Fuel Security Update

Operating Committee

June 10, 2021

Overview

June OC:

1. Background and review of previous fuel security efforts
2. Fuel Security Resource Adequacy Assessment Methodology & RTO Level Results for Fuel Security Monitoring
3. Fuel Security Phase III update

July OC:

1. Additional detailed results for Fuel Security Monitoring
2. Address questions & feedback from June OC

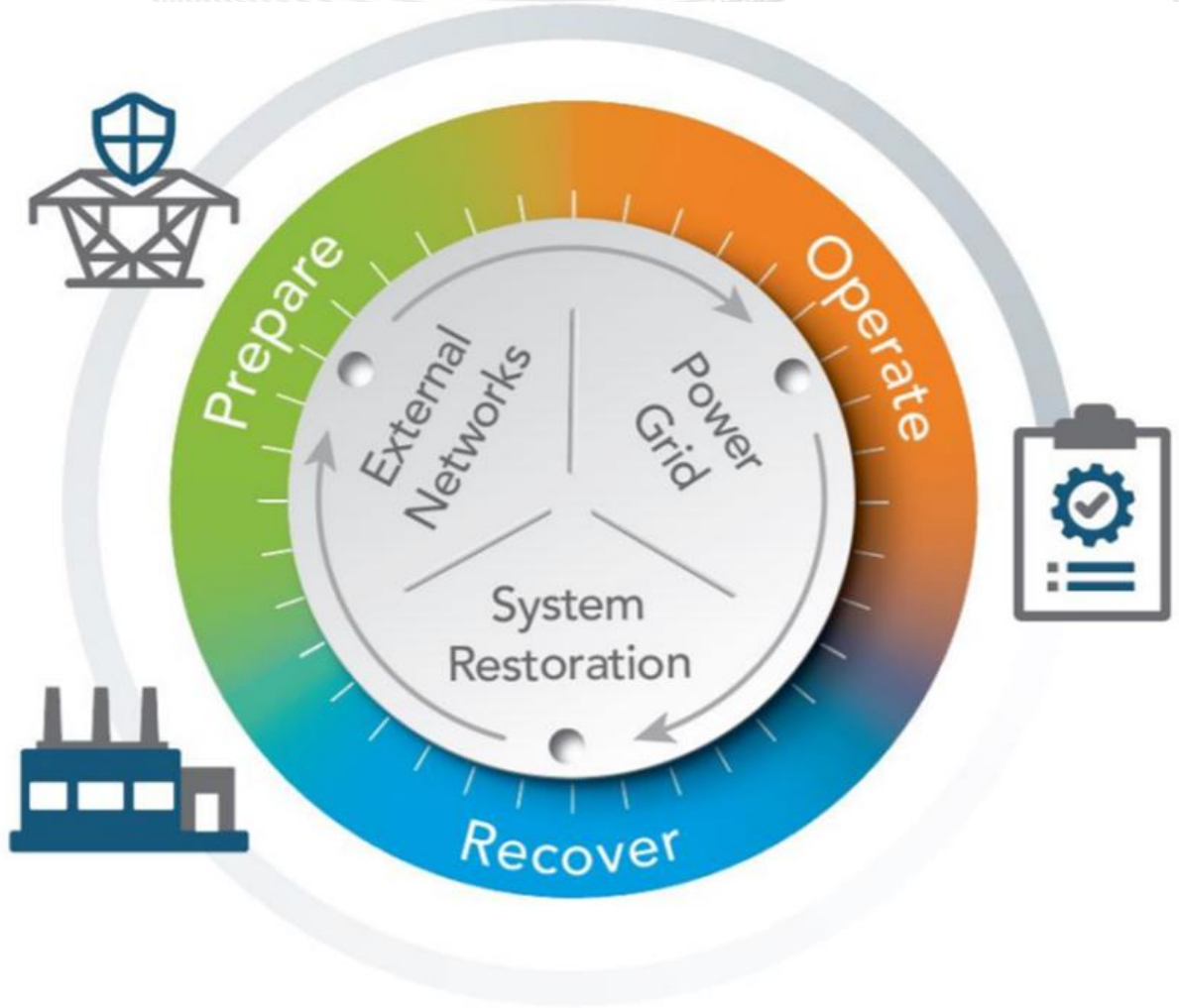
Fuel Security as Part of PJM Resilience Initiatives

Infrastructure

1. Enhanced Models & Analysis
2. RTEP Criteria
3. Cranking Path Redundancy

Supply

1. Attributes for Wholesale Supply
2. Fuel Security Analysis
3. Black Start Requirements



Operations Criteria

1. Load Loss Limits
2. Locational Limits
3. Interdependent Systems

Background: Fuel Security at PJM

2015–2017

PJM produces a series of reports on impacts of the changing landscape of the power industry, including a report evaluating the changing resource mix in PJM and reliability attributes.

2018

April: PJM releases a brief outlining its intent to perform further analysis on the topic of fuel security and its proposed approach to the process.

Nov./Dec.: PJM releases the results of its analysis and simulations and presents the data to its stakeholders, identifying some potential risks and vulnerabilities associated with fuel security.

2019

Feb./March: Problem Statement & Issue Charge presented to and approved by PJM stakeholders, identifying fuel security as an important component of reliability and resilience.

April – Dec.: Fuel Security Senior Task Force conducts additional analysis to evaluate options and provide recommendations to the larger PJM stakeholder body.

2020

Feb.: Operating Committee Work Plan updated to include periodic fuel security updates.

Dec.: MRC votes to sunset the FSSTF and continue to monitor parameters considered in the fuel security analysis and report to the MRC.

July/Sept.: Periodic updates provided to the Operating Committee.

Background: Three Phases of PJM Fuel Security

Phase I

Stress the system to identify potential system vulnerabilities related to fuel delivery infrastructure risks.

Phase II

Work through the PJM stakeholder process to identify if market, operational or planning changes are needed to address fuel security.

Phase III

Work with federal and state agencies alongside other industry sectors to address any specific security concerns, such as physical and cybersecurity risks.

Phase I: 2018 Fuel Security Analysis Scenarios

Dispatch	Retirement	Winter Load	Non-Firm Gas	Refueling	Pipeline Disruption (med. impact)	Pipeline Disruption (high impact)	Forced Outages
Economic	Announced	Typical 50/50 134,976 MW	62.5% Avail.	Moderate	Looped 1	Looped 1	Five-Year Avg.
Max. Emergency	Escalated 1	Extreme 95/5 147,721 MW	0% Avail.	Limited	Looped 2	Looped 2	Modeled Outages
	Escalated 2				Single 1	Single 1	
					Single 2	Single 2	

324
Combinations

pjm.com > Library > Reports & Notices > Fuel Security > 2018 Fuel Security Analysis

Phase I: 2018 Fuel Security Analysis Conclusions

There is NO immediate threat to the reliability of the PJM RTO.

[pjm.com > Library > Reports & Notices > Fuel Security > 2018 Fuel Security Analysis]

- PJM is reliable in the announced retirements and escalated retirements cases under all typical winter load scenarios.
- PJM is reliable in the announced retirements cases under all extreme winter load scenarios.

- Scenarios to identify points at which an assumption or combination of assumptions begin to impact the ability to reliably serve customers.
- The stressed scenarios resulted in a loss of load under extreme but plausible conditions.

Contributing factors:

- The level of retirements and replacements
- The level of non-firm gas availability
- The ability to replenish oil supplies
- The location, magnitude and duration of pipeline disruption
- Pipeline configuration

Phase II: 2019 Fuel Security Senior Task Force Work Streams

Risk Assessment

- Review scope of relevant risks
- Review Phase 1 analysis to identify opportunities for supplemental modeling
- Scenario development

Scenario Analysis

- Additional deterministic analysis utilizing Phase 1 approach
- Probabilistic analysis utilizing data on historical events to calculate conditional Loss of Load Expectation (LOLE)

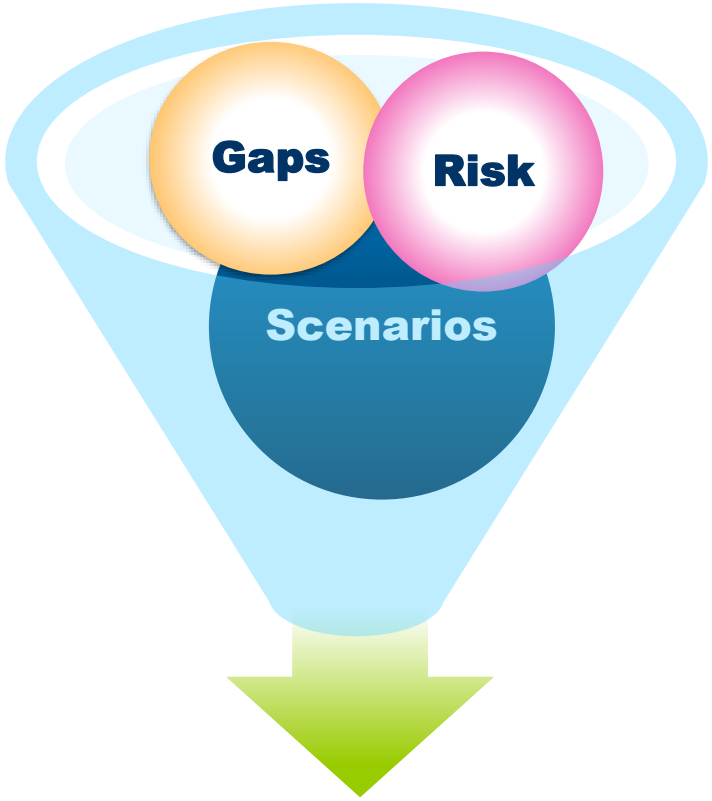
Gap Analysis

Assessment of existing market, operational and planning mechanisms to determine gaps in uncertainties/risks, procurement period, compensation and incentives

Inform stakeholder recommendation on moving forward to develop rule changes

pjm.com > Committees & Groups > Closed Groups > Fuel Security Senior Task Force

Phase II: 2019 FSSTF Summary



Multiple Potential Paths Forward

4,720,380 Scenarios	Phase I (324)	Phase II 4,720,056

- Gap analysis demonstrated there may be gaps in existing mechanisms in compensation and incentives
- Loss of load scenarios exist for extreme but plausible events
- No immediate threat

Cost Impacts

Dependent on expectations of scenarios and perceived value of loss load

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FSSTF Sunset After December 2019 MRC

Path 1: Status Quo

PJM continues to monitor and revisit with stakeholders if risk increases.

- Included in a stakeholder work plan
- Guidelines provided to stakeholders with opportunity to provide feedback

Path 2: Pre-Defined Criteria

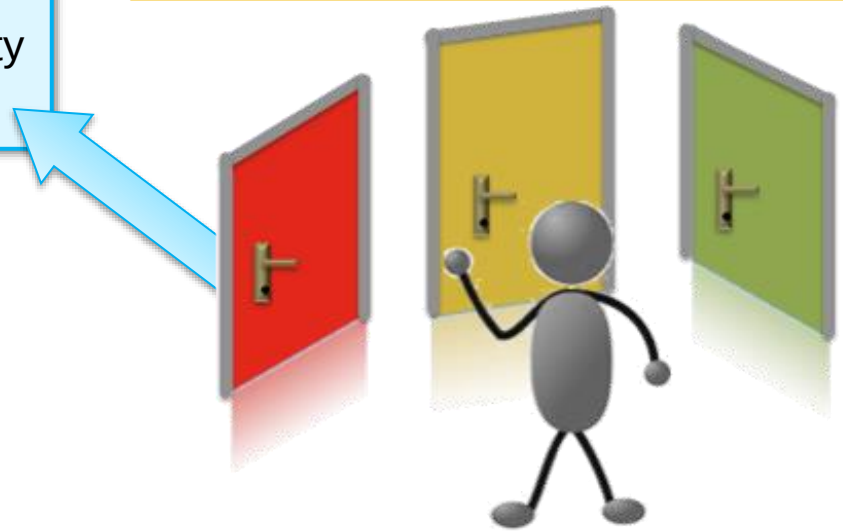
PJM and stakeholders develop criteria but do not develop solution until criteria is met.

- Criteria to be developed in 2020

Path 3: Solution Developed

Stakeholders develop a solution mechanism to automatically be triggered based on an embedded criteria.

- Criteria and solution mechanism to be developed in 2020



**All paths include incorporation of potential NERC guidelines/standards or FERC orders if applicable.*

Scope of Periodic Updates for Fuel Security

1. Fuel Security Monitoring

- Operational metrics, seasonal reporting and event analysis
- Fuel Security Resource Adequacy Assessment: LOLE sensitivity analysis of five-year ahead RTEP portfolio during extreme winter weather events

2. Updates on Fuel Security Phase III

Work with federal agencies and other industry sectors to analyze physical and cybersecurity risks

3. PJM Gas-Electric Coordination Team Efforts

Seasonal reporting and event analysis

4. Fuel Security-Related Industry Updates

NERC Electric-Gas Working Group (EGWG)

Fuel Security Monitoring

Recent Operational Assessments & Related Initiatives

Category	Related Assessments/Initiatives
Seasonal Operations Review	**Winter Operations Review (May 14, 2021 OC)** • Trends & system performance
Event Analysis	**Winter Lessons Learned (May 14, 2021 OC) Focus Areas:** • Review previous PJM and industry lessons learned • Review load shed procedures • Generator performance and preparedness • Gas pipeline, production and supply coordination **Winter Operations Assessment Follow-Up (June 7, 2021 OC)**

Fuel Security Resource Adequacy Assessment

- Probabilistic “stress test” of most recent five-year ahead Regional Transmission Expansion Plan (RTEP) portfolio using historical cold snap events

- General Considerations:
  - Going forward, assessment will be conducted during the first quarter of each year as the RTEP portfolio is developed in February of each year.
    - 2021 assessment uses 2026/2027 RTEP portfolio.
  - Inputs to the assessment will be updated by December of each year. The updates will involve rolling in data on each of the inputs from the previous winter season.

Methodology Overview

Additional Details Posted With OC Materials

Inputs

- Winter hourly load shapes derived from historical cold snaps
- Forced outage rates (fuel security-related and random)
- Wind/solar capacity factors
- Generic disruptions of variable impact

Procedure

- Set impact of generic disruption at X MW
- Calculate conditional LOLE based on each historical cold snap
- Aggregate LOLE values by delivery year
- Calculate average conditional LOLE

Output

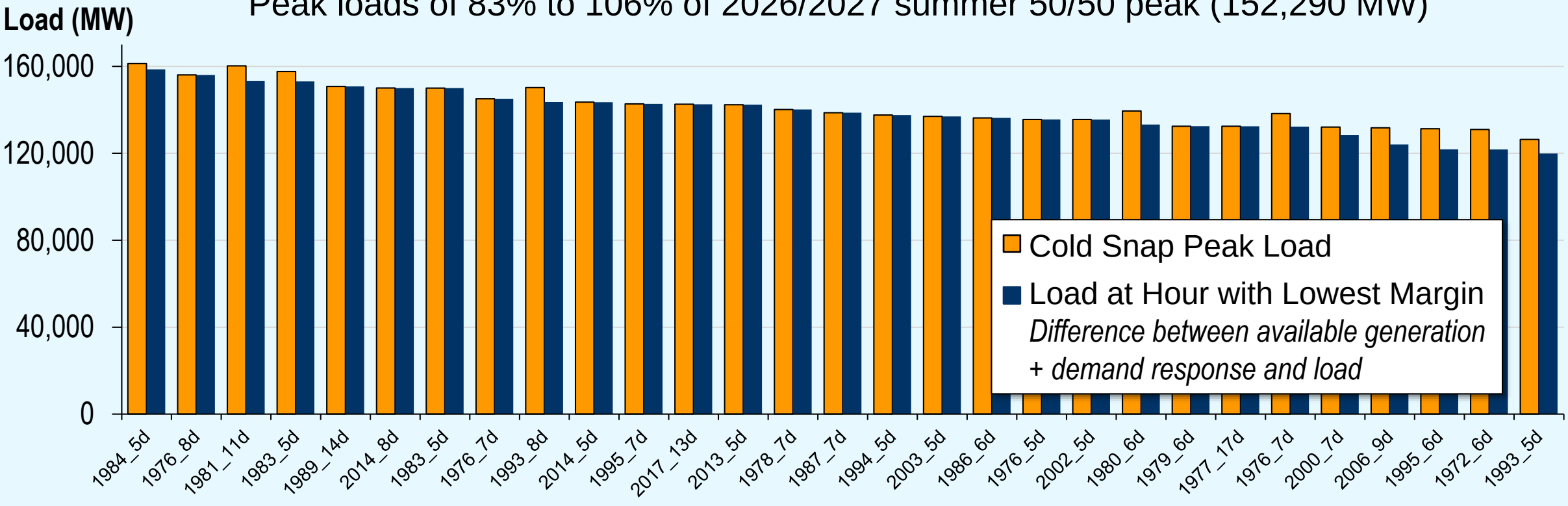
Portfolio's LOLE conditional on the occurrence on a generic disruption of size X MW coincident with a cold snap

Cold Snap & Load Scenarios

Analyzed 29 cold snap scenarios, consistent with 2021 PJM load forecast:

Peak loads of 94% to 120% of 2026/2027 winter 50/50 peak (134,799 MW)

Peak loads of 83% to 106% of 2026/2027 summer 50/50 peak (152,290 MW)



Generator Availability in Cold Snap Scenarios

Thermal & Hydro Forced Outages *During Hour With Lowest Margin*

	Fuel Security Forced Outage Rate (FS-FOR) Unavailability as Share of ICAP					Aggregate Random Forced Outage Rate (R-FOR), *EXCLUDING* FS-Related Outages
	Natural Gas	**Nuclear**	**Oil**	**Coal**	**Hydro**	
Avg.	14.3%	0.0%	1.9%	0.6%	0.6%	8.3%
Min.	7.3%	0.0%	0.0%	0.1%	0.1%	7.9%
Max.	17.5%	0.0%	4.0%	2.6%	0.8%	9.5%

Solar & Wind Availability *During Hour With Lowest Margin*, as Share of Nameplate

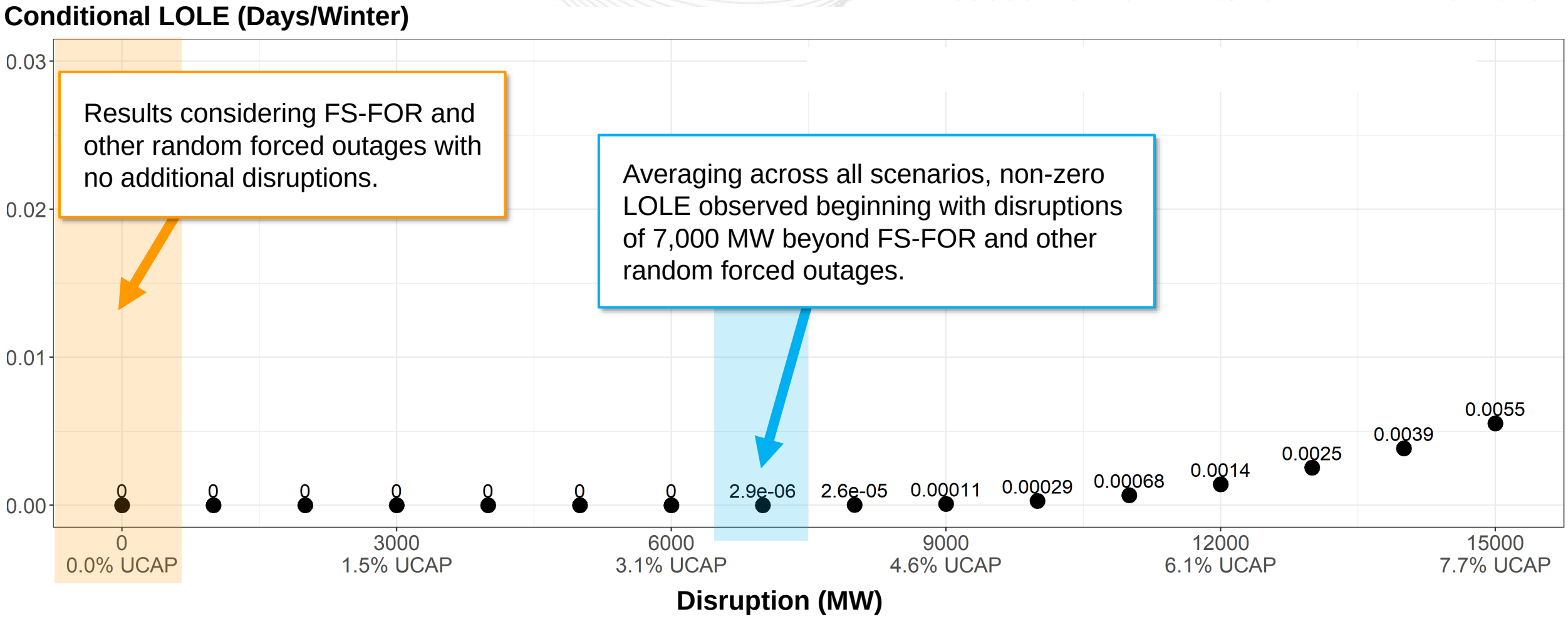
	Solar	**Wind**
Avg.	1.0%	39.9%
Min.	0.0%	16.3%
Max.	9.3%	63.2%

Example Common-Mode Megawatt Losses as Context for Generic Disruptions

Disruption Type	Worst Case Potential Loss (MW)	Assumptions
Natural Gas Pipeline Contingency with Electric System Impact	4,945	Worst case; units with dual fuel or alternate pipeline are not able to switch.
Regulatory Event Impacting Nuclear Generation	32,300	All nuclear units in the PJM footprint are required to come offline concurrently.
Regional Event Impacting Nuclear Generation	10,000–16,000	A localized event, such as severe weather pattern, requires nuclear generation in a localized region to come offline concurrently.
Coal Barge Disruption	12,800	River freezing, or similar, leads to fuel delivery issues impacting all coal units that rely exclusively on barge fuel deliveries. Assumes coal piles are already running low.
Coal Rail Disruption	9,600	Rail failure, or similar, leads to fuel delivery issues impacting all coal units that rely exclusively on rail fuel deliveries. Assumes coal piles are already running low.
Coal Truck Disruption	3,200	Trucking availability, or similar, leads to fuel delivery issues impacting all coal units that rely exclusively on truck fuel deliveries. Assumes coal piles are already running low.
Non-Coal Barge Disruption	2,800	River freezing, or similar, leads to fuel delivery issues impacting all non-coal units that rely exclusively on barge fuel deliveries.
Non-Coal Truck Disruption	3,800	Trucking availability, or similar, leads to fuel delivery issues impacting all non-coal units that rely exclusively on truck fuel deliveries.
Wind Turbine Shutdown Due to Operating Limits	3,800	Extreme low temperatures, or similar, requires wind turbines in a localized region being forced to come offline concurrently.

Average Additional* LOLE, Conditional on Disruption Size, **RTO**

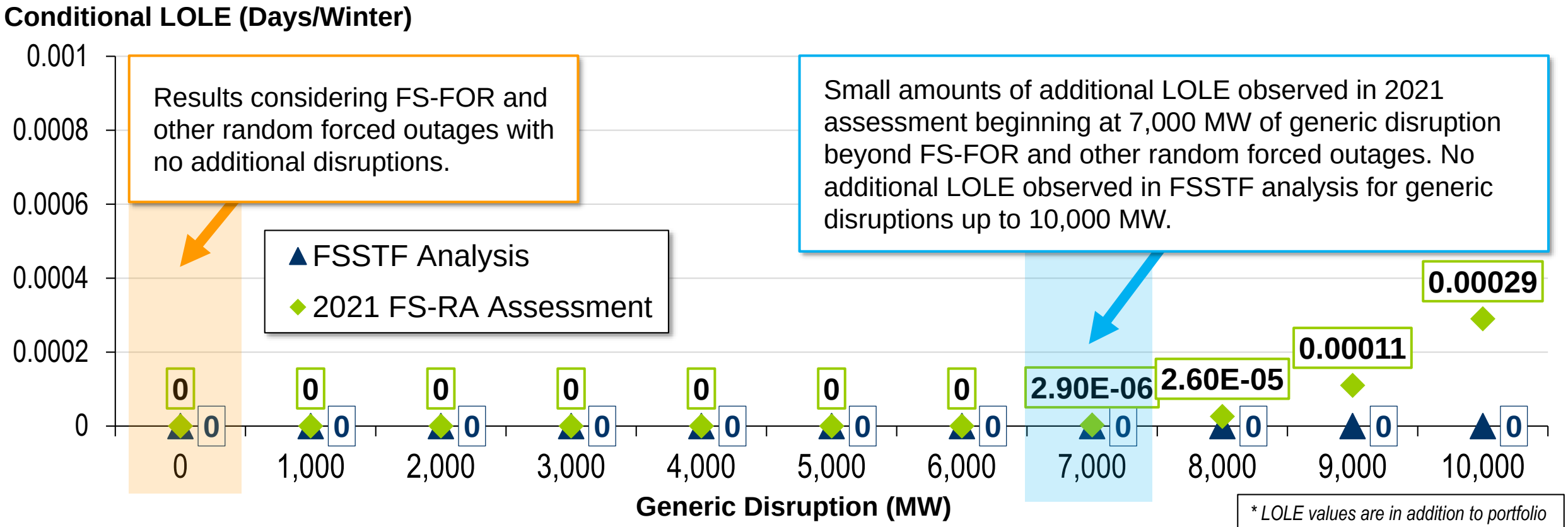
2021 FS-RA Assessment of 2026/2027 RTEP Portfolio



** LOLE values are in addition to portfolio LOLE outside of the winter period.*

Average Additional* LOLE, Conditional on Disruption Size Comparison to FSSTF Results, **RTO**

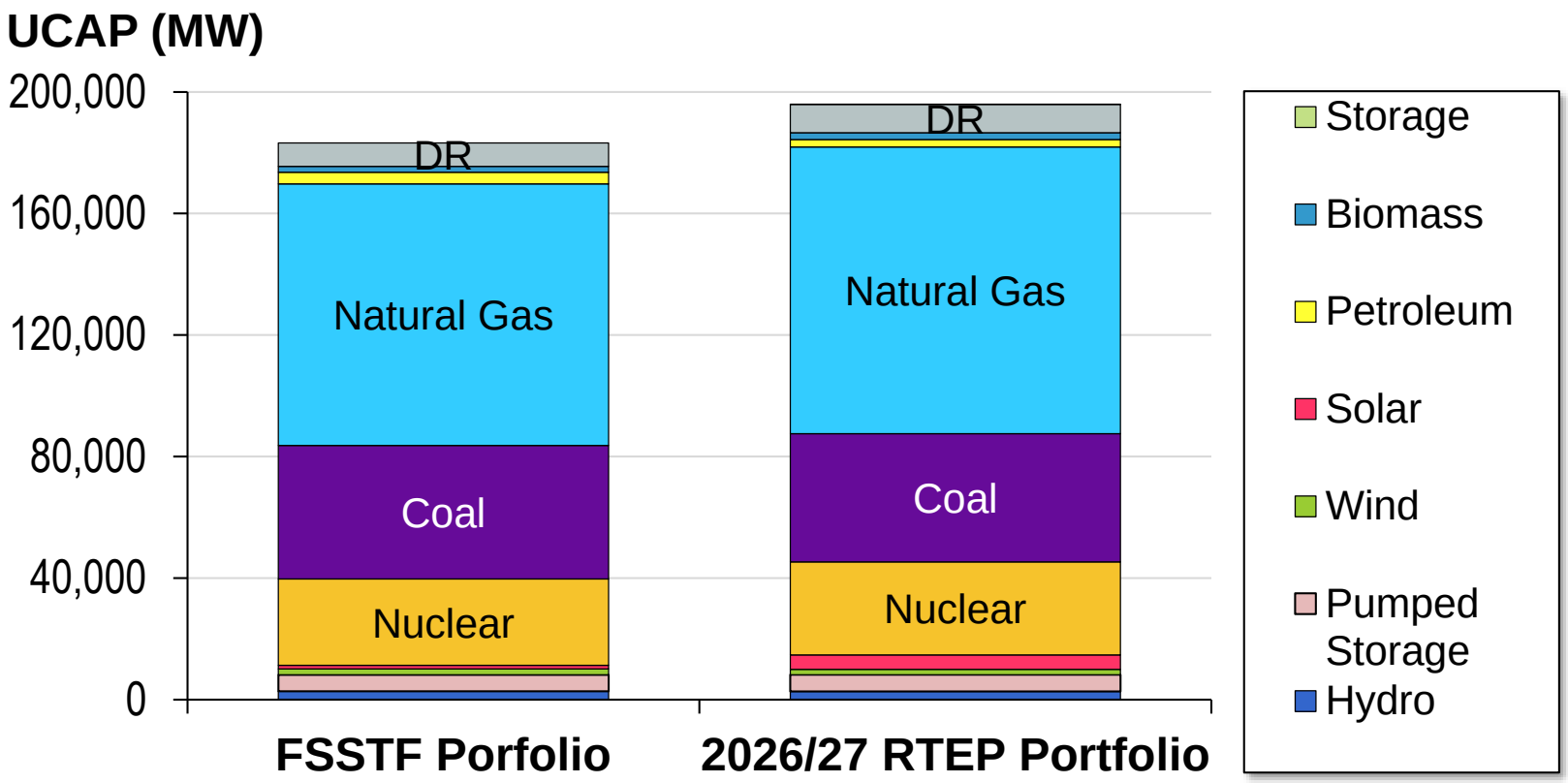
Comparison With Caveats:	• Portfolio changes put **downward** pressure on LOLE • Simulation of more extreme winter loads puts **upward** pressure on the LOLE



** LOLE values are in addition to portfolio LOLE outside of the winter period.*

Portfolio Changes Put **Downward** Pressure on LOLE

Increase in generation with high simulated unavailability during cold snaps, but higher overall UCAP reserve levels (22% vs 28%) in 2026/2027 RTEP portfolio compared to FSSTF portfolio.



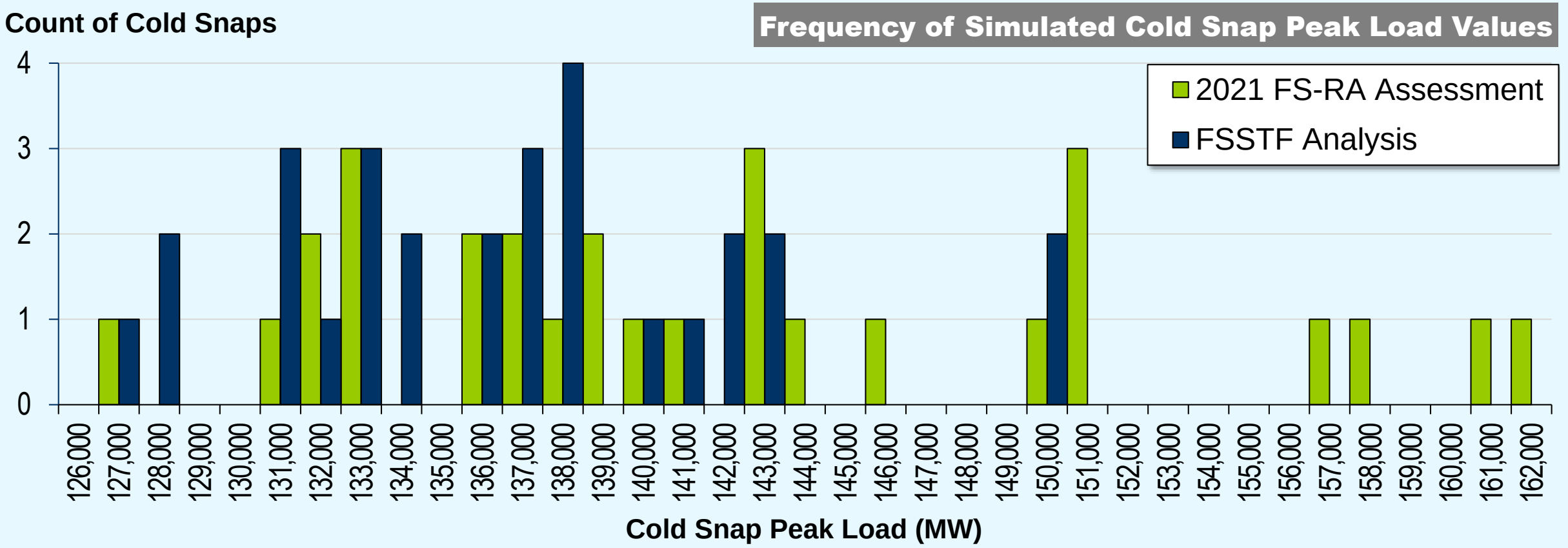
Percent Change in Resource Type UCAP MW	
• Hydro	-2%
• Pumped Storage	1%
• Wind	-7%
• **Solar**	**311%**
• Nuclear	8%
• Coal	-4%
• **Natural Gas**	**10%**
• Petroleum	-36%
• Biomass	16%
• DR	22%
• Storage	100%

Lowest simulated winter availability

Highest simulated fuel-related unavailability

Simulation of More Extreme Loads Puts **Upward** Pressure on the LOLE

Load forecast model updates result in higher extreme winter loads.



Fuel Security Monitoring Next Steps

July OC:

1. Additional detailed results for Fuel Security Monitoring
2. Address questions & feedback from June OC

Fuel Security Phase III Update

Fuel Security Phase III

Q4 2019

Initiated collaboration with a major interstate gas pipeline on identification of physical and cyber threat scenarios to study

Q1 2020

PJM and pipeline personnel met with FERC, TSA, PHMSA to review threat scenario studies

Q2 2020

PJM and pipeline engaged in analysis of worst case physical and cyber attack scenarios involving complete loss of multiple compressor stations and loss of a portion of a key mainline pipe segment

Q3 2020

Q4 2020

Reviewed results of the scenarios and impacts with federal agencies

Beyond

- Initial results, simulated on 2023 portfolio, indicated impacts to the BES were limited as system conditions never went beyond the implementation of demand response
- Will continue to evaluate opportunities for future analysis

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Fuel Security Update

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