Different Utilizations of Probabilistic Forecasts

Erik Ela, Aidan Tuohy

UVIG Forecasting Workshop

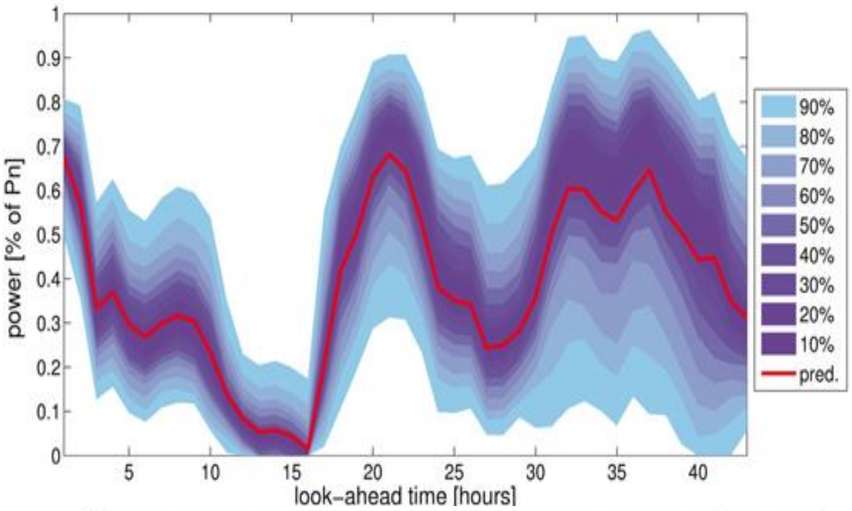
June 20, 2017

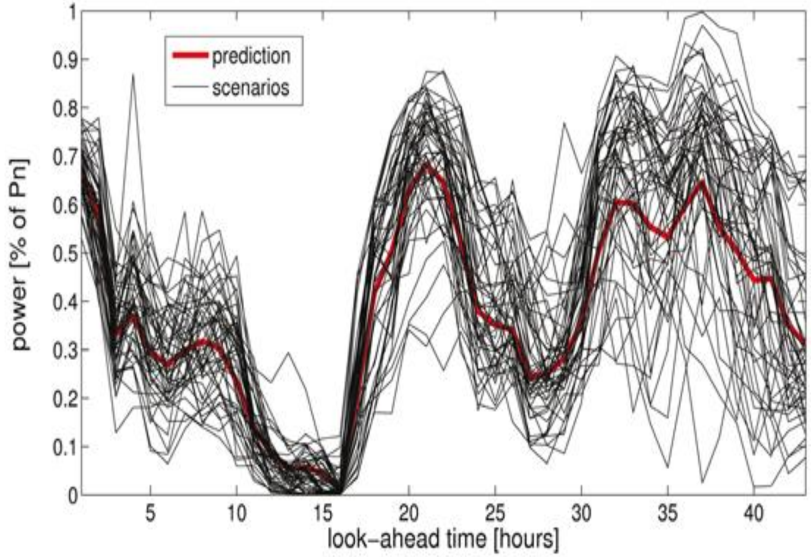
Probabilistic VG Forecasts – Motivation

- With increasing levels of VG, operations will be more concerned with uncertainty than before → need tools that can manage this uncertainty

- Uncertainty can be characterized in a number of ways and is already provided by some vendors
  - Probabilistic information as a probability distribution function
  - Confidence intervals or probability of exceedance levels
  - Ensembles/multiple forecasts
  - Probability-weighted Scenarios for how the future may unfold

- Operations or planning/integration study applications





Probabilistic data, in useful form, can be used for more than awareness

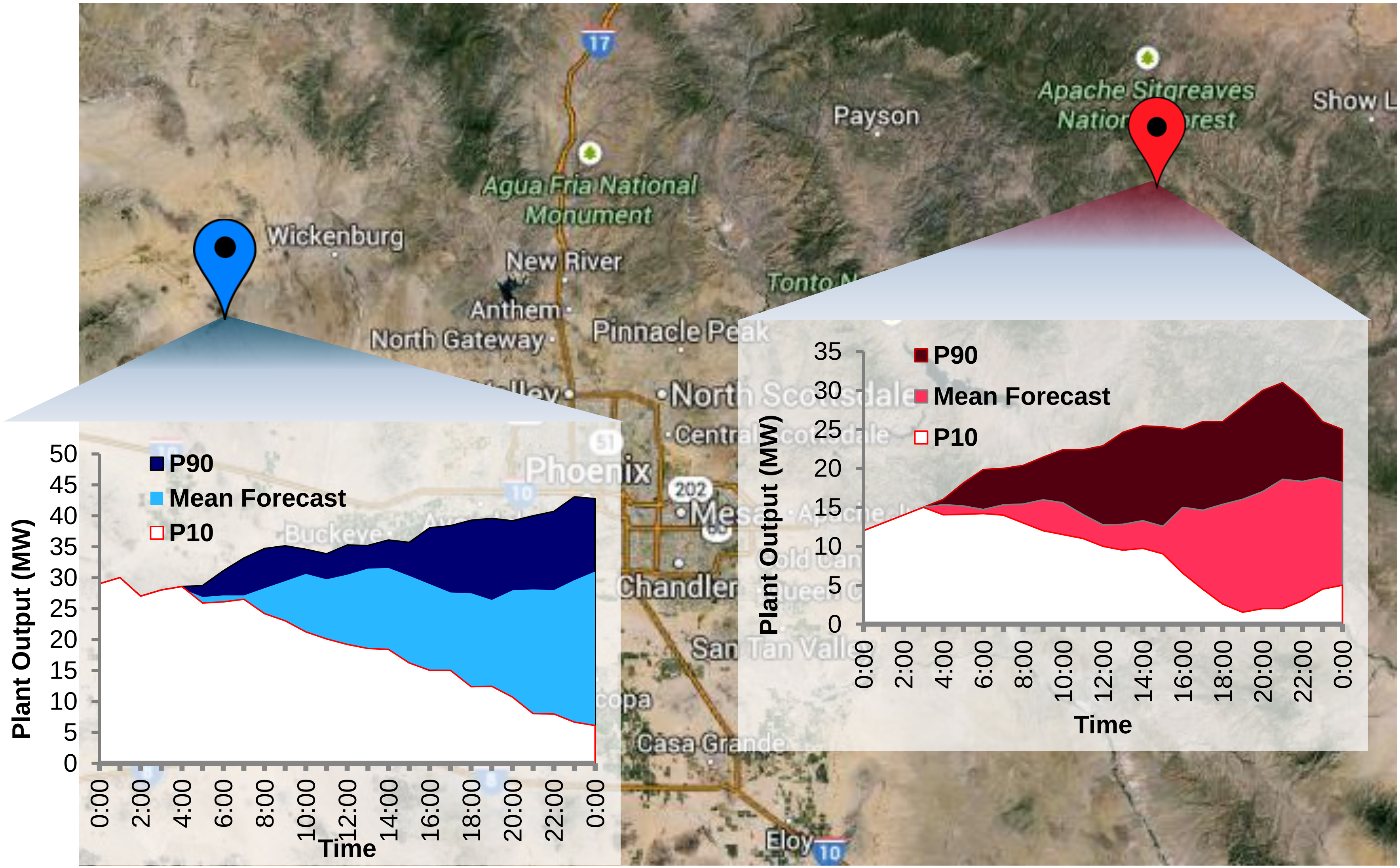
Probabilistic Forecasts – Current Areas of Interest

1. Which applications for decision making can probabilistic forecast have the greatest value?
2. How to measure the accuracy of probabilistic forecasts
3. What type of probabilistic forecasts are optimal/practical in different applications to manage uncertainty
4. How to quantify the benefits associated with probabilistic forecasts

- Specific focus on making probabilistic forecast information actionable in operations (lead to efficient decision-making)

Develop the mechanisms needed to include forecast uncertainty to enable advanced tools to be evaluated for operations and planning

Making Actionable Decisions From Probabilistic Forecasts



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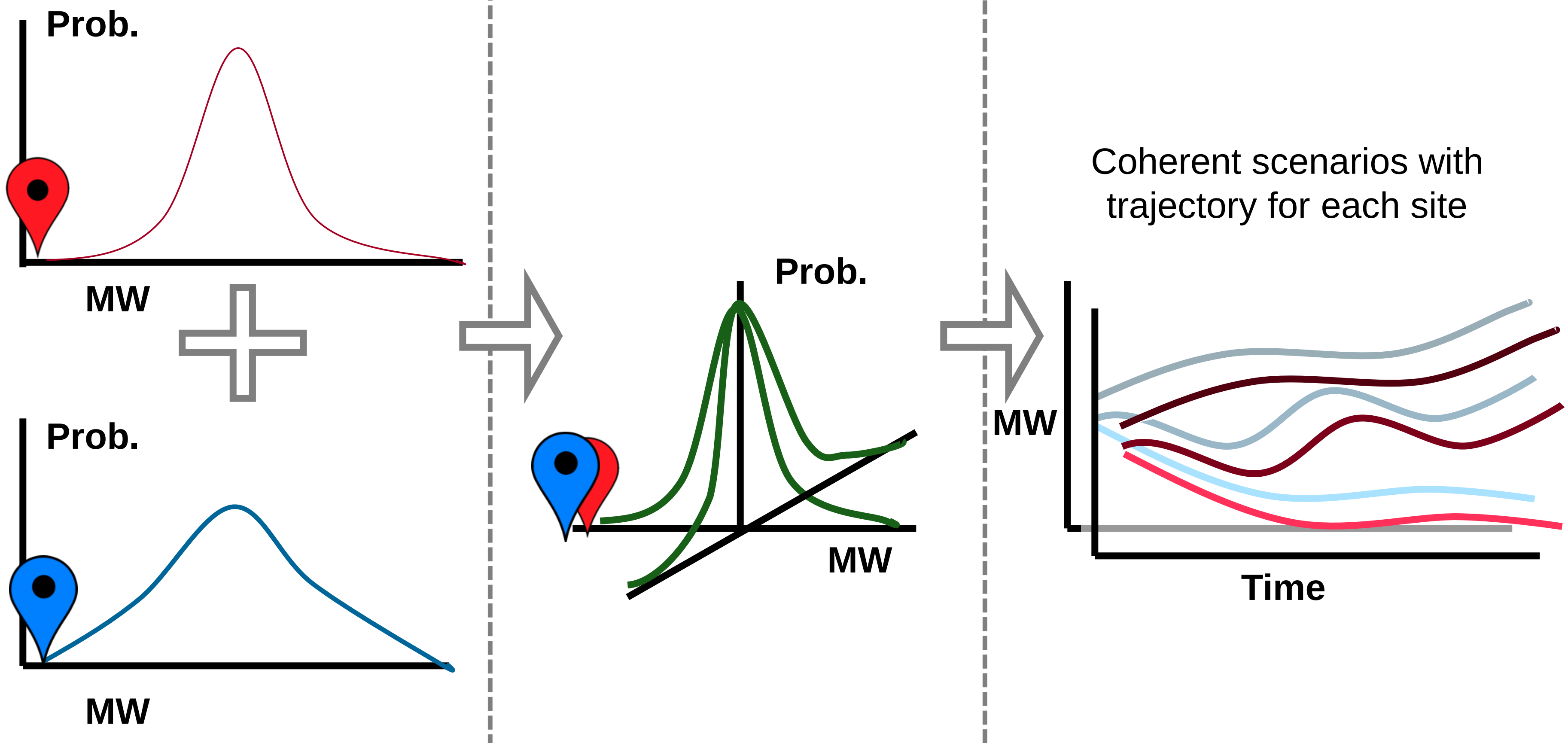
Probabilistic Trajectories

Step 1: Probabilistic Site Forecasts

Step 2: Probabilistic Aggregate Forecast

Step 3: Forecast Trajectories



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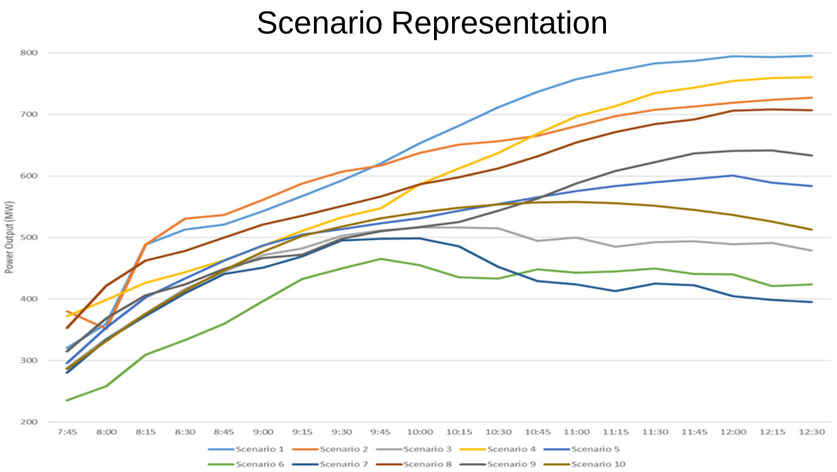
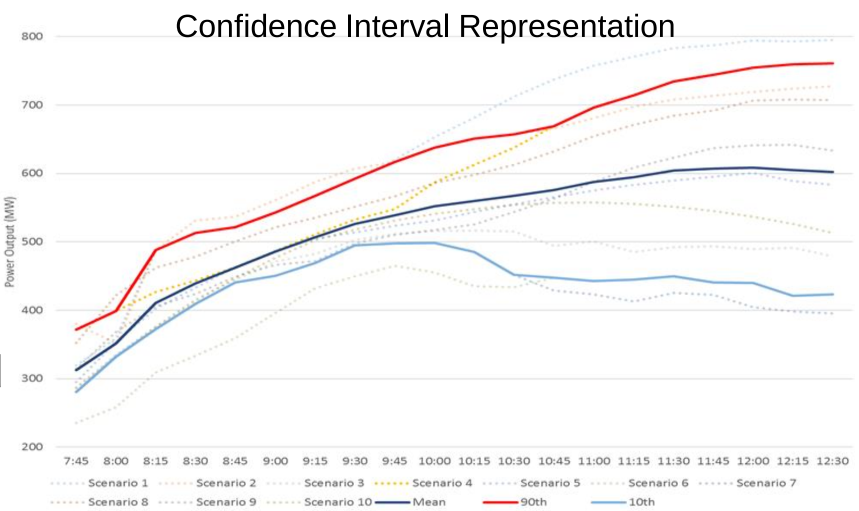
Probabilistic Forecasting Applications

- Multiple manners to determine uncertainty:
  - Run models with variation in the inputs that have uncertainty
  - Run different weather or power conversion models
  - Statistical analysis based on previous results (analog)
  - Can be displayed in numerous manners, including confidence intervals, scenarios, distributions, etc.

- Being used in practice for a number of regions – examples include
  - Spain (REE): confidence intervals set reserve requirements
  - Swissgrid: stochastic optimization for week ahead reserve procurement based on generator availability and cost
  - ERCOT: wind ramping forecast



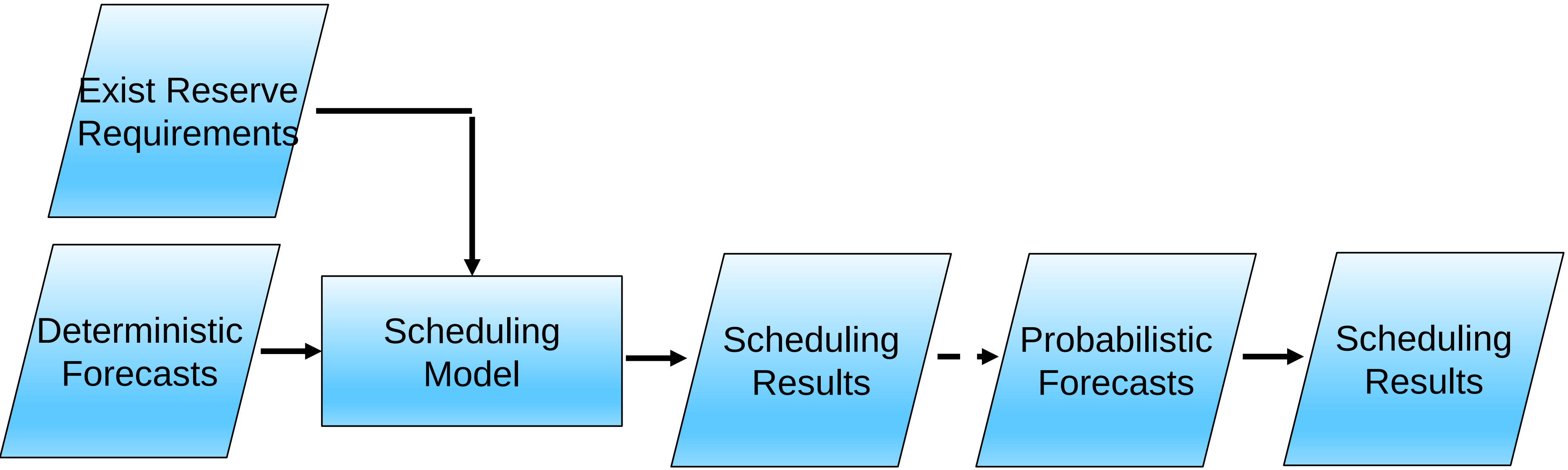


Probabilistic Forecasting Applications

Application	Description	In use?
Stochastic Scheduling (STUC)	Committing or dispatching resources to meet multiple potential scenarios based on minimizing the expected cost	N/A
Robust optimization-based Unit commitment and dispatch	Similar to STUC, but only using the “worst case” scenario to ensure the decisions are robust towards those situations	N/A
Do Not Exceed Dispatch VER Limits	Using probabilistic forecasts to determine the likelihood of VER providing greater energy than expected that can exceed balancing capabilities or network limit violations	ISO-NE
Outage Planning	Using long-term probabilistic forecasts to determine whether it is optimal to take certain units or transmission facilities out for maintenance when it is likely they are not needed and economic losses are minimal	N/A
Energy Market Trading (E.g., virtual trading)	Using potential scenarios and probability of those scenarios to assist in taking financial positions within the market (either as a VER, load, or virtual trader). Longer term probabilistic forecasts can also be used for long-term markets, like financial transmission rights.	Yes
Level of frequency response	Using probabilistic forecasts to understand the level of frequency response (or synthetic inertia) a wind plant or collection of wind plants can provide	N/A

Others: Real-time contingency analysis, topology switching, reserve scheduling

Scheduling with Probabilistic Forecasts



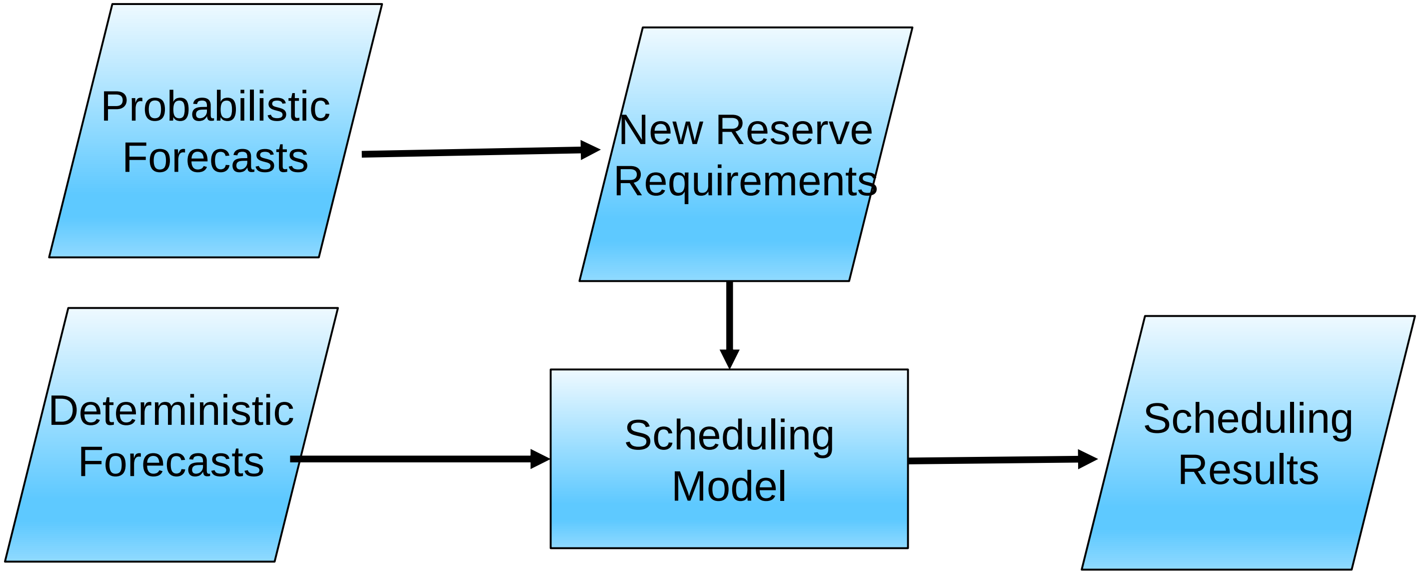
Probabilistic forecast format only limited by comfort level of operator

1. Determine Schedules through deterministic forecasts and existing reserve rules

2. Review probabilistic forecasts to see whether existing results may lead to challenges

3. Adjust schedules accordingly

Scheduling with Probabilistic Forecasts



Uncertainty Bounds (confidence intervals) likely more useful than scenarios.

1. **Determine Reserve Requirements that can meet uncertainty bounds**
2. **Determine schedules through deterministic forecasts and new reserve requirements**

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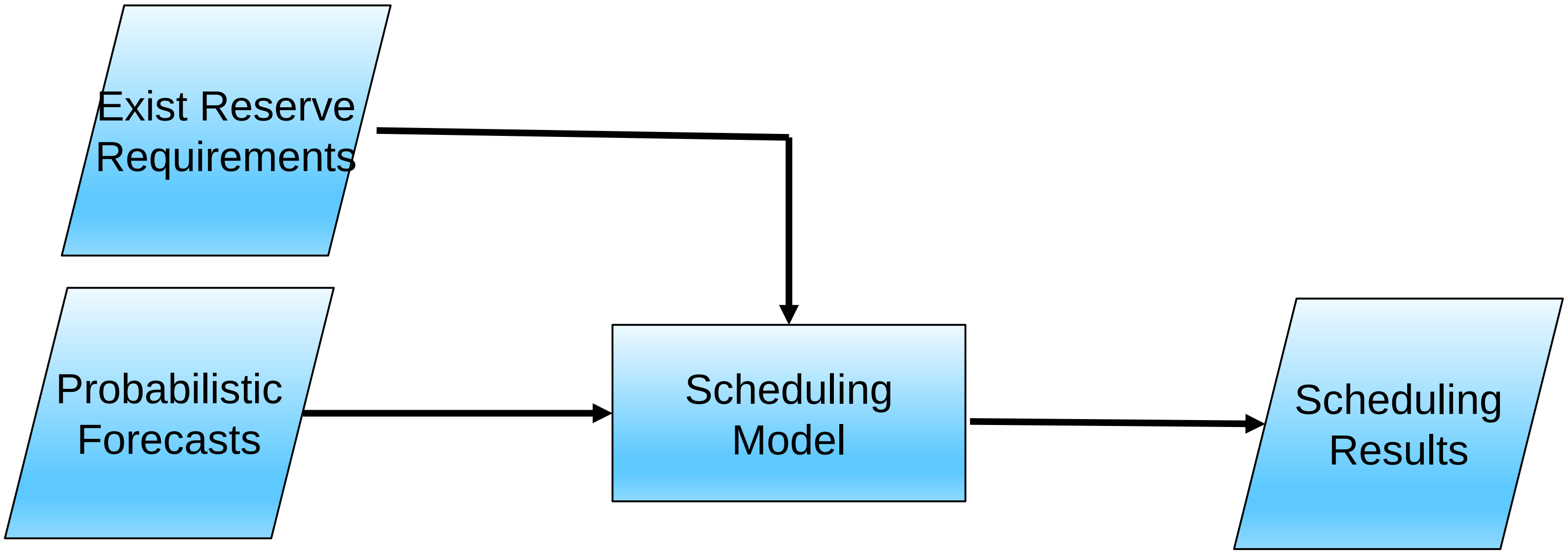
Scheduling with Probabilistic Forecasts

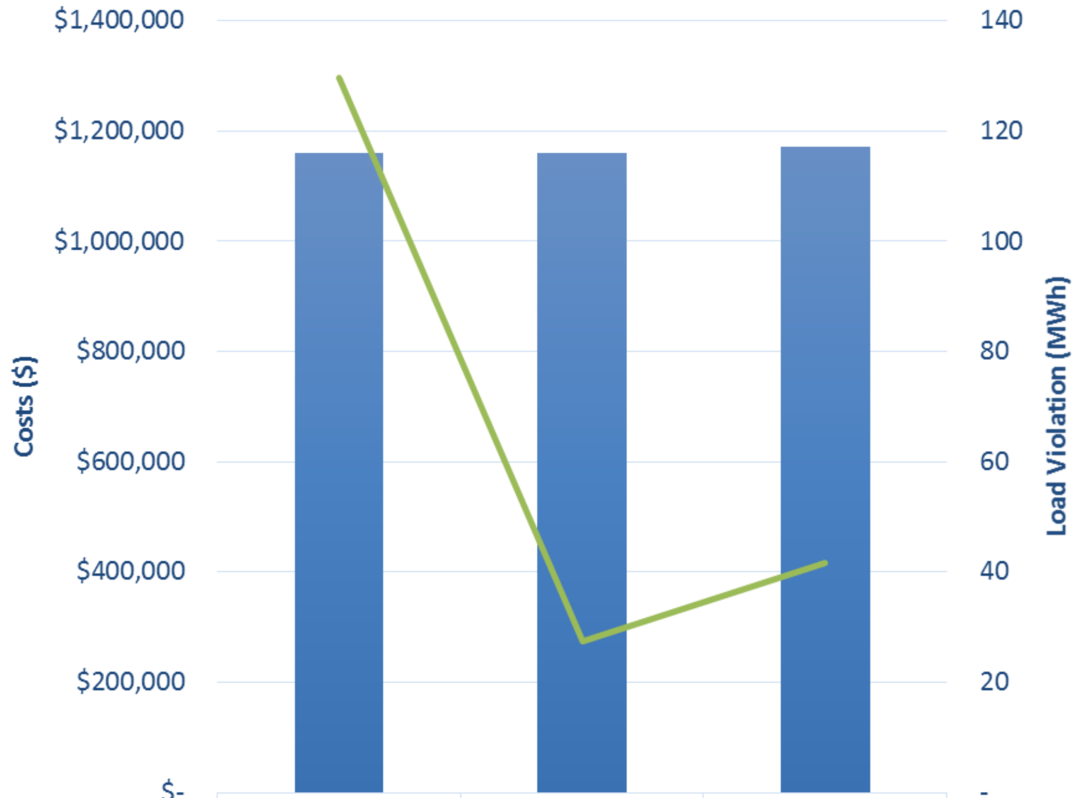


Current state of scheduling tools require discrete inputs, scenario-based forecasts most useful for stochastic programming, confidence intervals for robust optimization

1. **Incorporate probabilistic forecasts in scheduling model with existing reserve rules**

2. Using discretized version of probabilistic forecasts, determine scheduling results via stochastic, interval, robust commitment and/or dispatch procedure

Comparing different ways of using probabilistic forecasts



	Base	Advanced Scheduling Case - Stochastic	Dynamic reserve case
Operating Costs	$1,158,623.84	$1,159,343.98	$1,170,118.82
Change from Base	0%	0%	1%
Load Violation	129.58	27.50	41.67

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Stochastic Optimization in Different Stages

	First-stage decisions	Second-stage decisions
Resource adequacy	Investment decisions, dedicated RA resources	Production
Stochastic Outage Scheduling	Unit maintenance scheduling	Production
Stochastic DASCUC	Start-up and shut-down indicators, and unit status for all long-start generators	Unit status for all quick-start generators and dispatch and reserve schedules for all generators
Stochastic RTSCUC	Start-up and shut-down indicators for quick-start generators in binding intervals	Start-up and shut-down indicators for quick start units in look-ahead intervals. Dispatch and reserve schedules for all units and intervals.
Stochastic RTSCED	Dispatch and reserve schedules for all units in binding intervals	Dispatch and reserve schedules in look-ahead intervals

Which decisions are binding will influence the type of benefit observed

Challenges

1. Computational burden of sophisticated applications that use probabilistic forecast make practical applications challenging
2. Valid probabilistic forecast data – a poor probabilistic forecast is just as bad as a poor deterministic forecast, but accuracy more difficult to measure
3. Trust in probabilistic forecast still required for auto-decision-making
4. Electricity market design – Markets are complex, stakeholders want simplicity, probabilistic LMPs, etc., add to complexity

Many of these challenges are being overcome. Some require the "next best" solution.

Together…Shaping the Future of Electricity

Questions & Feedback?