Operational Probabilistic Tools for Solar Uncertainty (OPTSUN)

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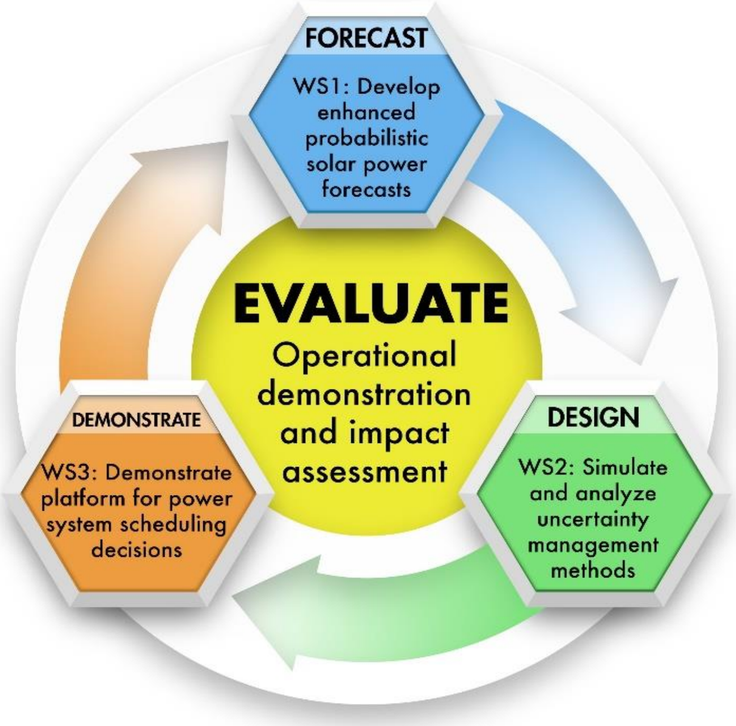
Project Technical Approach – Three Workstreams

- A Forecasting Work Stream to develop and deliver probabilistic forecasts with targeted improvements for utility scale and behind-the-meter (BTM) solar
- A Design Work Stream to identify advanced methods for managing uncertainty based on results from advanced scheduling tools
- A Demonstration Work Stream to develop and demonstrate a scheduling management platform (SMP) to integrate probabilistic forecasts and scheduling decisions in a modular and customizable manner



Utility Demonstrations To Be Employed

- Hawaiian Electric
  - Oahu: 600 MW+ of solar already installed on system with daytime load of <1200 MW
  - Focus on Oahu system operations in next few years, leveraging existing work:
    - Probabilistic solar, wind and net load forecasting in the SWIFT forecasting tool
    - EPRI study of operating reserve requirements using FESTIV tool
  - Insights will inform new automation and EMS tools, and provide operator confidence

- Southern Company
  - Over 1300 MW of solar installed, with up to 3000 MW expected by 2020
  - Develop detailed operational models for current and 2020 solar fleet across footprint
  - Builds on previous DOE SUNRISE project and other ongoing EPRI R&D

- Duke Energy
  - Focus on Duke Energy Carolinas (DEP and DEC), with approx. 2 GW installed, and >6 GW in queue
  - Will demonstrate use of forecasts in parallel with real time operations in Carolinas, with probabilistic forecasts also being provided and assessed in Florida
  - Leverage existing sensor network and forecasting of solar at distribution and transmission level

Project Team and Org Chart

Utility Demonstration Partners

Southern Company
Will Hobbs
Kyle Corley
Rodney O'Bryant

Hawaiian Electric
Henry Lee
Shari Ishikawa

Duke Energy
Rhett Trease
Stanton Lanham
Nick Keener

Principal Investigator
Aidan Tuohy, EPRI

Contract Manager
Dave Morrison, EPRI

Workstream 1
Forecast Development & Delivery
Lead: Daniel Kirk-Davidoff, AWS

Steve Young, AWS
John Zack, AWS
Tim Melino, AWS
Aidan Tuohy, EPRI
Eamonn Lannoye, EPRI Intn'l
Ranga Pitchumani, VT

Workstream 2
Simulation and Design of Scheduling Process
Lead: Erik Ela, EPRI

Miguel Ortega-Vazquez, EPRI
Nikita Singhal, EPRI
Robin Hytowitz, EPRI
Aidan Tuohy, EPRI
Eamonn Lannoye, EPRI Intn'l
Russ Philbrick, Polaris
Ranga Pitchumani, VT

Workstream 3
Platform Development and Demonstration
Lead: Aidan Tuohy, EPRI

Adam Wiginton, EPRI
Eamonn Lannoye, EPRI Intn'l
Erik Ela, EPRI
Robert Entriken, EPRI
Russ Philbrick, Polaris
Ranga Pitchumani, VT
Daniel Kirk-Davidoff, AWS

Forecasting Workstream: State of the Art Probabilistic Forecasting

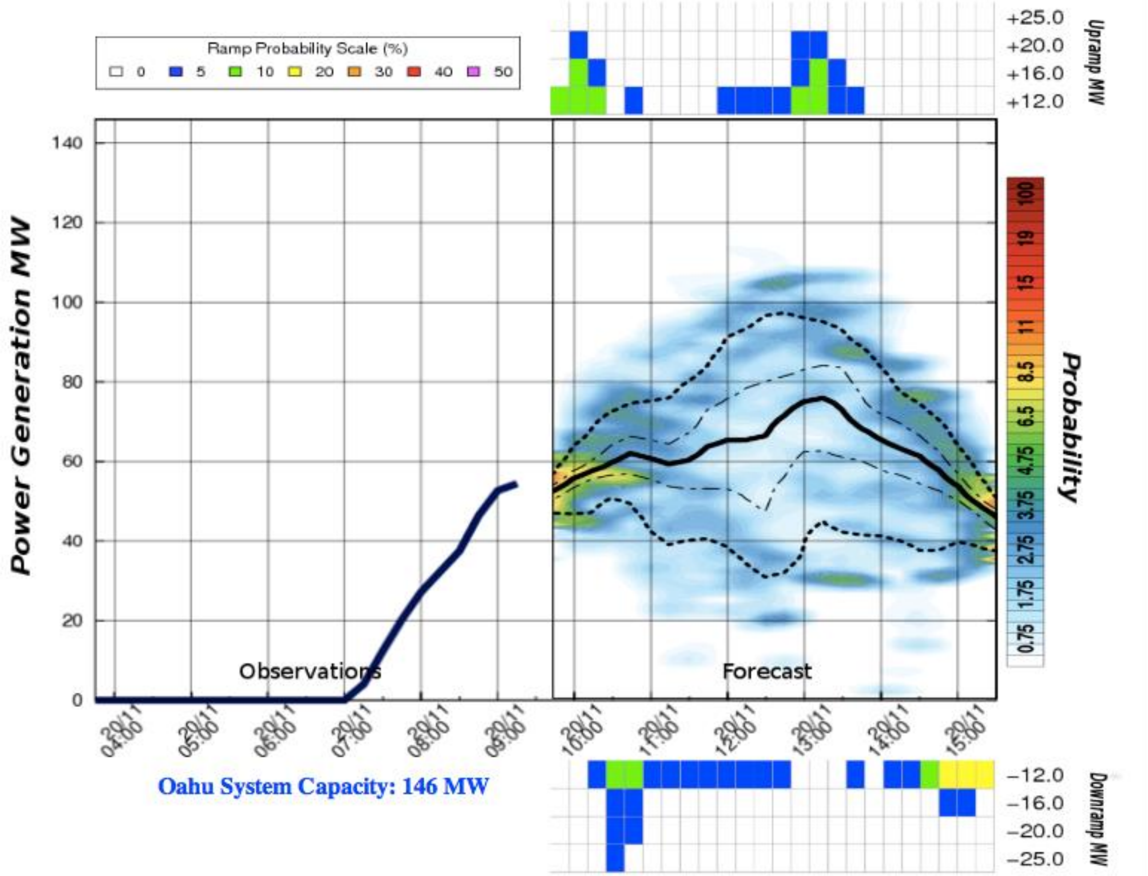
- Led by AWS

- Each utility to receive application-focused forecasts

- Improved modeling of uncertainty
  – Forecast model ensembles will be customized for each application
  – Ensembles will include NWP and other forecast models: e.g. time series, satellite cloud tracking
  – Will consider uncertainty factors typically not well represented in NWP ensembles such as sub-grid scale cloud effects, aerosol variations and irradiance to power

- Targeted visualization of probabilistic forecasts
  – Build on existing AWST displays
  – Scenario generation methods will be examined

- Ongoing evaluation and improvement of the probabilistic forecasts
  – Evaluation will focus on metrics for reliability, sharpness and resolution attributes
  – Primary objective is to improve resolution (ability to accurately differentiate changes in the PDF among forecast scenarios – e.g. between forecast cycles)



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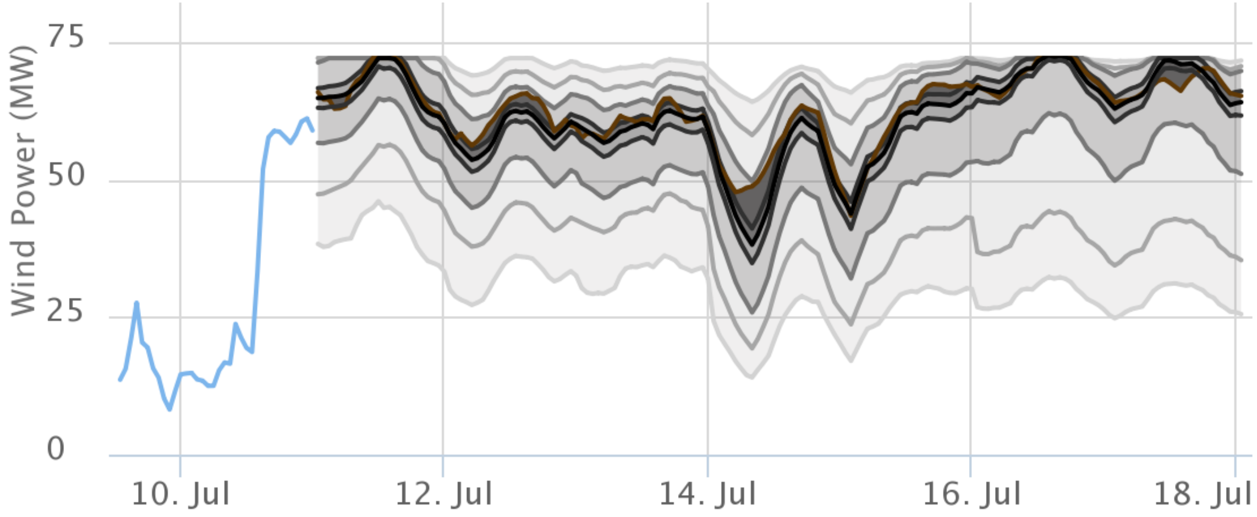
CURRENT PRACTICE IN PROBABILISTIC FORECASTING

We forecast wind and solar generation for utilities and grid operators, providing various percentiles of the cumulative probability distribution.   Operators tend to pay by far the most attention to the 50th percentile. To convince them to pay attention to the full distribution we need to do a better job clarifying the reliability and usefulness of the full distribution.



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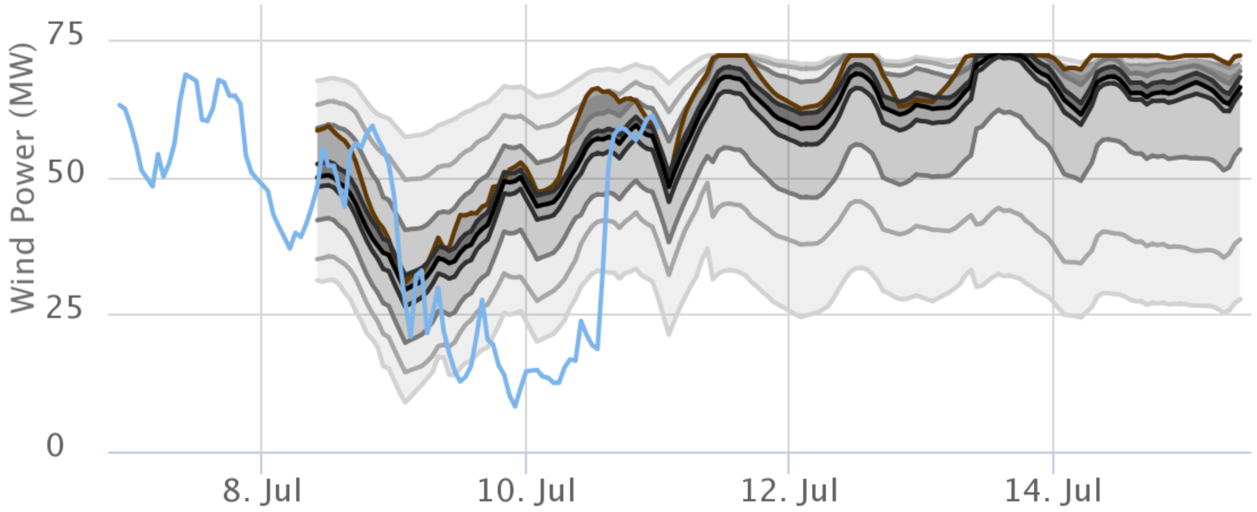
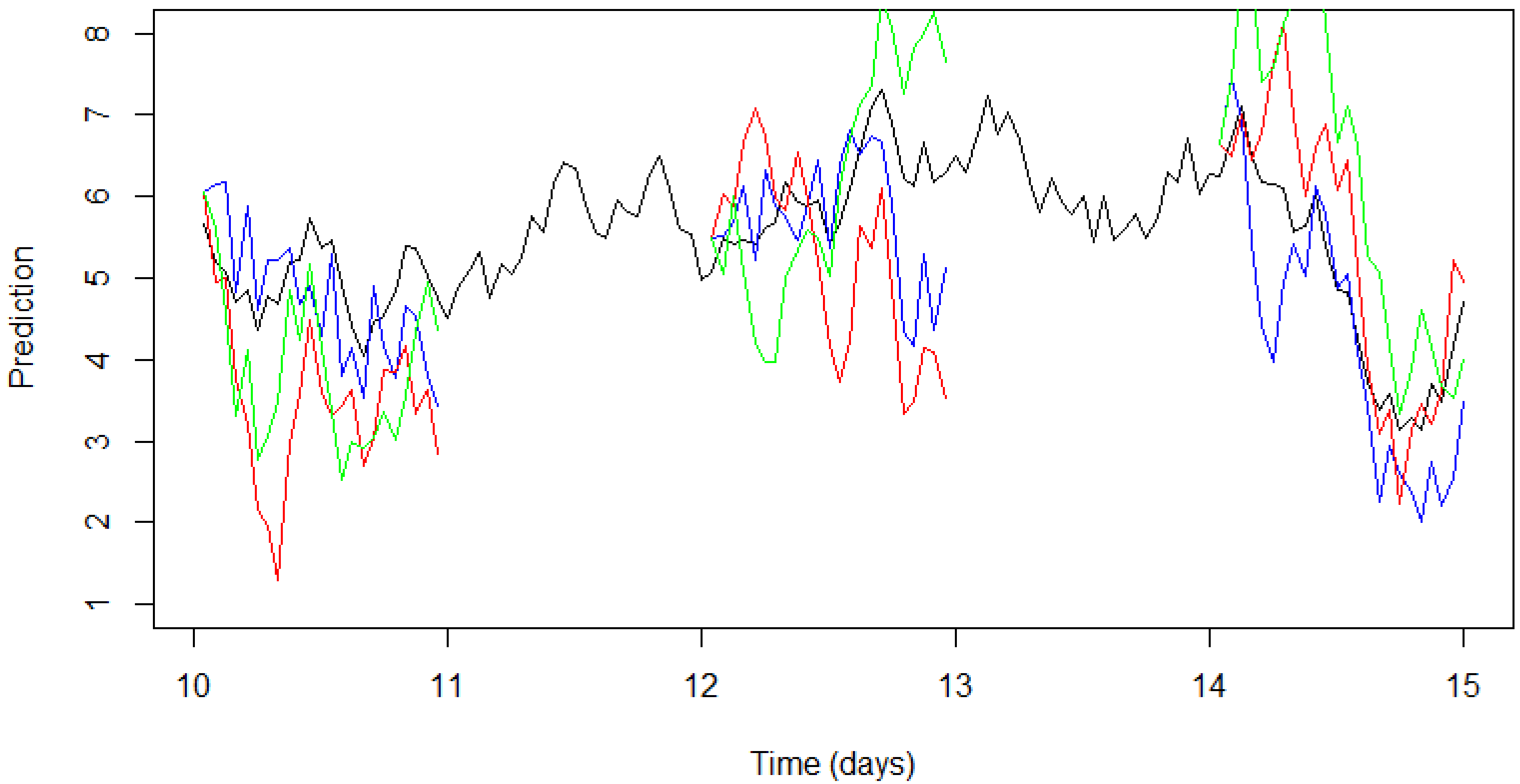


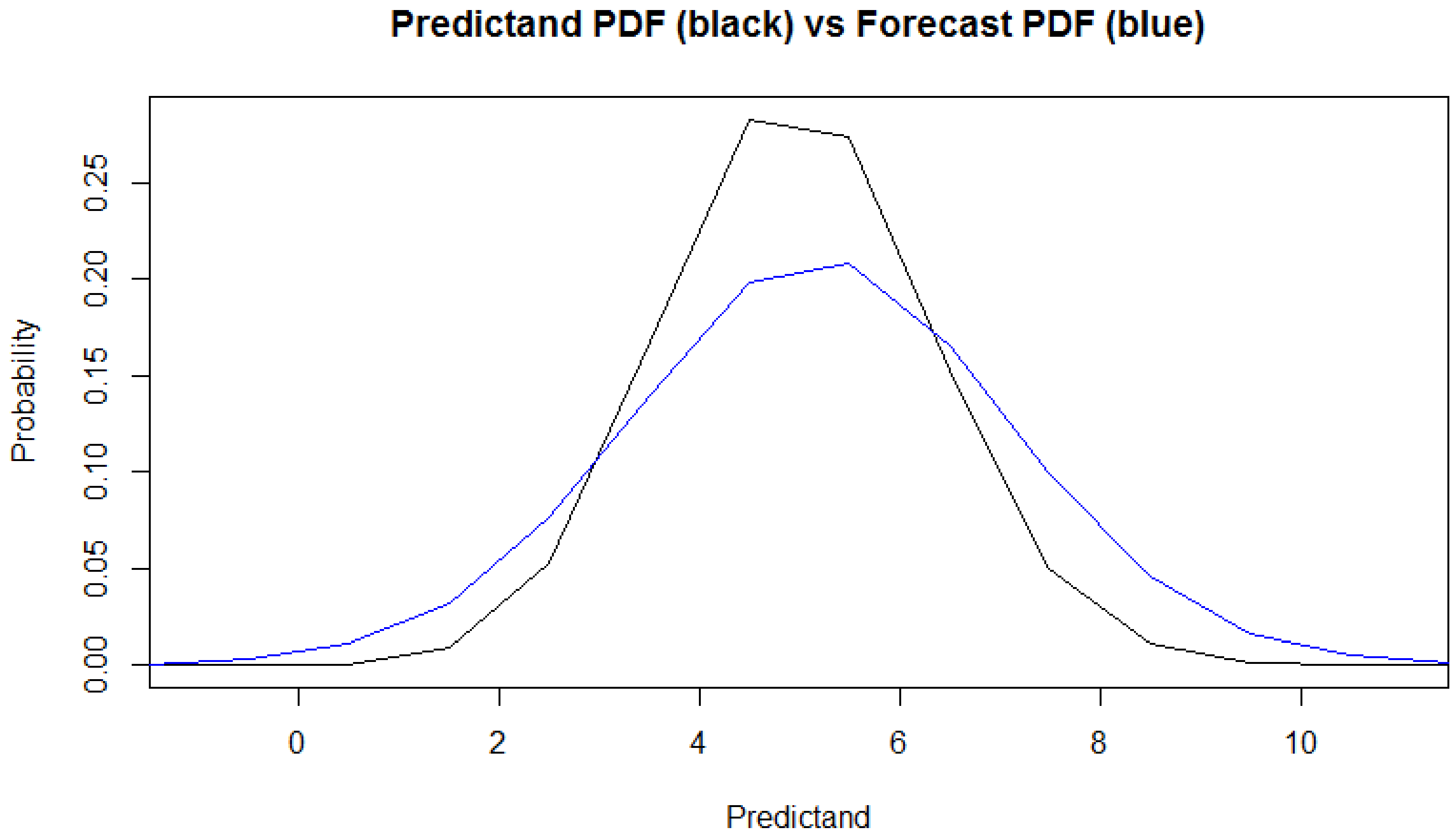
TOY MODEL OF PROBABILISTIC FORECAST

Start with a multimodel ensemble: in this case the forecast and the validation are just ar1 noise.



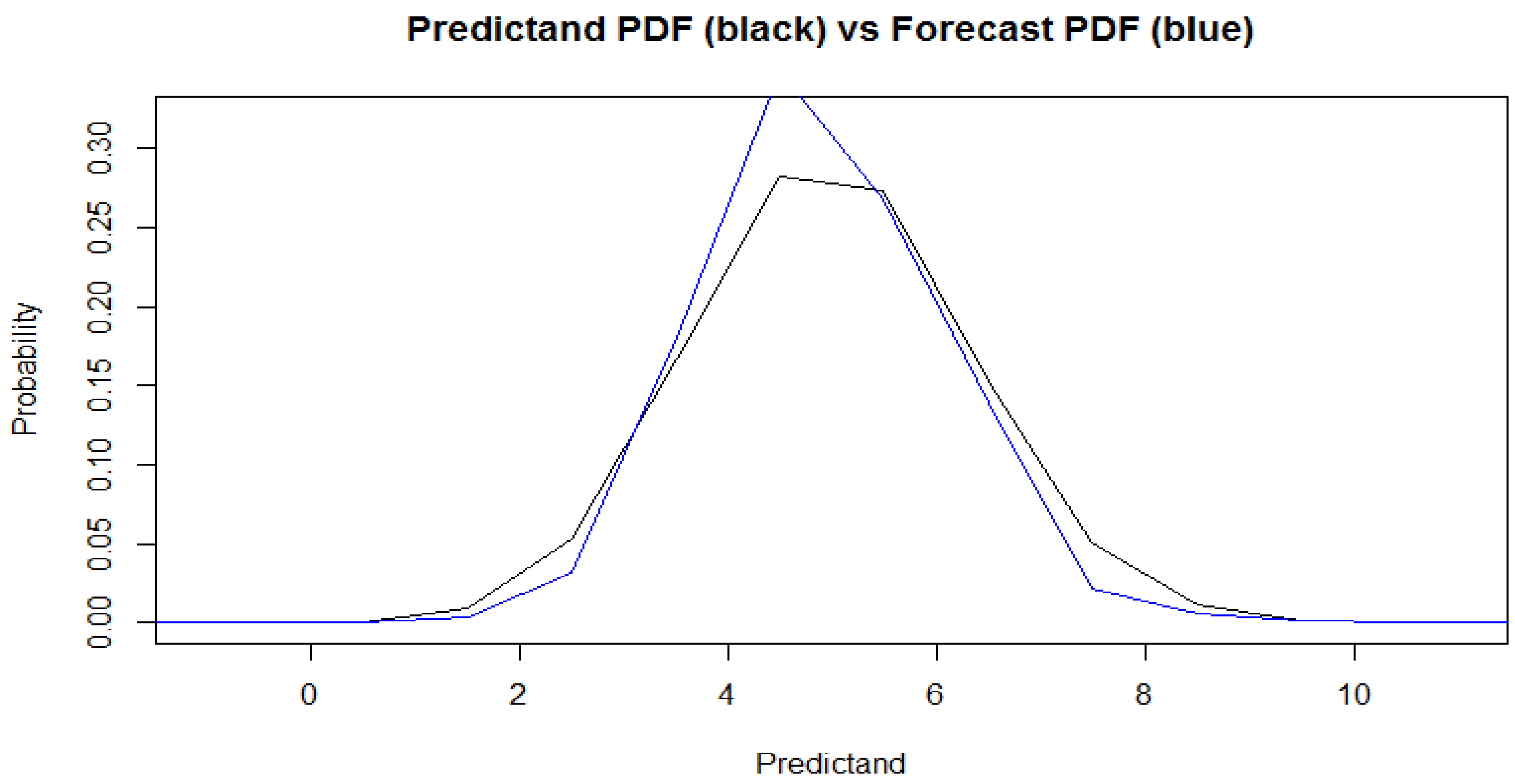
DISTRIBUTION OF ALL FORECASTS

Compare the probability distribution of the forecast and the validation: not a great match. What can we do?



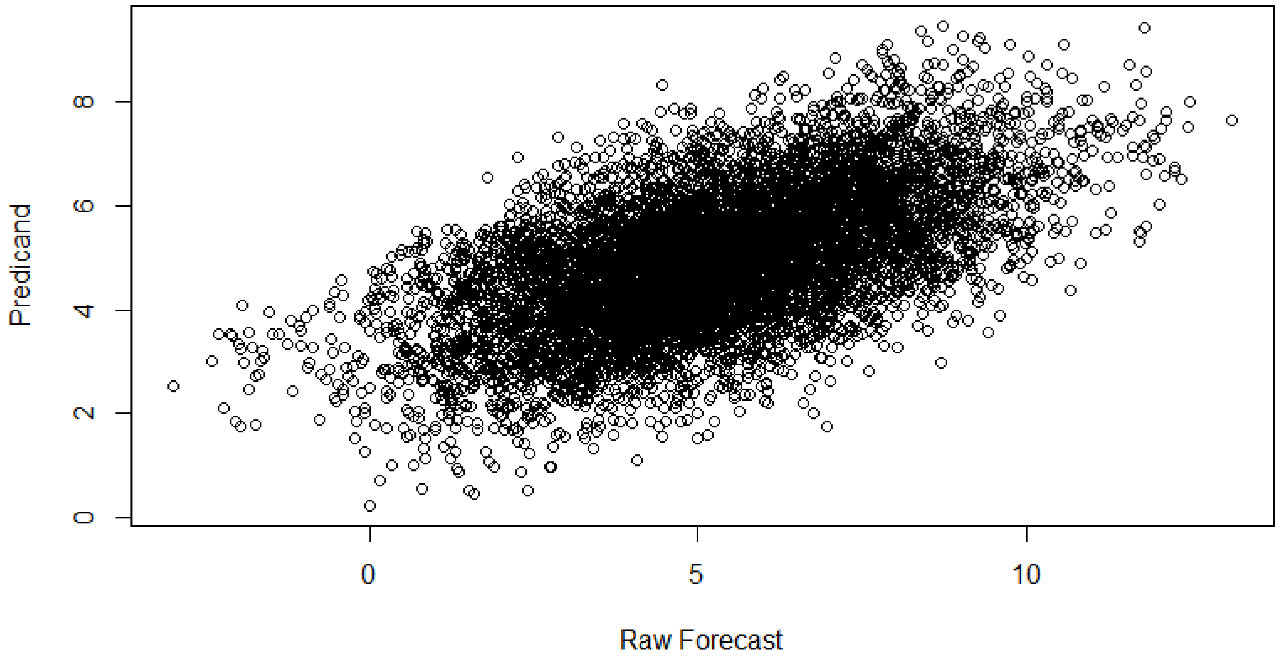
DISTRIBUTION OF ALL FORECASTS

Post-processing by a machine learning tool improves the fit of the probability distribution.   Forecasts are inputs (“features”), validation is truth (“labels”).



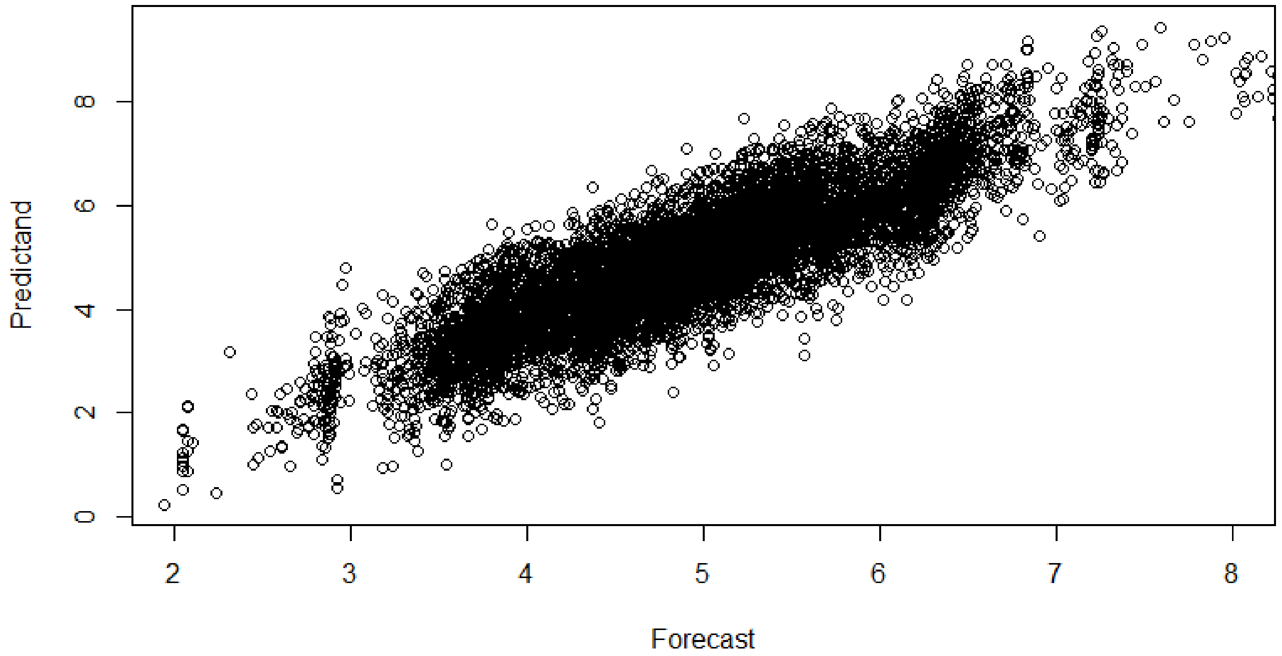
IMPROVING THE PDF CAN BE ASSOCIATED WITH A BETTER FORECAST

Original Forecast (50th percentile)



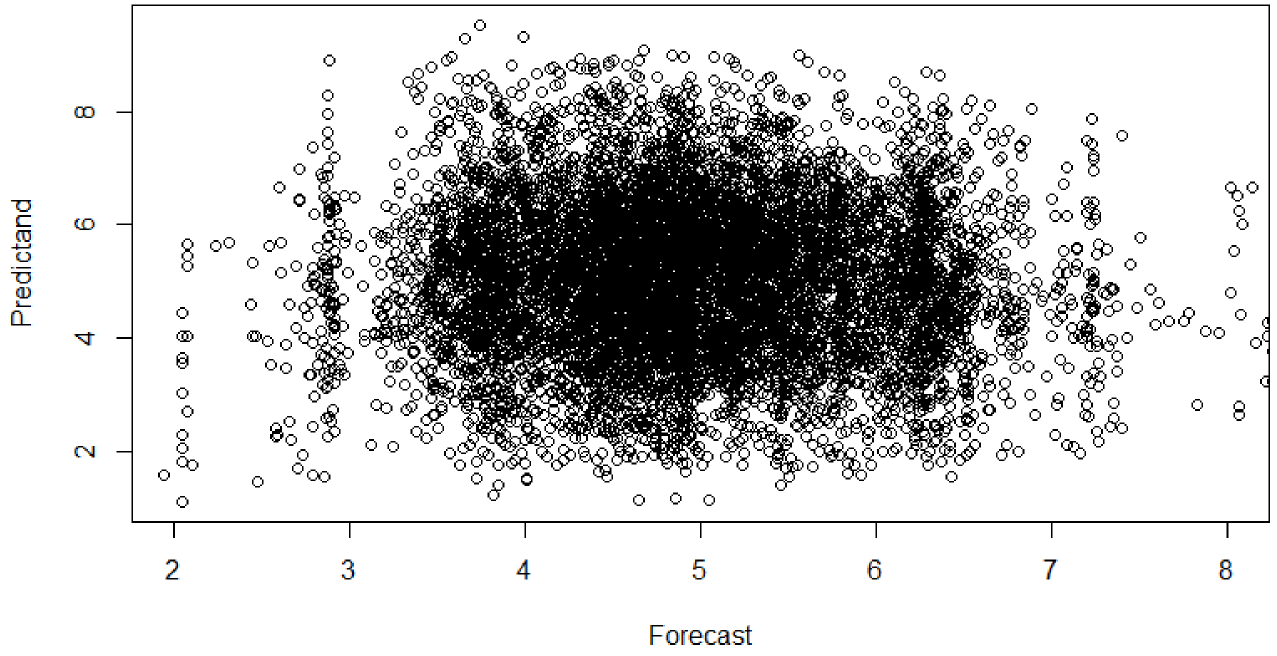
IMPROVING THE PDF CAN BE ASSOCIATED WITH A BETTER FORECAST

Machine-learning improved forecast (50th percentile)

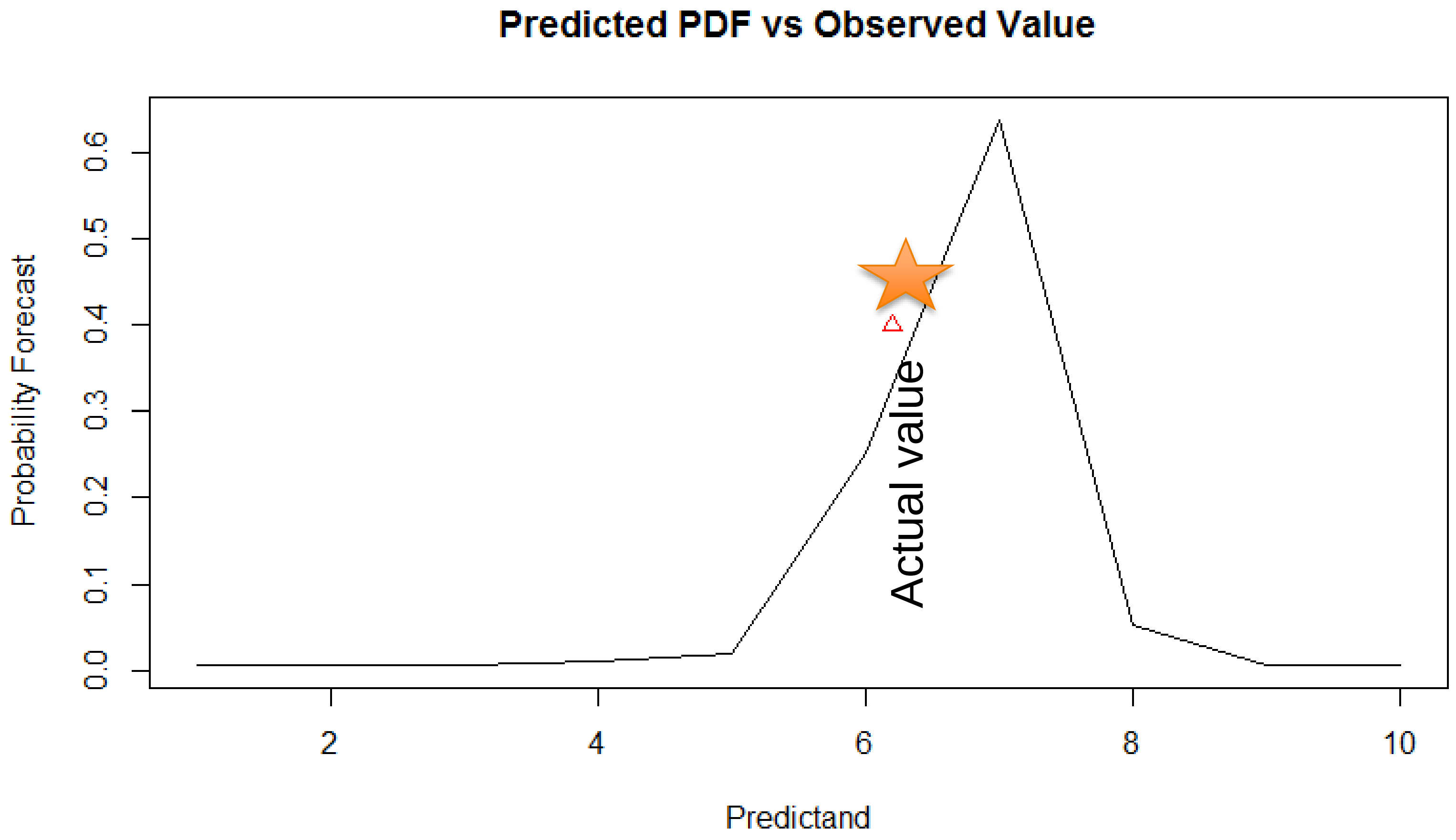


BUT CORRECT PDF IS NO GUARANTEE OF A GOOD FORECAST

The years in this model all have the same PDF, so you can swap years in the forecast and have a great PDF match, but zero correlation between the forecast and the validation



WE NEED A MEASURE OF FORECAST SKILL THAT COMBINES PDF ACCURACY AND PRECISION



WE NEED A MEASURE OF FORECAST SKILL THAT COMBINES PDF ACCURACY AND PRECISION

S: Score (calculated for each observation, can be averaged over a range of observations)

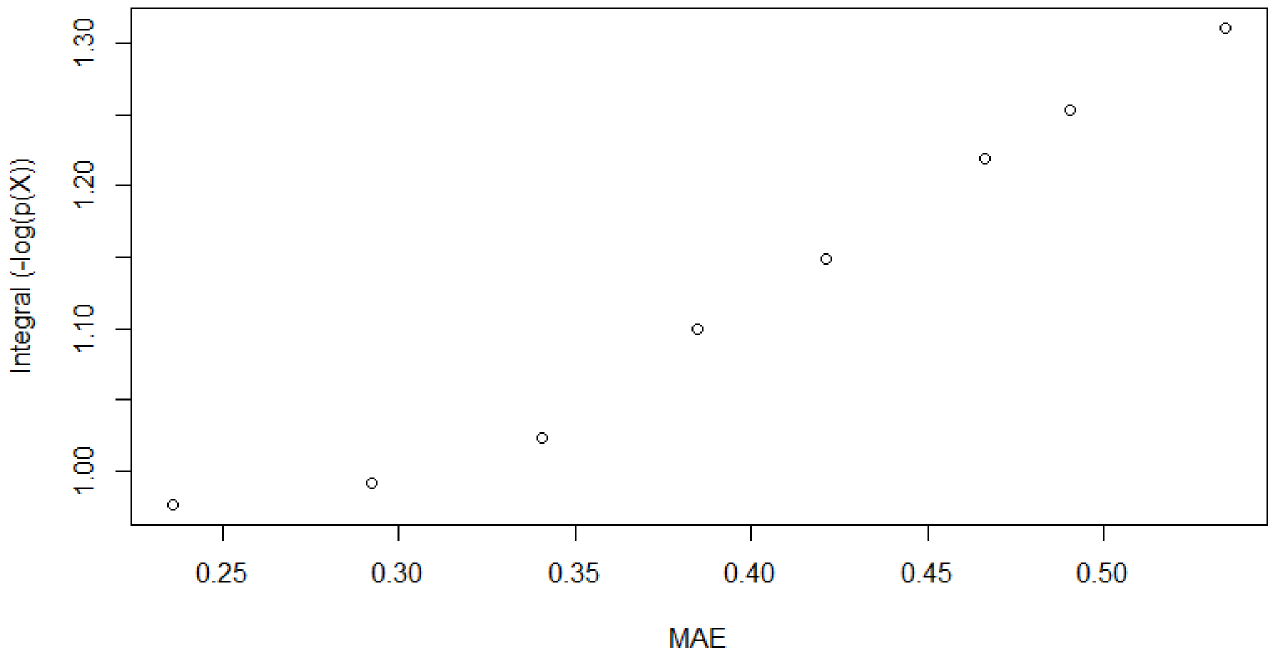
$p(x)$: predicted probability that the predictand will have the value *x*

X: actual observed value of the predictand at the time in question

Ignorance: $$S[p(x), X] = -\log p(X)$$

Proper linear score: $$S[p(x), X] = \int p^2(z)dz - 2p(X)$$

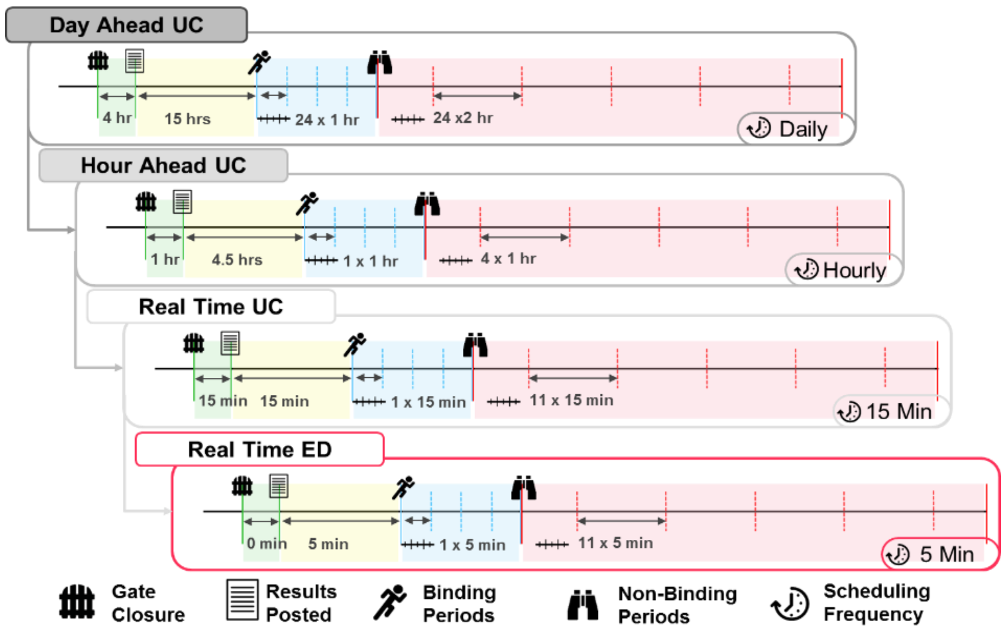
IGNORANCE VS MEAN ABSOLUTE ERROR OF 50TH PERCENTILE FORECAST

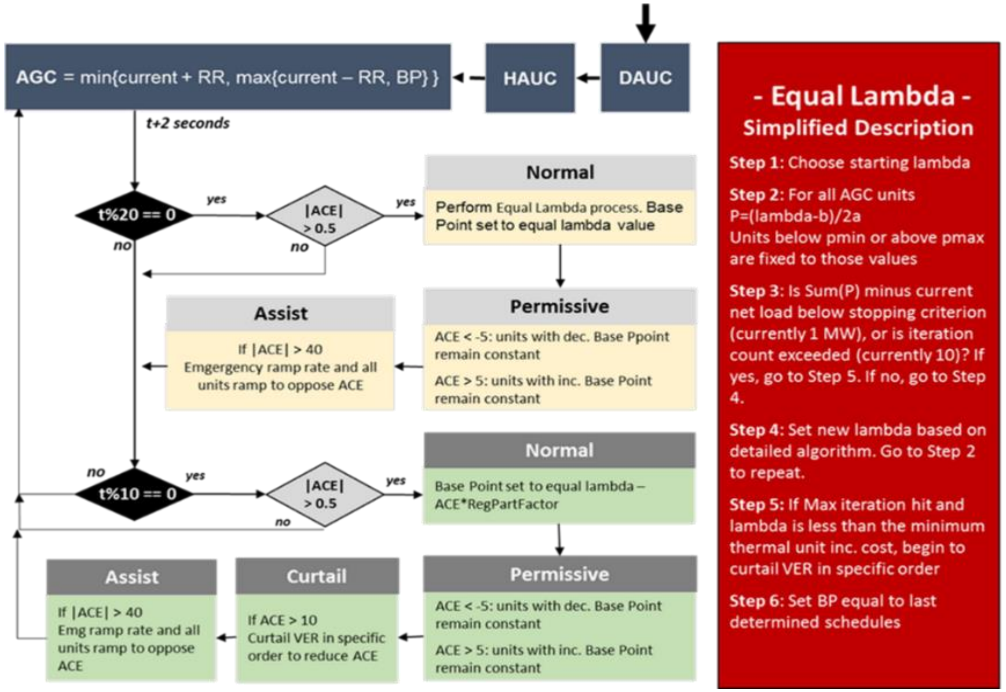


At low values of MAE, Ignorance is not falling off with continued improvements in MAE because the predicted probability distribution is getting very sharp, but biases are not decreasing: this is a forecast problem that can be addressed to improve performance.

Design Workstream – Industry Leading Multi-Stage Modeling Tools

- Develop accurate models to understand how best to use probabilistic forecasts
  - Represent Day(s) Ahead, Hour(s) ahead and real time commitment and dispatch of the system
  - Include **forecast uncertainty** and means to manage risk (stochastic programming & reserves)





- **PSO** to be used for Duke and Southern: Focus on 5-minute and longer intervals
  - Have used to study CAISO/WECC and TVA in the past
  - Will produce specific designs for operational processes
- **FESTIV** is used for Hawaiian Electric case study – 2 second time resolution
  - Necessary for smaller island systems
  - Will add stochastic programming capabilities and probabilistic forecasting

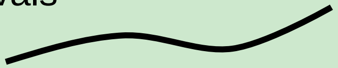
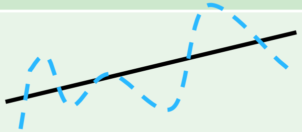
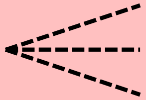
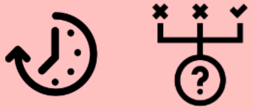
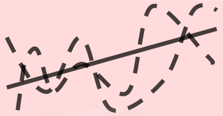
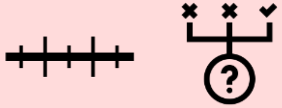
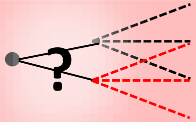
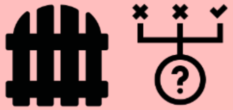
Operating Reserve Needs

1. Hold capacity now to meet the **variability** that occurs **within** the **current** scheduled time interval.

2. Hold capacity now to prepare for **anticipated variability** that occurs **after** the current time interval.

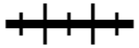
3. Hold capacity now to prepare for **uncertain outcomes** that occur in **current or future** scheduled time intervals.

Advanced Scheduling Strategies impact on reserves

Cause	Type	Explicit Representation	Approximating Reserve Examples
Variability	Between Intervals 		Flexible ramping reserve
Variability	Within Interval 		Regulation reserve
Uncertainty	Between Intervals 		Flexible ramping reserve
Uncertainty	Within Interval 		Contingency reserve
Uncertainty	Before First Interval 		None currently proposed

Key

 **Multi Period Scheduling with Look Ahead**

 **Shorter Scheduling Intervals**

 **Closer Gate Closure**

 **Stochastic or Robust Scheduling**

 **Increased Scheduling Frequency**

Design Workstream – New Uncertainty Management Strategy Identification and Quantification

Advanced Scheduling Formulation

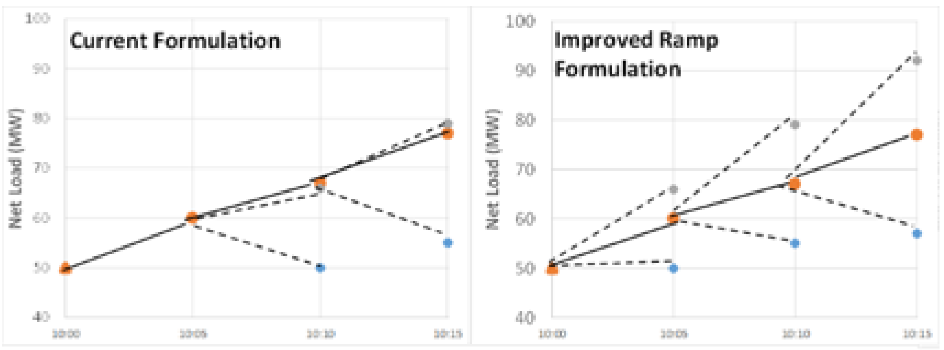
- **Stochastic programming techniques to quantify benefits of advanced scheduling**
- PSO and FESTIV both have this capability already, will improve as required for full utility integration, in order to determine how these strategies can improve operations

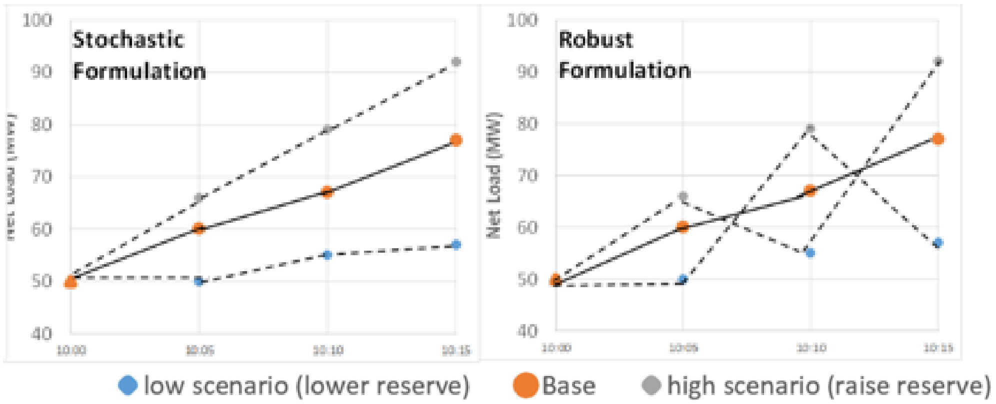
Reserve Determination Module

- **Developed based on results from stochastic optimization as one potential strategy for managing uncertainty in scheduling processes**
- Deterministic number that may provide most of benefits of full stochastic optimization

Assess Benefits of Strategies

- **Includes production costs, system reliability (load violations or area control error), inadvertent interchange, cycling metrics, curtailment, etc.**
- Aim is to improve costs of managing uncertainty by 10% (not total costs)





Advanced tools will identify specific algorithms and processes for demonstration

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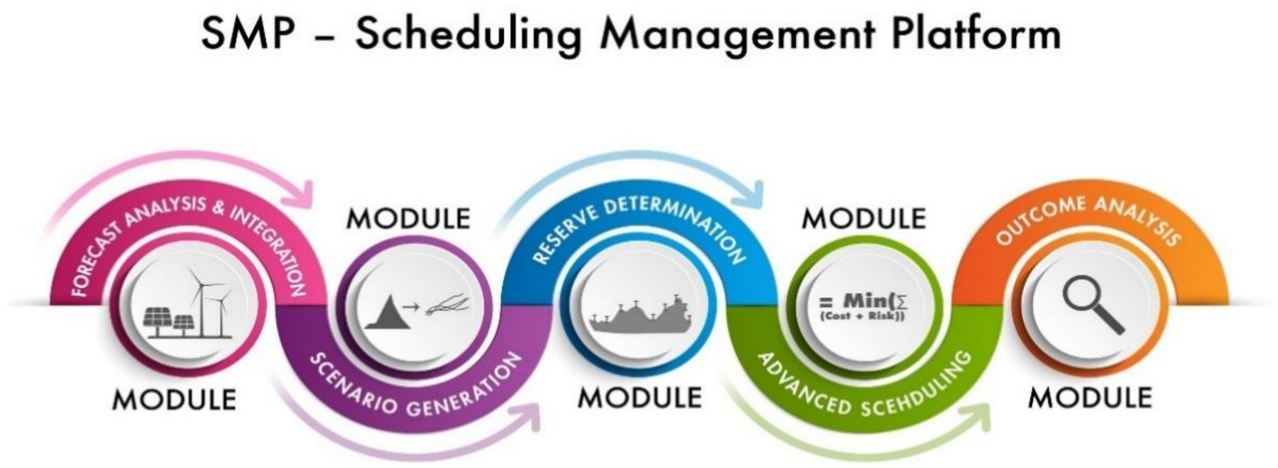
Demonstration Workstream - SMP



- Results from Workstreams 1 and 2 will inform development of a Scheduling Management Platform
  - Modular approach to allow for more flexibility and further development in future R&D and demonstrations
  - Customized, where appropriate, for each utility, to ensure that their specific energy management processes can leverage toolset
- Demonstration will run for at least six month period in a development environment – ongoing analysis of the outcomes
- Significant focus on datastreams between different modules
  - Display probabilistic information, provide scheduling process inputs and/or optimization algorithm, call on either existing utility UC/ED processes, or PSO/FESTIV (if their capabilities are needed), etc.
- Individual modules developed will be delivered as code/software tool, with guidelines for incorporation into other systems based on their specific needs

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Demonstration Workstream: Full Integration to Inform Operations Decisions

- Demonstration will run for at least six month period
  - Sufficient time to demonstrate potential benefits
  - Studies will also quantify benefits in Design Workstream

- Significant focus on datastreams between different modules
  - Will be able to display probabilistic information
  - Will provide scheduling process inputs and/or optimization algorithms
  - Where appropriate, will call on either existing utility UC/ED processes, or PSO/FESTIV (if their capabilities are needed)
  - Ongoing analysis of the benefits for operators and project team to track progress

- Individual modules developed will be delivered as code/software tool, with guidelines for incorporation into other systems based on their specific needs

Market Transformation

- Ultimate target market is utilities and ISOs
  - Successful implementation of integrated tools will demonstrate effectiveness and increase system operator confidence in applied probabilistic forecasts
  - EPRI already lead R&D project (to provide $109k cost share) with 19 utilities and ISOs engaged
  - 50+ utilities/ISOs participate in EPRI's Grid Operations and Planning R&D area that includes regular EPRI webcasts and meetings that will be used to disseminate results

- Forecasting community to also benefit through improved understanding of use cases for probabilistic forecasts, and improved probabilistic methods

- Methods demonstrated will be documented providing roadmap for other systems implementation or in academia/research setting
  - Vertically integrated demonstrations, allows flexibility to alter processes as required to make best use of tools and provides more detail on distributed PV for BTM analysis
  - Code/tools made available removing confidential or commercially sensitive information
  - Reports/webcasts provide updates to industry/academia to on a regular basis

Leverage significant technology transfer experience to ensure DOE funding can transform this area of power system operations in a relatively short time period

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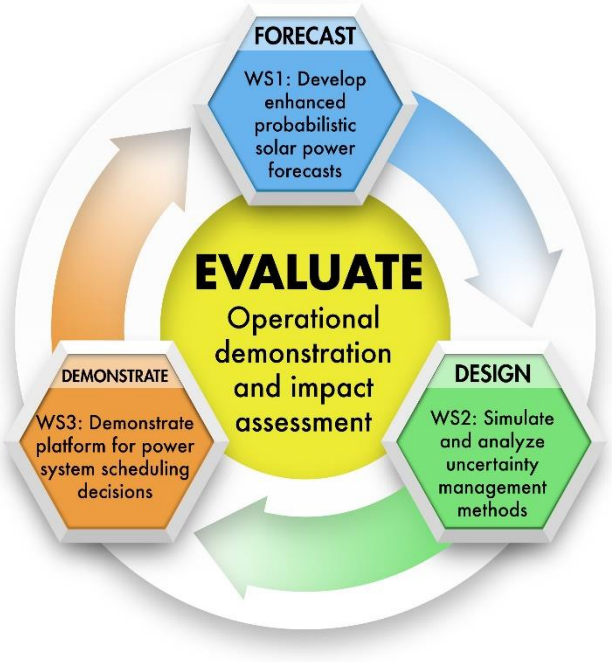

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