Future System Operations with an Evolving Grid

NARUC-ESIG Training Session

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Why Must Grid Operations and Planning Evolve?

Changing Generation Mix

Active Distribution Systems

Consumer Control and Electrification

Topics

Advanced Operational Simulation Tools

Renewable Forecasting

Ancillary Services Evolution

Technologies and Future Operational Issues

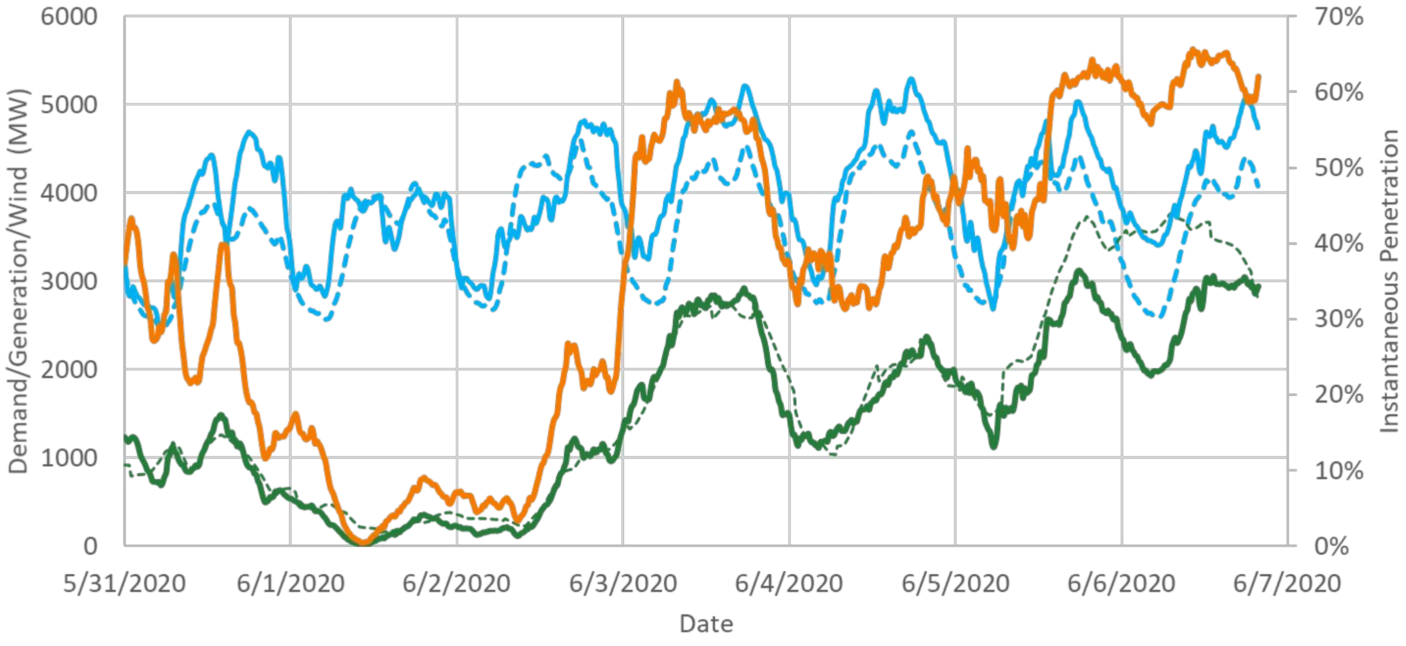
Advanced Operational Simulation

Variability and Uncertainty Considerations

Scheduling & Dispatch
- Increase operating reserve
- Masking of load (DER)
- Ensuring frequency response

Ops Planning & Real-Time
- Outage scheduling
- Changing flows & limits

Operational Simulation Tools
- Capture uncertainty and flexibility needs
- Ensure limits are managed

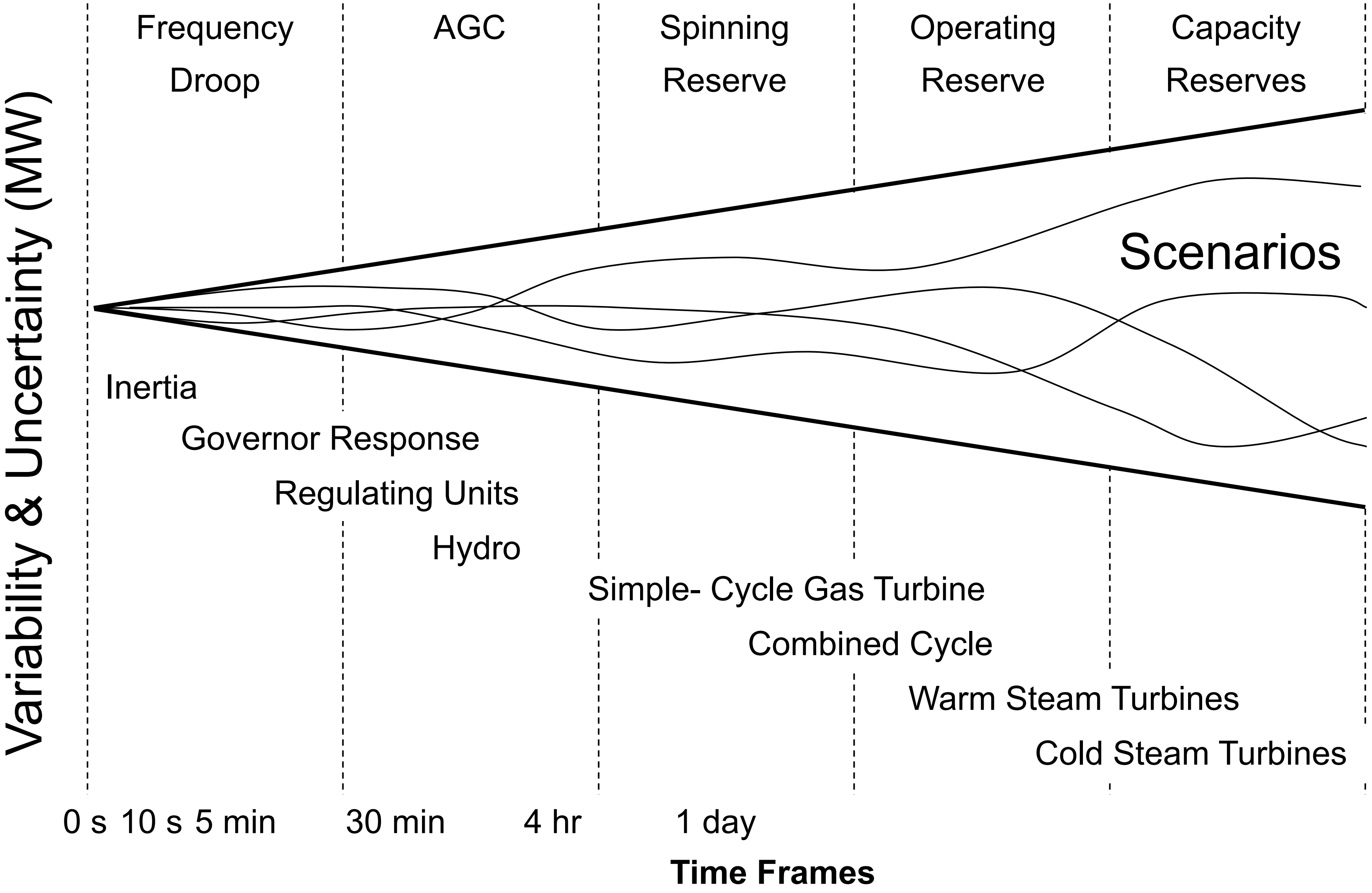


Data from Eirgrid.com

Limit renewables to 70% of generation (and curtailed when over this)

Average penetration of 35% of generation, 40% of demand

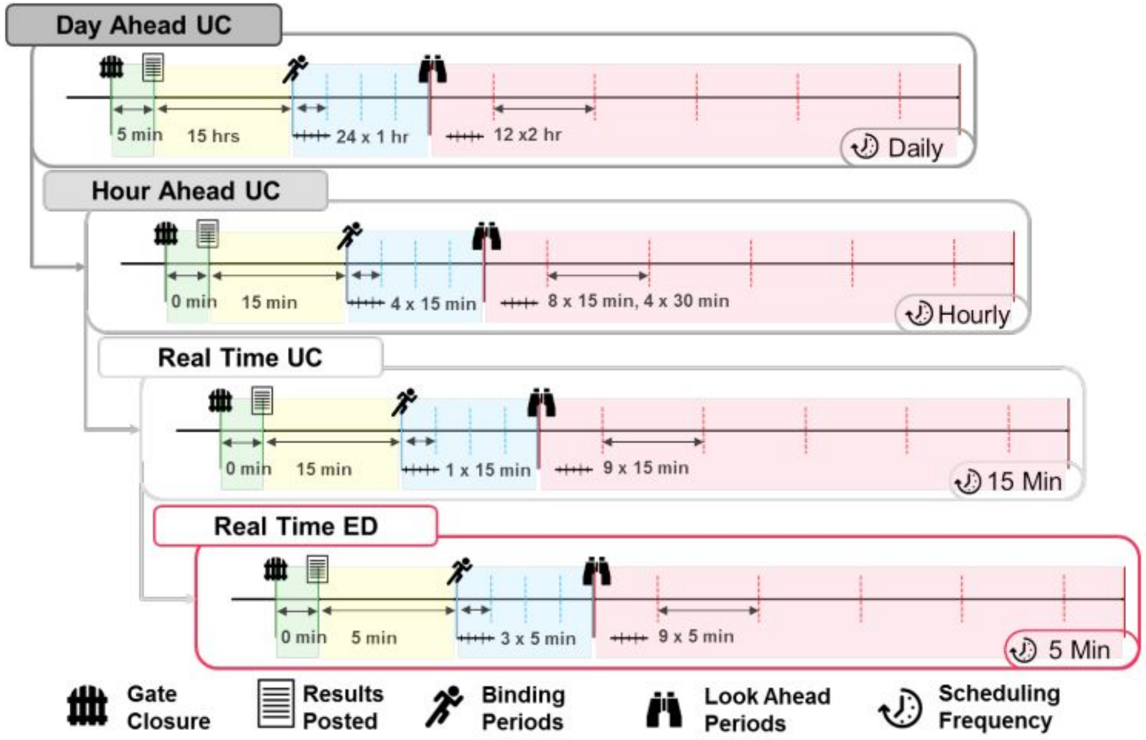
Time Frames and Uncertainty



Source: Russ Philbrick, PES General Meeting, Detroit, July 2011

Operational Simulation Tools

Detailed models will ensure operations with high VER can be studied in detail

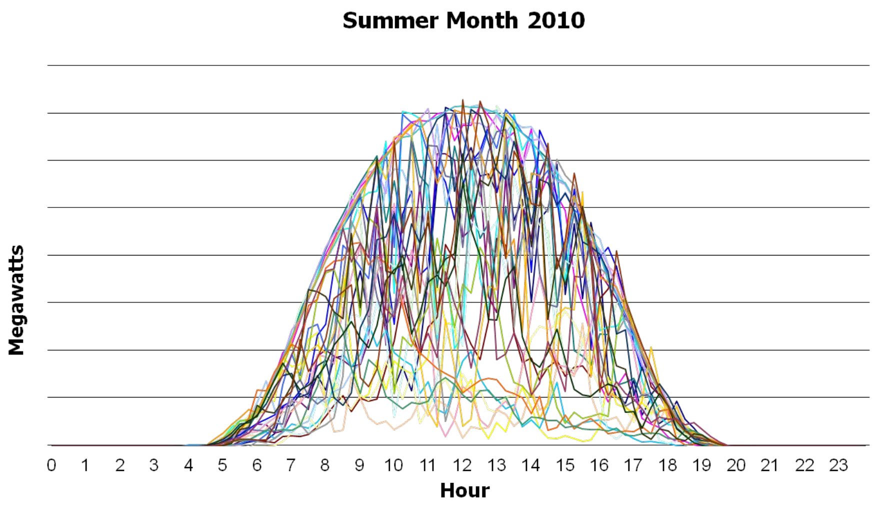


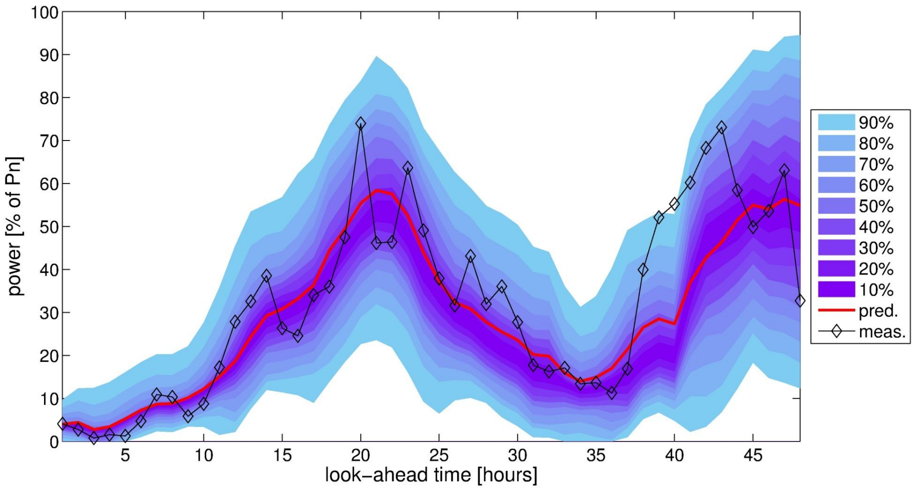
Capabilities Required

- High temporal and spatial resolution
  - 5-min, nodal models are ideal
- Representation of uncertainty
  - Multi-cycle modeling (on right)
- Accurate modeling of flexibility of system
  - Storage, demand, generator start/stop and ramping
  - Cycling costs
- Neighboring system interactions
- Reserve requirements

Gaps and New Research Areas

- Advanced renewable integration study techniques
- Evaluation of renewable resource impacts, renewable forecast benefits
- Multi-timescale scheduling approach
- Representing new ancillary services
- Natural gas pipeline and market integration
- Incorporation of new technologies (energy storage, demand response)
- New scheduling techniques (e.g., stochastic scheduling)
- Distribution system interaction
- New market design and pricing mechanisms





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Flexibility During COVID-19

Risk Mitigation Strategies

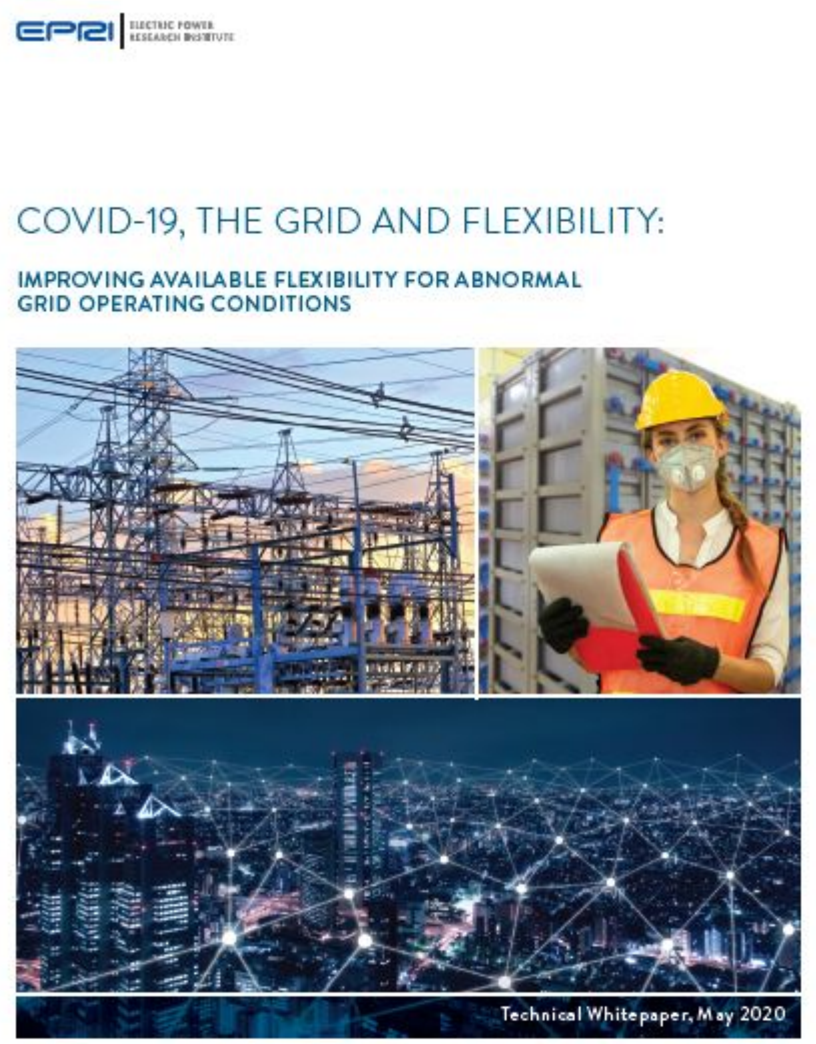
- Planning timeframe
- Markets / Dispatch timeframe
- Redispatch & Emergency Actions

Flexibility to Manage Over-Supply Risk

- Reducing demand during COVID
- Restrictions or inability to 'curtail' certain generation resources
- Accessing additional flexibility through markets, services and emergency measures

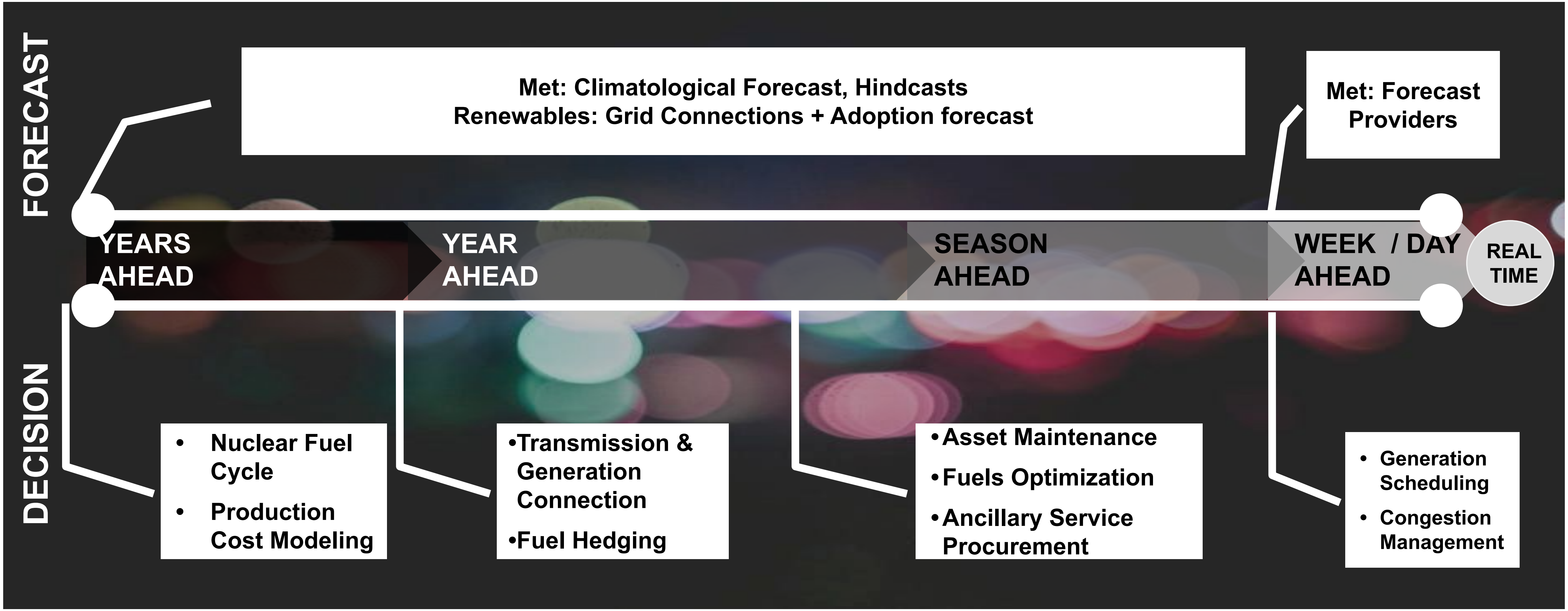
Simplified Flexibility Roadmap

- Right Now, Next, Then
- Actions for strategy, planning, operations, dispatch groups



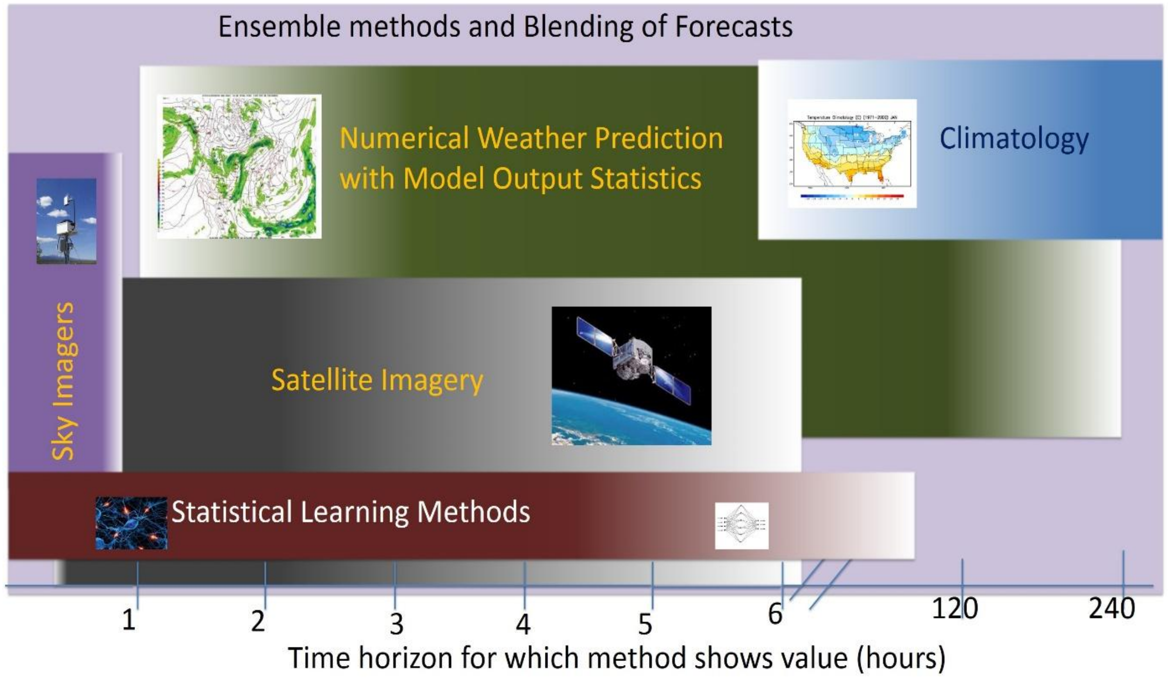
Renewables and Load Forecasting

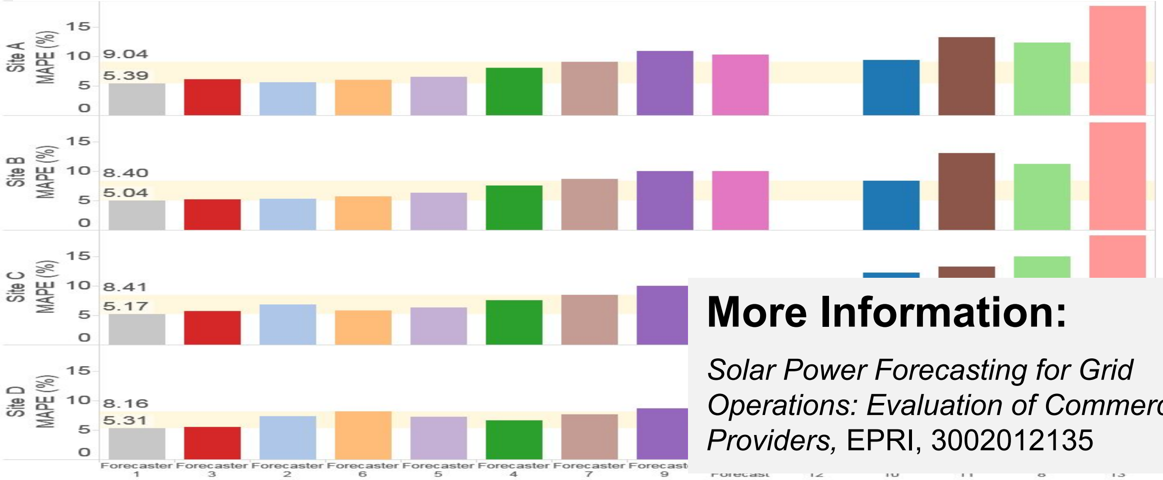
Bulk System Forecast Uses



Forecasting to Improve Operational Visibility

- Forecasting can be used to improve understanding of future wind, solar and load (and other DER) output
- Significant improvement in recent years, through improved models, data and sensor deployment
- Greater understanding of how wind and solar forecasts perform and how they can be used to operate the system

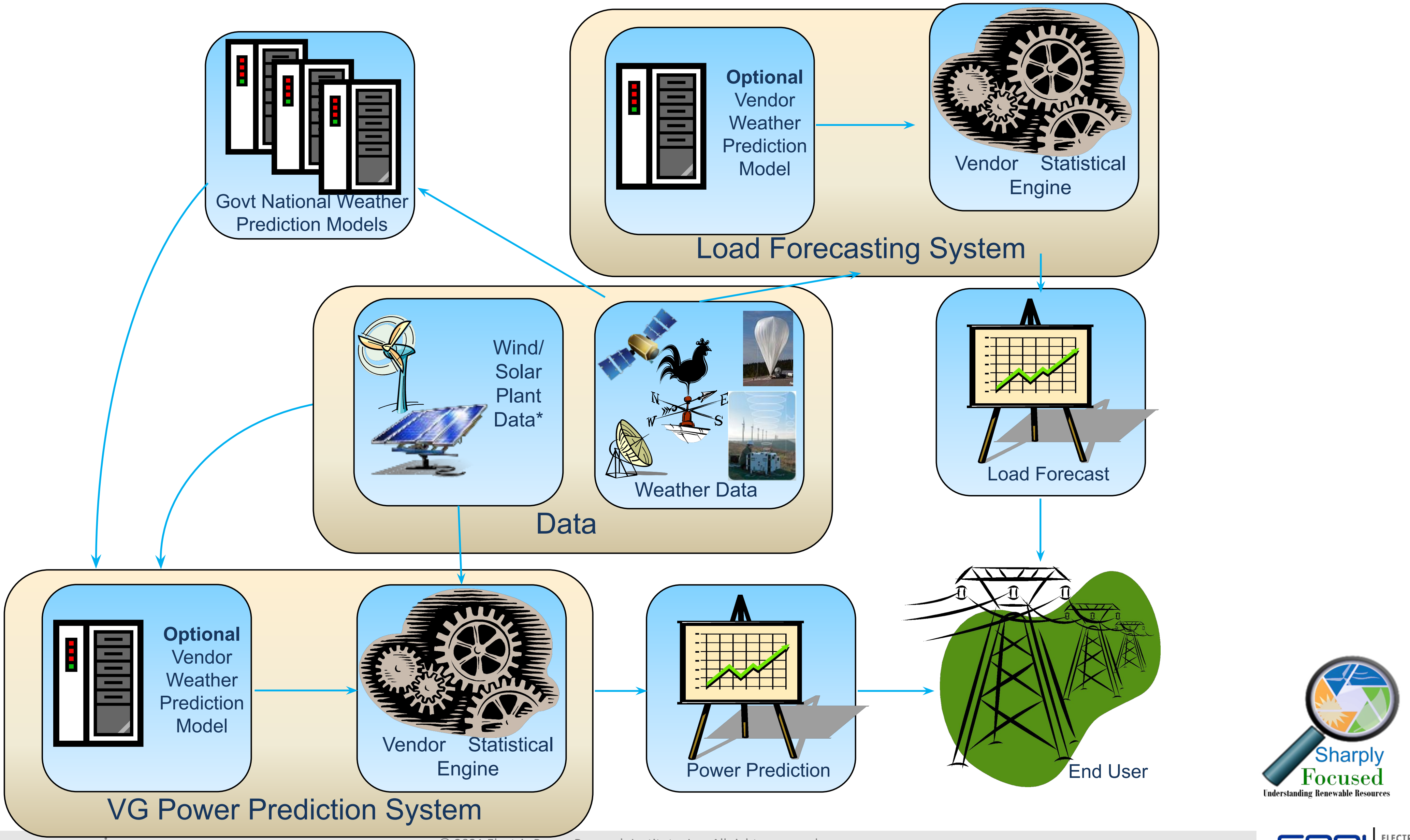




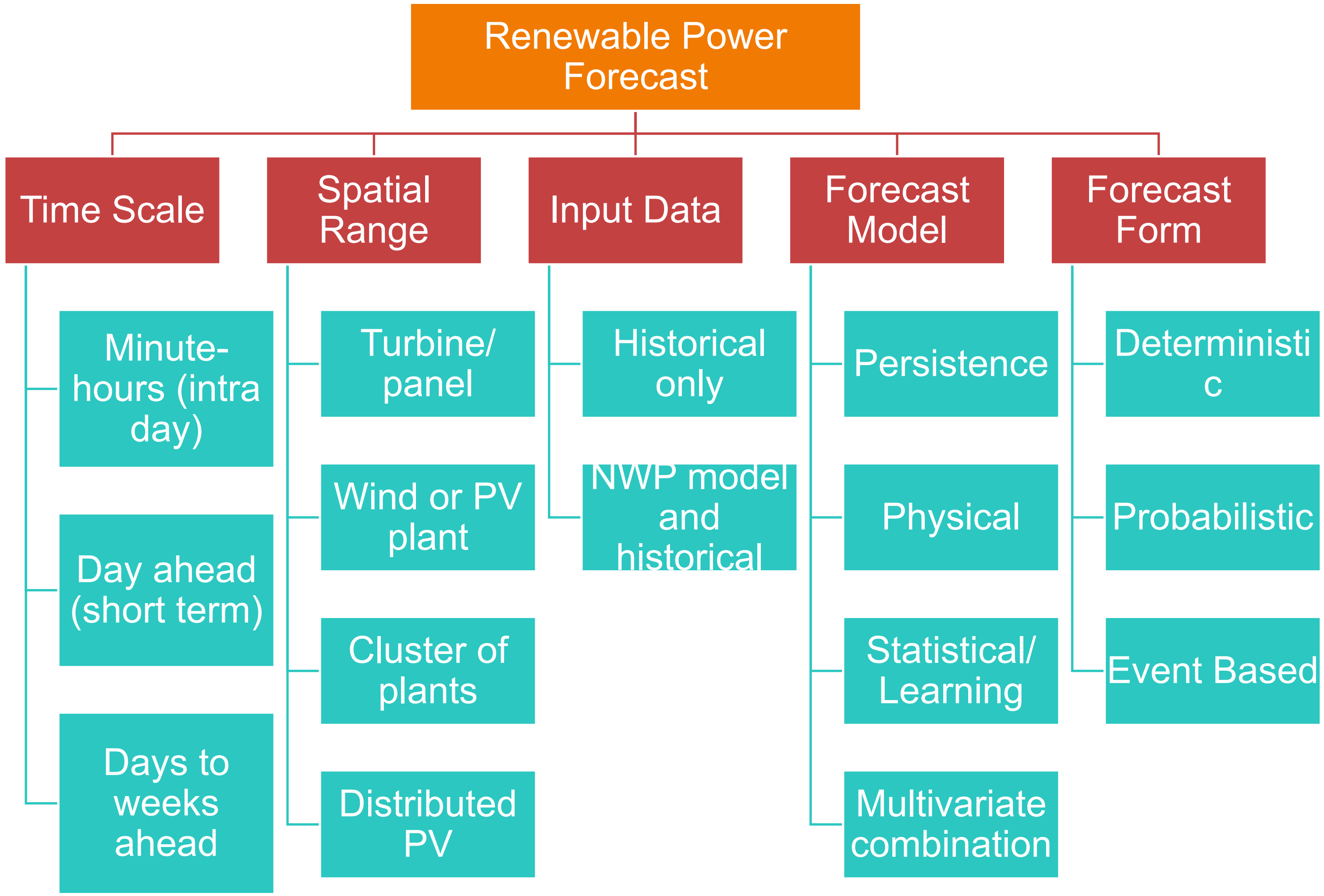
More Information:

Solar Power Forecasting for Grid Operations: Evaluation of Commercial Providers, EPRI, 3002012135

Forecasting Electricity Supply and Demand



Forecast Classification



Adopted from IEC TR 63043 “Renewable energy power forecasting technology”, 2020

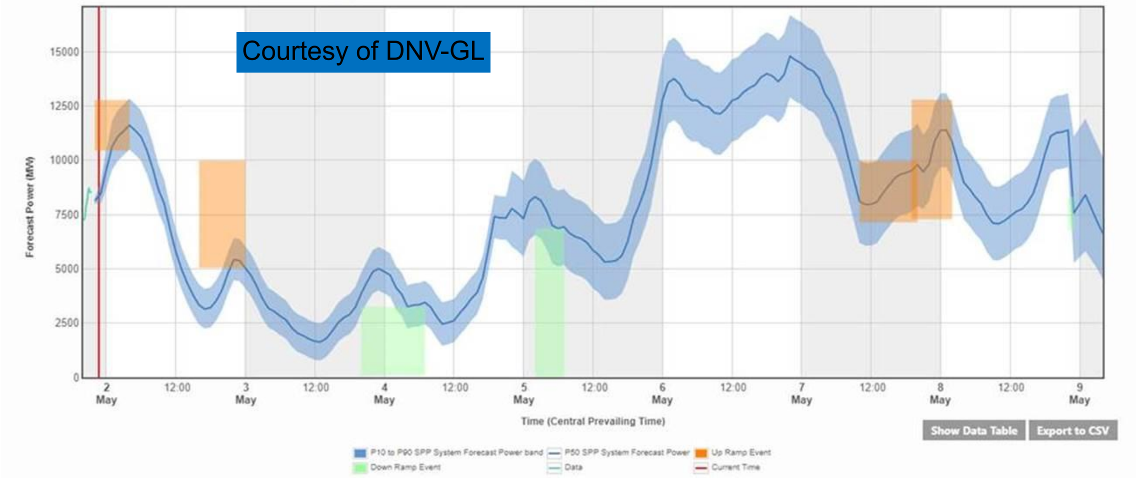
Any renewable forecast will be combination of these

Status of Renewable Forecasting in Power Systems

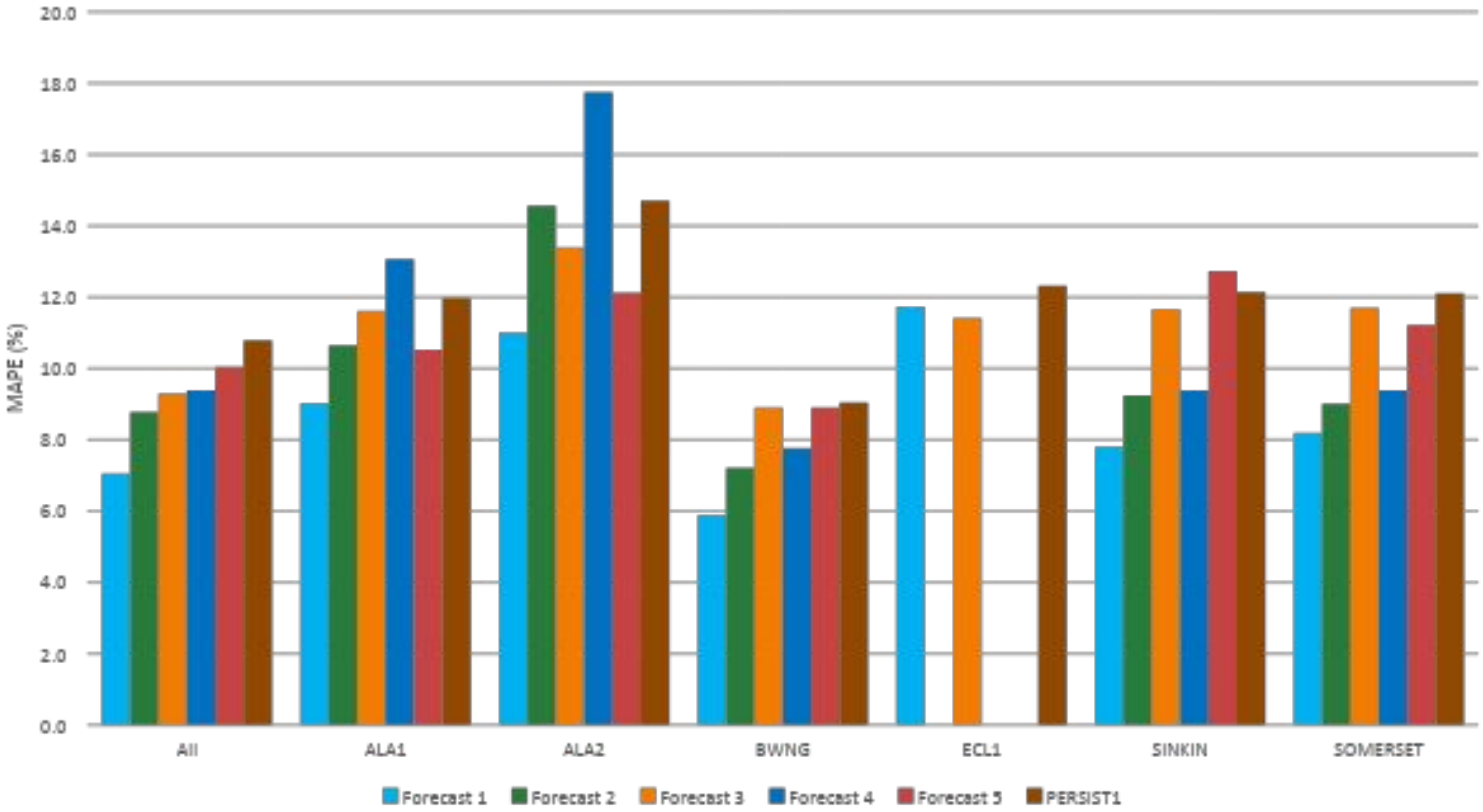
- **All system operators now use centralized wind and solar power forecasting, where penetration levels are sufficient (> few percent)**
  - Many other non-TSO areas and utilities also use renewable power forecasting
- **Used for multiple applications**
  - Day(s) ahead and short term (5-60 mins) forecasts used
  - Used in clearing markets and operational planning
  - Different time horizons, frequency of provision and granularity provided to different users based on their needs
- **Ramp forecasts are also used by some operators**
  - Some may prefer to just use one forecast
  - Some are using ensembles provided by vendor, or multiple vendors
- **Cost allocation of forecast provision varies by region**
- **Almost all applications are <u>deterministic</u> in nature!**

Examples of Forecast Products

- Deterministic 'best guess' forecast
  - Most typical forecast
  - Easiest to use and understand
- Probabilistic forecast
  - Confidence intervals around deterministic forecast
  - Scenario based forecasts
  - Used for awareness or to support decisions
- Event based forecast
  - Shows high risk periods for awareness
- Situational awareness
  - Figures of the services territory with weather patterns
  - Regional generation spread, etc.

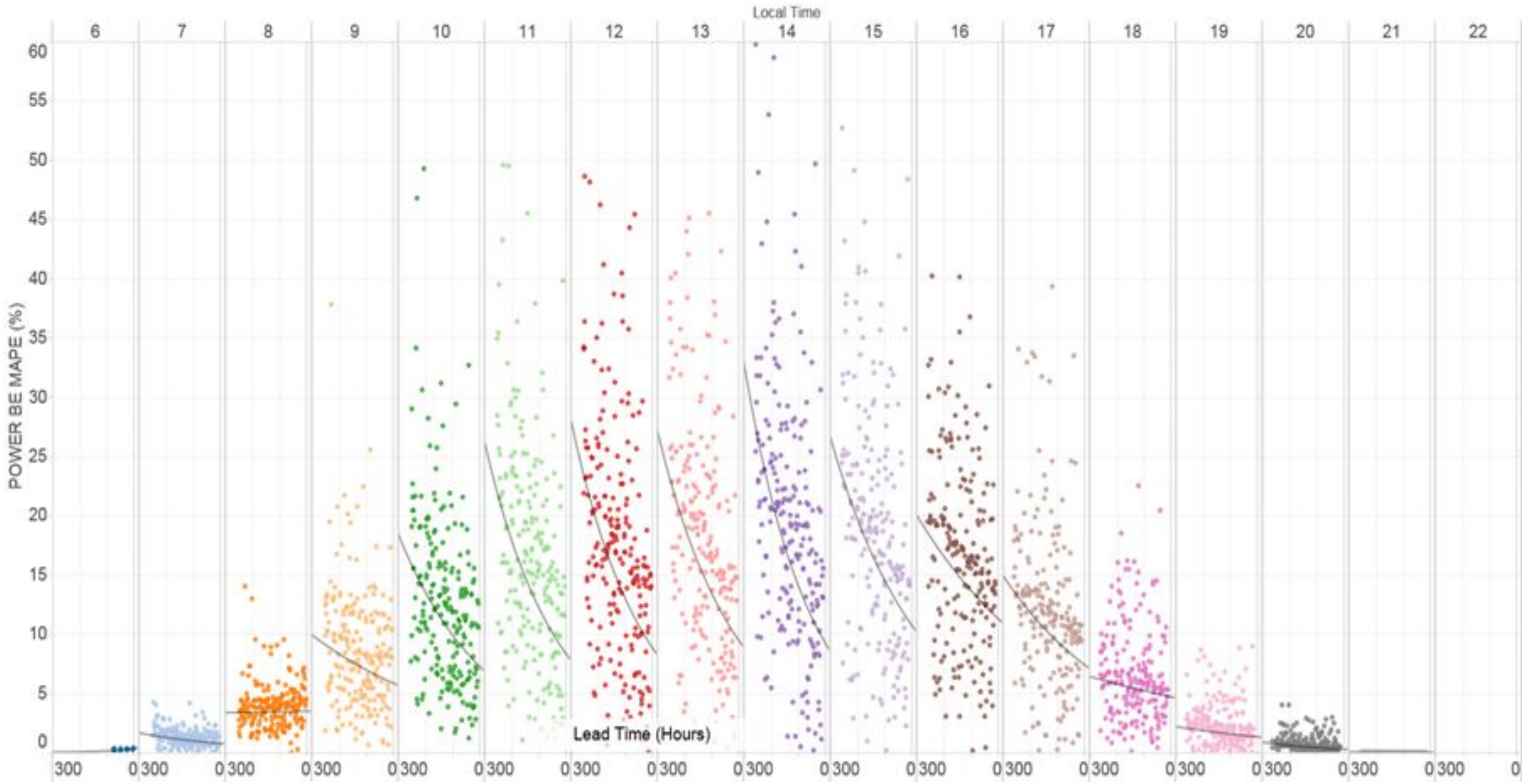


Forecasting Metrics – Mean Absolute Error – CPS Energy



Performance varies widely for different forecasters and across solar farms,
due to data availability and technology

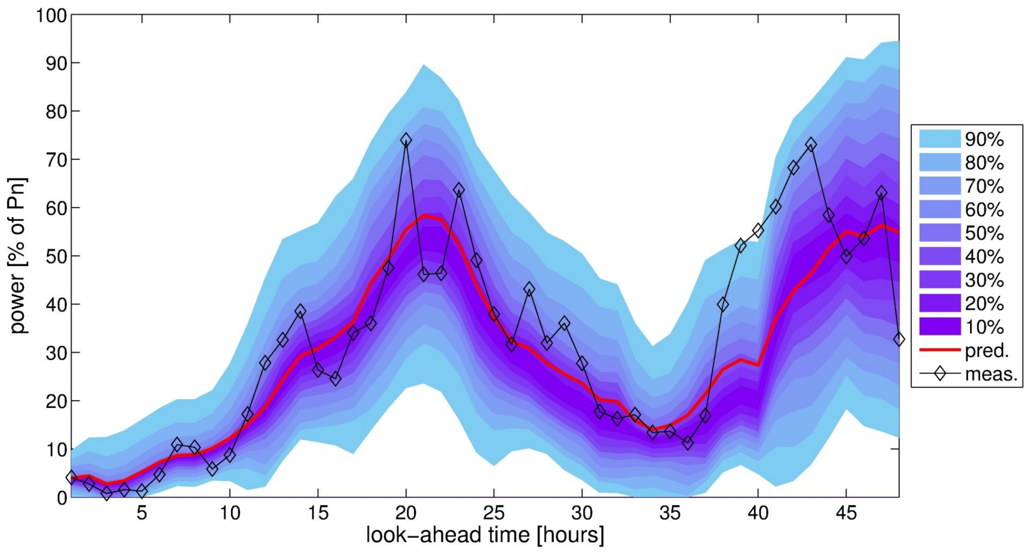
Performance of forecast by time of day and look ahead

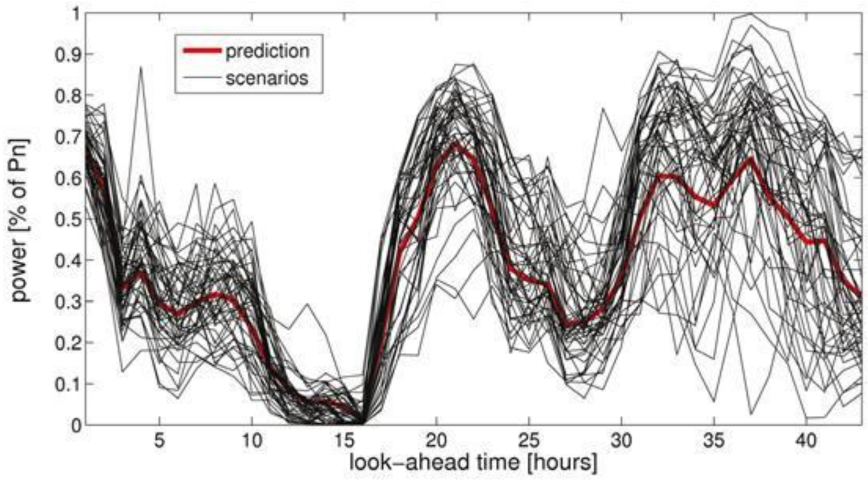


More info: *Solar Power Forecasting for Grid Operations: Evaluation of Commercial Providers,* Electric Power Research Institute, December 2017. Palo Alto, CA. 3002012135

Why use probabilistic forecasts?

- May have pushed close to limit of what we can do with best guess for some applications
- Takes advantage of risk-based methods such as stochastic programming
- Captures outliers (assuming data is representative)
- Should be more economically efficient while can also be more reliable than traditional methods
- May give us better rationale for responding to some extreme events, e.g. extreme cold



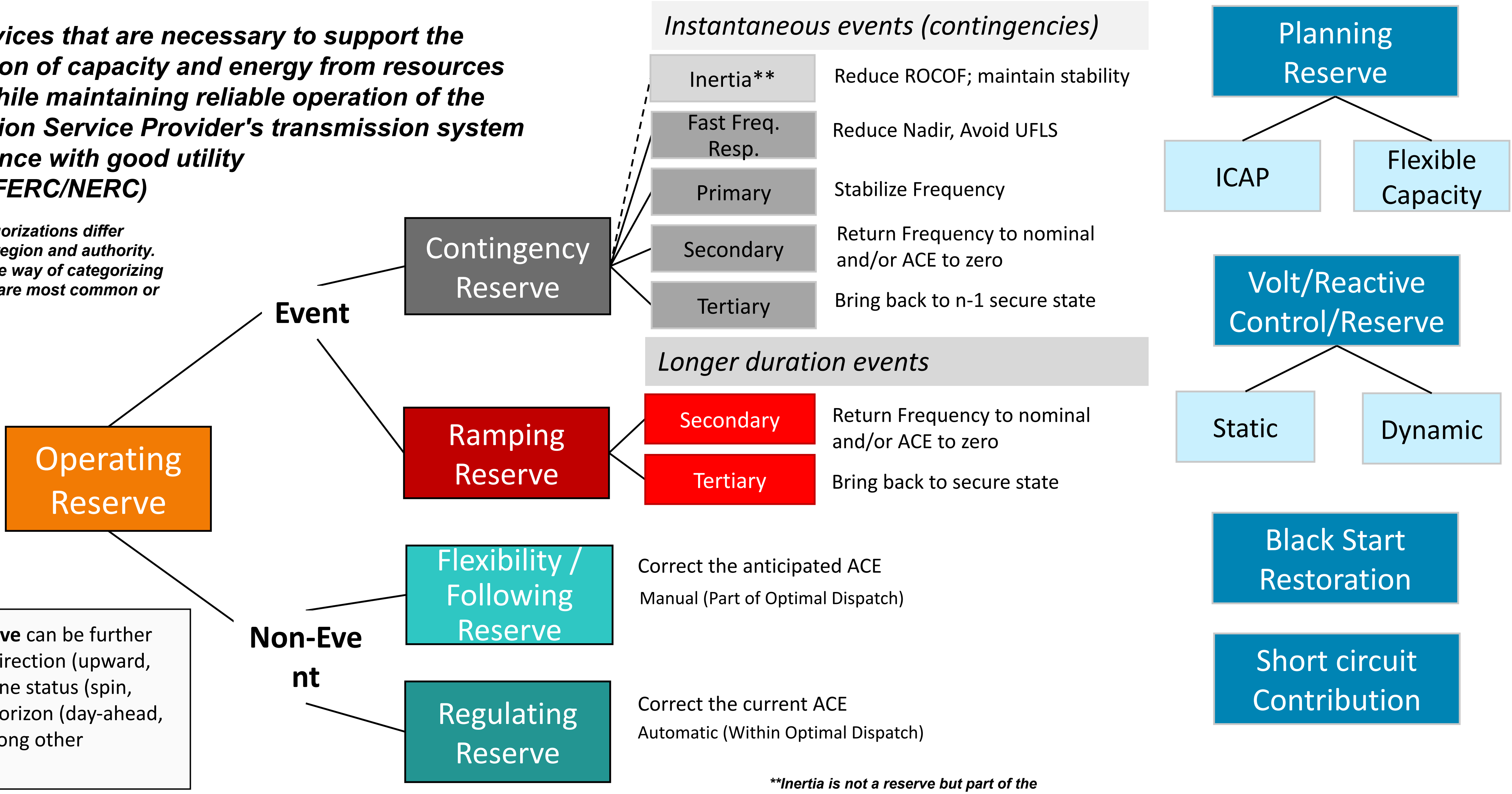


Evolution of Ancillary Services

Ancillary Services* (Bulk Power System)

Those services that are necessary to support the transmission of capacity and energy from resources to loads while maintaining reliable operation of the Transmission Service Provider's transmission system in accordance with good utility practice. (FERC/NERC)

****Terms and categorizations differ substantially by region and authority. This is simply one way of categorizing using terms that are most common or most descriptive.***



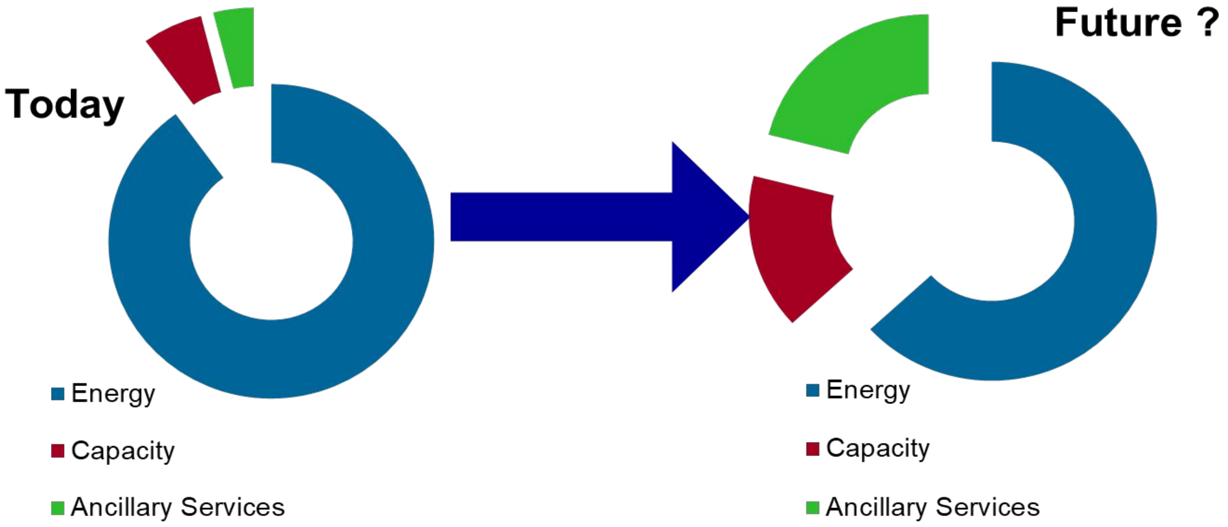
Operating Reserve can be further categorized by direction (upward, downward), online status (spin, non-spin), and horizon (day-ahead, hour-ahead) among other characteristics.

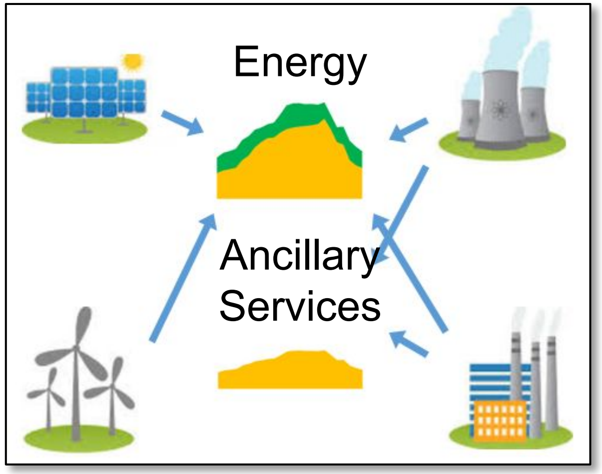
****Inertia is not a reserve but part of the instantaneous event correction process.***

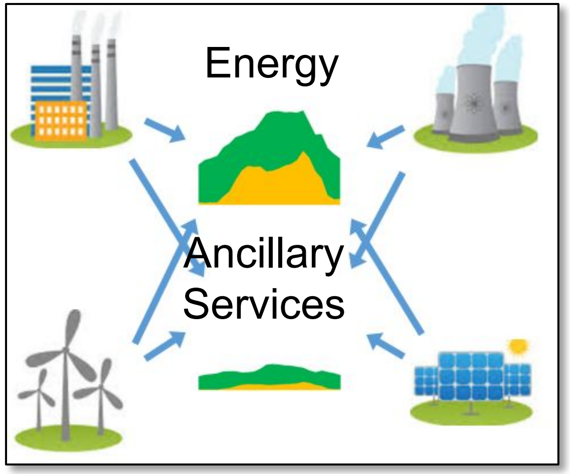
Adapted from Ela et al., *An Enhanced Dynamic Reserve Method for Balancing Areas*, EPRI, Palo Alto, CA: 2017. 3002010941.

Evolving Wholesale Energy and A/S Markets

- More resources for fewer periods?
- Incentives for flexibility?
- Incentives for “essential reliability services”?
- What is the right price?
- Interfacing transmission/wholesale with distribution/retail?
- Changing resource mixes: Technology agnostic vs. realism?
- Simplicity vs. complexity?







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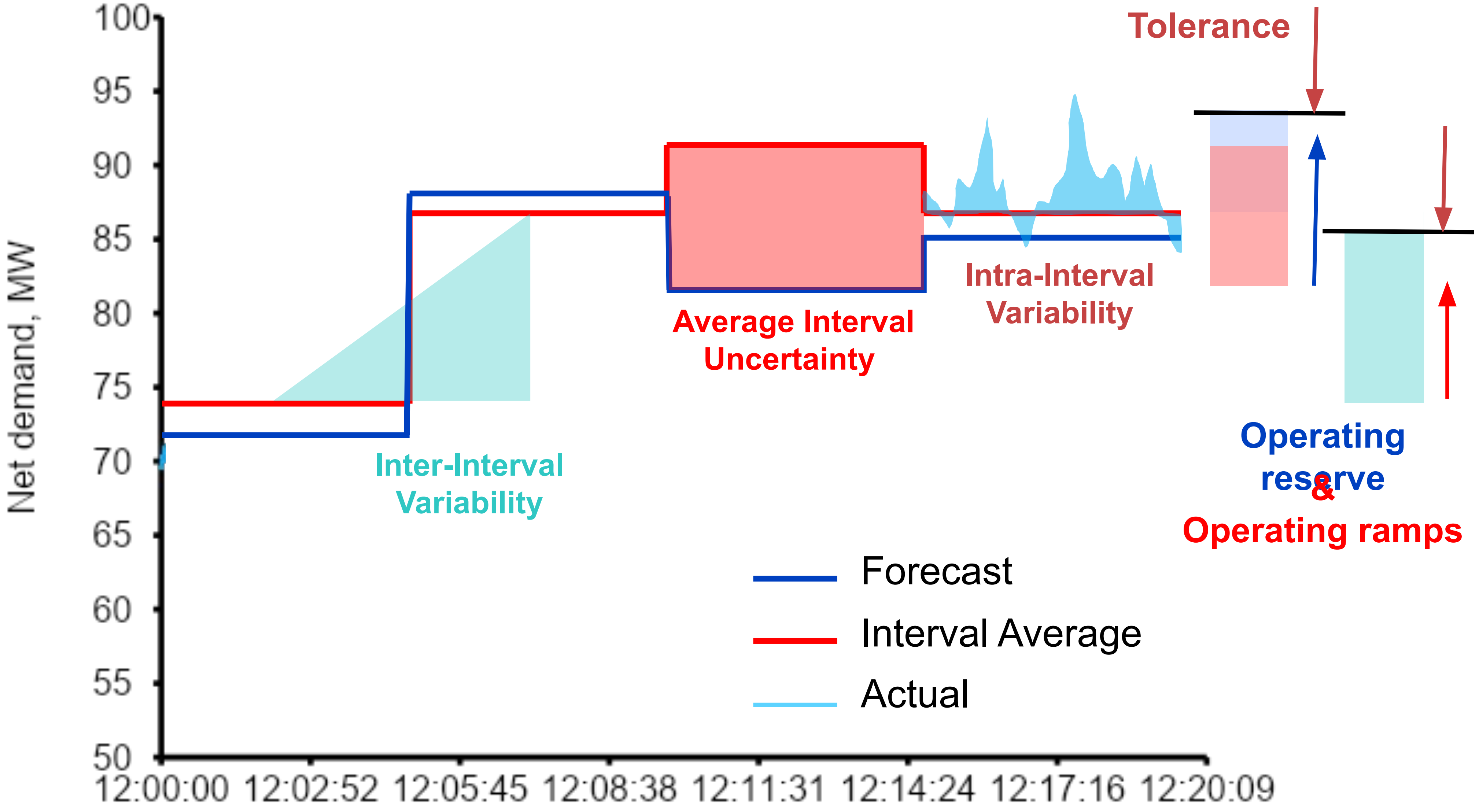
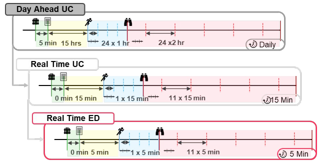
What are the Reserve Needs?



EPRI Dynamic Reserve Requirement Method

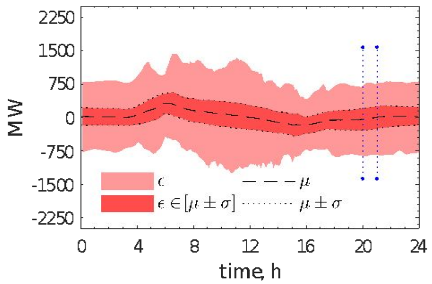
Reserve Characteristics

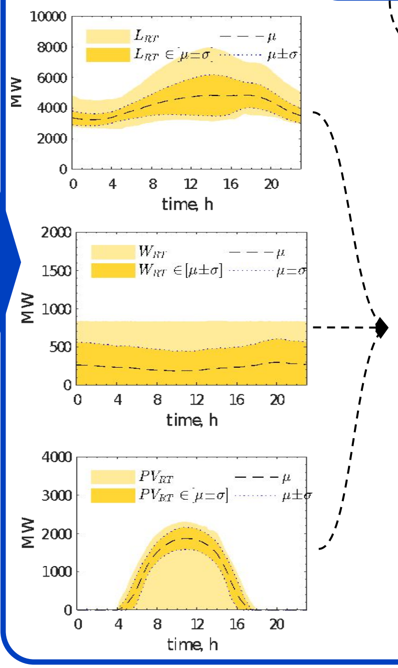
BA process:
- Held
- Released
- Direction

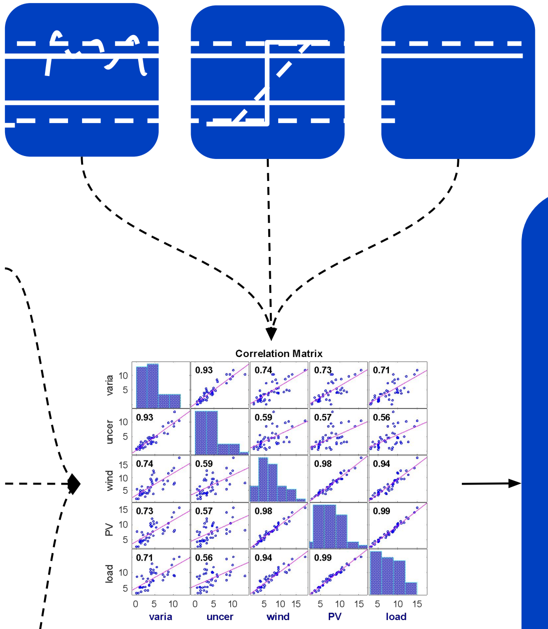


Historical Assessment

Historical assessment to determine the exact reserve requirements



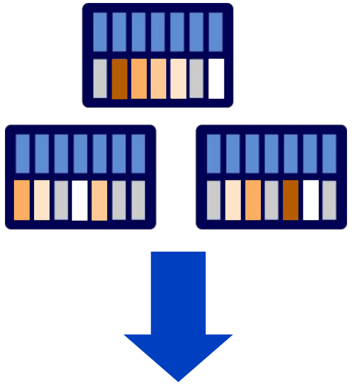




Categorize type and source

Explanatory variable:
- Temporal:
  - Hour
  - Season
  - Week/wknd
- Production:
  - P-level
  - Δ→
  - Δ←
  - |Δ|

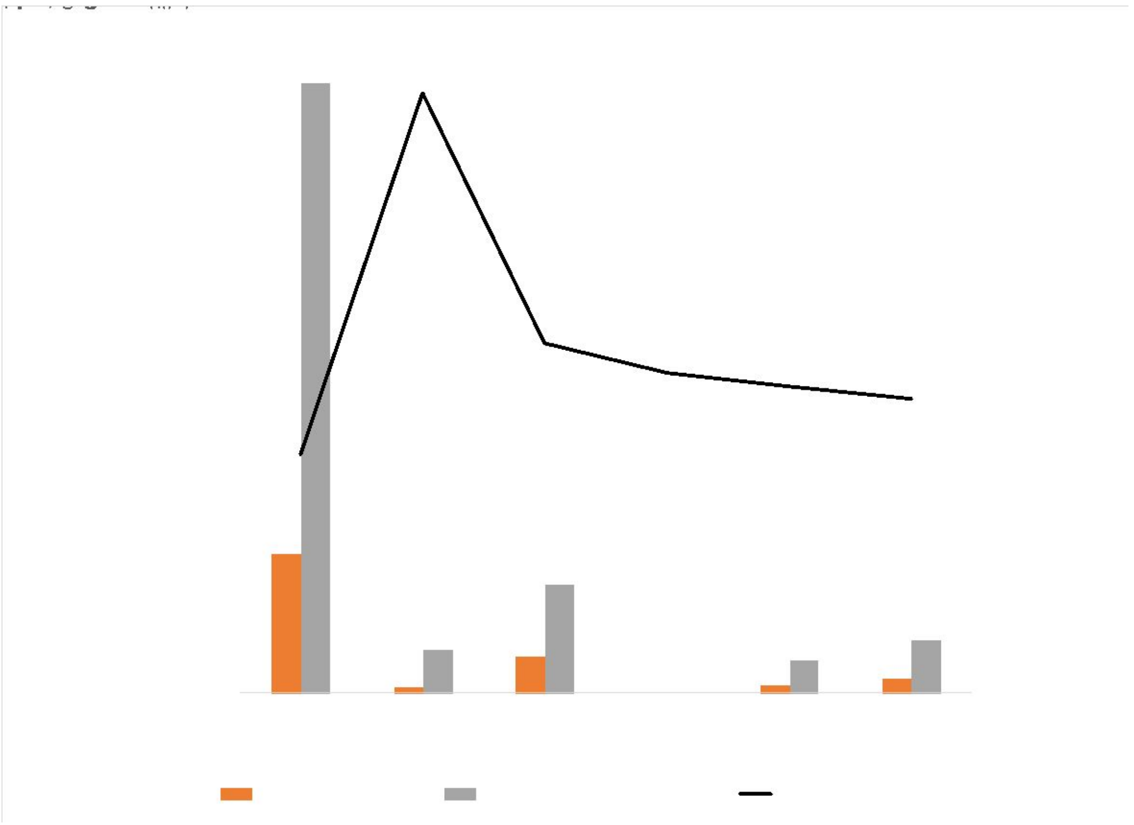
Assemble using best explanatory variables



$R_t = f(\cdot)$

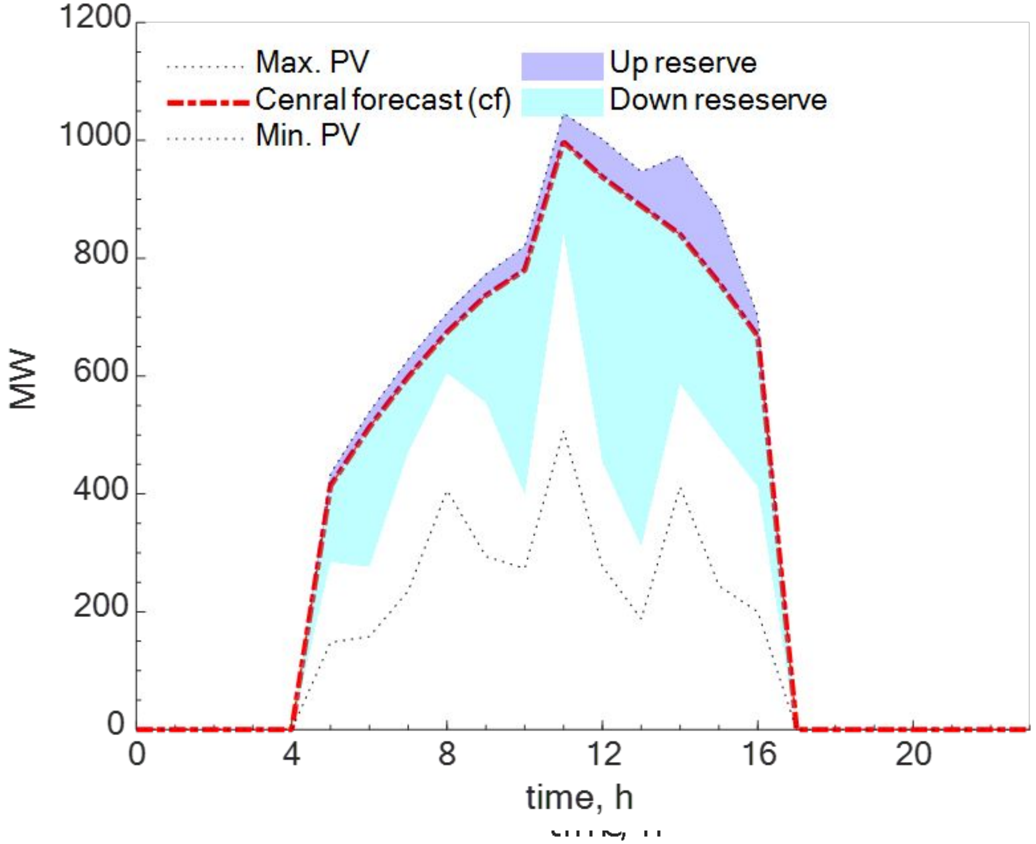
Reserve requirement is "forecasted," just like load or RES production

Managing Risk in Operations



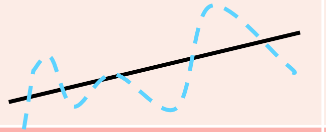
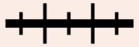
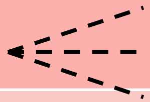
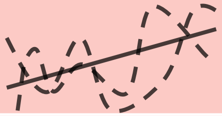
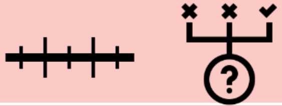
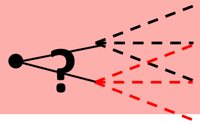
Cost reductions while improving reliability

DOE OPTSUN: Probabilistic Methods

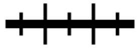


Scheduling and reserves tools to manage uncertainty in real time

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**

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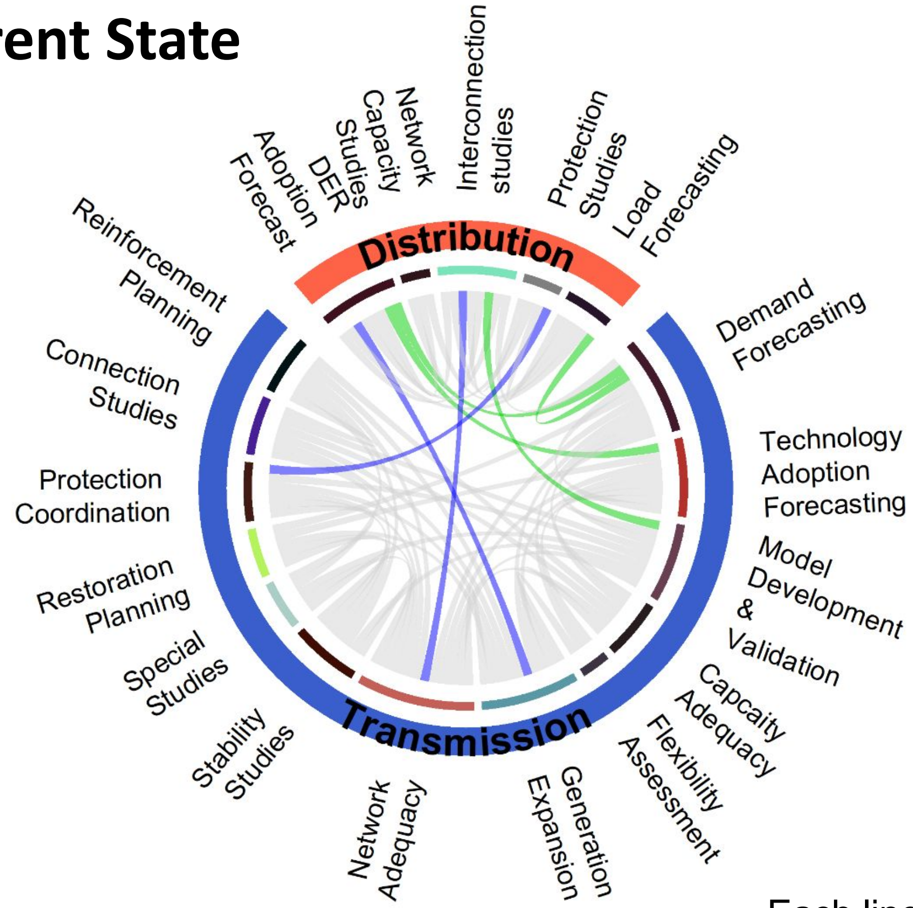
T&D Coordination

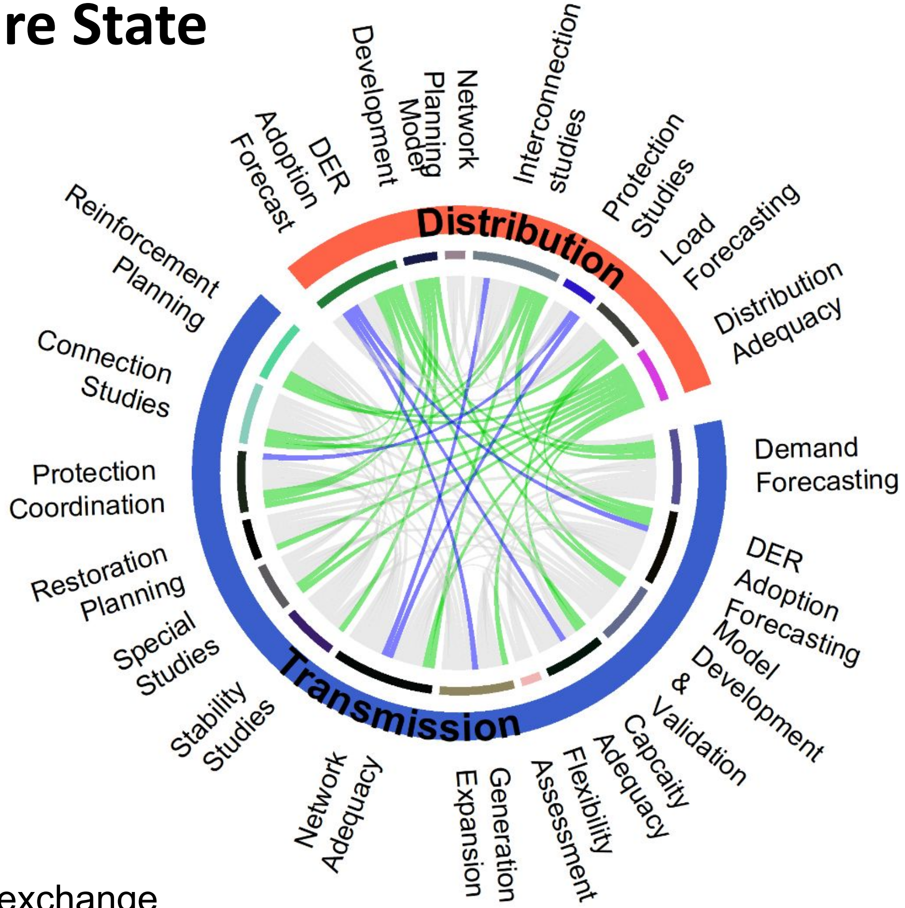
Increasing Needs for Tx/Dx Interactions: Transmission Planning

Work supported by Ali Ghassemian and Dan Ton of the U.S. DOE Office of Electricity, Advanced Grid Research and Development under contract ANL 6F-30562 Mod 2 FE.

Current State



Future State



Each line represents a data exchange
Blue lines represent data be sent from transmission to distribution
Green lines represent data be sent from distribution to transmission
Grey lines represent data be exchanged within distribution or transmission

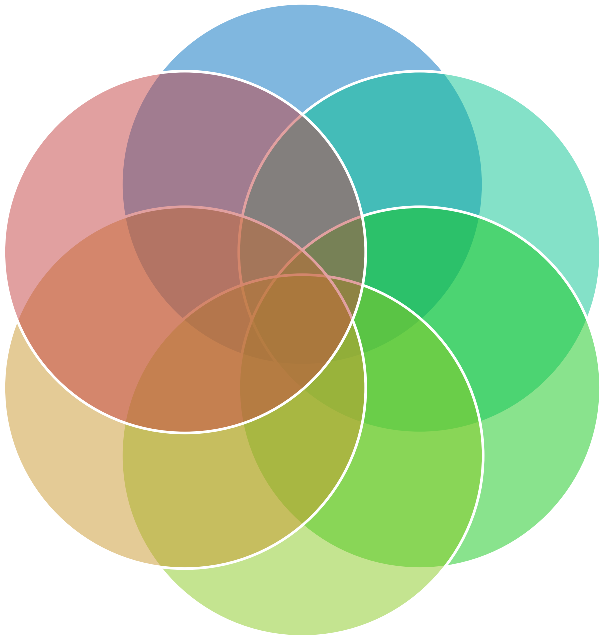
DER Integration Design Principles

Design …

To Do No Harm

A Level Playing Field

For Observability & Control



For System Flexibility

To Engage New Market Participants

For Congested Grids

+ existing market objectives

Catalytic Industry Features For DER Activation

FACTOR	Example
Grid Codes	IEEE 1547:2018
Metering & Visibility	Texas: DREAM proposal California: low-cost telemetry trial
Bulk system flexibility & strength	Large interconnections
Industry & market Structures	LMPs, retail competition
Distribution Hosting Capacity	DER Collector networks
Incentives / Tariff Structures	German direct marketing

FERC ORDER 2222

A High Level Overview

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What is a DER? What is a DER Aggregator?

DER: *any resource located on the distribution system, any subsystem thereof or behind a customer meter*

DERA: *Entity that aggregates one or more DER for purposes of participation in RTO and ISO markets*

What are the Key Implementation Challenges?

Operational Coordination → Aggregator Management → Metering and Telemetry → Market Design

How Does 2222 Enable DER to Participate in ISO/RTO Markets?

Key Eligibility Requirements

- All DER technologies can **heterogeneously** aggregate to meet RTO/ISO requirements, if aggregation is at least **100 kW** in size
- Aggregation as ***geographically broad as technically feasible***
- Data, bidding, metering, and telemetry for DERA aligned with existing requirements but **balanced** with existing infrastructure, reduce burden on small resources
- Limit compensation for the **same service** in other programs

ORDER 2222 enables DER participation in ISO/RTO Markets

Who does this impact?

Customers
DER
Aggregators
Distribution Utilities
RTOs/ISOs
Retail Entities

How Will Market Participation Be Coordinated?

- **Main market interface:** RTO/ISO ↔ AGGREGATOR
- **Key Elements of Coordination**
  - Distribution utility **preclears** DER to join an aggregator
  - Distribution utility may **override** DERA schedule to ensure distribution system safety and reliability
  - **Data sharing** practices between all parties
  - Allow for regional **flexibility** in coordination framework

What is the Timeline?

ISO tariff modifications due within 270 days.
Implementation date part of each RTO/ISO proposal.

Relevant EPRI Research Areas

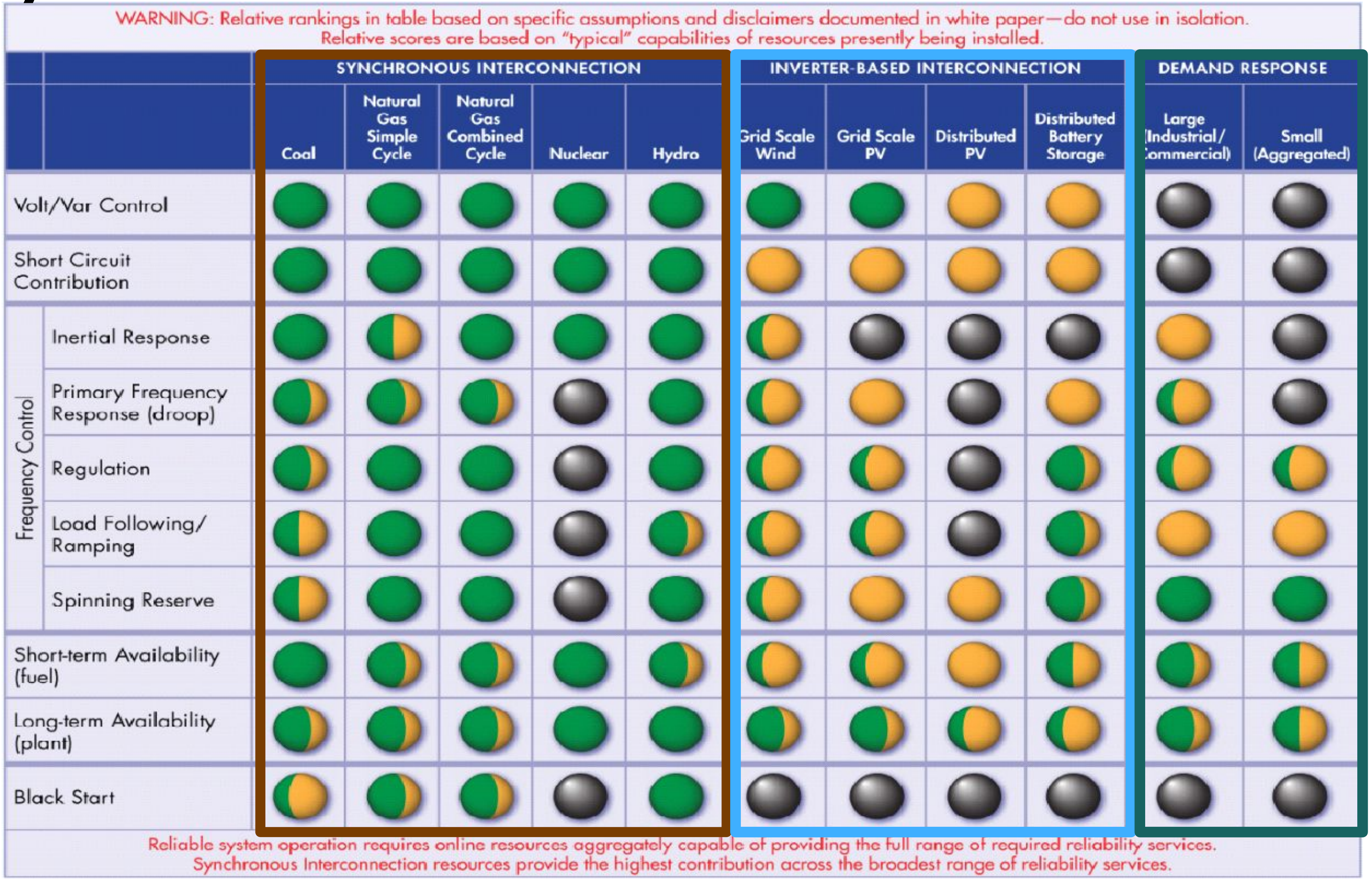
Grid Operations & Planning | DER & DER Integration | Information & Communications | Energy Utilization

New operational practices and challenges

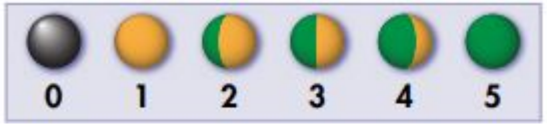
Relative Reliability Contributions for Various Resources

- Must ensure reliability when considering new resource mix
- Not all resources are equal in "Reliability Capability"
- Synchronous resources broader & deeper ability to support reliability
- Reliability is not only consideration: Sustainability, Diversity, Economics, Emissions, among others
- Likely needs updating (2015)

EPRI whitepaper (2015): Contributions of Supply & Demand Resources to Required System Reliability Services (3002006400)

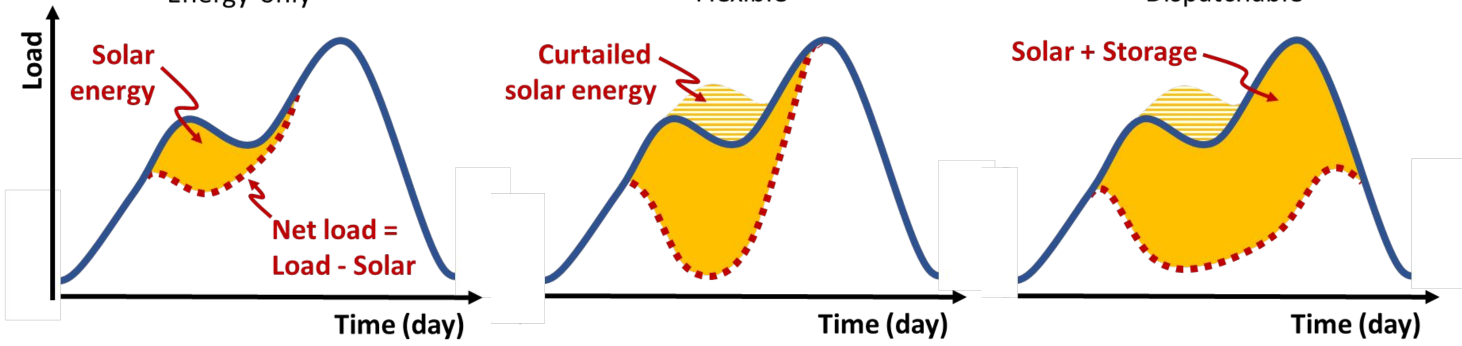


Relative score for currently installed technologies:



Dispatchable Renewables

- "Headroom" = Curtailment
- VARs
- Storage – battery, bulk, hydro



"Smart" Inverter and Central Controls

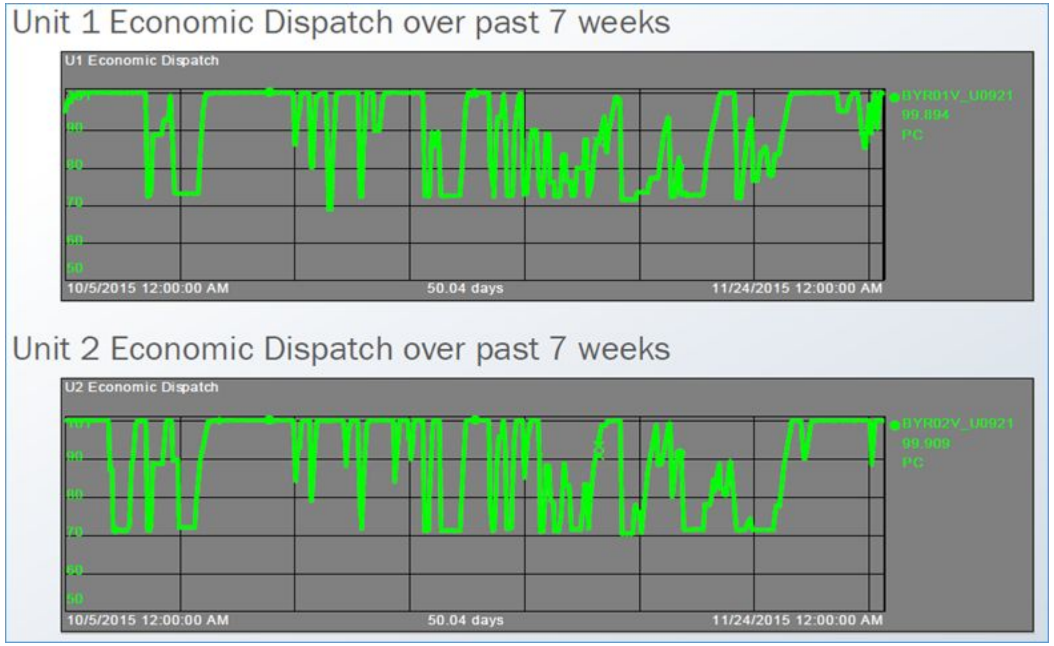
Source: Louton C., et. al. "Demonstration of Essential Reliability Services by a 300-MW Solar Photovoltaic Power Plant". NREL Technical Report. March 2017.

Energy Storage

Plant-Level Controls Underutilized for Dispatchability - Energy Storage for Firmer Capacity

Nuclear Power Plant Flexible Operations

- Past Operating Experience (OE) in the United States
  - Until mid-1980's nuclear plants were used for frequency control
  - Nuclear Regulatory Commission changed their rules for reactor power control
  - Columbia NPP has decades of flexible operations to balance river flowage
- France
  - 58 reactors with over 30 years of flexible OE
  - Output can vary between 20% and 100% power within 30 minutes, twice a day for load following
  - Provide primary and secondary frequency control
  - Use grey control rods to vary reactor power



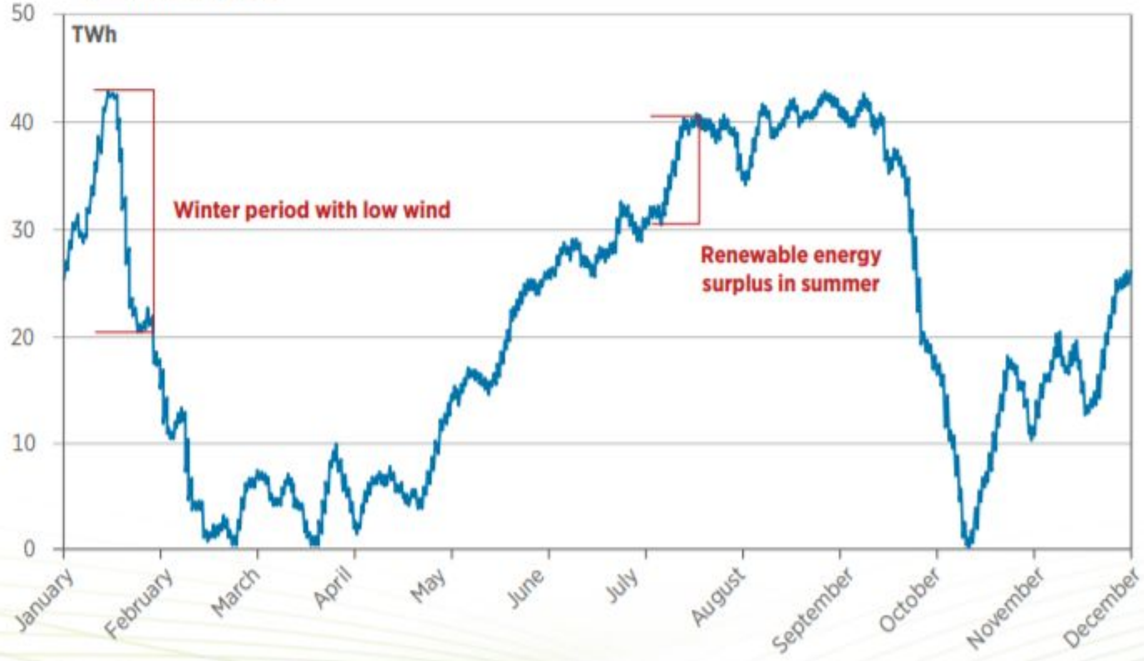
Data provided by Exelon for a PWR

Nuclear power plants can provide flexibility

Hydrogen to integrate RES

- Potential to use hydrogen as long duration storage as well as provide energy to other industries
- Electrolyzer ability to provide services to the grid
- Potential to use hydrogen with existing plants to keep services available
- Will be particularly valuable as need for seasonal shifting increases

Figure 6: Role of hydrogen in electricity storage, Germany: 95% decarbonisation scenario, 2050

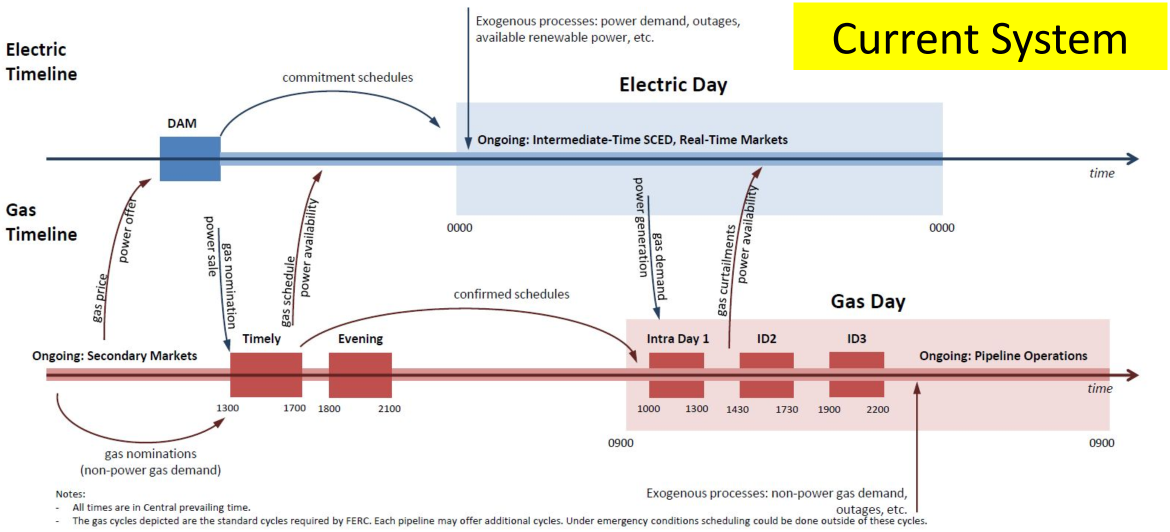


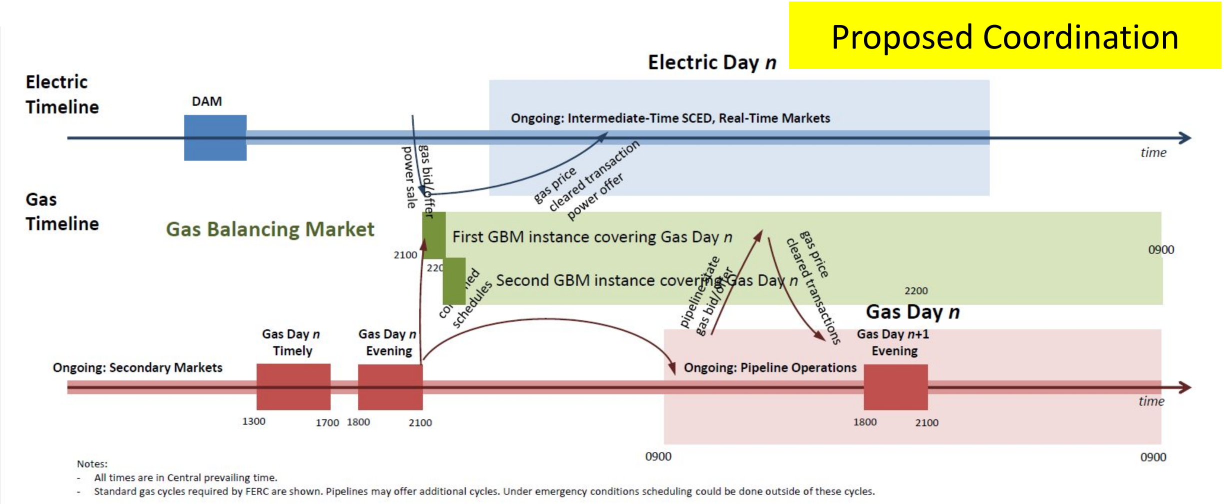
Source: LBST, 2019

Gas Electric Coordination Needs

- Potential for lack of flexibility in fuel supply for flexible gas plants due to lack of coordination
  - Gas markets not well aligned with electricity markets
  - Pipeline operations are challenged by increased variability and uncertainty
  - Difficult to forecast gas needs day ahead for those providing balancing services

- Need to improve
  - Modeling capabilities (better has electric modeling such as ARPA-E GECO project)
  - Market/operational decision processes
  - Potential to co-optimize resources





From Alex Rudkevich, Gas Electric Co- Optimization (GECO): Market Realities and Modeling Challenges, ESIG Spring Workshop 2019

Conclusions

- Advanced study tools allow us to understand issues before they come up, and we can also learn from leading regions
- Forecasting of renewables and load becomes more important in future system operations
- Ancillary services requirements and methods will evolve, moving to increased recognition of changing nature of system
- New and existing technologies can provide the services and balancing functions required as we continue to decarbonize

Together…Shaping the Future of Electricity

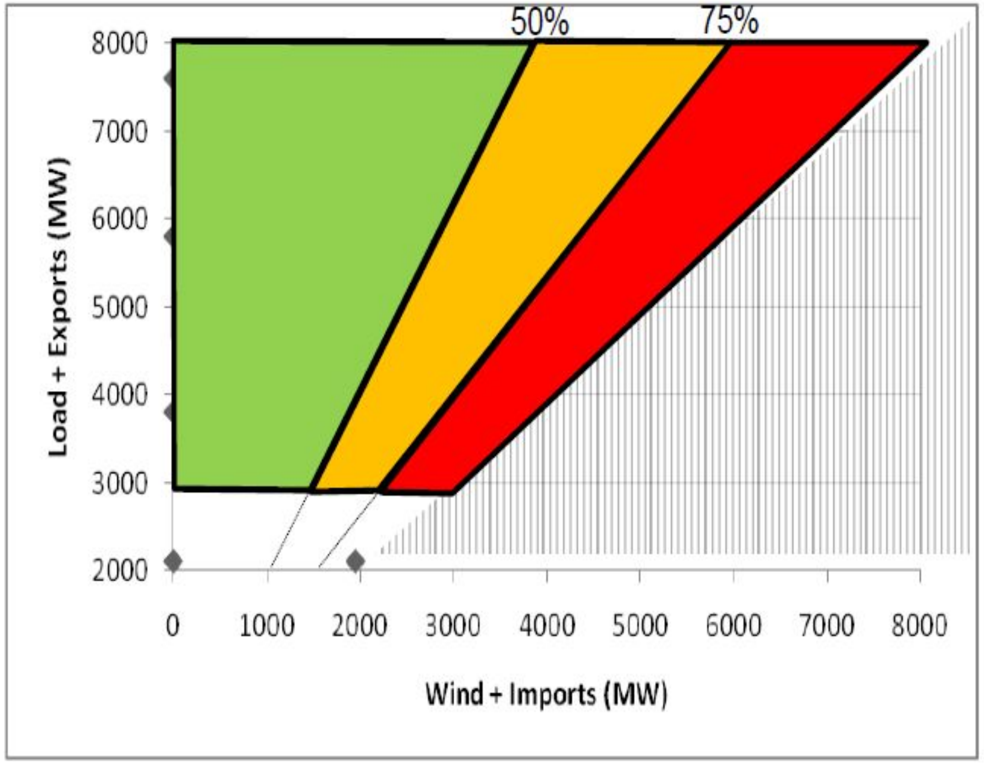
Considering stability limits in dispatch

- Example: Ireland has limit on System Non-Synchronous Penetration based on transient and frequency stability (detailed studies completed)

- System Non Synchronous Penetration metric

$$SNSP = \frac{Wind(or\ other\ inverter\ based) + Imports}{Demand + Exports}$$

- Scheduling tools need to account for this in order to more effectively commit and dispatch the system while ensuring operational reliability



EirGrid: Originally limited to 50%, now at >70%