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Evaluation of Sub-Annual Designs for PJM's RPM

Potential Benefits of Sub-Annual Markets

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October 29, 2025

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Agenda

- Clarification of study scope (forward vs. prompt)
- Survey responses
- Sub-annual features of resource adequacy in PJM
- Potential benefits of sub-annual markets
- Next steps

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Sub-Annual Features of Resource Adequacy in PJM

Changing System and Market Conditions

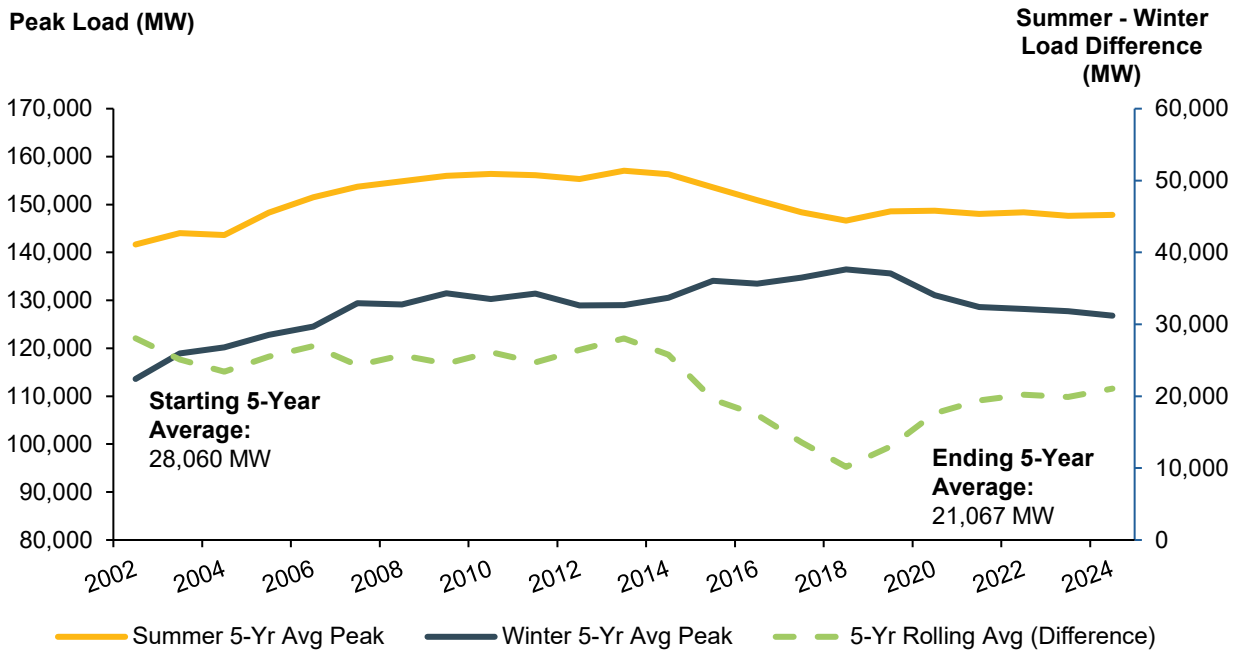
Today's market and system conditions create risk spread throughout the year

- In the past, given market conditions and technologies, risks were concentrated in one season and technology performance was (relatively) uniform across the year
- Today, circumstances have changed:
  - Winter peaks are growing relative to summer peaks
  - The winter load distribution differs from summer
  - Technology performance varies substantially across the year
  - Changes in the mix of resources in and entering the system
  - Even when summer peaks exceed winter peaks, differences in resource performance and load distributions across the year shifts resource adequacy risks across sub-annual periods
  - Rapid load growth driven by large loads (e.g., data centers)

Past Gap Between Summer and Winter Peak Loads

Gap between summer and winter peak was relatively constant through mid-2010s, but has declined modestly in the past decade

PJM 5-Year Rolling Average Summer and Winter Peaks
1998 - 2024



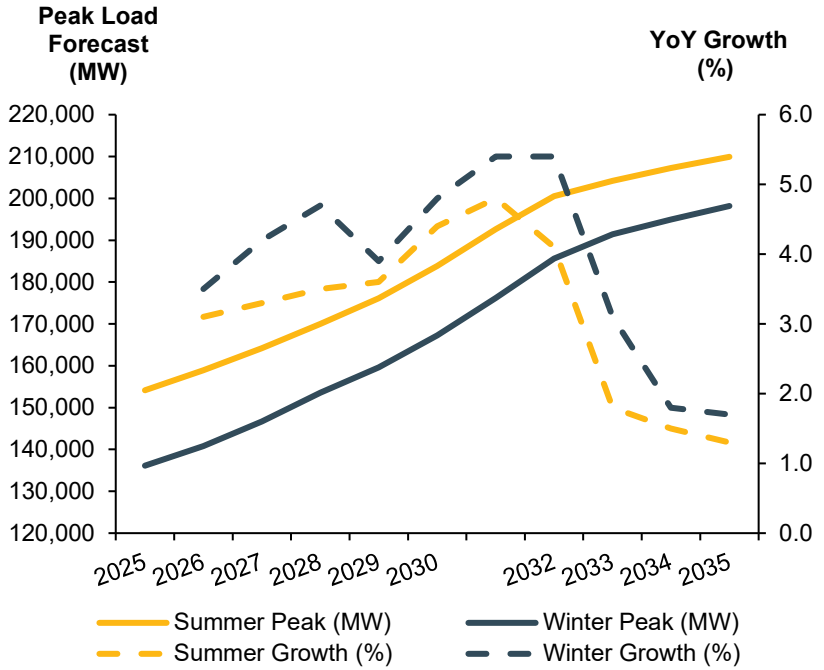
Source: [1] PJM, "2025 Load Forecast Tables", available at https://www.pjm.com/-/media/DotCom/planning/res-adeq/load-forecast/2025-load-report-tables.xlsx.

Expected Gap Between Summer and Winter Loads

Winter peaks expected to continue modest growth relative to summer peaks

- The PJM-wide region is expected to be summer-peaking through the 2030s
- However, winter peak load is expected to grow faster than the summer, especially in shorter-term forecasts
  - PJM 2025 Load Forecast Report projects RTO-wide 10-year average annual winter growth at 3.8%, summer growth at 3.1%
- Winter peak load growth driven by expected transportation and heating electrification (*e.g.*, heat pumps)
- Summer peak load growth moderated by rooftop solar

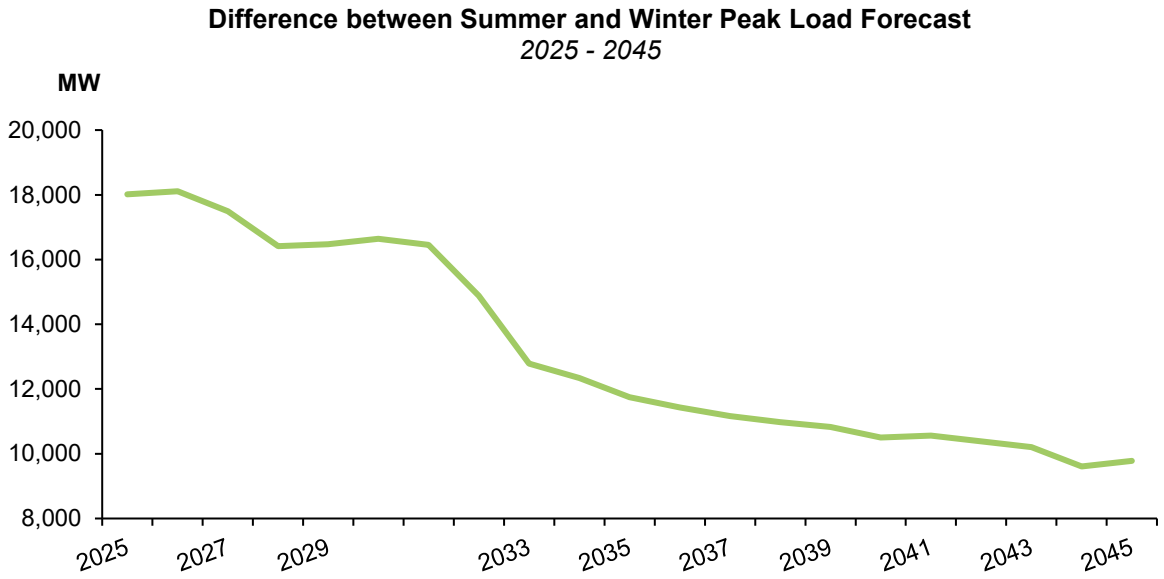
PJM RTO-Wide 2025 Peak Load Forecast
2025-2035



Sources: [1] PJM, "2025 Load Forecast Report Tables", available at https://www.pjm.com/-/media/DotCom/planning/res-adeq/load-forecast/2025-load-report-tables.xlsx. [2] PJM, "PJM Long-Term Load Forecast Report", January 24, 2025, p. 6. [3] PJM, "ELCC Class Ratings for the 2026/2027 Base Residual Auction", https://www.pjm.com/-/media/DotCom/planning/res-adeq/elcc/2026-27-bra-elcc-class-ratings.pdf.

Expected Gap Between Summer and Winter Loads

Gap between summer and winter peak loads projected to shrink



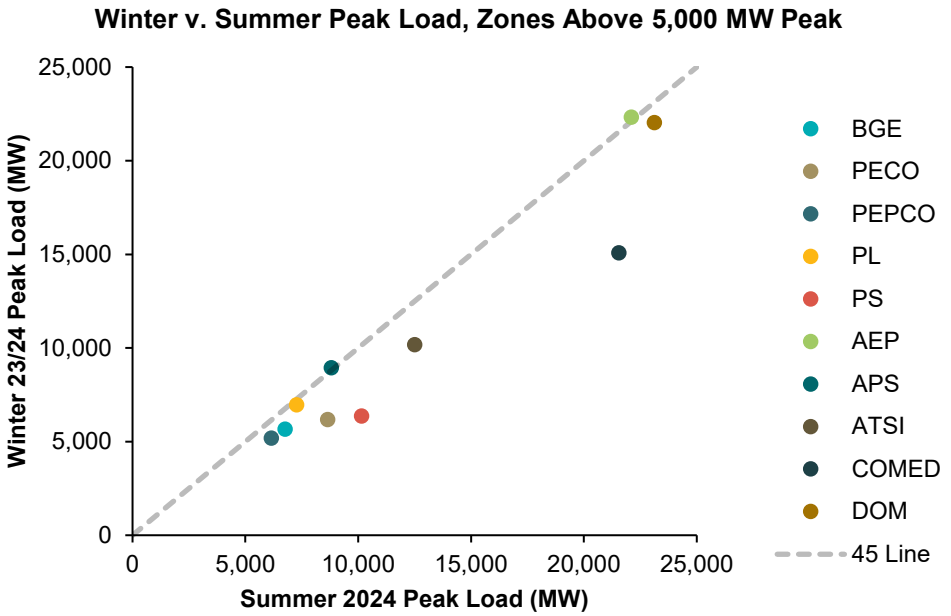
PJM forecasts that the gap between summer and winter peak loads will drop from 18,000 MW in 2025 to less than 10,000 MW in 2045

Source: [1] PJM, "2025 Load Forecast Report Tables", available at https://www.pjm.com/-/media/DotCom/planning/res-adeq/load-forecast/2025-load-report-tables.xlsx.

Locational Variation in Summer and Winter Peak Loads

PJM system includes summer and winter peaking zones

- Currently, gap between summer and winter peaks differs across the region
- Three out of 21 zones are currently winter-peaking
  - APS: Allegheny Power Systems
  - AEP: American Electric Power
  - EKPC (smaller than 5,000 MW, not shown in figure)
- Summer-winter ratio differs across the region
  - Commonwealth Edison (COMED) has the largest summer-winter ratio of zones above 5,000 MW (1.43)



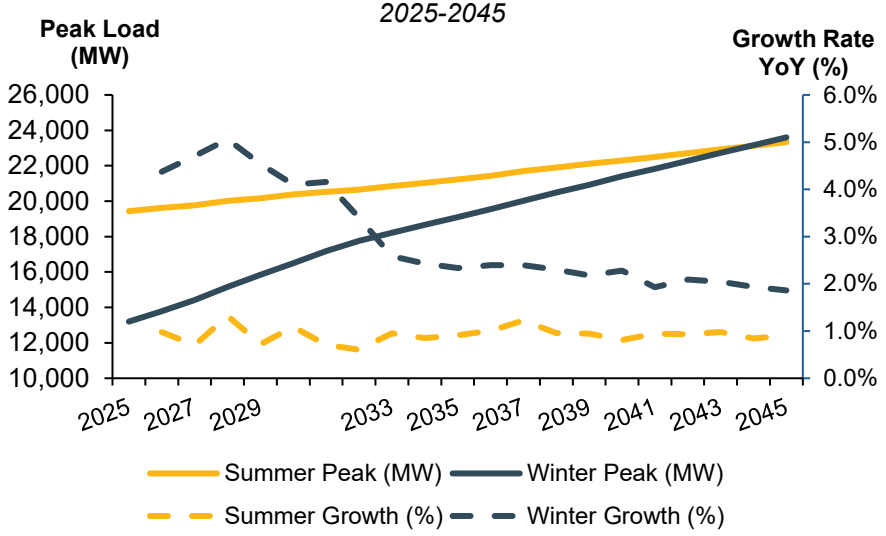
Source: [1] PJM, "2025 Load Forecast Report Tables", available at https://www.pjm.com/-/media/DotCom/planning/res-adeq/load-forecast/2025-load-report-tables.xlsx.

Locational Variation in Summer and Winter Peak Loads

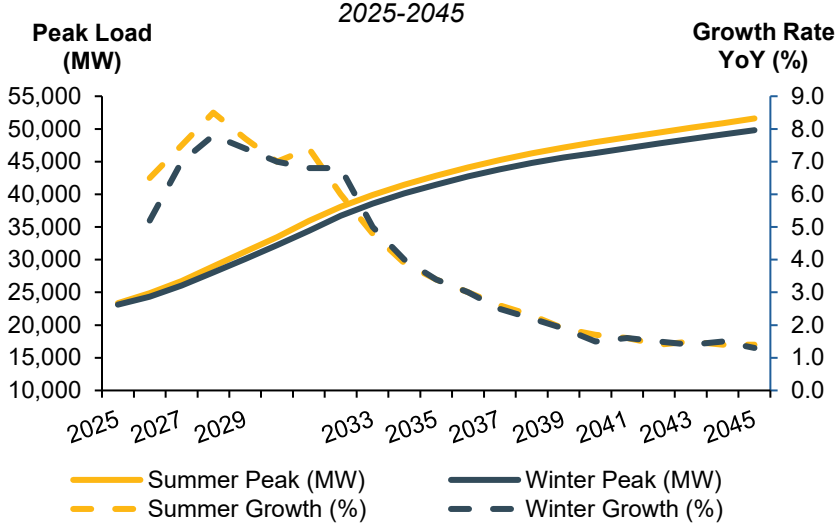
Trends in summer/winter peak load ratios are expected to vary across zones

- For example:
  - New Jersey zones are expected to be winter-peaking by 2044 with NJ policy supporting electrification of homes and commercial spaces
  - Dominion (DOM) sees high growth rates across both seasons driven by large loads

New Jersey (AE, JCPL, RECO, PS) Forecasted Peak Load
2025-2045



Dominion (DOM) Forecasted Peak Load
2025-2045

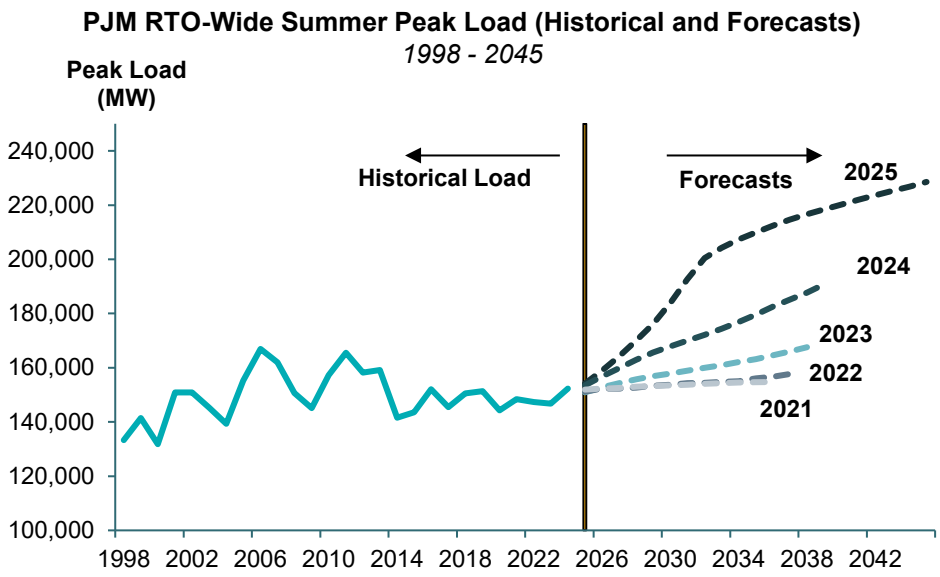


Source: [1] PJM, "2025 Load Report Tables", available at https://www.pjm.com/-/media/DotCom/planning/res-adeq/load-forecast/2025-load-report-tables.xlsx. [2] PJM, "PJM Long-Term Load Forecast Report", January 24, 2025, available at https://www.pjm.com/-/media/DotCom/library/reports-notices/load-forecast/2025-load-report.pdf, p. 8. [3] PJM, "Energy Transition in PJM 2023", February 24, 2023, available at https://www.pjm.com/-/media/DotCom/library/reports-notices/special-reports/2023/energy-transition-in-pjm-resource-retirements-replacements-and-risks.ashx, p. 14.

Data Center Growth

Tightening capacity market due to rapid load growth

- Historically, PJM experienced relatively flat load growth, but current forecasts show major increase



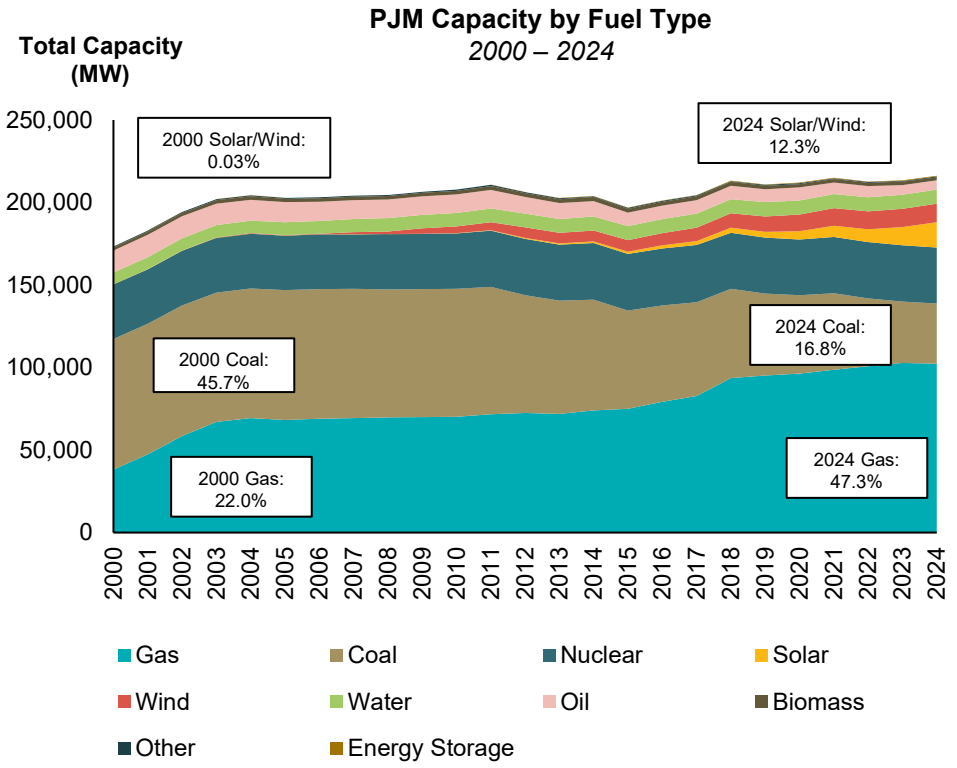
- Rapid forecasted demand growth driven by large loads (*i.e.*, data centers)
  - PJM projects data centers will be 12% of summer peak by 2030
  - Large regional variation–*e.g.*, ~83% increase in Dominion summer peaks (including "Data Center Alley") from 2025 to 2035
  - *Substantial* uncertainty about actual growth
- Short-term tightening of demand and supply → clearing at steeper part of demand curve and/or price caps
- Impacts on: summer/winter relative peaks (given varying regional summer/winter peak ratios); ELCCs (system-wide v. zonal), etc.

Sources: [1] PJM, "2025 Load Forecast Tables", available at https://www.pjm.com/-/media/DotCom/planning/res-adeq/load-forecast/2025-load-report-tables.xlsx. [2] PJM, "2025 Load Forecast Report", p. 6. [3] PJM, "Load Growth in PJM", 2024, available at https://opsi.us/wp-content/uploads/2024/10/4.-20241022-McGlynn-OPSI-Load-Growth-Slides-Session-4.pdf, p. 8.

Capacity Resources

Technology performance varies across seasons

- Resource mix is gradually changing
  - Increased reliance on gas
  - Growth in solar and wind
  - Renewables account for majority (~82%) of generation queue
- Extreme weather impacts resource performance
  - More severe weather conditions, particularly in the winter (e.g., long periods of extreme cold) → increased correlated outage risk



Sources: [1] PJM, "Energy Transition in PJM", February 24, 2023, available at https://www.pjm.com/-/media/DotCom/library/reports-notices/special-reports/2023/energy-transition-in-pjm-resource-retirements-replacements-and-risks.ashx, p. 13. [2] S&P Capital IQ, PJM Historical and Future Power Plant Capacity.

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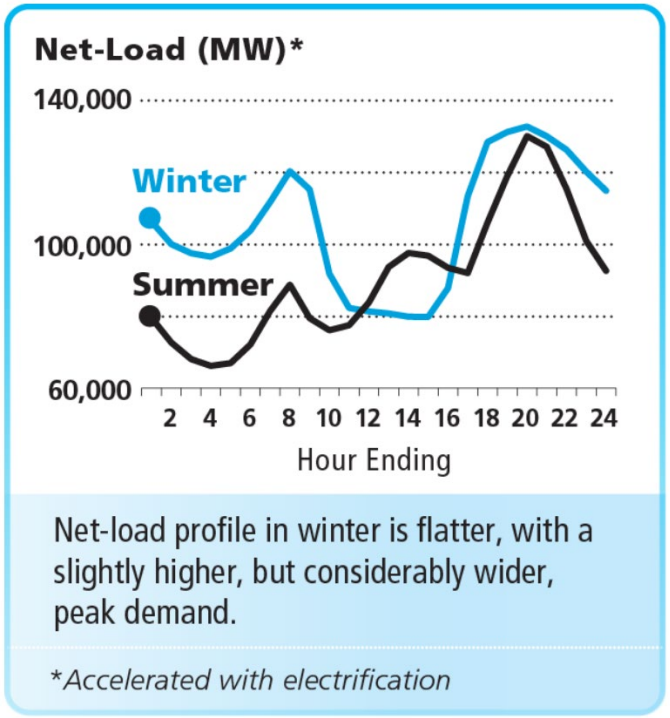
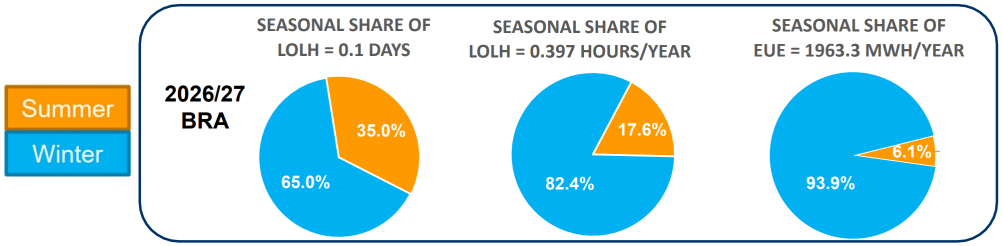
Current Summer / Winter Risks

Fuel security risk differs in summer vs. winter

- Event duration and size differ across seasons:
  - Summer events are shorter, with smaller shortfalls
  - Winter events are longer, with larger shortfalls
- Different seasonal patterns reflect:
  - Greater energy/fuel shortfall – rather than capacity shortfall – in winter
  - Intra-day pattern of heating and electric generation in high demand periods

Hourly Net Load in Summer and Winter
PJM, 2022 Study





Sources: [1] PJM, "Energy Transition in PJM: Emerging Characteristics of a Decarbonizing Grid", May 17, 2022, p. 3. [2] PJM, "2026/27 BRA IRM, FPR and ELCC Class Ratings", March 13, 2025, available at https://www.pjm.com/-/media/DotCom/committees-groups/committees/pc/2025/20250313-special/2026-2027-irm-fpr-elcc-and-winter-risk.pdf, p. 8. [3] PJM, "2025 PJM Effective Load Carrying Capability and Reserve Requirement Study", October 22, 2025, available at https://www.pjm.com/-/media/DotCom/planning/res-adeq/elcc/2025-pjm-elcc-rrs.pdf, p. 50.

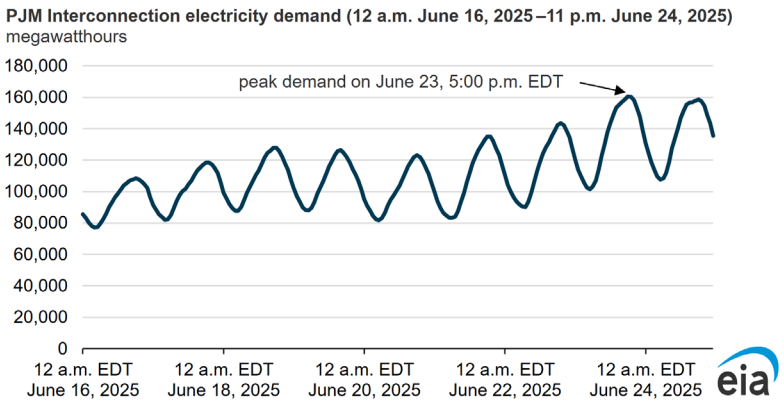
Recent Emergency Events

Recent emergency events consistent with modelled summer/winter differences

Winter events extend across multiple days, while summer events are characterized by sharp peaks in concentrated periods

PJM '25 Summer Peak

Electricity Demand Surged from Heat Wave

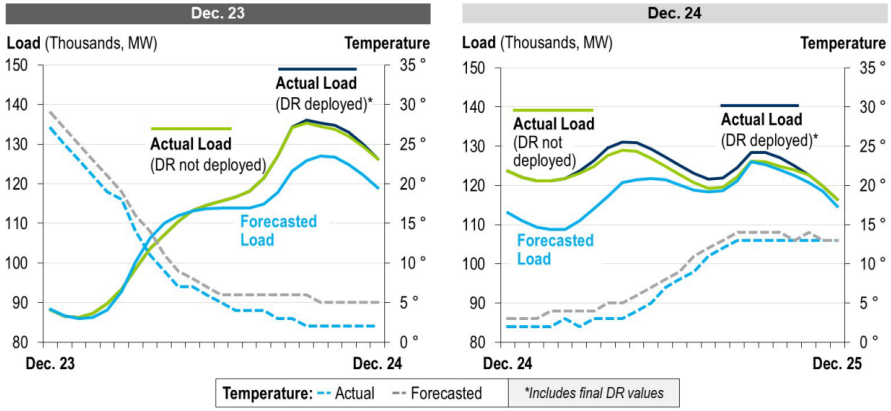


- Electricity demand reached multi-year high on June 23, 2025, due to a heat wave
- PJM's 2024 top 5 coincident peaks were **heavy peaks** >147,000 MW, all at 6 PM

- In December 23-25, 2022, Winter Storm Elliott brought extreme cold to the region
- Sustained period of elevated load, with shallow throughs

Winter Storm Elliott

Multi-day, Elevated Demand



Sources: [1] PJM, "Winter Storm Elliott Analysis and Recommendation", July 17, 2023, available at https://www.pjm.com/-/media/DotCom/library/reports-notices/special-reports/2023/20230717-winter-storm-elliott-event-analysis-and-recommendation-report.pdf, p.39. [2] EIA, "Today in Energy", June 2025, available at https://www.eia.gov/todayinenergy/detail.php?id=65604. [3] PJM, "Summer 2024 RTO Coincident Peaks (MW)", November 14, 2024, available at https://www.pjm.com/-/media/DotCom/planning/res-adeq/load-forecast/summer-2024-peaks-and-5cps.ashx, p. 2.

Implications

Changing system and market conditions have varying implications for sub-annual nature of resource adequacy risk

Changing Market/System Condition	Implication for Resource Adequacy (*all else equal*)
Winter peaks growing relative to summer peaks	• Increasing resource adequacy risk in winter relative to summer
Winter load distribution differs from summer	• Resource adequacy risks will not reflect only magnitude of the peak
Sub-annual variation in technology performance	• Value provided by resources varies by sub-annual period • Aggregate supply of capacity varies by sub-annual period
Changes in the mix of resources in and entering the system	• Value provided by resources evolves over time • Aggregate supply of capacity evolves over time
Rapid load growth driven by large loads (*e.g.*, data centers)	• Affects all factors listed above given regional variation in load growth, impact on ELCCs, etc.

Uncertainty and on-going evolution of all market/system conditions

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Potential Benefits of Sub-Annual Markets

Objectives of Capacity Markets

Dual objectives of reliability and economic efficiency

Need for sub-annual market should be grounded in standard electricity market design criteria:

Reliability

- Provide "missing money" to secure sufficient resources to meet the resource adequacy target (*i.e.*, 1-in-10 LOLE)
- Reliably and sustainably meet this objective – *i.e.*, ensure the system can adjust to changing demands, market conditions and technologies

Economic efficiency

- **Productive efficiency:**
  - Achieve a given level of resource adequacy (e.g., the target) at the lowest economic cost
  - Achieve the most reliable outcome for a given cost (to the extent that realized resource adequacy differs from the target)
- **Allocative efficiency:**
  - Create price signals that consistently reflect the value of capacity in reducing risk (e.g., expected unserved energy) to incentivize short-term allocation and long-term investment

Potential Benefits of Sub-Annual Markets

Sub-annual market increases granularity in capacity market

Increased granularity can address changing system and market conditions

- Differences in the value of incremental capacity in reducing resource adequacy risks across sub-periods
- Differences in particular resources' ability to mitigate resource adequacy risks across sub-periods
- Differences in resources' costs of supplying capacity across sub-periods

Sub-annual market can better address challenges of changing system and market conditions

- Provides **flexible market** that adjusts to changes in resource mix and customer demands
- Provides **more accurate price signals** reflecting supply and demand in each sub-period
- May result in **less volatile pricing** (*e.g.*, under changes in relative supply across sub-periods)

Potential Benefits of Sub-Annual Markets (cont.)

Sub-annual market increases granularity in capacity market

1. Improves market efficiency
2. Lowers costs
3. Improves reliability and quality of service

Improves short-term allocation of resources

Improves long-term investment decisions

Improvements in market outcomes need to be weighed against incremental administrative costs of implementing market changes and any on-going increase in annual administrative costs

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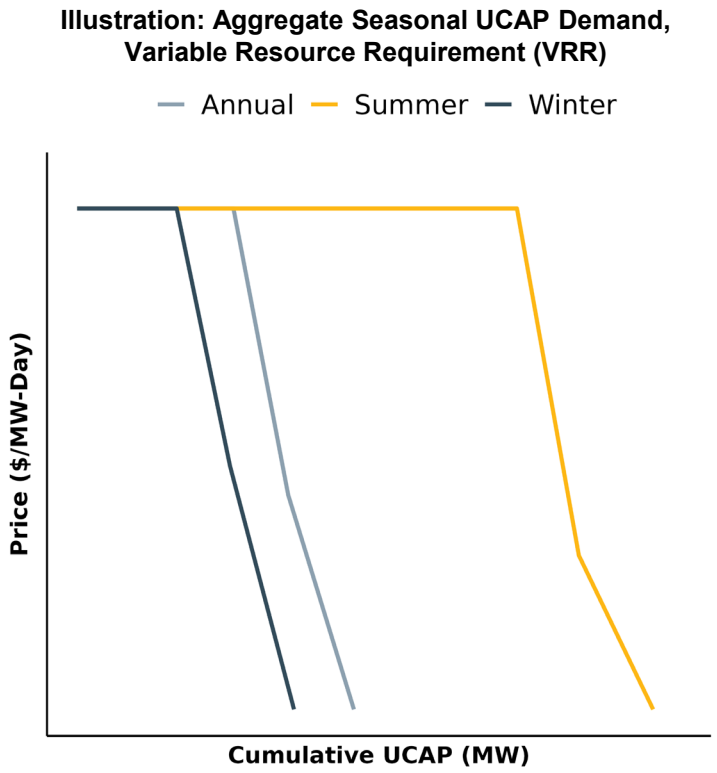
Accounting for Sub-Annual Variation in Value of Marginal Capacity

Sub-annual market increases granularity in capacity market



- Value of incremental capacity (UCAP) can vary across sub-periods
  - Value of capacity in winter *de minimis* at lower capacity than summer
  - Demand curve slope (reflecting WTP above/below requirement) can vary across sub-periods
- A sub-annual market can account for these differences

Note: illustrated demand curves assume an equal price cap by sub-period. There are other approaches, and use of this approach for this illustration does not represent an endorsement of this approach

Accounting for Resource Performance

Aligns individual resource compensation with performance

- Capacity resources' ability to mitigate resource adequacy risks varies across sub-periods
- A sub-annual market can account for differences in each resource's capacity accreditation across sub-periods – this has multiple effects
- ***First***, resources are compensated based on sub-period accreditation
- This better aligns compensation and incentives with the value of the service provided by resources

Resource Class	2026/2027 BRA ELCC Annual	Estimated 2026/2027 BRA ELCC Summer	Estimated 2026/2027 BRA ELCC Winter
Nuclear	95%	96%	95%
Coal	83%	86%	82%
Gas Combined Cycle	74%	95%	71%
Gas Combustion Turbine	60%	96%	54%
Onshore Wind	41%	10%	46%
Offshore Wind	69%	22%	77%
Solar Fixed Panel	8%	22%	6%
Solar Tracking Panel	11%	32%	7%
4-Hr Battery Storage	50%	94%	43%

Sources: [1] PJM, "2026/27 BRA IRM, https://www.pjm.com/-/media/DotCom/committees-groups/committees/pc/2025/20250313-special/2026-2027-irm-fpr-elcc-and-winter-risk.pdfFPR, and ELCC Class Ratings", March 13, 2025, available at, p.25. [2] PJM, "ELCC Class Ratings for the 2026/2027 Base Residual Auction", https://www.pjm.com/-/media/DotCom/planning/res-adeq/elcc/2026-27-bra-elcc-class-ratings.pdf, p. 1.

Accounting for Resource Performance (cont.)

Improves stability of ELCC resource accreditation

- ***Second***, current annual ELCC ratings demonstrate some year-to-year variability driven largely by changes in the relative share of seasonal risk (due to, *e.g.*, large load additions and changing load profiles)
  - Variability in ELCCs has been identified as a concern of certain capacity suppliers
- Sub-annual market will reduce variability from changes in relative seasonal risk, likely diminishing ELCC year-to-year variability
  - Lower ELCC variability can benefit market participants by supporting financial hedging of RPM positions

Evolution of PJM's ELCC Values
2025/26 – 2027/28

Delivery Year	Nuclear	Coal	Gas CC	Offshore Wind	Solar Fixed Panel	4-Hr Battery Storage
DY 2025/26	95%	84%	79%	60%	9%	59%
DY 2026/27	95%	83%	74%	69%	8%	50%
DY 2027/28	95%	83%	74%	67%	7%	58%

Accounting for Resource Performance (cont.)

Improves stability of ELCC resource accreditation

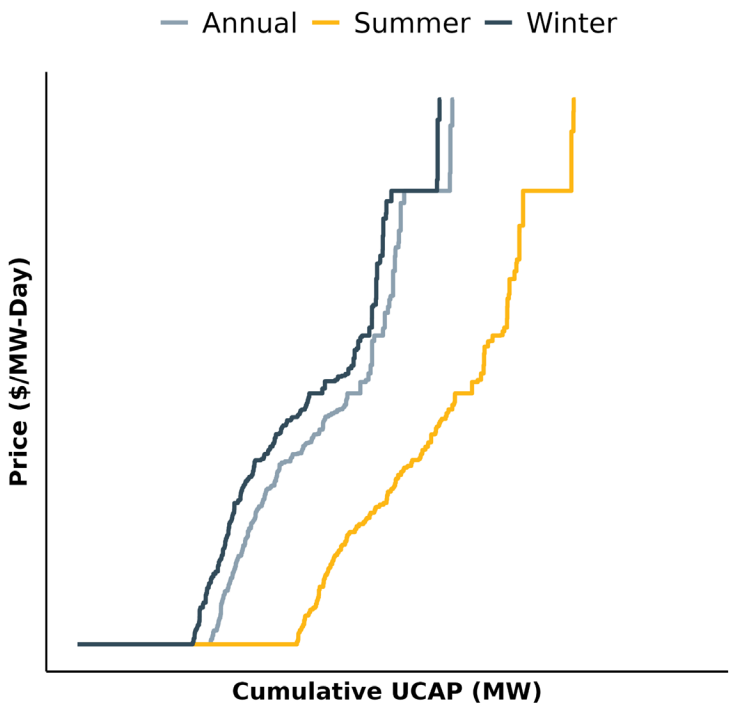
- ***Third,*** a sub-annual market can improve the representation of resource adequacy within LDAs by improving the accuracy of resource accreditation for resources within LDAs
  - At present, ELCC values for all resources – inside and outside LDAs – reflect an RTO-level system and risk patterns, not performance reflecting specific transmission constraints and local LDA system conditions and risk patterns
  - Thus, measured (RTO) annual ELCC values may differ from the actual LDA values due to multiple factors, such as differences between RTO and LDA sub-annual risk profiles and system/resource conditions
- A sub-annual market can mitigate differences in RTO and LDA ELCC values associated with differences in sub-period relative RA risk
- Improved alignment of accredited UCAP within LDAs can lead to more accurate LDA pricing and improved investment signals, by more accurately representing the impact of deliverability constraints and the locational value of resources

Accounting for Resource Performance (cont.)

Pricing that reflects aggregated performance of all capacity resources

- ***Fourth***, with sub-period accreditation, market clearing reflects the aggregate capacity (UCAP) that resources supply given the actual capabilities of the fleet's resources
- Total capacity (UCAP) can vary across sub-periods given differences in accreditation across sub-periods
- At present:
  - Summer UCAP is greater than winter UCAP
  - The difference is driven by many factors, including lower winter gas resource accreditation
  - Supply that is based on annual accreditation is similar to the winter supply given the larger share of total risk in the winter period

Illustration: Aggregate Seasonal UCAP Supply, Based on Estimated 27/28 Class Average Accreditation Values



Capacity Resource Supply

Helps recognize and bring more supply to the system

- In the current annual market, differential resource capability/performance across seasons creates an asymmetric financial risk given an annual “average” ELCC and capacity performance (CP)
- Matched seasonal offers are currently offered to allow market participants to manage this risk; however, this option may constrain clearing of supply facing this risk
- A sub-annual market can mitigate this constraint:
  - By better matching ELCCs with likely performance, a sub-annual market can better align CP financial risks with resource capabilities
  - Improved alignment can reduce reliance on matching seasonal offers, which may increase liquidity and resource supply

Accounting for System Performance

Locational pricing that reflects sub-period deliverability

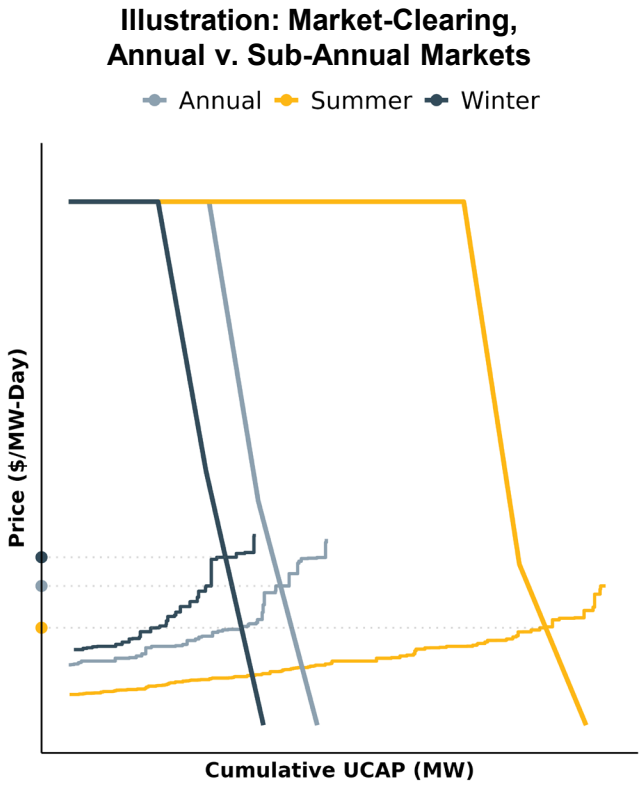
- Transmission resources' ability to deliver electricity varies with many factors, including weather conditions and system resources
- A sub-annual market can account for differences in deliverability across sub-periods and thus improve price signals within transmission-constrained localities
- In PJM:
  - Deliverability measured by Capacity Emergency Transfer Limits (CETLs), which capture deliverability of capacity resources to locations
  - At present, CETLs are set to reflect summer ratings, although winter CETLs would likely be higher
  - A sub-annual market could account for sub-period CETLs, which would likely lower winter locational prices (all else equal)

More Accurately Accounts for Demand and Supply

Pricing that reflects net effect of demand and supply changes

- Market-clearing prices reflect adjustments to both demand and supply that capture sub-period characteristics
- Sub-annual market creates differential price signals reflecting marginal value of UCAP in each sub-period
- Sub-annual market allocates short-term UCAP procurement with value of marginal resources across sub-periods
- Sub-annual market improves efficiency of long-term capital decisions (new investment and retirement)

Illustrative sub-annual market reveals greater price/value of UCAP in winter than summer:
- Creates incentives for technologies that have greater relative UCAP in winter than summer
- Creates incentives for supply and investments in greater winter UCAP

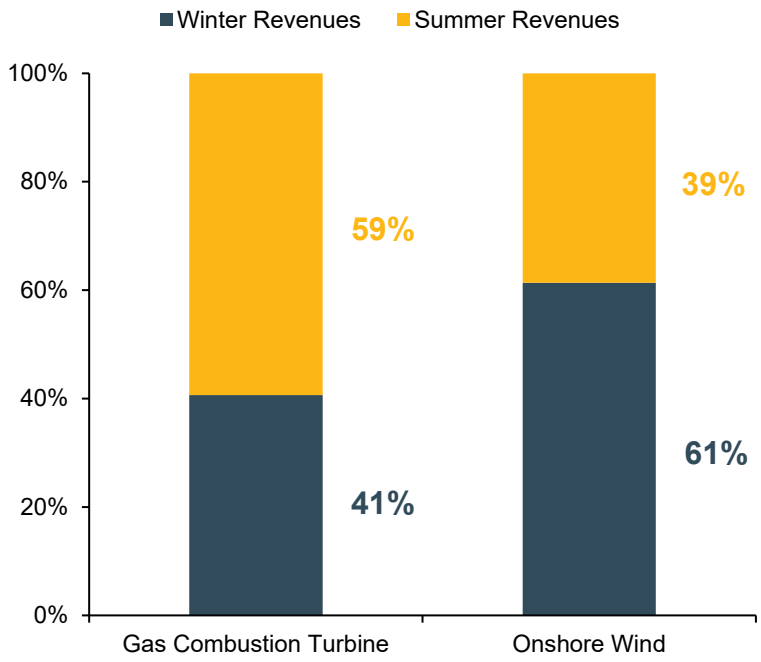


More Accurately Accounts for Costs

Resource costs can vary across sub-periods

- Resource costs of supplying capacity ("missing money") may vary across sub-periods
  - **Avoidable Cost Rate (ACR):** Elements of ACR may vary with sub-periods (*e.g.*, winter weatherization costs)
  - **Net EAS Offset:** The net EAS Offset can vary across sub-periods, with technology classes earning greater revenues in one sub-annual period than the other

Seasonal Net EAS Revenues, as a Fraction of Annual Revenues
Gas Combustion Turbine and Onshore Wind



Source: [1] Hourly Net EAS by Zone and Technology Type, provided by PJM.

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Next Steps

Next Steps

- Stakeholder presentations in November and December
- Final Report posted on December 19, 2025
- Stakeholder presentation (report review) following the report release in January

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Thank You

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