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Evaluation of Sub-Annual Designs for PJM's RPM

Discussion of Scope and Approach

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Agenda

- Assignment, Scope and ISO-NE Study Experience
- Overview of Sub-Annual Market Assessment
- Description of Quantitative Analysis: Capacity Market Model
- Next Steps

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Assignment, Scope and ISO-NE Study Experience

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Context

Changes in Region's Grid Prompting Consideration of Capacity Market Changes

- PJM and its stakeholders are considering modifications to approaches used to achieve resource adequacy
- One particular modification is a **sub-annual capacity market**
  - Proposed previously by PJM in 2023
  - Now of interest to PJM stakeholders based on the approved Issue Charge brought forward by Governor Shapiro's office.

- Analysis Group has been asked to prepare a report evaluating sub-annual markets, to The Sub-Annual Capacity Market Senior Task Force to be responsive to the Issue Charge.

ISO New England Experience

Changes in Grid Prompted Consideration of Capacity Market Changes

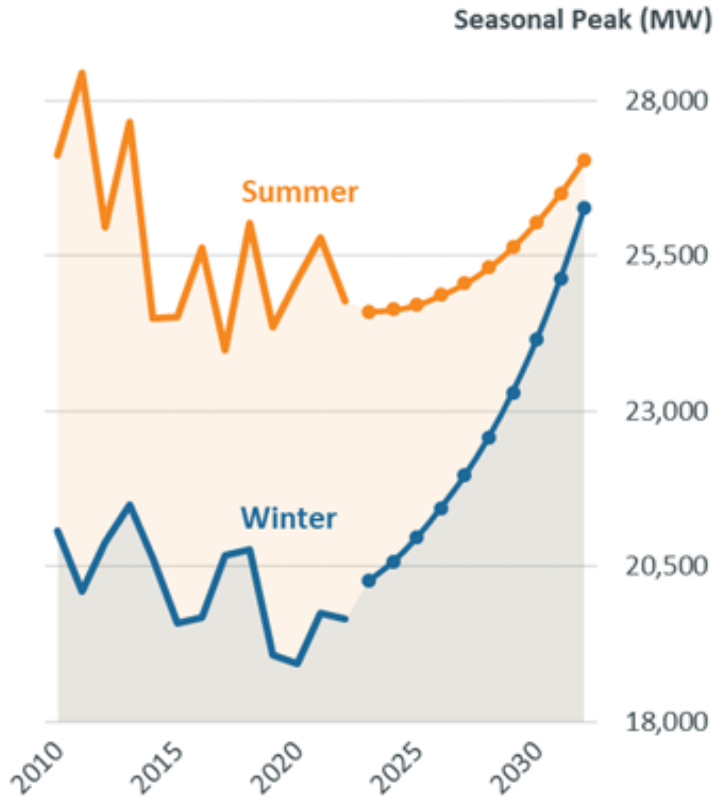
- Analysis Group recently completed an analysis of sub-annual markets for **ISO New England**
- New England's electricity system and markets are undergoing *many* changes that affect resource adequacy outcomes given, in part:
  - **growth in demand** from electrification
  - **weather-related reliability risks**
  - **technological innovation** improving the performance and cost of new technologies (e.g., intermittent renewables, storage)
  - **state energy policies**, many aimed at decarbonizing the region's grid
- PJM's markets are experiencing many of the same impacts as well as others not prevalent in New England (e.g., growth in demand from data centers)

ISO New England Experience

Changes in Region's Demands on System Resources

- **Changes in the profile of resource adequacy risks** across the year
  - Increase in winter peaks relative to summer due to electrification of heating and transport
  - Evolving understanding of impact of winter fuel risks, including gas and oil system constraints, in affecting longer duration energy constraints

ISO-NE Forecast of Summer and Winter Net Peak Demand



Source: ISO-NE 2023 Regional System Plan

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ISO New England Experience

Changes in Region's Demands on System Resources

- Increased spreading of resource adequacy risk throughout the year, rather than predominately during (summer) peak load periods

ISO-NE Forecast Loss of Load Hour Distribution, FCA 16, 2025-26

Hour of Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	-	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-	-	-	-
8	0.02%	-	-	-	-	-	-	-	-	-	-	-	0.02%
9	0.06%	-	-	-	-	-	-	-	-	-	-	<0.005%	0.06%
10	0.05%	-	-	-	-	-	-	-	-	-	-	<0.005%	0.05%
11	0.04%	-	-	-	-	<0.005%	-	-	-	-	-	<0.005%	0.04%
12	0.03%	-	-	-	-	0.02%	-	<0.005%	-	-	-	<0.005%	0.06%
13	0.04%	<0.005%	-	-	-	0.31%	<0.005%	0.01%	-	-	-	0.01%	0.37%
14	0.04%	<0.005%	-	-	-	1.56%	<0.005%	0.26%	-	-	-	0.02%	1.89%
15	0.06%	<0.005%	-	-	-	3.35%	0.02%	1.50%	-	-	-	0.03%	4.95%
16	0.09%	<0.005%	-	-	-	4.81%	0.04%	3.82%	-	-	-	0.09%	8.85%
17	0.23%	<0.005%	-	-	-	6.07%	0.11%	6.43%	<0.005%	-	-	0.45%	13.28%
18	4.51%	<0.005%	-	-	-	7.69%	0.19%	9.80%	<0.005%	-	-	2.67%	24.87%
19	2.57%	<0.005%	-	-	-	6.92%	0.11%	7.93%	<0.005%	-	-	1.64%	19.18%
20	2.57%	<0.005%	-	-	-	5.52%	0.02%	5.64%	<0.005%	-	-	1.51%	15.28%
21	0.99%	<0.005%	-	-	-	3.70%	0.01%	3.06%	<0.005%	-	-	0.73%	8.49%
22	0.43%	<0.005%	-	-	-	1.37%	<0.005%	0.42%	<0.005%	-	-	0.32%	2.55%
23	0.05%	<0.005%	-	-	-	<0.005%	-	<0.005%	-	-	-	<0.005%	0.06%
24	<0.005%	-	-	-	-	-	-	-	-	-	-	-	<0.005%
Monthly	11.79%	0.03%	-	-	-	41.31%	0.50%	38.87%	<0.005%	-	-	7.49%	100.00%

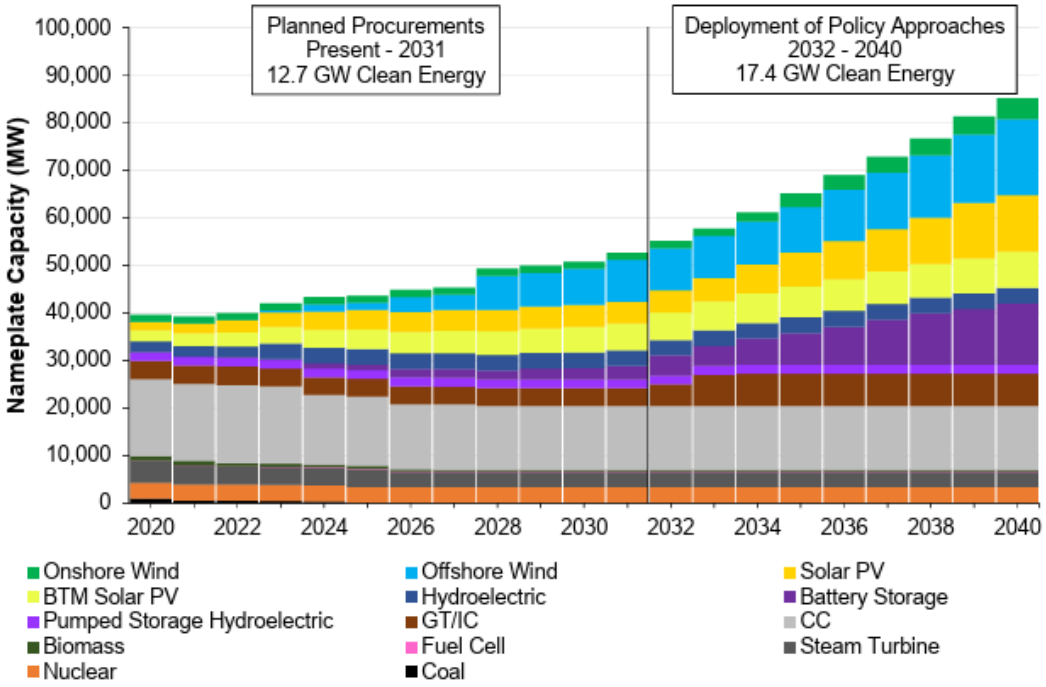
Source: ISO-NE, Resource Capacity Accreditation, FCA16 Base Case, April, 2023

ISO New England Experience

Changes in Region's Grid Prompting Consideration of Capacity Market Changes

- **Changes in the resource mix** in and entering the system, with increases in non-emitting resources and new technologies (e.g., intermittent renewables, storage) and reductions in dispatchable fossil resources
- Sub-annual variation in resources' contributions to achieving resource adequacy
  - For example, weather-dependent intermittent renewables, storage resources (given character of resource adequacy risks), gas-dependent resources (if gas system is potentially constrained or at risk to contingencies)

ISO-NE Actual and Forecast Resource Mix Under Planned Procurement and Policy Targets



Source: Analysis Group, Pathways Study, 2022

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ISO New England Experience

Plan to Begin Market Design Phase in 2026

- Analysis Group study recommended that the region pursue seasonal market (and prompt market) enhancements to ISO-NE forward-annual capacity market
- ISO-NE proposed and FERC approved plan to delay next capacity auction (FCA19) until February 2028, for capability period 2028/29
- Provides region with opportunity to modify market to implement:
  - Prompt market structure (market design in 2025)
  - Seasonal market structure (market design planned for 2026)

Assignment

Assess Prompt and Seasonal Capacity Market Approaches

- Analysis Group Report will evaluate potential for sub-annual (seasonal) market design for PJM's Reliability Pricing Model (RPM)
- The report will:
  - Describe the general features of sub-annual markets
  - Identify specific design features and alternatives approaches (but not develop detailed designs)
  - Provide information on the potential tradeoffs (impacts) from switching to a sub-annual market
  - Identify issues that would need to be addressed if the region pursues a sub-annual market
  - Provide recommendations

Approach

Analytic, Quantitative and Non-quantitative Approaches

- Study will draw on multiple sources of information
  - Metrics relevant to current and forecast sub-annual resource adequacy in PJM
  - Experience from other ISOs/RTOs (particularly, ISO-NE, MISO, NYISO)
  - Analytic/economic models
  - Modeling analysis to quantify changes in certain market outcomes, including prices, quantities and costs – *not* a full analysis of a complete design proposal
- Evaluation to reflect multiple criteria, including economic efficiency, customer payments, and reliability
  - Alignment with existing RPM criteria (locational price signals, technology neutrality, performance incentives, long-term investment signals, etc.)
- Study will consider interactions with other aspects of PJM capacity market design
  - Forward market structure (rather than prompt/spot market structure)
  - Linear demand (VRR) curve (rather than demand curve reflecting marginal ELCC/MRI)
- Study will consider transition issues, including potential options and impacts

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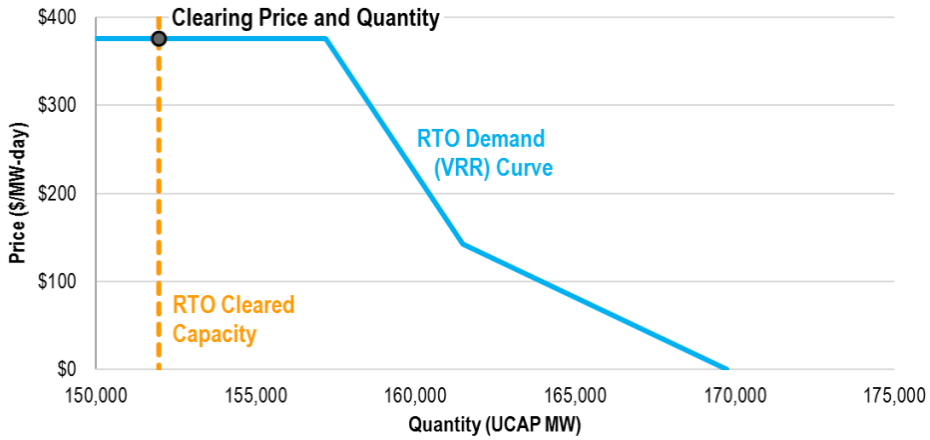
Overview of Sub-Annual Market Assessment

Existing Forward Capacity Market

Annual Capacity Product

- In the current capacity market, capacity is procured through a single annual auction procuring an annual capacity product
  - When designed, annual product covered resource adequacy risks that occurred primarily (if not exclusively) in summer
  - System and market conditions may make this model less suitable for current market conditions – e.g., resource adequacy risk spread throughout the year (including winter fuel/energy security risks), season-varying resource contributions to resource adequacy

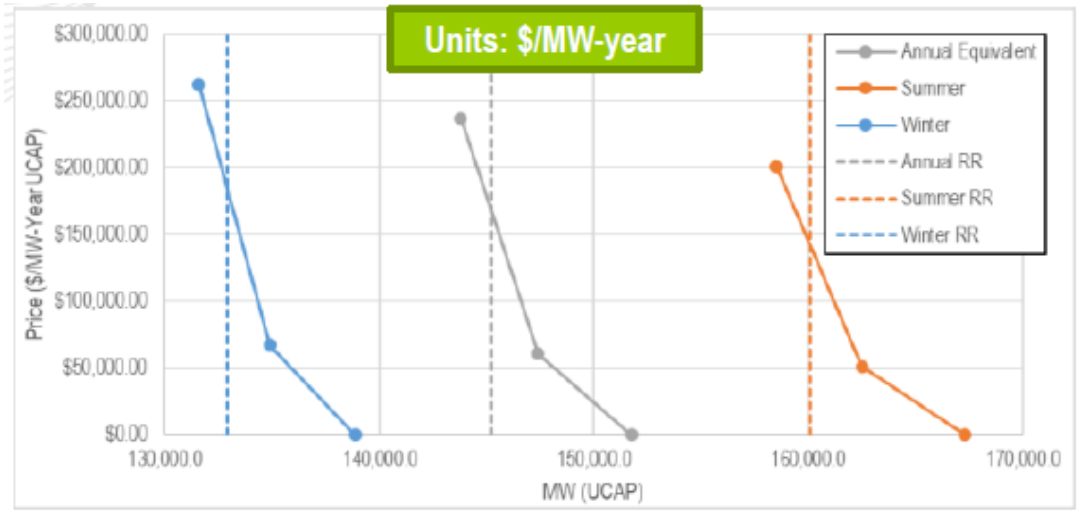


Sub-Annual Market

Sub-Annual Market Increases Granularity in Capacity Market

- With a sub-annual market, capacity is procured through multiple sub-annual products (e.g., 2 or 4 sub-annual products) rather than one product
- Resource adequacy reflects the cumulative effect of sub-annual market outcomes
- In principle, increased granularity can:
  - **Improve efficiency** – 1-in-10 resource adequacy target achieved at lower cost
  - **Improve reliability/quality of service** – accreditation that more accurately reflects resources' varying sub-annual contributions to resource adequacy

Illustrative Annual and Sub-Annual Demand Curve



Sub-Annual Market Assessment

Multiple Impacts to Demand and Supply

- Demand for capacity (through the demand curves) can reflect:
  - The value of capacity in reducing resource adequacy risks given season-specific (marginal) reliability impacts
  - Seasonal differences in contributions to resource adequacy given the need to ensure sufficient revenues for new entry at the reliability criteria
    - That is, seasonal demand curves must ensure that revenues across seasons cover the cost of new entry if sum of reliability impacts (LOLE) across seasons (given cleared capacity in each season) exceeds the 0.1 days/year reliability criterion
- Supply offers for capacity can reflect:
  - Seasonal differences in resource contributions to resource adequacy
  - Seasonal differences in going-forward costs given seasonal differences in operating cost, net energy market revenues and costs per unit of capacity (given resource accreditation differences)

Sub-Annual Market Assessment

Sub-Annual Market Would Affect All Market Features

- Number and length of seasons (e.g., 2 vs. 4 seasons, equal/varying-length seasons)
- Demand
  - Sub-annual demand curves
  - Demand curve requirements (e.g., cumulatively meet 1-in-10 annual requirement)
- Supply
  - Sub-annual resource capacity ratings, resource accreditation, and resource qualifications
  - Sub-annual CETL values
  - Sub-annual capacity obligations and charges, including potential changes to planned maintenance and outage rules
- Fixed Resource Requirement – potential changes to align with the sub-annual capacity market design

Sub-Annual Market Assessment

Sub-Annual Market Would Affect All Market Features

- Auction
  - A sub-annual auction structure with sub-annual clearing prices sufficient to compensate generator annual revenue requirements.
  - Sub-annual resource offer caps and minimum offer price requirements if capable of exerting buyer side market power.
  - Simultaneous v. sequential auctions
  - Offer structure (e.g., seasonal and annual offer requirements)
- Energy and reserve market – potential changes to must offer requirements (e.g., sub-annual requirements)
- Market mitigation
- Transition mechanisms necessary to implement a sub-annual capacity market by the desired timeframe.

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Description of Quantitative Analysis: Capacity Market Model

Modeling Analysis

Quantitative Analysis of Sub-Annual Market Impacts

- Quantitative analysis will compare annual and sub-annual market outcomes
  - Provides information on expected impacts to prices, payments and quantity of capacity procured (with implications for reliability)
  - Provides concrete illustration of the impact of sub-annual market design on market-clearing and outcomes
  - Analysis will be built on a simulation of RPM capacity auction clearing
- Presentation today provides ***preliminary*** thinking about modeling analysis

Model Overview

Capacity Market Simulation Model Structure

- The capacity market model simulates capacity auction outcomes
  - Market outcomes reflect the market-clearing price and quantity given a supply curve comprising offers from existing and new resources at their net going forward cost (GFC) and the administratively determined demand curve
  - Simulation designed to capture key – but not all – features of PJM's RPM
  - Analysis designed to reliably capture *impacts* of changes in market rules
  - Analysis reflects static scenarios – it is *not a forecast* and *does not account for dynamic market responses* such as entry and retirements (across commitment periods)

Market-Clearing

Market-Clearing Reflects Intersection of Supply and Demand

- Auction determines CSOs and prices through optimization of the objective function (cost-minimization)
- Result is market-clearing where offer curve intersects demand curve (conditional on zonal constraints)
- ***Price*** is intersection of supply curve (offers and vertical components) with demand curve
- ***Quantity*** reflects quantity of resources in offer stack needed to meet demand

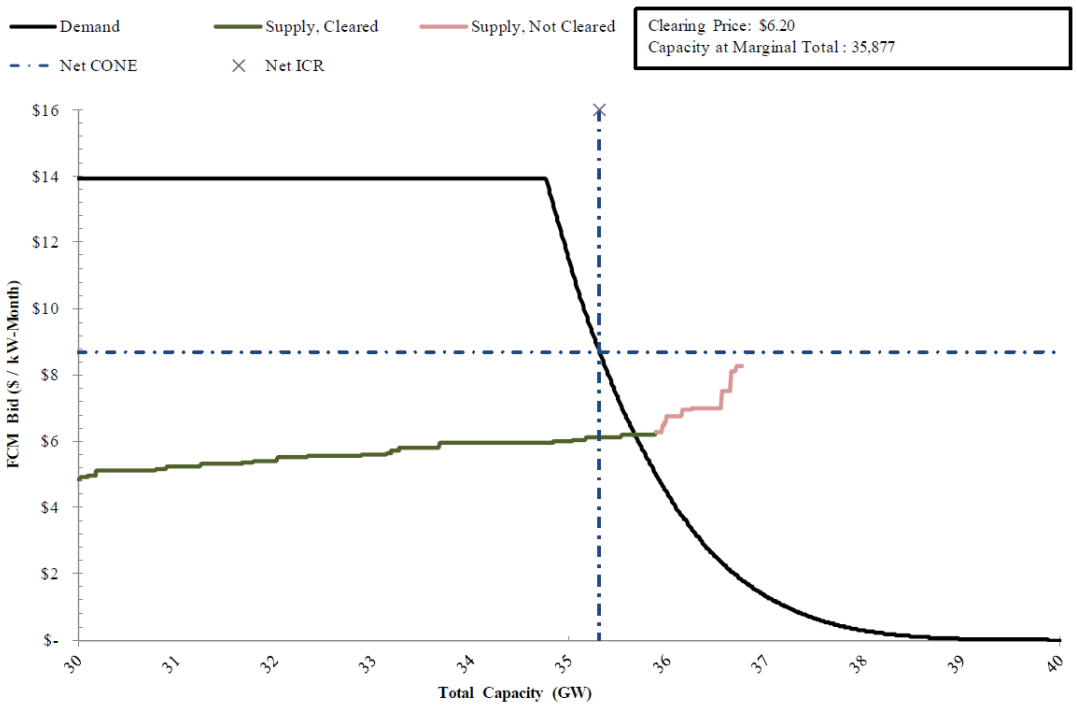
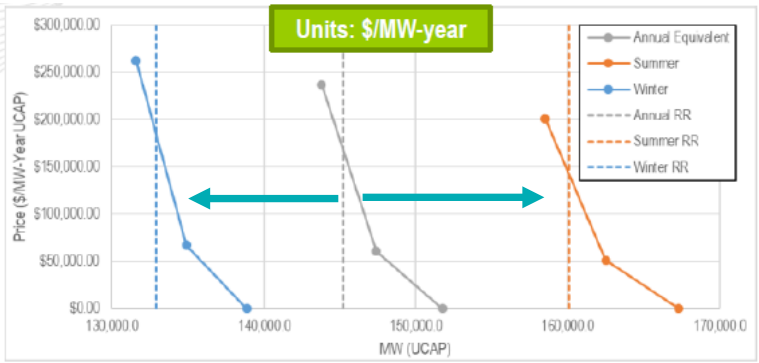


Figure from prior Analysis Group report (ISO-NE 2016 Economic Analysis)

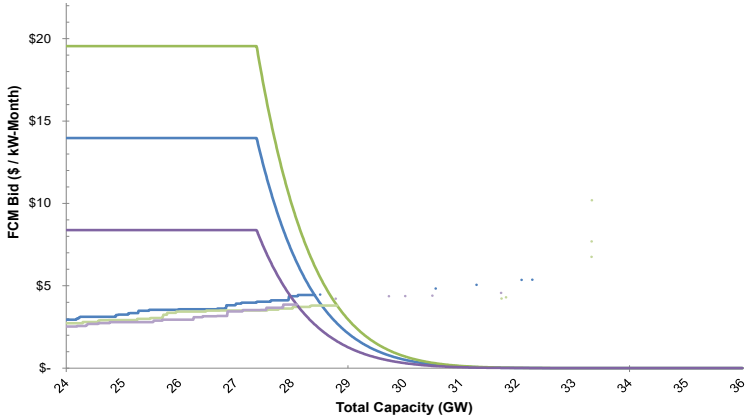
Model Overview

Demand Curves Using Two Approaches

- **Current VRR design**: Sub-annual VRR curves to reflect horizontal shifts in VRR curve (given relative resource adequacy risk across sub-annual periods)



- **Marginal ELCC/MRI-based demand curves**: Considered as a sensitivity



- **Demand curves to include:**
  - Zonal/LDA constraints
  - Price caps: sub-annual and annual

Model Overview

Supply Offers

- Resource-specific GFC, including fixed costs and net energy and ancillary service (EAS) offset, consistent with PJM reference price and net CONE calculations
- Quantity to account for resource accreditation
- Supply of resources to reflect resources offering supply into the most-recent RPM, anticipated/in-construction additions and retirements, and future additions, as appropriate with scenarios
- Marginal offers – prorating of all marginal offers supplies to exactly clear demand with supply

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Changes Under Sub-Annual Design

Seasonal Demand Curve

- To account for the impact of sub-annual market design, the analysis quantifies certain differences in demand and supply under the sub-annual market
  - These adjustments reflect some but not all impacts of sub-annual seasonal markets
- Potential changes to supply offers:
  - Net EAS revenues, expected CP revenues and quantity of offered capacity differ based on sub-annual performance and accreditation
  - Greater share of annual fixed costs attributed to winter than summer due to winterization costs
- Potential changes to demand curve to reflect the sub-annual period values
  - Analysis will reflect horizontal shifts in current annual VRR curve shape and, in sensitivities, use available marginal ELCC/MRI curves
  - Seasonal demand curves adjusted to ensure “at criteria” conditions – that is, the market revenues need to ensure sufficient revenues to incent new capacity when market is at the (0.1 LOLE/year) resource adequacy criterion given (1) reliability outcomes (lost load) across both seasons and (2) revenues across both seasons

Modeling Analysis

Quantitative Analysis of Sub-Annual Market Impacts

- Analysis will be formed over a range of scenarios – potential scenarios include:
  - Future years and supply/demand assumptions to capture variation:
    - **Resource mix** and
    - **Demand / supply surplus** (i.e., tightness in market supply)
  - Alternative **ELCC values**
  - Alternative **sub-annual reliability risk** (e.g., allocation of risk to summer and winter periods)
  - Alternative **demand curve framework**: VRR and marginal ELCC/MRI

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Next Steps

Next Steps

- Future meetings
  - September – overview of sub-annual markets in other ISOs/RTOs
  - Additional stakeholder presentations in October, November and December
- Final Report posted on December 19, 2025 and Report review in January

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