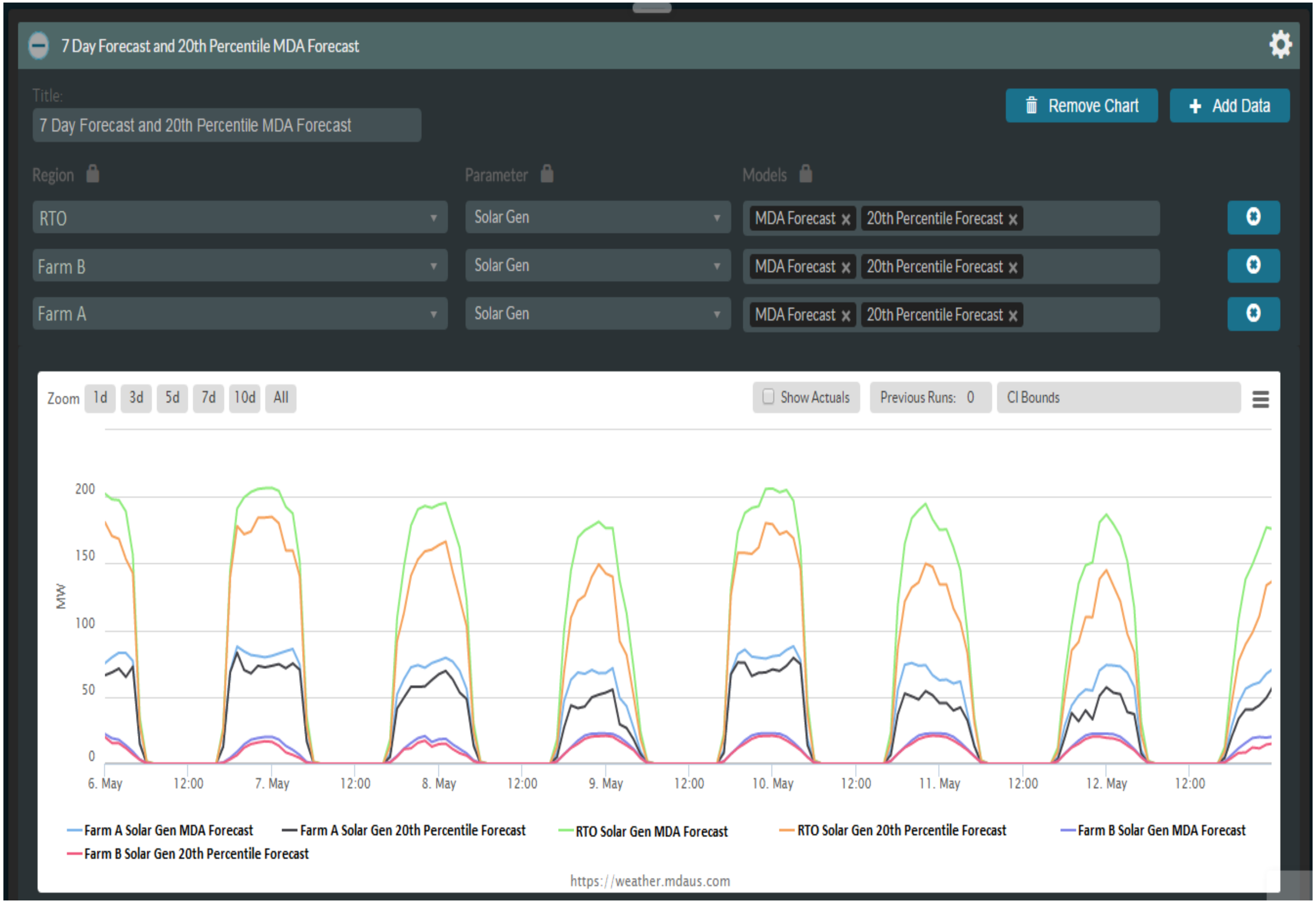
Last 10 days official estimate vs. 24-h forecast

Solar Forecasting Web Display

Best forecast **and 80% probability of exceedance**

RTO total and two of the farms selected to show different:

- Capacity
- Location, thus sunny or cloudy at different times
- Tracking, thus different shapes of daily profile



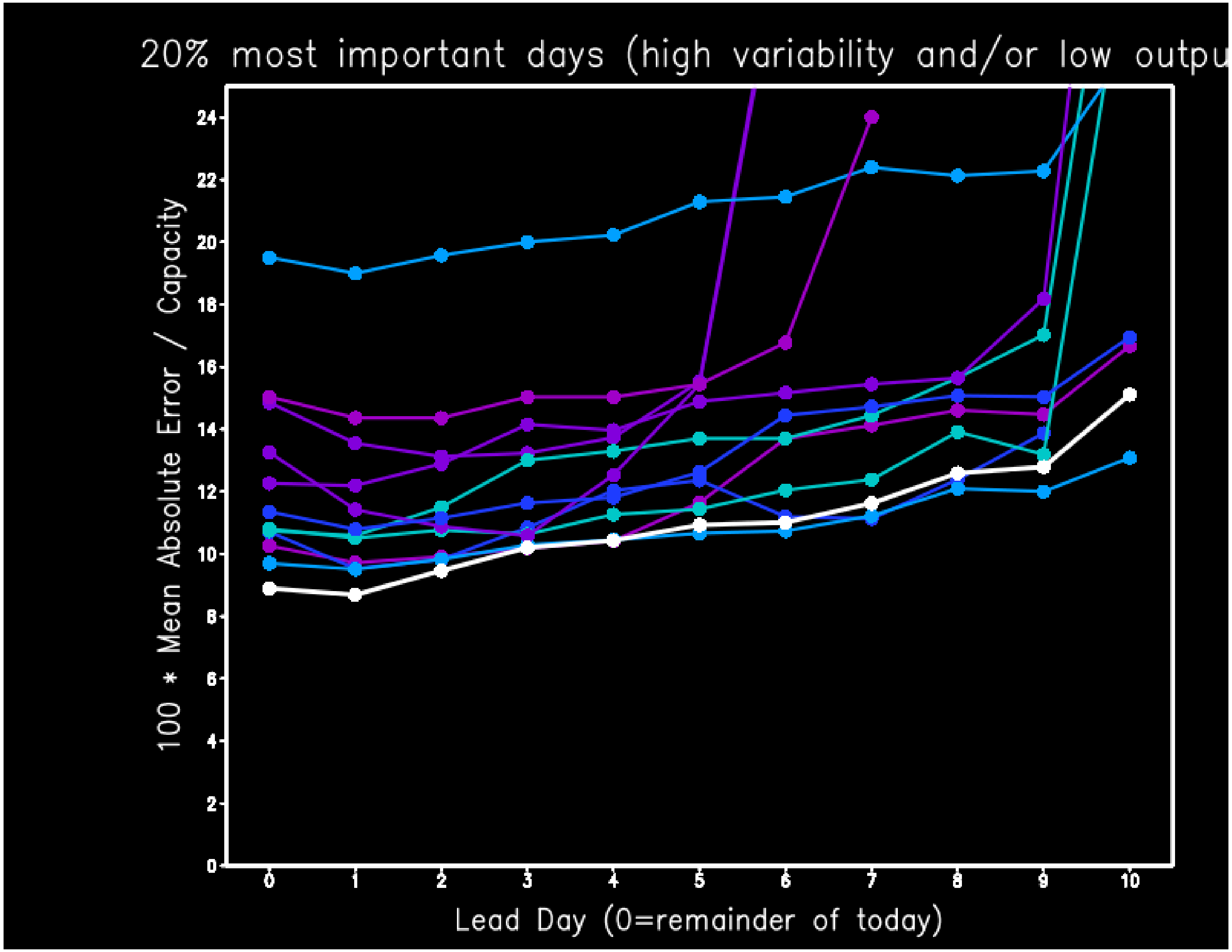
Solar Forecasting Skill

MDA is current solar forecast provider for multiple RTOs –after competitive multi-month trials against other vendors

- Fixed tilt and single axis and dual axis tracking sites
- Sites in areas of variable cloudiness and storminess, others in seasonally sunny/arid locations
- Some sites had well-established history, others were new
- Service includes retrieving real-time site data from RTO
- Trial included aggregate distribution system (behind the meter) forecasts for zones covering several counties
- Trial included 80% probability of exceedance as conservative guidance for ensuring adequate resources when solar generation is low or uncertain

Solar Forecasting Skill vs. Other Vendors

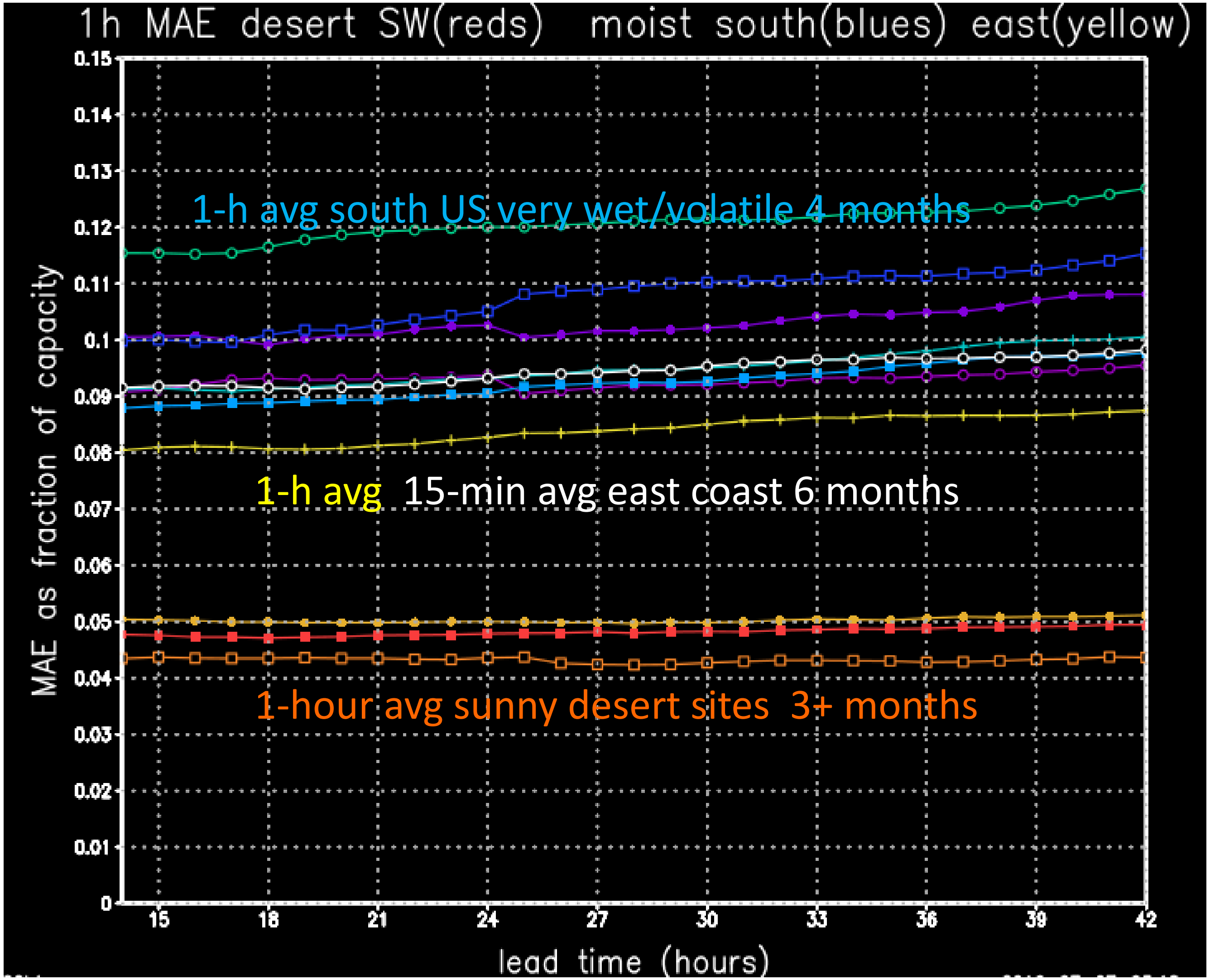
- Daily importance parameter assigned to each day, separately each site.
- Days ranked more important if actual power was low (cloudy day) or highly variable
- Forecast hourly MAE was calculated for the 20% of "most important" days at each site



Solar Forecasting Skill – Day ahead

Skill varies by site and weather:

- Mostly sunny = easier to predict
- Sun tracking arrays rest flat overnight → morning/evening ramps require knowledge of panel motion

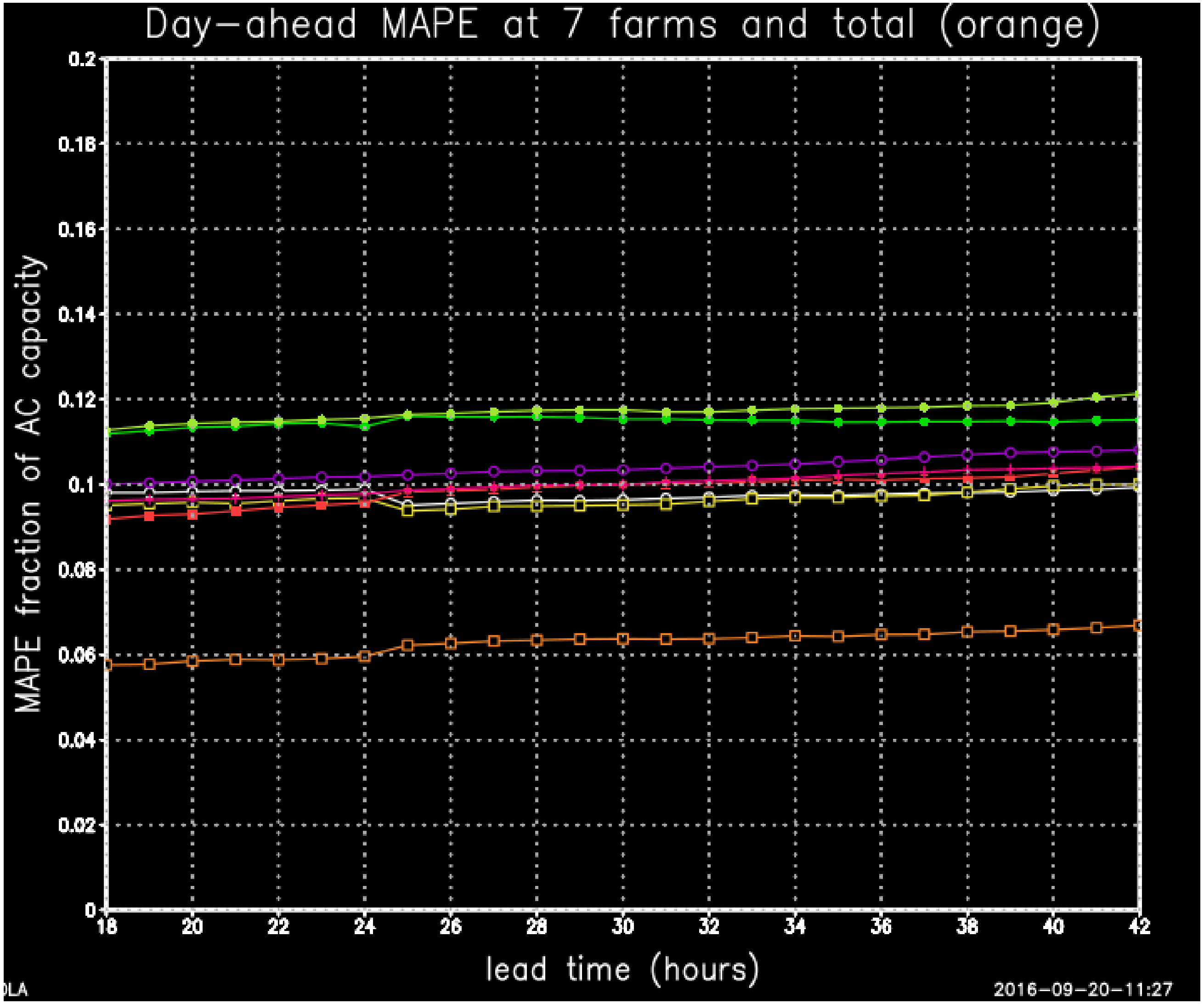


Solar Forecasting Skill – Aggregate best

Skill at 7 farms and aggregate (orange).

Aggregate has much better skill

Sample=hourly for 6 months

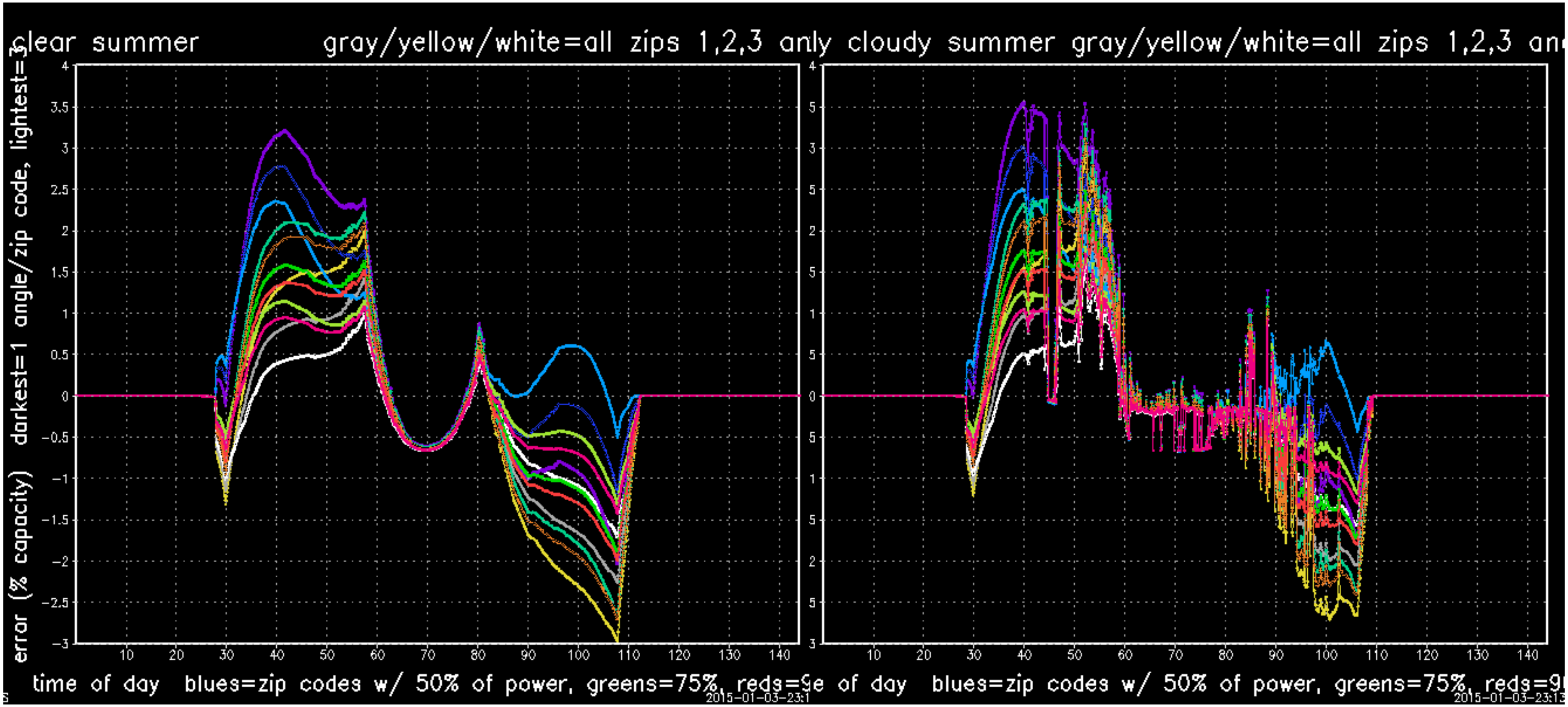


Solar Forecasting Skill – Behind-the-meter

California 160,000+ sites

Comparison: Aggregate all sites with exact orientations/tracking vs. select samples

sunny summer day variable clouds summer day

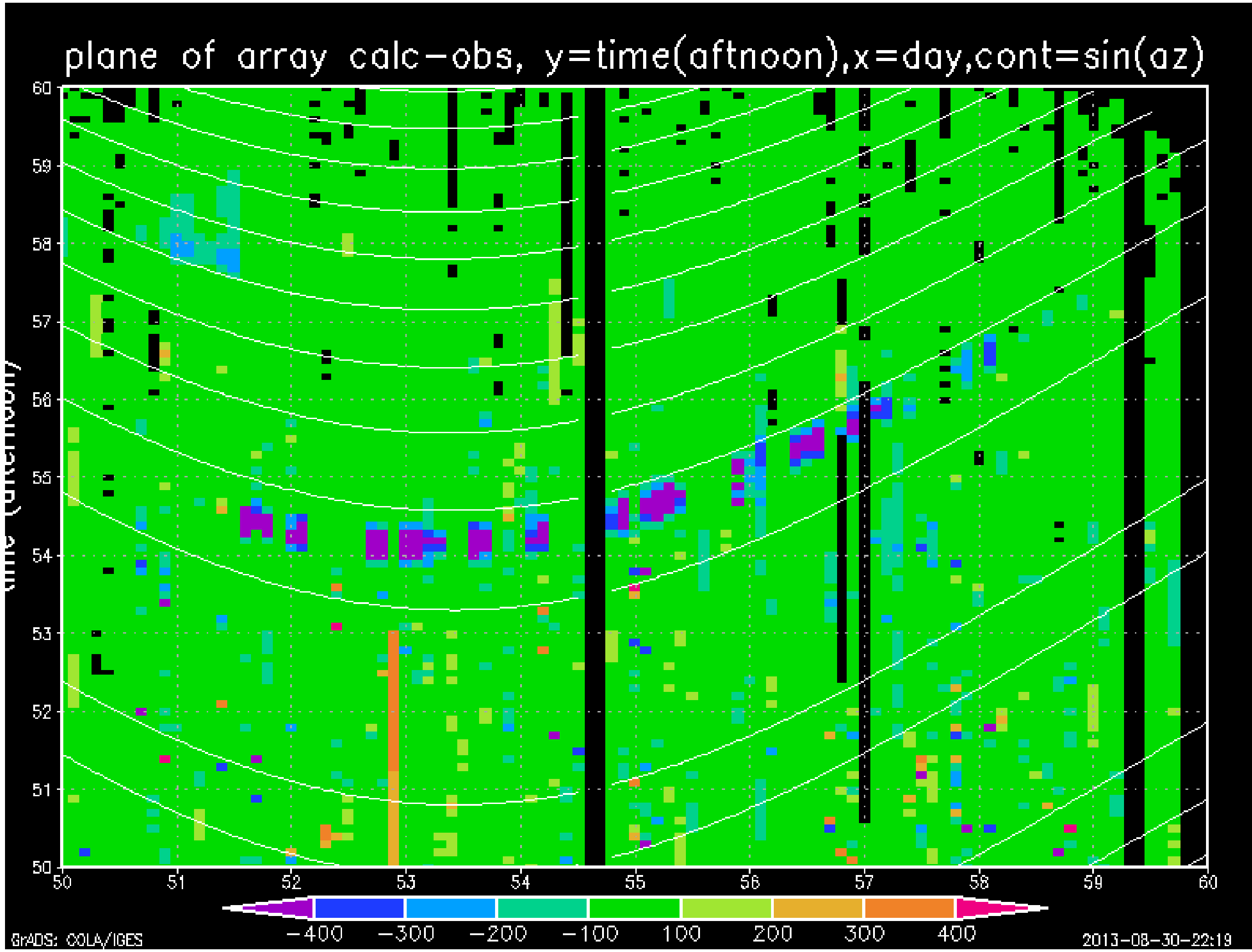


Algorithms detect site anomalies

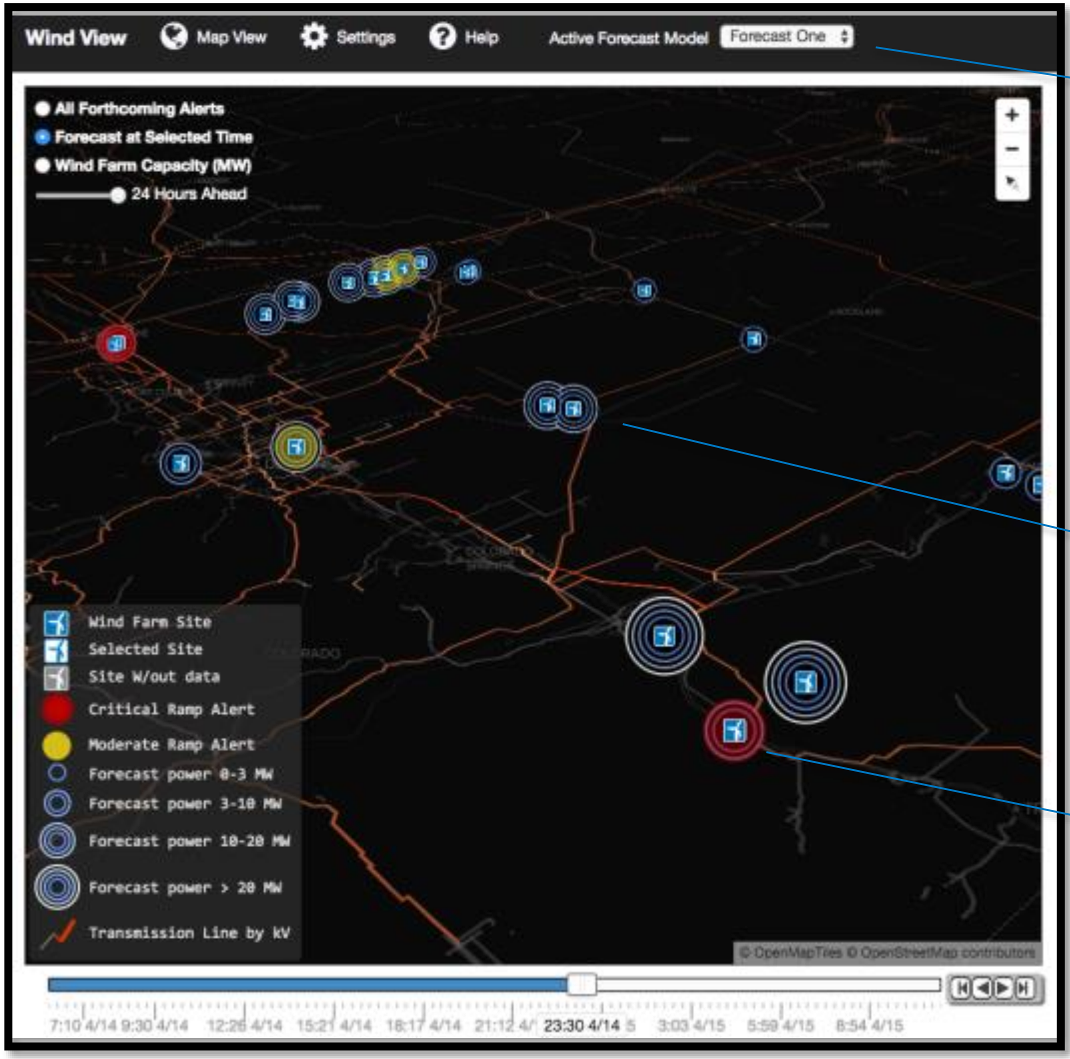
Example of site issues MDA can detect and handle:

PV site with irradiance monitoring

Small shadow fell across irradiance monitor



WindView



Wind power forecast models provide operators with information helpful in determining future production output and potentially disruptive events

A map view displays data for wind farms, planning regions, transmission lines, and forecast values

Visual cues alert users when situations arise that require attention

WindView

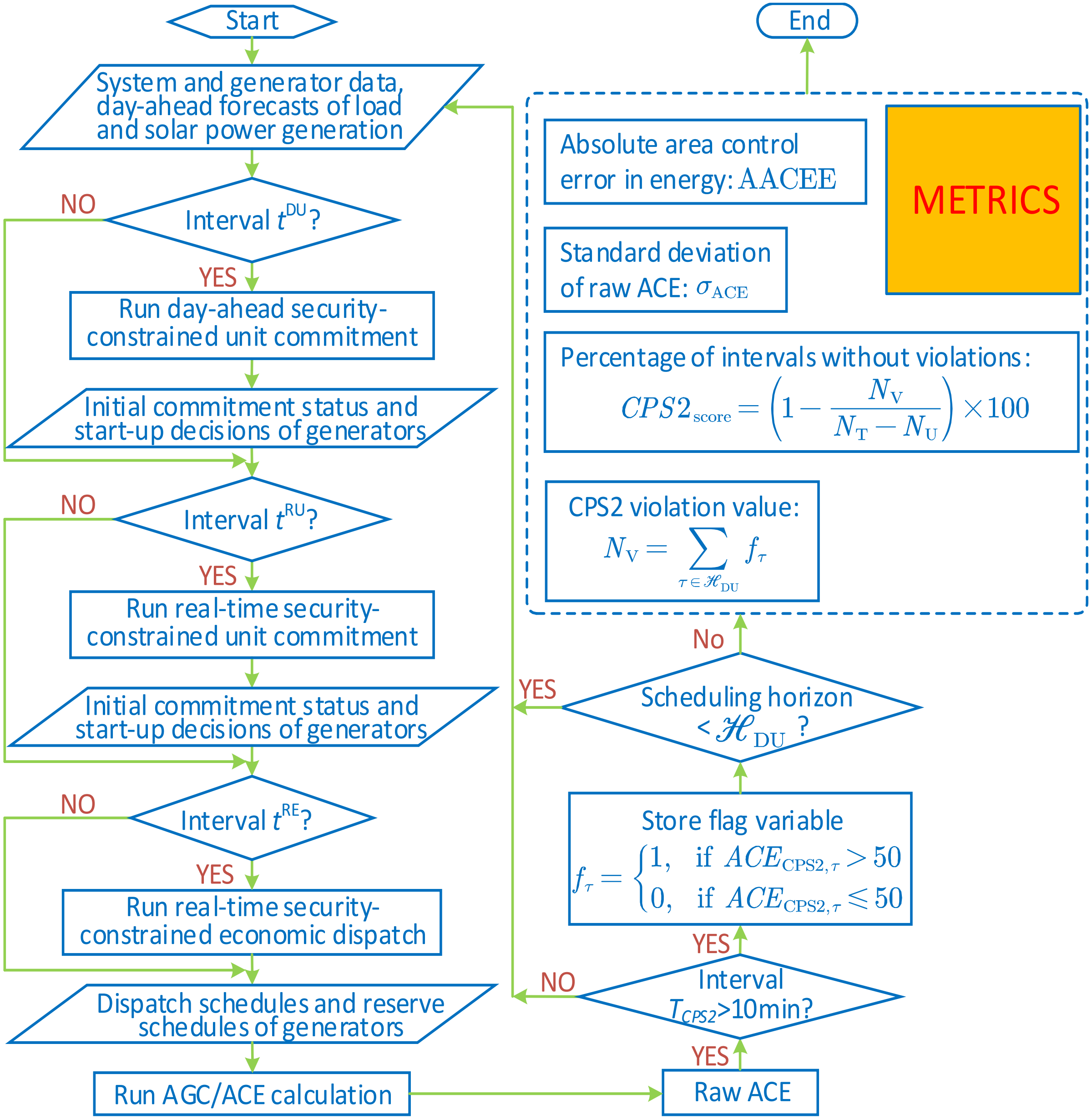
Settings for alert thresholds, forecast settings, and more provide a customizable experience

Map views provide tools for a variety of scenarios and time-frames

An abundance of visual data is made available via the map

Data is navigable in both time and space

FESTIV Flowchart



Project Schedule

Milestone ◆ Go/No-Go ●

		Budget Period 1					Budget Period 2				Budget Period 3		
		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
Task 1.1	Develop Probabilistic Solar Power Forecasts												
1.1.1	Create Probabilistic Solar Power Forecasting Algorithms												
1.1.2	Create Probabilistic Behind-the-Meter Solar Power Forecasts												
M1.1	Demonstrate ability to produce the full spectrum of forecast probabilities at multiple timescales, including day-ahead and subhourly				◆								
Task 1.2	Develop Adaptive Reserve Algorithms												
1.2.1	Grid Condition Clustering												
1.2.2	Grid Condition Forecasting												
1.2.3	Develop Adaptive Reserve Algorithm												
M1.2	Demonstrate that the adaptive reserve algorithms can reduce total reserves by more than 25%				◆								
Task 1.3	Develop Risk-Parity Dispatch Algorithm												
1.3.1	Determine Dynamic Costs												
1.3.2	Develop Risk-Parity Algorithm												
M1.3	Demonstrate that the risk-parity algorithm consistently converges to the optimal solution in less than 4 minutes for a small utility system					◆							
Task 1.4	Develop Situational Awareness Tool, SolarView												
M1.4	Complete solar-specific features in the software, and successfully demonstrate the SolarView capabilities to the solar program manager			◆									
G/NG-1	All Year 1 milestones completed					●							
Task 2.1	Validate Probabilistic Solar Power Forecast												
2.1.1	Collect Ground Truth Data and Produce Utility-Scale Probabilistic Forecasts Operationally												
2.1.2	Provide Probabilistic Behind-the-Meter Solar Power Forecasts Operationally												
2.1.3	Coordinate with Validation Team												
M2.1	Completed successful validation of the probabilistic forecasts according to the standards adopted by the Topic Area 1 awardee								◆				
Task 2.2	Ingest Probabilistic Forecasts into ISO Energy Management System												
M2.2	Successfully ingest probabilistic solar power forecasts into the ISO's system with more than 95% reliability during a 1-month period									◆			

Project Schedule (2)

Task 2.3	Estimate Adaptive Reserve Economic and Reliability Impacts
2.3.1	Create Adaptive Reserve Time-Series Data
2.3.2	FESTIV 118-Bus Simulations of Dynamic Reserve Impacts
2.3.3	FESTIV ISO Simulations of Adaptive Reserve Impacts
M2.3	Reduce total production costs when compared to the case without adaptive reserves.
Task 2.4	Estimate Risk-Parity Dispatch Economic and Reliability Impacts
2.4.1	Incorporate Risk-Parity Algorithm into FESTIV
2.4.2	FESTIV Simulations of Risk-Parity Dispatch Impacts
M2.4	Increase reliability scores when compared to the case with standard economic dispatch and deterministic forecast.
G/NG-2	All Year 2 milestones completed
Task 3.1	Provide Operational Probabilistic Forecasts
3.1.1	Provide and Ingest Operational Forecasts
M3.1	Successfully deliver probabilistic solar power forecasts to the ISO's system with more than 98% reliability during the demonstration period
Task 3.2	Incorporate Adaptive Reserves into ISO Test Environment
3.2.1	Implement Adaptive Reserves
M3.2	Demonstrate robust utilization of the adaptive reserve algorithms in the iTest system for a continuous period of 1 month
Task 3.3	Incorporate Risk-Parity Dispatch into ISO Test Environment
3.3.1	Analyze Historical Data to Determine Risk Parameters
3.3.2	Demonstrate Risk-Parity Implementation
M3.3	Demonstrate robust utilization of the risk-parity dispatch in the iTest system for a continuous period of 1 month
Task 3.4	Provide the ISO Operator Training on Situational Awareness Tool
3.4.1	Develop SolarView Training
3.4.2	Deliver SolarView Training
M3.4	Conduct a minimum of two training sessions for the ISO's operators

Project Team, Experience, and Qualifications

Qin Wang, Ph.D.	NREL	• Research engineer in the Power System Design and Studies group. • Worked as a market operation engineer at Midcontinent Independent System Operator prior to joining NREL. • Expertise in the area of power system operations, electricity market design, and renewable energy integration. • Published more than 30 peer-reviewed papers and has been involved in multiple projects funded by DOE and industry.
Pengwei Du, Ph.D.	ERCOT	• Lead engineer for renewable integration with expertise in the area of grid operations, RE integration, and renewable forecasting. • Previously a senior research engineer at PNNL.
Anthony R. Florita	NREL	• Research engineer for the Power System Design and Studies group. • Specializes in data science, statistical methodology, and the modeling and simulation of multi-physics systems. • Published 50+ peer-reviewed papers in the areas of solar energy, model predictive control, and building-to-grid modeling.
Jonathan Duckworth	NREL	• Analyst and developer in the Geospatial Data Science Group focusing on spatial application development and interactive data visualization. • Primary developer for the OpenCarto platform, a web framework creating online geographic information system applications focused on data visualization.
Christopher Cassidy	MDA	• Principal data engineer responsible for the operation and maintenance of the renewable power forecasts for wind and solar generation.