Fuel Security
Phase 1 Analysis Results

Special MRC

November 1, 2018

Next Fuel Security Special MRC:
November 26

Please send fuel security-related questions to:

natalie.tacka@pjm.com

Agenda

Conclusions, Background and Assumptions → Announced Retirements Analysis → Escalated Retirements Analysis → Conclusions and Next Steps

Note: The analysis is neither meant to be predictive of future conditions nor meant to imply that analyzed scenarios are unavoidable.

Conclusions

- There is **NO** immediate threat to the reliability of the PJM RTO.
- 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.
- By design, PJM created stressed scenarios that were intended to discover the point(s) at which an assumption or combination of assumptions begin to impact the system's ability to reliably serve customers. The stressed scenarios resulted in a loss of load under extreme, but plausible conditions.
- In the stressed scenarios, assumptions that are contributing factors to the level of load shed include combinations of:
  - 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

Fuel Security Summary

FOCUS

1. Define fuel security **considering 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 incorporation of vulnerabilities into PJM's markets
3. **Phase 3: Ongoing Coordination**
   Address specific security concerns identified by federal and state agencies

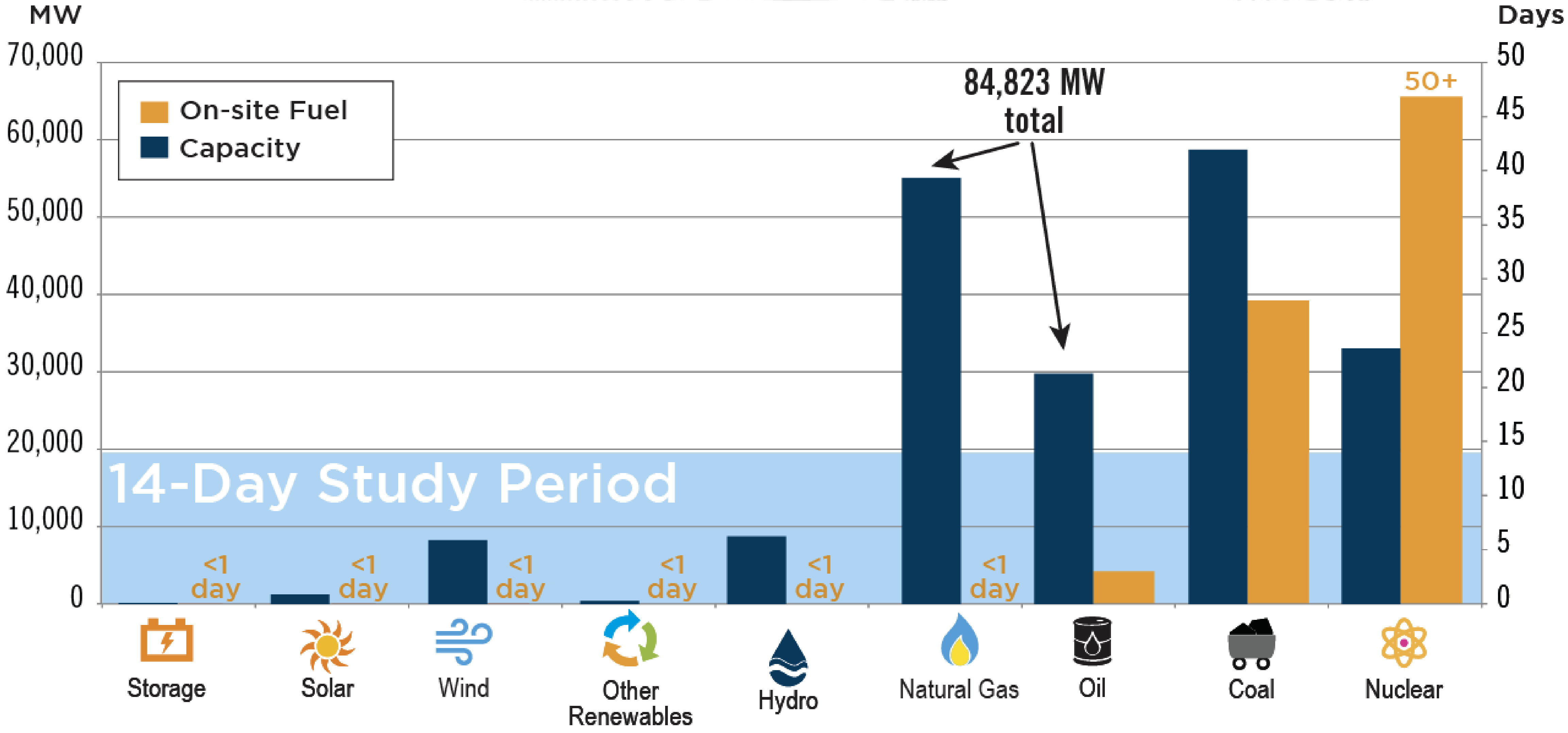
TIMING

May–November 2018
Analysis

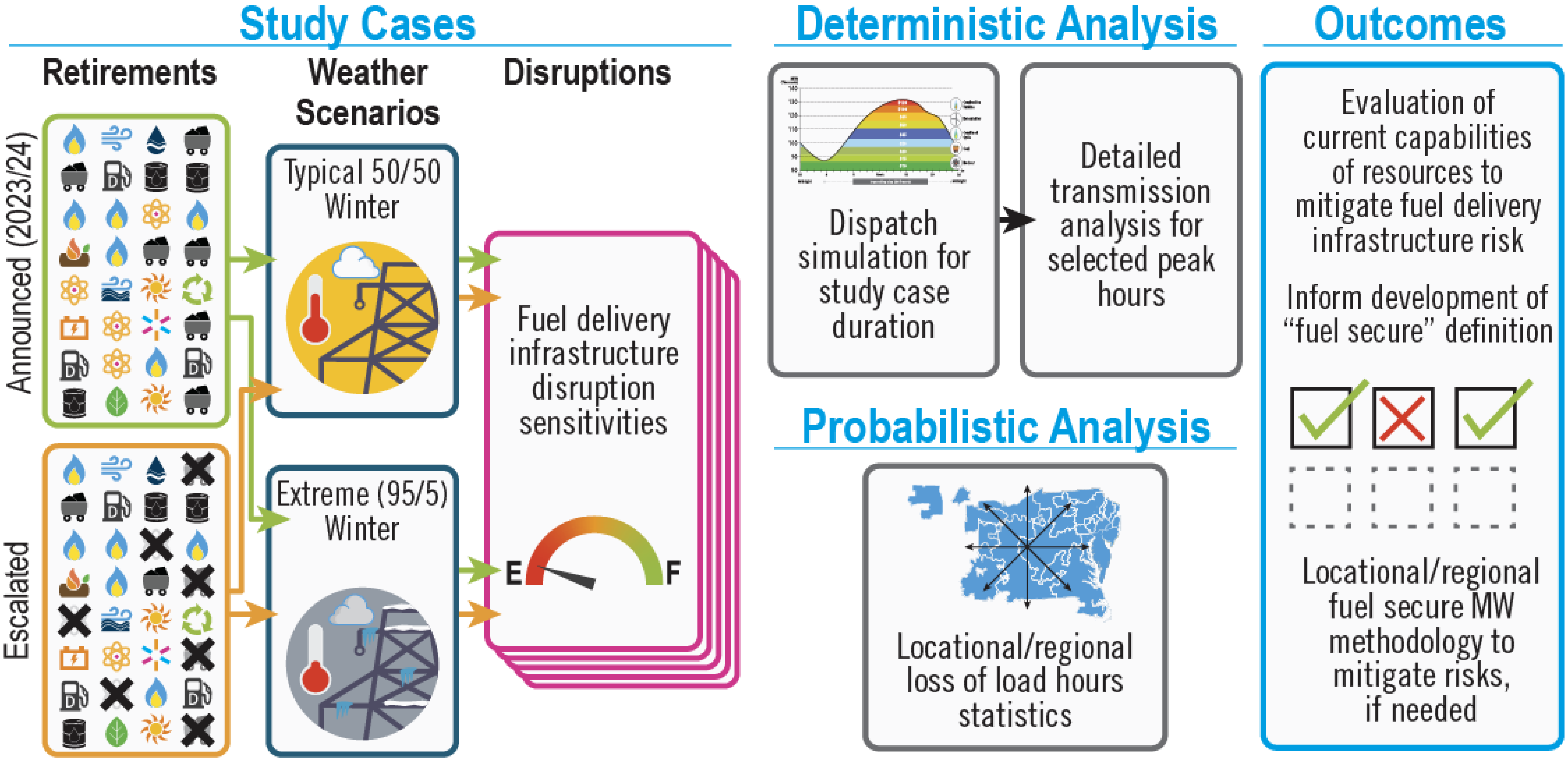
May 2018–December 2019
Phase 3 ongoing coordination

2019/2020
Phase 2: Assess market design in 2019 and target solution filed with FERC early 2020

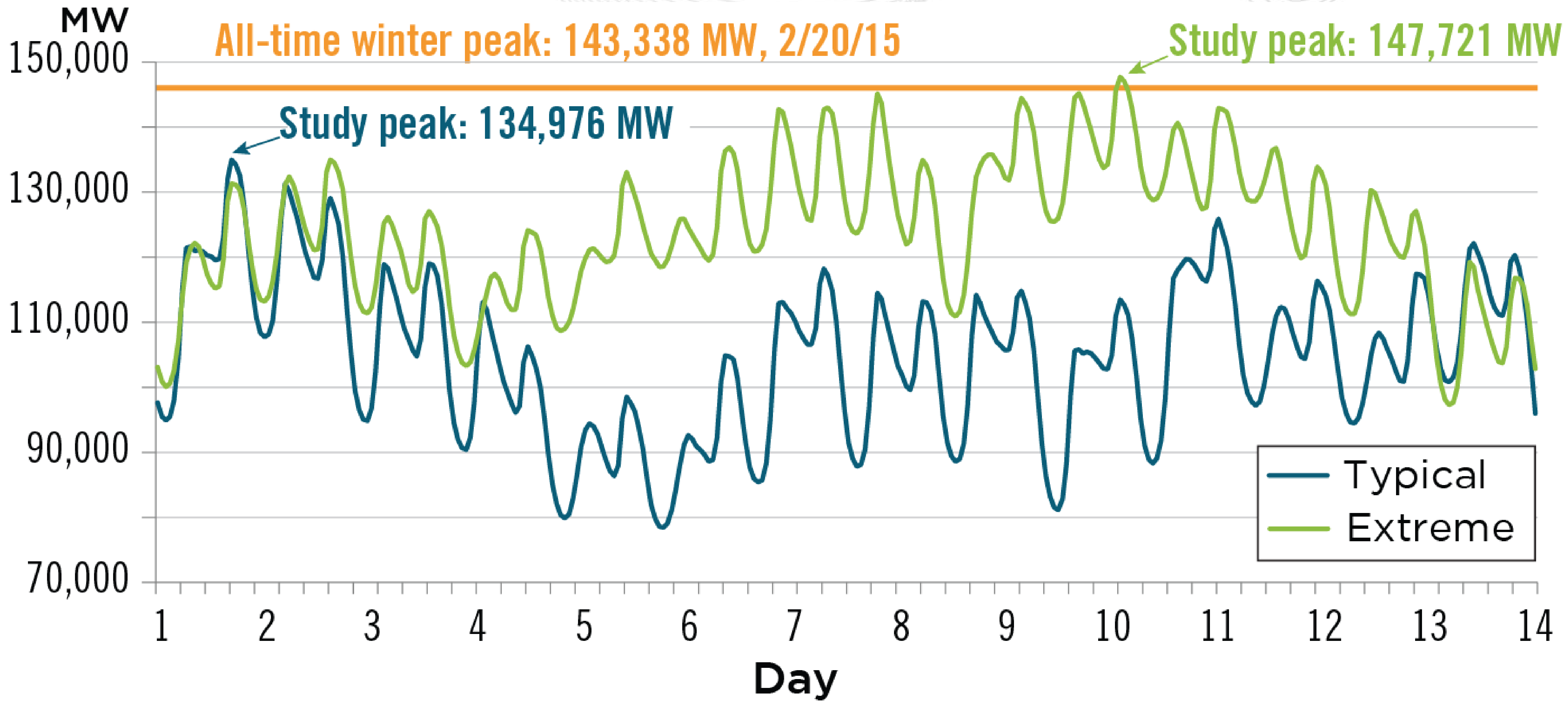
Understanding the Study



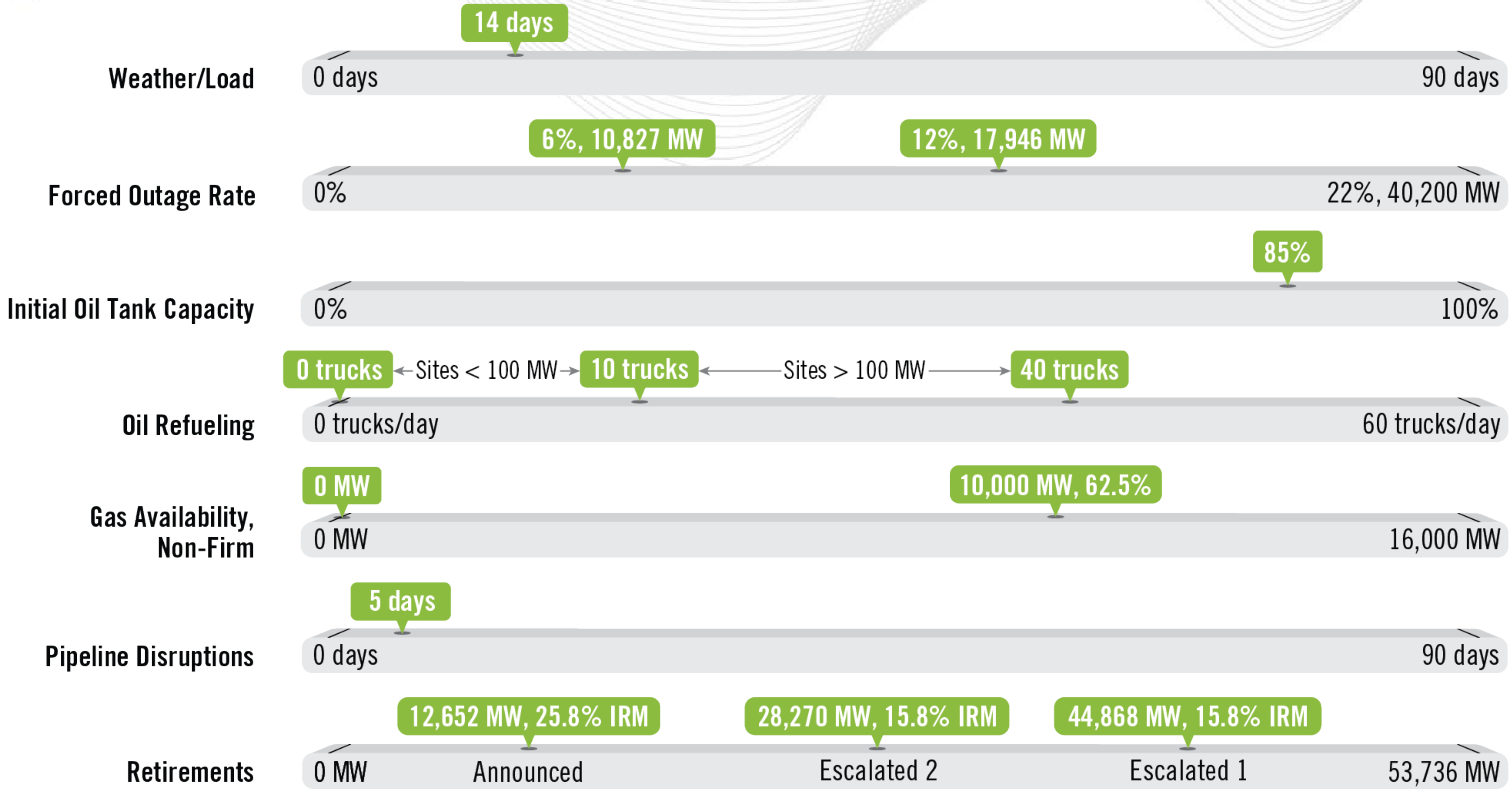
Approach Overview



Winter Load in 14-Day Periods



Key Model Assumption Ranges



Scenarios Analyzed

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	

300+
combinations

Conclusions, Background and Assumptions

Announced Retirements Analysis

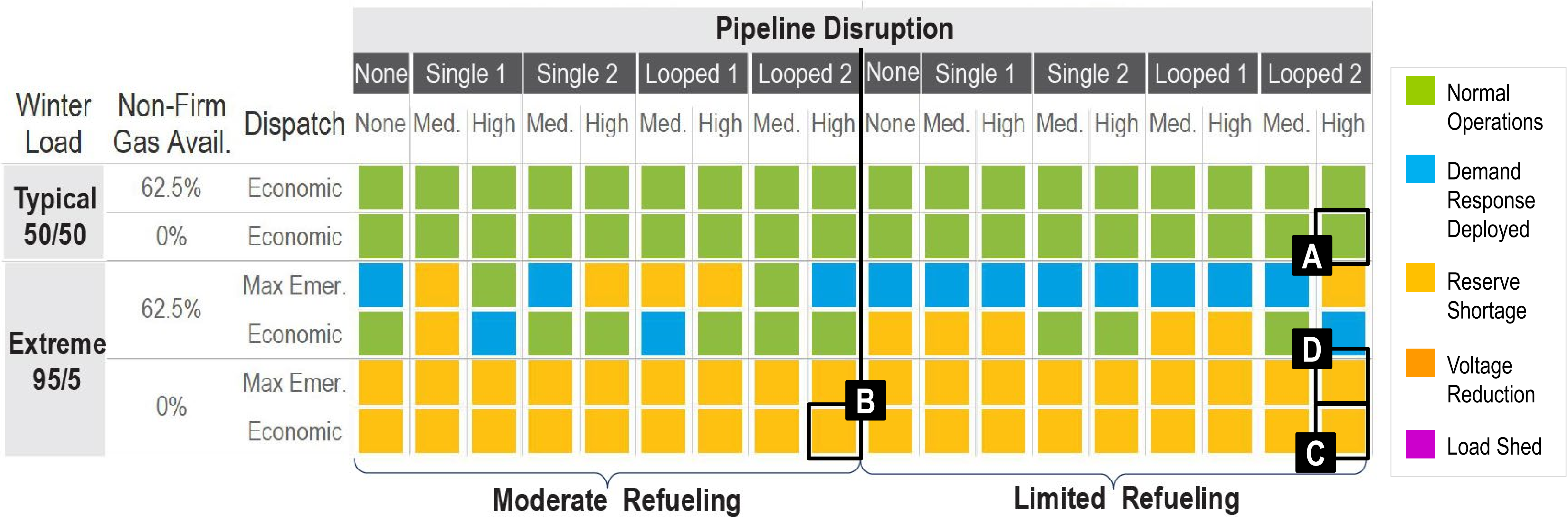
Escalated Retirements Analysis

Conclusions and Next Steps

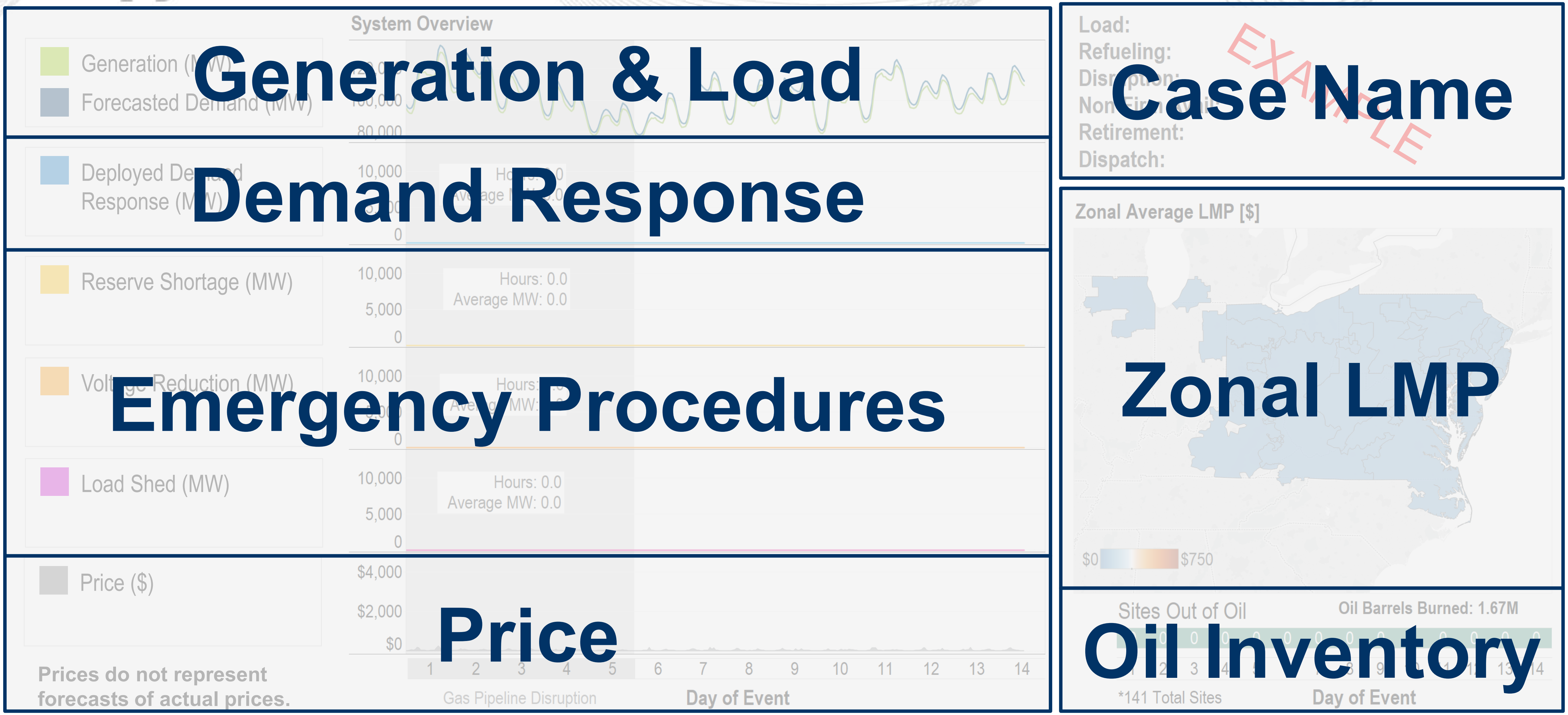
Announced Retirements Analysis

Emergency Procedures Summary

Announced Retirement Models



Announced Retirements Scenario Model: Example

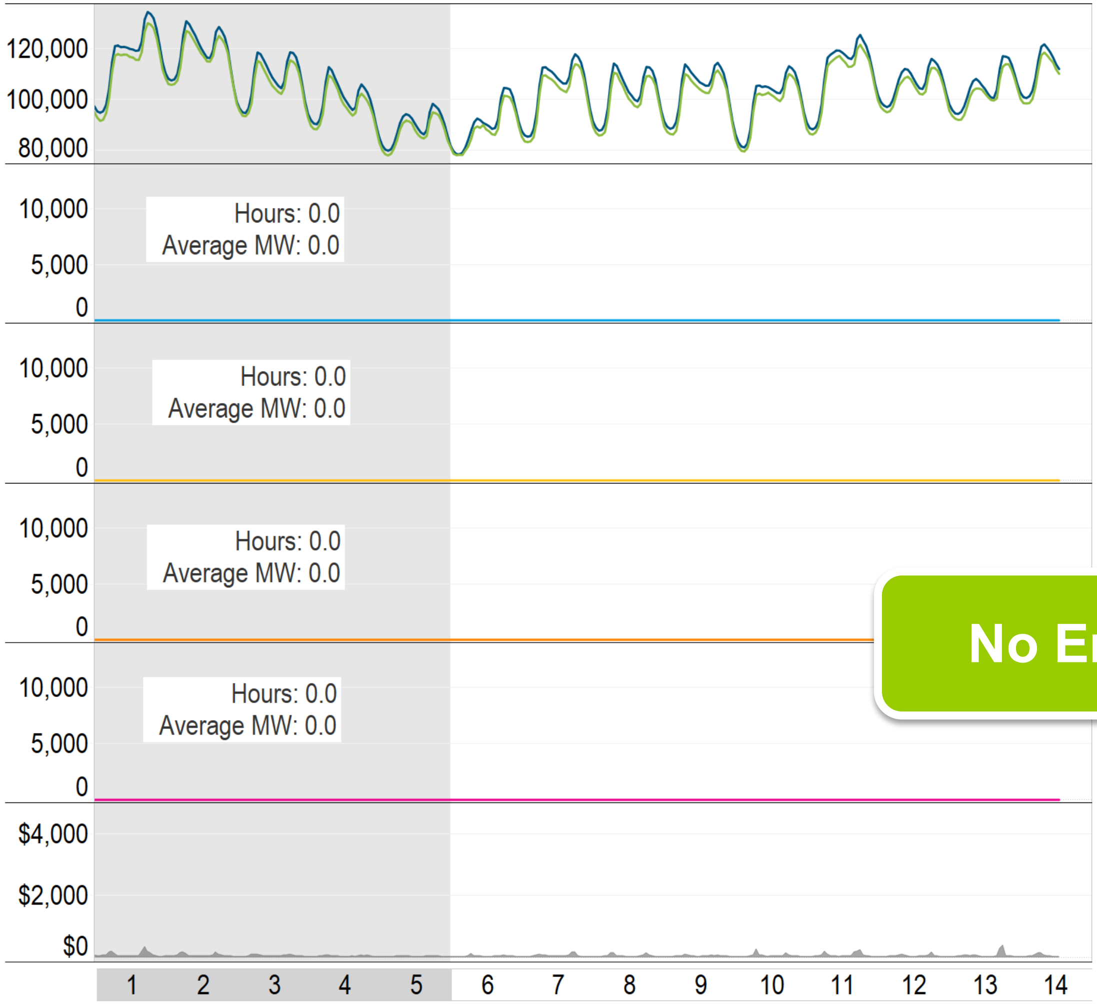


Announced Retirements Scenario Model A

- Generation (MW)
- Forecasted Demand (MW)
- Deployed Demand Response (MW)
- Reserve Shortage (MW)
- Voltage Reduction (MW)
- Load Shed (MW)
- Price ($)

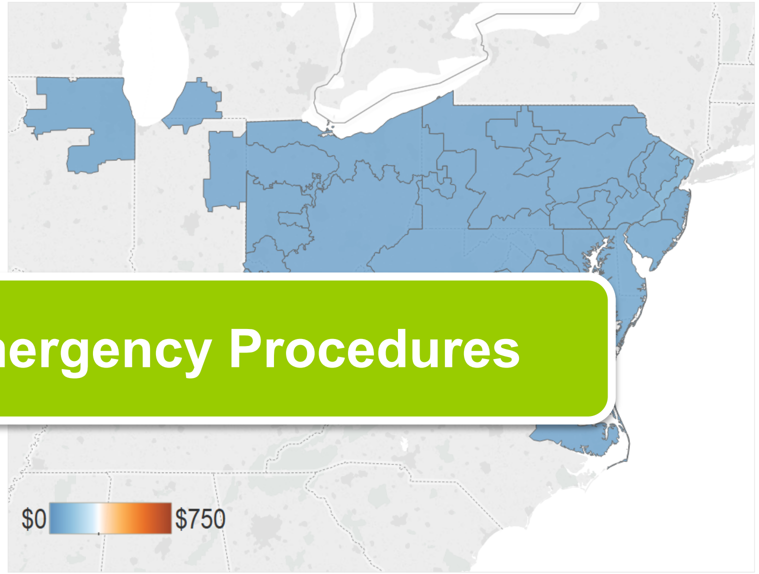
Prices do not represent forecasts of actual prices.

System Overview



Load:	Typical
Refueling:	Limited
Disruption:	Looped 2 High
Non-Firm Avail:	0%
Retirement:	Announced
Dispatch:	Economic

Hourly Zonal Average LMP [$]



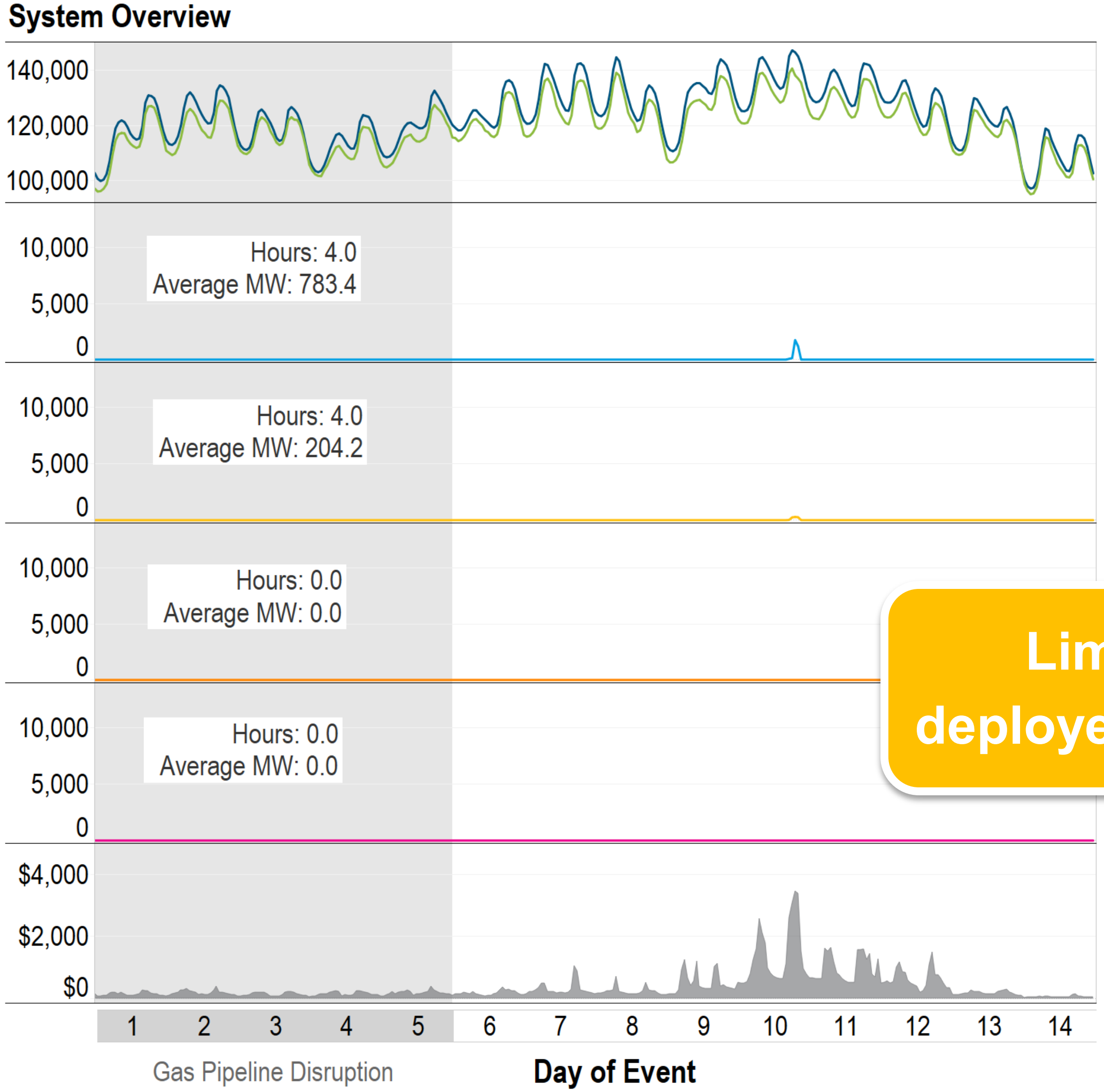
No Emergency Procedures

Sites Out of Oil **Oil Barrels Burned: 0.68M**

Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sites Out of Oil	0	0	0	0	0	0	0	0	0	0	0	1	0	0

*141 Total Sites

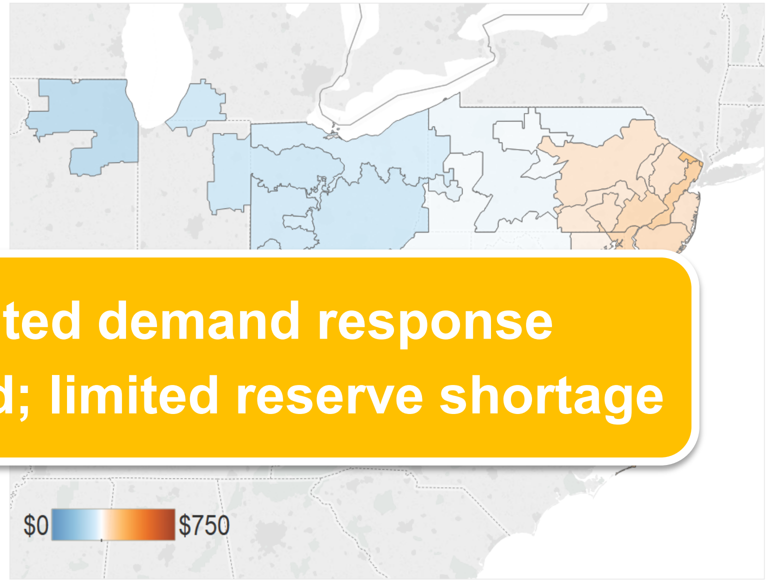
Announced Retirements Scenario Model B



Prices do not represent forecasts of actual prices.

Load:	Extreme
Refueling:	Moderate
Disruption:	Looped 2 High
Non-Firm Avail:	0%
Retirement:	Announced
Dispatch:	Economic

Hourly Zonal Average LMP [$]



Limited demand response deployed; limited reserve shortage

Sites Out of Oil

Oil Barrels Burned: 5.28M

0	0	0	0	1	1	3	2	4	9	22	21	3	1
1	2	3	4	5	6	7	8	9	10	11	12	13	14

*141 Total Sites

Day of Event

Announced Retirements Scenario Model C

Generation (MW)
Forecasted Demand (MW)

Deployed Demand Response (MW)

Reserve Shortage (MW)

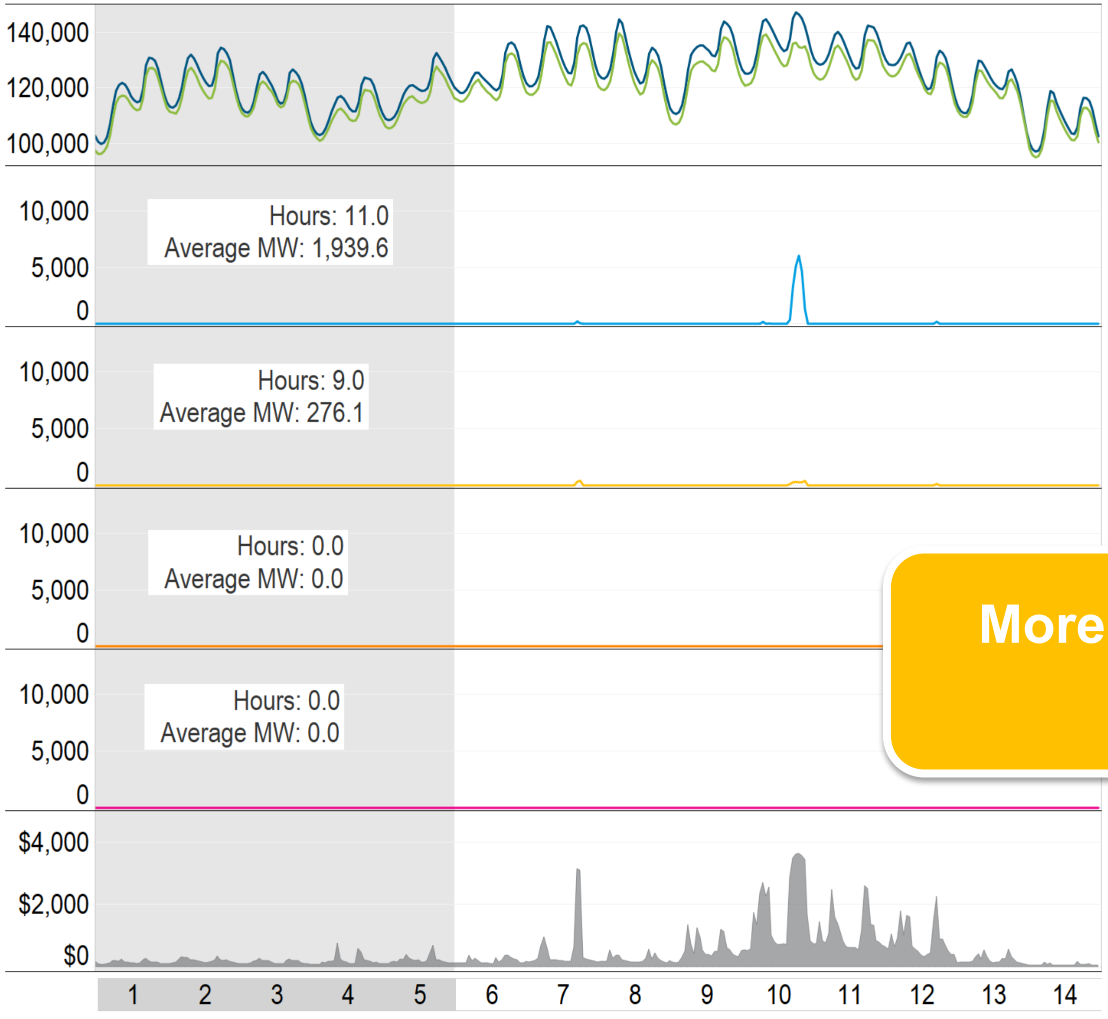
Voltage Reduction (MW)

Load Shed (MW)

Price ($)

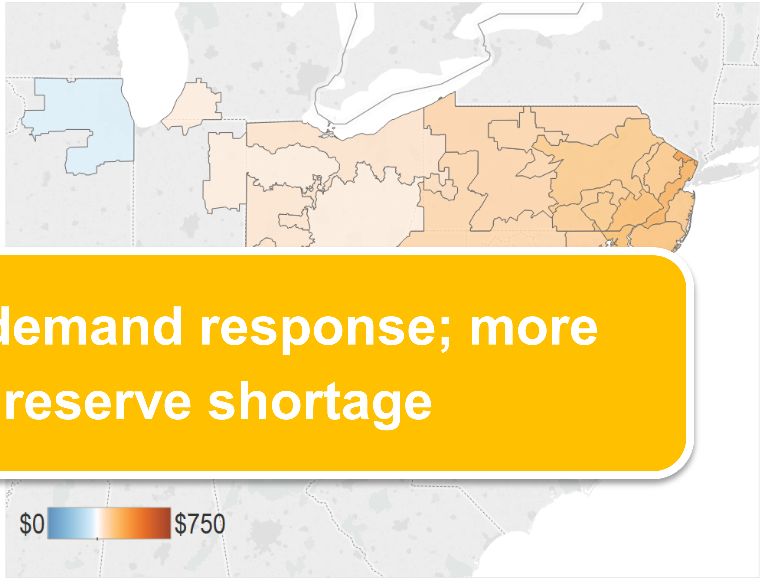
Prices do not represent forecasts of actual prices.

System Overview



Load:	Extreme
Refueling:	Limited
Disruption:	Looped 2 High
Non-Firm Avail:	0%
Retirement:	Announced
Dispatch:	Economic

Hourly Zonal Average LMP [$]



More demand response; more reserve shortage

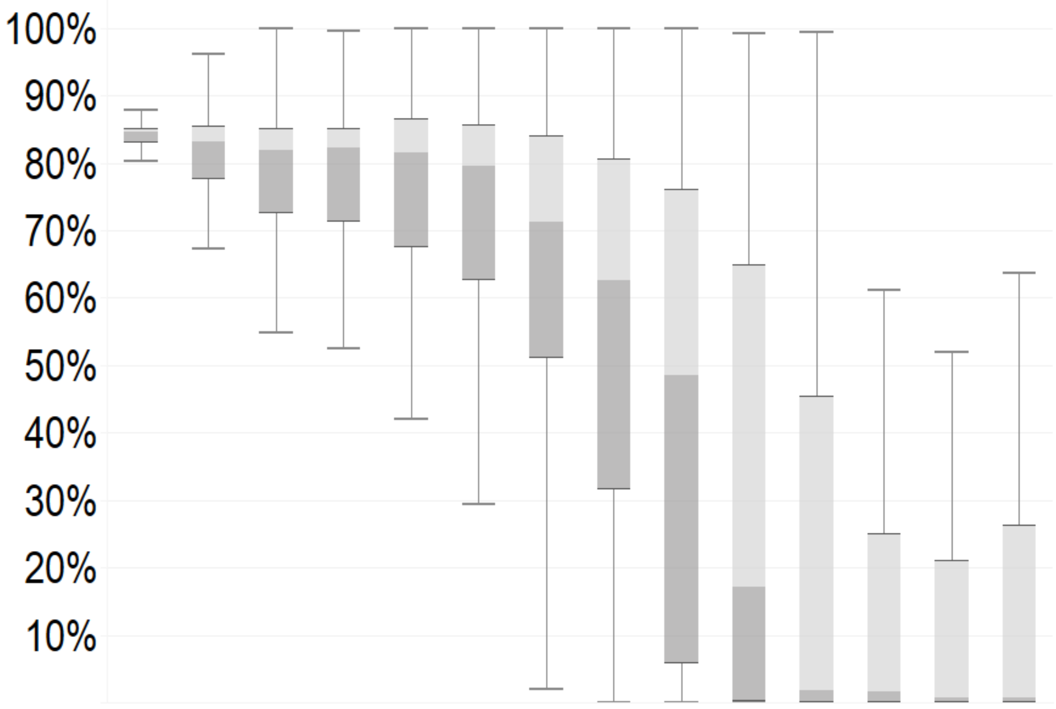
Sites Out of Oil **Oil Barrels Burned: 4.55M**

Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sites Out of Oil	0	3	6	7	8	12	16	21	47	61	74	80	74	66

*141 Total Sites

Oil Inventory | Sites Out of Oil

Limited Refueling



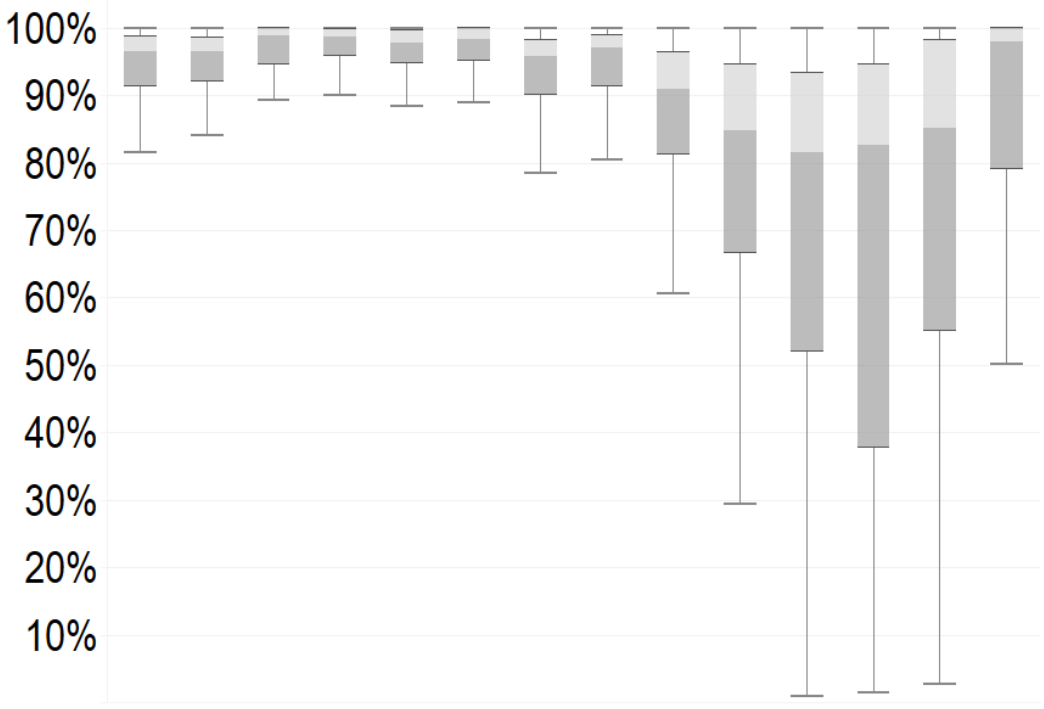
Sites Out of Oil

0	3	6	7	8	12	16	21	47	61	74	80	74	66
1	2	3	4	5	6	7	8	9	10	11	12	13	14

*141 Total Sites

Day of Event

Moderate Refueling



Sites Out of Oil

0	0	0	0	1	1	3	2	4	9	22	21	3	1
1	2	3	4	5	6	7	8	9	10	11	12	13	14

*141 Total Sites

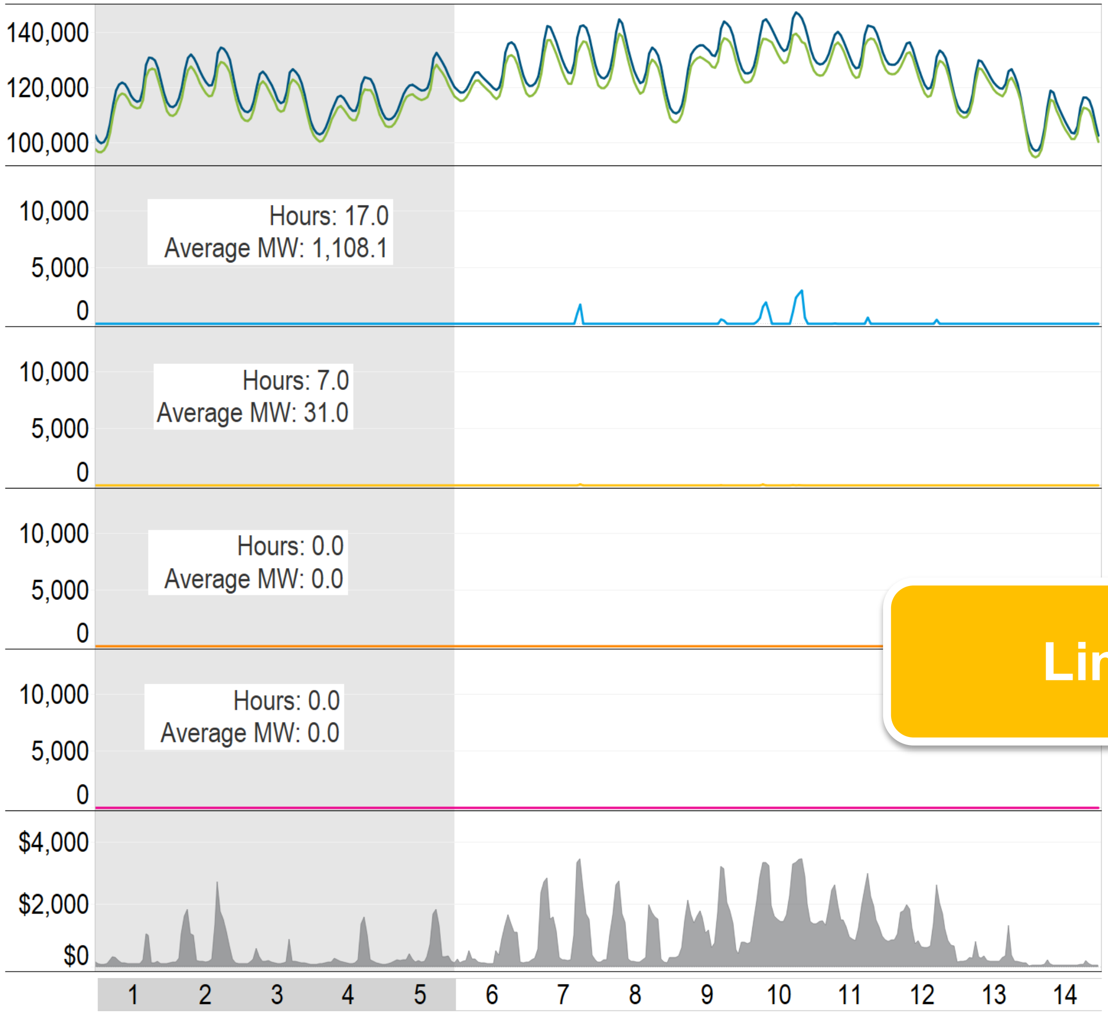
Day of Event

Announced Retirements Scenario Model D

- Generation (MW)
- Forecasted Demand (MW)
- Deployed Demand Response (MW)
- Reserve Shortage (MW)
- Voltage Reduction (MW)
- Load Shed (MW)
- Price ($)

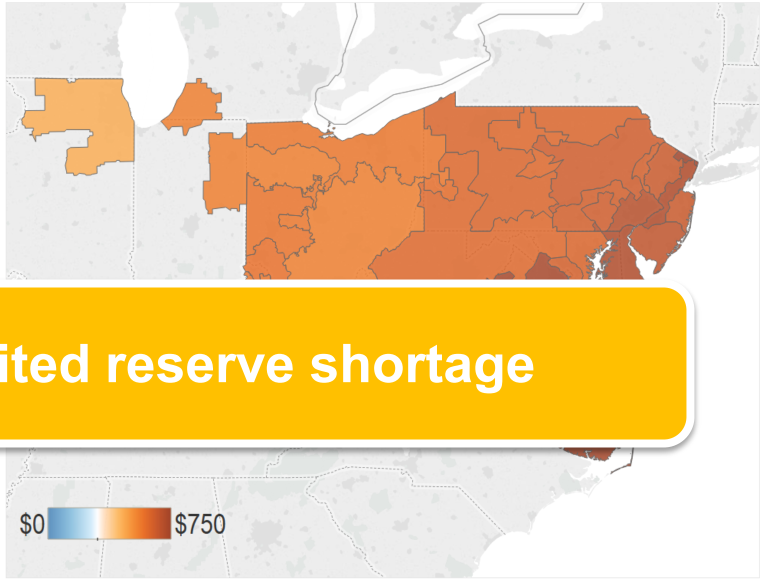
Prices do not represent forecasts of actual prices.

System Overview



Load:	Extreme
Refueling:	Limited
Disruption:	Looped 2 High
Non-Firm Avail:	0%
Retirement:	Announced
Dispatch:	Max Emergency

Hourly Zonal Average LMP [$]



Limited reserve shortage

Sites Out of Oil

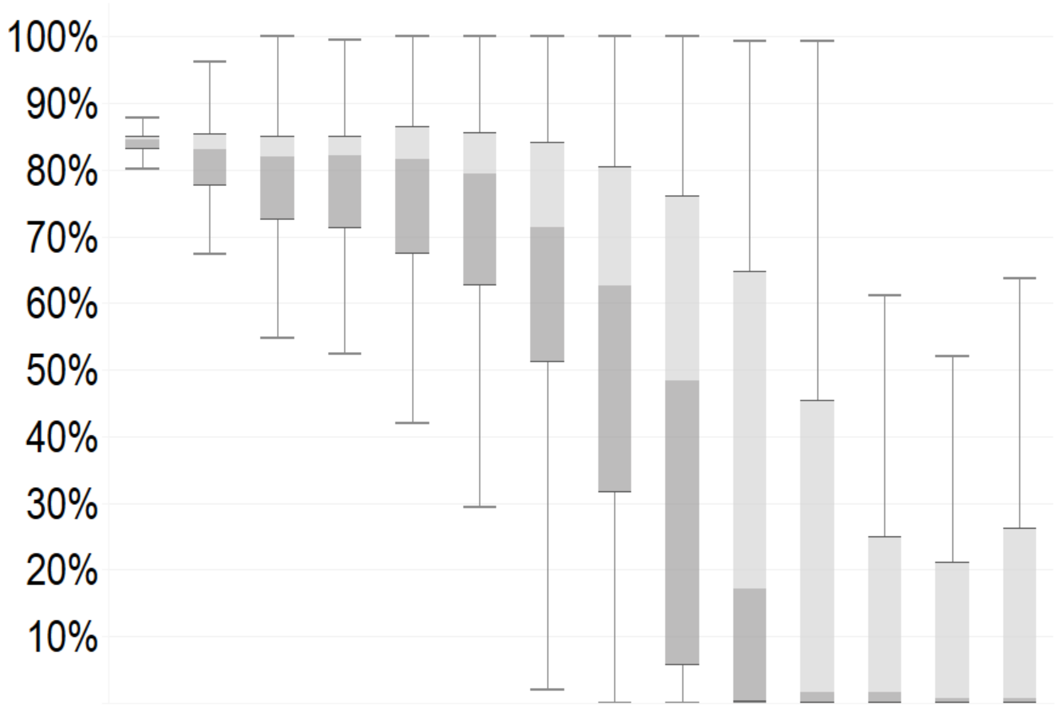
Oil Barrels Burned: 1.32M

Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sites Out of Oil	0	0	0	0	0	0	0	3	6	9	13	16	14	14

*141 Total Sites

Oil Inventory | Dispatch Comparison

Economic Dispatch



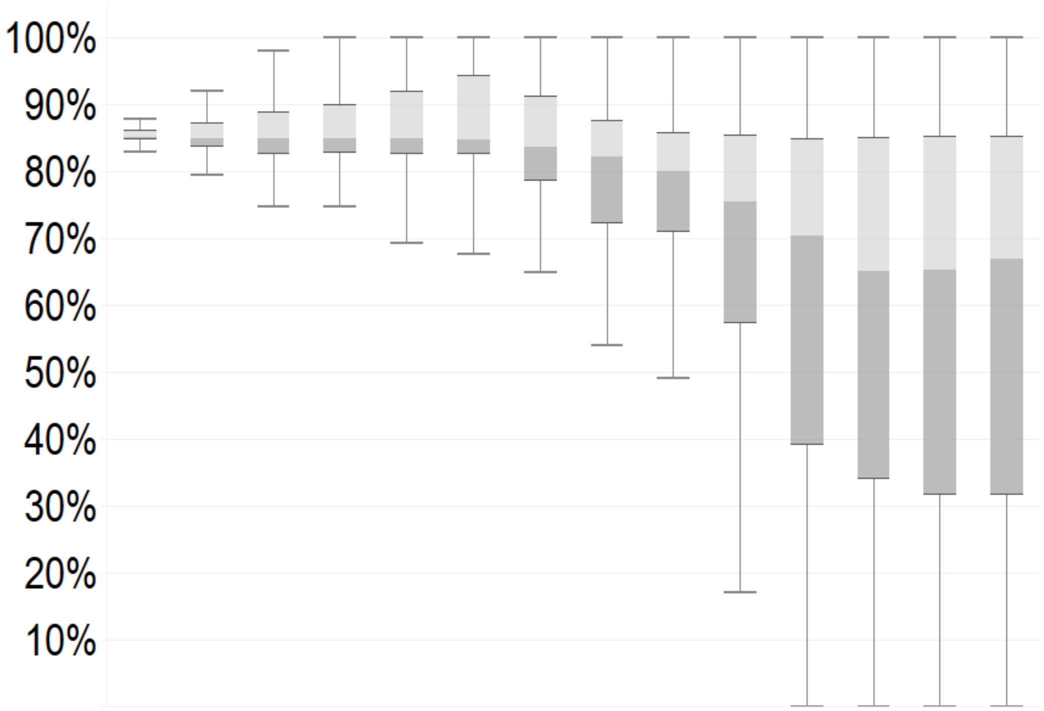
Sites Out of Oil

Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sites Out of Oil	0	3	6	7	8	12	16	21	47	61	74	80	74	66

*141 Total Sites

Day of Event

Max. Emergency Dispatch



Sites Out of Oil

Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sites Out of Oil	0	0	0	0	0	0	0	3	6	9	13	16	14	14

*141 Total Sites

Day of Event

Conclusions, Background and Assumptions

Announced Retirements Analysis

Escalated Retirements Analysis

Conclusions and Next Steps

Escalated Retirements Analysis

Methodology, Escalated Retirement 1

Retirement

2021 Market Efficiency Planning Model
Net Energy Revenue

+

2021/2022 Capacity Auction
Capacity Revenue

−

Avoidable Cost Rate
(Fixed costs)

=

Forecasted
Profit & Loss

Replacement

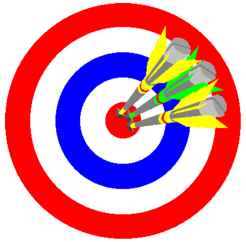
Replacement
for
2023
Delivery Year

→

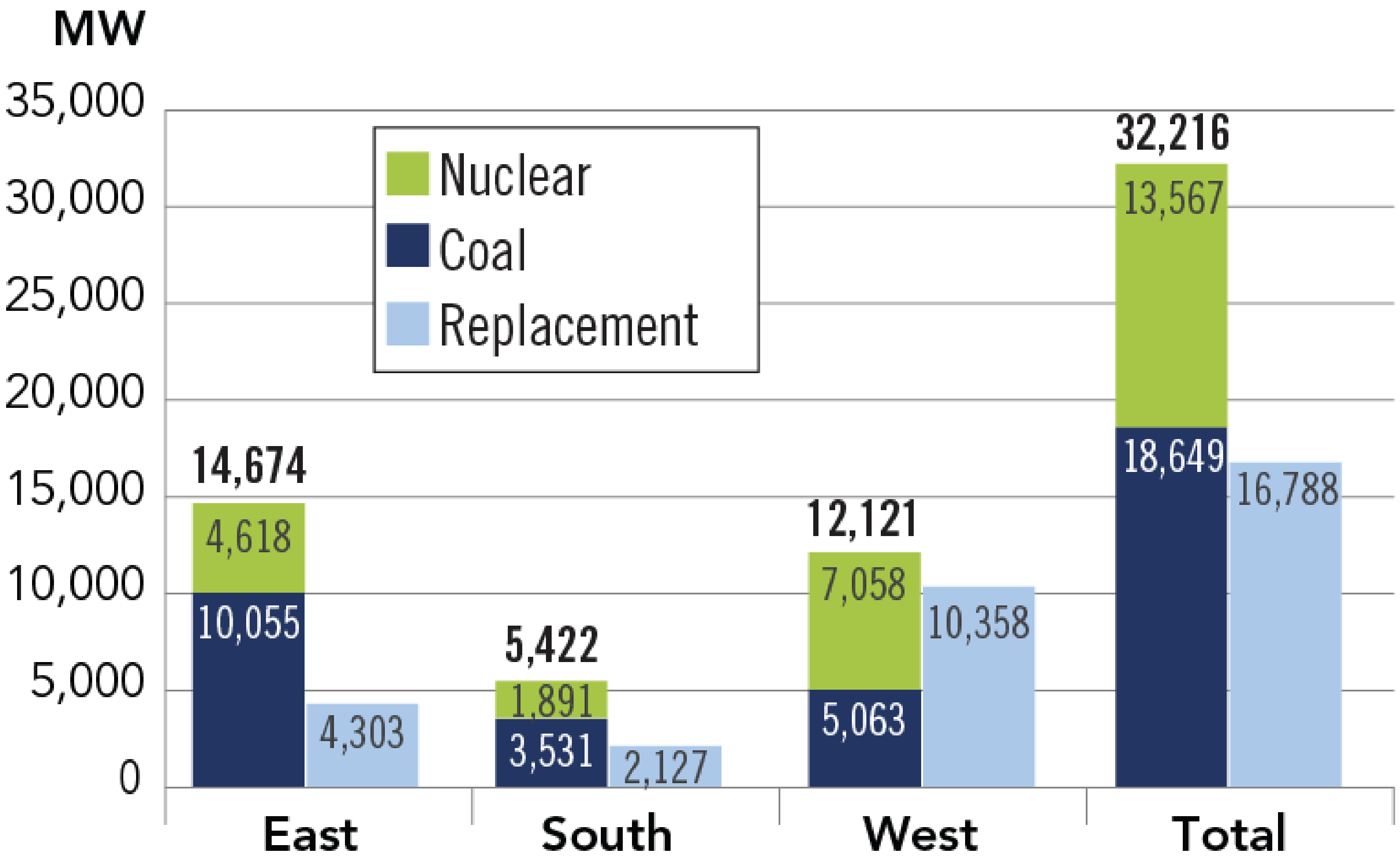
Facility Service Agreement Units
Commercial Probability

→

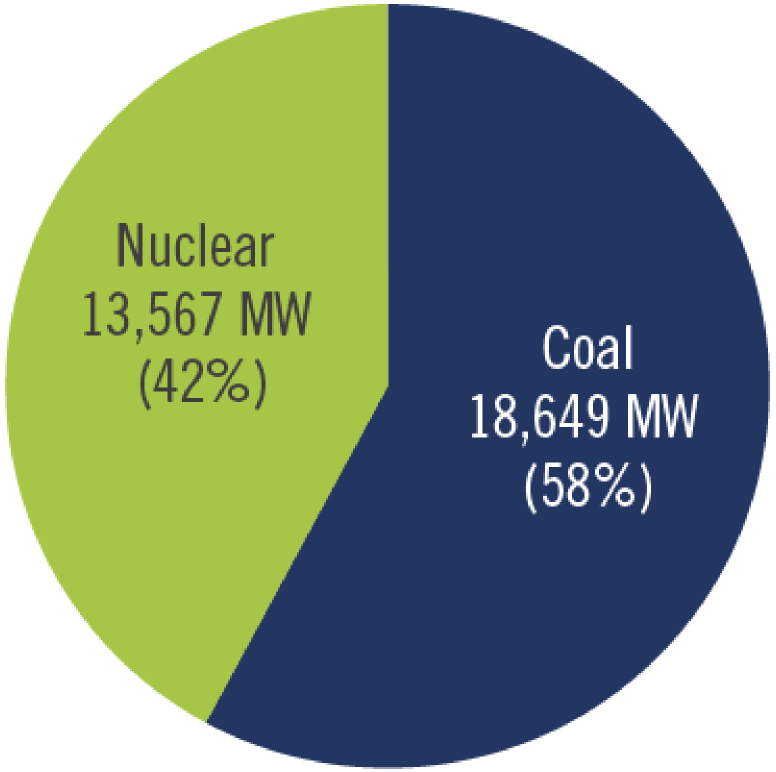
15.8% IRM



Escalated Retirement 1 Portfolio



Total MW Retired:
32,216



Natural gas is 96% of replacement megawatts

Retirement

2021 Market Efficiency Planning Model
Net Energy Revenue

+

2021/2022 Capacity Auction
Capacity Revenue

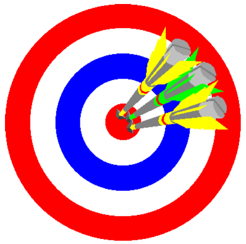
−

Avoidable Cost Rate
(Fixed costs)

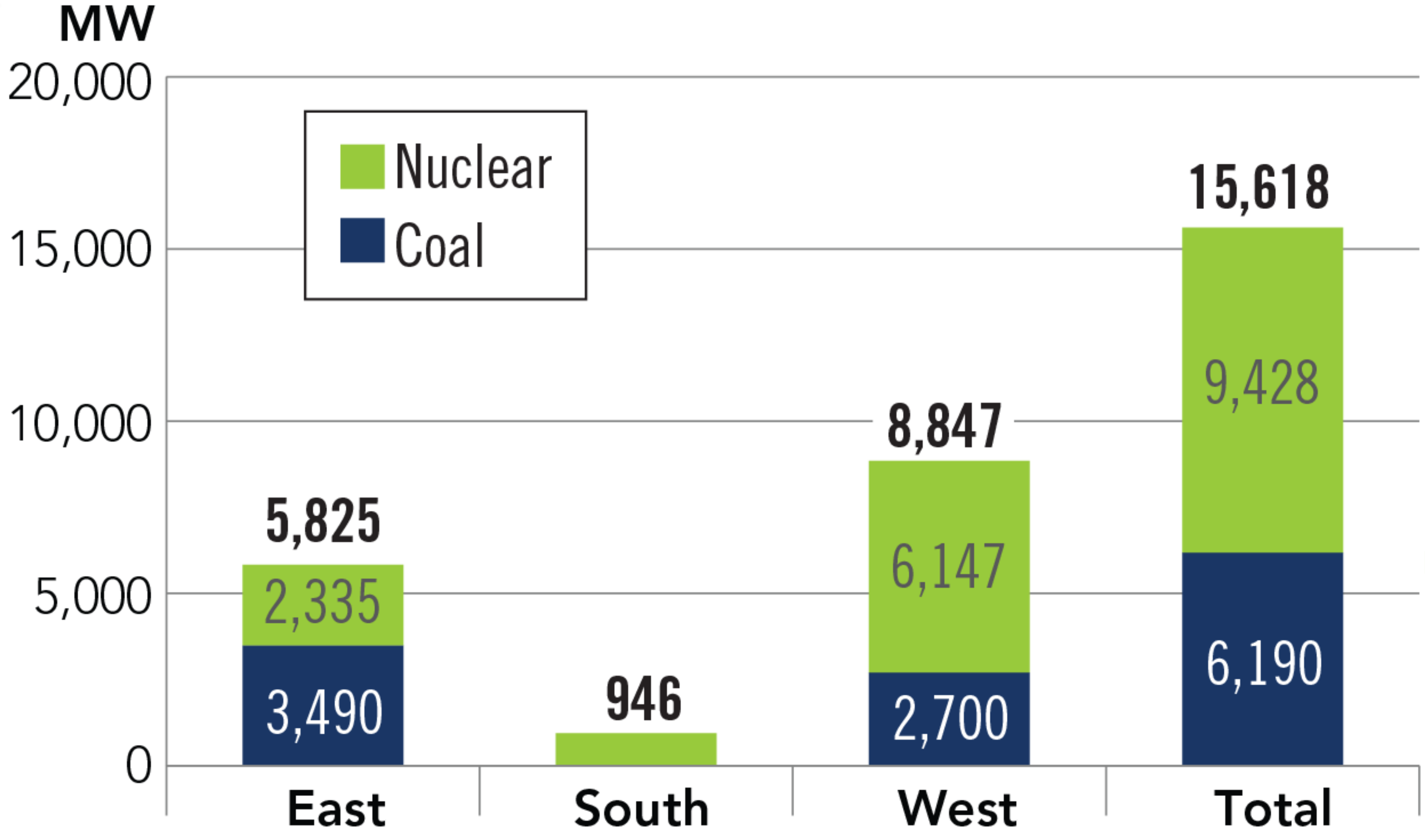
=

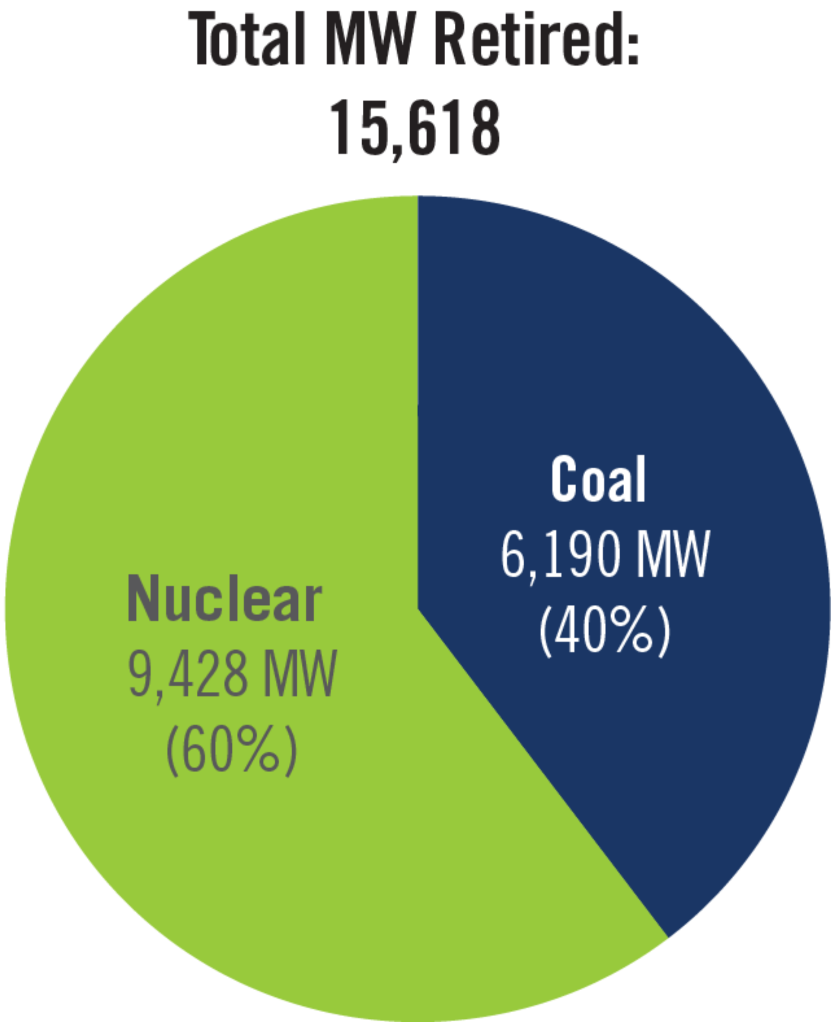
Forecasted
Profit & Loss

15.8% IRM



Escalated Retirement 2 Portfolio





Emergency Procedures Summary
Escalated Retirement Models

Winter Load	Retirement	Non-Firm Gas Avail.	Dispatch	Pipeline Disruption																	
				Moderate Refueling									Limited Refueling								
				None	Single 1		Single 2		Looped 1		Looped 2		None	Single 1		Single 2		Looped 1		Looped 2	
				None	Med.	High	Med.	High	Med.	High	Med.	High	None	Med.	High	Med.	High	Med.	High	Med.	High
Typical 50/50	Escalated 1	62.5%	Economic																		
		0%	Economic																		
	Escalated 2	62.5%	Economic																		
		0%	Economic																		
Extreme 95/5	Escalated 1	62.5%	Max Emer.																		
			Economic																		3
		0%	Max Emer.	4	4	5	4	6	5	7	4	14	37	41	48	37	41	46	62	49	78
			Economic	9	10	11	9	10	9	13	9	22	43	44	56	42	46	47	63	53	83
	Escalated 2	62.5%	Max Emer.																		
			Economic																		
		0%	Max Emer.	4	3	5	4	4	4	4	3	4	11	12	13	13	14	14	15	14	22
			Economic	7	7	7	7	7	6	8	7	7	19	19	20	19	20	19	26	21	34

E F G

- Normal Operations
- Demand Response Deployed
- Reserve Shortage
- Voltage Reduction
- Load Shed

Escalated Retirements 1 Scenario Model E

Generation (MW)

Forecasted Demand (MW)

Deployed Demand Response (MW)

Reserve Shortage (MW)

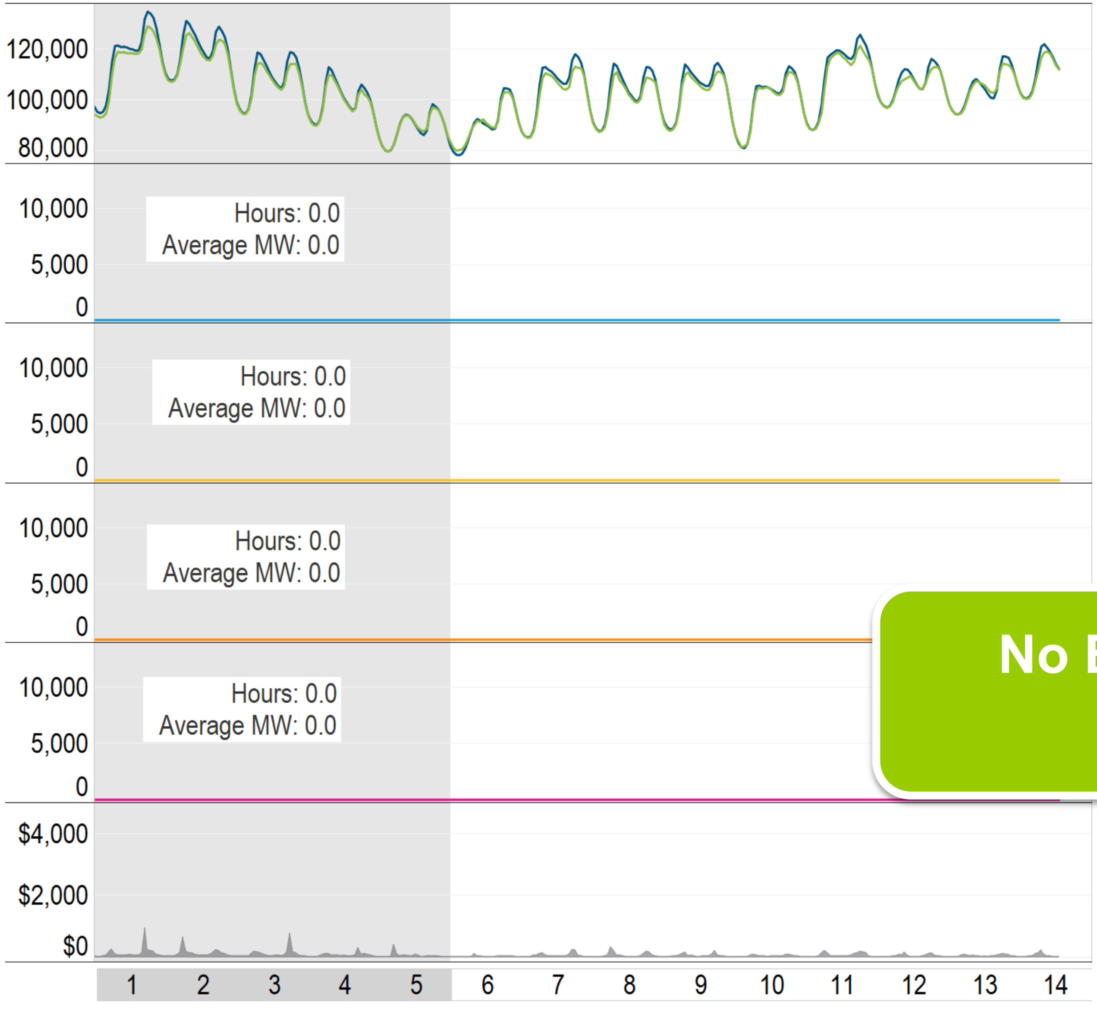
Voltage Reduction (MW)

Load Shed (MW)

Price ($)

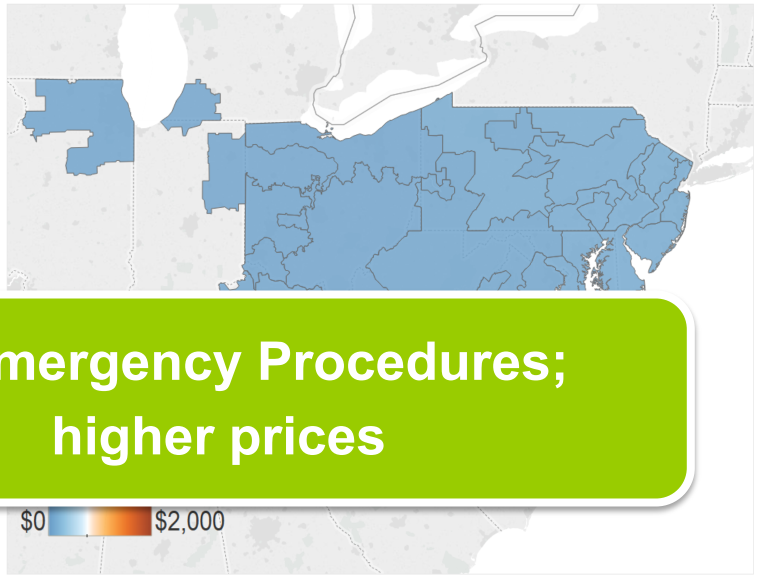
Prices do not represent forecasts of actual prices.

System Overview



Load:	Typical
Refueling:	Limited
Disruption:	Looped 2 High
Non-Firm Avail:	0%
Retirement:	Escalated 1 (32 GW)
Dispatch:	Economic

Hourly Zonal Average LMP [$]



No Emergency Procedures; higher prices

Sites Out of Oil **Oil Barrels Burned: 1.22M**

Sites Out of Oil	1	3	4	5	4	5	8	15	16	16	16	16	16	16
Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14

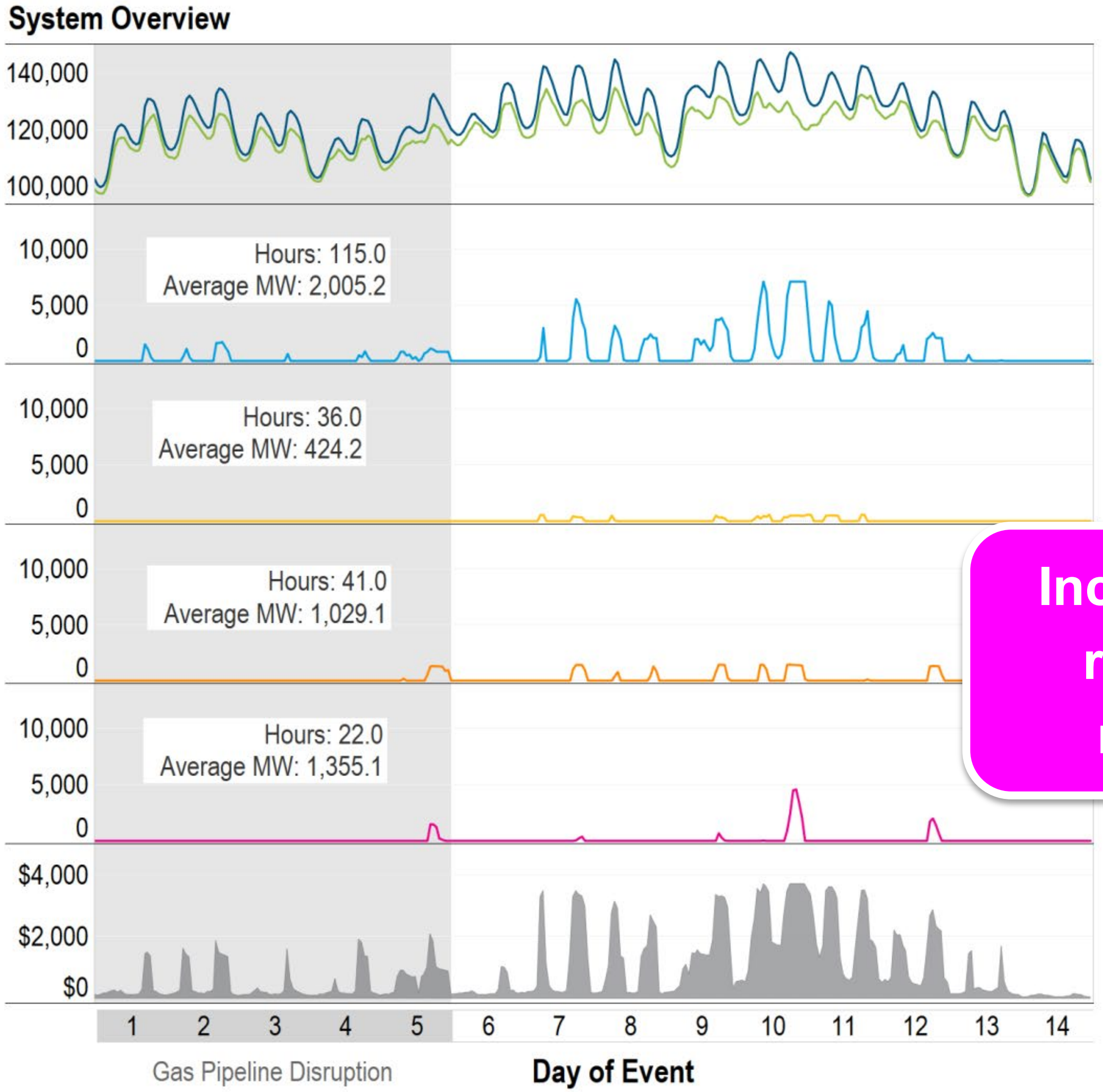
*141 Total Sites

Day of Event

Escalated Retirements 1 Scenario Model F

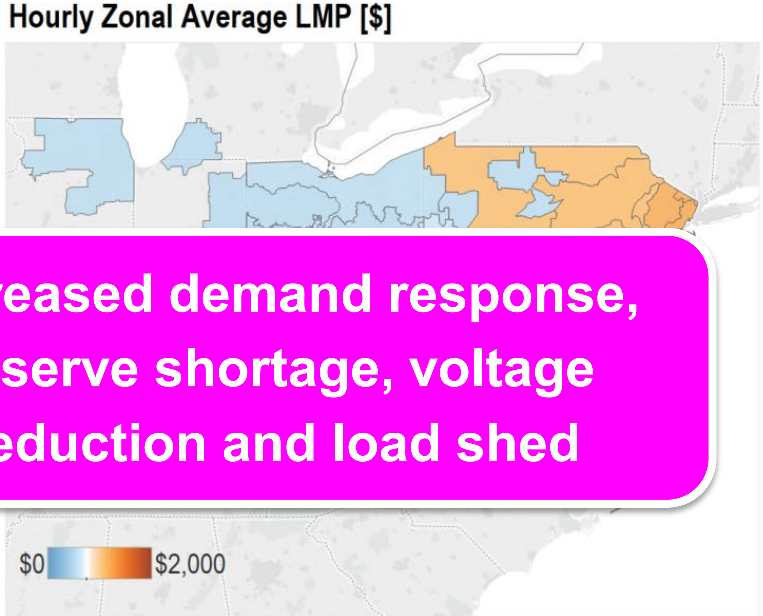
- Generation (MW)
- Forecasted Demand (MW)
- Deployed Demand Response (MW)
- Reserve Shortage (MW)
- Voltage Reduction (MW)
- Load Shed (MW)
- Price ($)

Prices do not represent forecasts of actual prices.



Load:	Extreme
Refueling:	Moderate
Disruption:	Looped 2 High
Non-Firm Avail:	0%
Retirement:	Escalated 1 (32 GW)
Dispatch:	Economic

Increased demand response, reserve shortage, voltage reduction and load shed



Sites Out of Oil

Oil Barrels Burned: 7.82M

Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sites Out of Oil	0	2	1	3	4	4	6	7	12	21	29	28	17	1

*141 Total Sites

Escalated Retirements 1 Scenario Model G

Generation (MW)

Forecasted Demand (MW)

Deployed Demand Response (MW)

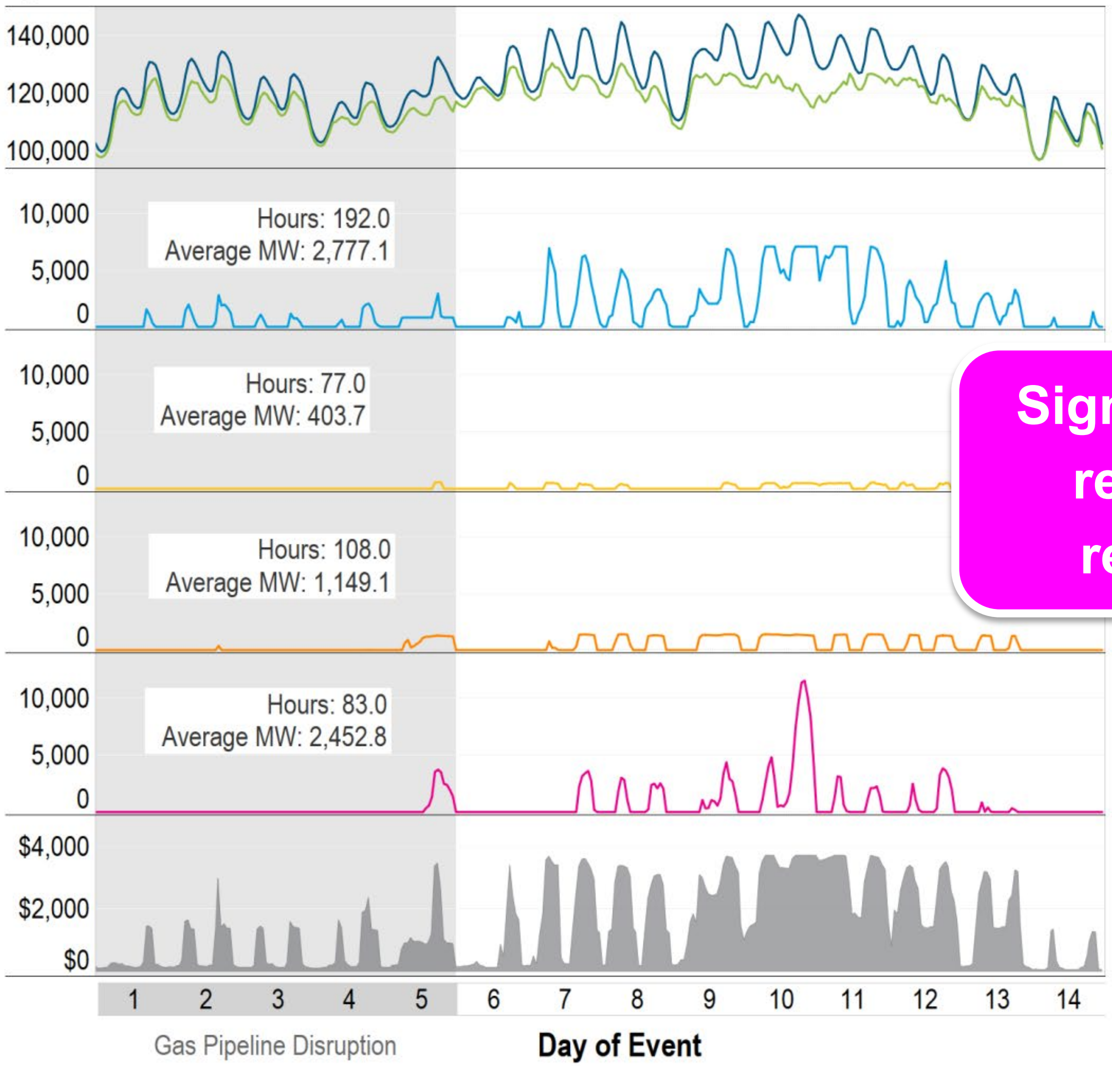
Reserve Shortage (MW)

Voltage Reduction (MW)

Load Shed (MW)

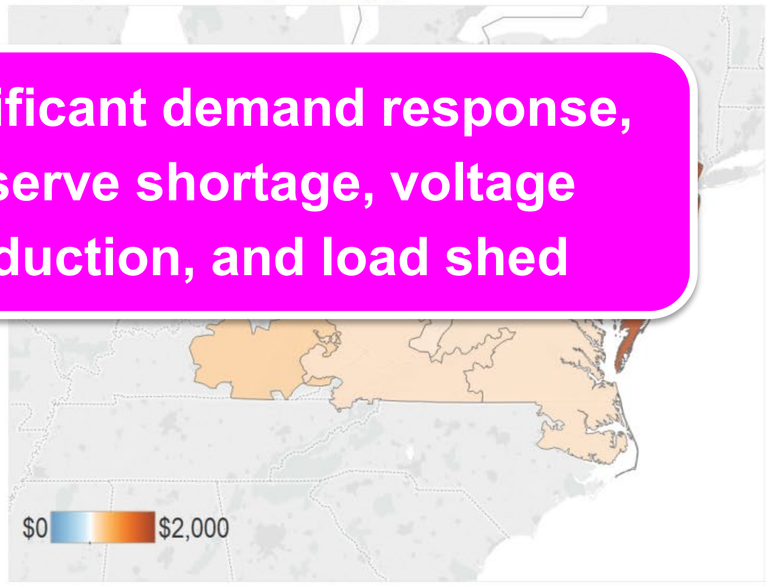
Price ($)

Prices do not represent forecasts of actual prices.



Load:	Extreme
Refueling:	Limited
Disruption:	Looped 2 High
Non-Firm Avail:	0%
Retirement:	Escalated 1 (32 GW)
Dispatch:	Economic

Hourly Zonal Average LMP [$]



Significant demand response, reserve shortage, voltage reduction, and load shed

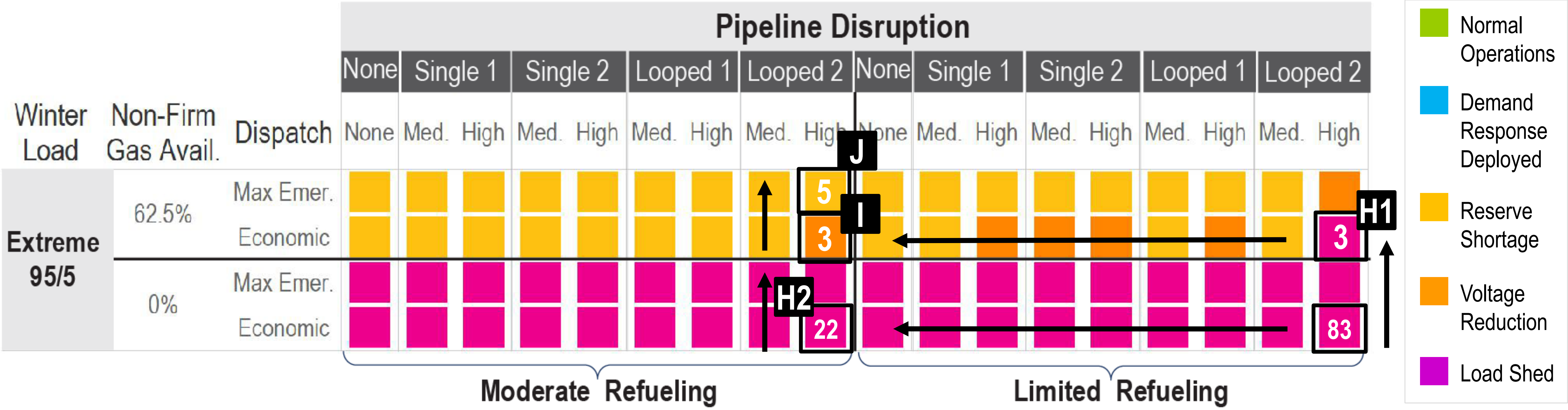
Sites Out of Oil

Oil Barrels Burned: 6.41M

Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sites Out of Oil	3	15	24	36	48	58	70	90	97	98	109	107	108	95

*141 Total Sites

Emergency Procedures Summary
Impact of Assumptions



Conclusions, Background and Assumptions

Announced Retirements Analysis

Escalated Retirements Analysis

Conclusions and Next Steps

Conclusions and Next Steps

Conclusions

- There is **NO** immediate threat to the reliability of the PJM RTO.
- 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.
- By design, PJM created stressed scenarios that were intended to discover the point(s) at which an assumption or combination of assumptions begin to impact the system's ability to reliably serve customers. The stressed scenarios resulted in a loss of load under extreme, but plausible conditions.
- In the stressed scenarios, assumptions that are contributing factors to the level of load shed include combinations of:
  - 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

Next Steps

While there is **NO** imminent threat, Fuel Security is an important component of ensuring reliability – especially if multiple risks come to fruition. The findings underscore the importance of PJM exploring proactive measures to value fuel security attributes, and PJM believes this is best done through competitive wholesale markets.

To continue stakeholder engagement, PJM will:

1. Host a follow-up Special Markets & Reliability conference call on Nov. 26, 2018 at 1– 3 p.m. to address questions that may arise as stakeholders review the study results further after today's presentation.
2. Publish a paper detailing the background, method/approach, analysis results, conclusions and next steps in mid-December 2018.
3. Schedule a Special Markets & Reliability meeting after the scheduled Markets & Reliability meeting on Dec. 20, 2018 to discuss the additional detail provided in the white paper.
4. Introduce a Problem Statement and Issue Charge for stakeholder consideration in first quarter 2019 with any potential market rule changes targeted to be filed with FERC in early 2020.

As part of Phase 3 work efforts, PJM will continue to work with key agencies within the federal government and impacted industries to further define fuel security assumptions and scenarios defined by the Department of Energy.

Appendix

Terminology

Term	Definition
Assumption	Input variable that is assumed to be true in the study, based on research and discussion with experts and industry groups.
Probabilistic Analysis	Aims to provide a realistic estimate when some variables are unknown. A multi-area reliability simulation was used to assess system adequacy to serve load by performing loss of load expectation analysis
Deterministic Analysis	Analysis of various combinations of input assumptions performed using dispatch simulation analysis and reliability transfer analysis
Security Constrained Economic Dispatch Analysis	Deterministic analysis tool used to perform security constrained unit commitment and security constrained economic dispatch analyses over a time horizon to simulate and model scenarios
Reliability Transfer Analysis	Deterministic analysis tool used to perform contingency analysis to calculate CETL/CETO
Typical Winter Load	Winter load level of 134,976 MW, which has probability of occurring every other year (50:50)
Extreme Winter Load	Winter load level of 147,721 MW which has probability of occurring once every 20 years (95:5)
Locational Disruption	Gas pipeline break. Categorized by location and pipeline design into Looped 1, Looped 2, Single 1 and Single 2. Looped pipeline design consists of a parallel pipeline delivery system while single pipeline design consists of a single pipeline delivery system.

Terminology (cont.)

Term	Definition
Non-Firm Gas Availability	Interruptible gas
DR Deployment	Demand Response Deployment; this action is a pre-emergency action
Reserve Shortage	Reserve Shortage is triggered when 10 min Synchronized Reserves are less than the largest generator in the RTO; depending on system conditions a reserve shortage will trigger additional emergency procedures such as a voltage reduction warnings and manual load shed warnings. These warnings are classified as emergency procedures.
Voltage Reduction Action	Voltage reduction action enables load reductions by reducing voltages at the distribution level; PJM estimates a 1-2% RTO load reductions resulting from a 5% load reductions in transmission zones capable of performing a voltage reduction.
Manual Load Shed Action	Manual load shed action enables zonal or system wide load shed. This is the last step of all emergency procedure actions.
eFORd	Expected forced outage rate
LOLH	Loss of load hours

External Coordination & Outreach Update

Outreach	Information Collected	Study Impact
PJM Generation Owner Surveys	Unit-specific information and statistics	Baseline data and unit-specific study inputs
Direct Generation Owner Conversations	Detailed information about oil refueling operations	On-site oil inventories and oil refueling assumptions
Natural Gas Pipelines & Industry Groups	Operating information and reliability details	Study scenario development and natural gas supply assumptions/disruptions
Renewable Resource Industry Groups	Operating information and disruption details	Study scenario development and dispatch
DR Representative & Industry Groups	Operational information and expected customer response	Baseline data and unit-specific study inputs
Coal Industry Groups	Supply chain and transportation logistics information	Study scenario development and refueling assumptions
Nuclear Industry Groups	Operational information and logistics	Baseline data and unit-specific study inputs
Department of Energy	Information on physical/cyber threat actors and capabilities to impact gas pipelines. PJM will work with DOE to determine level of information sharing with PJM stakeholders (and define risk scenarios).	**Phase 3 Input:** Disruption events for extreme cyber and physical threats PJM will work with gas pipelines to assess impacts.

Assumptions

Category	Typical	Extreme
Study Year	2023/24	2023/24
Weather Scenario	14 days	14 days
Load Scenario	50/50 - 1 in 2 (135k peak)	95/5 - 1 in 20 (147k peak)
Load Profile	2011/12 winter	2017/18 winter
Dispatch	Economic	Economic & Optional Block Load (Max Emergency)
Scheduled Interchange	Total interchange with neighboring systems limited to +/-2,700 MW	Total interchange with neighboring systems limited to +/-2,700 MW
Interruptable Gas Availability	62.5%	62.5% & 0%
Oil Tank Starting Inventory	85%	85%
Oil Refueling (>100 MW site)	40 trucks and 10 trucks (sensitivity) daily refueling rate (Oil inventory at each site will be capped at max tank capacity) In model, refueling was applied every 12 hours, with assumed daily mmBtu divided up accordingly	40 trucks and 10 trucks (sensitivity) daily refueling rate (Oil inventory at each site will be capped at max tank capacity) In model, refueling was applied every 12 hours, with assumed daily mmBtu divided up accordingly

Assumptions (cont.)

Category	Typical	Extreme
Oil Refueling (<100 MW site)	10 trucks and 0 trucks (sensitivity) daily refueling rate (Oil inventory at each site will be capped at max tank capacity). In model, refueling was applied every 12 hours, with assumed daily mmBtu divided up accordingly	10 trucks and 0 trucks (sensitivity) daily refueling rate (Oil inventory at each site will be capped at max tank capacity). In model, refueling was applied every 12 hours, with assumed daily mmBtu divided up accordingly
Fuel Prices	2023 futures prices adjusted by day-to-day fluctuations in price (volatility)	2023 futures prices adjusted by day-to-day fluctuations in price (volatility)
Disruption (medium impact)	5 day 50-100% break + 9 day no impact	5 day 50-100% break + 9 day no impact
Disruption (high impact)	5 day 100% break + 9 day 20% derate	5 day 100% break + 9 day 20% derate
Expected Forced Outages	Historical 5 year average discounting gas and oil fuel supply outages	Regression model expected outage rates discounting gas and oil fuel supply outages
Renewable Modeling	2017/2018 Cold Snap Profile	2017/2018 Cold Snap Profile
Demand Response	7,092 MW modeled locationally based on MW cleared by zone and nodal modeling	7,092 MW modeled locationally based on MW cleared by zone and nodal modeling
Distributed Energy Resources	Impacts of DER are explicitly accounted for in the load forecast	Impacts of DER are explicitly accounted for in the load forecast

Assumptions (cont.)

Category	Typical	Extreme
Energy Efficiency	Energy Efficiency is explicitly accounted for in the load forecast	Energy Efficiency is explicitly accounted for in the load forecast
Retirement Sensitivity	Two separate retirements scenarios were analyzed. As part of the economic analysis, PJM and IMM nuclear and coal units "at-risk" economic retirement analysis including relevant input from NEI and ACCCE as well as latest nuclear cost estimates published by EPA. A separate analysis was performed retiring coal and nuclear generation down to IRM without replacement.	Two separate retirements scenarios were analyzed. As part of the economic analysis, PJM and IMM nuclear and coal units "at-risk" economic retirement analysis including relevant input from NEI and ACCCE as well as latest nuclear cost estimates published by EPA. A separate analysis was performed retiring coal and nuclear generation down to IRM without replacement.
Retirement Sensitivity Replacement Capacity Approach	IRM $\geq$ 15.8%. Replacement resources reflective of PJM Interconnection Queue. Replacement Combined Cycle Natural gas resources will be modeled as firm supply and transport. Replacement Combustion Turbine Natural Gas resources will be modeled as dual fuel with interruptible gas.	IRM $\geq$ 15.8%. Replacement resources reflective of PJM Interconnection Queue. Replacement Combined Cycle Natural gas resources will be modeled as firm supply and transport. Replacement Combustion Turbine Natural Gas resources will be modeled as dual fuel with interruptible gas.

Winter Load Forecast

Typical Winter Load (50/50)

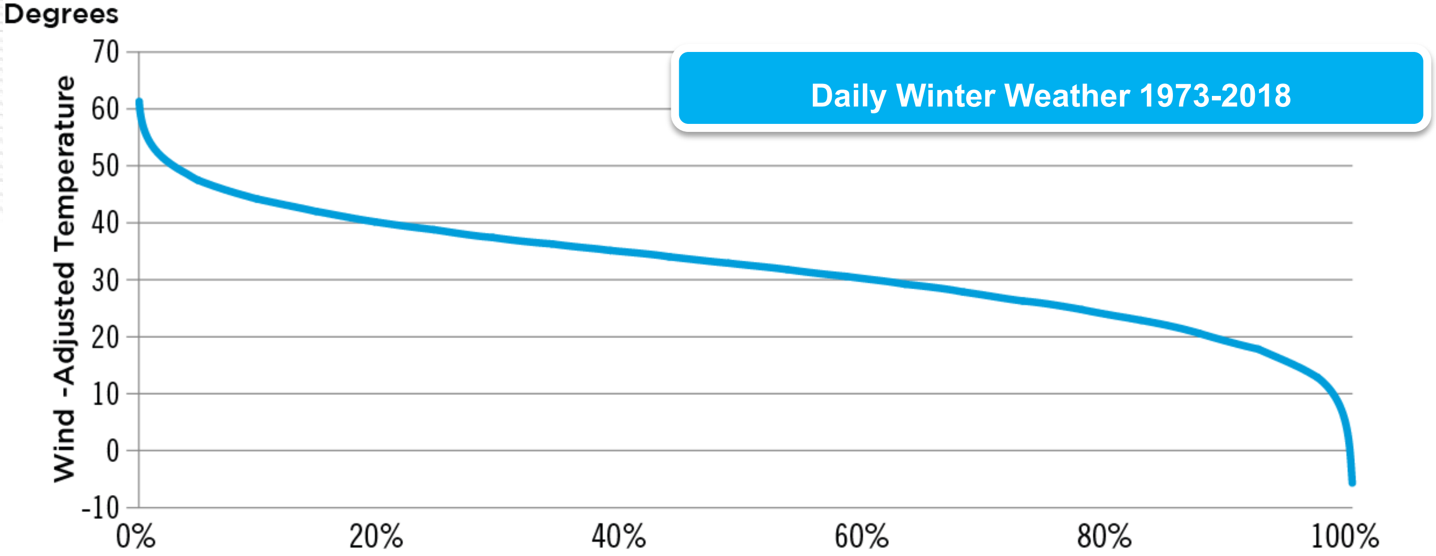
- **Peak = 134,976 MW**
  Winter 2023/24 forecast
- Average 50/50 winter hourly load shape from 2011/12

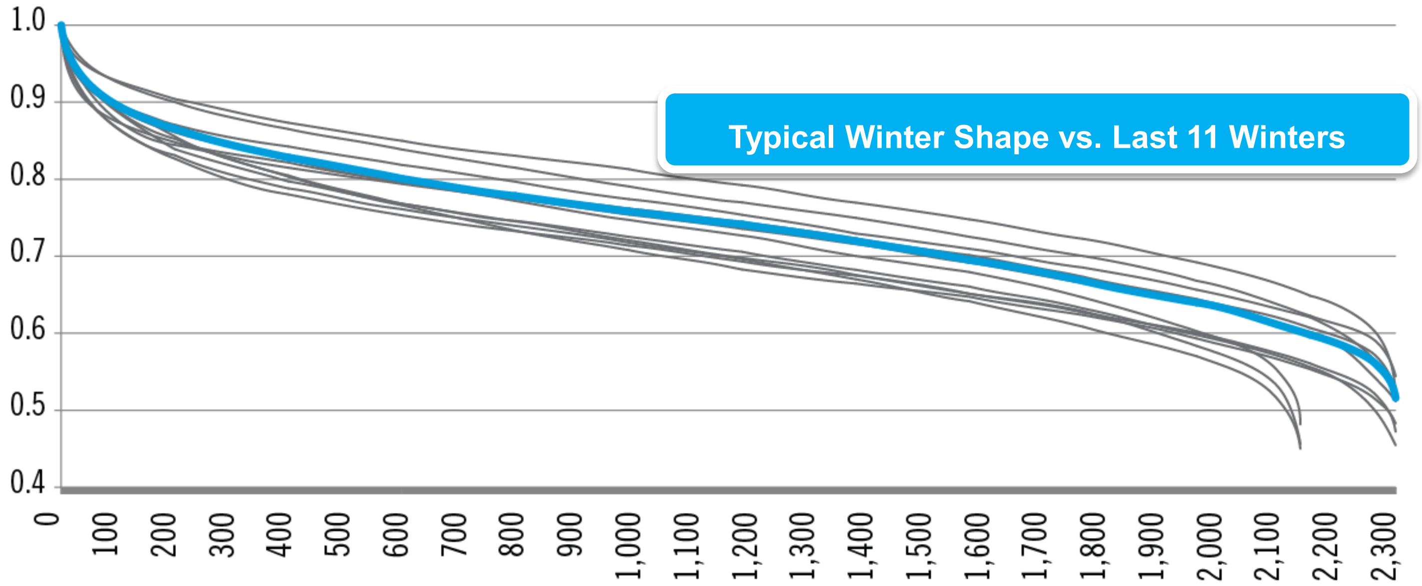
Extreme Winter Load (95/5)

- **Peak = 147,721 MW**
  Median of three historical cold snaps in last 45 years

1989 peak	**1994 peak**	**2017/18 peak**
95th percentile	99th percentile	82nd percentile

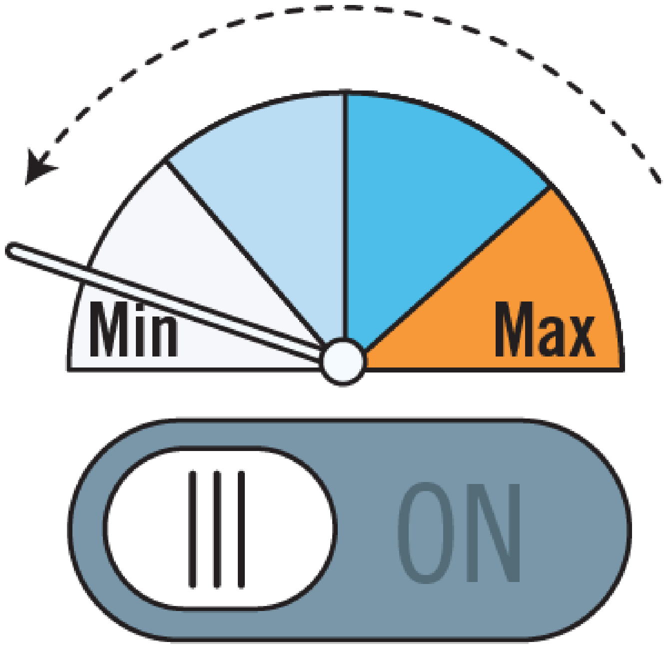
- 2017/18 winter hourly load shape



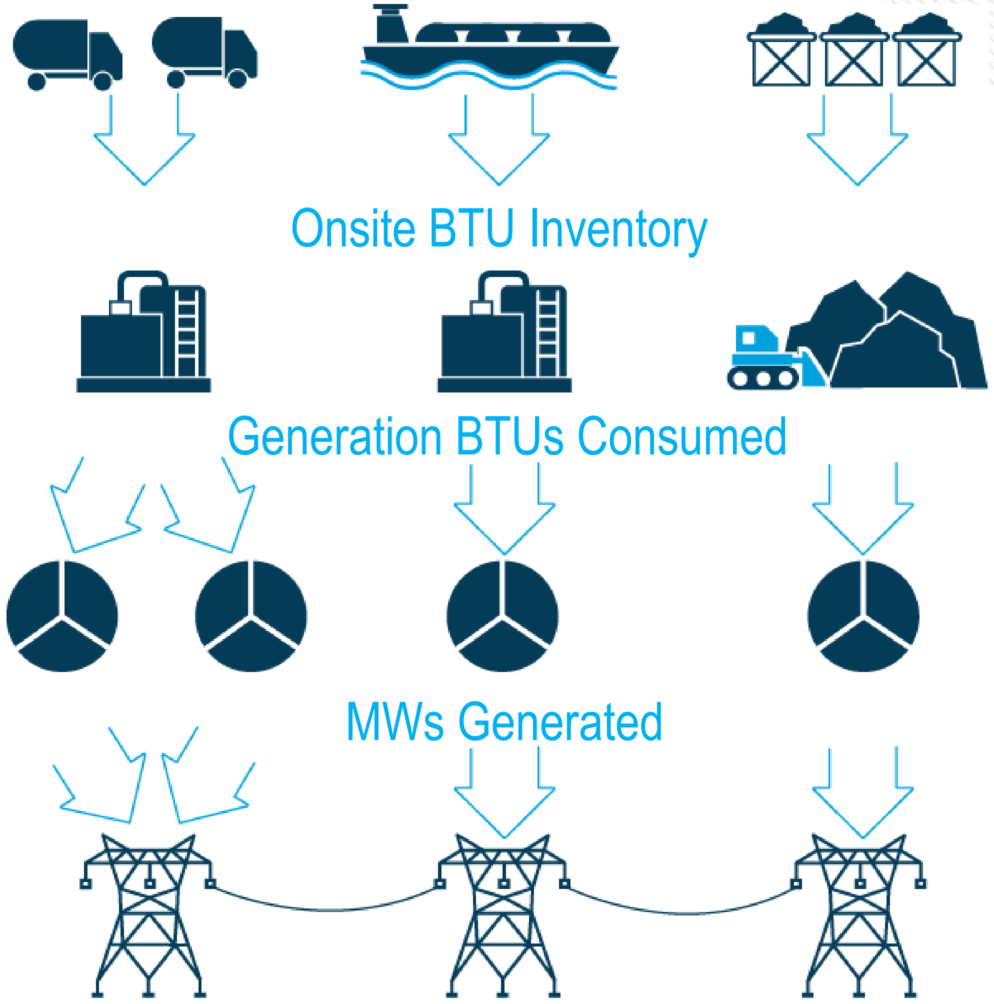


Estimated Capacity Performance Demand Response (CP DR)= **7,092 MW for 2023/24**

CP DR amount cleared in the 2021/22 Base Residual Auction + **Fixed Resource Requirement (FRR)**



- CP DR is reduced by three-year average 32 percent replacement rate.
- CP DR will be used for both Base Case and Extreme Weather Case.
- DR will be modeled in the simulation prior to a load shed event consistent with existing procedures.



Study refueling based on transportation method and maximum on-site inventory

- **Transportation for base studies** will be the assumed limiting factor rather than fuel.

Starting Coal Inventory – unit-specific seasonal inventory target

Starting Oil Inventory – 85 percent of max tank capacity

- **Oil refueling sensitivities** will be run modeling a range of 10 to 40 truck deliveries per day for sites > 100 MW and 0 to 10 trucks per day for sites < 100 MW to determine the magnitude of impact refueling has.

Duration of Pipeline Disruption

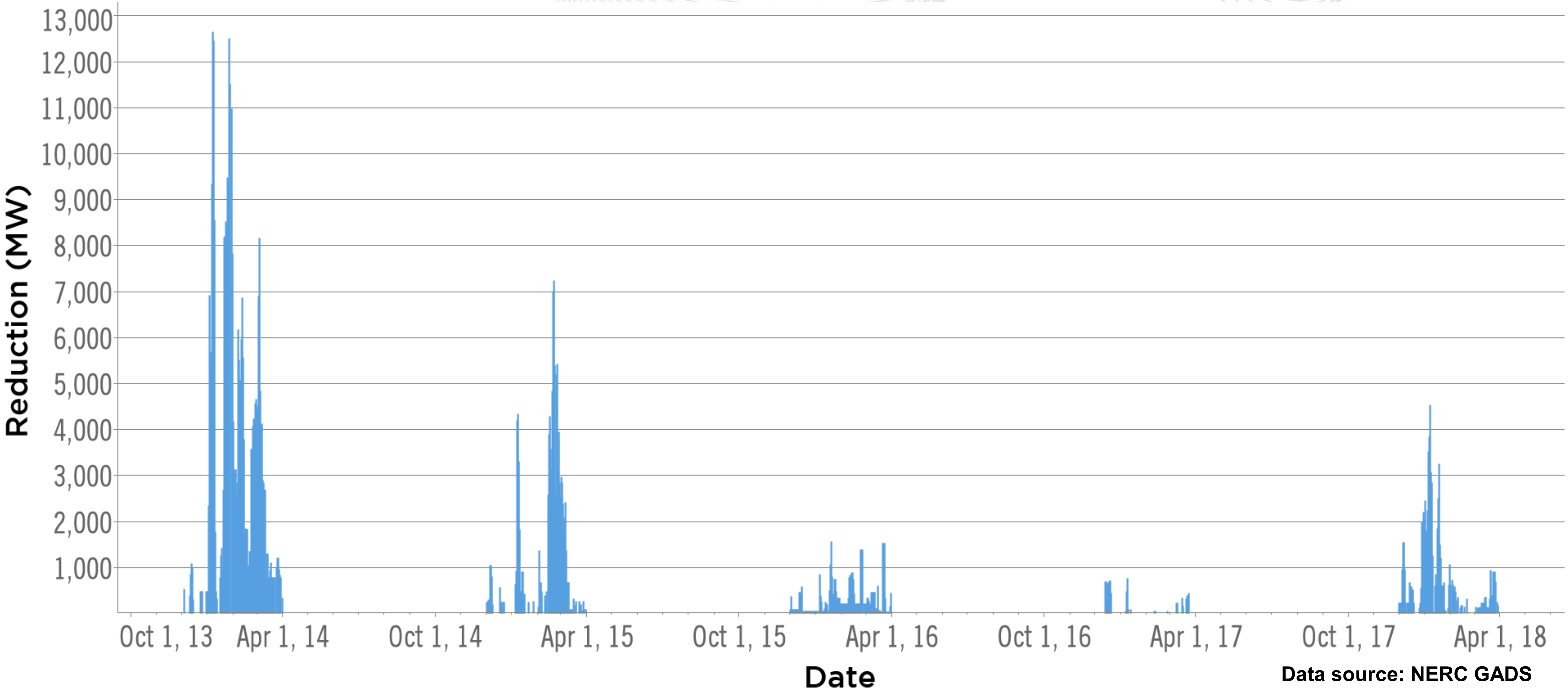
Typical and Extreme Winter

IMPACT	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14
Medium	50% or 100% firm capacity reduction*					All firm capacity available								
High	100% firm capacity reduction					20% firm capacity reduction**								

* Firm capacity reduction level depends on pipeline design redundancy.

** 20% of capacity remains unavailable due to assumed PHMSA (Pipeline Hazardous Material and Safety Administration) requirements.

Lack of Fuel Gas Reductions



Data source: NERC GADS

Generator Outage Model Update

95/5 weather in 1989 + 2017/18 cold snap = 2023/24 cold snap

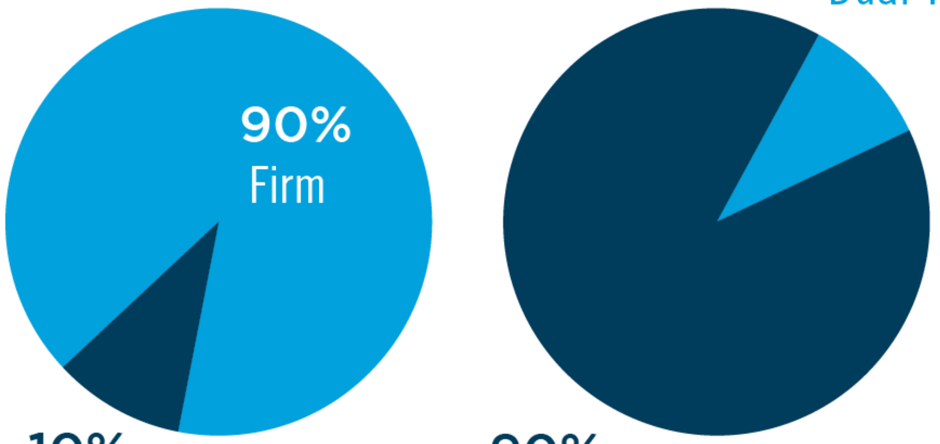
Category	Key Variables	Correlation
Unit Characteristic	Age	✓
Weather	Wind Adj. Temp.	—
	Persistent Cold Weather	✓
Utilization	Run hours	—
	Basepoint Volatility	✓

- Goal – % generator forced outage rate
- Using Jan. 2014 through 2018 data

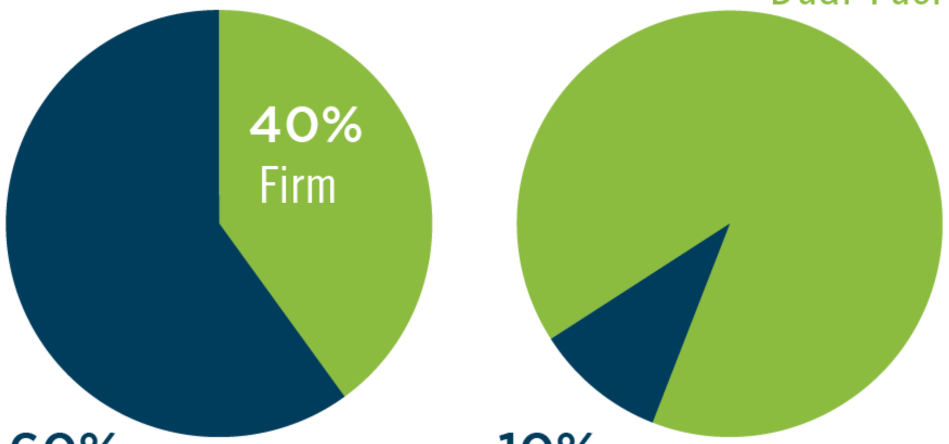
Natural Gas Generation Trends

Fuel trends for recently commercial and queue natural gas generators since 2017

Combined Cycle — 95%
17,000 MW



Combustion Turbine — 5%
800 MW



Natural Gas Delivery Disruption Scenarios

Pipeline	Single-Fuel Disruption (MW)			Dual-Fuel Disruption (MW)	Total Disruption (MW)
	Non-Firm	Firm			
Looped 1	2,690	3,094	**5,784**	**7,931**	**13,715**
Looped 2		3,015	4,483	4,100	8,583
Retirement Scenario Total		+ 435	+ 435	+ 225	+ 660
	1,468	3,450	**4,918**	**4,325**	**9,243**
Single 1		1,821	3,004		4,277
Retirement Scenario Total		+ 774	+ 774		+ 774
	1,183	2,595	**3,778**	**1,273**	**5,051**
Single 2	330	750	**1,080**	**3,641**	**4,721**

Escalated Retirements 1 Scenario Model H1

Generation (MW)
Forecasted Demand (MW)

Deployed Demand Response (MW)

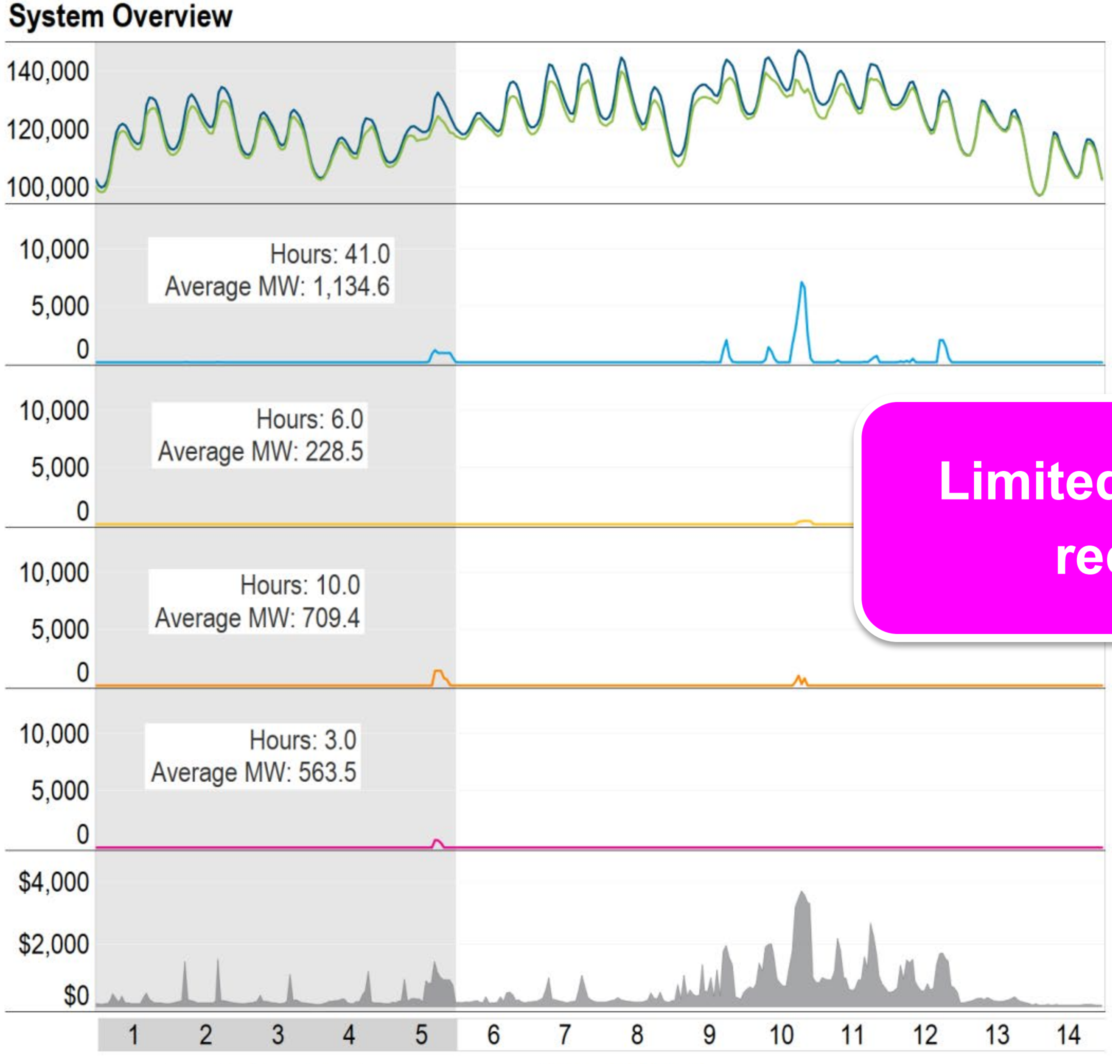
Reserve Shortage (MW)

Voltage Reduction (MW)

Load Shed (MW)

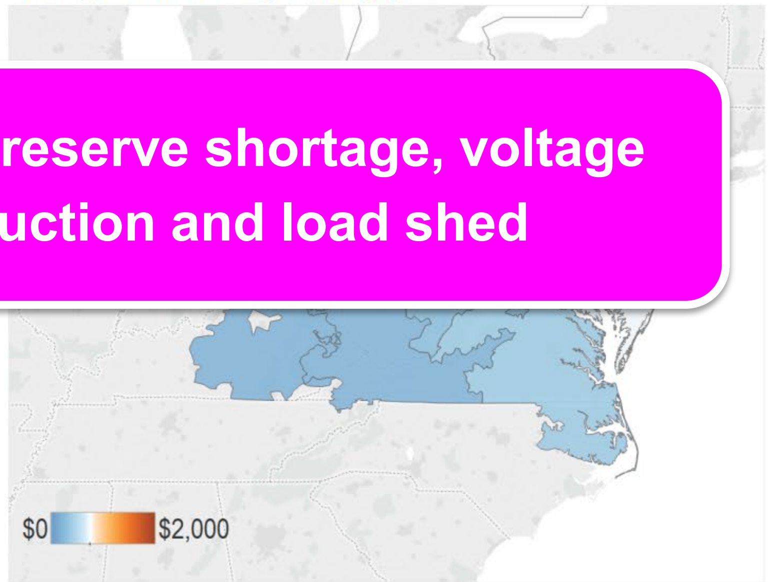
Price ($)

Prices do not represent forecasts of actual prices.



Load:	Extreme
Refueling:	Limited
Disruption:	Looped 2 High
Non-Firm Avail:	62.50%
Retirement:	Escalated 1 (32 GW)
Dispatch:	Economic

Hourly Zonal Average LMP [$]



Limited reserve shortage, voltage reduction and load shed

Sites Out of Oil

Oil Barrels Burned: 5.25M

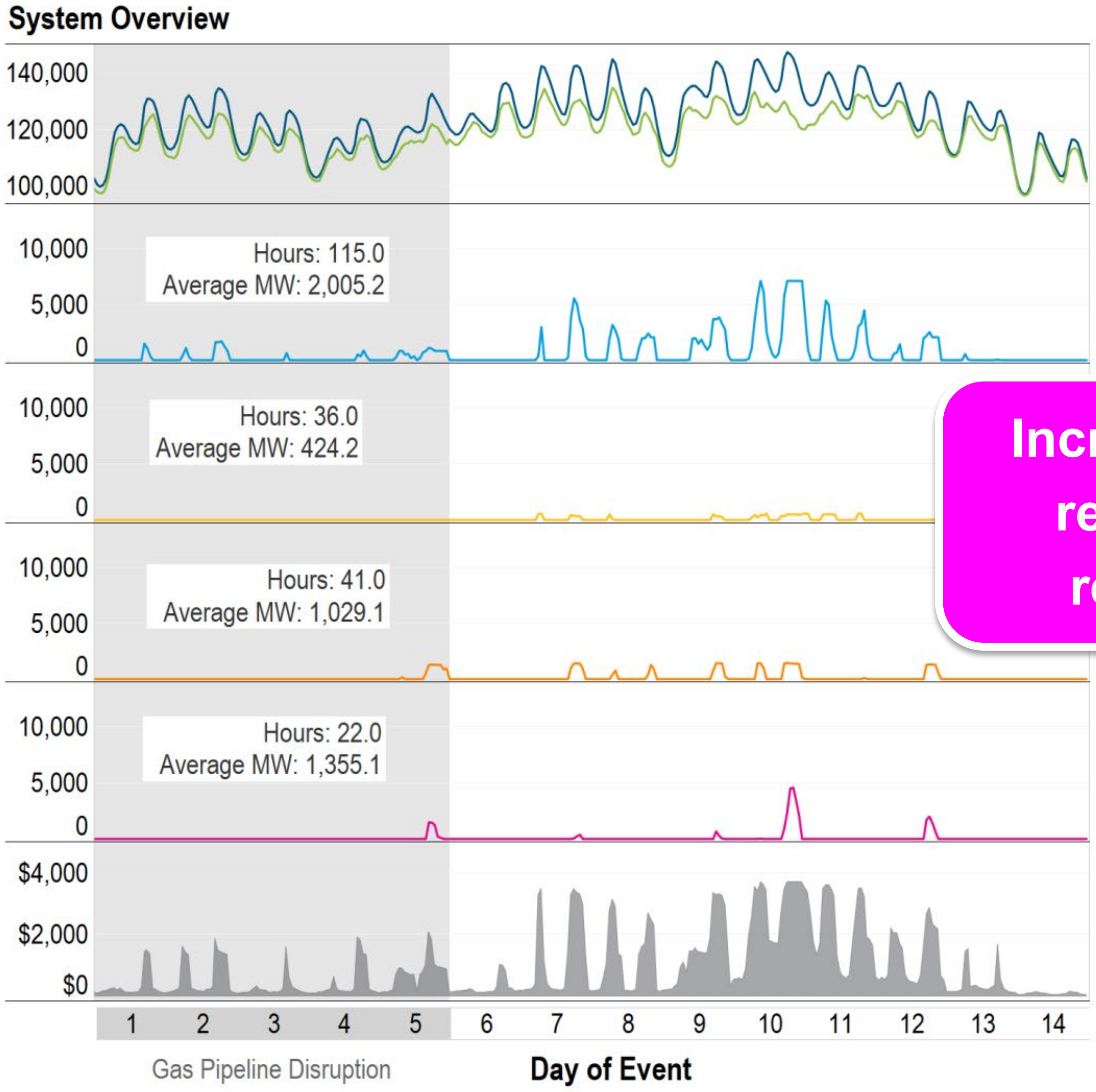
Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sites Out of Oil	1	5	8	13	19	22	38	54	61	68	87	88	87	76

*141 Total Sites

Escalated Retirements 1 Scenario Model H2

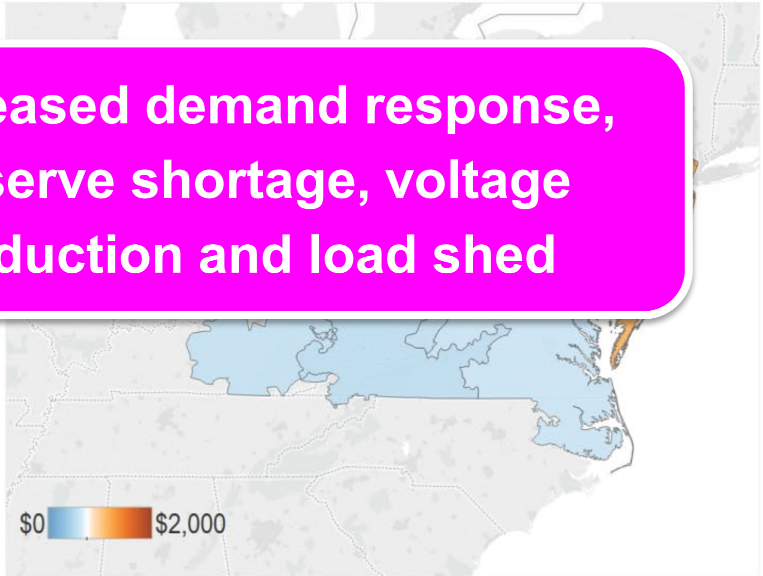
Generation (MW)	
Forecasted Demand (MW)	
Deployed Demand Response (MW)	
Reserve Shortage (MW)	
Voltage Reduction (MW)	
Load Shed (MW)	
Price ($)	

Prices do not represent forecasts of actual prices.



Load:	Extreme
Refueling:	Moderate
Disruption:	Looped 2 High
Non-Firm Avail:	0%
Retirement:	Escalated 1 (32 GW)
Dispatch:	Economic

Hourly Zonal Average LMP [$]



Increased demand response, reserve shortage, voltage reduction and load shed

Sites Out of Oil

Oil Barrels Burned: 7.82M

Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sites Out of Oil	0	2	1	3	4	4	6	7	12	21	29	28	17	1

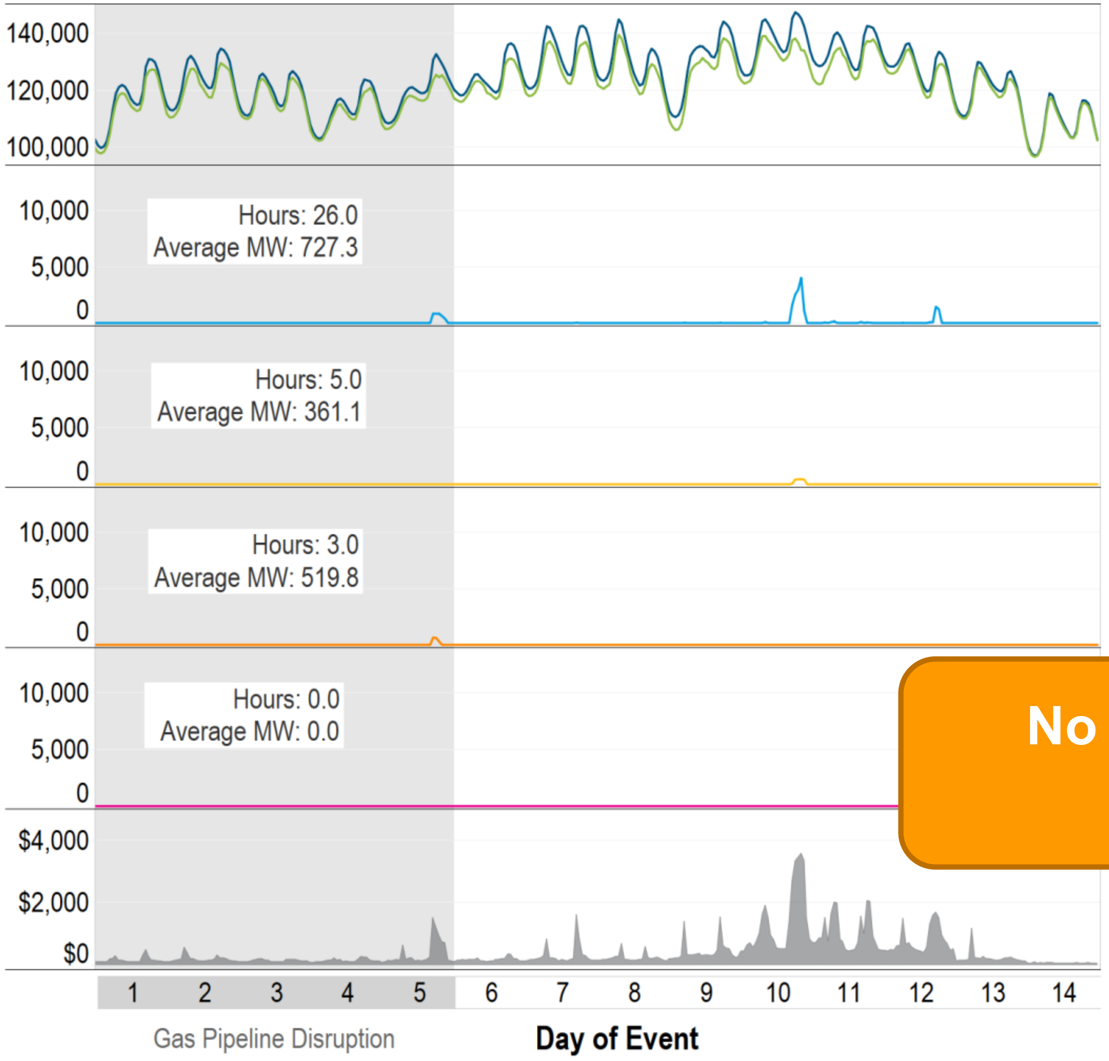
*141 Total Sites

Escalated Retirements 1 Scenario Model I

- Generation (MW)
- Forecasted Demand (MW)
- Deployed Demand Response (MW)
- Reserve Shortage (MW)
- Voltage Reduction (MW)
- Load Shed (MW)
- Price ($)

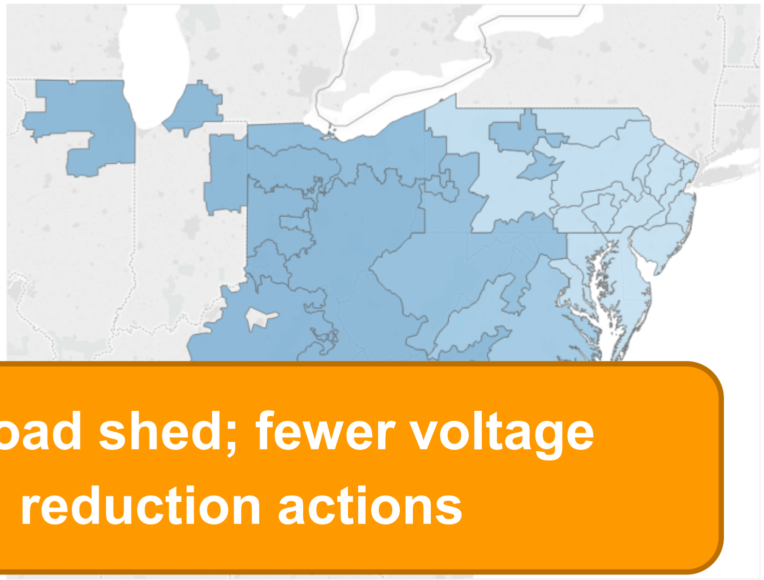
Prices do not represent forecasts of actual prices.

System Overview

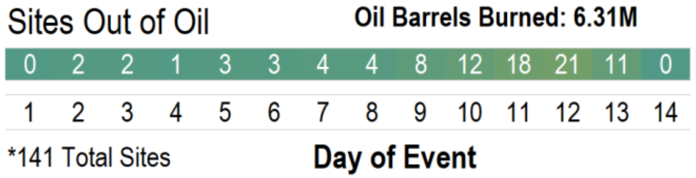


Load:	Extreme
Refueling:	Moderate
Disruption:	Looped 2 High
Non-Firm Avail:	62.50%
Retirement:	Escalated 1 (32 GW)
Dispatch:	Economic

Hourly Zonal Average LMP [$]



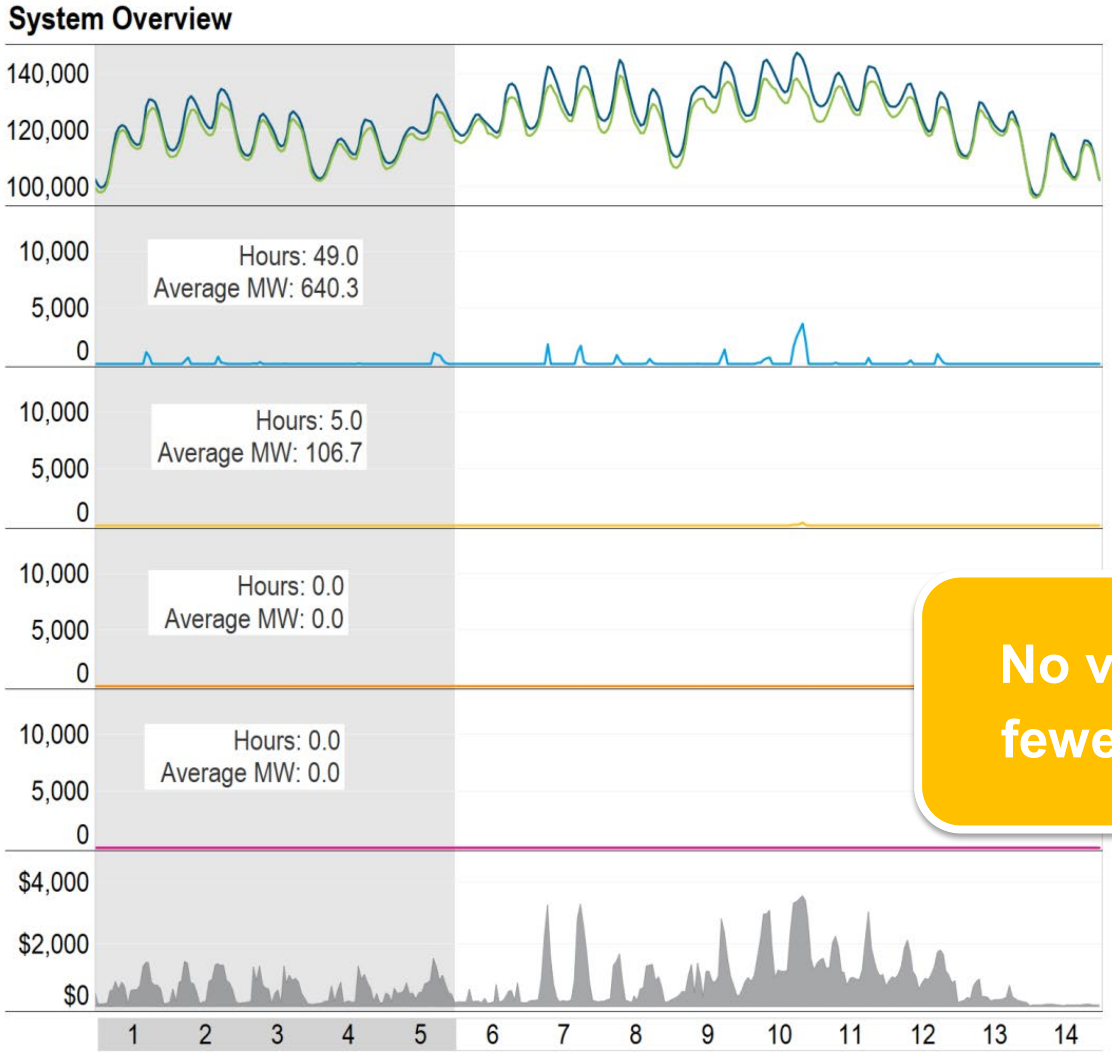
No load shed; fewer voltage reduction actions



Escalated Retirements 1 Scenario Model J

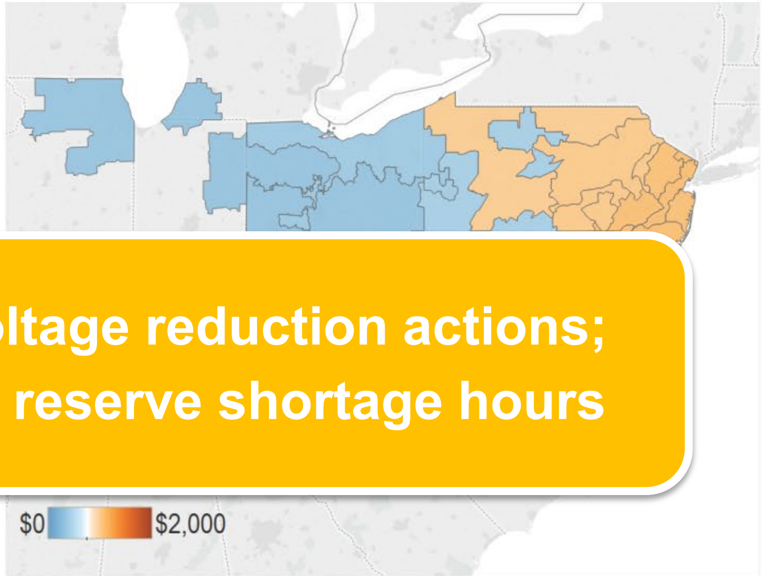
- Generation (MW)
- Forecasted Demand (MW)
- Deployed Demand Response (MW)
- Reserve Shortage (MW)
- Voltage Reduction (MW)
- Load Shed (MW)
- Price ($)

Prices do not represent forecasts of actual prices.



Load:	Extreme
Refueling:	Moderate
Disruption:	Looped 2 High
Non-Firm Avail:	62.50%
Retirement:	Escalated 1 (32 GW)
Dispatch:	Max Emergency

Hourly Zonal Average LMP [$]



No voltage reduction actions; fewer reserve shortage hours

Sites Out of Oil

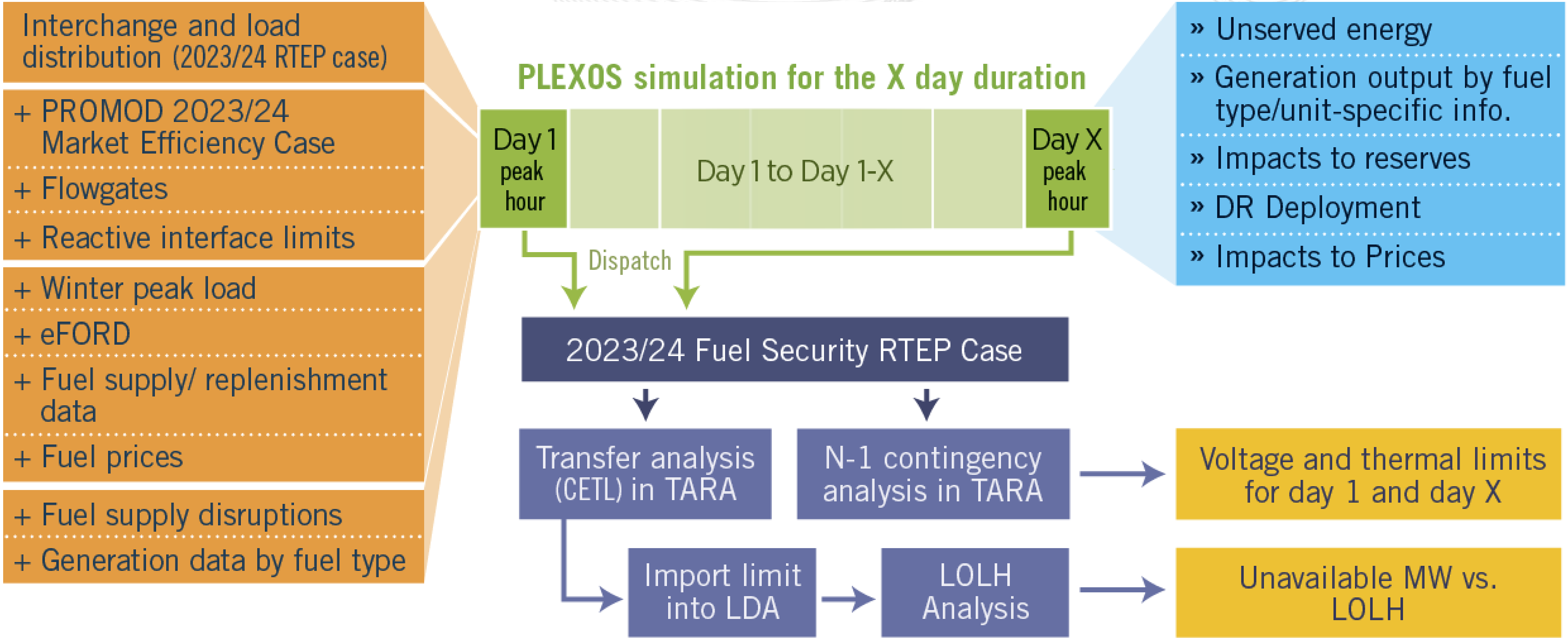
Oil Barrels Burned: 2.30M

Day of Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sites Out of Oil	0	0	0	0	0	0	0	0	0	0	0	0	0	0

*141 Total Sites

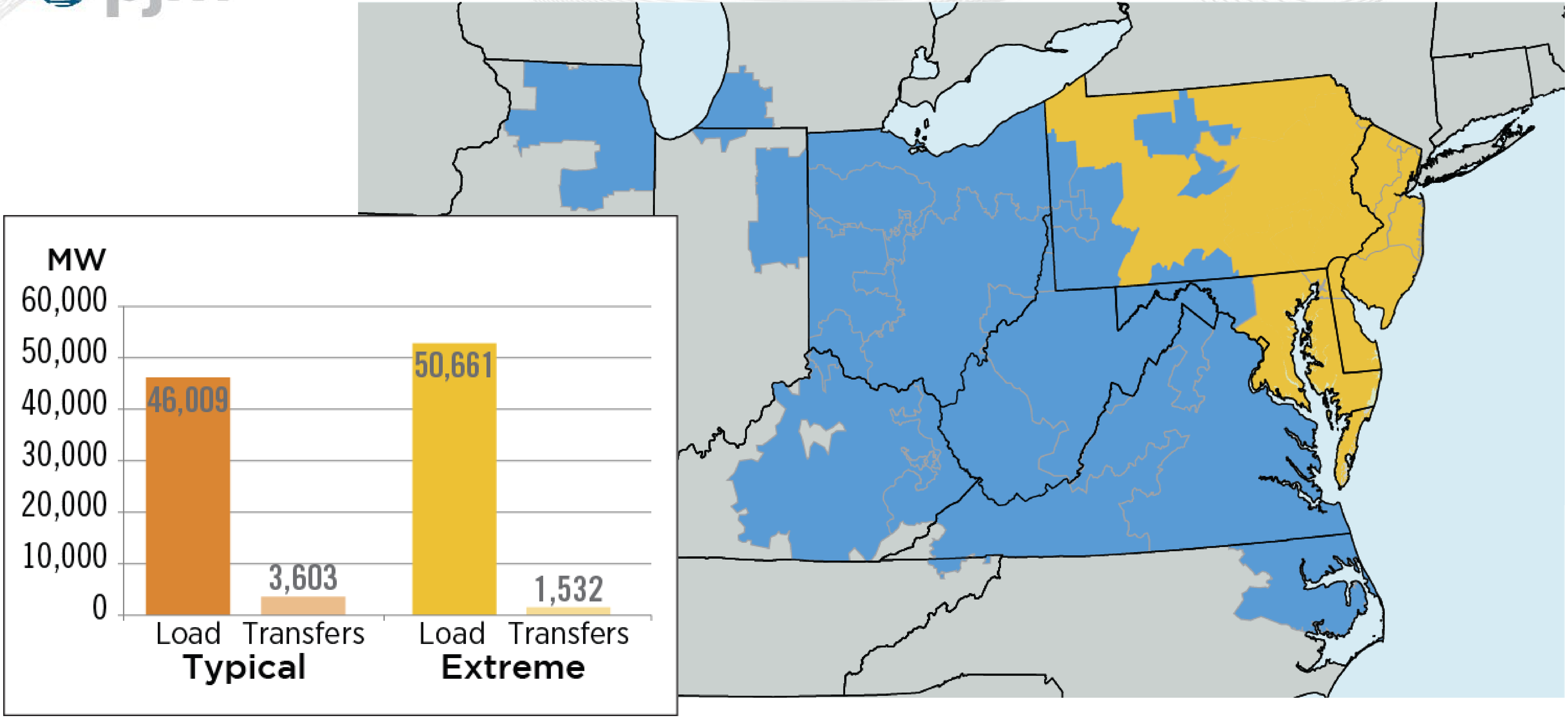
Day of Event

Fuel Security Analysis: Overview



Reliability Transfer Analysis

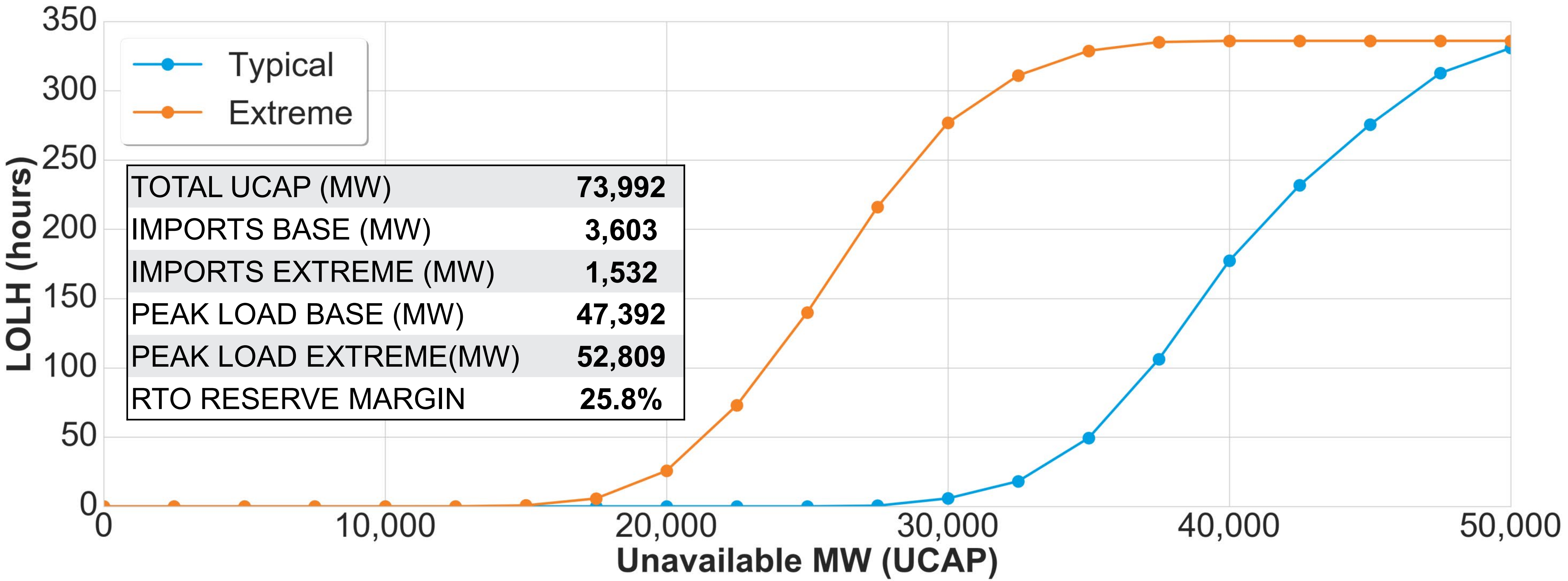
Mid-Atlantic Zone



Expected Loss of Load Hours Analysis

Loss of Load Hours (LOLH)

Mid-Atlantic Zone | Typical vs. Extreme (Announced Retirements)



TOTAL UCAP (MW)	**73,992**
IMPORTS BASE (MW)	**3,603**
IMPORTS EXTREME (MW)	**1,532**
PEAK LOAD BASE (MW)	**47,392**
PEAK LOAD EXTREME(MW)	**52,809**
RTO RESERVE MARGIN	**25.8%**