Winter Storm Elliott

Mike Bryson, Sr. Vice President – System Operations

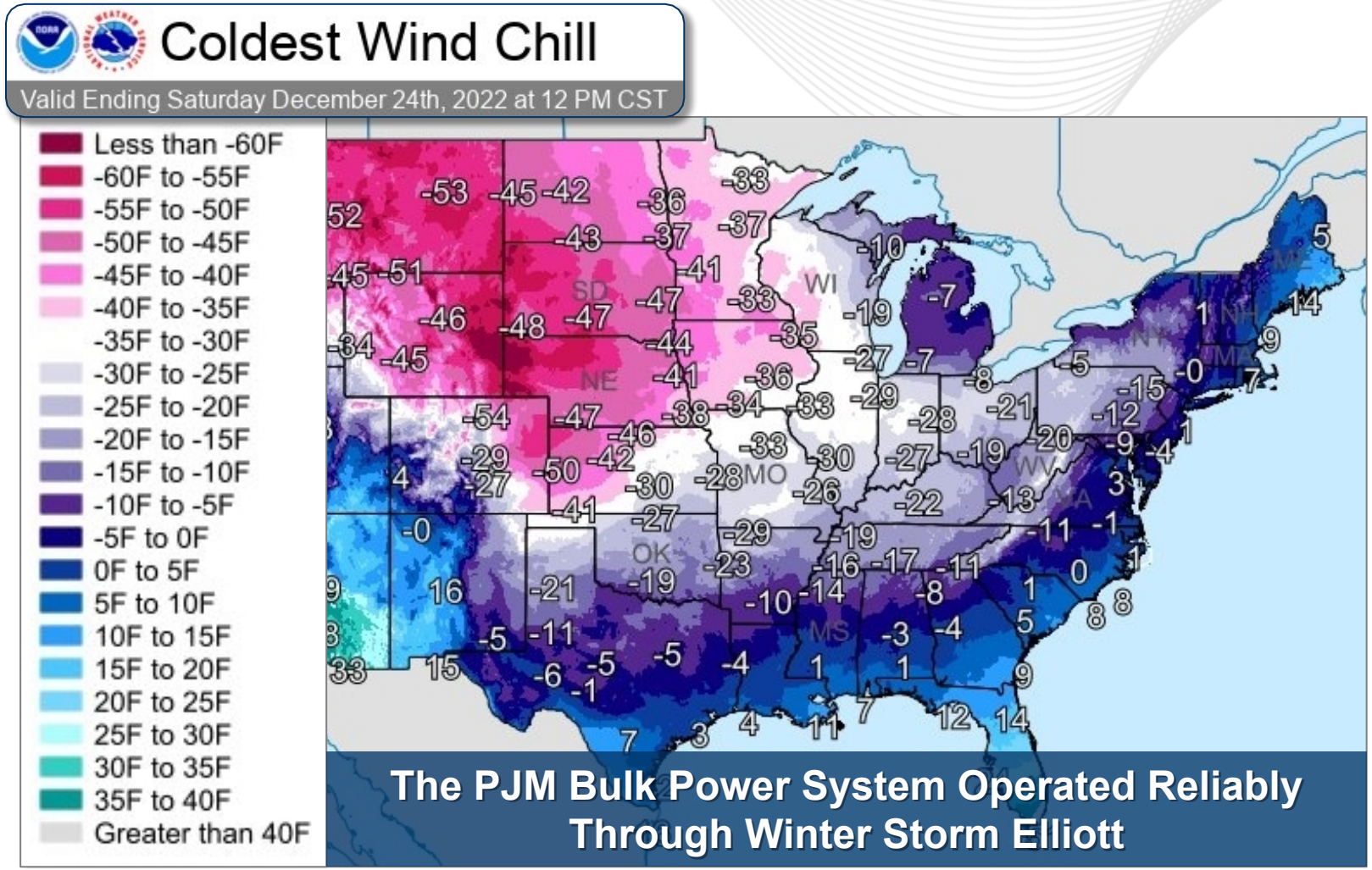
Donnie Bielak, Sr. Manager – Dispatch

Stu Bresler, Sr. Vice President – Market Services

Brian Chmielewski, Manager – Real-Time Market Operations

Susan Kenney, Manager – Market Settlements Development

Winter Storm Elliott



Source: NOAA and the National Weather Service; Graphic created on Dec. 21, 2022.

Source: NOAA

Temperatures across the RTO plummeted beginning on Dec. 23 and lasted into the morning of Dec. 25 with record lows in some areas as well as record drops in some regions.

PJM Prepares Extensively for the Winter

Winter readiness assessments: data collection on fuel inventory, supply and delivery characteristics, emissions limitations, and minimum operating temperatures

Meetings with federal and state regulators and neighboring systems to review winter preparations; weekly operational review meetings with major natural gas pipeline operators

PJM's Cold Weather Preparation Guideline and Checklist for generation owners includes everything from increasing staffing for weather emergencies to performing required maintenance activities.

April 2023 NERC winterization standard implementation is important. PJM feedback to NERC and FERC: New reliability standards need to be stronger and implemented sooner.

Prior to Storm, PJM Issued Winter Advisory and Alerts

Dec. 20, 2022

Cold Weather Advisory for Western Region From Dec. 23–26 (Later Expanded to Entire RTO)

- Prepare to take freeze-protection actions, such as erecting temporary windbreaks or shelters, positioning heaters, verifying heat trace systems, or draining equipment prone to freezing.
- Review weather forecasts, determine any forecasted operational changes, and notify PJM of any changes.
- Members are to update PJM with operation limitations associated with cold weather preparedness. Operating limitations include: generator capability and availability, fuel supply and inventory concerns, fuel switching capabilities, environmental constraints, generating unit minimums.

Dec. 21, 2022

Cold Weather Alert Issued for the Western Region for Dec. 23

- Generation dispatchers review fuel supply/delivery schedules in anticipation of greater-than-normal operation of units.
- Generation dispatchers monitor and report projected fuel limitations to PJM dispatcher and update the unit Max Run field in Markets Gateway if less than 24 hours of run time remaining.
- Generation dispatchers contact PJM Dispatch if it is anticipated that spot market gas is unavailable, resulting in unavailability of bid-in generation.

Dec. 23, 2022

Second Cold Weather Alert Issued for the Entire RTO for Christmas Eve, Dec. 24

PJM's Dec. 23 Operating Plan Was Conservative

PJM accounts for uncertainty and unplanned events as it develops the operating plan for every day.

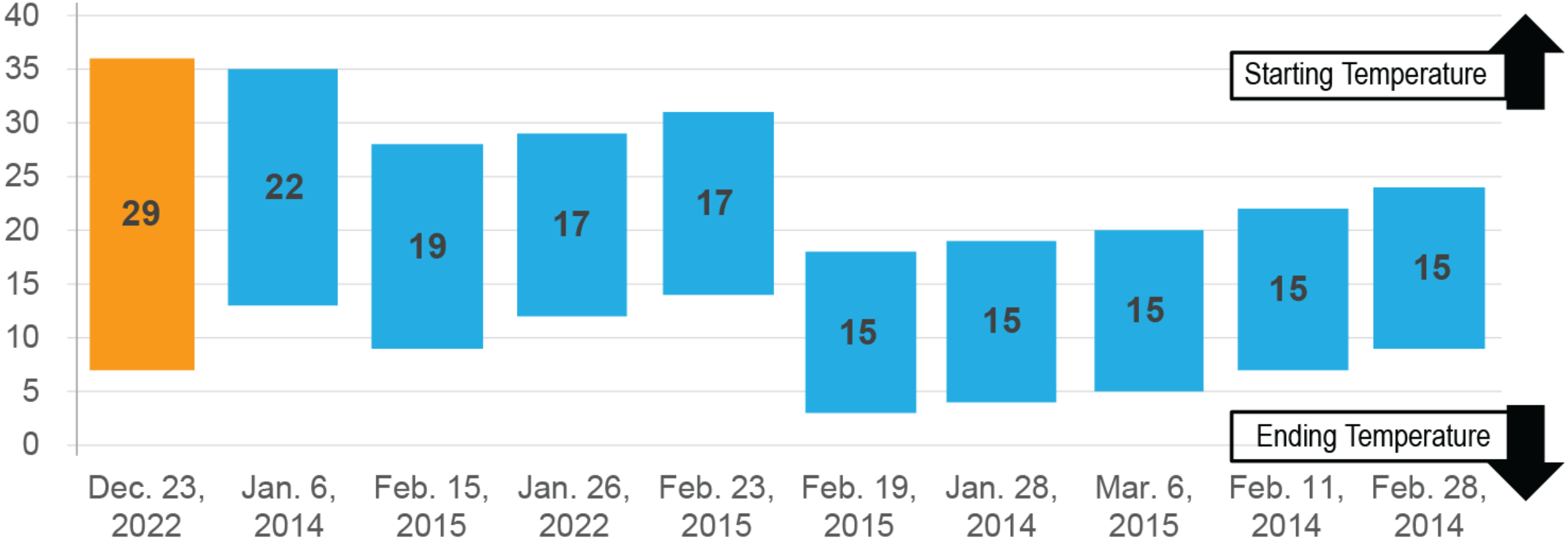
- Given the expected weather, PJM was conservative in developing the operating plans for Dec. 23.
- Forecast load was 126,968 MW.
- PJM called over 155,750 MW into the operating capacity for the day.

Based on generator availability data submitted to PJM, we believed we had almost 29 GW of reserve capacity available to absorb load and generation contingencies and to support our neighboring systems.

Preliminary Data

Most Drastic Temperature Drop in a Decade

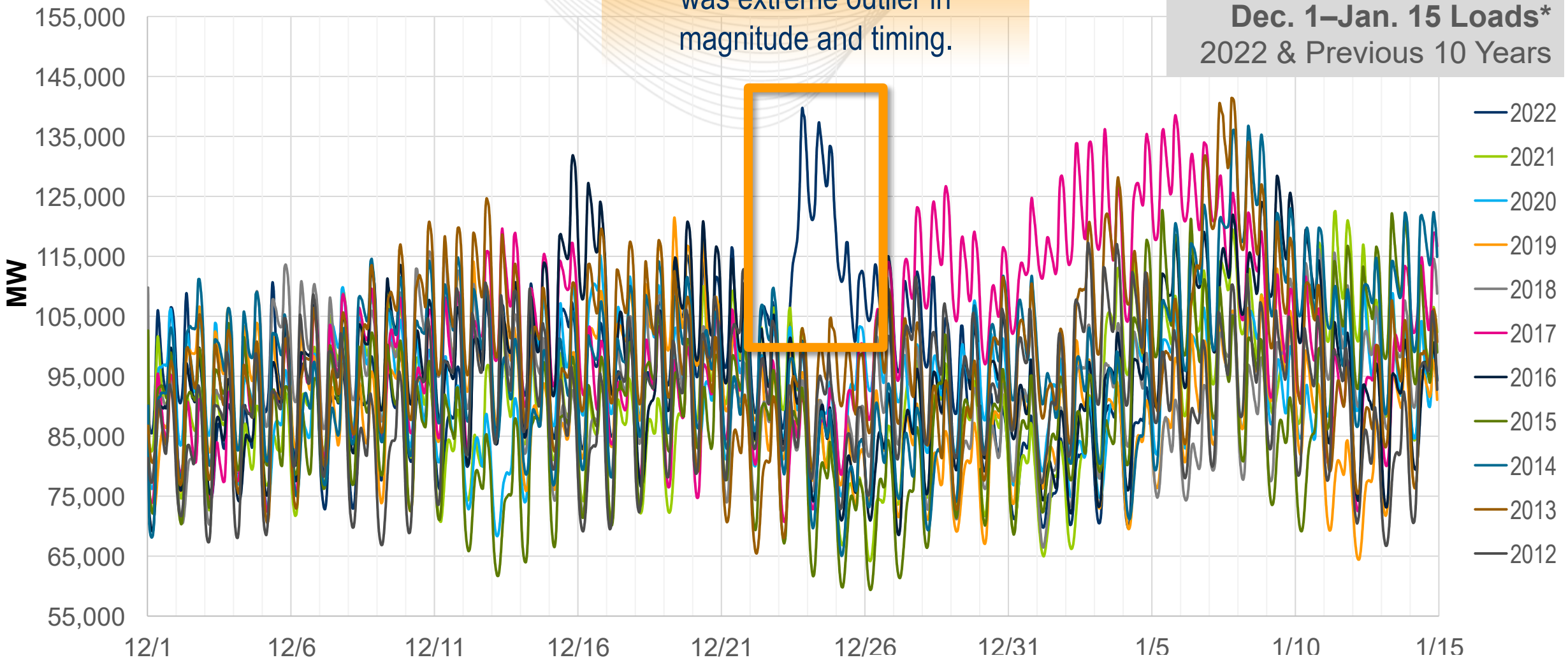
Top Ten 12-Hour Temperature Drops Ending Under 15°



2022 Holiday Load
(Preliminary Data)

2022 holiday weekend load was extreme outlier in magnitude and timing.

Dec. 1–Jan. 15 Loads*
2022 & Previous 10 Years

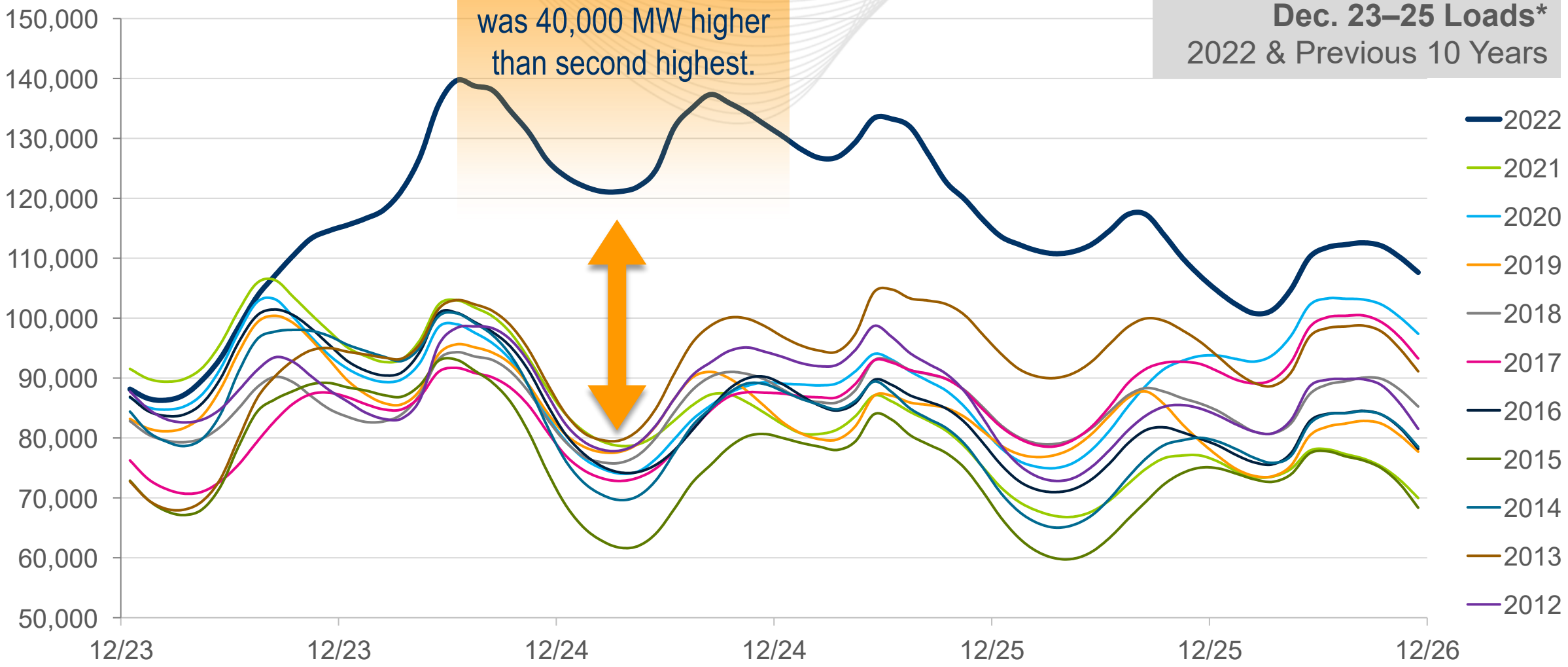


*Note: Load values include the estimated demand response (DR) added back.

Load Stayed Unusually High Overnight

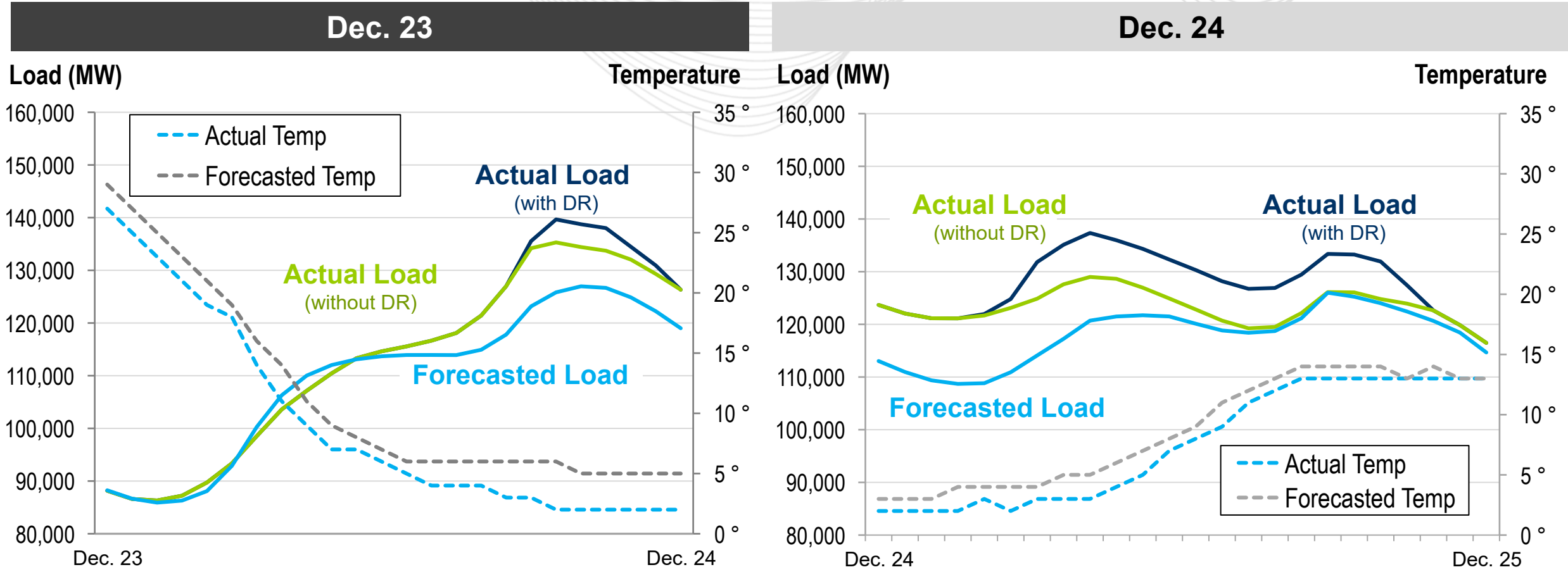
(Preliminary Data)

Christmas Eve valley was 40,000 MW higher than second highest.



*Note: Load values include the estimated demand response (DR) added back.

Actual Load Came in Higher Than Forecast
(Preliminary Data)

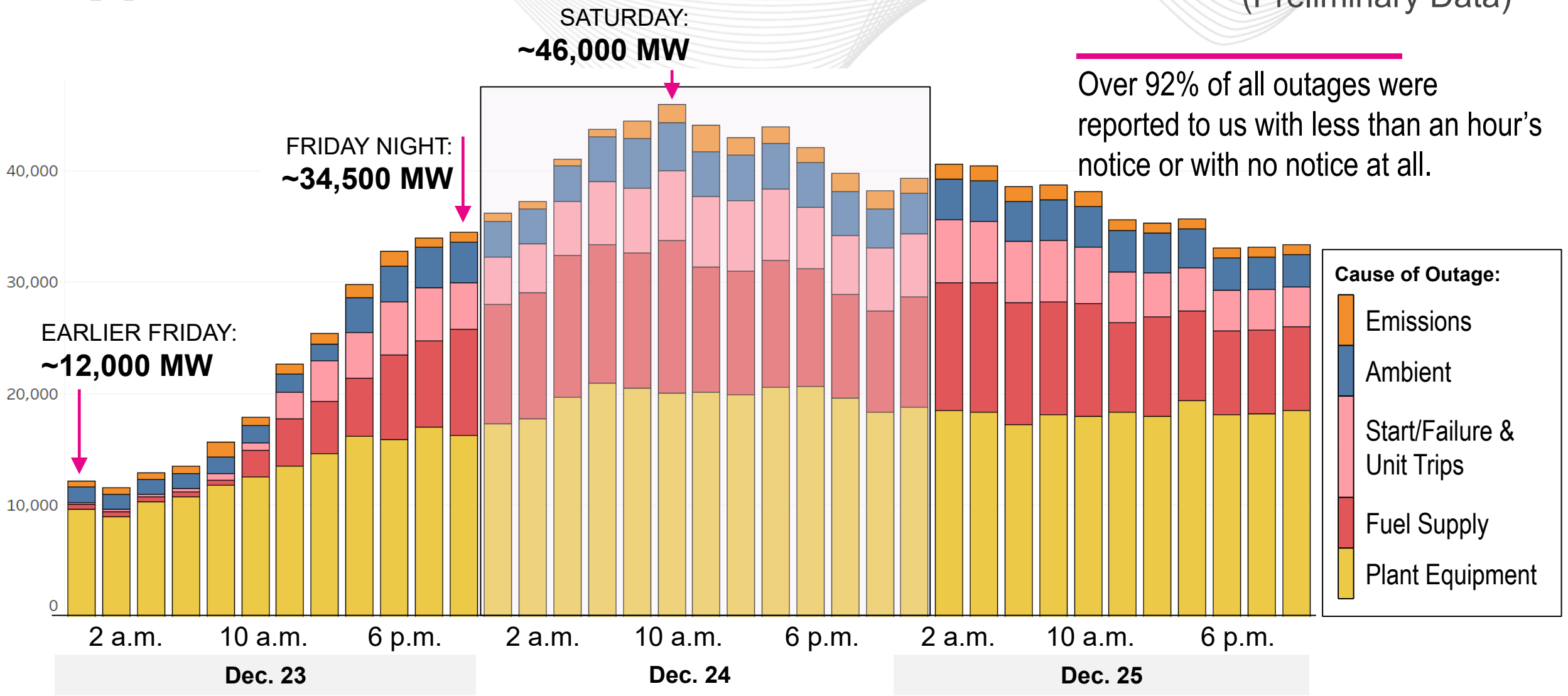


Actual load came in over 10% over forecast.

- Severe cold and blizzard conditions
- Most drastic temperature drop in a decade
- Early occurrence of cold weather
- Holiday impacts: rare instance of under-forecasting

As We Called Reserves, a Significant Portion of Fleet Failed To Perform

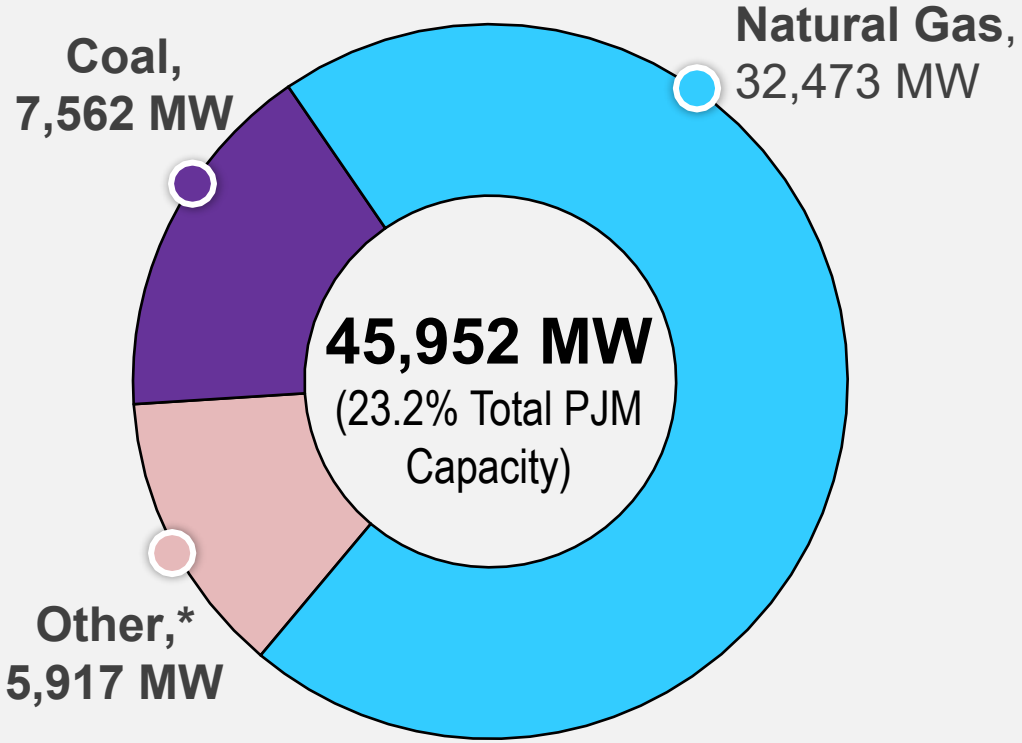
(Preliminary Data)



Over 92% of all outages were reported to us with less than an hour's notice or with no notice at all.

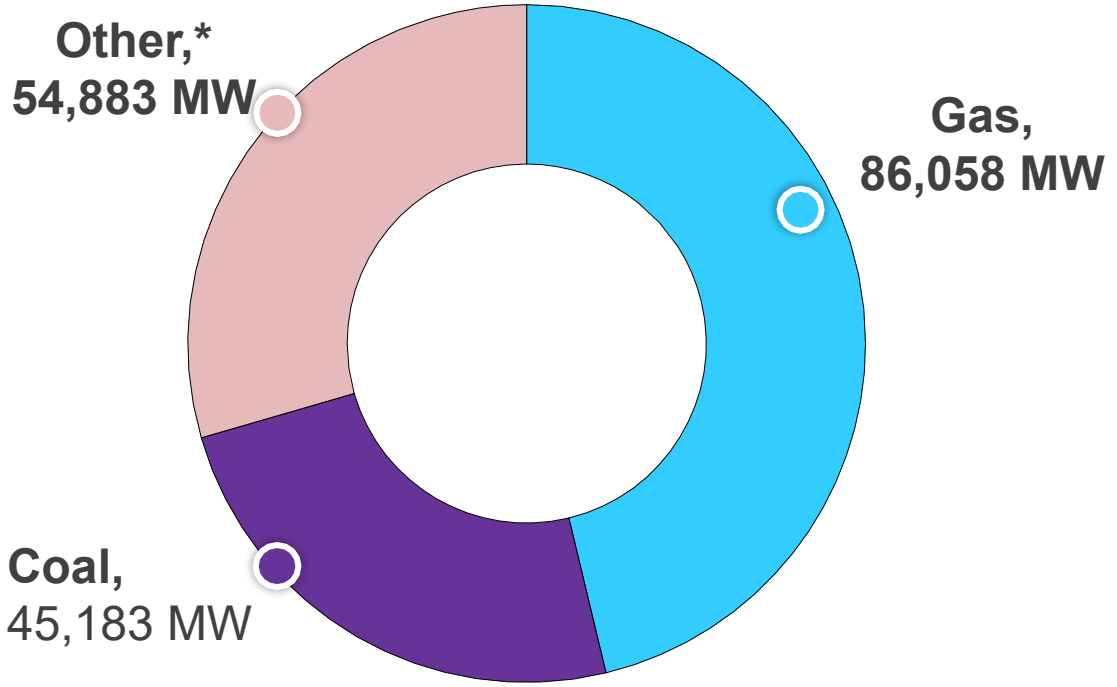
Generator Performance
(Preliminary Data)

TOTAL FORCED OUTAGES – DEC. 24, 2022



*Other = nuclear, oil, wind, solar, etc.

GENERATOR UCAP
2022/2023 DELIVERY YEAR



PJM's Total Fleet Capacity – **186 GW**

Certain Generation Was Unable To Start at Stated Start Times
(Preliminary Data)

- In addition to forced outages, ~6,000 MW of steam generation was called but was not on-line as expected per their time to start for the morning peak on Dec. 24.

  The vast majority of these resources were gas-fired resources.

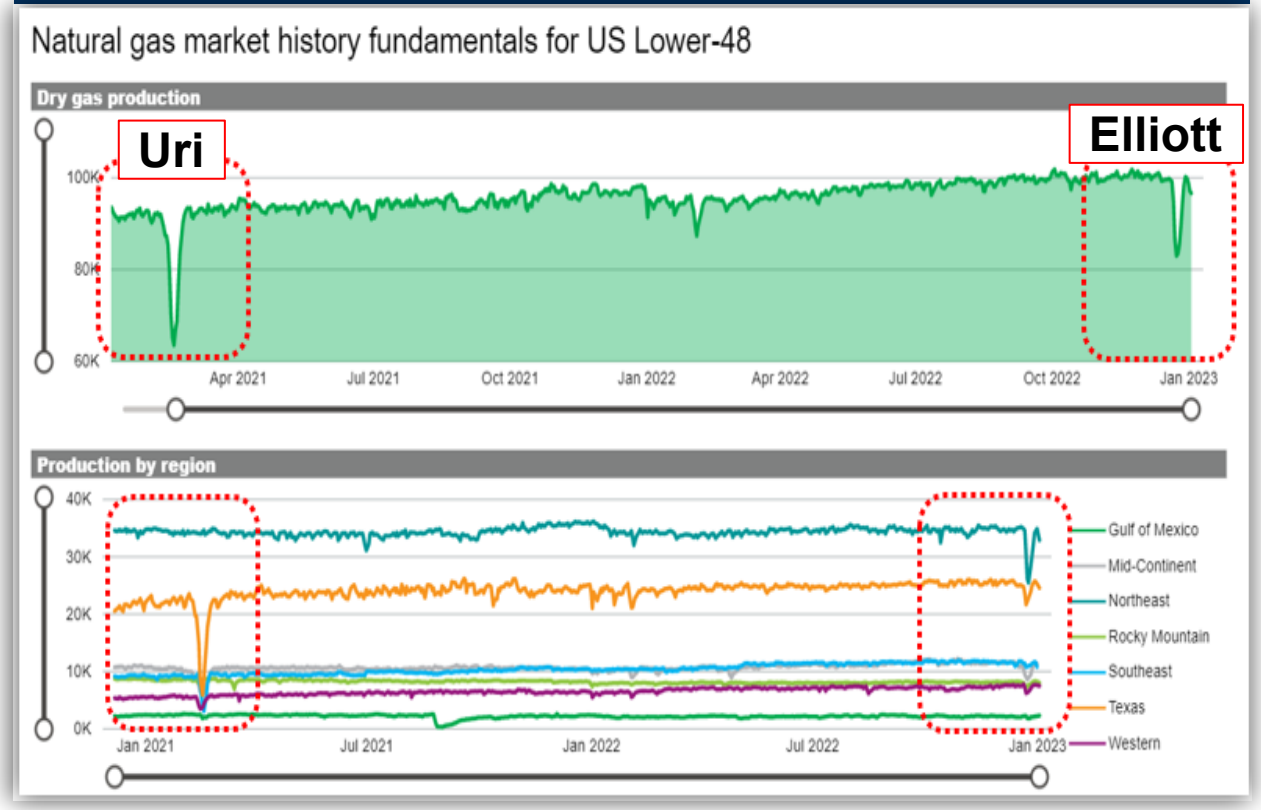
- The high rates of generator outages also limited our ability to replenish pond levels for pumped storage hydro prior to the morning peak on Dec. 24.

  That left PJM with extremely limited run hours for pumped storage generation.

- Between forced outages, derates, generators that did not start on time, and the inability to fill pumped storage hydro ponds, PJM was dealing with ~57 GW of generator unavailability for the Dec. 24 morning peak.

Natural Gas Production Declines
Uri (February 2021) vs. Elliott (December 2022)

Jan. 1, 2021, through Jan. 2, 2023



Northeast: Marcellus and Utica Shale; Data Source: S&P Global

Uri (February 2021)

- 30% nationwide production decline
- All production loss in Texas and Southwest
- No production loss in Appalachia

Elliott (December 2022)

- 20% nationwide production decline
- Largest percentage of total decline in Appalachia (Marcellus and Utica), which saw a nearly 30% drop in daily production
- Production has returned to near pre-event levels.

Emergency Procedures
(Preliminary Data)

- **Cold Weather Alert issued** from 07:00 on 12/23 through 23:00 on 12/25 for Western Region.
- **Cold Weather Advisory** extended to 07:00 on 12/23 through 23:00 on 12/26 for Western Region.

- **12/23 17:30–22:15** – Pre-Emergency Load Mgmt. Reduction Action – RTO 30-minute response product
- **12/23 17:30–23:00** – Maximum Generation Emergency Action, Issues EEA2
- **12/23 17:45–21:30** – Emergency Load Mgmt. Reduction Action and a NERC level EEA2
- **12/23 18:00–22:15** – Pre-Emergency Load Mgmt. Reduction Action, 60-minute response product
- **12/23 23:00** – Max. Generation Emergency Alert/Load Mgmt. Alert for 12/24

PAI Trigger

- **12/24 04:25–22:00** – Max. Generation Emergency Action
- **12/24 04:52–18:34** – Voltage Reduction Alert issued for RTO
- **12/24 05:16–21:08** – Emergency Energy Request
- **12/24 07:15–18:15** – Voltage Reduction Warning and Reduction of NCPL
- ***17:45 – DOE issues Emergency Order under Section 202 (c) of Federal Power Act***
- **12/24 22:30** – PJM downgrades EEA2 to EEA1.

PAI Trigger

Dec. 20

Cold Weather Advisory from 07:00 on 12/23 through 23:00 on 12/25 for Western Region.

PJM expands Cold Weather Advisory to the entire RTO on 12/22.

Dec. 21

- **Cold Weather Alert issued** from 00:00 on 12/24 through 23:59 on 12/25 for the RTO.
- **12/23 10:14–10:25** – Synch. Reserve Event
- **12/23 16:17–18:09** – Synch. Reserve Event

Dec. 23

Dec. 24

- **12/24 00:04–00:30** – 100% Synchronized Reserve Event initiated for the PJM RTO region.
- **12/24 02:23–03:24** – 100% Synchronized Reserve Event initiated for the PJM RTO region.
- ***PJM Issues Call for Conservation effective 04:00 on 12/24 through 10:00 on 12/25.***
- **12/24 04:20–20:30** – Emergency Load Mgmt. Reduction Action and a NERC level EEA2 issued – All load mgmt.
- **12/24 04:23–05:51** – 100% Synchronized Reserve Event initiated for the PJM RTO region.

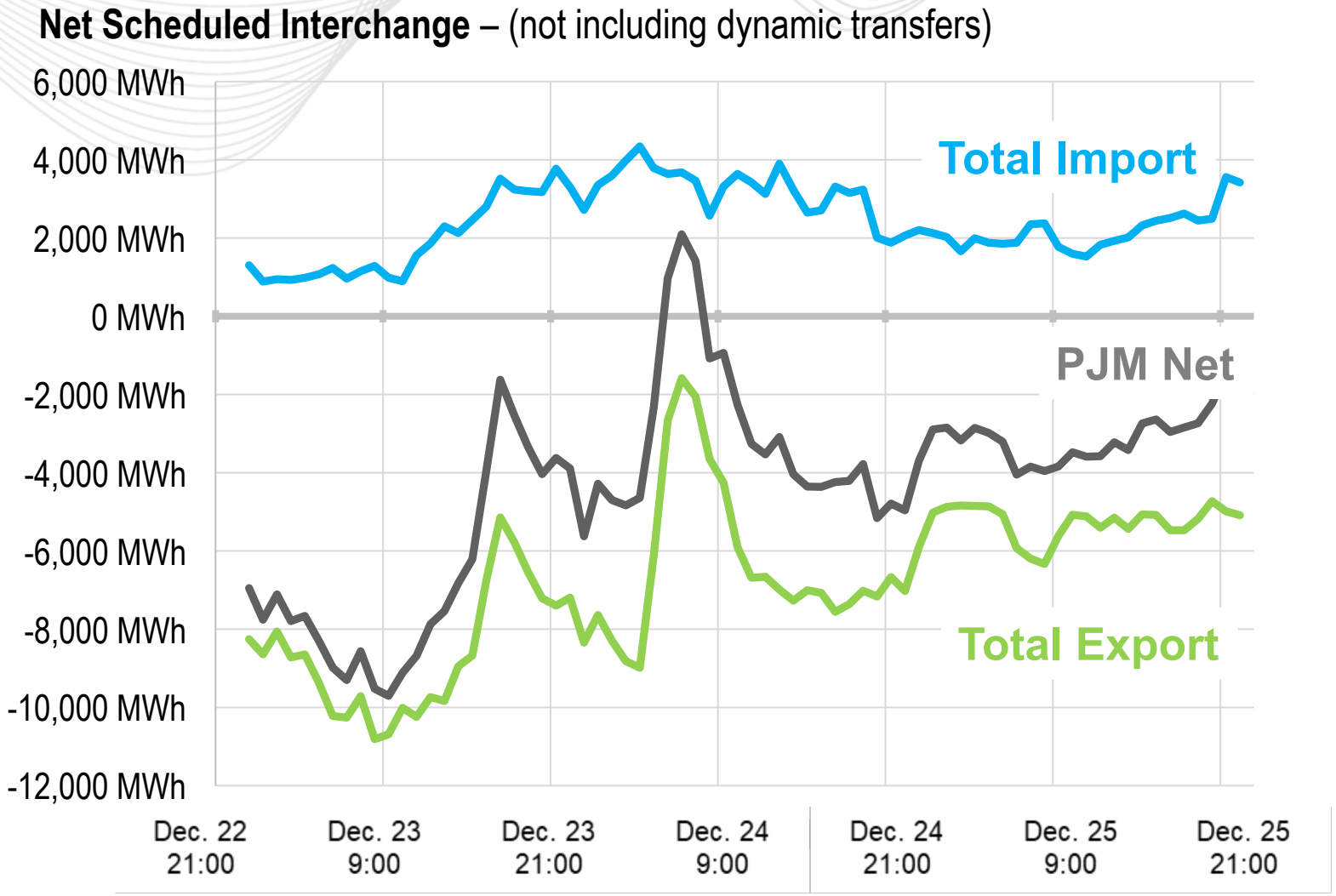
PAI Trigger

Dec. 25

- **12/25 08:55** – Cold Weather Alert issued from 07:00 on 12/26 through 23:00 on 12/26 for Western Region
- **12/25 22:00** – EEA1 ends

Interchange: Dec. 23–25

Dec. 20	PJM total exports began increasing and peaked on Dec. 23 at 9 a.m. at 10,811 MWh.
Dec. 23	PJM began curtailing exports as our capacity position deteriorated due to the generation failures that we were having.



PJM Media Outreach

Used Media, Press Releases and Social Media Sites

pjm News

FOR IMMEDIATE RELEASE

Contact: PJM News, at PJMNews@pjm.com or toll free at 866-PJM-NEWS (866-756-6397)

PJM ASKS CONSUMERS TO CONSERVE ELECTRICITY

Cold Weather Continues to Push Electricity Use Higher

(Valley Forge, PA – Dec. 23, 2022) – PJM Interconnection, the electricity grid operator for 65 million people in 13 states and the District of Columbia, has requested the public in its region to conserve electricity. The call for conservation was prompted by continuing frigid weather.

The request is being made throughout PJM.

PJM Interconnection Retweeted

NJ Board of Public Uti... @ · Dec 24, 2022

Our regional grid operator is asking the public to conserve electricity through 10:00AM on December 25, 2022 as frigid temps continue.

What you can do:

- Set thermostats lower, if health permits
- Postpone use of major appliances
- Turn off non-essential lights & appliances

PJM Interco... @pjmint... · Dec 24, 2022

PJM asks consumers to... the face of continuing... pjm.com/-/media/abou...

42

PJM Intercon... @pjmint... · Dec 24, 2022

Update from PJM Senior Vice President of Operations Mike Bryson.

27 84 69

Worked With Utility Partners

PJM Interconnection Retweeted

Kentucky Po... @Kentucky... · Dec 24, 2022

PJM urging Kentucky Power customers to reduce use of electricity without sacrificing safety. Cold temps creating demands on power system. Minor adjustment to thermostats can make a difference. Info here: facebook.com/KentuckyPower - Thank you!

2 7 10

Analysis and Lessons Learned

What's next for PJM and members?

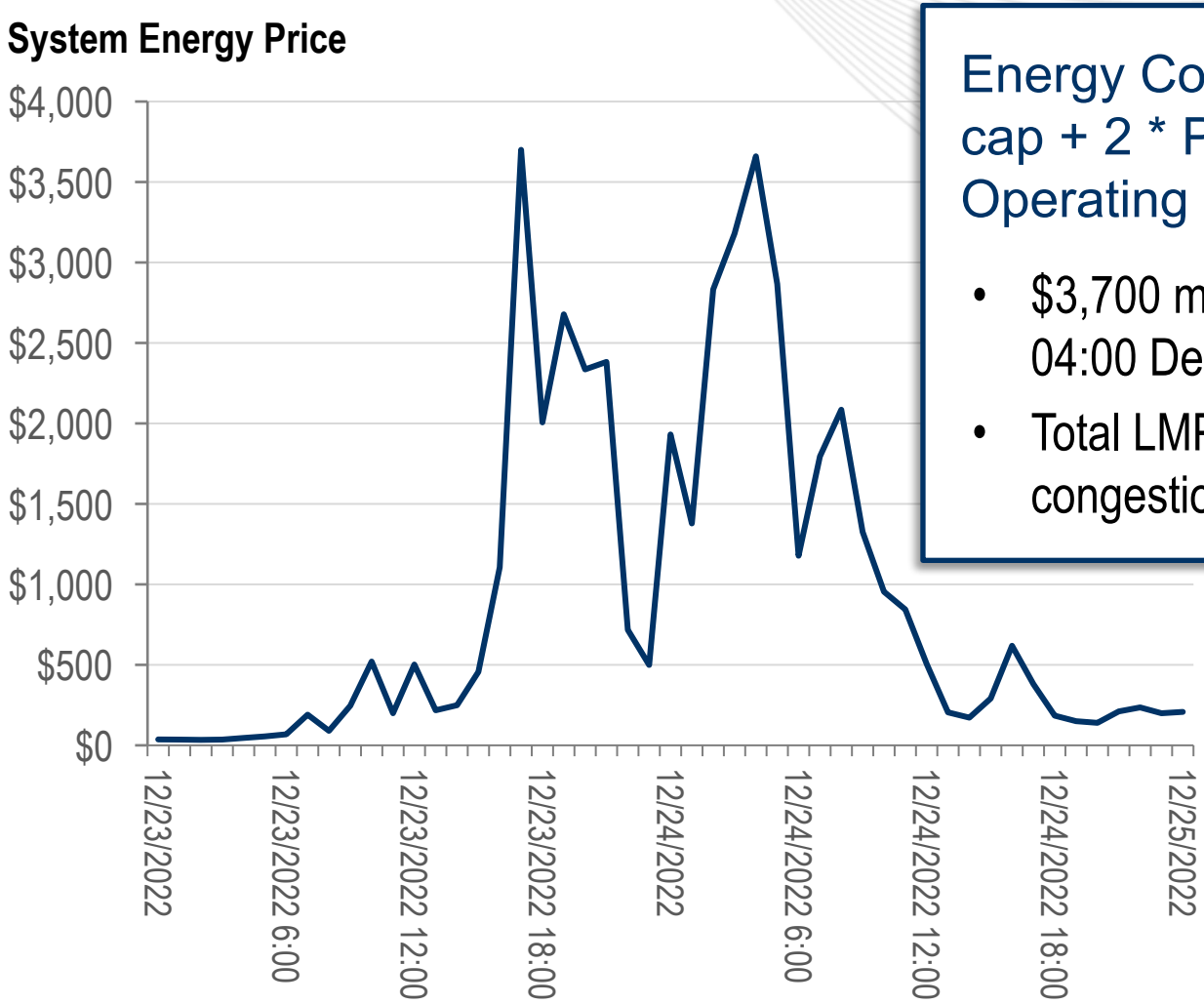
Look at some immediate actions to be prepared for the rest of this winter.

- Cold Weather Advisory steps
- Data request from affected resources
- Load forecast approach

PJM is doing a full analysis estimated mid-April.

NERC/FERC has announced a nationwide investigation. PJM has received requests for information from Reliability First and SERC.

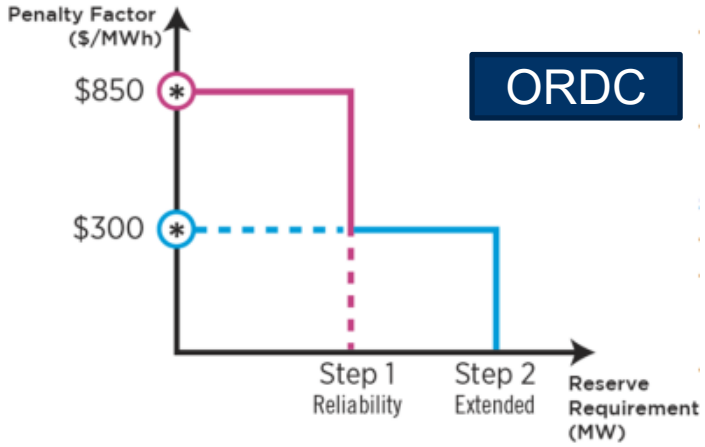
System Energy Price Overview



Energy Component of LMP is capped at the energy offer cap + 2 * Penalty Factor from first step of reserve Operating Reserve Demand Curve (ORDC).

- $3,700 multiple intervals, including all of 17:00 Dec. 23 and most of 04:00 Dec. 24
- Total LMPs were above this level when factoring in locational congestion and loss prices for multiple intervals.

Penalty Factor sets a price for being unable to meet the reserve requirement.



Impacts of Congestion

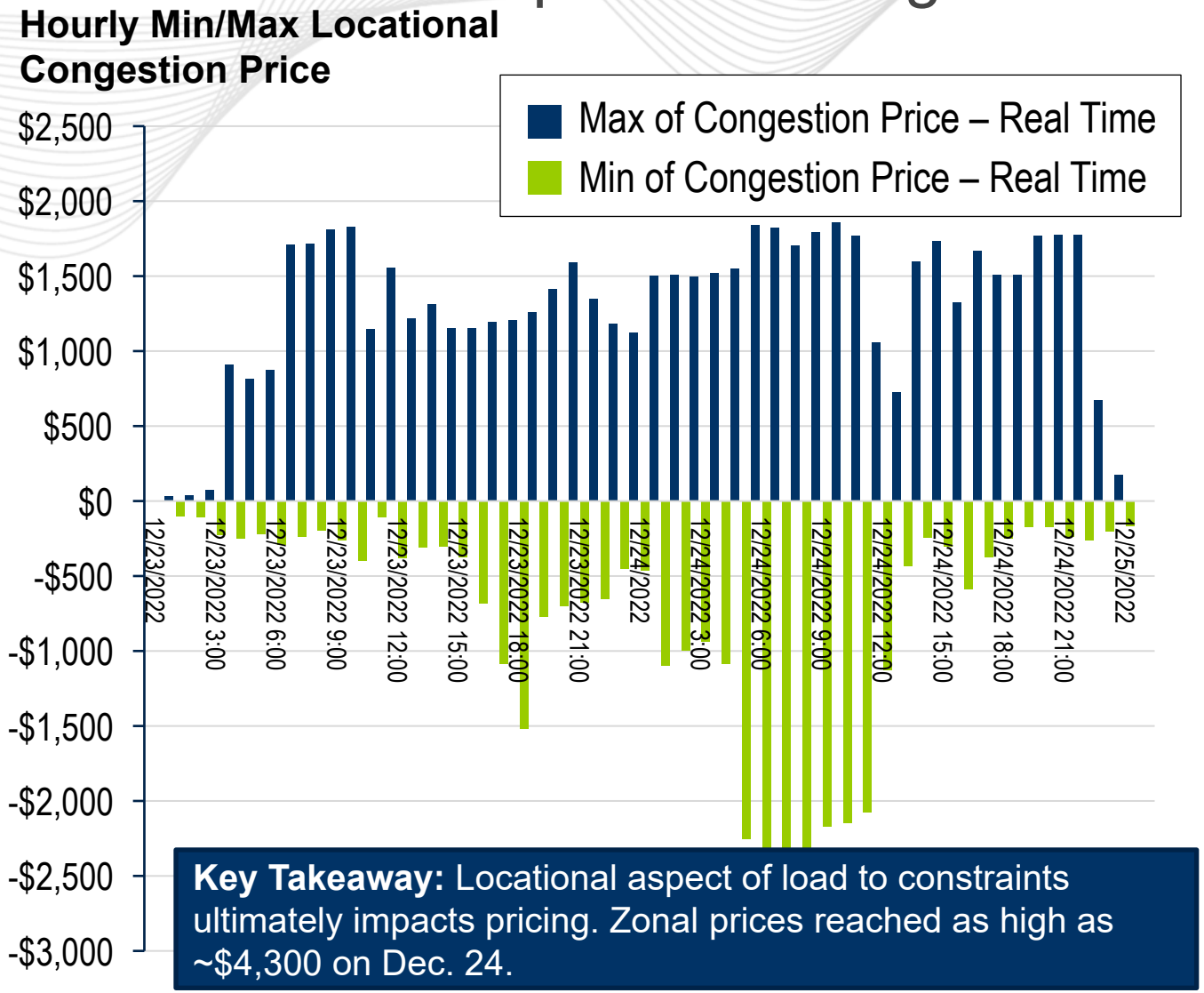
Dec. 23

27 of 35 active constraints bound at the transmission constraint penalty factor for at least one 5-min. interval.

Dec. 24

28 of 42 active constraints bound at the transmission constraint penalty factor for at least one 5-min. interval.

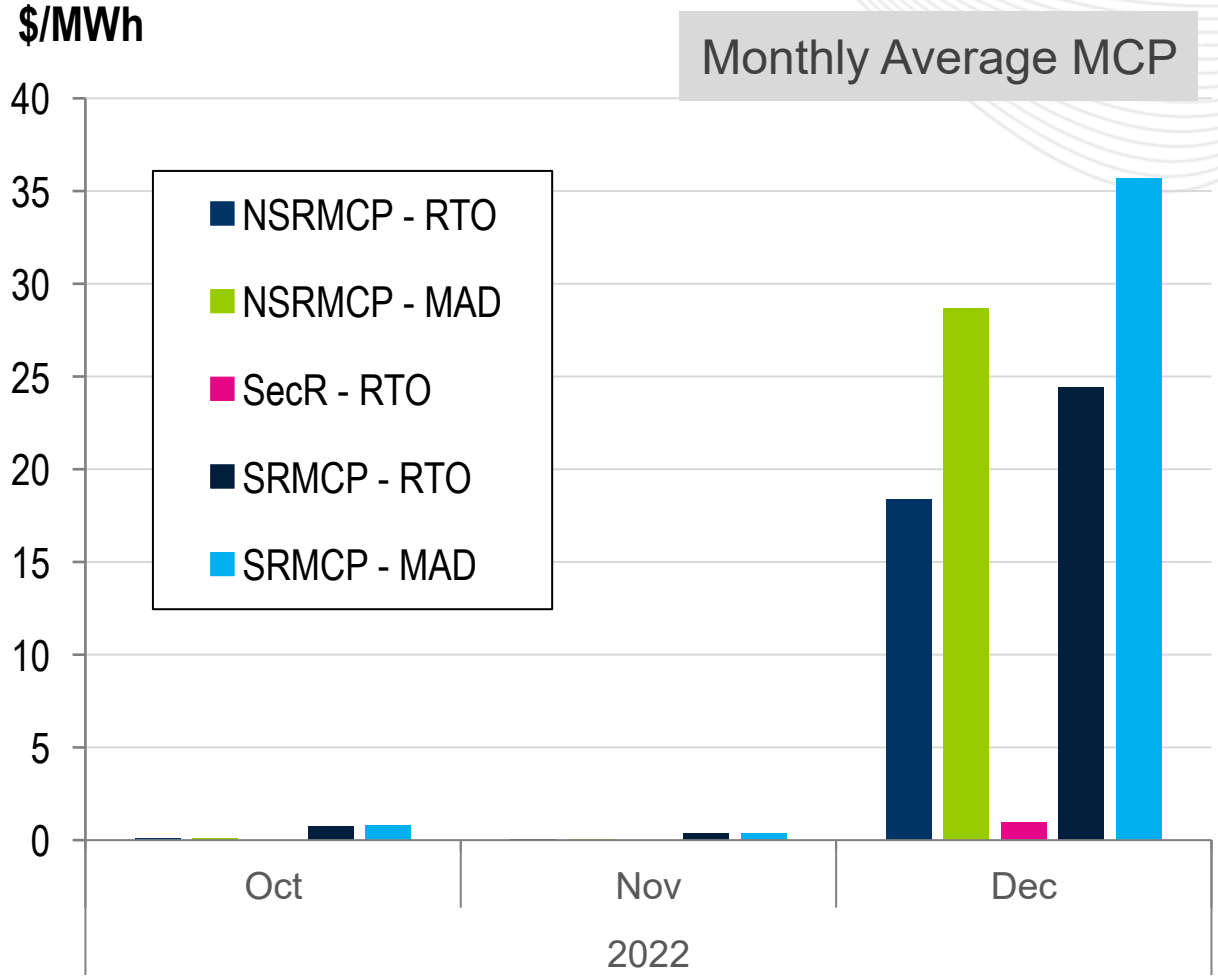
Transmission Constraint Penalty Factors
These are parameters used by the Security Constrained Economic Dispatch (SCED) applications to determine the maximum cost of the re-dispatch incurred to control a transmission constraint. Default is $2,000/MWh.



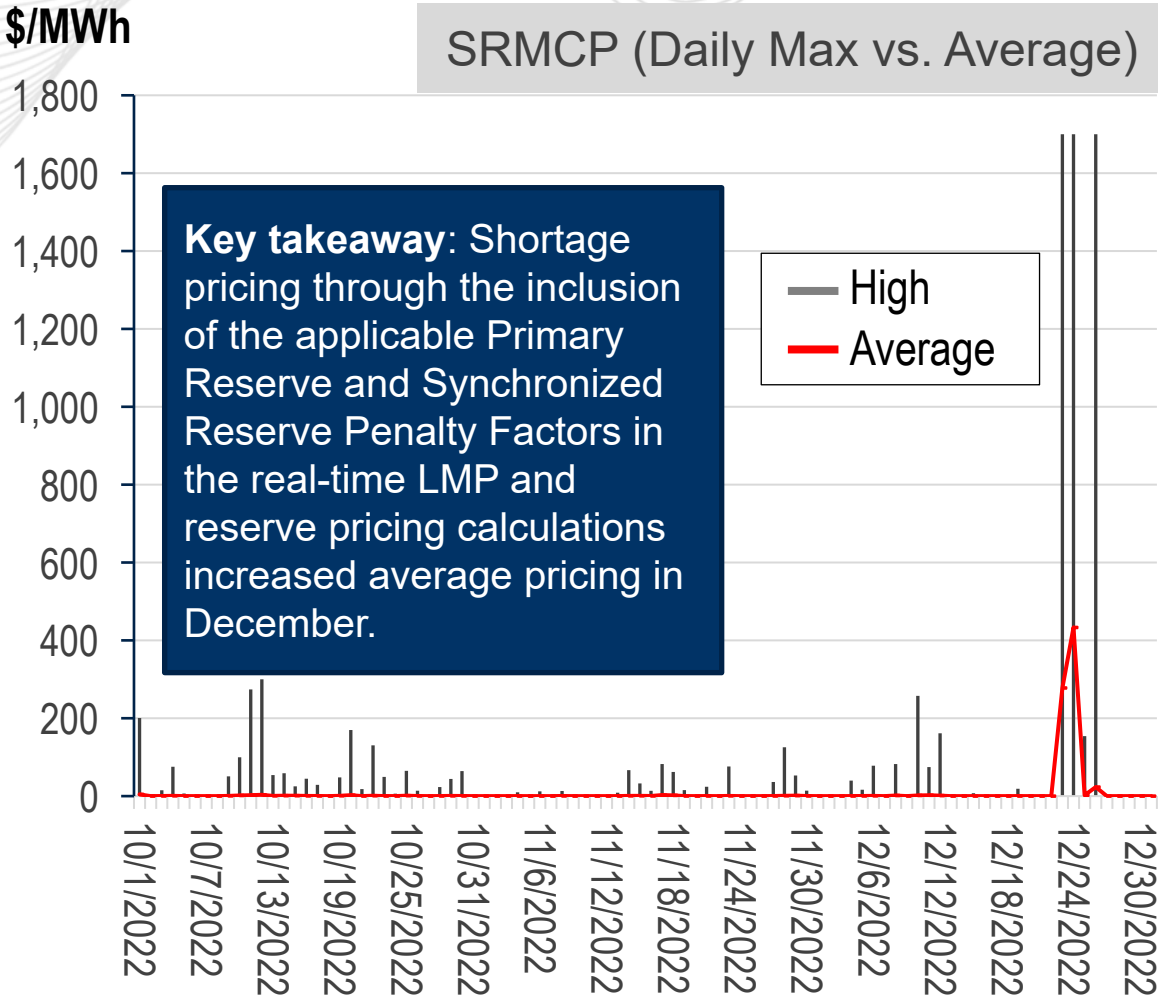
Key Takeaway: Locational aspect of load to constraints ultimately impacts pricing. Zonal prices reached as high as ~$4,300 on Dec. 24.

Reserve Market Clearing Prices

Monthly Average MCP



SRMCP (Daily Max vs. Average)



Key takeaway: Shortage pricing through the inclusion of the applicable Primary Reserve and Synchronized Reserve Penalty Factors in the real-time LMP and reserve pricing calculations increased average pricing in December.

Shortage Intervals – Friday, Dec. 23

71 Shortage Intervals approved by Dispatch between 16:30 and 22:45.

All intervals reviewed and validated during LMP verification on Dec. 27.

Number of Intervals	Reserve Penalty Factors
45	MAD & RTO – Primary
21	MAD & RTO – Primary & Synchronized
2	MAD & RTO – Primary & RTO – Synchronized
3	RTO Primary

Shortage Intervals – Saturday, Dec. 24

134 Shortage Intervals approved by Dispatch between 00:15 and 16:15.	All intervals reviewed and validated during LMP verification on Dec. 27.

Number of Intervals	Reserve Penalty Factors
69	MAD & RTO – Primary
37	MAD & RTO – Primary & Synchronized
16	MAD & RTO – Primary & RTO – 30-Minute
1	MAD & RTO – Primary & RTO – Synchronized
11	RTO Primary

Load Management Deployment (Pre-Emergency and Emergency Demand Response)

<table>
<tr><td rowspan="3">Load Management dispatched for all zones in the RTO.</td><td colspan="2">Deployed and released in tranches (Emergency vs. Pre-Emergency, 30-, 60- or 120-minute lead time, and zone) based on system conditions</td></tr>
<tr><td>Dec. 23, 2022 – Approximately 4,000 MW of capacity deployed</td><td>17:30 (first notification) through 22:15 (last release)</td></tr>
<tr><td>Dec. 24, 2022 – Approximately 7,000 MW of capacity deployed</td><td>04:20 (first notification) through 20:30 (last release)</td></tr>
<tr><td colspan="3">Load Management is required to consumer at or below the firm service load level. Facility may reduce load or postpone electricity consumption.</td></tr>
</table>

PAI Overview

Maximum Generation Emergency Actions Prompted
277 PAI Intervals Across Dec. 23 and Dec. 24

Start	End	# Intervals
Dec. 23, 2022 17:30	Dec. 23, 2022 23:00	**66**
Dec. 24, 2022 04:25	Dec. 24, 2022 22:00	**211**

Affected All Resources in the Entire RTO, Including External Capacity Resources

PAI Actions to Date

Member Communications Sent	During PAI	Timing and cause
	Following PAI	Retroactive replacement transaction information (400 received)
		Preliminary Balancing Ratio information
	Preliminary Balancing Ratios calculated and posted to Data Miner	

Balancing Ratio

The Balancing Ratio is calculated during each Performance Assessment Interval (PAI) to determine each generation capacity resource's obligation to deliver energy.

Balancing Ratio (BR) =

$$\frac{\text{Total Actual Generation and Storage Performance + Net Energy Imports + DR and PRD Bonus Performance*}}{\text{All Generation and Storage Committed Capacity Commitments (UCAP)}}$$

**Note: DR and PRD Bonus Performance are not included in the Preliminary Balancing Ratio due to data submission timelines.*

Preliminary Balancing Ratios

Date/Time	Area(s)	Average BR	Min BR	Max BR
Dec. 23 17:00–23:00	RTO	85.48%	83.00%	86.58%
Dec. 24 04:25–22:00	RTO	80.62%	78.39%	82.73%

Resource Performance Evaluation

Performance is evaluated for each committed capacity resource for each 5-minute interval of a performance assessment event.

Performance Shortfall (per interval) =

Expected Performance	−	Actual Performance	−	Total Excused MW
Committed Capacity MW * Balancing Ratio		Actual Generation + Ancillary Services		• Approved planned or maintenance outages • MW scheduled down due to economic dispatch • MW scheduled down due to manual dispatch

Capacity Resources with a positive Performance Shortfall are subject to a Non-Performance Charge = Performance Shortfall * Non-Performance Charge Rate

Non-Performance Charge Rate for Performance Shortfalls

The Non-Performance Charge Rate is based on yearly Net CONE, a divisor (i.e., an assumed 30 Emergency Action hours per year) and the number of Real-Time Settlement Intervals in an hour.

Charge Rate =

(Net CONE * # days in the Delivery Year) / (30 * 12)

Locational Deliverability Area	Net CONE ($/MW-Day, ICAP Price)	Non-Performance Charge Rate ($/MW-interval)
ATSI	218.79	221.83
ATSI-CLEVELAND	218.79	221.83
BGE	214.87	217.85
COMED	235.27	238.54
DAY	214.82	217.80
DEOK	212.27	215.22
DPL-SOUTH	224.18	227.29
EMAAC	246.18	249.60
MAAC	232.67	235.90
PEPCO	246.34	249.76
PPL	237.69	240.99
PS-NORTH	254.8	258.34
PSEG	254.8	258.34
RTO	247.26	250.69
SWMAAC	230.61	233.81

Note: Non-Performance Charge Rates are calculated for each LDA modeled for the delivery year.

Estimated Non-Performance Charges

PJM's ***rough estimate*** of non-performance charges for Dec. 23 and Dec. 24 is in the $1 billion to $2 billion range.

This estimate is provided as an initial reference point only and can change materially.

It includes preliminary excusals for MW scheduled down due to economic dispatch. It is subject to further change (*increase or decrease*) based on:

- Changes to the final balancing ratio
- Approval of retroactive replacement transactions
- Further review of actual resource performance data
- Further review of excusals due to economic dispatch
- Inclusion of excusals for:
  - Approved planned or maintenance outages
  - MW scheduled down due to manual dispatch

Note: FRR entities could have elected physical penalty in lieu of financial prior to DY.

Bonus Credits: Allocation of Collected Non-Performance Charges

Revenue ***collected*** from payment of Non-Performance Charges is distributed to resources (of any type, even if they are not Capacity Resources) that perform above expectations during each PAI.

- The credit is based on the ratio of its Bonus Performance quantity to the total Bonus Performance quantity (from all resources and PRD Providers for the same PAI).
- Bonus Performance quantity = Actual Performance minus Expected Performance and is capped at the scheduled megawatt quantity.

Billing Timing

OATT Attachment DD, Section 10A

(j)The Office of the Interconnection shall bill charges and credits for performance during Performance Assessment Intervals within three calendar months after the calendar month that included such Performance Assessment Intervals, provided, for any Non-Performance Charge, the amount shall be divided by the number of months remaining in the Delivery Year for which no invoice has been issued, and the resulting amount shall be invoiced each such remaining month in the Delivery Year or during the first month of the next Delivery Year if three months do not remain in the current Delivery Year.

- PJM is currently working through the billing timeline to account for any non-payment risk and liquidity concerns.
- Additional information will be provided at the Jan. 24 Risk Management Committee meeting.

Performance Assessment Next Steps

• Review resource performance and excusals	• Retroactive replacement transaction review and approval	• Release of preliminary resource performance data (targeted by first full week of February)
• Demand Response/Price Responsive Demand compliance data submission (due Feb. 14, 2023)		*Dependency for calculation of final balancing ratio*