Update on Fuel Security Initiative

Special MRC

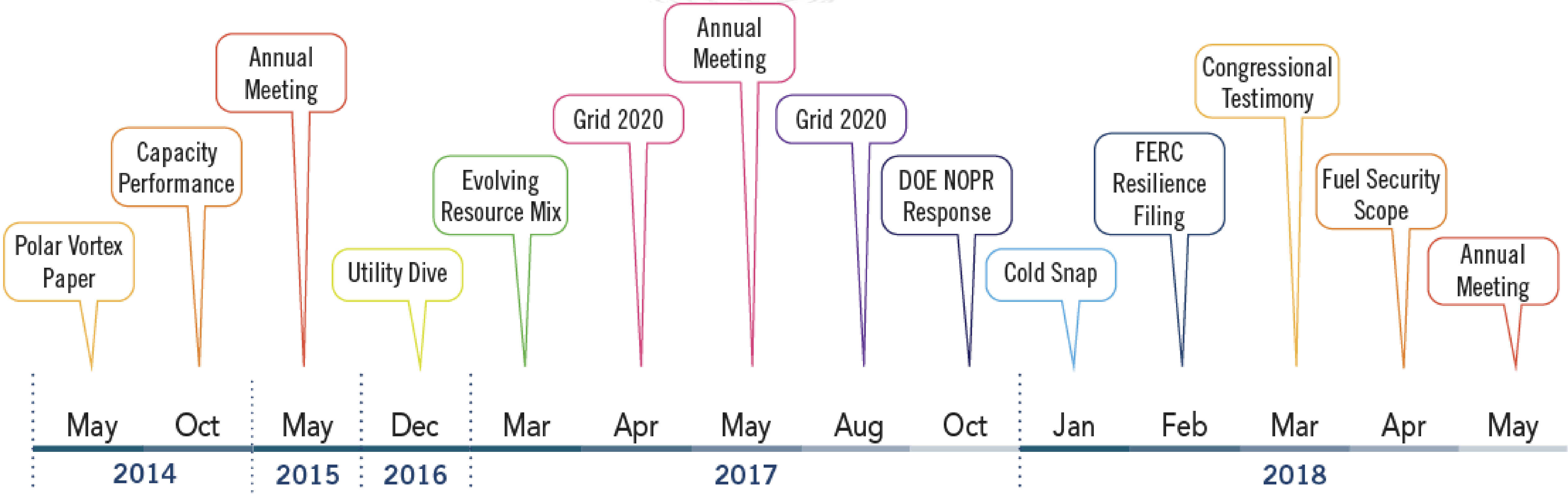
June 28, 2018

Agenda

- Overview
- External Coordination & Stakeholder Feedback
- Analysis Approach & Assumptions
- Next Steps

Overview

Resilience: How Did We Get Here?



Fuel Security Timeline

Initial MRC

MRC: Assumptions

MRC: Phase II

High Level Storyboard

Communications Plan

FERC Filing

May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr

2018 | 2019

Phase I Analysis
Identify potential system vulnerabilities and develop criteria to address them

Phase II Modeling/Market Design
Develop methodology to incorporate vulnerabilities to PJM's markets if needed

Phase III Ongoing Coordination
Address specific security concerns identified by federal and state agencies

Fuel Security Summary

FOCUS

1. Define fuel security as risks in fuel delivery to critical generators
2. Reaffirm the value of markets to achieving a cost-effective, fuel-secure fleet of resources
3. Identify fuel security risks with a primary focus on resilience
4. Establish criteria to value fuel security in PJM markets

APPROACH

1. **Phase 1: Analysis**
   Identify potential system vulnerabilities and develop criteria to address them
2. **Phase 2: Modeling**
   Model of incorporation of vulnerabilities into PJM's markets
3. **Phase 3: Ongoing Coordination**
   Address specific security concerns identified by federal and state agencies

TIMING

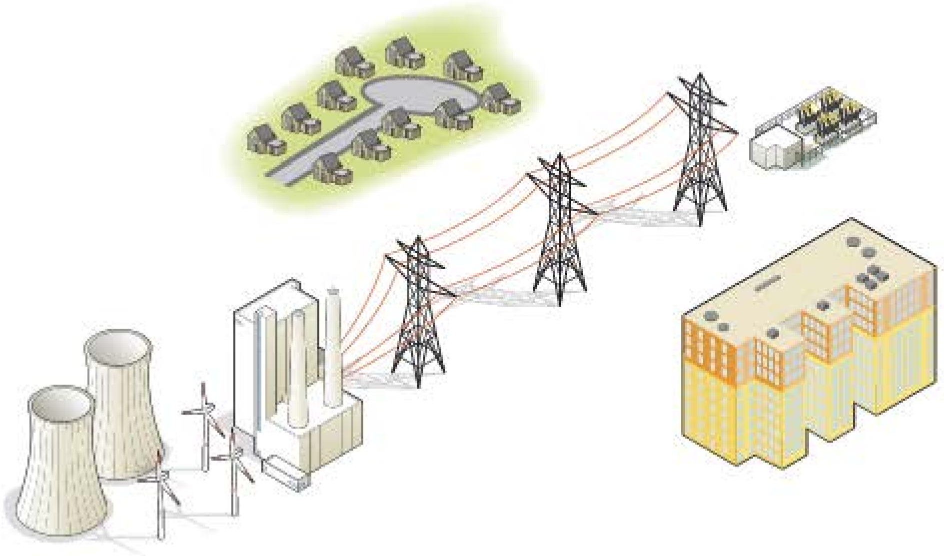
May–July 2018:
Analysis

Aug.–Oct. 2018:
Modeling/Market Design

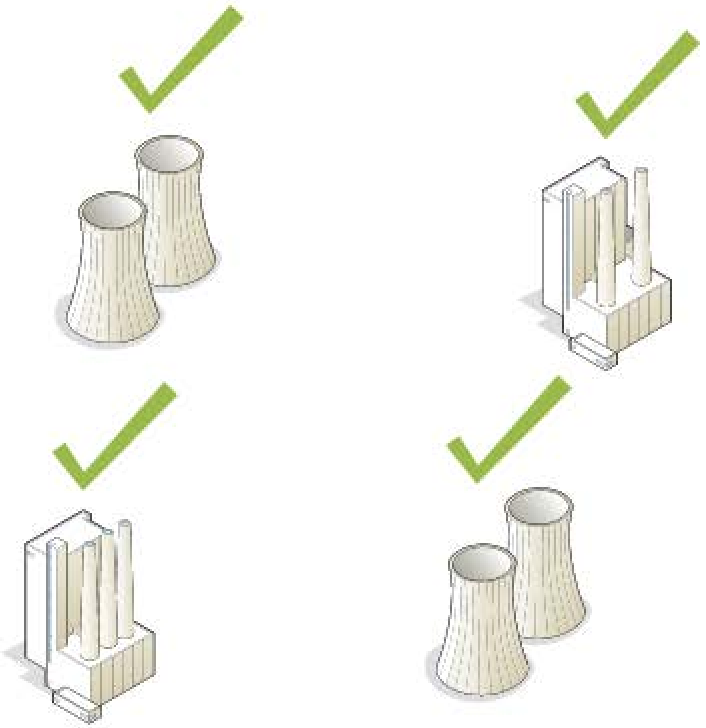
Nov. 2018–March 2019:
Ongoing coordination
January 2019: FERC filing

Fuel Security vs. Capacity Performance

Fuel security looks at the whole system



Capacity Performance looks at each unit individually



External Coordination & Stakeholder Feedback

Outreach Efforts

Purpose: Solicit feedback on PJM Fuel Security Analysis assumptions and approaches as applicable to their industries.

- Generation Owner Survey
- Individual stakeholder sessions as needed/requested
- Natural Gas Council (represents the pipelines, LDCs, producers and marketers)
- National Coal Transportation Association
- Nuclear Energy Institute (NEI)
- Grid Strategies (intermittent resources)
- Department of Energy
- NERC/ReliabilityFirst
- ISO-NE
- NYISO

Stakeholder Feedback

Purpose: Solicit feedback on PJM Fuel Security Study through comment period (comments were due June 8, 2018)

- Stakeholders provided feedback from various perspectives
- PJM reviewed comments
- Incorporating feedback into PJM fuel security study
  - Scenario information
  - Assumptions
  - General study feedback

External Case Study Engagement

Purpose

- Identify key objectives, assumptions and findings from each study
- Reflect key variables that can assist with PJM's fuel security analysis

Author Organization	Current Studies PJM Has Reviewed
The Brattle Group	Defining Reliability for a New Grid - Maintain Reliability and Resilience Through Competitive Markets
Natural Gas Council	Natural Gas Systems: Reliable & Resilient
Quanta Technology	Ensuring Reliability and Resilience: A Case Study of the PJM Power Grid
NEI	The Impact of Fuel Supply Security on Grid Resilience in PJM
ISO New England	Operational Fuel-Security Analysis
Lincoln Laboratory (MIT)	Interdependence of the Electricity Generation System and the Natural Gas System and Implications for Energy Security

Fuel-Related Data Collection

- Fuel-specific periodic survey open to generation owners June 8–22
- Targeted based on 2017 eDART seasonal fuel survey

Key focus areas include:

- Fuel delivery issues encountered during recent Cold Snap
- Pre-winter inventory and refueling strategies
- Natural gas pipeline parameters potentially affecting unit operations
  - Operating pressures and details around switching to alternate pipeline
- Hydro storage capability

Analysis Approach & Assumptions

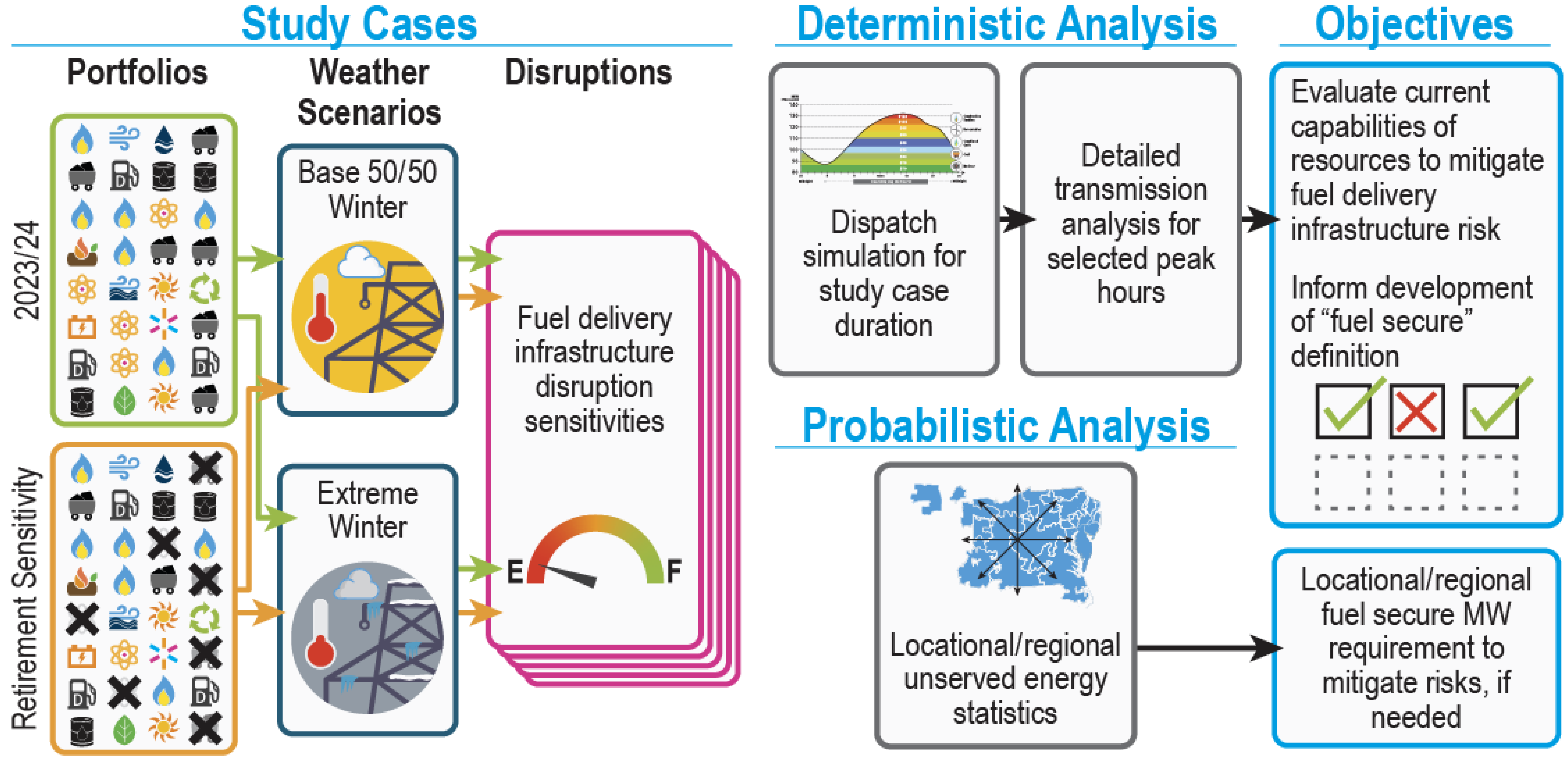
Goals of Fuel Security Analysis – Phase 1

1. Identify fuel delivery infrastructure risks on a locational basis

2. Evaluate current capabilities of resources in PJM to mitigate risks under weather-induced and man-made fuel delivery disruptions

3. Determine if and when any market-based mechanism would be needed to mitigate risk to PJM operations

Approach Overview



Generation Portfolio Assumptions

	Retirements	Replacement
Base Portfolio	Announced retirements accounted for in 2023 Winter RTEP case	Queue projects accounted for in 2023 Winter RTEP case
Retirement Sensitivity	• *Coal*: Based on plant age and size, reference IMM/PJM units at risk methodologies • *Nuclear*: Based on public analysis of future costs and revenues in IMM State of the Market Report	• Assuming trends in generation queue and commercial probabilities • Replace ICAP based on maintaining: – Expected Planning Reserve Margin *(Phase 1a)* – IRM (16.6 percent) *(Phase 1b)*

Base 50/50 Winter

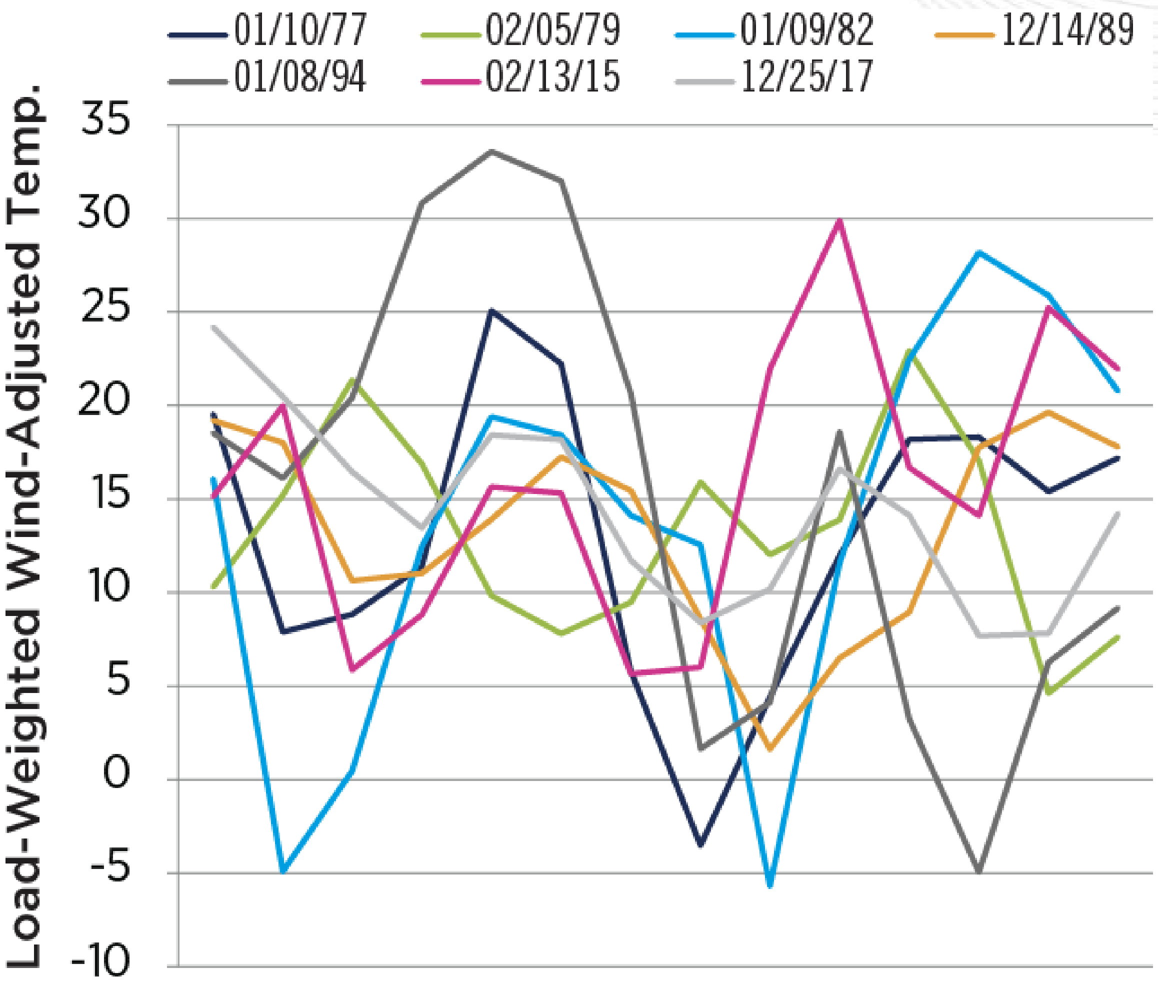
- Peak Load: 134,435 MW based on forecast for Winter 2023/24
- Average winter hourly load shape

Extreme Winter

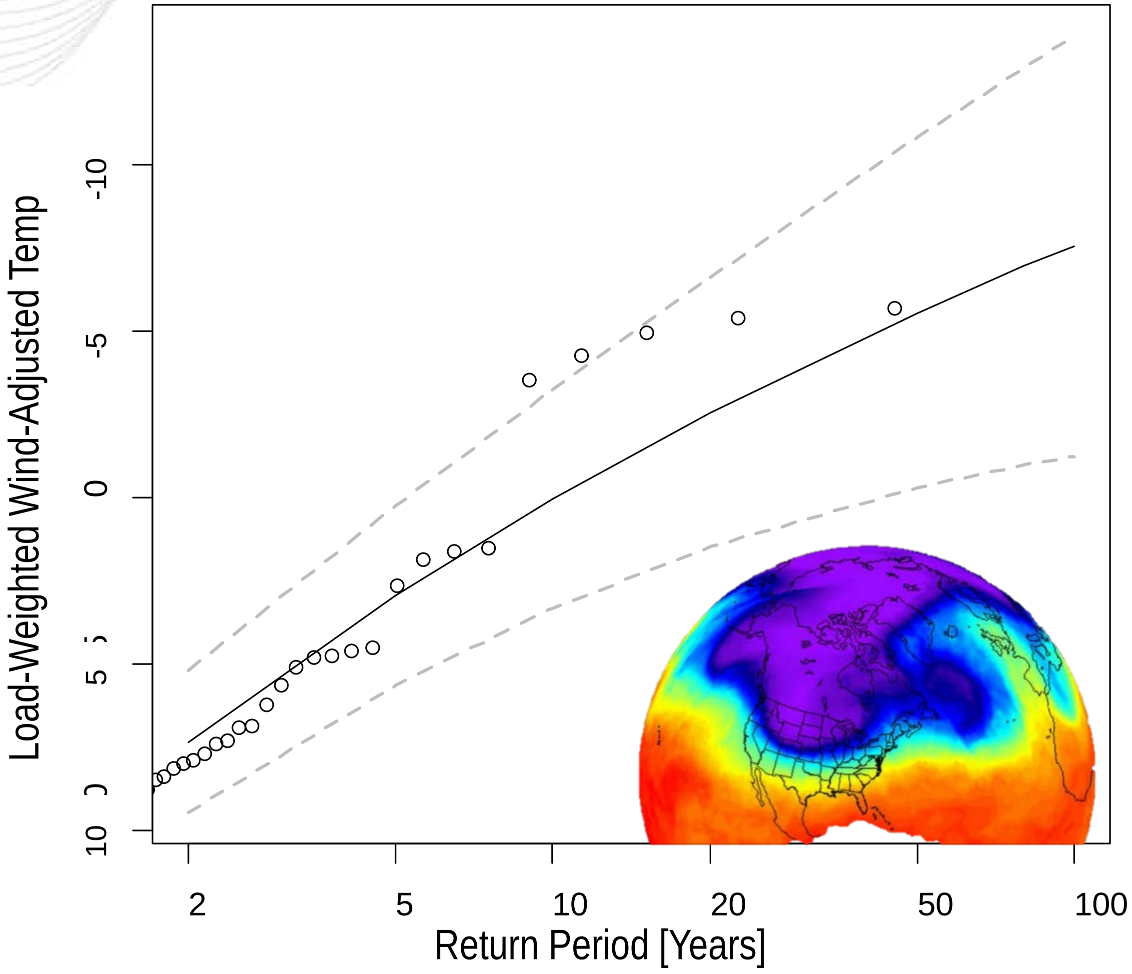
- Estimated probability (1 in X yrs.) of extreme winter scenario using:
  - Historical daily wind chill (wind adjusted temperature) for current PJM footprint
  - Historical consecutive days of extreme wind chill
- 2017/18 winter hourly load shape

Extreme Value Analysis

Historical Cold Snaps



1-in-X Cold Snap



Extreme Winter Weather Evaluation

- PJM examined weather for the current PJM footprint back to 1973 and identified seven cold snaps of significant duration.

- PJM computed the average daily temperature at each weather station for each day of the last 45 winters. A PJM RTO average temperature was determined based on a load-weighted average across all 40+ weather stations.

- Focus on extreme temperature and duration.

Historical Cold Snap Impact on 2023/24 Winter Peak Load

2023/24 Peak: 147,771 97th percentile		
1989		
Date	Avg Temp	Wind Adj Temp
11-Dec-89	29.0	28.8
12-Dec-89	26.7	26.5
13-Dec-89	24.2	23.7
14-Dec-89	19.9	19.2
15-Dec-89	19.1	18.0
16-Dec-89	12.9	10.6
17-Dec-89	11.7	11.0
18-Dec-89	14.3	13.9
19-Dec-89	17.4	17.3
20-Dec-89	16.3	15.5
21-Dec-89	10.2	8.6
22-Dec-89	3.0	1.6
23-Dec-89	7.4	6.5
24-Dec-89	10.4	9.0
25-Dec-89	19.0	17.8
26-Dec-89	21.8	19.6
27-Dec-89	18.5	17.8
28-Dec-89	28.5	27.9
29-Dec-89	31.1	30.9
30-Dec-89	35.2	35.0
14-day Avg	*14.4*	*13.3*

2023/24 Peak: 150,442 99th percentile		
1994		
Date	Avg Temp	Wind Adj Temp
5-Jan-94	25.5	24.1
6-Jan-94	28.8	28.5
7-Jan-94	30.0	29.5
8-Jan-94	20.4	18.5
9-Jan-94	17.0	16.1
10-Jan-94	21.0	20.4
11-Jan-94	31.2	30.8
12-Jan-94	33.9	33.6
13-Jan-94	32.3	32.0
14-Jan-94	22.4	20.6
15-Jan-94	4.5	1.6
16-Jan-94	5.2	4.1
17-Jan-94	19.8	18.6
18-Jan-94	5.9	3.3
19-Jan-94	-4.0	-4.9
20-Jan-94	6.3	6.3
21-Jan-94	9.9	9.2
22-Jan-94	22.9	22.2
23-Jan-94	32.0	30.9
24-Jan-94	39.8	39.1
14-day Avg	*16.1*	*15.0*

2023/24 Peak: 140,159 88th percentile		
2017/18		
Date	Avg Temp	Wind Adj Temp
22-Dec-17	44.1	44.0
23-Dec-17	43.7	42.6
24-Dec-17	34.9	34.4
25-Dec-17	27.3	24.2
26-Dec-17	21.2	20.5
27-Dec-17	17.0	16.5
28-Dec-17	14.1	13.5
29-Dec-17	18.6	18.4
30-Dec-17	19.0	18.2
31-Dec-17	12.6	11.7
1-Jan-18	9.3	8.4
2-Jan-18	11.0	10.2
3-Jan-18	17.1	16.6
4-Jan-18	17.4	14.1
5-Jan-18	10.4	7.7
6-Jan-18	9.3	7.8
7-Jan-18	14.9	14.2
8-Jan-18	29.6	28.7
9-Jan-18	34.5	34.3
10-Jan-18	37.9	37.3
14-day Avg	*15.6*	*14.4*

Focus of Fuel Delivery Infrastructure Risk

- Natural Gas Delivery Disruptions
  - PJM-identified disruptions on vulnerable locations on major pipelines that impact large pockets of generation (*Phase 1a*)
  - DOE-identified cyber and physical threats to fuel delivery infrastructure in the PJM footprint (*Phase 1b*)

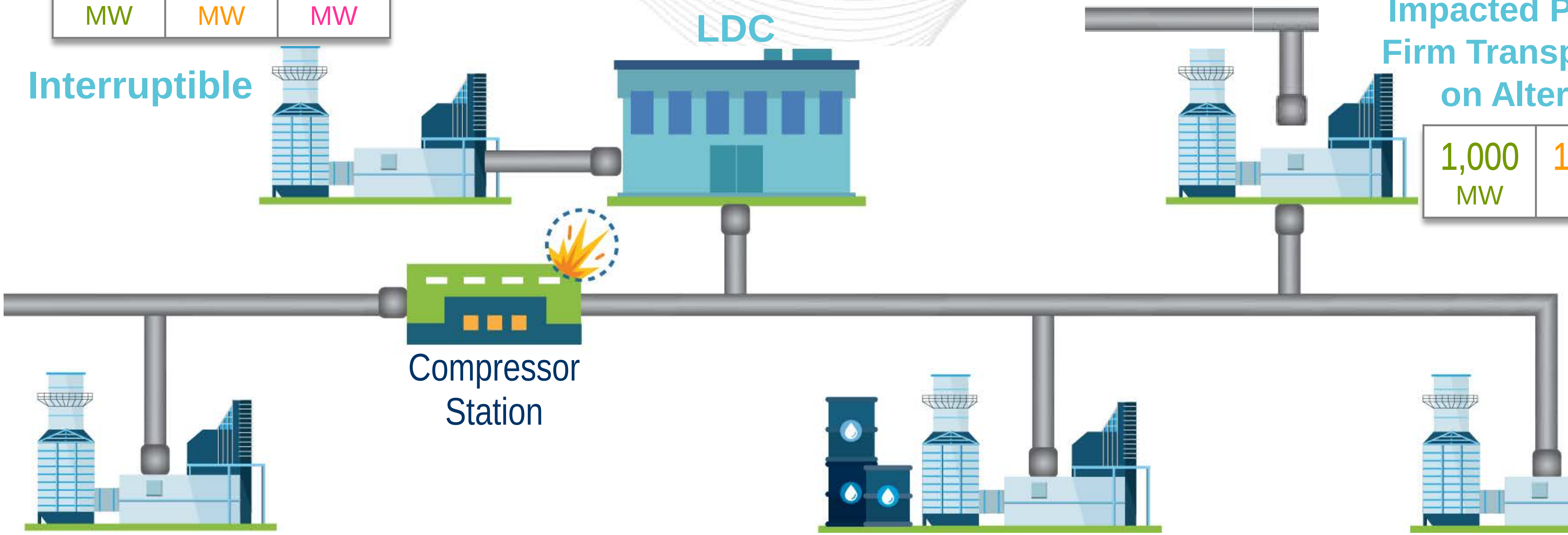
- Oil Delivery Disruptions
  - Conservative assumptions about fuel replenishment

- Other Resource Types
  - Generator forced outage rates will account for issues with less dynamic fuel delivery (e.g., frozen coal piles).
  - Incorporation of other resource type disruptions is still under review.

Natural Gas Disruption Sensitivities
Generation Assumptions

Phase 1a		Base Winter Load Scenario	Extreme Winter Load Scenario
No Disruption		• Units with firm transportation are available. • Interruptible transportation is limited.	• Units with firm transportation are available. • Units with interruptible transportation run on dual fuel (if capable), otherwise unavailable.
Credible Disruptions	Medium Impact Disruption 50% pipeline capacity reduction downstream of failure	• Output of units with firm transportation on impacted pipeline reduced to 50% of EcoMax. • Firm transportation on alternate pipeline is available. • Units with interruptible transportation on impacted pipeline run on dual fuel (if capable) otherwise unavailable. • Interruptible transportation on alternate pipeline is limited.	• Output of units with firm transportation on impacted pipeline reduced to 50% of EcoMax. • Firm transportation on alternate pipelines available. • Units with interruptible transportation on impacted pipeline run on dual fuel (if capable), otherwise unavailable.
	High Impact Disruption 100% pipeline capacity reduction downstream of failure	• Firm transportation on alternate pipelines available. • Units with interruptible transportation on impacted pipeline run on dual fuel (if capable) otherwise unavailable. • Interruptible transportation on alternate pipeline is limited.	• Units with firm transportation run on dual fuel (if capable) or are unavailable. • Firm transportation on alternate pipelines available. • Units with interruptible transportation on impacted pipeline run on dual fuel (if capable), otherwise unavailable.

Base Winter Scenario Example



Interruptible

600 MW	0 MW	0 MW

Interruptible on Impacted Pipeline, Firm Transportation on Alternate

1,000 MW	1,000 MW	1,000 MW

1,000 MW unit

Interruptible with Dual Fuel

1,000 MW	1,000 MW	1,000 MW

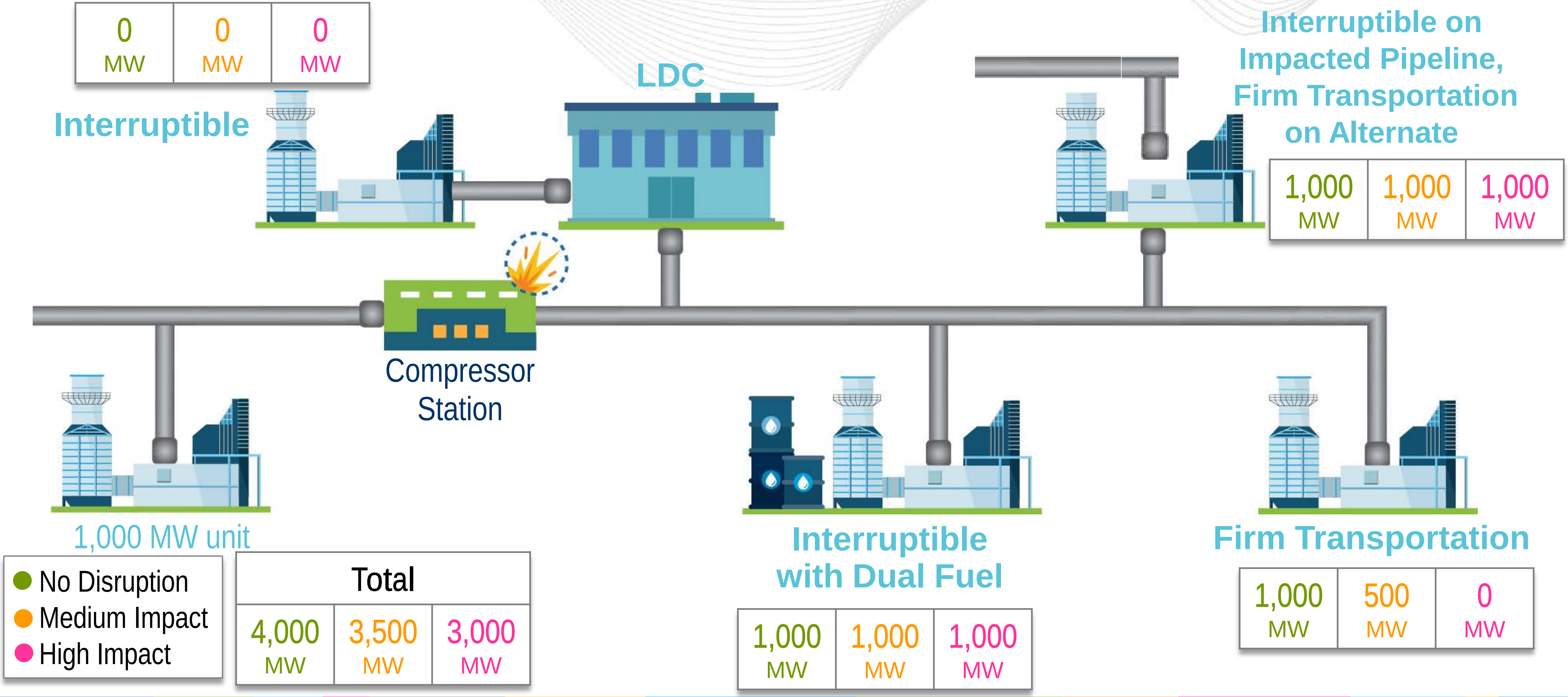
Firm Transportation

1,000 MW	500 MW	0 MW

- No Disruption
- Medium Impact
- High Impact

Total		
4,600 MW	3,500 MW	3,000 MW

Extreme Winter Scenario Example



Operational Assumptions

	Base 50/50 Weather Scenario	Extreme Weather Scenarios
Model Year (2023/24)	• Most up-to-date future winter RTEP case • Accounts for announced generation retirements, queue generation with ISAs and/or has cleared in RPM, and associated transmission upgrades	
Renewable Output	Hourly winter profiles for wind and solar	
Transmission Outages	None	
External Interchange	No external imports beyond long-term, full path firm transactions (includes pseudo ties)	
Contingencies	Account for monitored contingencies, including gas-electric contingencies	
Demand Response	Includes a determination of when DR capacity would be deployed	
Energy Efficiency	Accounted for in load forecasts	

Operational Assumptions (continued)

	Base 50/50 Weather Scenario	Extreme Weather Scenarios
Generation Capabilities	• Dual fuel capability • Supply and transportation contracts • Maximum on-site fuel inventories; depletion based on unit heat rates • Conservative unit parameters to account for winter operations (e.g., cycling capability)	
On-Site Fuel Replenishment	Full inventory at start, and set MWh limitation based on anticipated number of refuels during study period (from outreach on refueling logistics)	Full inventory at start, and set MWh limitation based on: 1. No replenishment for duration of simulation 2. Anticipated number of refuels during study period (from outreach on refueling logistics)
Generation Outages	• Five-year unit average EFORd • Fuel delivery outage causes for natural gas and oil excluded	• Historic cold-snap forced outage rates • Fuel delivery outage causes for natural gas and oil excluded
Emissions Limits	Not a constraint on operations	
Fuel Prices	Fuel price forecasts for 2023/24	Forecasts for 2023/24 scaled for weather impacts

Study Case Summary

🟢 Phase 1a (July/Aug)
🟠 Phase 1b (Aug/Sept)

		Base Winter Load Scenario			Extreme Winter Load Scenario		
		Base Portfolio	Retirement Sensitivities		Base Portfolio	Retirement Sensitivities	
			Expected Reserve Margin	IRM (16.6%)		Expected Reserve Margin	IRM (16.6%)
Disruption Sensitivities	None	🟢	🟢	🟠	🟢	🟢	🟠
	Medium Impact (PJM)	🟢	🟢	🟠	🟢	🟢	🟠
	High Impact (PJM)	🟢	🟢	🟠	🟢	🟢	🟠
	DOE-identified	🟠	🟠	🟠	🟠	🟠	🟠

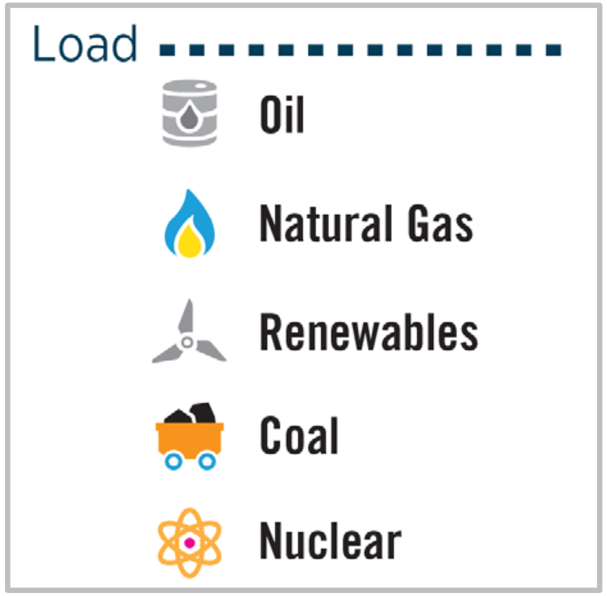
Dispatch Simulation Objectives

- Evaluate current capabilities of resources to mitigate fuel delivery infrastructure risk by determining impact of event on:
  - On-site fuel depletion
  - Transmission system
  - Ability to serve load

- Inform "fuel secure" definition as reference point in assessing current capabilities of resources
  - For example, "fuel secure" resources must demonstrate the capability to serve load at max output for XX hours or min output for YY hours to mitigate a ZZ-day duration risk.
  - All technology types/combinations would be eligible to demonstrate this criteria.

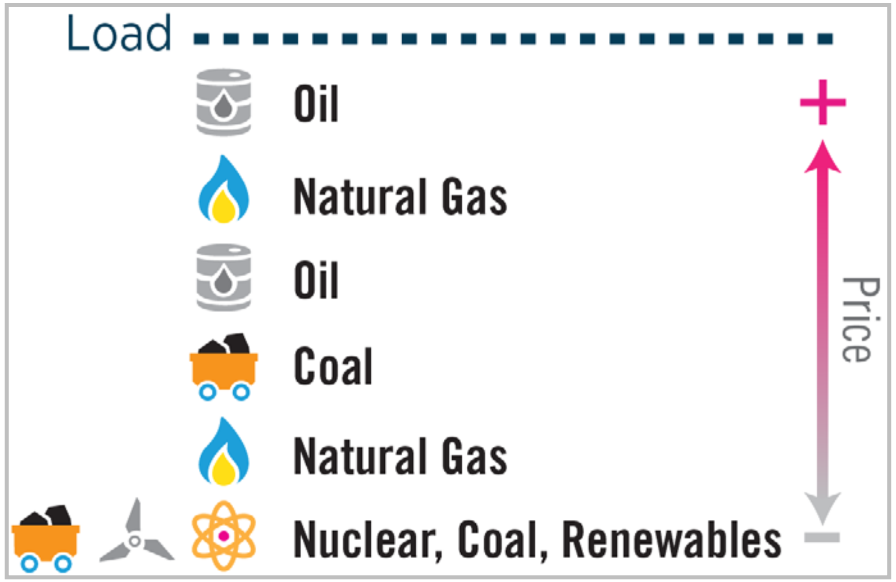
Block Dispatch

Blocks of units turned "on" based on resource type and winter capacity factors



Economic Dispatch

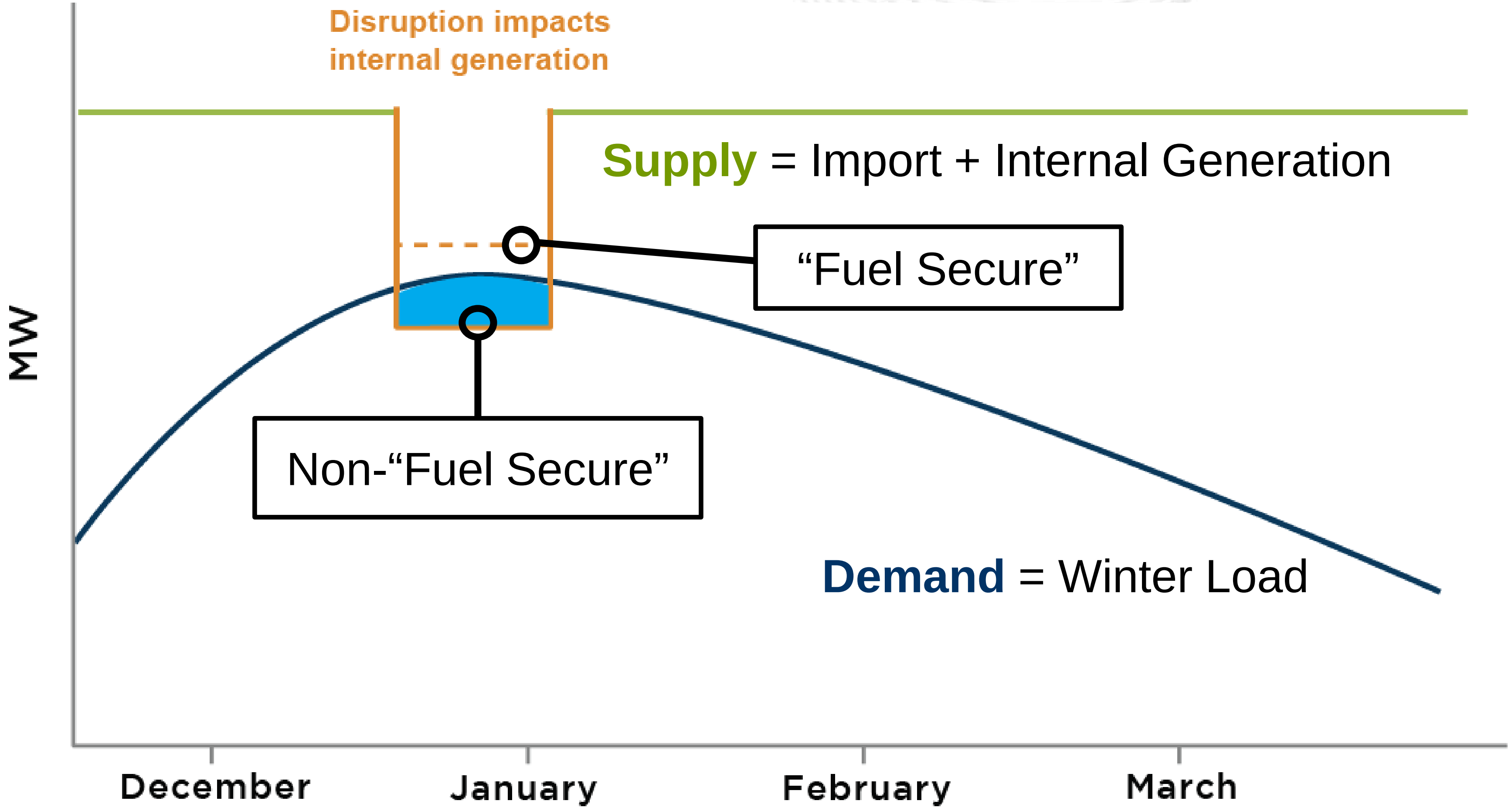
- Security constrained optimization taking input constraints on generation (on-site fuel inventory, gas availability) and fuel prices into account
- May show faster on-site fuel depletion when oil is more economic than gas



Detailed Transmission Analysis

- Use latest winter RTEP base case (2023/24)
- Examine N-1 conditions on both the transmission and gas systems
- Determine thermal and/or voltage issues in each scenario
- Determine impact of scenarios on transfer limits across PJM

Evaluate Locational "Fuel Secure" MW Requirement



Results of transfer limit analysis used to determine locational requirements such that reliability objective (EUE or LOLH) is met

Phase 1 Next Steps

- Gather stakeholder feedback
- Meet with industry representatives to refine assumptions
- Continue discussion with DOE to define extreme cyber and physical threat sensitivities
- Determine how to incorporate disruptions to resource types besides natural gas and oil
- Provide update on progress of Phase 1 in July