Integration of Multiple Timescales and Decisions of the Electric Power System

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EPRI Grid Operations and Planning

Energy Systems Integration 102

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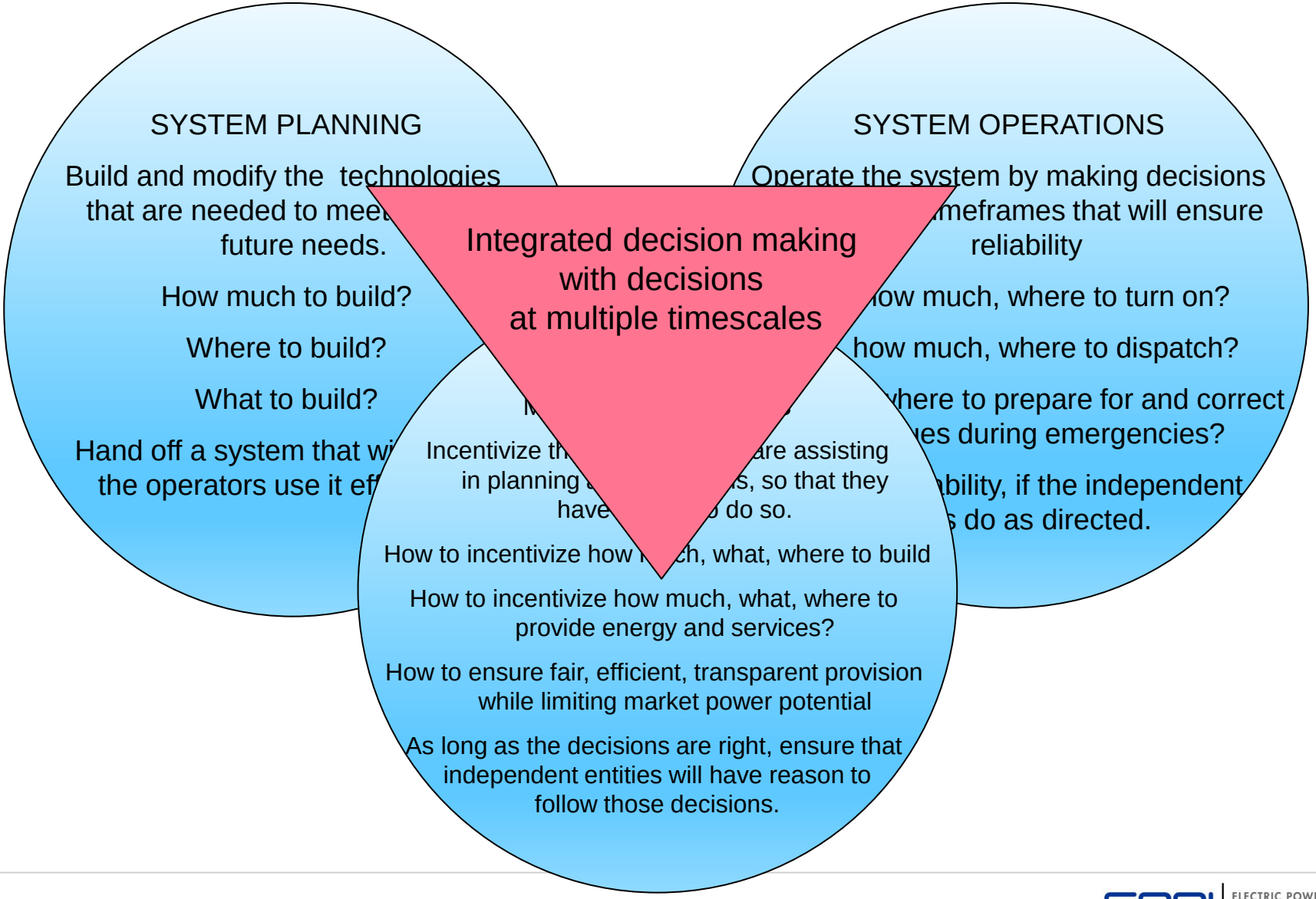
Outline

- Overview: What is the importance of understanding the impacts of multiple timescales
- Planning
- Operations
- Markets
- Modeling approaches
- Impacts of increasing variability and uncertainty

Planning, operations and markets



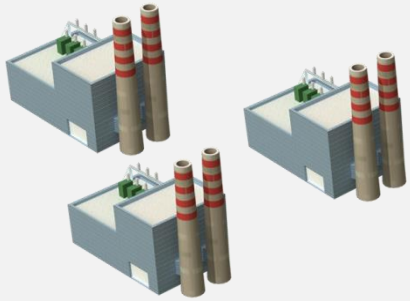
Planning

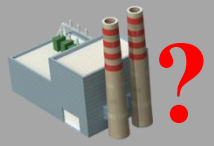
System Planning

- Planning for infrastructure needs
  - Transmission
  - Distribution
  - Gas Pipelines
- Planning for Generatio needs
  - Conventional
  - Renewable
  - Behind the meter, storage
- Each has a different construction time
- Integrated plannin decisions could ge crowded!

System Planning – Uncertainty

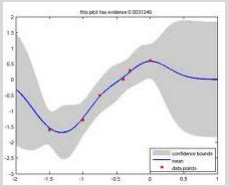
Generation





Energy Policy

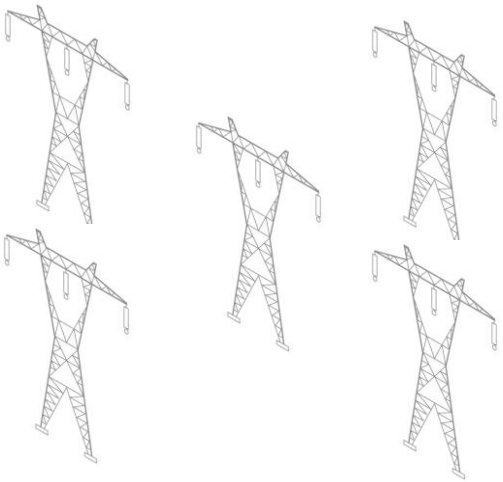
Fuel Prices



Gen Output/Dispatch

Transmission

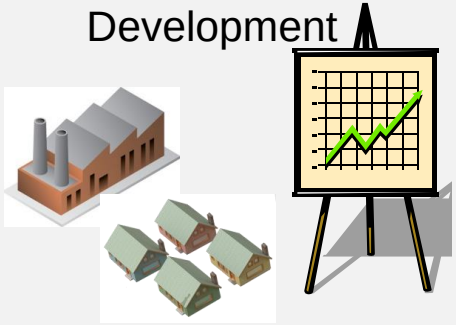
Reliability Projects



Economic Projects

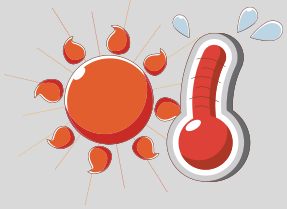
Contingency Depth

Future Load Development



Macro-Econ. Uncertainty

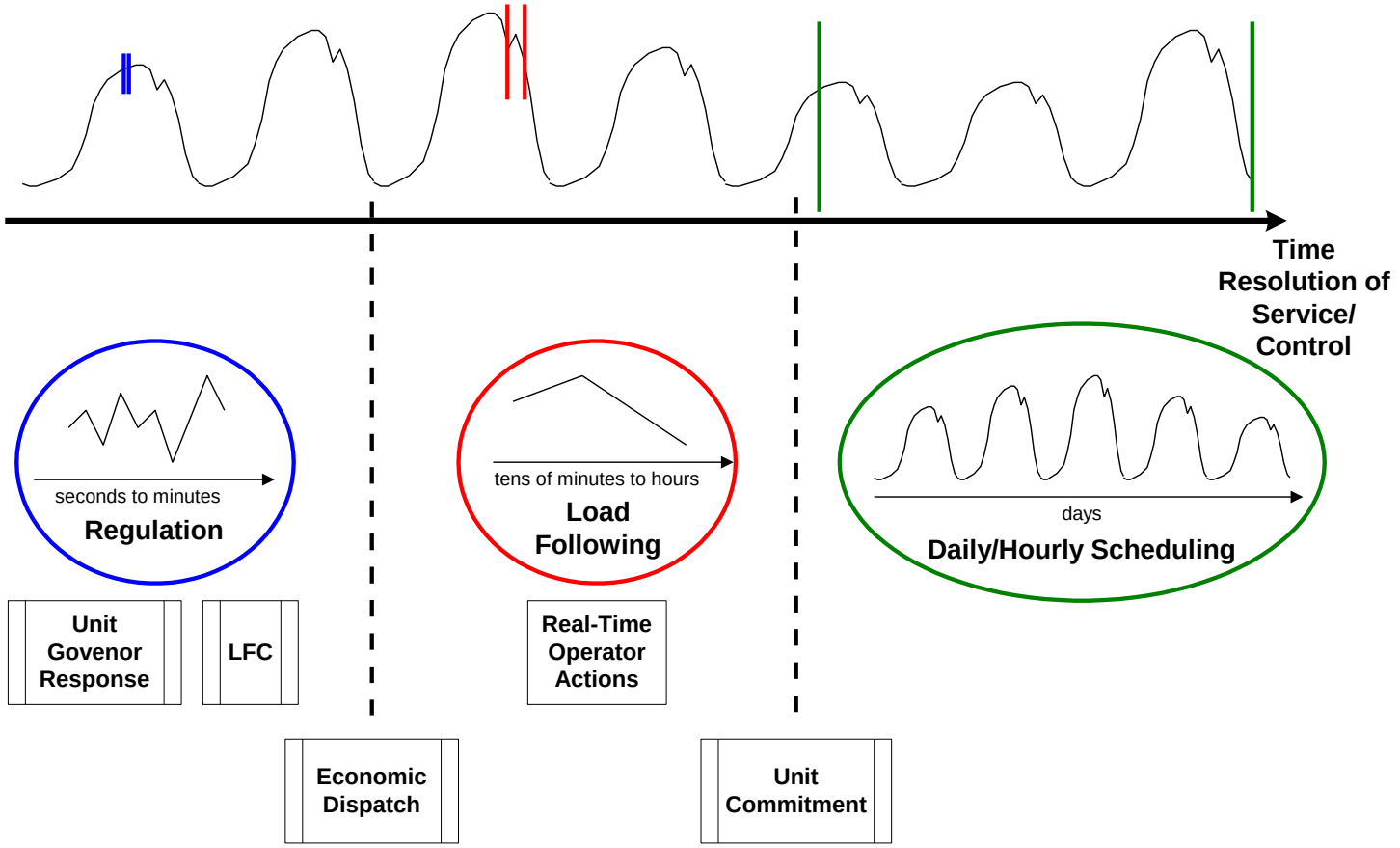
Distributed Resources



Extreme Weather/Load

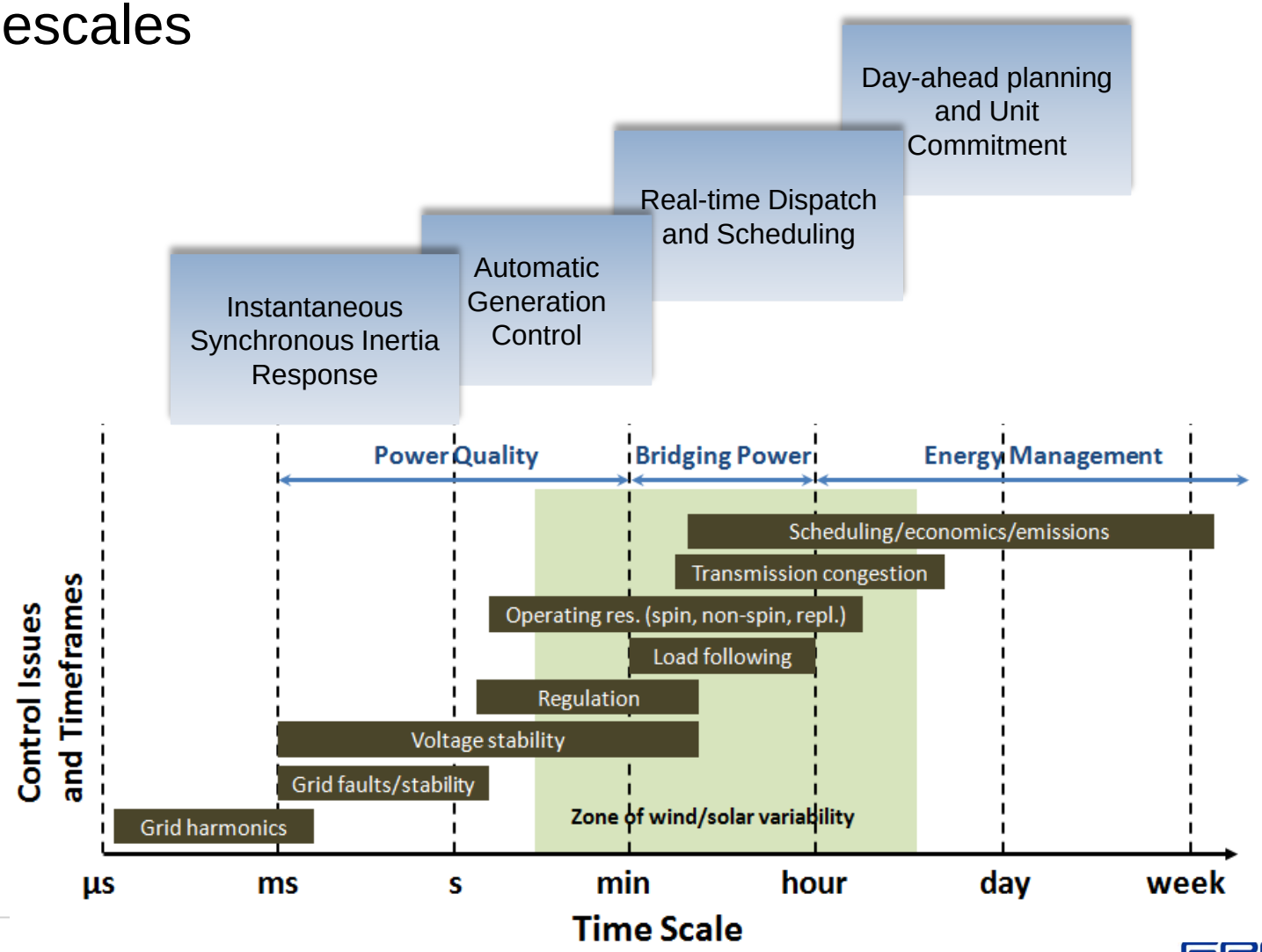
Operations

Changing Patterns require different Operational Decisions



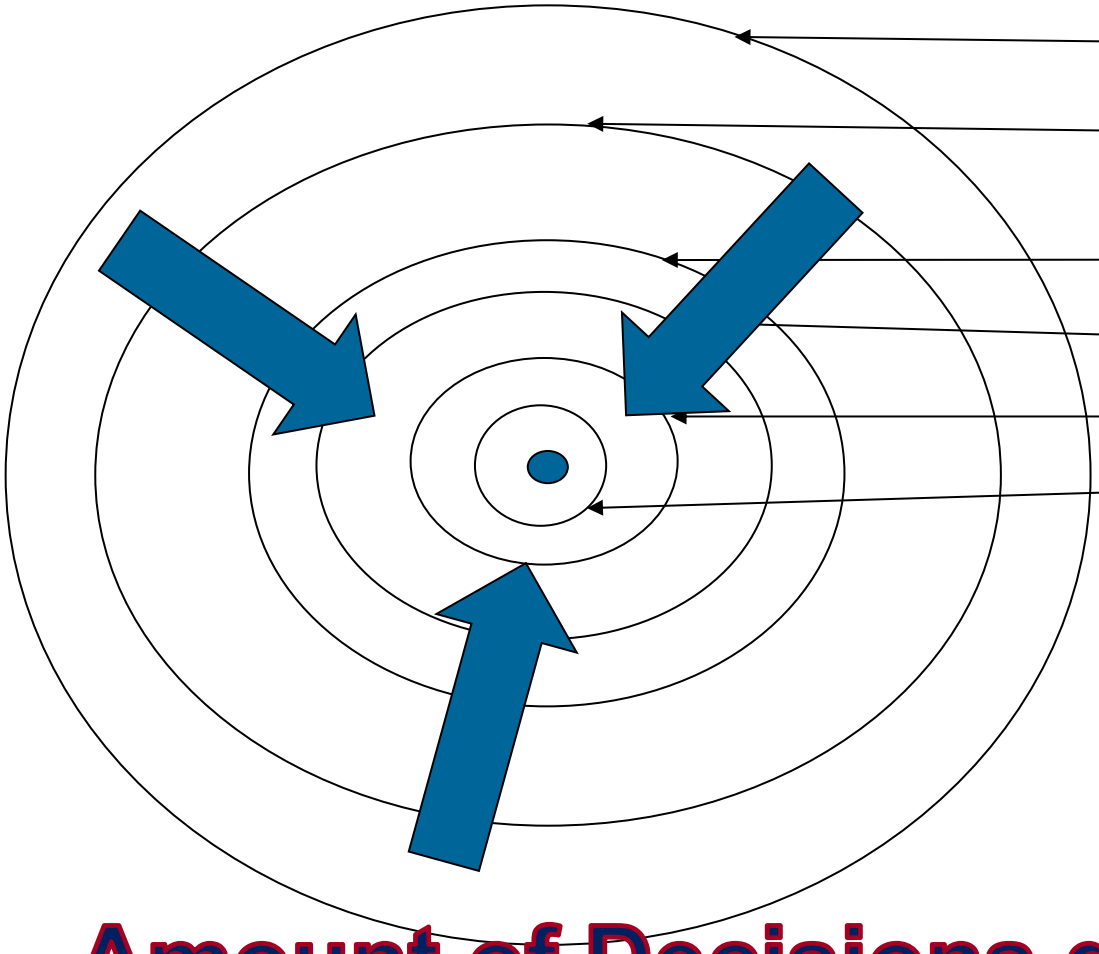
Bulk Power System Operations

- Power System Operational decisions divided among timescales



Decision Circle

Uncertainty decreases



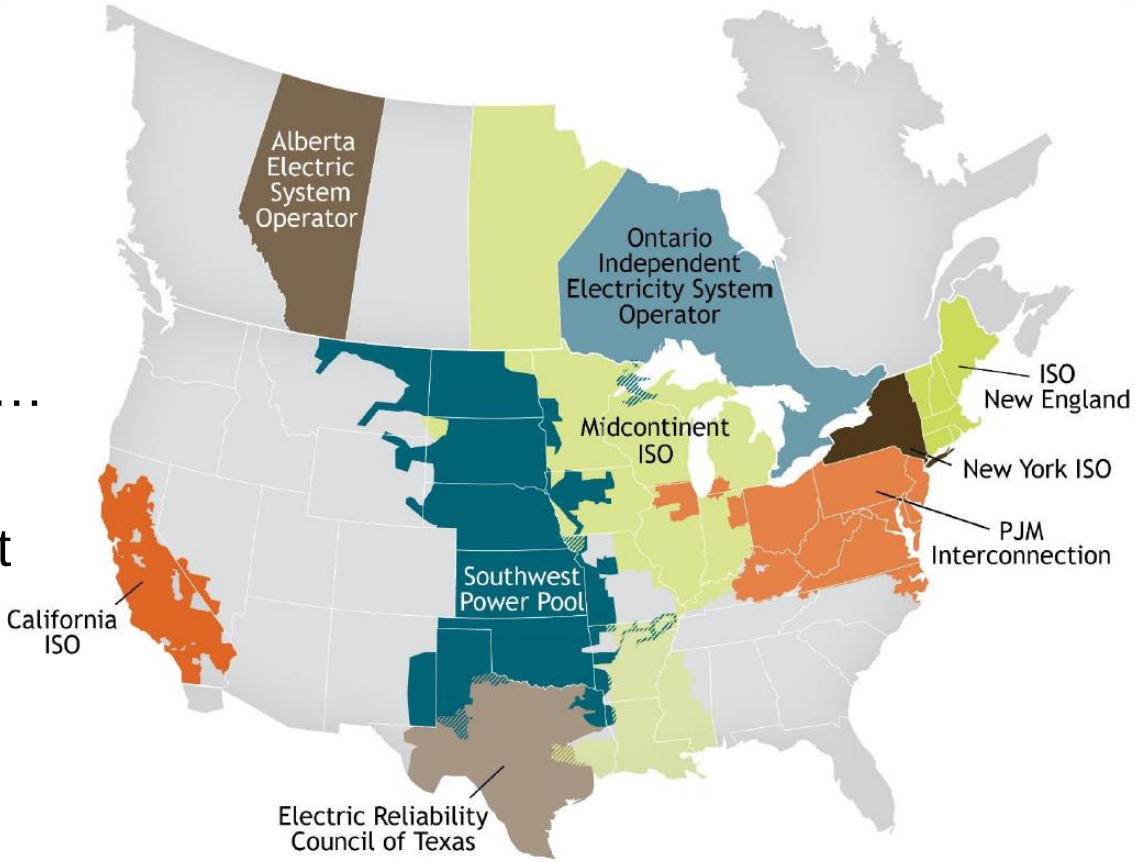
Amount of Decisions decreases

Adapted from Y. Chen, MISO slides

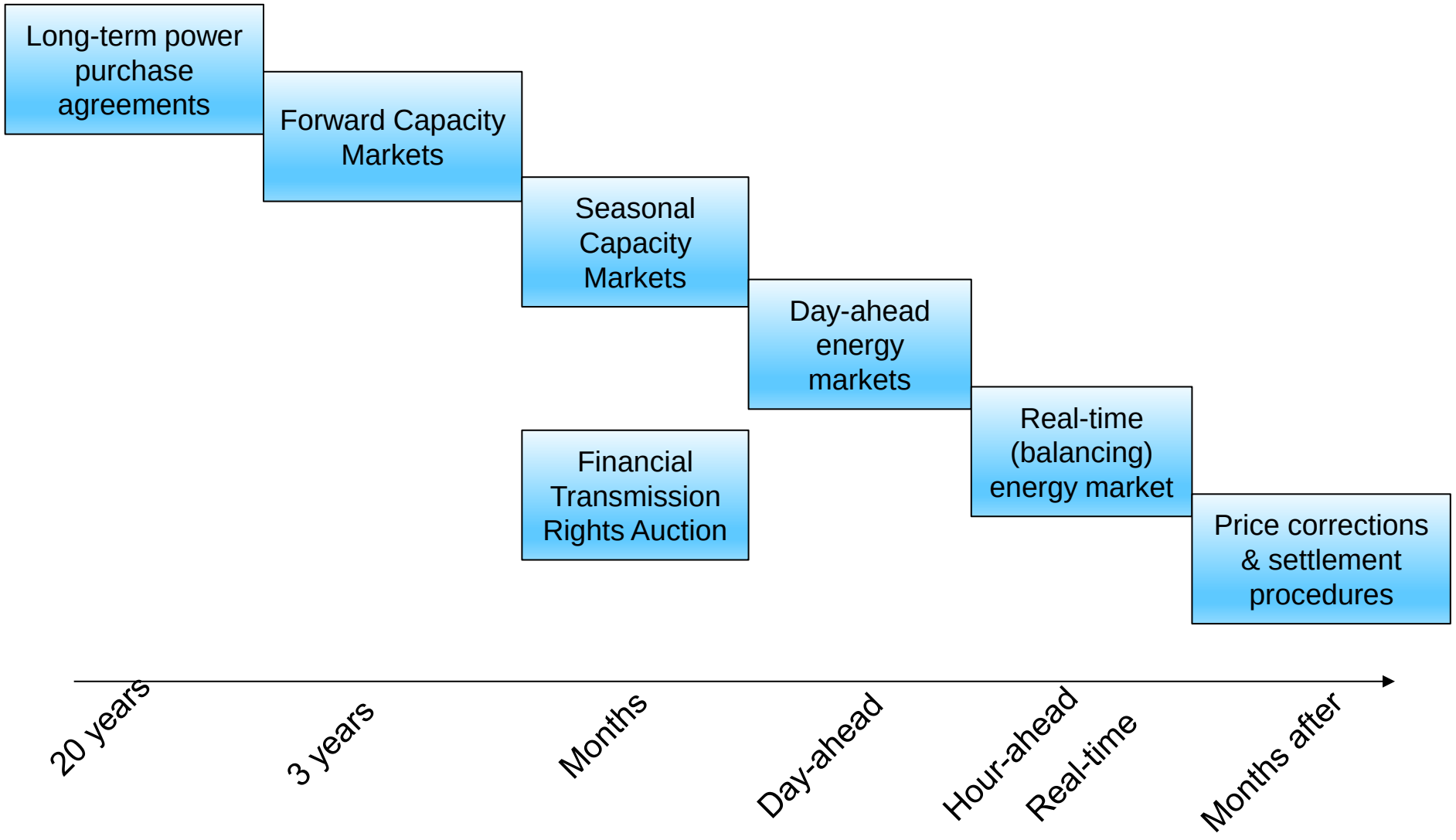
Markets

Electricity Markets

- Both restructured and vertically integrated areas
- Trading, pricing, and incentive structures all exist at different timescales
- System Planning and System Operations Plus…
- Do it so that independent entities have a reason to listen to you.

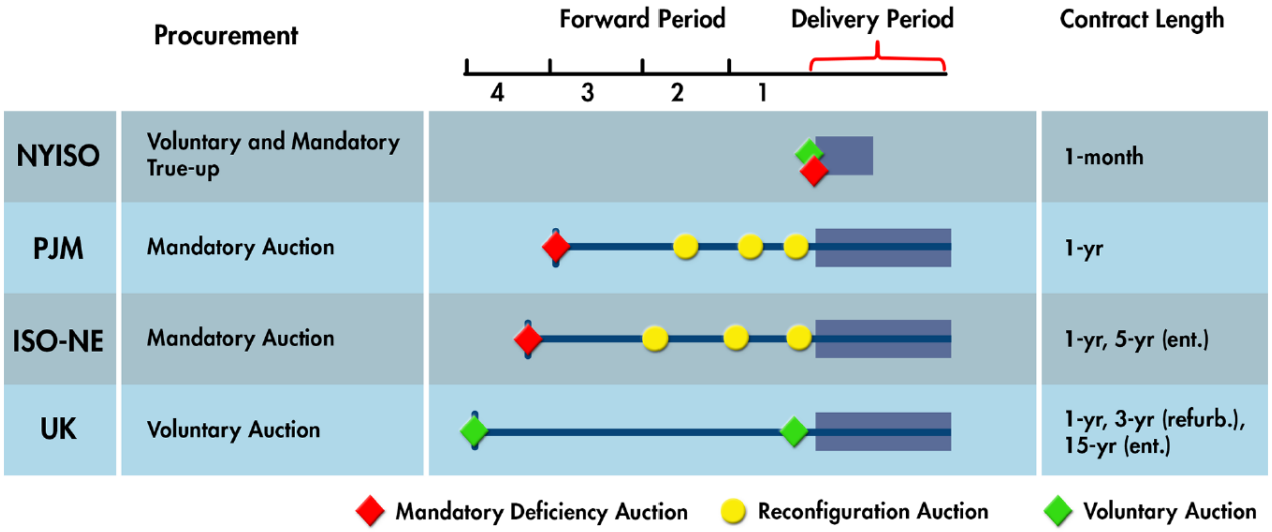


Electricity Markets at Multiple Timescales



Variety

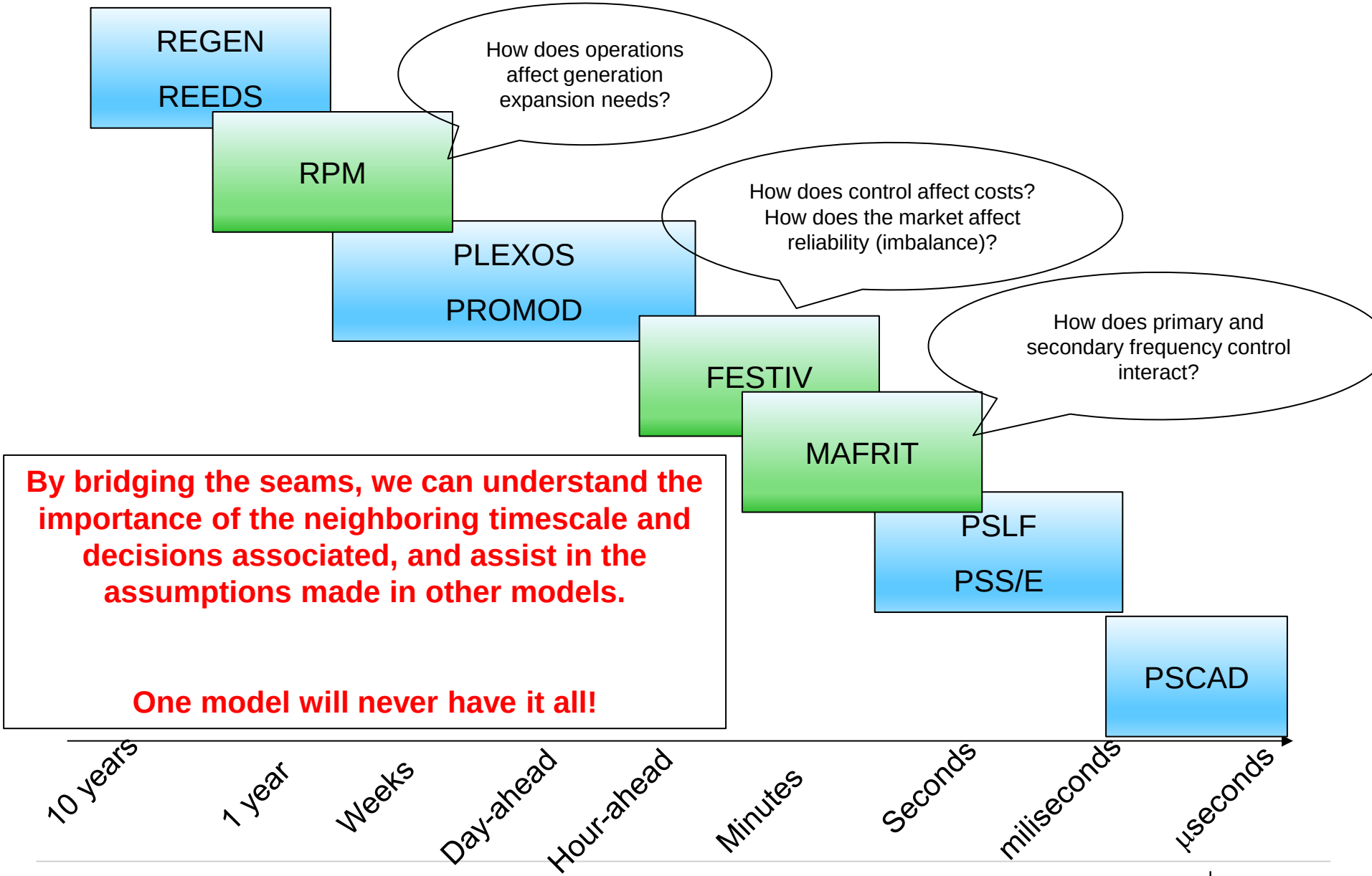
- Each market has different rules
- Different time frames, different market clearing horizons, different market updates, different settlement intervals
- Adds complexity to these issues



G. Anstey and M. Schönborn, "The British Capacity Market: Reflections on a Visible Hand," *Energy Market Insights*, no. 11, Dec. 2014.

Modeling Multiple timescales

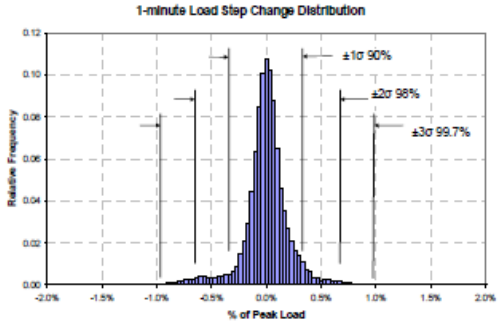
Bridging the Seams with Advancing Models

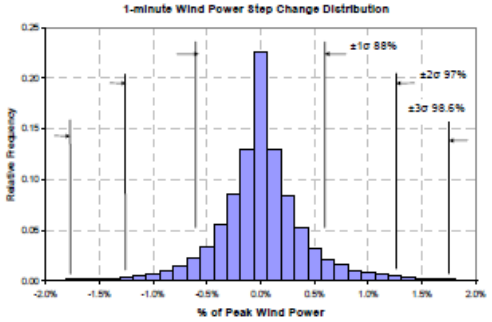


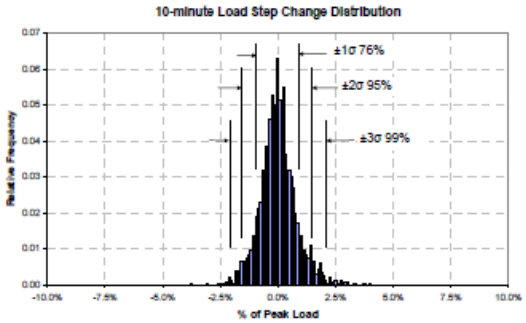
By bridging the seams, we can understand the importance of the neighboring timescale and decisions associated, and assist in the assumptions made in other models.

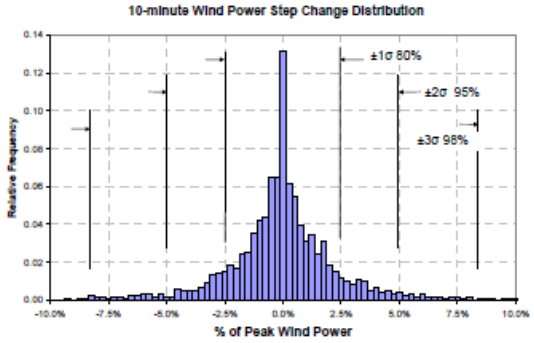
One model will never have it all!

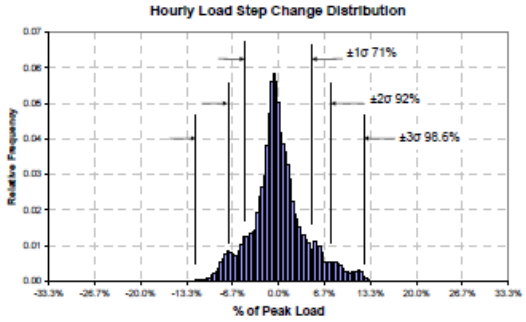
Variability Occurs at Multiple Timescales

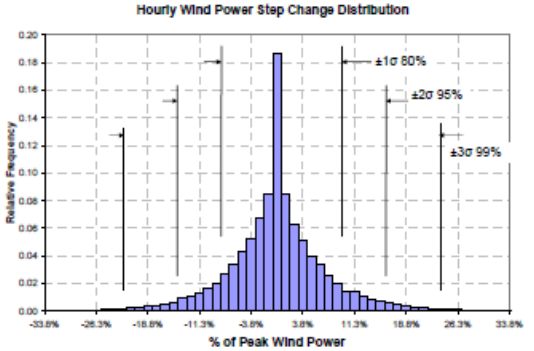


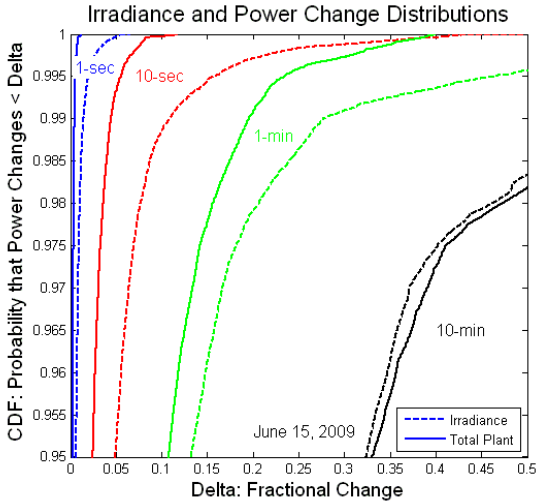










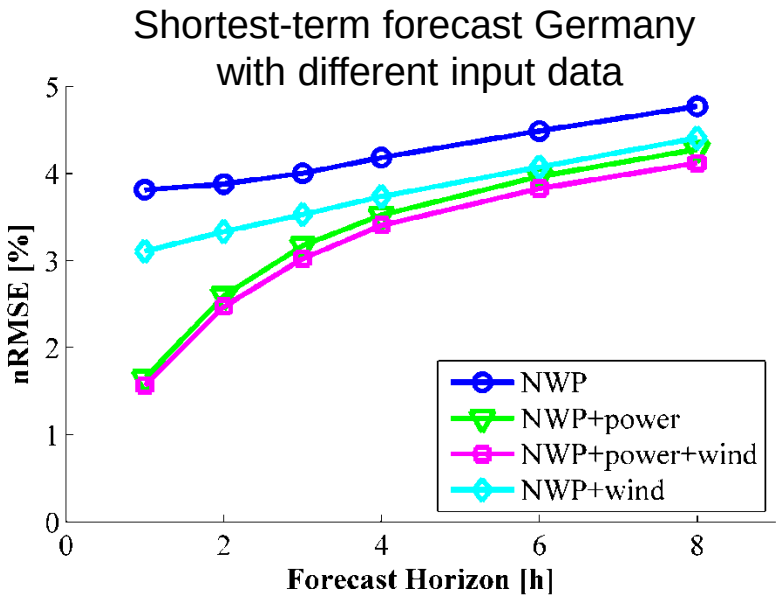


A. Mills et al, "Understanding Variability and Uncertainty of Photovoltaics for Integration with the Electric Power System," *Electricity Journal,* 2009.

Wan. Y. (2005). *A Primer on Wind Power for Utility Applications.* NREL/TP-500-36230. Golden, CO: NREL.

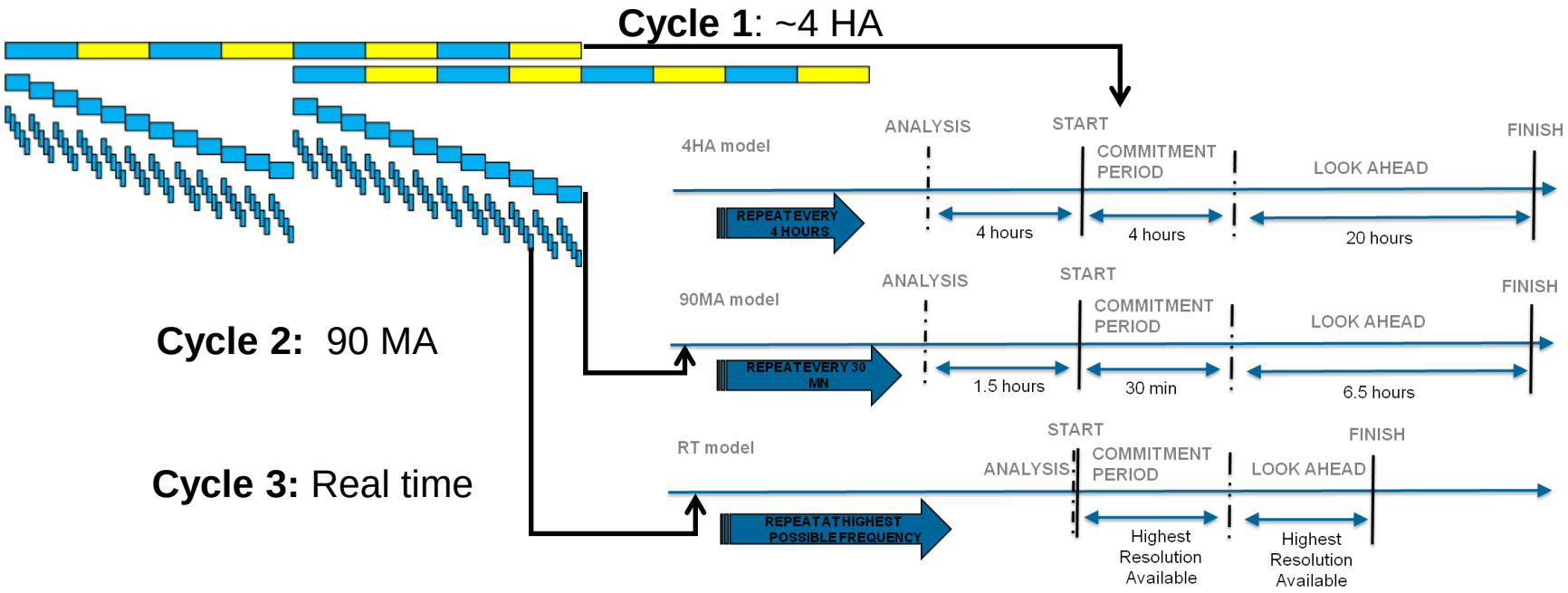
Uncertainty Occurs at Multiple Timescales

- Forecasting occurs at different horizons
  - Annual, day-ahead, hours-ahead
- Load, wind, solar, DR, PEV
- Probabilistic vs. Deterministic



Peak Load	Wind Generation	Annual Operating Cost Savings	
		SOA Forecast vs. No Forecast	Perfect Forecast vs. SOA Forecast
64 GW	7.5 GW	$ 68M	$ 19M
64 GW	12.5 GW	$ 160M	$ 38M
33 GW	3.3 GW	$ 95M	$ 25M
65 GW	5.0 GW	$ 20M	$ 20M
65 GW	10.0 GW	$ 180M	$ 60M
65 GW	15.0 GW	$ 510M	$ 10M

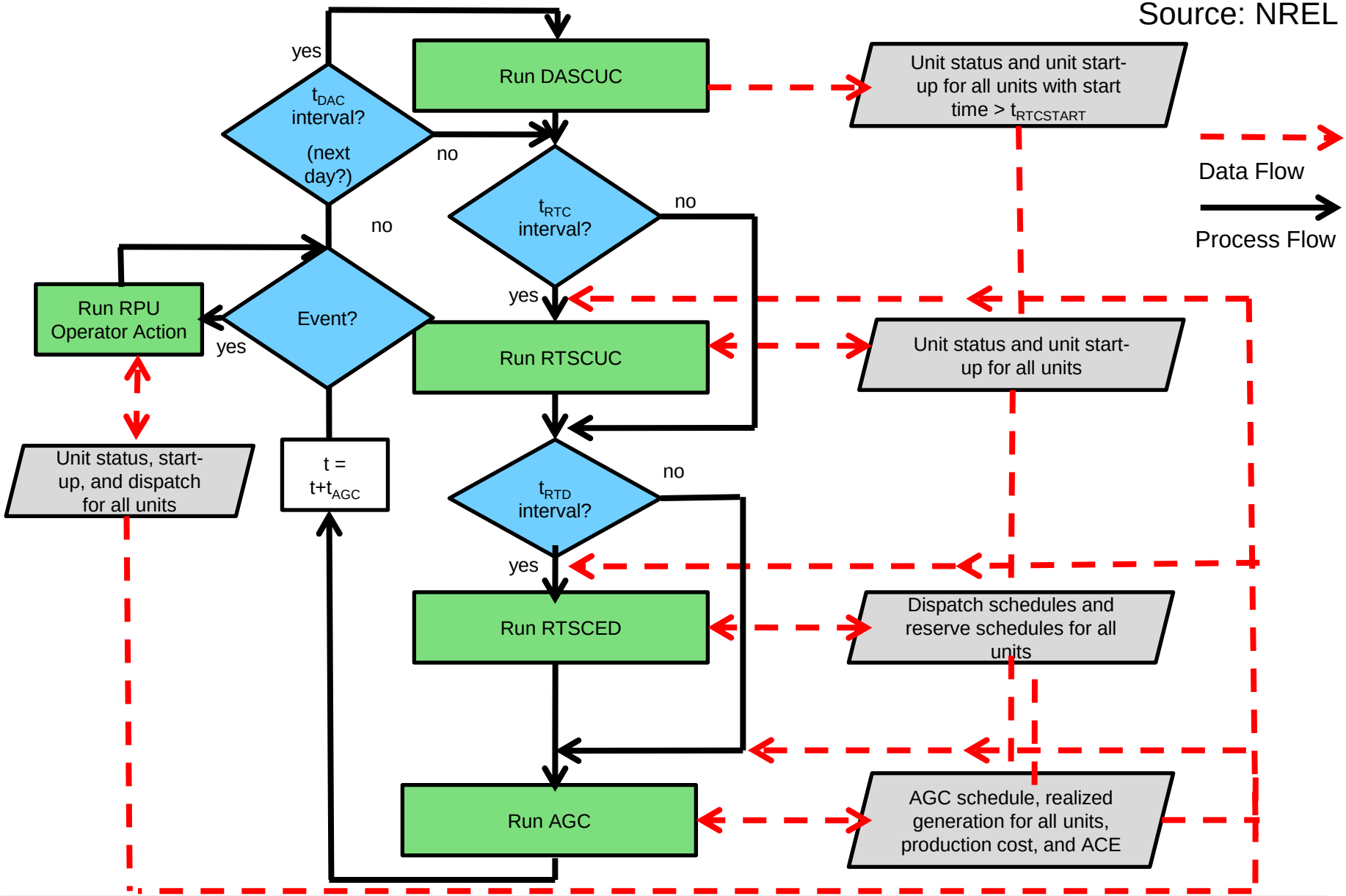
Multiple Decision Cycles: Example



- Decisions can be clock based (e.g. every x hours or minutes) or event driven (e.g. if net load is expected to change by more than X MW in the next Y hours)
- Clock based scheduling implemented in ISOs.
- Event driven scheduling in places such as UK

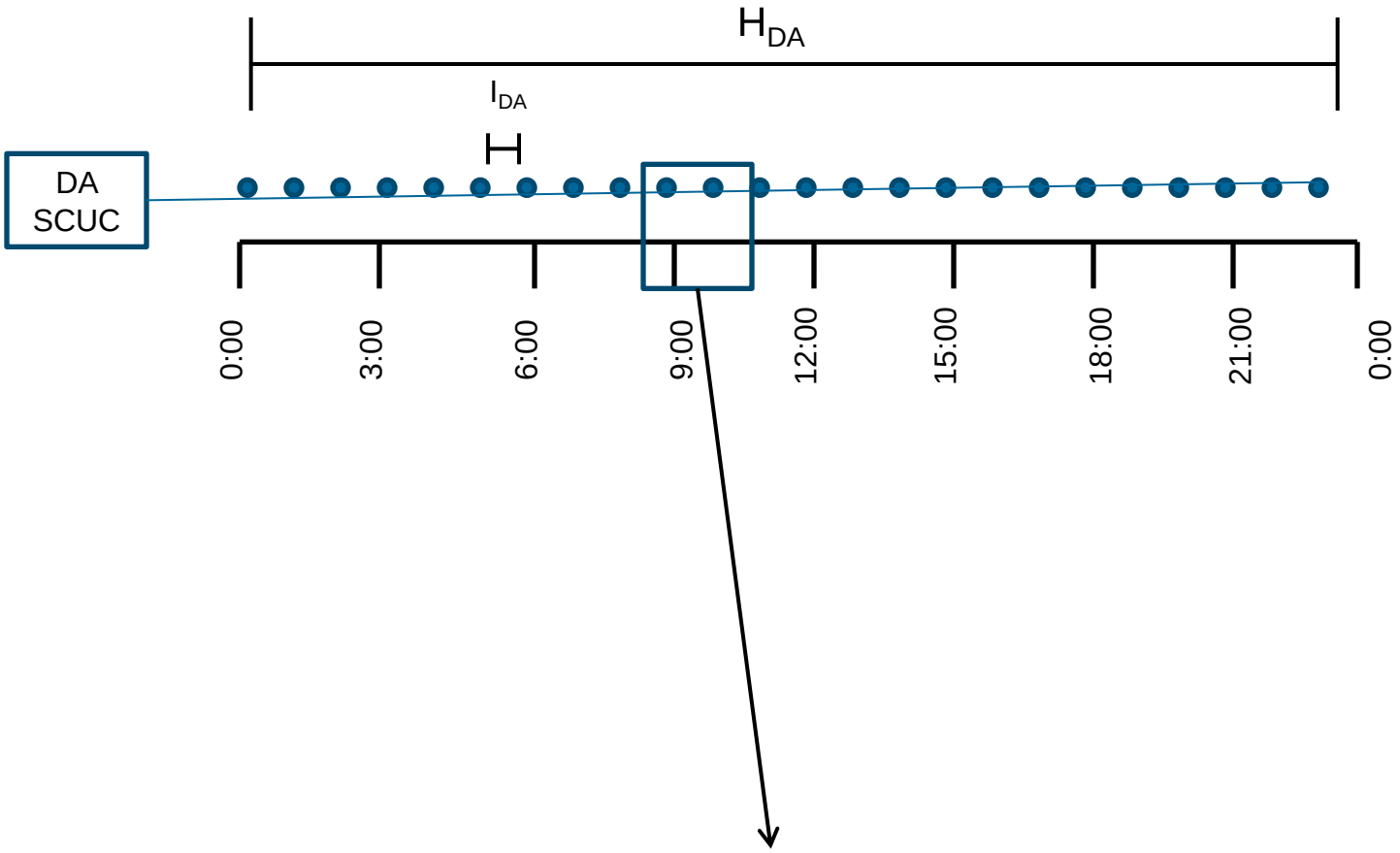
Source: PSO

FESTIV Flow Diagram

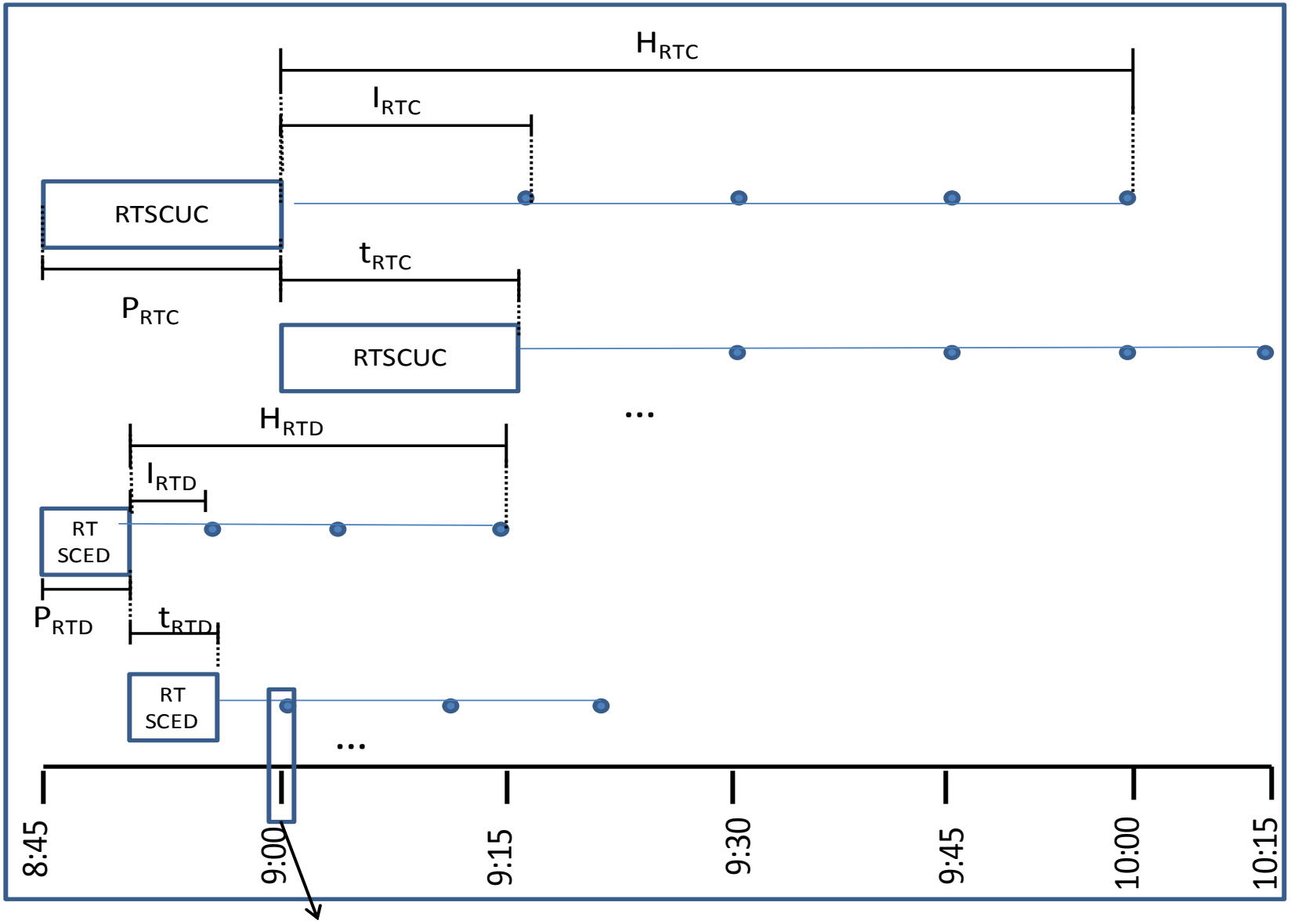


Ela, O'Malley, "Studying the variability and uncertainty of variable generation at multiple timescales," IEEEE Trans. Power Syst., 2012

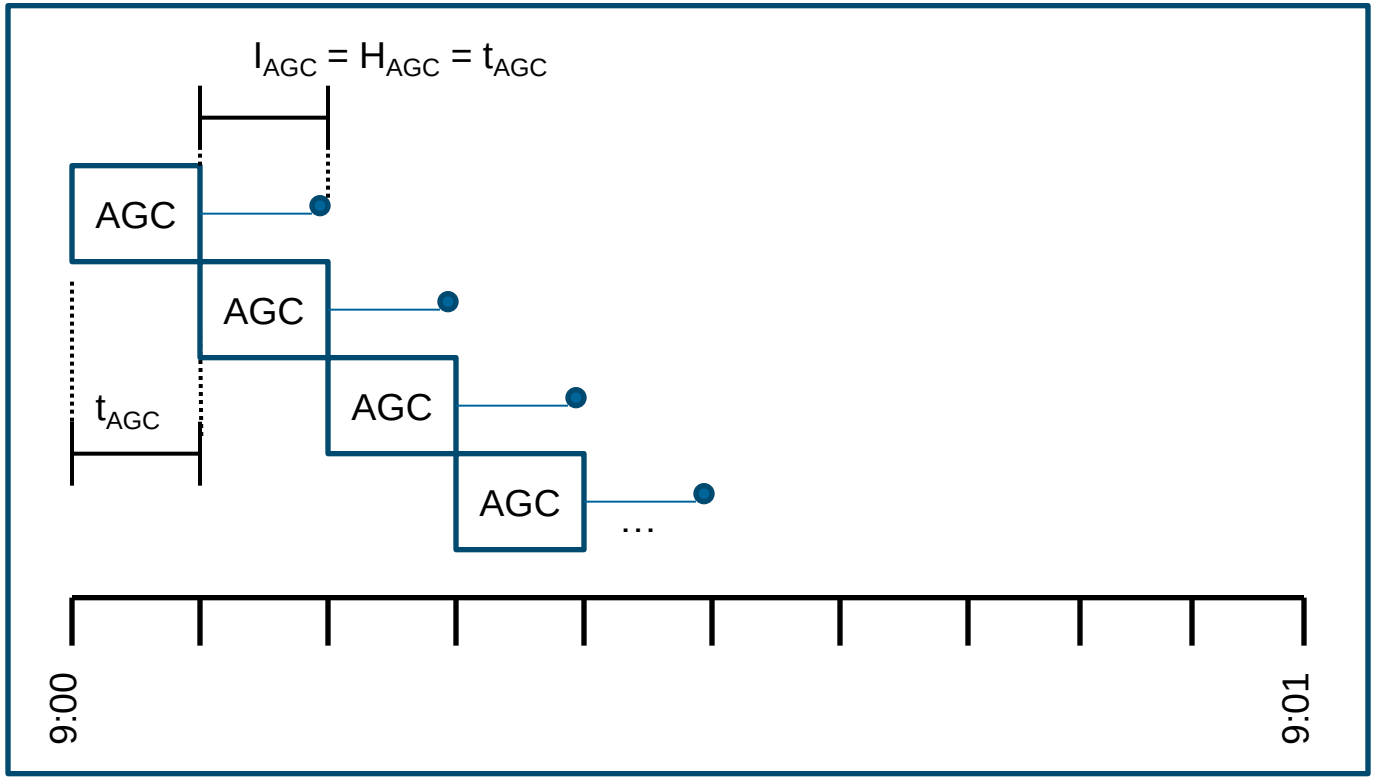
DASCUC parameters



RT SCUC/SCED parameters



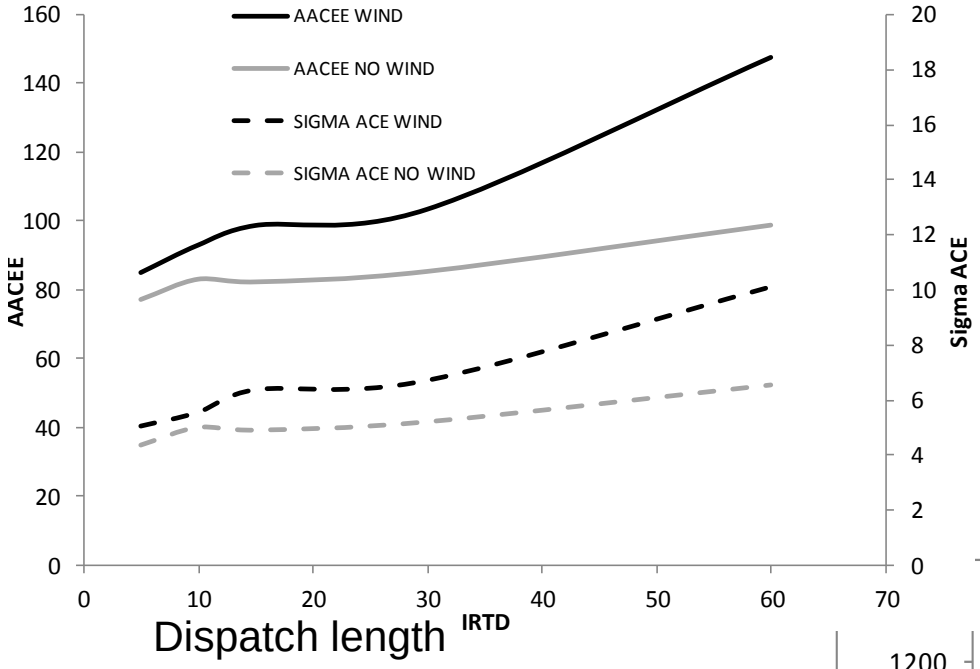
AGC parameters



Timescale adjustments

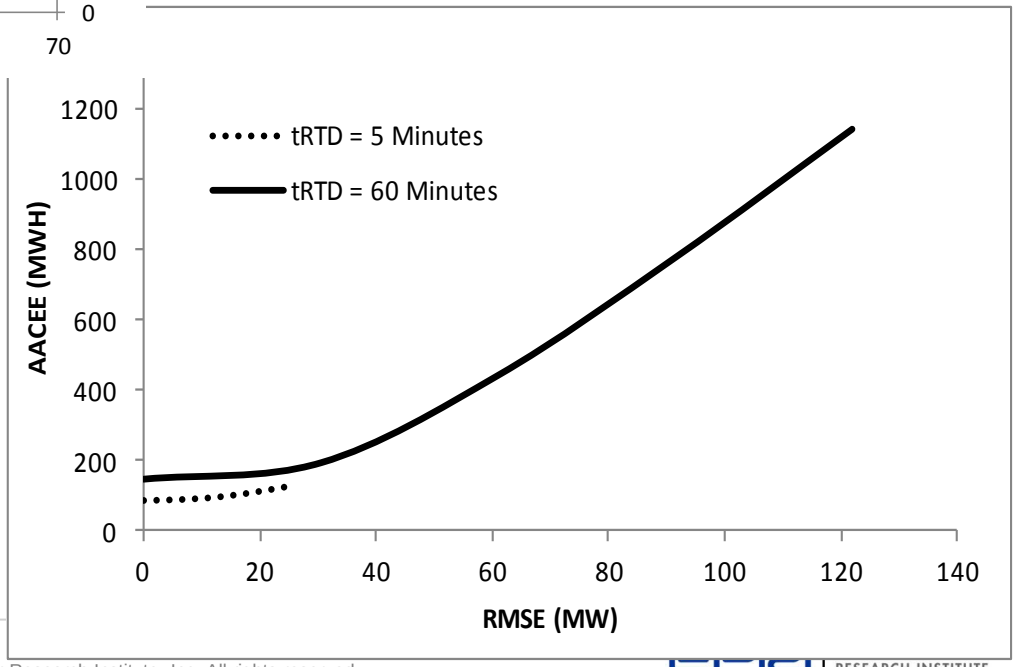
Time frame adjustment	Example	Impact
Increased time resolution	Move from hourly to fifteen minute Day-ahead Unit commitment	Better ability to meet expected variability occurring within the scheduling interval
Increased time horizon	In five-minute dispatch, also look ahead an hour	Better ability to meet expected variability occurring after the interval
Faster Update Frequency	Update the intra-day commitment every hour rather than every four hours	Better and more accurate information to reduce impacts of uncertainty

Timescales of operational procedures have different impacts



Variability

Uncertainty



Different Decisions at Different Time Frames

Procedure	Time frame	Decision	Made by	Based on
Annual Maintenance Scheduling	Annual or seasonal	When to take unit out for maintenance	Generating units coordinated by ISO	When prices are lowest, when generator not needed for reliability
Long-term unit commitment	Week or more	When to start very slow-starting units (nuclear, super-critical coal)	ISO	Minimizing Production costs and reliability needs
Day-ahead unit commitment	24 or 48 hours	When to start steam turbines	ISO	Minimizing Production costs and reliability needs
Intra-day unit commitment	4-6 hours	When to start combined cycle plants	ISO	Minimizing Production costs and reliability needs
Real-time unit commitment	1-3 hours	When to start combustion turbines and other quick start (PSH)	ISO	Minimizing Production costs and reliability needs
Real-time economic dispatch	5 minutes – 1 hour	Economic dispatch point for all flexible units	ISO	Minimizing Production costs and reliability needs
Automatic generation control	2-6 seconds	Set point for units with automatic control	ISO	Minimize area control error

Changes to decisions process at different timescales may have different effects

- Increasing reserve for only that scheduling model based on educated information on variability and uncertainty
  - Reserve all “released” in subsequent models
- Compared to no reserve case
- Similar benefits to other methods (e.g., stochastic modeling, improved forecasting, etc.)

	Benefit
Day-ahead SCUC	Reduces costs
Real-time SCUC	Reduces the number of price spikes
Real-time SCED	Reduces the amount of imbalance (ACE)

What is the goal?

Timescales can have impact on incentives

- Using FESTIV Model
- 118-bus modified IEEE system, Perfect forecasts in all time frames, hourly day-ahead SCUC, 30-min real-time SCUC, 20% wind penetration, 6-second AGC, 24 hour simulation.

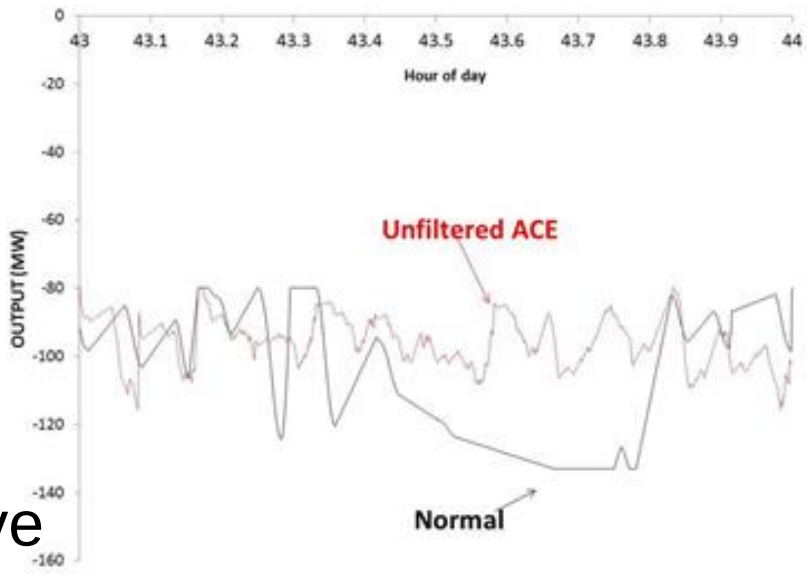
	SCED at 5-minute intervals	SCED at 1-minute intervals
Regulation Reserve	Regulation reserve at 1% load	No regulation reserve
σ_{ACE} (MW)	4.46	3.04
Cost ($)	$742,920	$742,351
Total Revenue ($)	$218,980	$211,274

- Improved reliability, same costs, but **less profit**. Missing money?

FESTIV Model:

Ela, O'Malley, "Studying the variability and uncertainty of variable generation at multiple timescales," IEEEE Trans. Power Syst., 2012

Uncovering New Findings

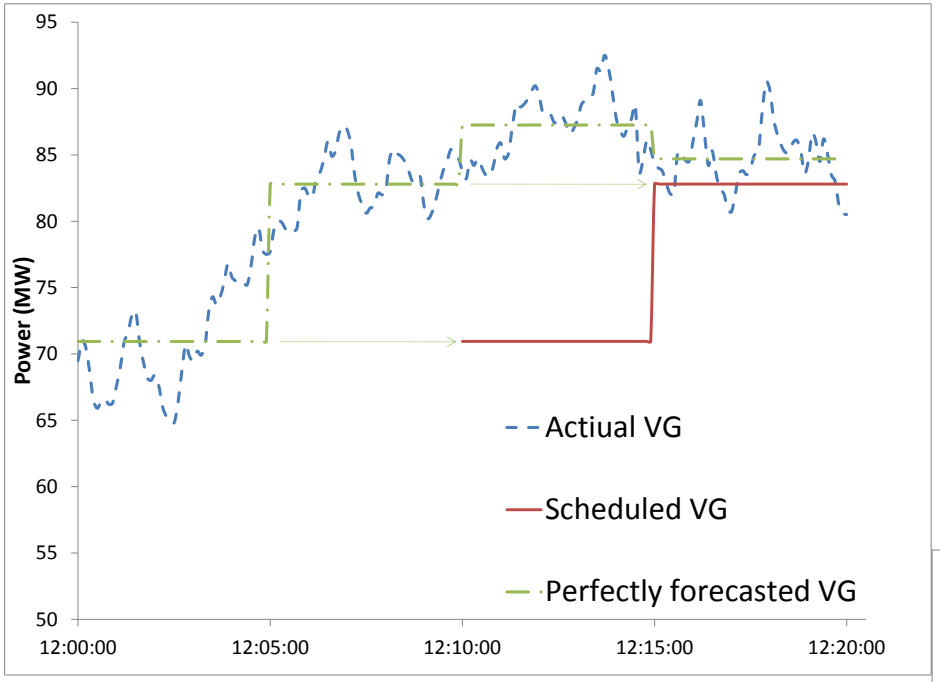


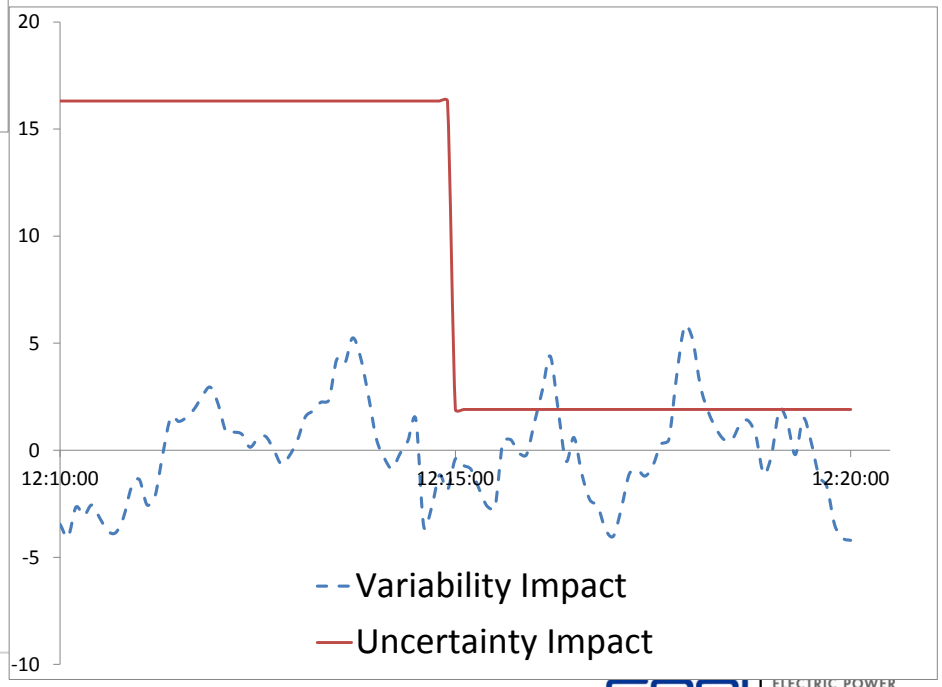
- Study with small change of adjustable speed pumped storage (PSH) plant, providing control with unfiltered raw ACE
- Impacts to reliability fairly intuitive
- System also had substantial cost savings
- AGC from PSH changed dispatch, it even changed day-ahead unit commitment!

	April		July	
	Scenario 3	Scenario 4	Scenario 3	Scenario 4
Cost	$3.032M	$2.941M	$5.021M	$4.924M
CPS2 Violations	45	44	15	14
AACEE [MWh]	2644.19	1992.00	2593.00	1233.00
sigma ACE [MW]	23.00	20.00	20.20	12.17

V. Koritarov et al., *Modeling and analysis of value of advanced pumped storage hydropower in the United States*, ANL/DIS-14/7, June 2014

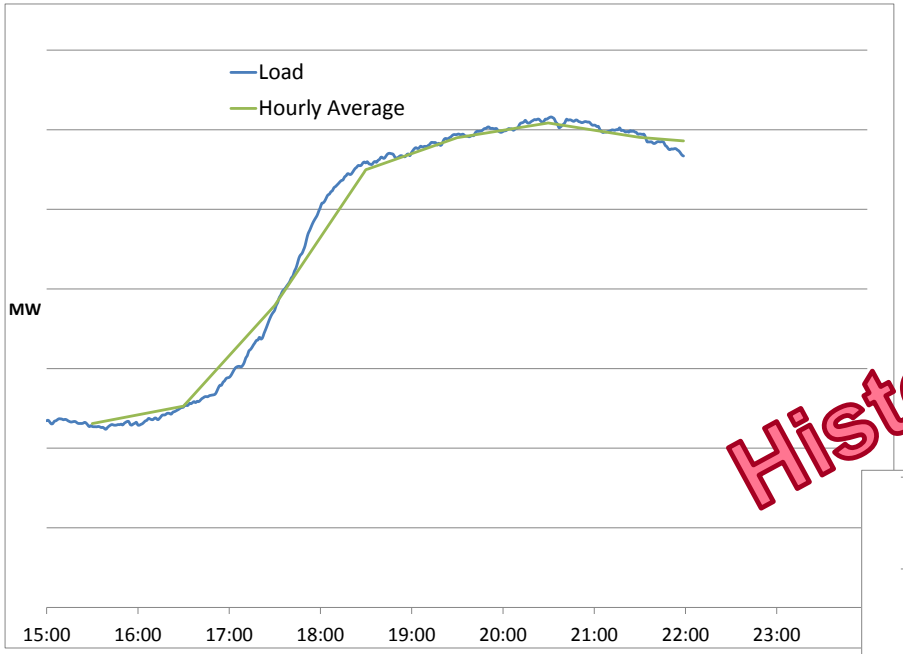
Impact from Variable Renewable Generation





Impact from variability and uncertainty.
Either may have larger impact.

Following Reserve

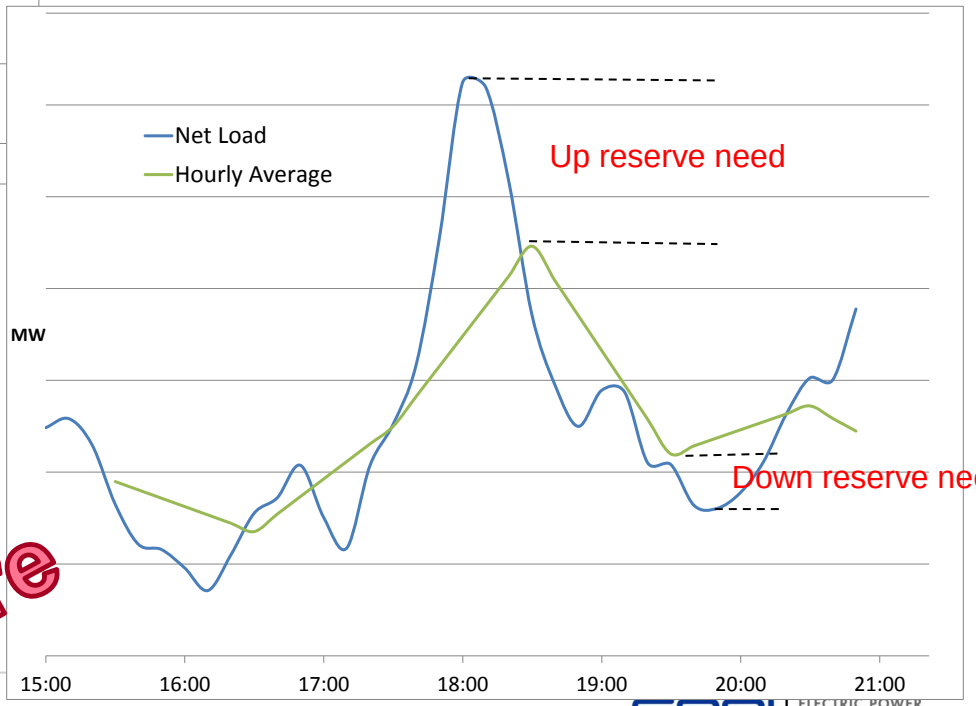


Historic

No longer a linear trending net load, may need reserve capacity within the scheduling interval

Prices and energy schedules: Based on hourly average

Commitment: Based on max/min



Future

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Summary

- Planning, operations, and markets each have objectives at different timescales
  - Work in unison
- Improvements in understanding and in computation have allowed us to dive deeper in allowing models to show impacts at multiple timescales
  - Important to look at timescale “seams” where different decisions may impact each other
  - You will never have a model that captures it all!
- New technologies (wind, solar, storage, DER, vehicles) can introduce greater impacts of benefits to the power system in terms of variability and uncertainty
  - Variability and uncertainty happen at different timescales and time horizons
  - Variability and uncertainty at different timescales have different impacts
  - Impacts of one timescale can affect decisions in other timescales
  - Increasing penetrations of these resources make looking across the timescales more important

Together…Shaping the Future of Electricity

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