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Reliability and the Future of the Electricity Grid:

A North American Bulk Power System Perspective

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Agenda Topics

- About NERC and what we do
- The changing resource mix
- The role of essential reliability services
- Accommodating high levels of renewables and natural gas generation
- Reliability implications of emerging environmental regulations

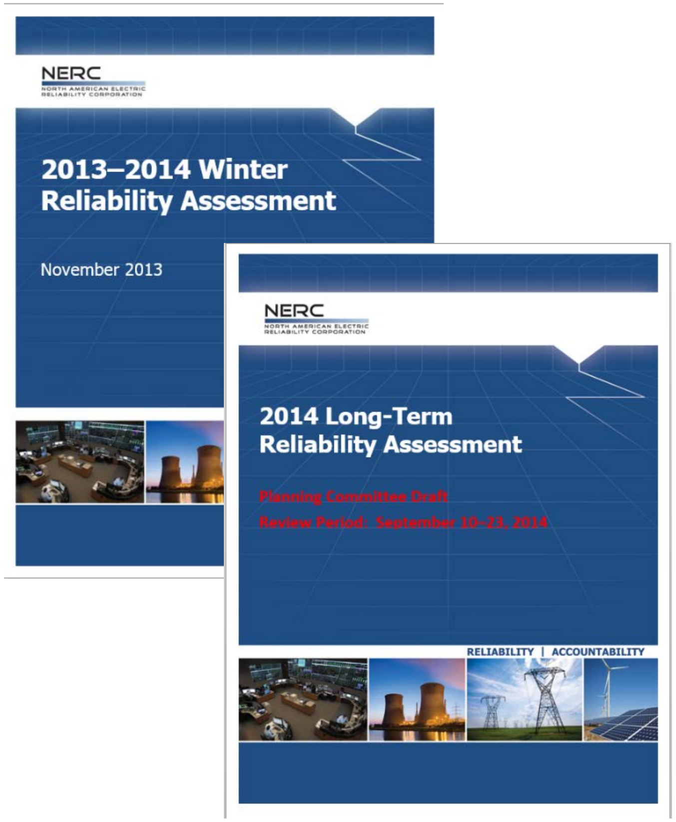
About NERC: Mission

To ensure the reliability of the North American bulk power system

- Develop and enforce reliability standards
- Assess current and future reliability
- Analyze system events and recommend improved practices
- Encourage active participation by all stakeholders
- Accountable as ERO to regulators in the United States (FERC) and Canada (NEB and provincial governments)

NERC Reliability Assessments

- Reliability
  - Resource Adequacy
  - Operating Reliability
- Transmission adequacy
- Demand and Generation forecasts
- Demand-Side Management
- Regional coordination
- Key issues - emerging trends
  - Technical challenges
  - Evolving market practices
  - System elements/dynamics
  - Potential legislation/regulation



Technically-Focused Groups at NERC

Chief Reliability Officer (Mark Lauby)

- Reliability Assessment
- System Analysis
- Reliability Risk Management
- Situational Awareness
- Event Analysis

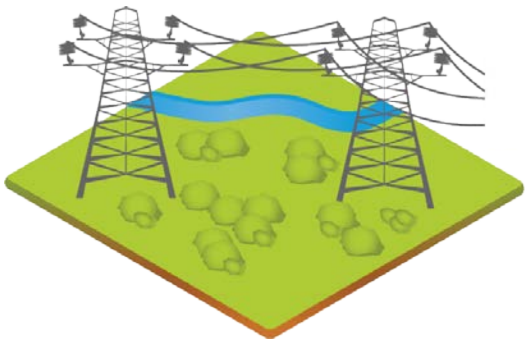
Planning Committee

Operating Committee

Event Analysis Subcommittee

Reliability Assessment	System Analysis	Reliability Risk Management	Situational Awareness	Event Analysis
• Periodic Assessments • ES&D / EIA-411 • Special Assessments	• Interconnection-wide Analysis • Model Validation • Event Forensics • BES Definition Exception Requests	• NERC Alerts • Lessons Learned	• Real-time information sharing • Daily RC calls	• >Cat2 Event Analysis • Root cause and cause coding

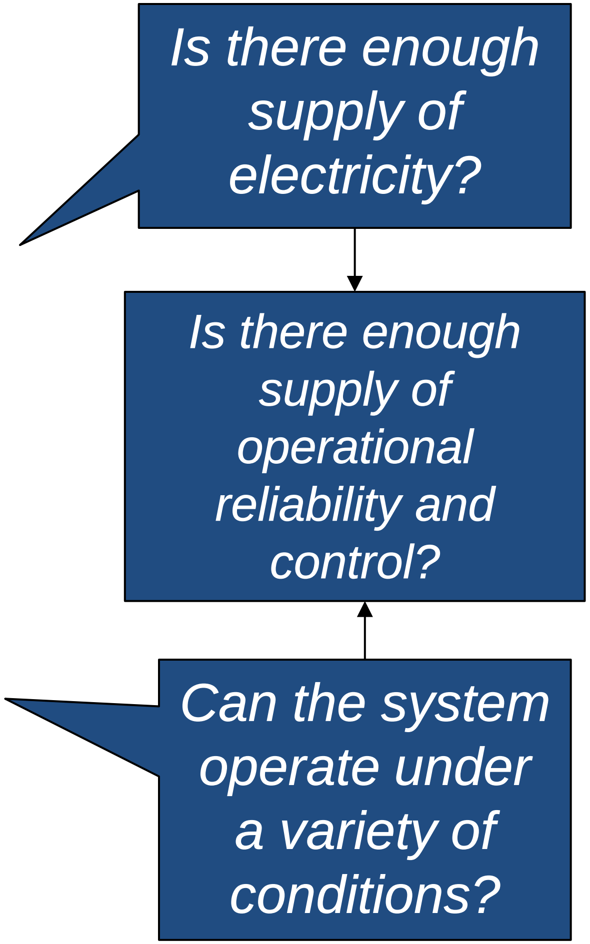
The Bulk Power System: By the Numbers

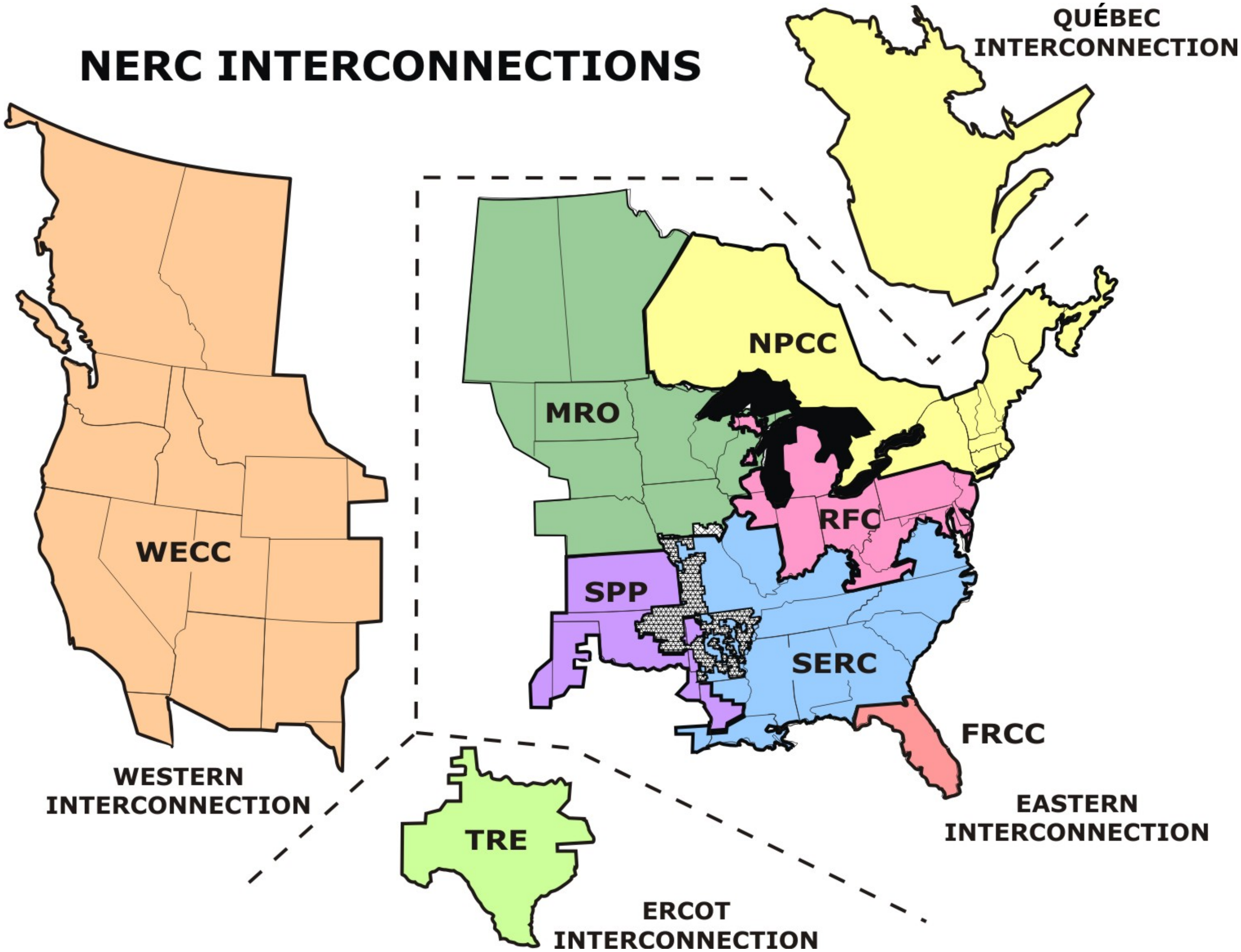

Generation	Transmission	Distribution
Over 5,000 plants	Over 483,000 circuit miles	Over 2,200,000 miles
Over 1,000,000 MW Total Peak Capacity	320 Transmission Operators	430 Distribution Providers
Peak Natural Gas Capacity – 42%	Over 2,000 Substations	Over 980,000 MW Peak Demand
Peak Coal Capacity – 27%	115kV – 735kV (AC), Some DC	<1% Peak Demand Annual Growth
Peak Renewables – 3%		~10 GW Solar PV

What is BPS Reliability?

- The ability of the BPS to meet the electricity needs of end-use customers at all times.
  - **Adequacy** — The ability of the bulk power system to supply the aggregate electrical demand and energy requirements of the customers at all times, taking into account scheduled and reasonably expected unscheduled outages of system elements.
  - **Operating Reliability** — The ability of the bulk power system to withstand sudden disturbances such as electric short circuits or unanticipated loss of system elements from creditable contingencies.



NERC Regions



NERC Assessment Areas

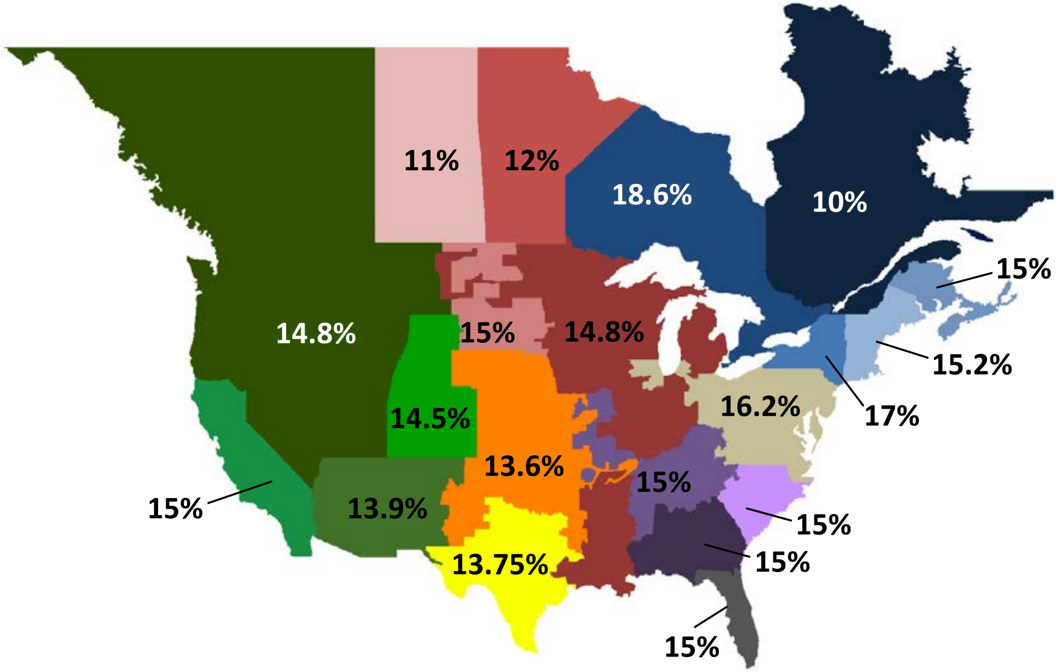
System Dynamic Character is Changing

- Retirement/displacement of conventional generation
  - Variable energy resources
  - Rapid penetration of electronically-coupled resources
- Essential Reliability Services
  - Reduced inertia
  - Frequency Reponses
  - Voltage Support
  - Ramping and flexibility needs
- Rapid penetration of new loads
- System controls and protection coordination
- Modeling and simulation constraints
- Increasing interface with distribution-centric resources

Resource Adequacy

NERC Planning Criteria
Planning Reserve Margins

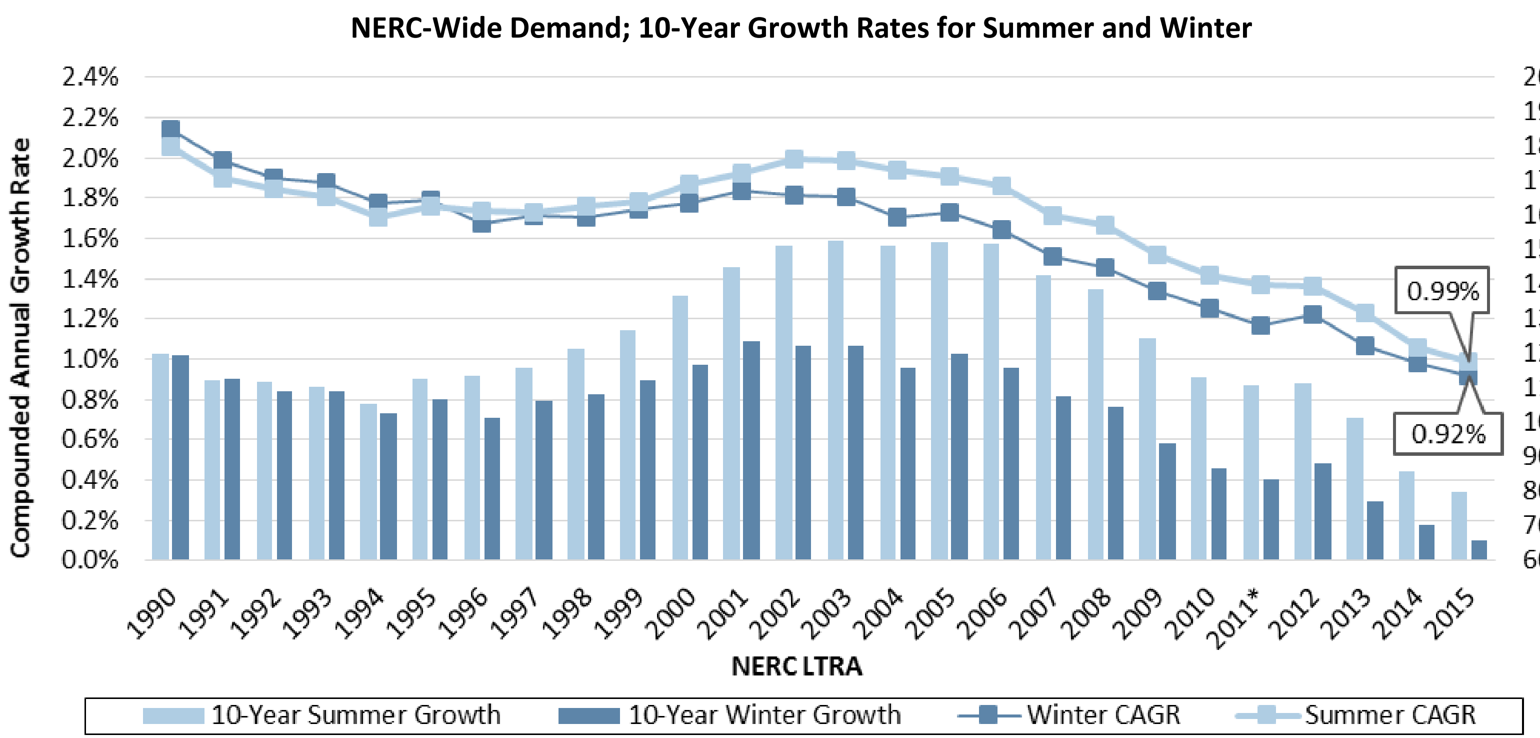
- Reference Margin Level (Target): Determined by loss-of-load expectation (LOLE) studies (varies by Assessment Area)



$$\text{Planning Reserve Margin (\%)} = \frac{[\text{Available Capacity} - \text{Net Internal Demand}]}{\text{Net Internal Demand}}$$

Reliability Finding #1: Reserve Margins in all Assessment Areas appear sufficient but continue to trend downward

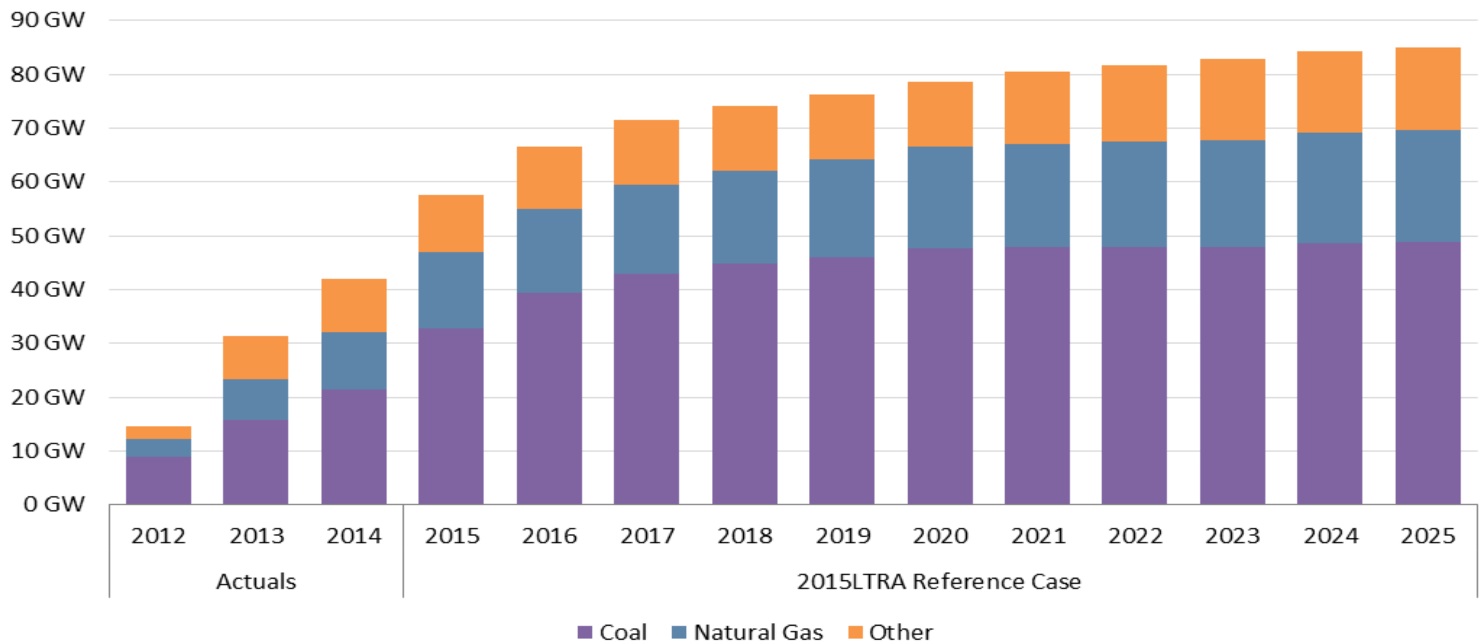
- Energy efficiency and conservation programs increase
- Continued growth in distributed photovoltaic solar and other behind-the-meter resources



Reliability Finding #2: A changing resource mix requires additional measures and approaches for assessing future reliability

- 21 GW of coal-fired units were retired between 2012 and 2014
- An additional 27 GW are scheduled to retire by 2025 (excludes impacts of EPA's proposed Clean Power Plan)

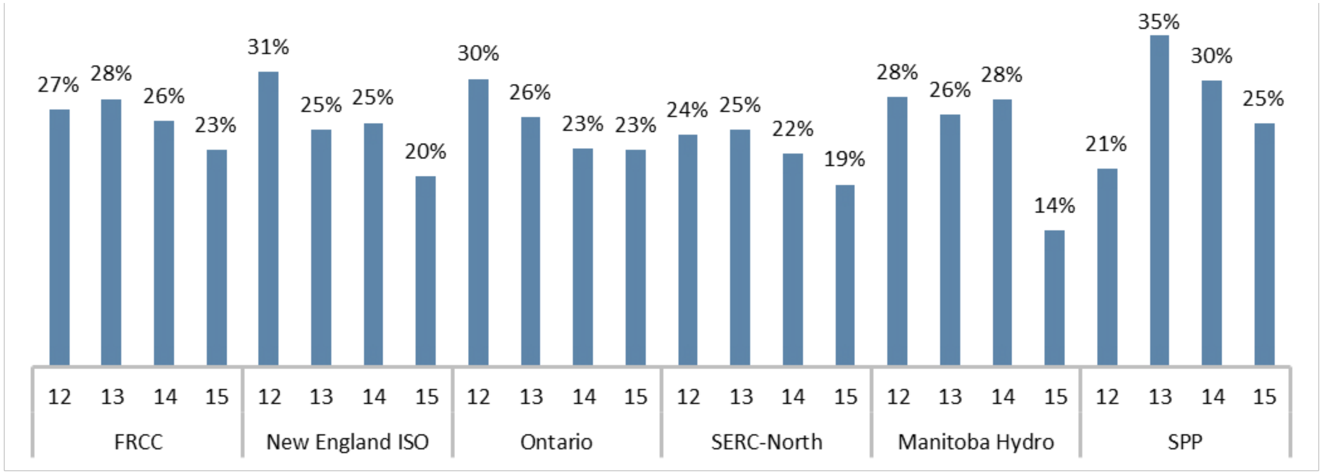
Cumulative Actual and Forecast Confirmed Retirements between 2012 and 2025



Reliability Finding #1: Reserve Margins in all Assessment Areas appear sufficient but continue to trend downward

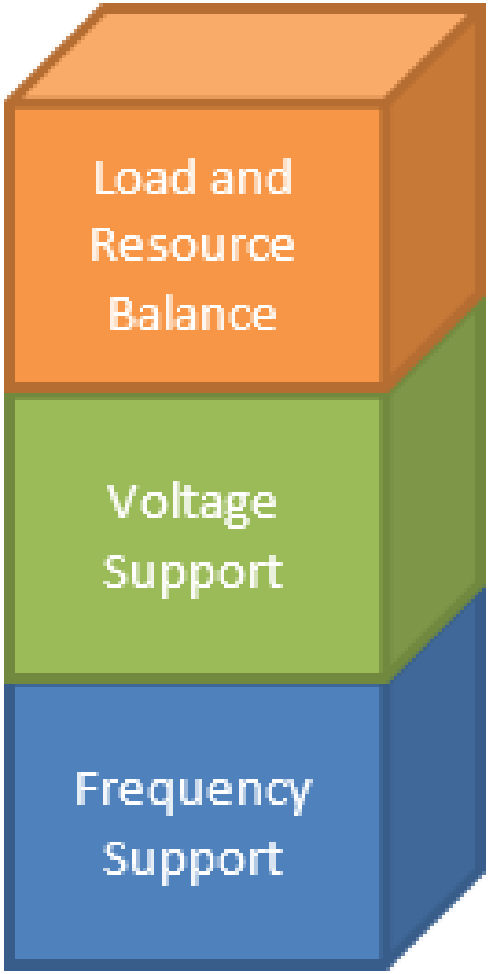
- All Assessment Areas meet Reference Reserve Margins in the short-term (1-5 years)
- Several Assessment Areas show declining trends in the amount of planning reserve margins despite low load growth

Declining Year-2 Anticipated Reserve Margins



Essential Reliability Services

ERS Fundamentals



- "Building blocks" of physical capabilities
- Accentuated by resource changes
- Not all MWs are equal
- Some partly covered through ancillary services
- Accommodate local/regional needs

Objectives of this Effort

- Goal is to inform, educate, and build awareness on the implications of the changing resource mix and how industry can evolve the system in a reliable manner
- Consider technical aspects of ERS when making decisions related to interconnecting new resources or market and tariff oversight
- Policy decisions have direct influence on changes in the resource mix, and thus can also affect the reliability of the bulk power system

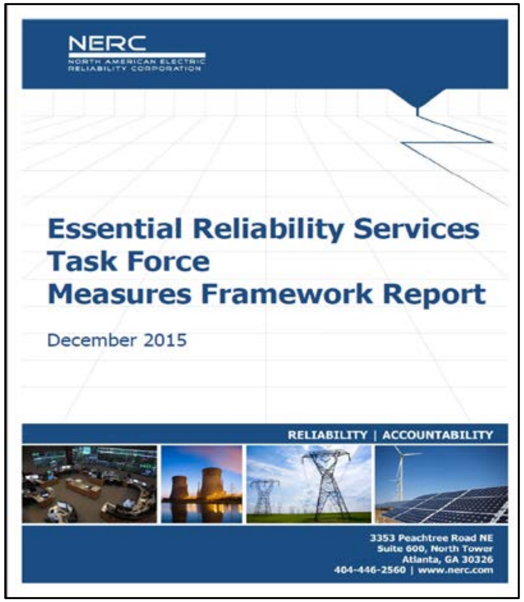
Key Achievements

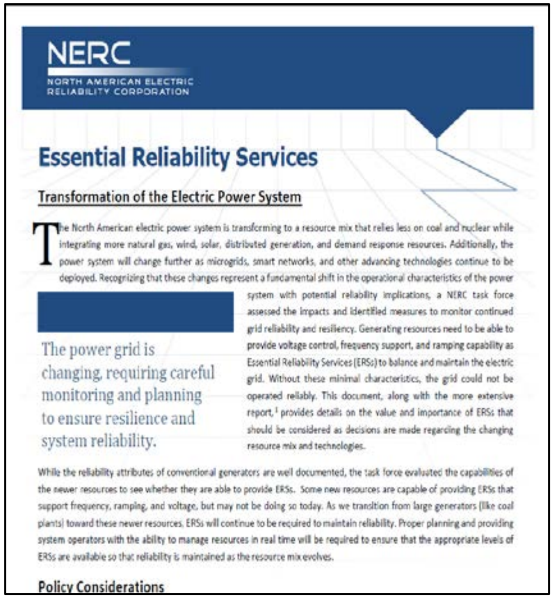
ERSTF work allowed NERC to:

- Inform, educate, and build awareness on the implications of the changing resource mix
- Consider technical aspects of ERS when making decisions related to interconnecting new resources or market and tariff oversight
- Have direct influence on policy decisions with regards to changes in the resource mix
    - FERC NOPR – Reactive Power Requirements for Non-Synchronous Generation
    - FERC NOI – Essential Reliability Services and the Evolving Bulk Power System – Primary Frequency Response

In 2015 NERC Board Approved

[Framework](#) Report | [Abstract](#) Document | ERS [Videos](#)





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Essential Reliability Services

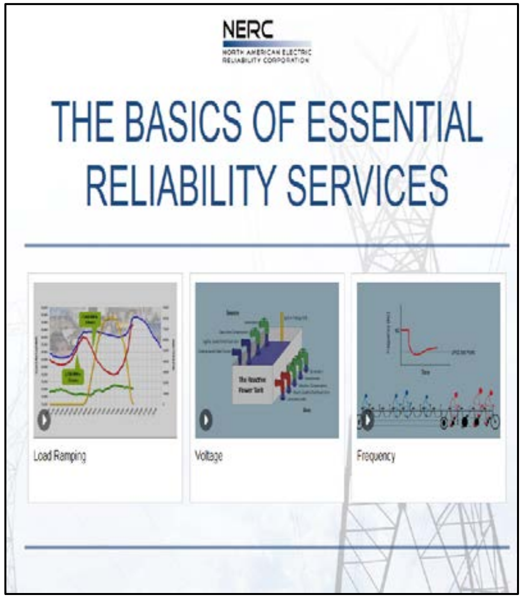
Transformation of the Electric Power System

The North American electric power system is transforming to a resource mix that relies less on coal and nuclear while integrating more natural gas, wind, solar, distributed generation, and demand response resources. Additionally, the power system will change further as microgrids, smart networks, and other advancing technologies continue to be deployed. Recognizing that these changes represent a fundamental shift in the operational characteristics of the power system with potential reliability implications, a NERC task force assessed the impacts and identified measures to monitor continued grid reliability and resiliency. Generating resources need to be able to provide voltage control, frequency support, and ramping capability as Essential Reliability Services (ERSs) to balance and maintain the electric grid. Without these minimal characteristics, the grid could not be operated reliably. This document, along with the more extensive report,[1] provides details on the value and importance of ERSs that should be considered as decisions are made regarding the changing resource mix and technologies.

The power grid is changing, requiring careful monitoring and planning to ensure resilience and system reliability.

While the reliability attributes of conventional generators are well documented, the task force evaluated the capabilities of the newer resources to see whether they are able to provide ERSs. Some new resources are capable of providing ERSs that support frequency, ramping, and voltage, but may not be doing so today. As we transition from large generators (like coal plants) toward these newer resources, ERSs will continue to be required to maintain reliability. Proper planning and providing system operators with the ability to manage resources in real time will be required to ensure that the appropriate levels of ERSs are available so that reliability is maintained as the resource mix evolves.

Policy Considerations



Why Primary Frequency Response Is Important

Essential for Reliability of the Interconnection

- Line of defense to prevent UFLS and prevent equipment damage

Compliance with NERC Standards BAL-003-1, BAL-001

- Support future regulations related to generator performance

Essential for System Restoration

- Coordinated droop response is critical for the interconnected system

To accurately predict system events (models)

- Tell-tale characteristics can identify system trends for proactive response

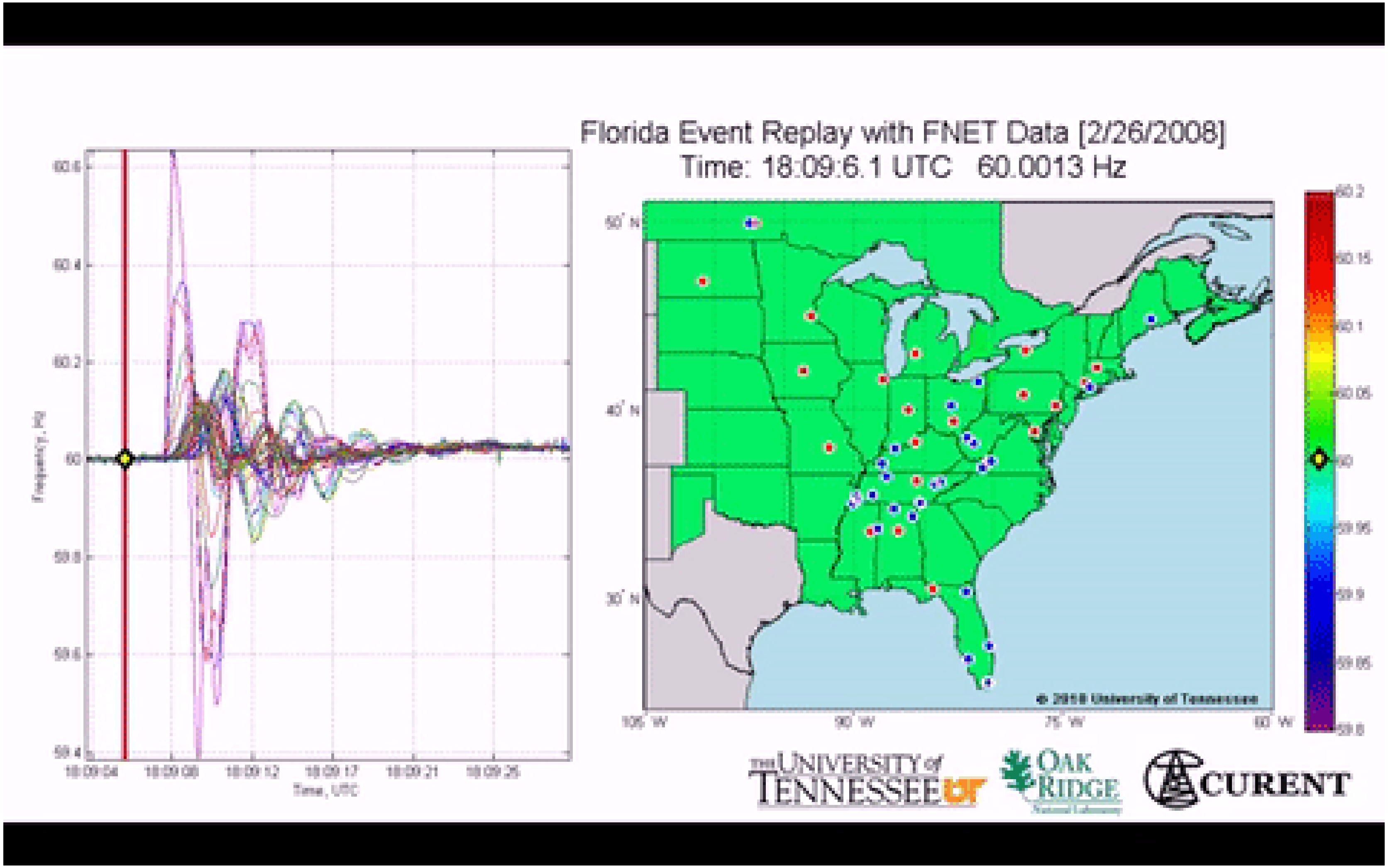
Risk to Reliability

- Potential for lower inertia with retirement of coal and oil-fired synchronous generators
- Higher penetration of renewables with potentially lower frequency response
- No assurance of adequate inertia or frequency response capability for some resource dispatch scenarios
- Trade-offs between inertia and Primary Frequency Response

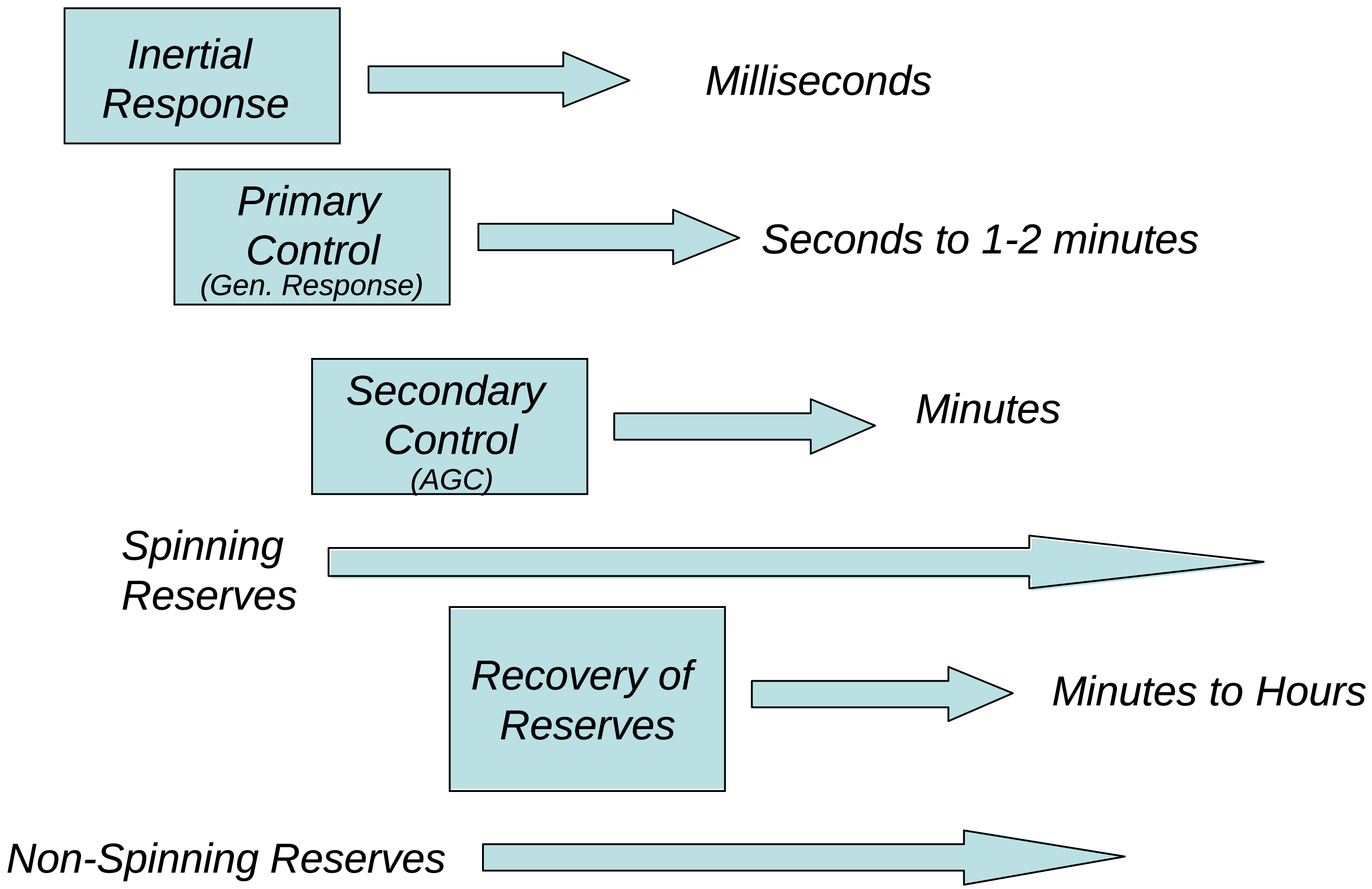
Conservative approach

All resources should have frequency responsive capability to assure that frequency response is available for any resource dispatch.

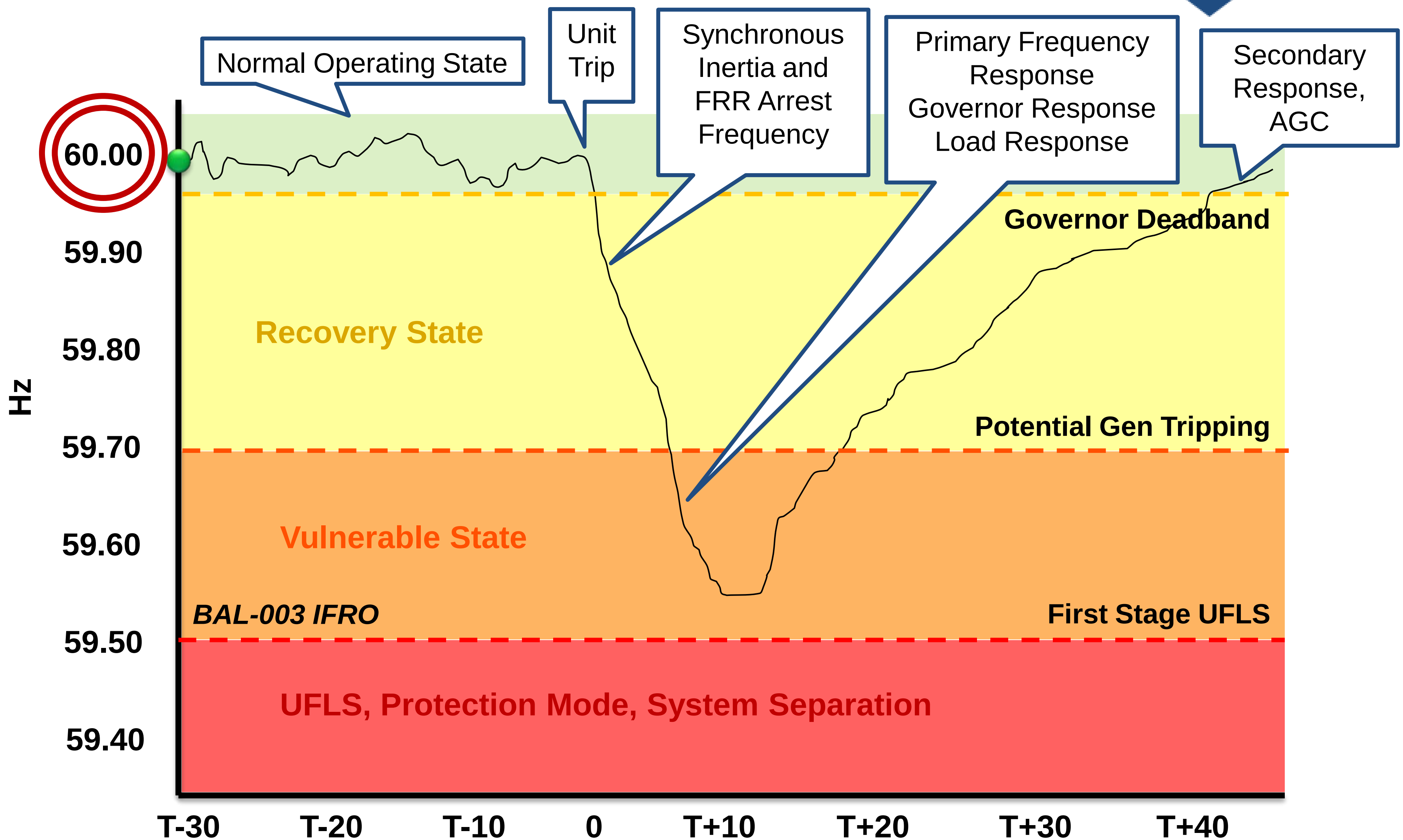
Frequency Excursion – Interconnection-wide Phenomena



Frequency Response Control Continuum



Anatomy of a Frequency Excursion with Recovery



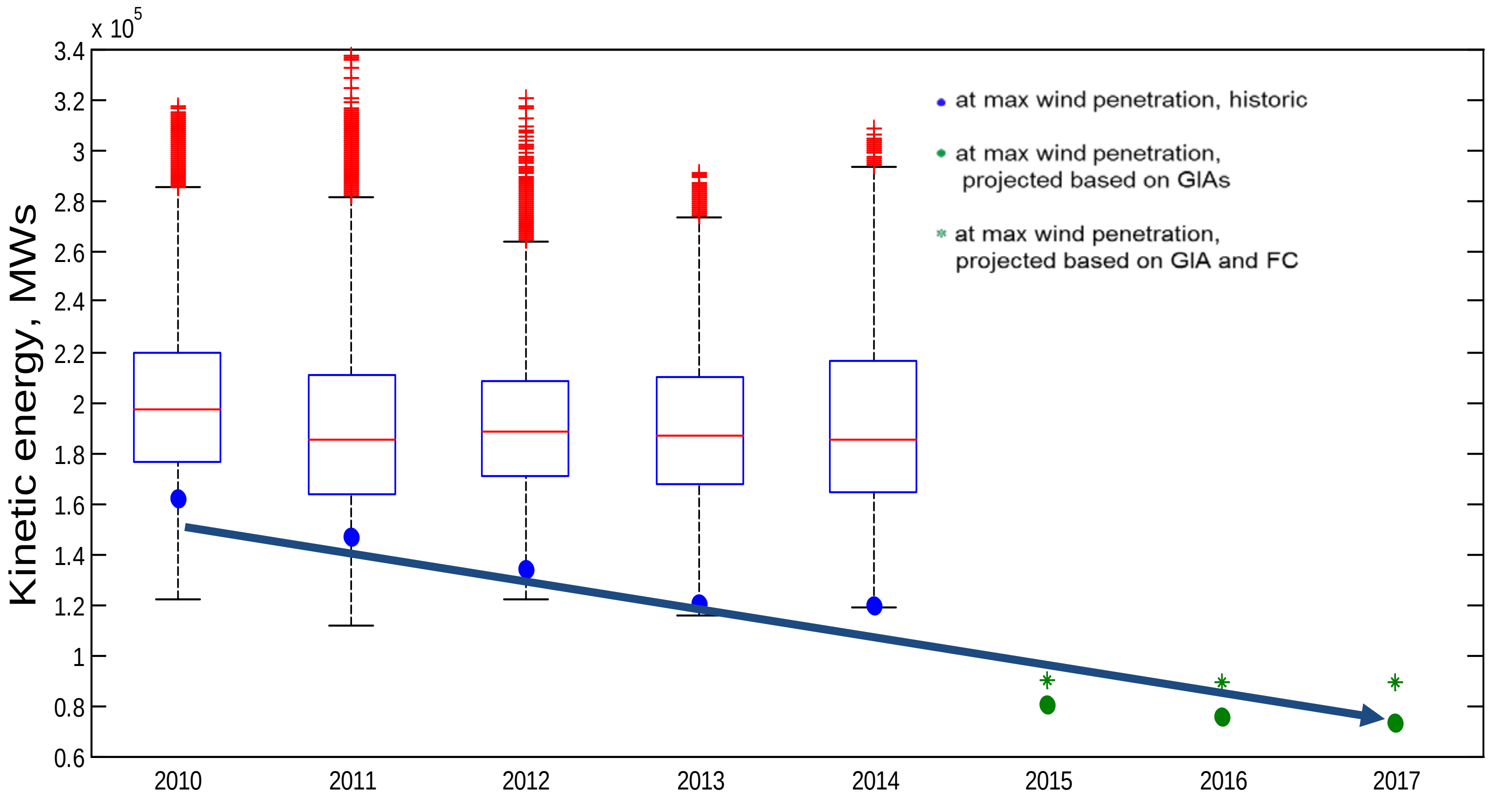
For illustrative purposes only. This is not real data. Actual trip settings and operational modes are different for each interconnection and not fixed at the levels shown.

Essential Reliability Measures

- Synchronous Inertial Response – Interconnection level
- Initial Frequency deviation following largest contingency
- Synchronous Inertial Response – Balancing Authority level
- Ramping capability
- Voltage performance
- Overall system reactive performance

Monitor Trends in Frequency

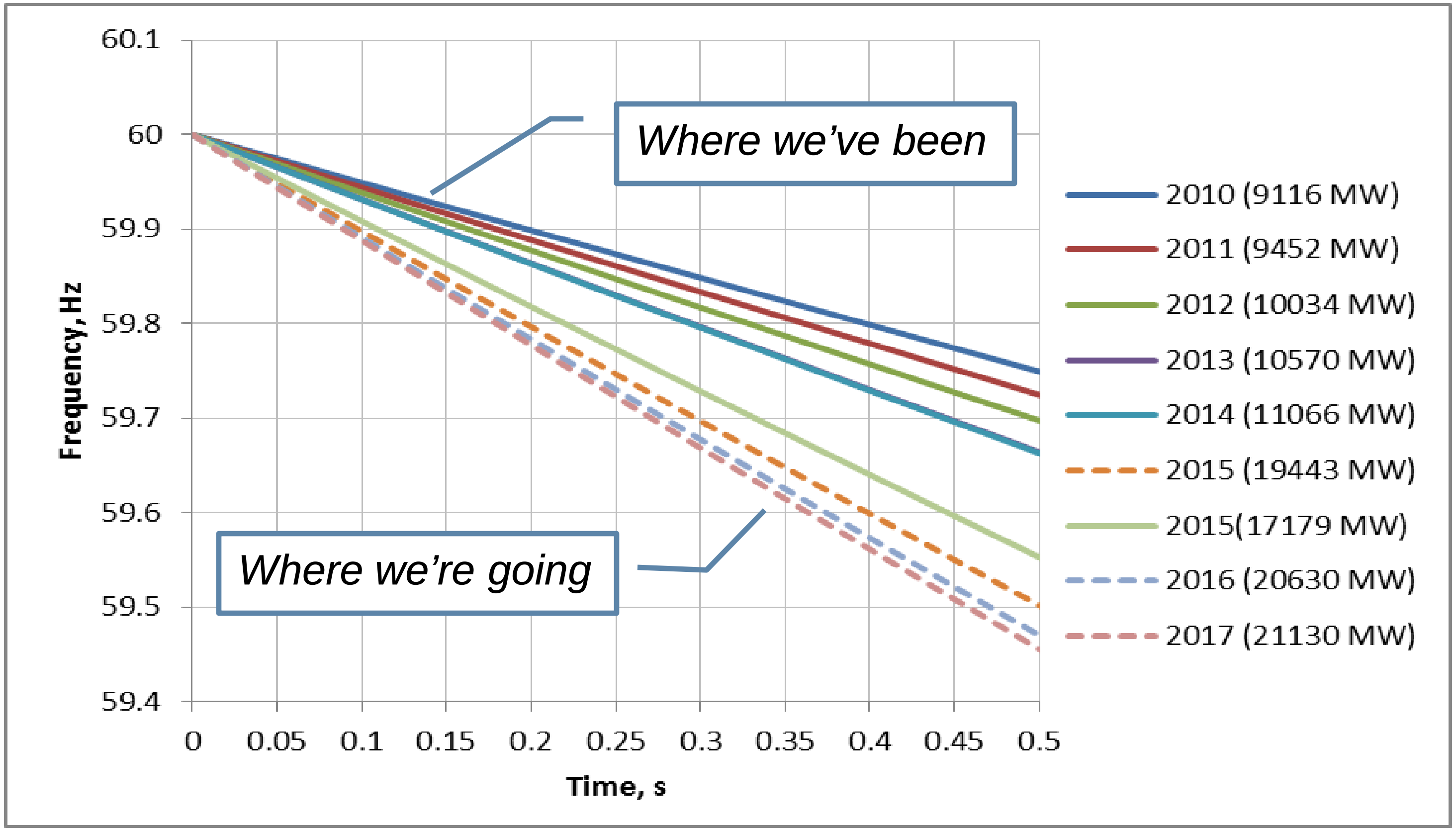
Synchronous inertia is declining……



ERCOT Historic Kinetic Energy Boxplots (2010–2017)

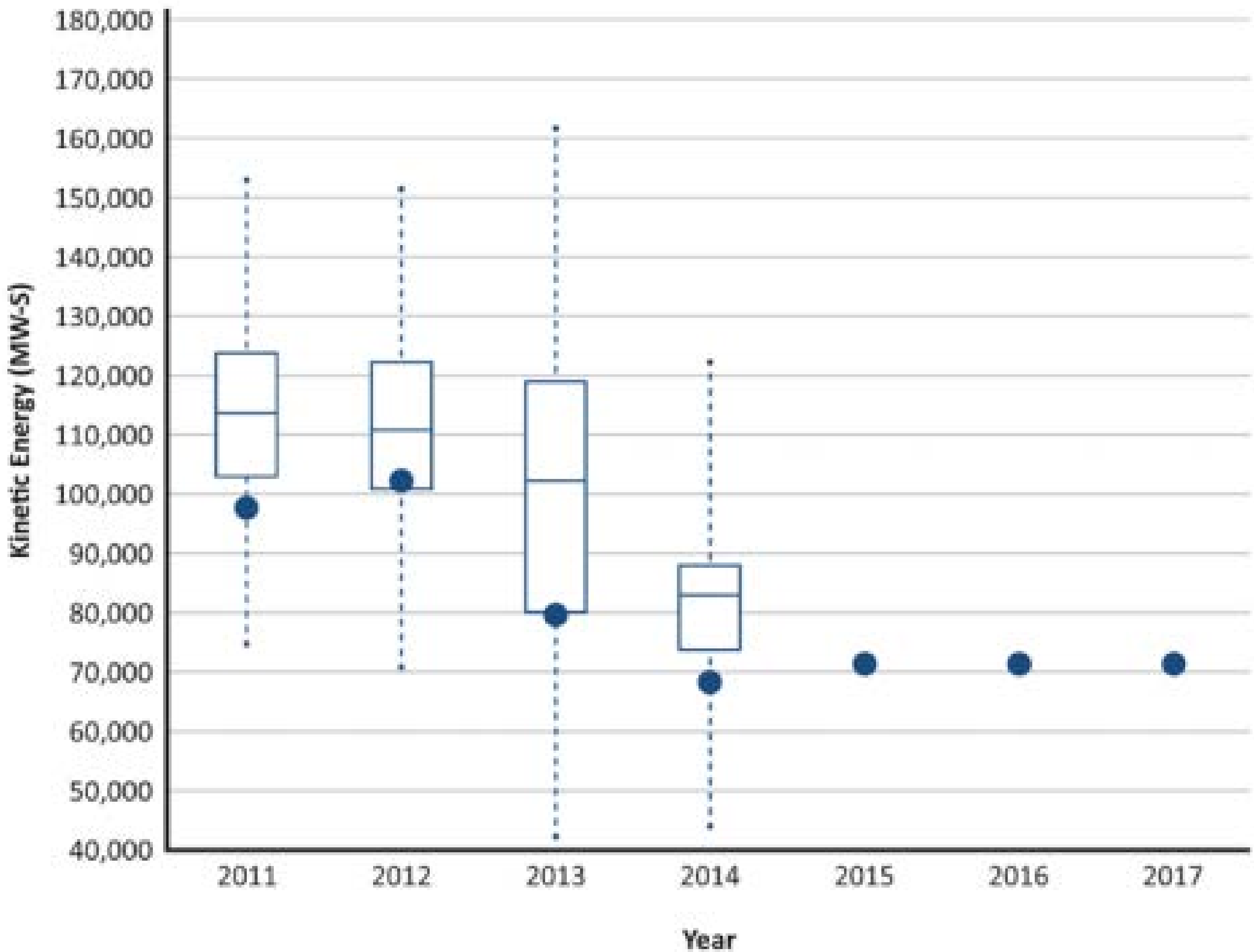
Frequency Deviation

Decline in inertia → Increase in Frequency Deviation



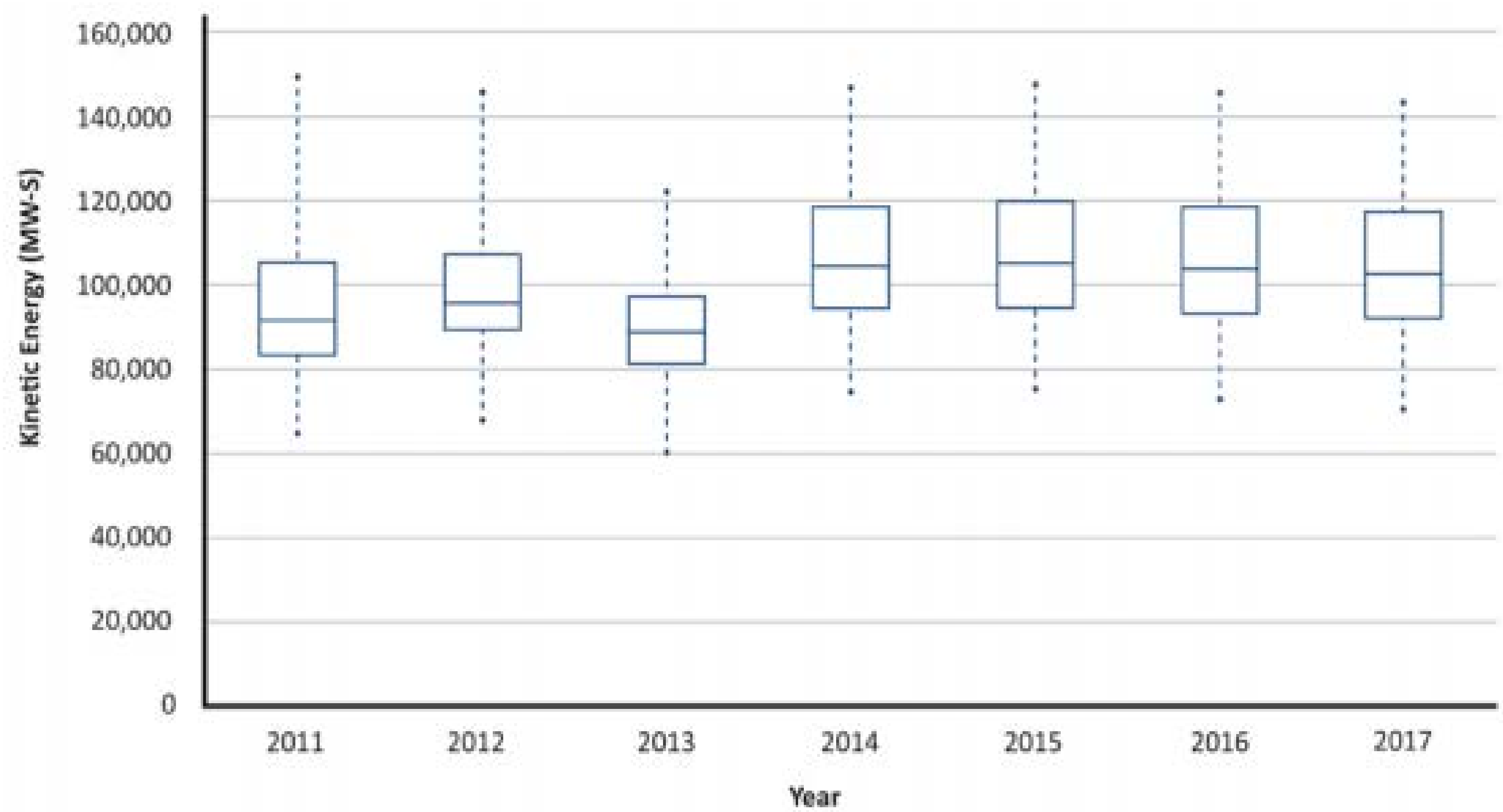
Calculated ERCOT System Frequency after 2750 MW Generation Trip (2010-2017)

…In Ontario



Historic boxplots and future projections of SIR at peak nonsynchronous generation penetration hour. Blue dots correspond to peak nonsynchronous generation penetration hour in each year.

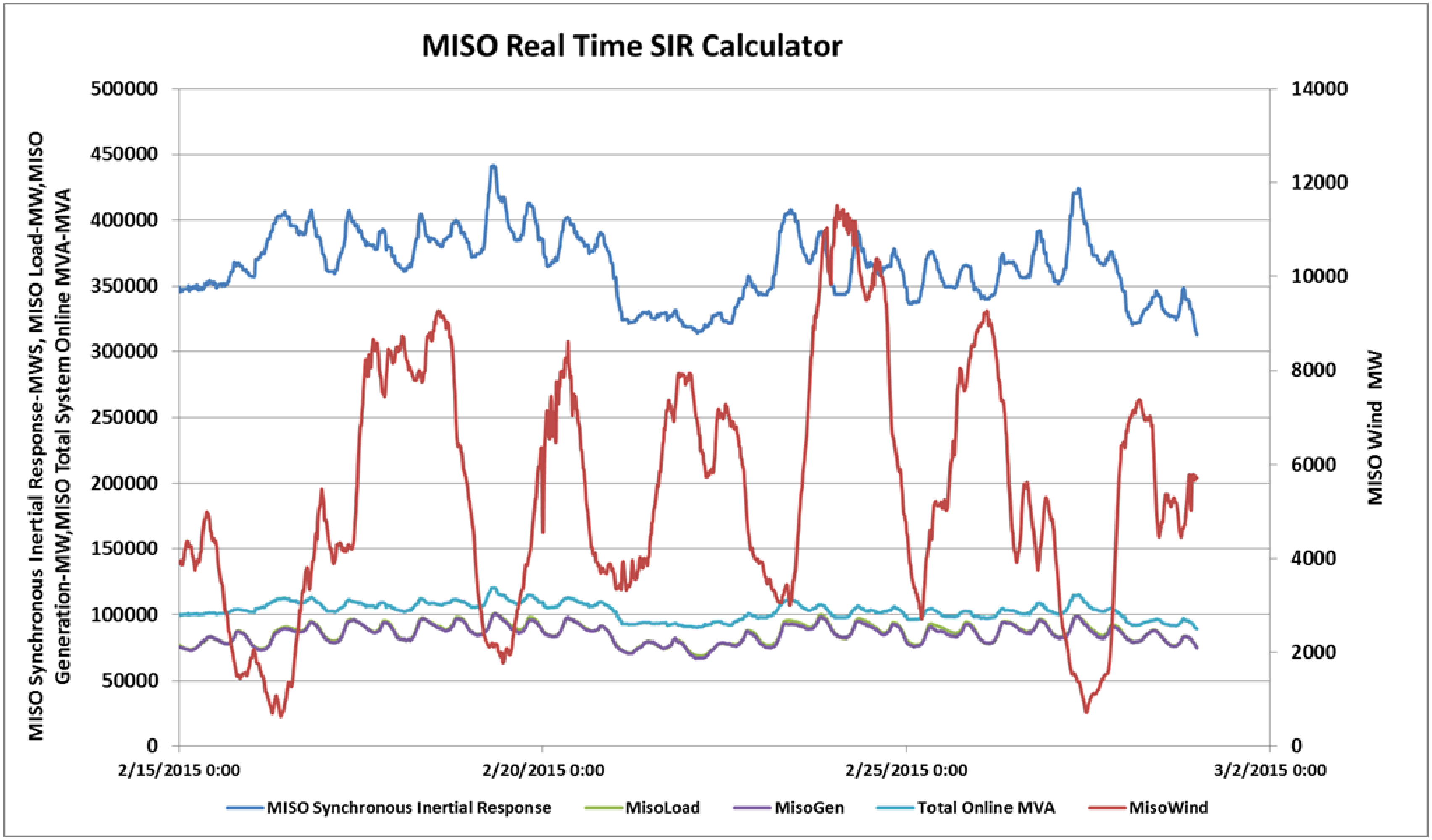
…In Southern



Historic boxplots and future projections of SIR at peak nonsynchronous generation penetration hour. Blue dots correspond to peak nonsynchronous generation penetration hour in each year.

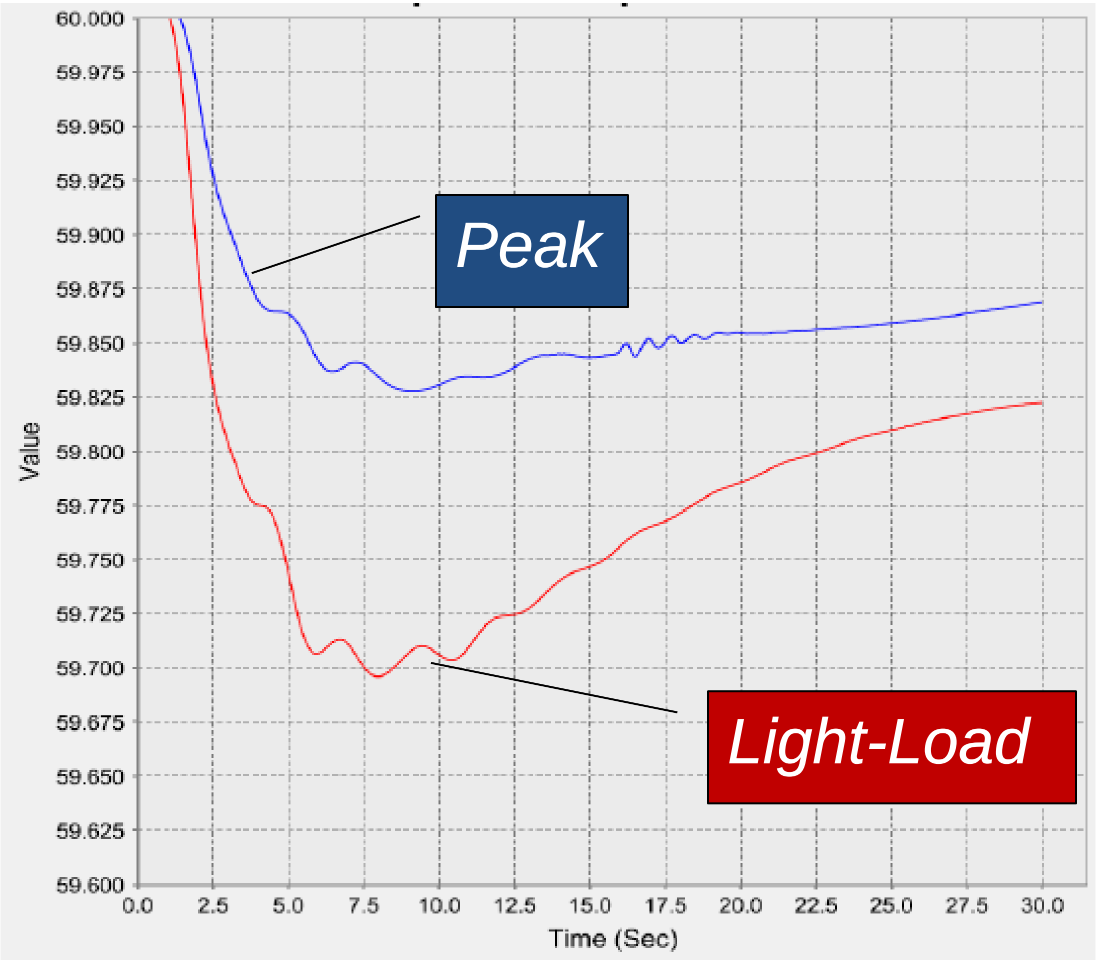
Measure 5 – Industry Practice

Real-time Synchronous Inertial Response (SIR) Monitor - MISO



Simulate Frequency Response With Different Resources

WECC – Loss of Two Palo Verde units (2,750 MW)



Peak Case

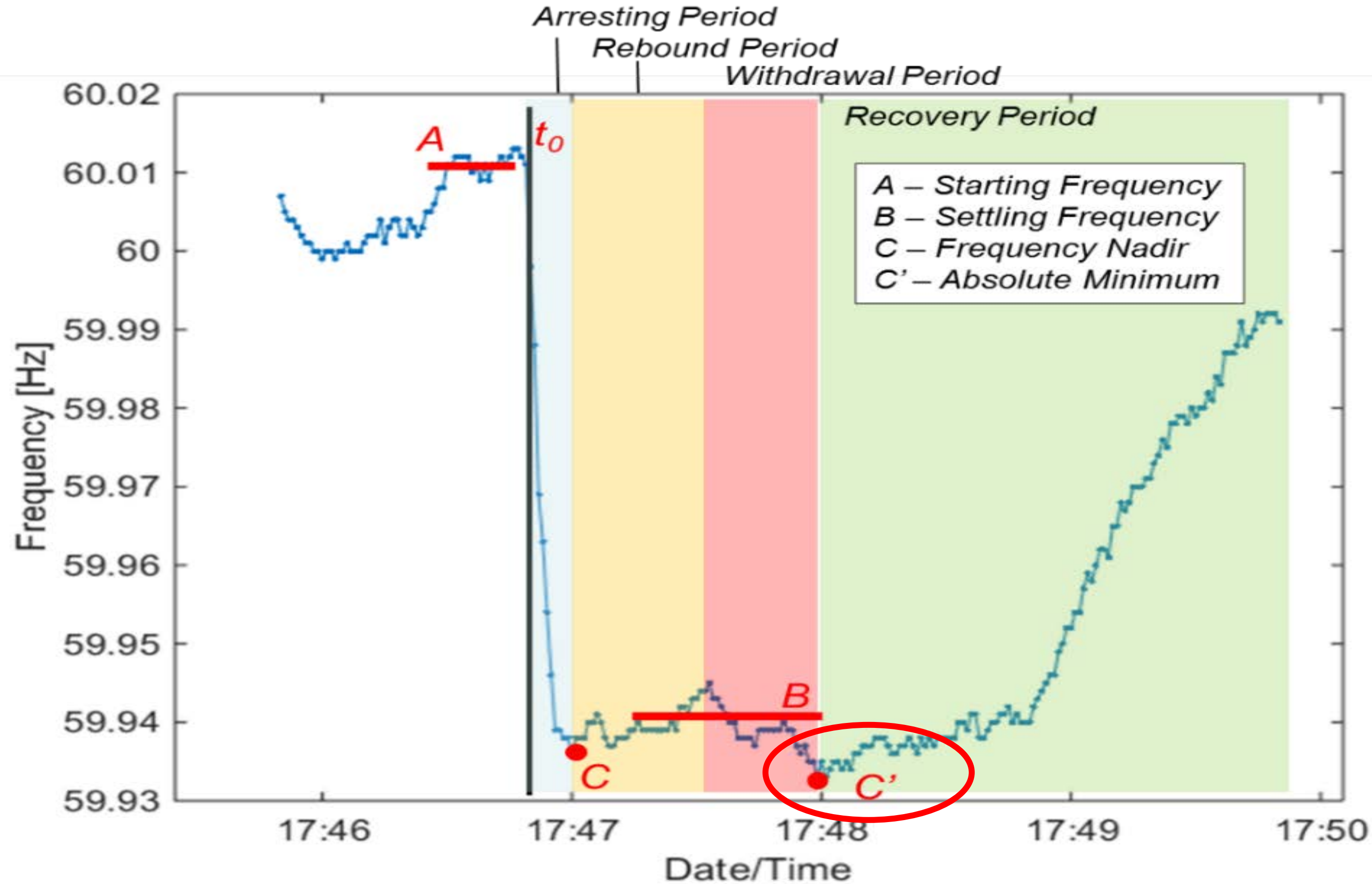
Robust resources and transmission online

Light-Load Case

Baseload and variable resources online, no midrange units

Need to Evaluate Frequency Response

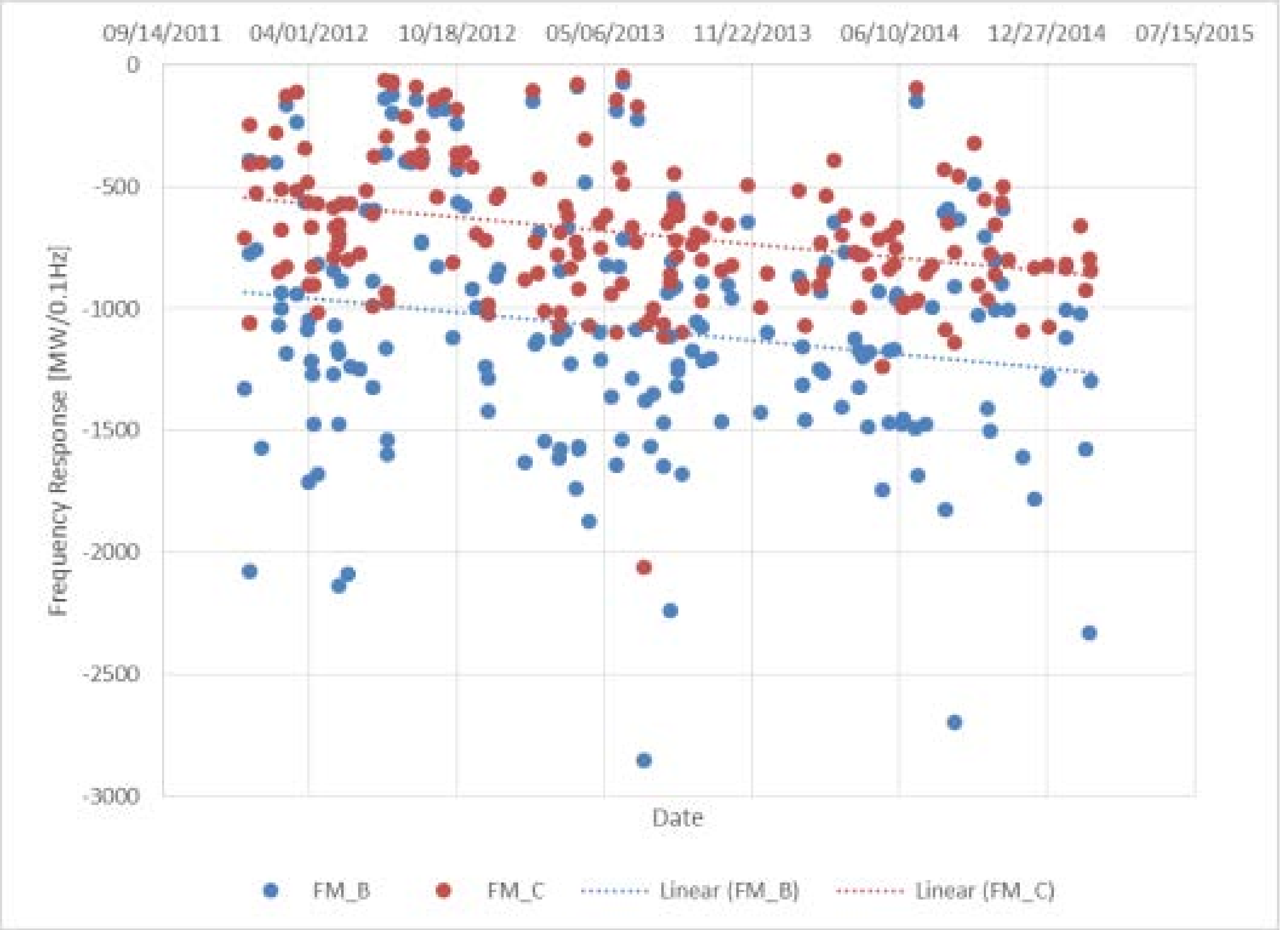
Need to evaluate Point C' – Governor Withdrawal



Frequency Response Example for Large Disturbance in Eastern Interconnection (with Governor Withdrawal)

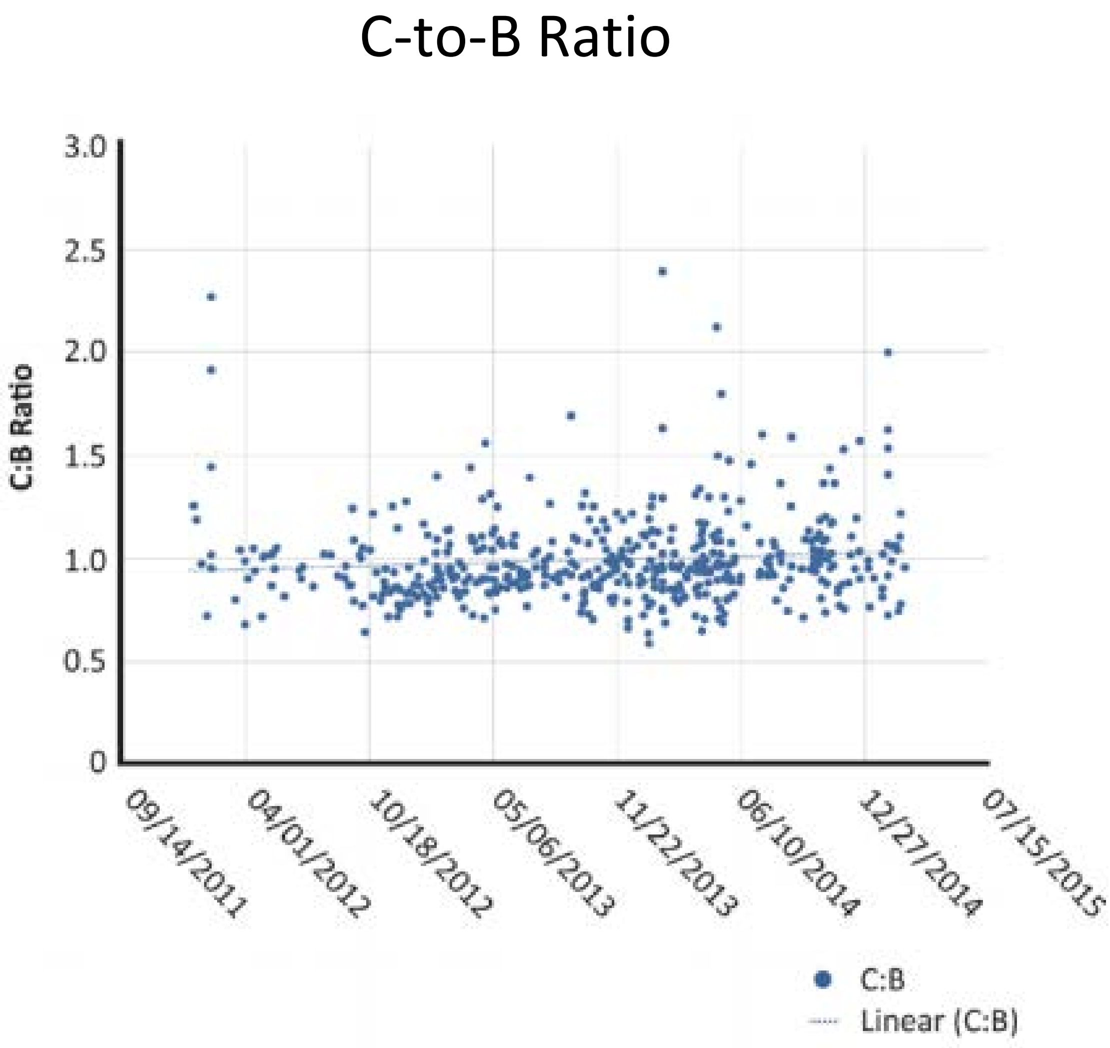
Western Interconnection Example

A-to-B and A-to-C Frequency Response



This indicates improved interconnection governor response to frequency deviations (mid 2011 – mid 2014)

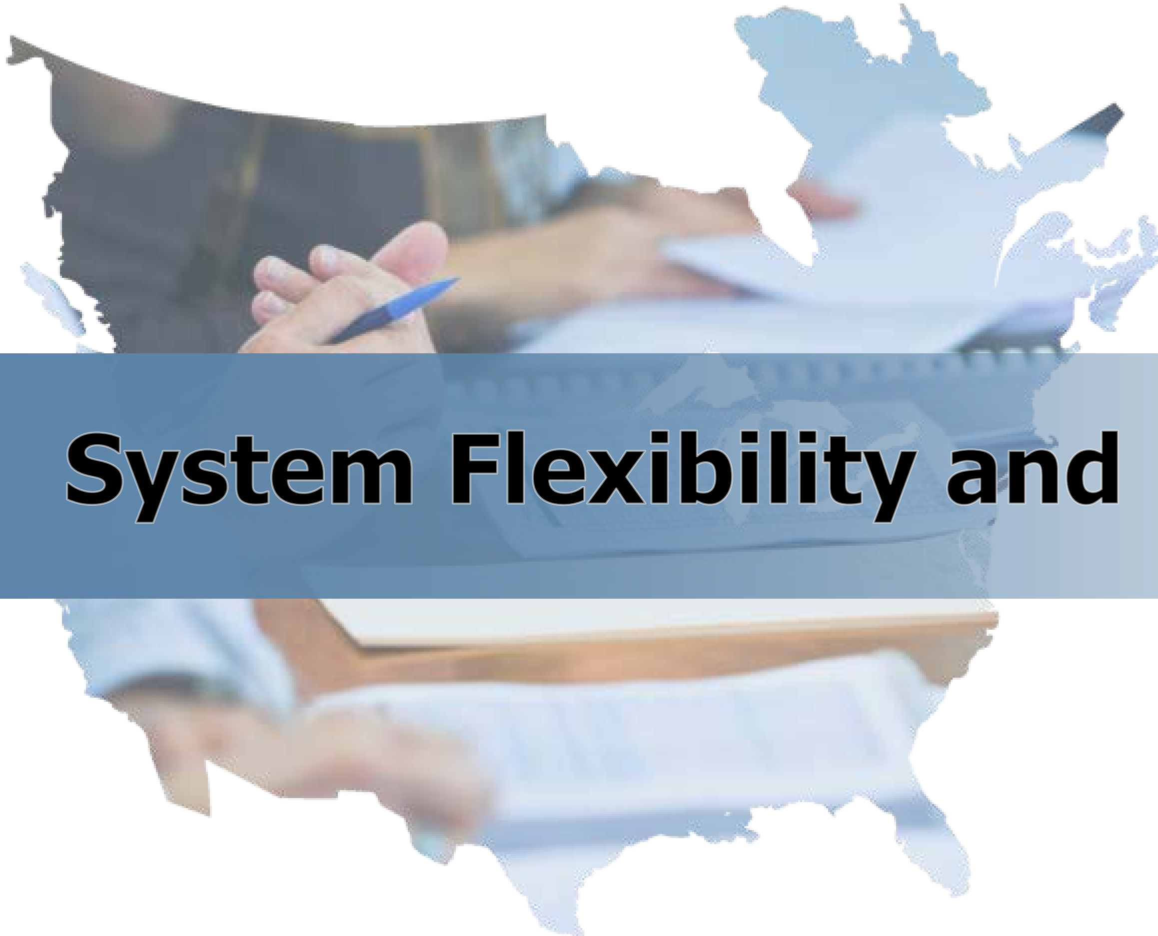
Eastern Interconnection Example



- Increasing trend, larger differences between C (Nadir) and B (Settling) points
- Improving B-Value
- Note the number of ratio <1, (nadir higher than settling point)

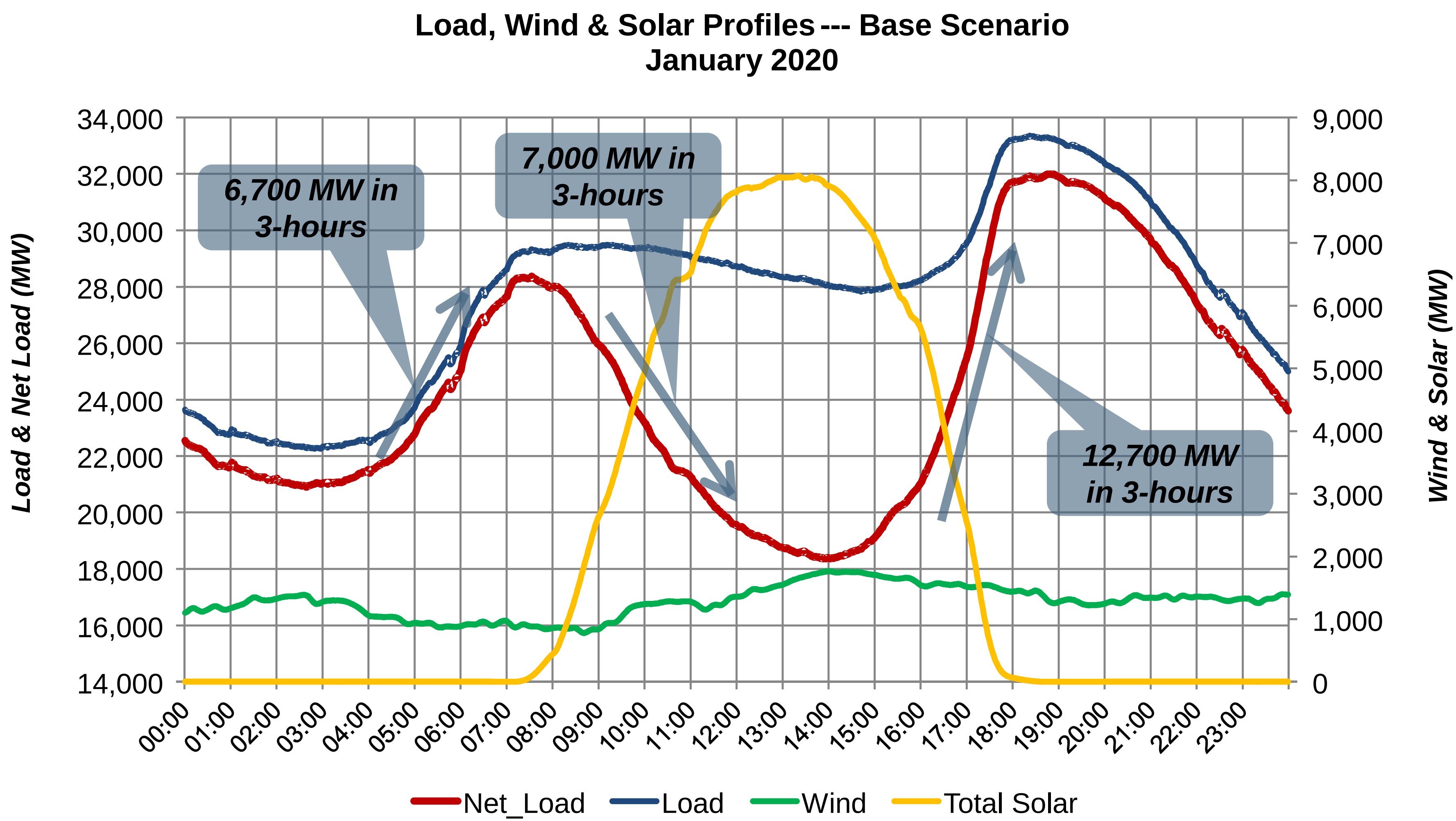
Focus Areas of Frequency Response

- BAL Standard
  - Does not guarantee performance for each event, measured by median performance
  - Provides consistent methods for measuring Frequency Response and determining the Frequency Bias Settings
- Asynchronous Resources
  - Modifying NERC Guidelines to include desired operating characteristics for all resources
  - Coordinating with IEEE on Standard 1547 for DER
  - Not currently required to have the capability to provide FR
- Planning
  - Frequency Response studies in the planning horizon



System Flexibility and Ramping

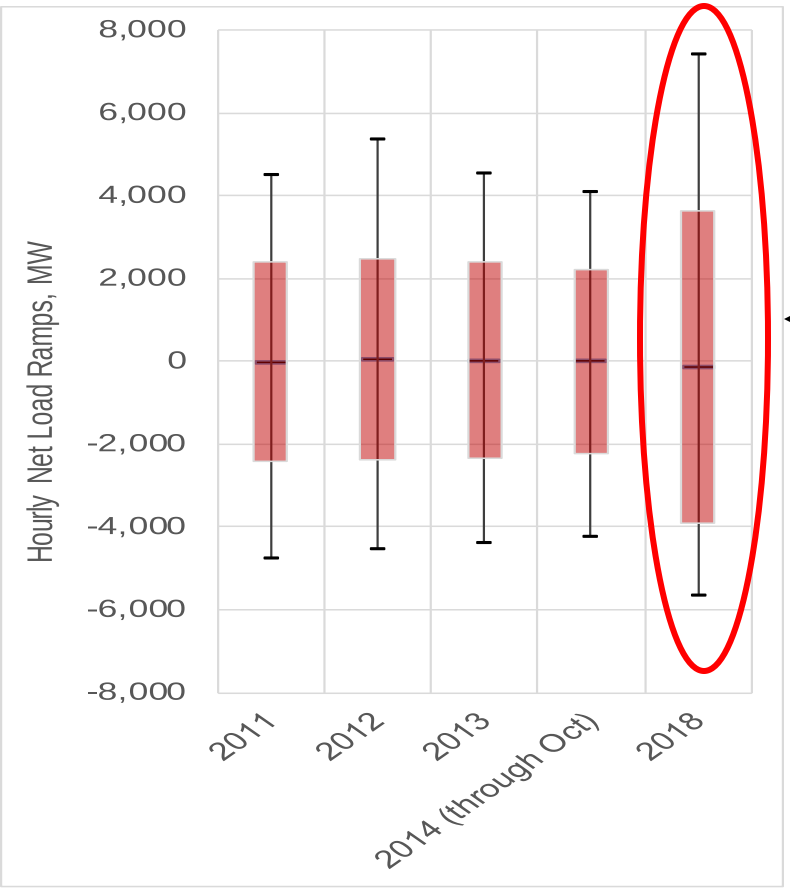
The Need For Flexibility: A Future, Not a Scenario



Net Load = Load - Wind - Solar

Slide 38

Need More Flexibility for Ramping

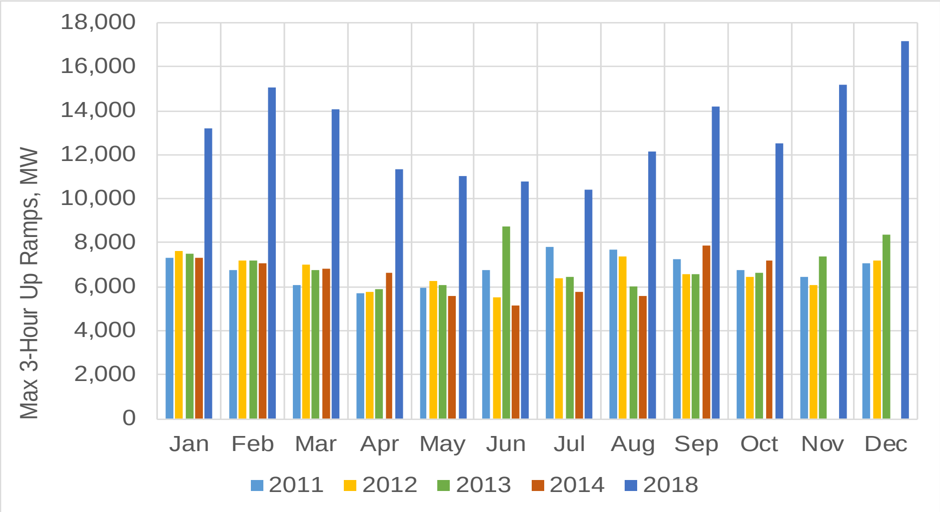


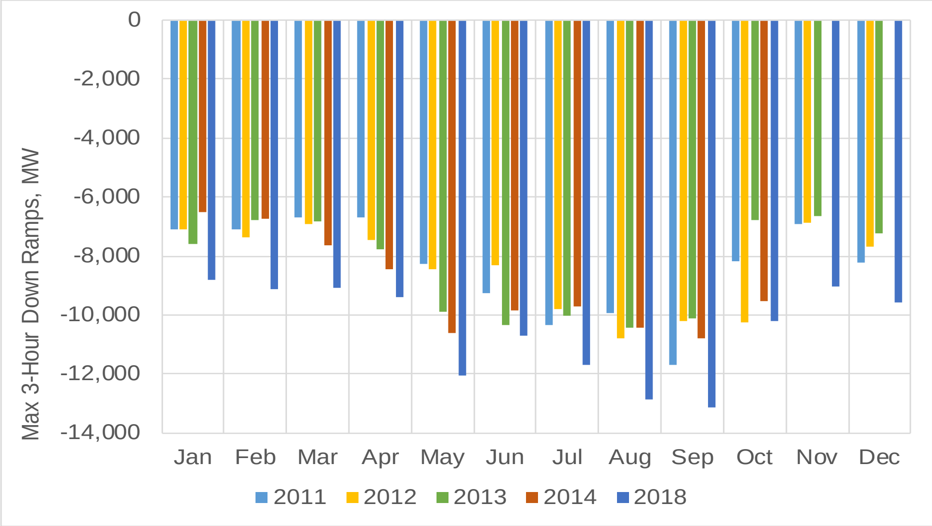
How do we address the need for flexibility?

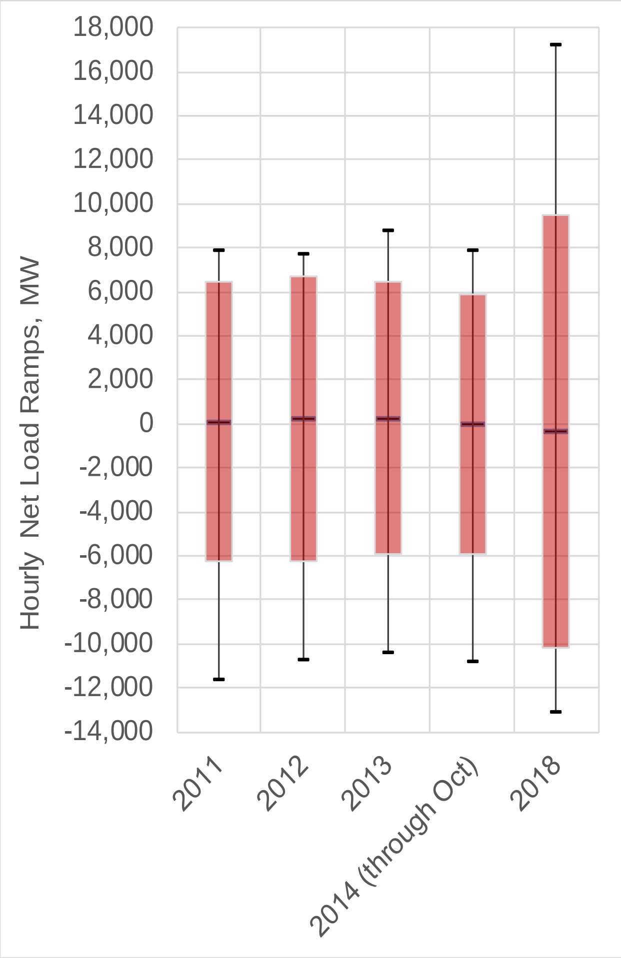
CAISO Yearly One-Hour Ramp Distribution

Red shaded area represents 2 σ from the mean

Ramping Flexibility Needed in California ISO (3-Hour Ramps)

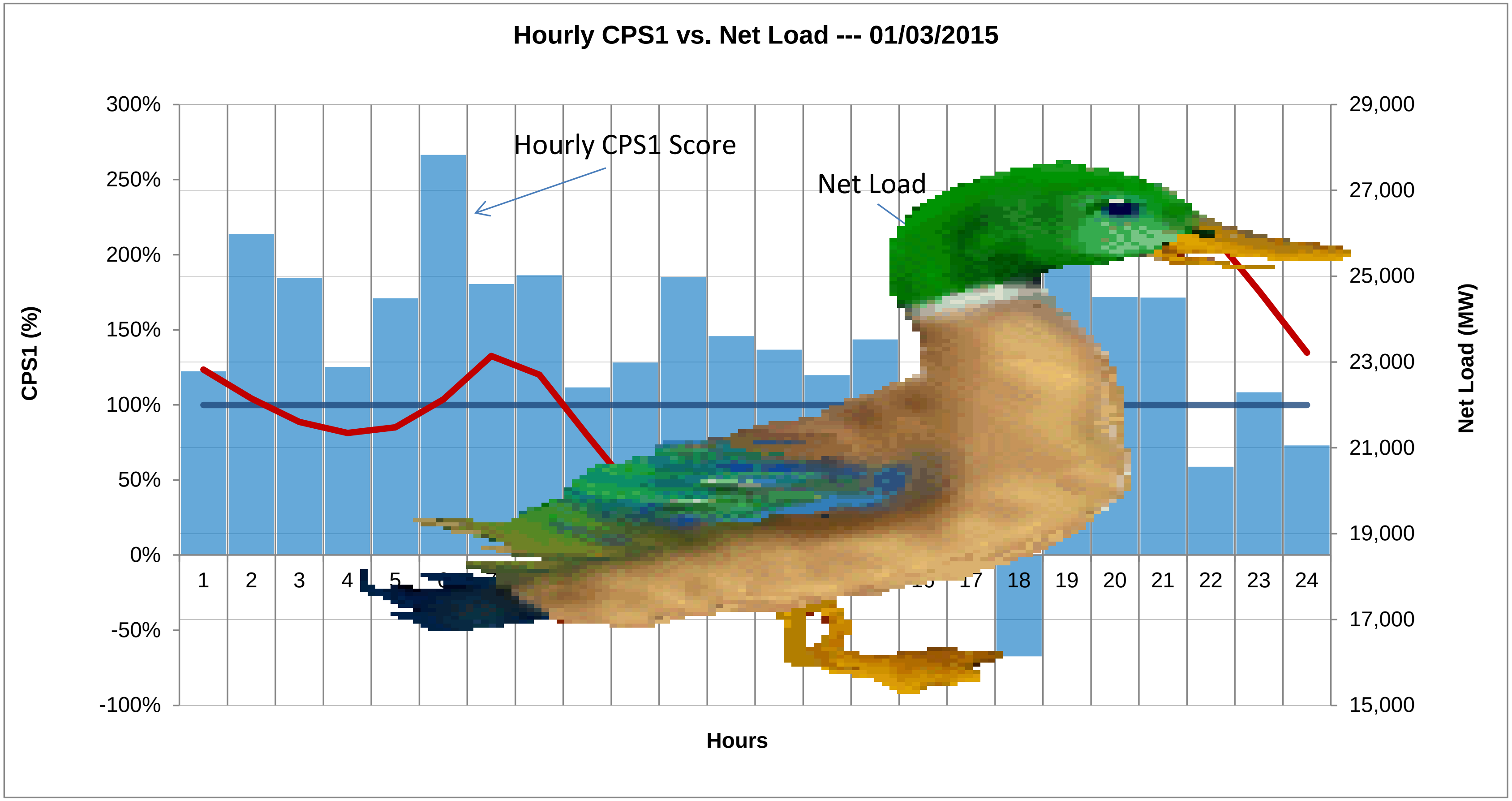






Hourly monitoring of CAISO's CPS1 Survey Found a Trend

CPS1 score dropped below 100% at steep evening upward net load ramps



Accommodating High Levels of Renewables

Three Key Considerations

Reliably integrating these resources into the bulk power system will require significant changes to traditional methods used for system planning and operation

Forecasting

- Variable Fuels Must Be Used When Available
- Forecast is only information; operator must make informed decisions
- "It's the ramps, not the ripples"
- Methods for calculating expected on-peak capacity

Flexibility

- More Ancillary Services
- Larger Balancing Authorities
- Flexible Resources
  - Storage
  - PHEV
  - Leverage fuel diversity of other variable resources

Transmission

- Interconnect variable energy resources in remote areas
- Construct/site/permit transmission to deliver power across long distances

Accommodating Large Amounts of Variable Resources

- No fundamental, technical barrier
- Evolution of transmission planning, system operating policy, market development and cross-border cooperation
- Solutions will be needed in the following areas:
  - Large balancing areas
  - Faster markets
  - Remove barriers to transmission
  - Need for forecasting
  - Grid codes
  - Dynamic models
  - Probabilistic planning methods
  - Incorporating need for flexibility in G&T planning
  - DSM and EV as sources of flexibility

All Generators Impose Operating Constraints

- Every resource has operating constraints that reflect characteristics of fuel and technology
  - Conventional limitations
  - Start-up times & costs
  - Minimum run times
  - Operating ranges
  - Ramp rate limitations
  - Forced outages & contingencies

- Fuel supply characteristics matter… for gas, nuclear, wind, solar, etc.
- The challenge of Variable Energy Resources (VER) is a bit different, but not unique

When is VER Integration Easier?

- Large system with diverse and dispersed generation fleet
- Majority of generators are dispatched every five minutes
- VER plants are efficiently dispatched (using a forecast that reflects their implicit resource characteristics)
- Generators (including VER) with “ride-through” capabilities
- Most generators (including VER) provide reactive support
- Even with a slow-ramping fleet (e.g., mostly coal plants), ramping is not a concern
  - Ramping capability actually increases during periods of high VER output because other units are backed down
  - More challenging when integrating distributed resources

When is VER Integration More Difficult?

- Inefficient VER dispatch
  - Using hour- or day-ahead forecasts
  - Lack of visibility and control
- Limited export and interchange capabilities
- Minority of generators dispatched or offering flexibility
  - Generation is self-scheduled or viewed as “can’t touch”
  - Incentives discourage using/building flexibility
  - “Inflexible floor” pushes other generation out of dispatch and creates a min-gen situation when VER output is high

System-wide constraints may make it difficult to commit flexibility and maintain a robust dispatch stack, creating “ramp scarcity”

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Need for Transmission

High levels of variable generation will require ***significant transmission additions*** *and reinforcements.*

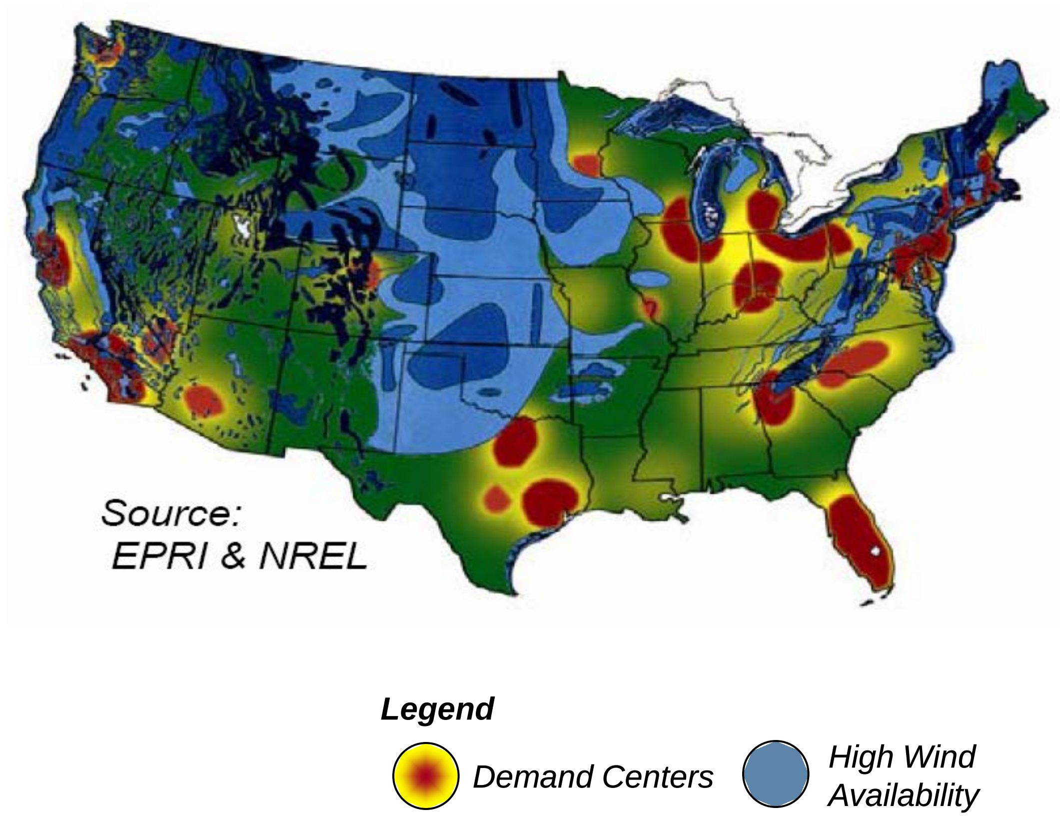
- ***Challenge***

  Interconnect variable energy resources in remote areas

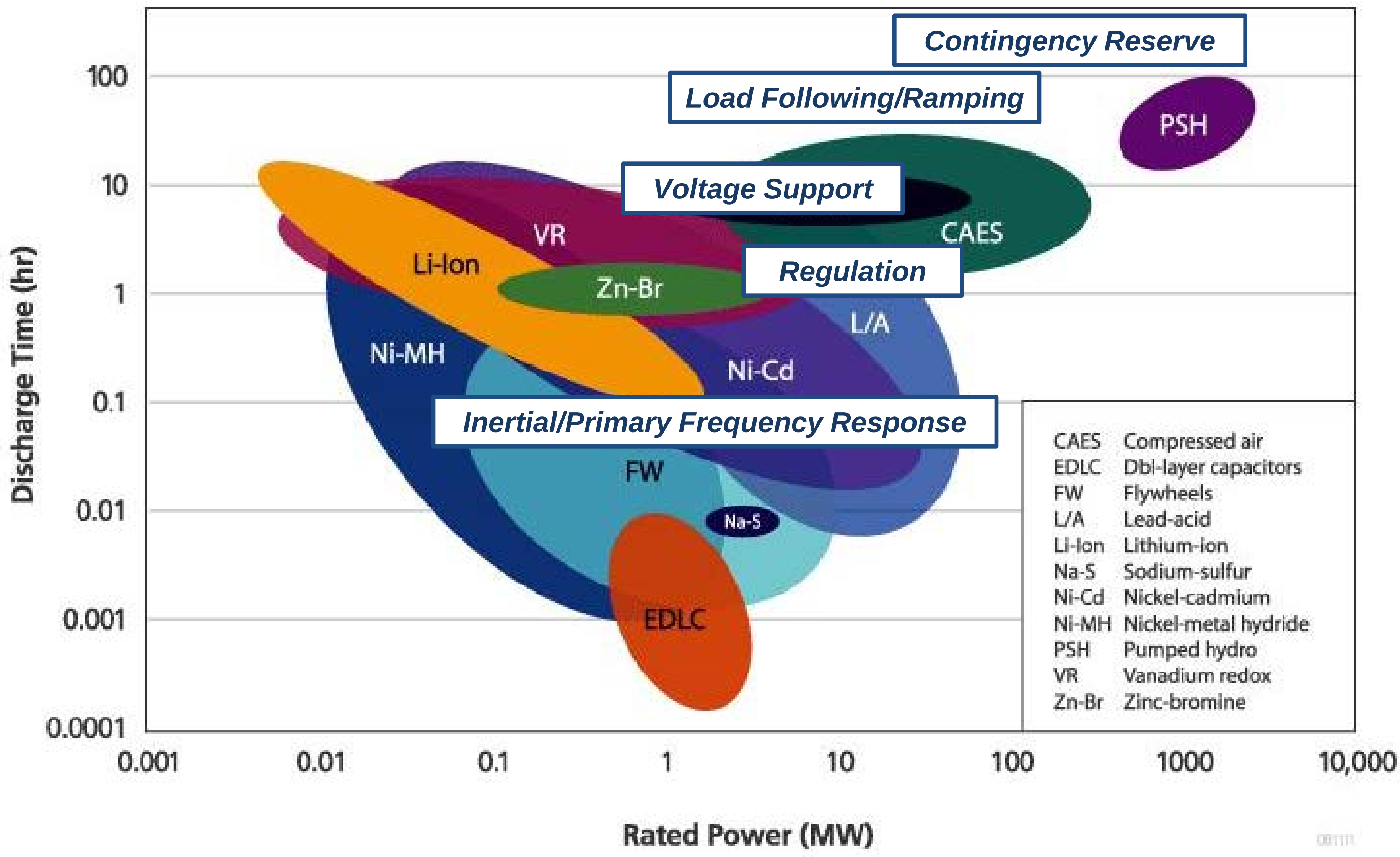
  Smooth the variable generation output across a broad geographical region

  Deliver ramping capability and ancillary services.

  Construct/site/permit transmission to deliver power across long distances.



Storage and Flexibility Functions

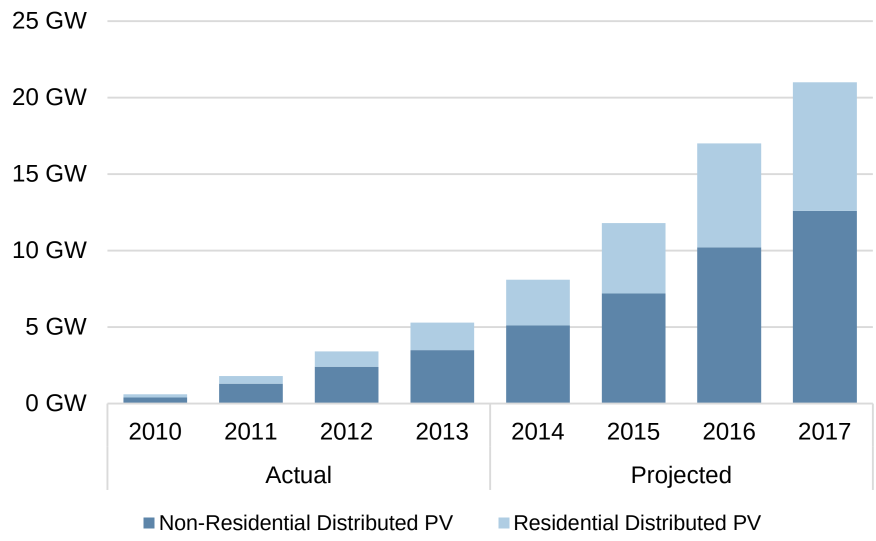


Distributed Generation

Reliability Finding #3: Operators and planners face uncertainty with increased levels of distributed energy resources and new technologies

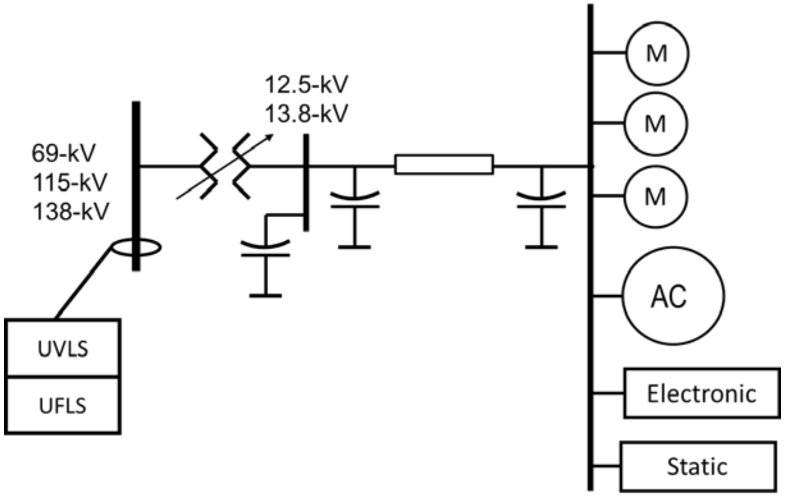
- Distributed energy resources (DERs) are contributing to changing characteristics and control strategies in grid operations.
- NERC is establishing a Task Force focused on examination of reliability impacts of large amounts of DER on the BPS.

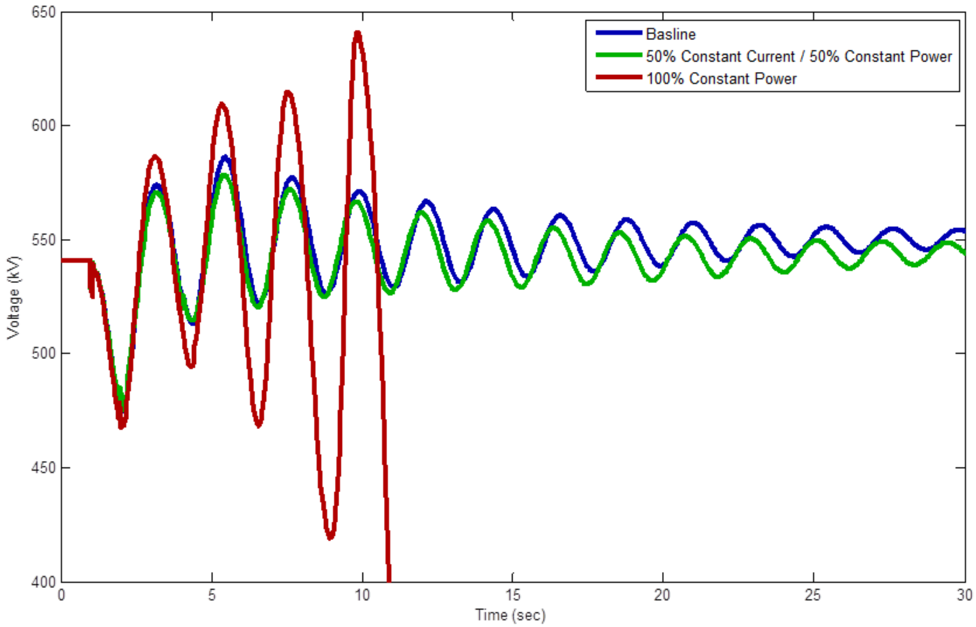
Actual and Projected Cumulative Distributed PV Installed Capacity in U.S. Since 2010



Changing Loads

- Load composition is changing
  - Electric vehicle charging
  - LED lighting
  - Variable speed drive motors
- This is changing fundamental assumptions for transmission system modeling

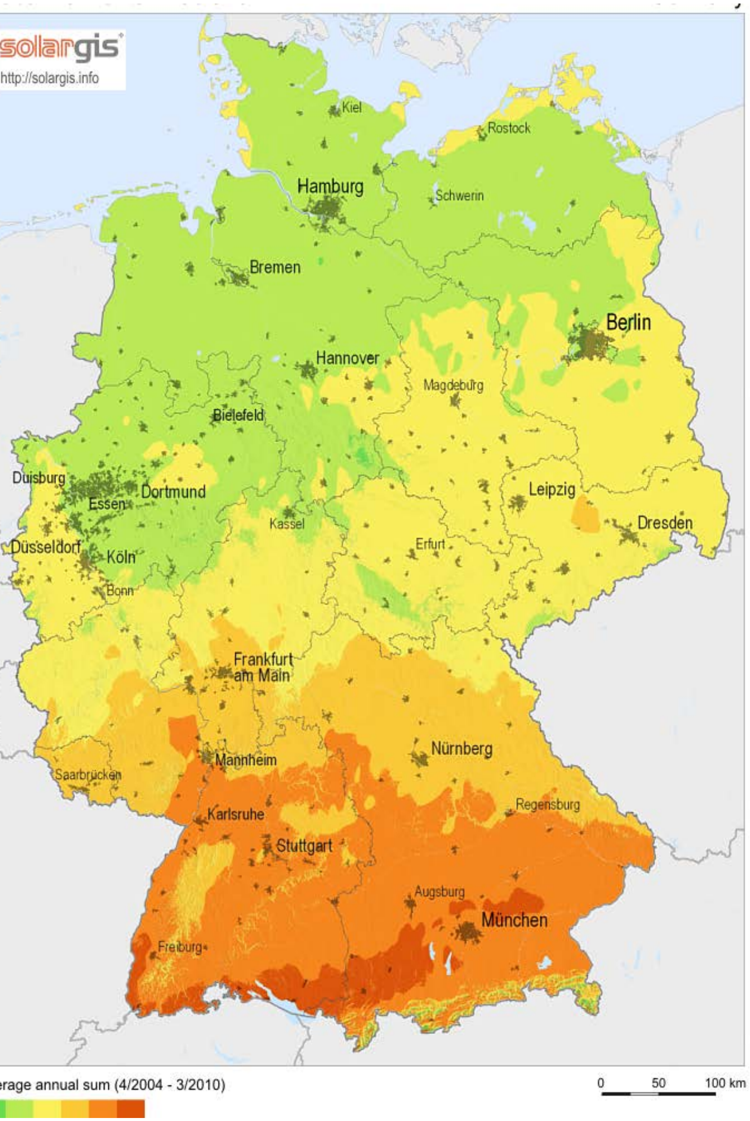


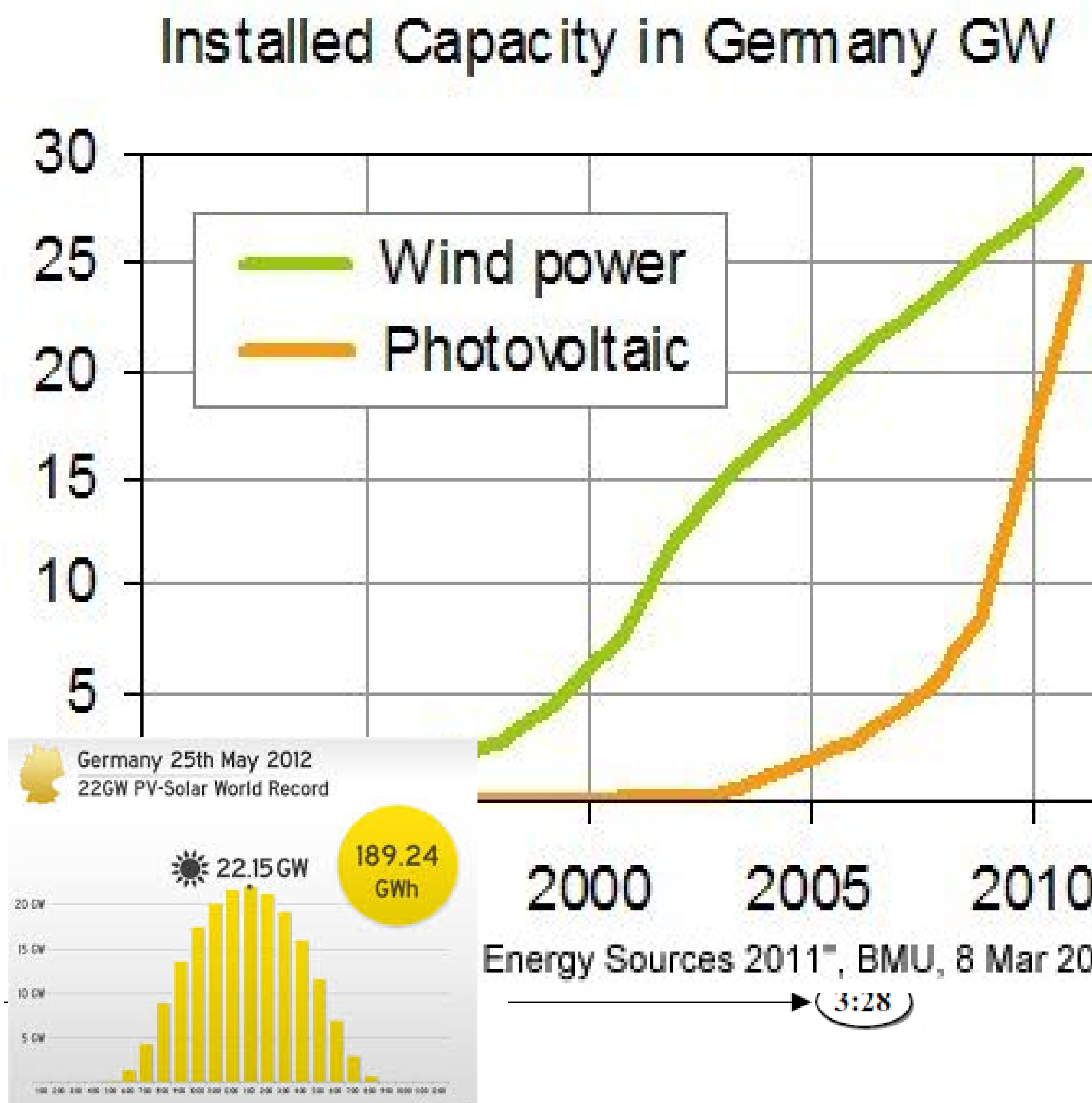


Disturbance Performance

- Large-scale deployment of DER without adequate voltage and frequency tolerance will negatively affect bulk system reliability and performance
- **Disconnections** during a frequency event propels frequency decay
- Disturbances on the transmission grid can cause a wide-spread, automatic, and simultaneous shutdown of distributed resources
- IEEE 1547 – inverter manufacturing standard for DERs

North America Can Learn From the Europeans





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The Control Shift

Distribution

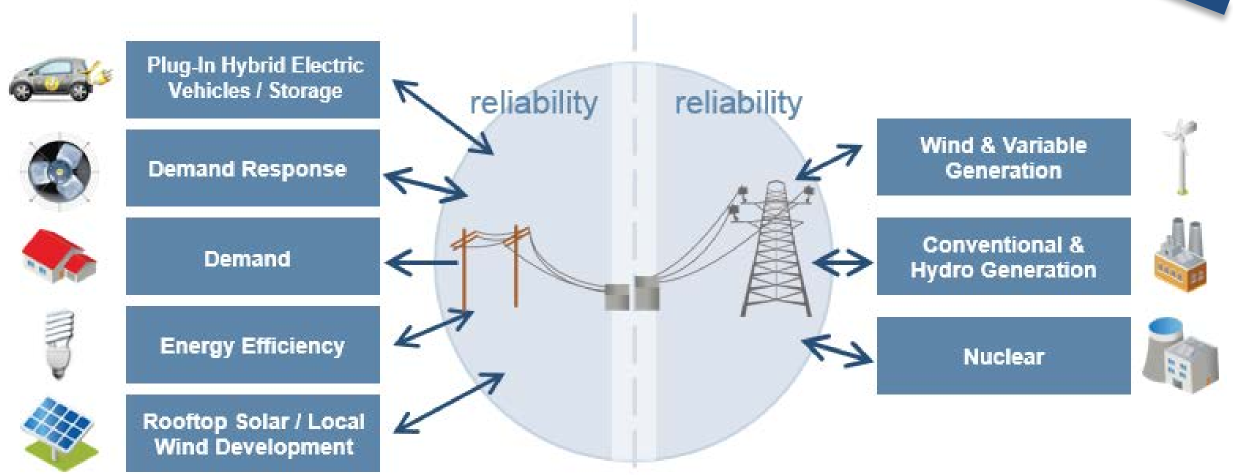
Bulk-Power System

10%

- Supports system inertia and recovery modes
- Dispatchable based on demand
- Centralized to System Operator

- Variability absorbed by load variability
- Operational characteristics do not permeate to BPS

90%



The Control Shift

Distribution

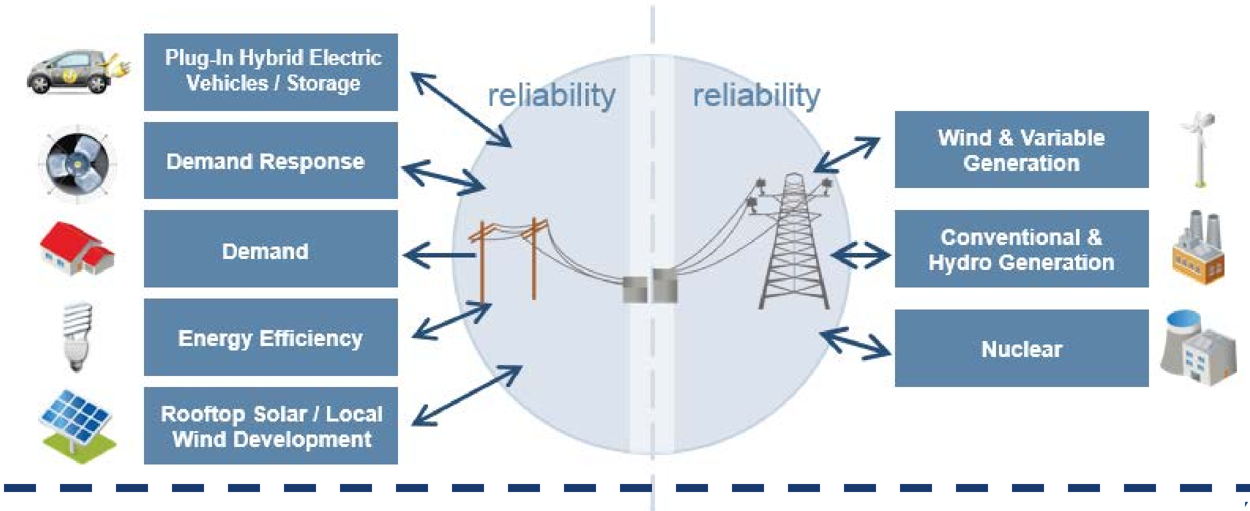
30%

- Disturbances permeate to BPS (common-mode)
- Dynamic and fast demand response
- Potential for overgeneration

Bulk-Power System

- More rigorous generator control Increased reliance on BPS generation
- Additional equipment to control local voltages

70%



The Control Shift

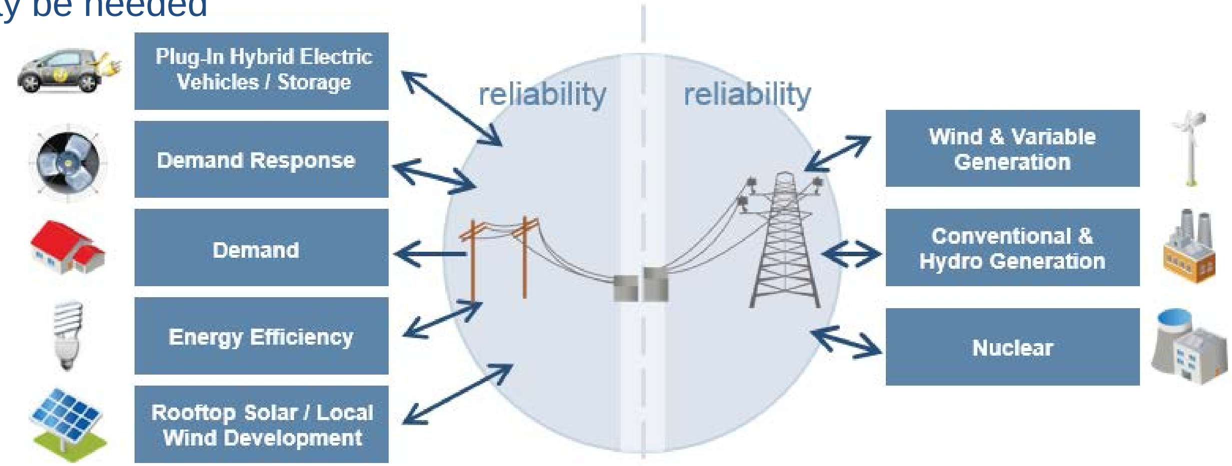
Distribution | **Integrated Power System** | **Bulk-Power System**

- Supports electricity services
- Provider of long-haul power transfers
- Reliability backbone

50%

- DERs must act as a system resource
- Storage, curtailment, coordination, grid support, and control
- Operator or aggregator function may be needed

50%



Recommendations

1	2	3
All new resources should have the capability to support voltage and frequency.	Monitoring of the ERS measures, investigation of trends, and use of recommended industry practices will serve as an early warning indicator to reliability concerns if issues are not addressed with suitable planning and engineering practices.	Further examination by NERC of the forecasting, visibility, and participation of DERs as an active part of the electric grid is needed.

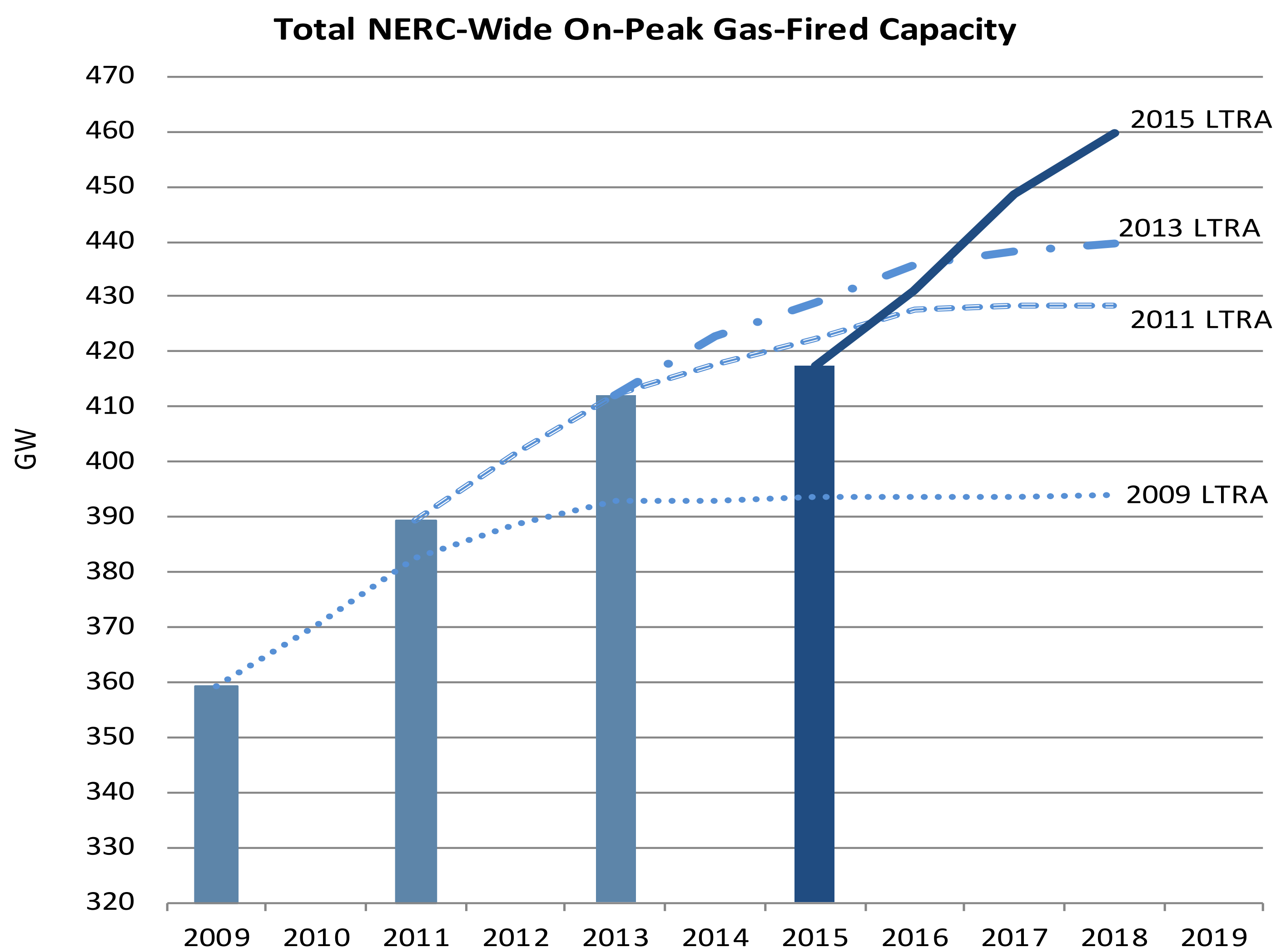
Natural Gas Generation Dependency

Increased Dependence on Natural Gas

An increased dependence on natural gas for generating electricity can amplify the bulk power system's exposure to interruptions in fuel supply, transportation, and delivery.

- Gas pipeline reliability impacts electric generation
- Electric system reliability impacts gas pipeline operations
- Pipeline planning and expansion are different from the electric equivalent
- Communications between pipeline operators and electric Reliability Coordinators are generally weak—though improving!

NERC's Annual Long-Term Projection



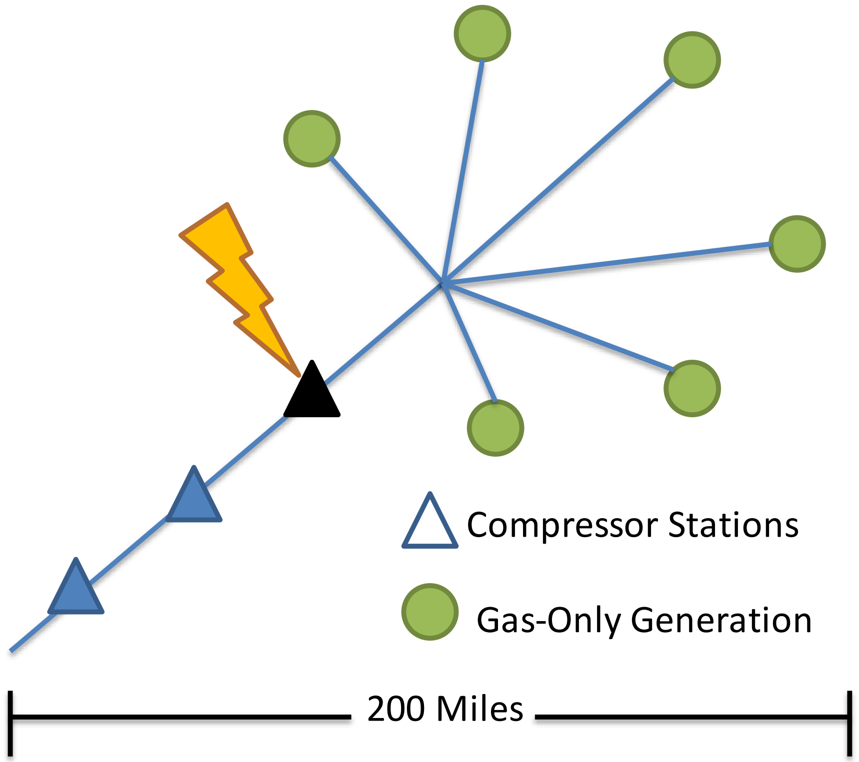
Growing Reliance on Gas-Fired Capacity

Gas-Fired Capacity as a Percent of Total Capacity (Eastern)			
MISO	New York (NYISO)	New England (ISO-NE)	PJM
39%	55%	54%	43%

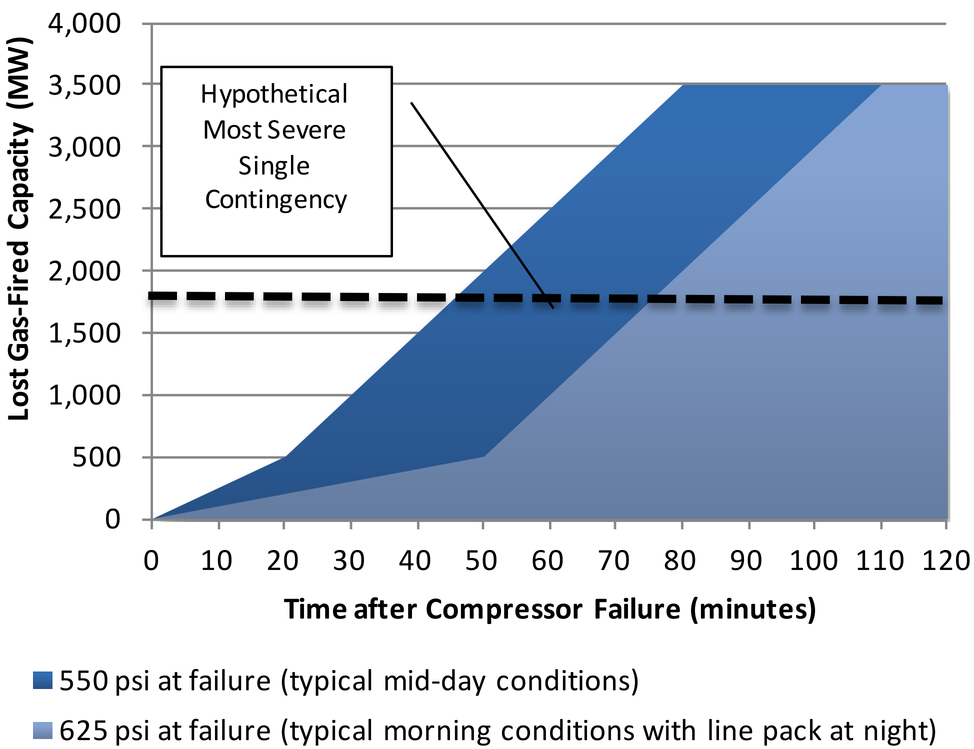



Pipeline Contingency Scenario

Compressor Failure Scenario



Time Profile of Capacity Loss



Electric Industry Risks and Recommendations

Resource Adequacy and Planning Challenges

- Integrating fuel disruption risks into planning reserve margins
- Probabilistic assessments and leveraging NERC GADS

Dual-Fuel and Storage

- Options can help bridge temporary fuel disruptions
- Considerations: cost, availability, testing, etc.

Operator Observability

- Promoted by FERC Order 787
- Real-time information sharing to promote risk-informed decisions

Non-Firm Fuel and Gas Scheduling

- Varying options for firm and non-firm delivery
- Extreme weather considerations

Market Options

Incentives for fuel and performance certainty

Aliso Canyon: Basics

- Aliso Canyon is a critical element of the Los Angeles (LA) Basin natural gas delivery system
  - Supports winter peak heating demand
  - Maintains pressure in gas distribution system (More challenging with rapid power plant ramping)
- Aliso Canyon currently has about 15 Bcf of working gas out of a total capacity of 86 Bcf
- Injections will not resume until safety testing or isolation of remaining 114 wells is completed

Aliso Canyon: LA Basin Power Supply

DC Interties
AC Paths

Midway- Vincent (Path 26) **4,000 MW**

Pacific DC Intertie (Path 65) **3,100 MW**

Intermountain (Path 27) **2,400 MW**

East of River (Path 49) **10,100 MW**

SDGE-CFE Import (Path 45) **800 MW**

Potential Impacted Generation

LA Basin:

- 9,800 MW natural gas generation
- ~95% of total local capacity

Rest of Southern California:

- >15,000 MW natural gas generation

Maximum Import Capacity

- 5,500 MW DC capacity
- 14,900 MW AC capacity
- 20,400 MW total*

* Typically limited to 17,000 - 18,000 MW

Aliso Canyon: BPS Reliability Concerns

- Fuel availability for local generation
  - Gas system deliverability without Aliso Canyon
  - Gas system outages (SoCal or on interstate pipelines)
  - Exogenous factors affecting supply (e.g., cold weather)
  - Curtailment priorities
- Generation resource adequacy
  - 95% of in-basin generation vulnerable to gas curtailment
  - Adequate generation resources exist to supply imports into the LA Basin, but this does not take into account local deliverability issues

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Aliso Canyon: BPS Reliability Concerns

- Electric import capacity (transmission)
  - 20.4 GW gross import capacity on five major transmission paths to LA Basin
  - Capacity is typically limited to 17-18 GW (stability limitation)
- Operational realities
  - Gas system pressure during electric generation ramping without storage support
  - Voltage support/stability if in-basin power plants curtailed below acceptable minimum load
  - Local gas generation is relied on to manage pre- and post-contingency flows

Key Takeaways

- Single-fuel dependency increases risk of BPS-impairing common-mode failures
- Risks to natural gas generation during summer season
- Expand gas-electric planning and coordination
  - A planning-based Reliability Standard should be considered
- Operational coordination between gas and electric industries decrease likelihood of wide-spread outage

Clean Power Plan Assessments

CPP Overview

- The CPP sets CO_2 emissions performance rates for affected power plants
- EPA identified 3 “Building Blocks”
  - Unit efficiencies
  - Transition to lower-carbon fuels
  - Transition to renewable/no-carbon generation
- EPA developes state goal –measured in mass and rate –based on each state’s unique mix of power plants in 2012

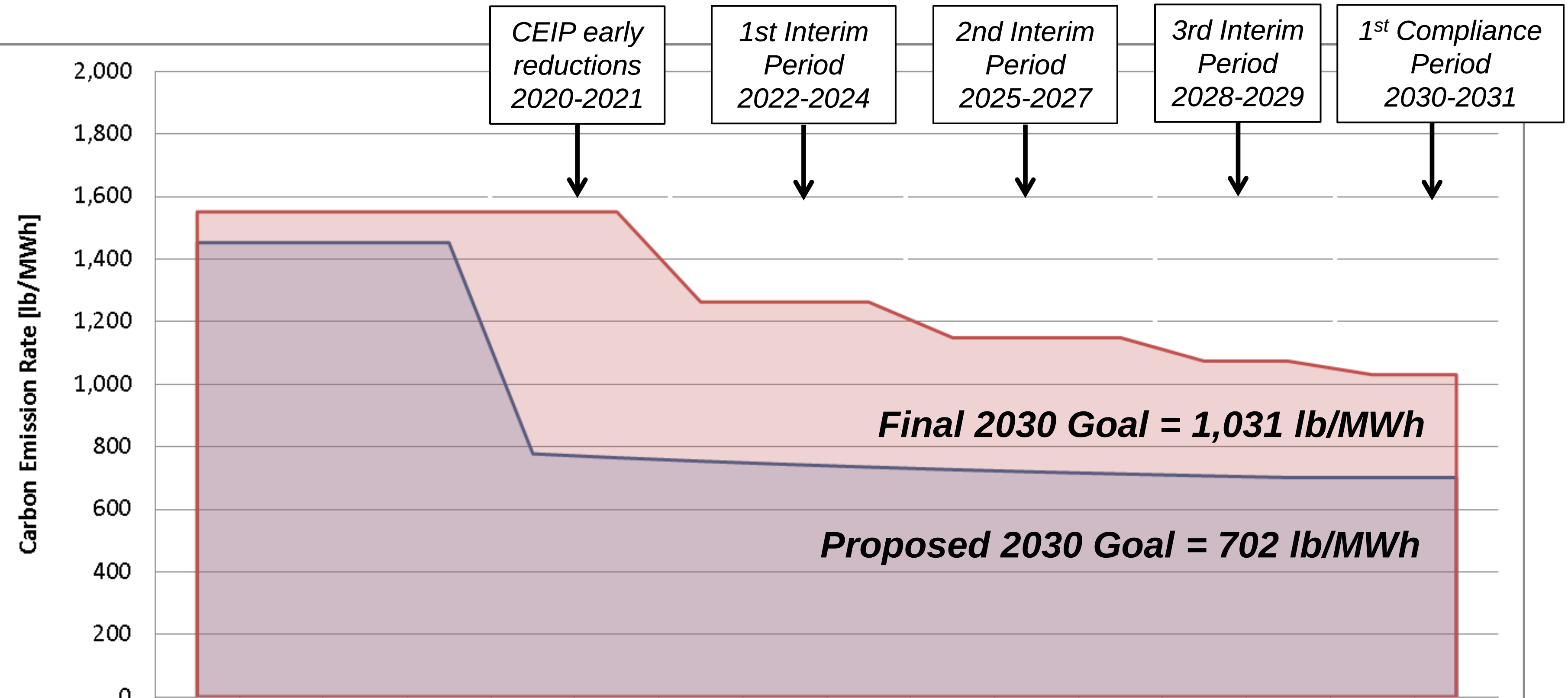
Clean Power Plan Timeline

Summer 2015	**August 3, 2015** – Final Clean Power Plan
1 Year	**September 6, 2016** – States make initial submittal with extension request or submit Final Plan
3 Years	**September 6, 2018** – States with extensions submit Final Plan
7 Years	**January 1, 2022** – Compliance period begins with three interim periods
15 Years	**January 1, 2030** – CO_2 Emissions Goals met

Source: EPA

Example of Envisioned Glide Slope

Example: Arizona



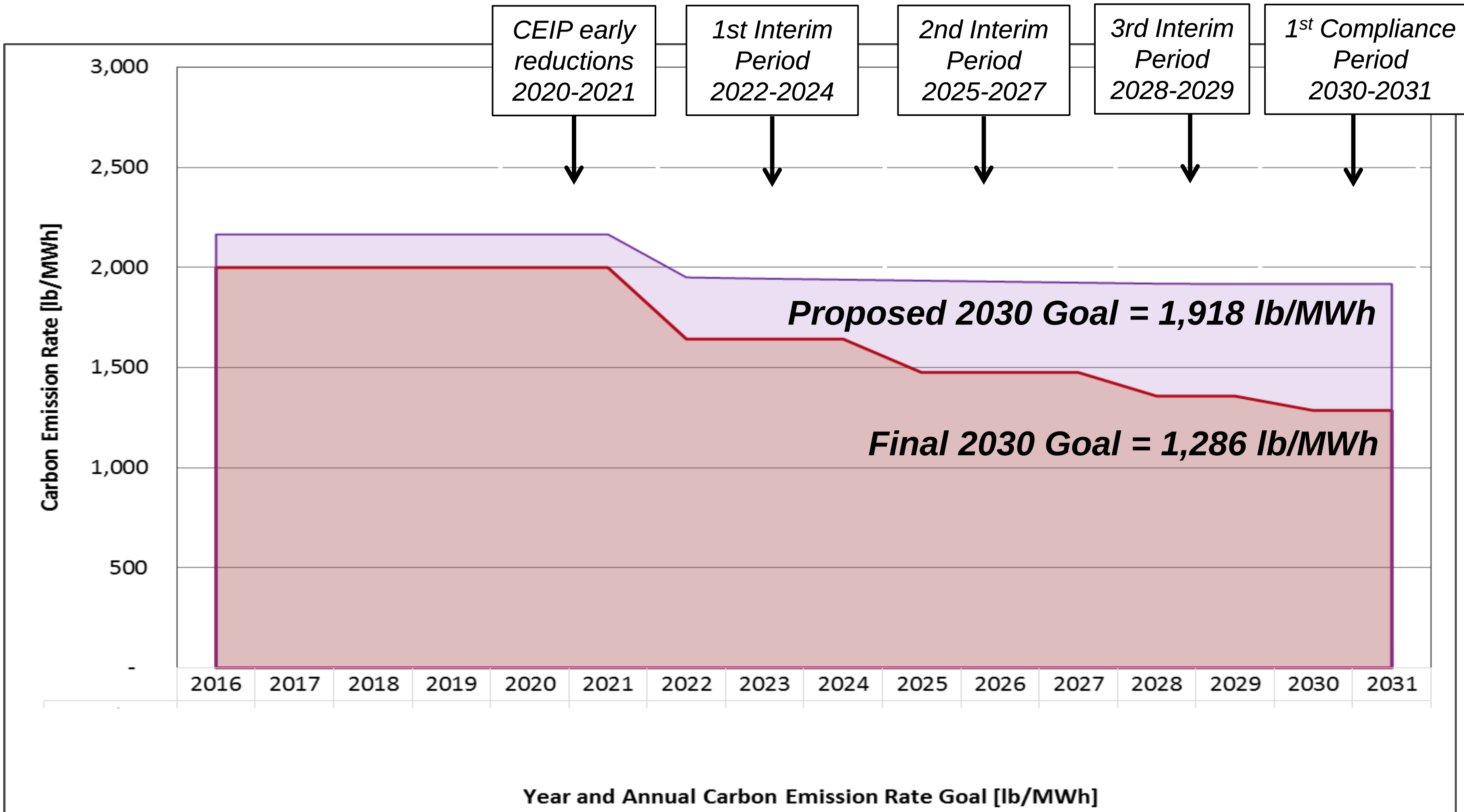
	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Proposed	1,453	1,453	1,453	1,453	778	765	754	744	735	727	720	713	707	702	702	702
Final	1,552	1,552	1,552	1,552	1,552	1,552	1,263	1,263	1,263	1,149	1,149	1,149	1,074	1,074	1,031	1,031

Year and Annual Carbon Emission Rate Goal [lb/MWh]

Source: Salt River Project

Example of Envisioned Glide Slope

Example: Kentucky



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Recommendations and Guidance to State Plan Developers

- Address roles and responsibilities of planning agencies and reliability authorities
  - NERC Planning Coordinators and Transmission Planners
- Maintain adequate Essential Reliability Services
  - Needed for the reliability operation of the Bulk-Power System
- Address future characteristics of resources
  - Cycling, availability, distribution, natural gas supply and transportation
- Identify changes to Reserve Margins needed for supply adequacy

Recommendations and Guidance to State Plan Developers

- Emphasize implications of the reliability assurance provisions
- Lessons learned from other systems that have experienced significant resource shifts (e.g., Ontario)
- Address implications of increased distributed resources and control challenges
- Discuss potential options for solutions, including technologies that can support reliability

Reliability Provisions

- Each state is required to demonstrate that it has considered reliability issues in developing its plan, including consultation with an appropriate reliability or planning agency
- EPA provides for a mechanism for a state to seek a revision to its plan in case unanticipated and significant reliability challenges arise
- Reliability safety valve to address situations where, due to an unanticipated event or other extraordinary circumstances, there is a conflict between the requirements imposed on an affected power plant and maintaining reliability

Source: EPA

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Ontario's Ambitious Transition

- Coal generators were flexible and locationally-strategic units that provided several services that are essential to the reliable operation of a power system, including:
  - capability to ramp output up and down to follow changing electric demand and to keep power transfers within reliable limits
  - voltage support to maintain network stability
  - frequency response to maintain balance in supply and demand
  - operating reserve to quickly replace a sudden generator loss
  - black-start capability to restore the system after a blackout2003

- Ontario declared coal-fired generation to retire by 2007
- The last coal plant retired in 2014

What was learned in Ontario?

- A realistic and flexible plan, reviewed and updated frequently
- Early attention by both industry and regulators to essential reliability services and transmission capability
- Demonstrated performance of new supply
- Long-term focus on demand reduction and management
- Flexibility in gas delivery arrangements and incentives for gas infrastructure

Ontario's experience also demonstrates that with focused objectives, flexible planning, and political persistence, transforming a power system to reduce its carbon emissions is achievable while maintaining reliability.

Remaining Uncertainties

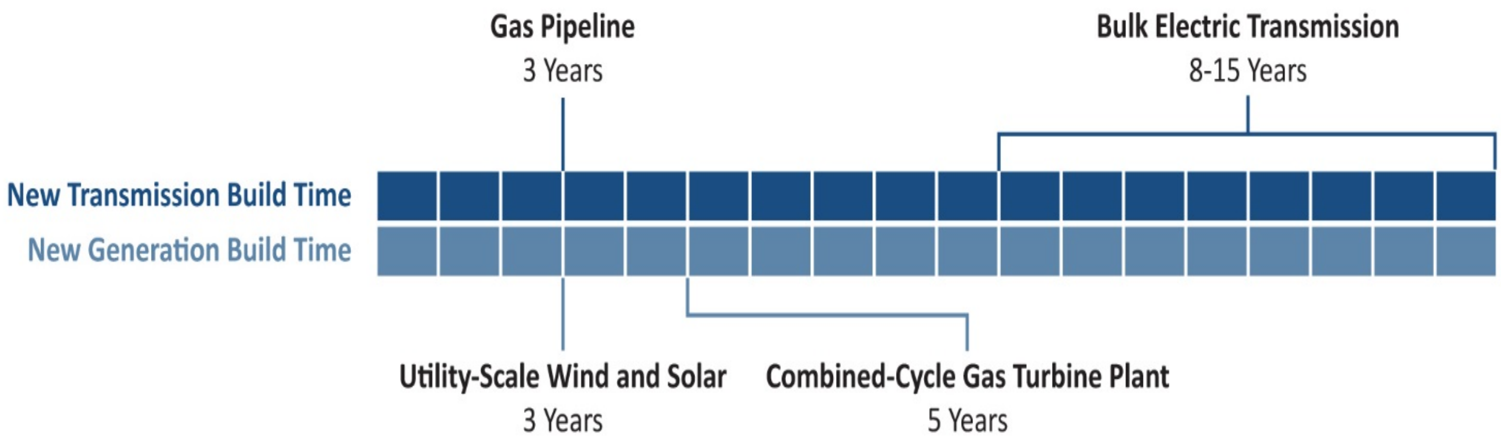
- What will the Federal Plan look like?
- Mass versus Rate
- Parallels to previous regulations?
- Uncertainty with neighboring state plans and available transfers
- Energy efficiency expectations
- Timing and location of retirements
- Robustness of trading
- Legal impediments
- Market sensitive information sharing

Timing Considerations for Energy Infrastructure Development

Transmission

Generation

Natural gas pipeline infrastructure

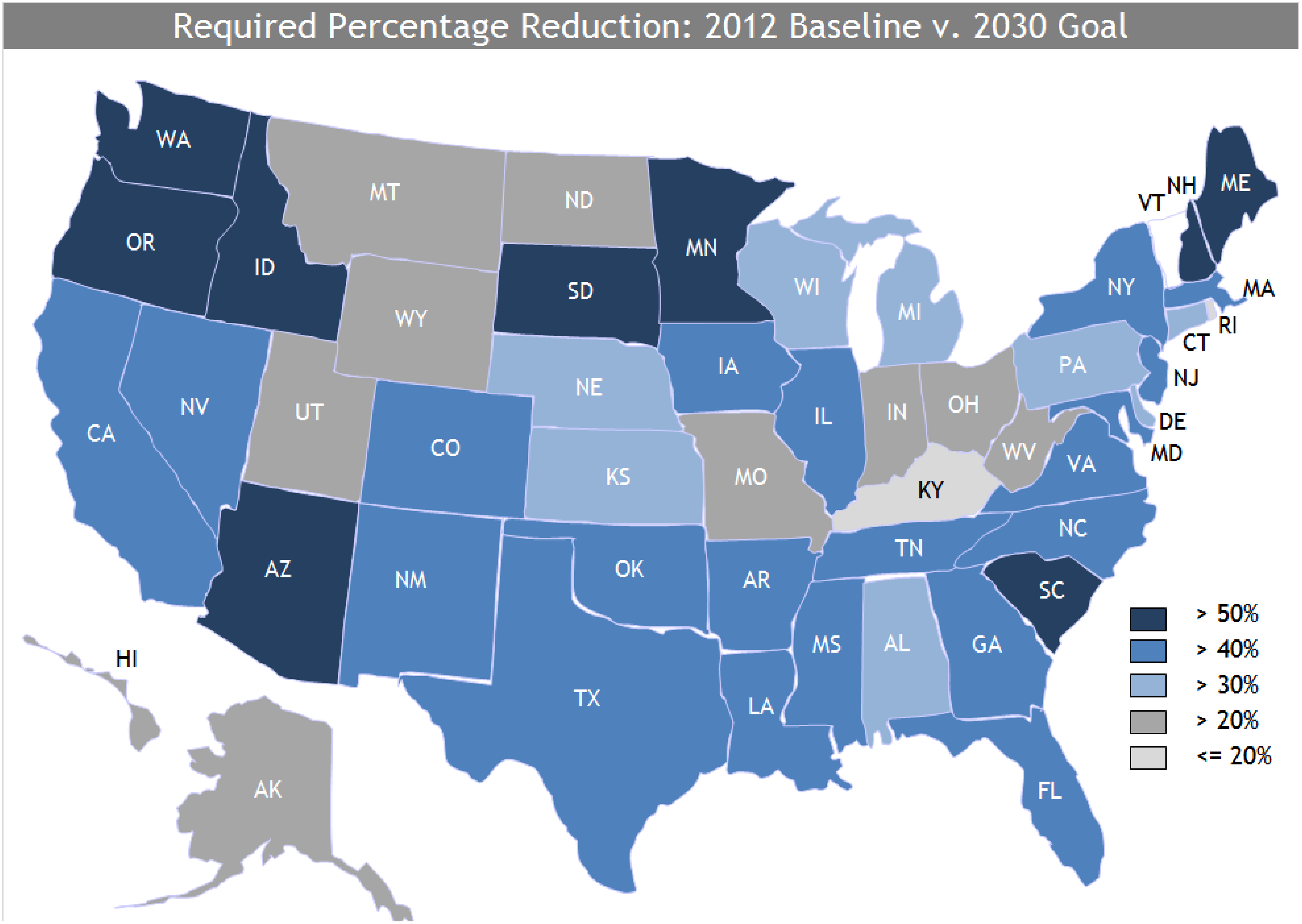


Preliminary Results from Phase II

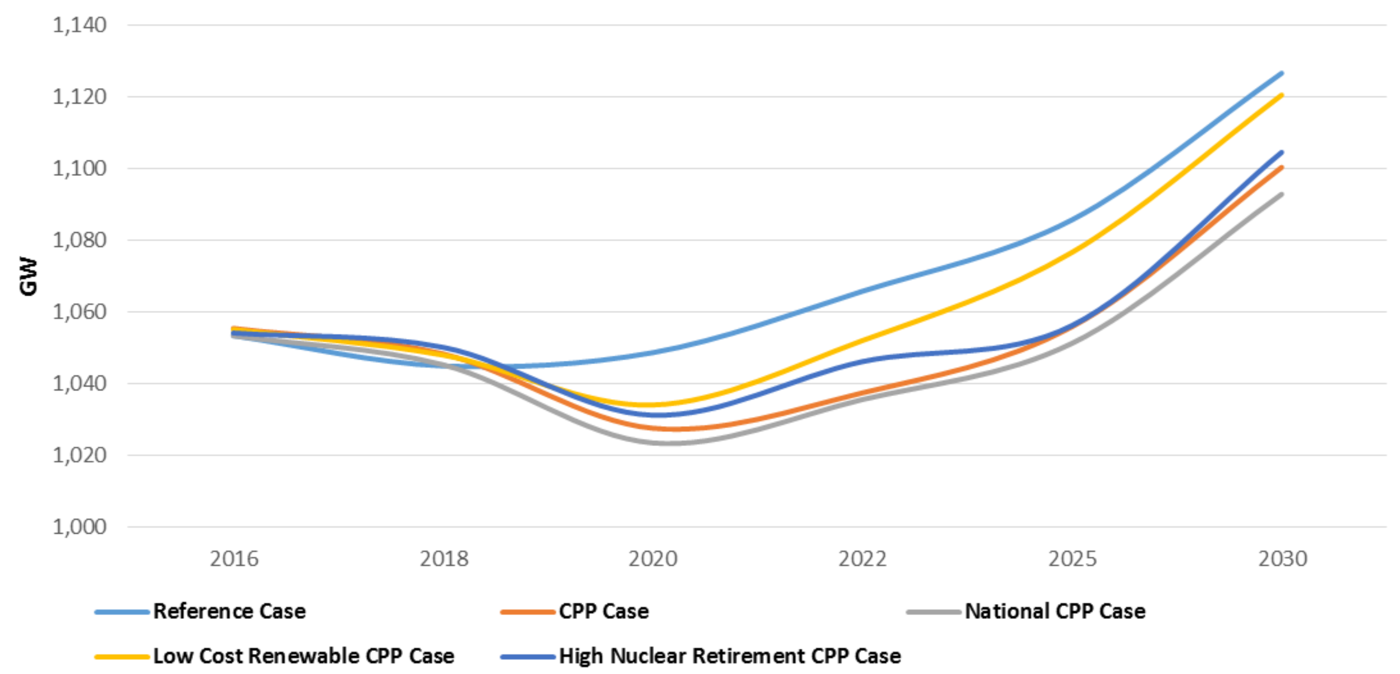
CPP Phase II Scenarios

Reference Case	• No CPP
Constrained Interstate Trading	• Intrastate trading develops, interstate constrained
Full Trading	• Full intrastate and interstate trading
High Renewables	• High penetration of renewables
Nuclear retirements	• Accelerated retirement of nuclear units

Emissions Reductions by State



Capacity Mix IPM

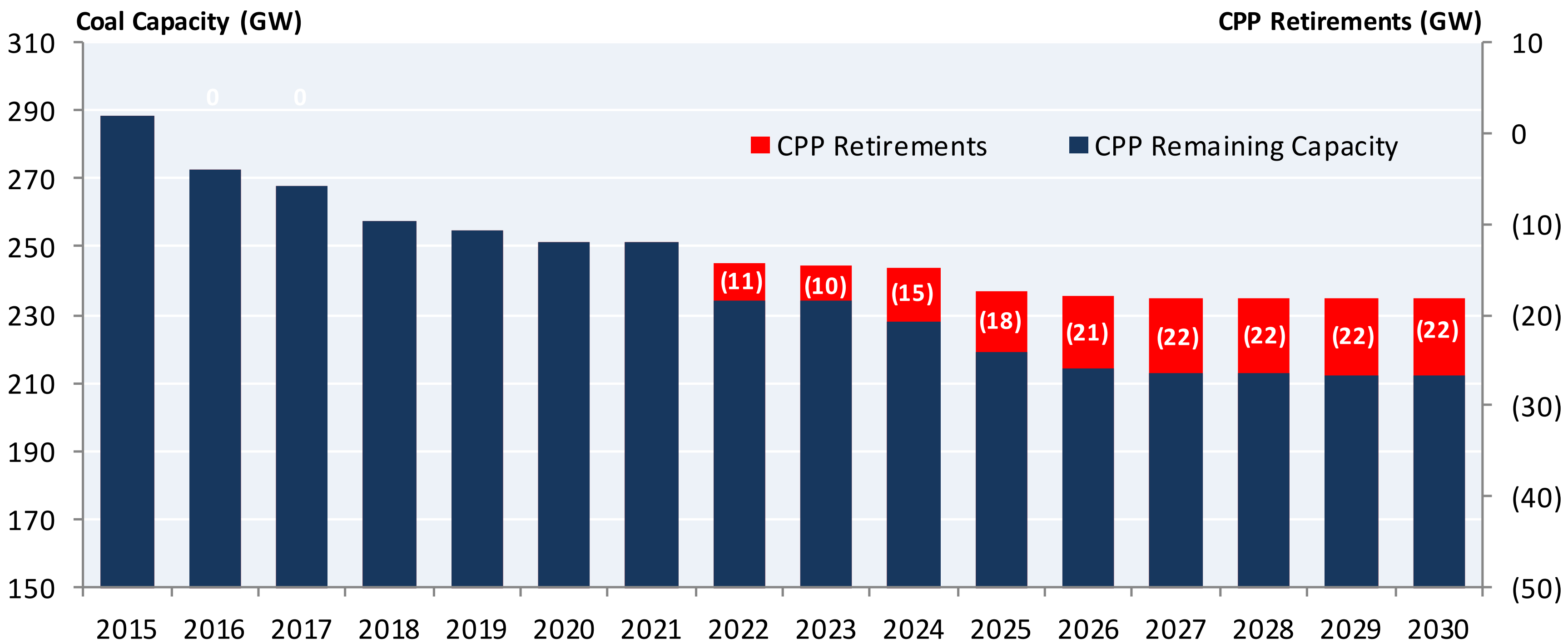


US. Capacity Mix (MW)

	2016	2018	2020	2022	2025	2030
Reference Case	1,053,453	1,045,032	1,048,733	1,065,837	1,085,788	1,126,684
CPP Case	1,055,516	1,048,389	1,027,661	1,037,504	1,055,964	1,100,434
National CPP Case	1,053,468	1,045,359	1,023,556	1,035,641	1,051,331	1,092,918
Low Cost Renewable CPP Case	1,055,207	1,048,055	1,034,126	1,052,093	1,076,704	1,120,590
High Nuclear Retirement CPP Case	1,054,216	1,050,231	1,031,275	1,046,222	1,056,304	1,104,614

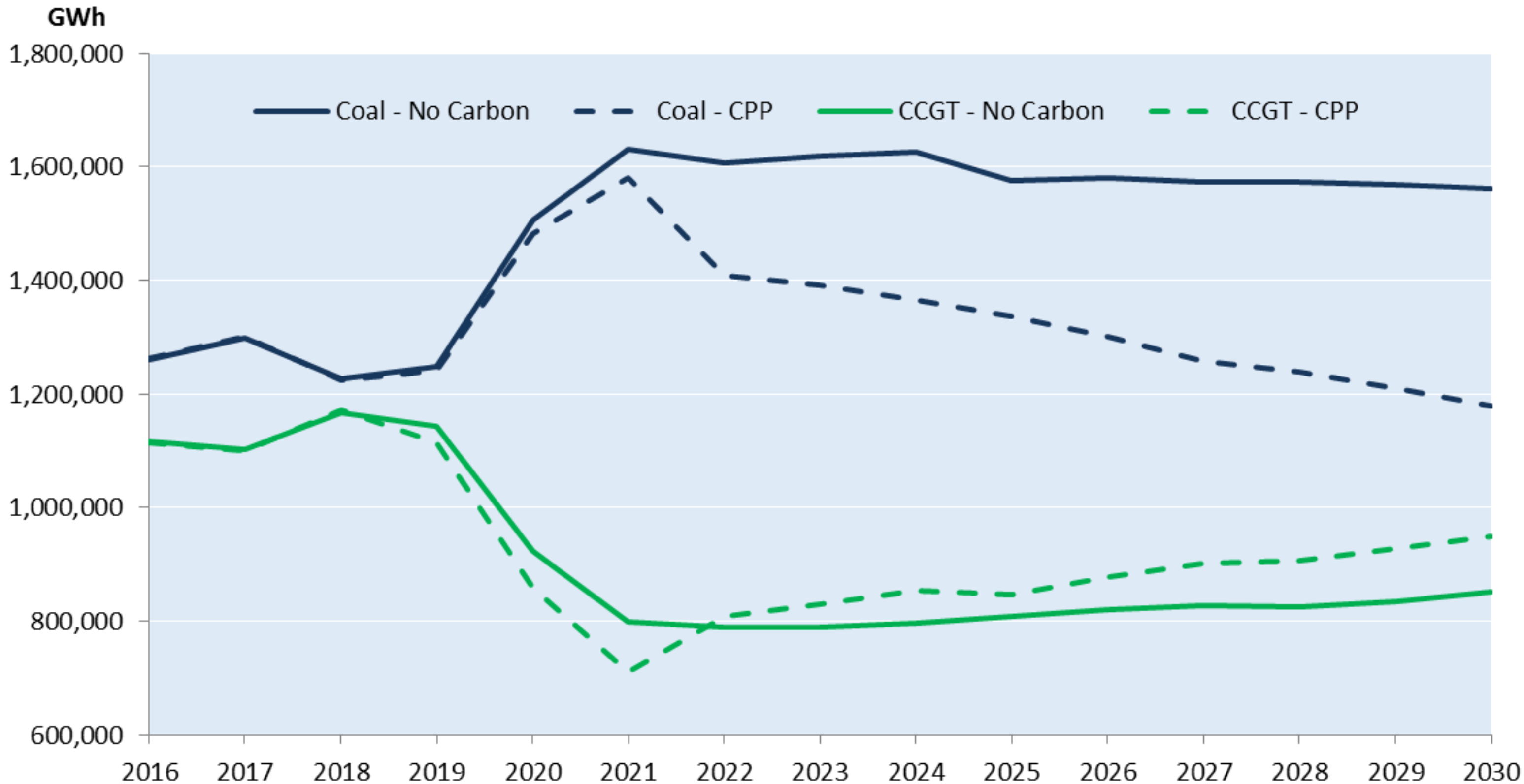
Preliminary – Do not cite

Coal Retirements Increase under the Clean Power Plan

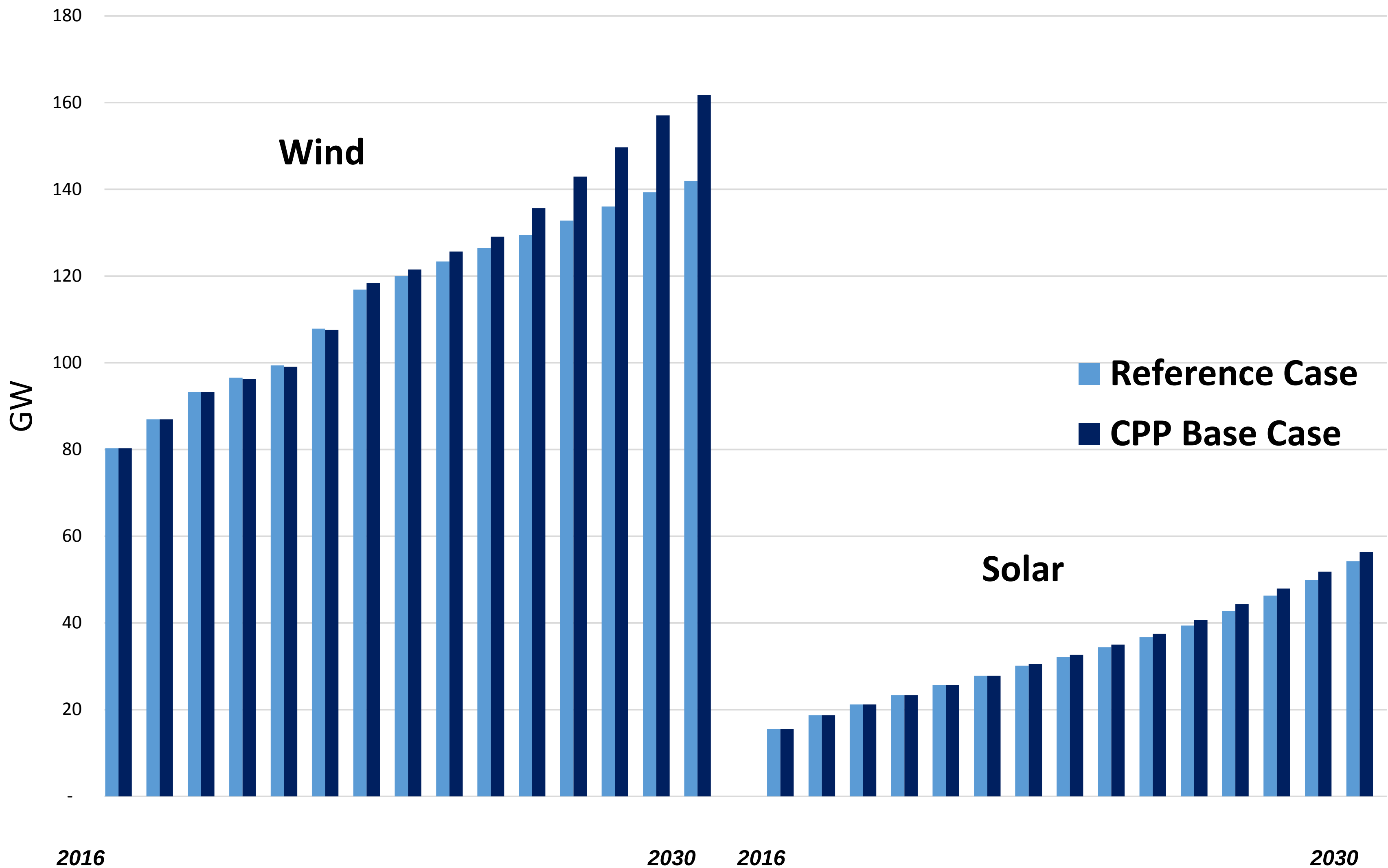


Preliminary – Do not cite

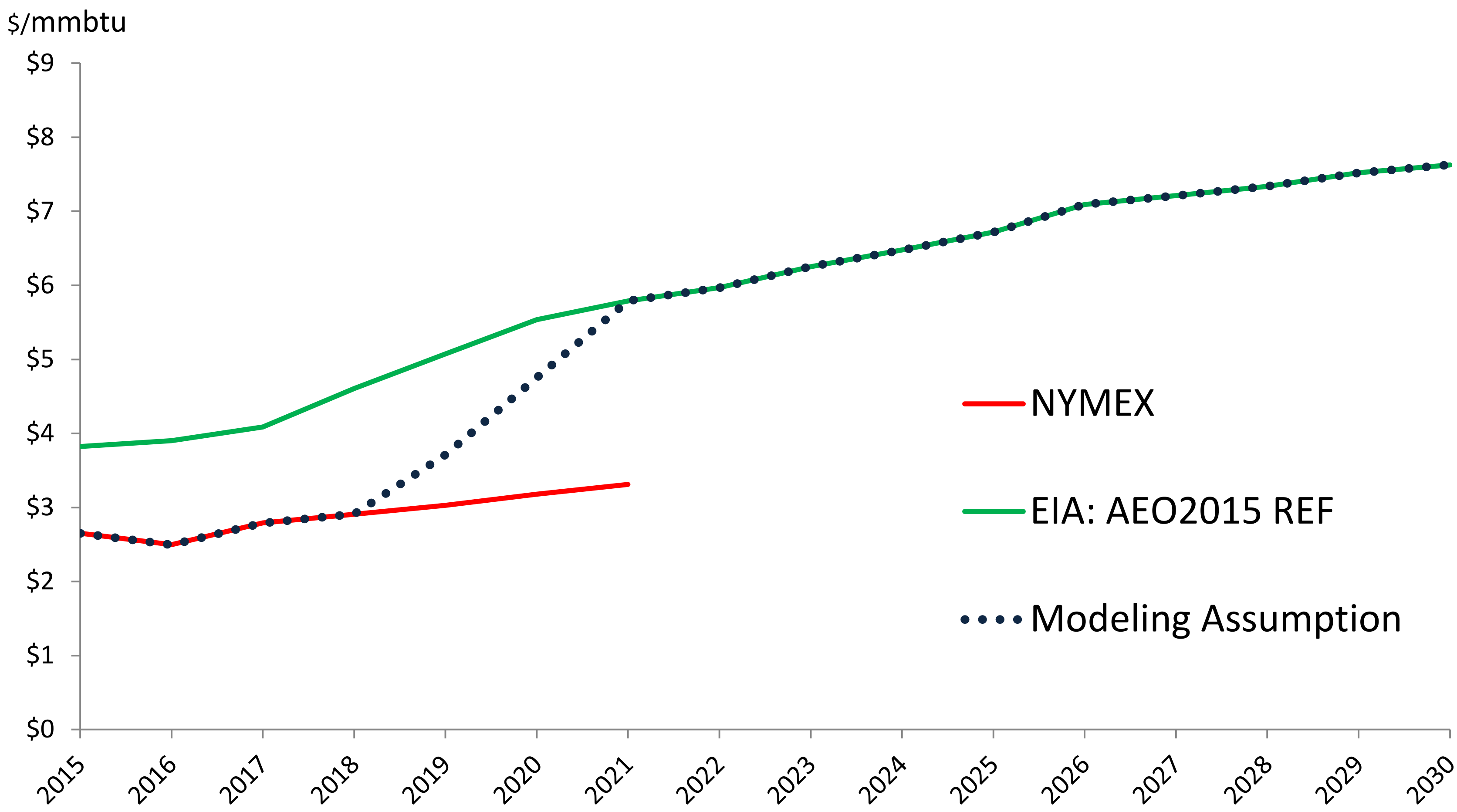
Declining Coal Generation as a Result of CPP



Wind and Solar Capacity Increase as a Result of the CPP



Major Driver: Natural Gas Prices Increase over Time



Closing Remarks

- Profound changes occurring on the BPS—resources and policies
- Lots of uncertainty in the future
  - nuclear, carbon, natural gas, climate trends, transmission
- New system behaviors and characteristics require new measurements for reliability
- Emerging reliability issues bring new technical (and political) challenges
- Must carefully balance costs and benefits
- Changes occurring irrespective of environmental regulations
- NERC is well positioned to study, evaluate, and assess the reliability of the Bulk Power System

Questions and Answers

Additional Material

- 2015 Long-Term Reliability Assessment
  http://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/2015LTRA%20-%20Final%20Report.pdf

- Essential Reliability Services Task Force Measures Framework Report
  http://www.nerc.com/comm/Other/essntlrlbltysrvcstskfrcDL/ERSTF%20Framework%20Report%20-%20Final.pdf

- Essential Reliability Services – Abstract (2-pager)
  http://www.nerc.com/comm/Other/essntlrlbltysrvcstskfrcDL/ERS%20Abstract%20Report%20Final.pdf

- The Basics of Essential Reliability Services (Multimedia Presentation)
  https://vimeopro.com/nerclearning/erstf-1

- Essential Reliability Services Task Force Website
  http://www.nerc.com/comm/Other/Pages/Essential-Reliability-Services-Task-Force-(ERSTF).aspx

Additional Information

NERC Reports on Accommodating High Levels of Variable Generation:

- DRAFT Joint NERC-CAISO Special Reliability Assessment: Maintaining Bulk Power System Reliability While Integrating Variable Energy Resources to Meet Renewable Portfolio Standards
- Performance of Distributed Energy Resources During and After System Disturbance
- Interconnection Requirements for Variable Generation, NERC, September 2012
- Potential Bulk System Reliability Impacts of Distributed Resources
- Methods to Model and Calculate Capacity Contributions of Variable Generation for Resource Adequacy Planning
- Ancillary Service and Balancing Authority Area Solutions to Integrate Variable Generation
- Operating Practices, Procedures, and Tools
- Potential Reliability Impacts of Emerging Flexible Resources
- Variable Generation Power Forecasting for Operations
- Standard Models for Variable Generation
- Flexibility Requirements and Potential Metrics for Variable Generation

NERC Reports on Accommodating and Increased Dependency on Natural Gas

- Primer (Phase I)
- Vulnerability Assessment (Phase II)

NERC Reliability Assessments (Long-Term and Seasonal)

- http://www.nerc.com/pa/RAPA/ra/Pages/default.aspx