Resource Adequacy and Capacity Accreditation in PJM

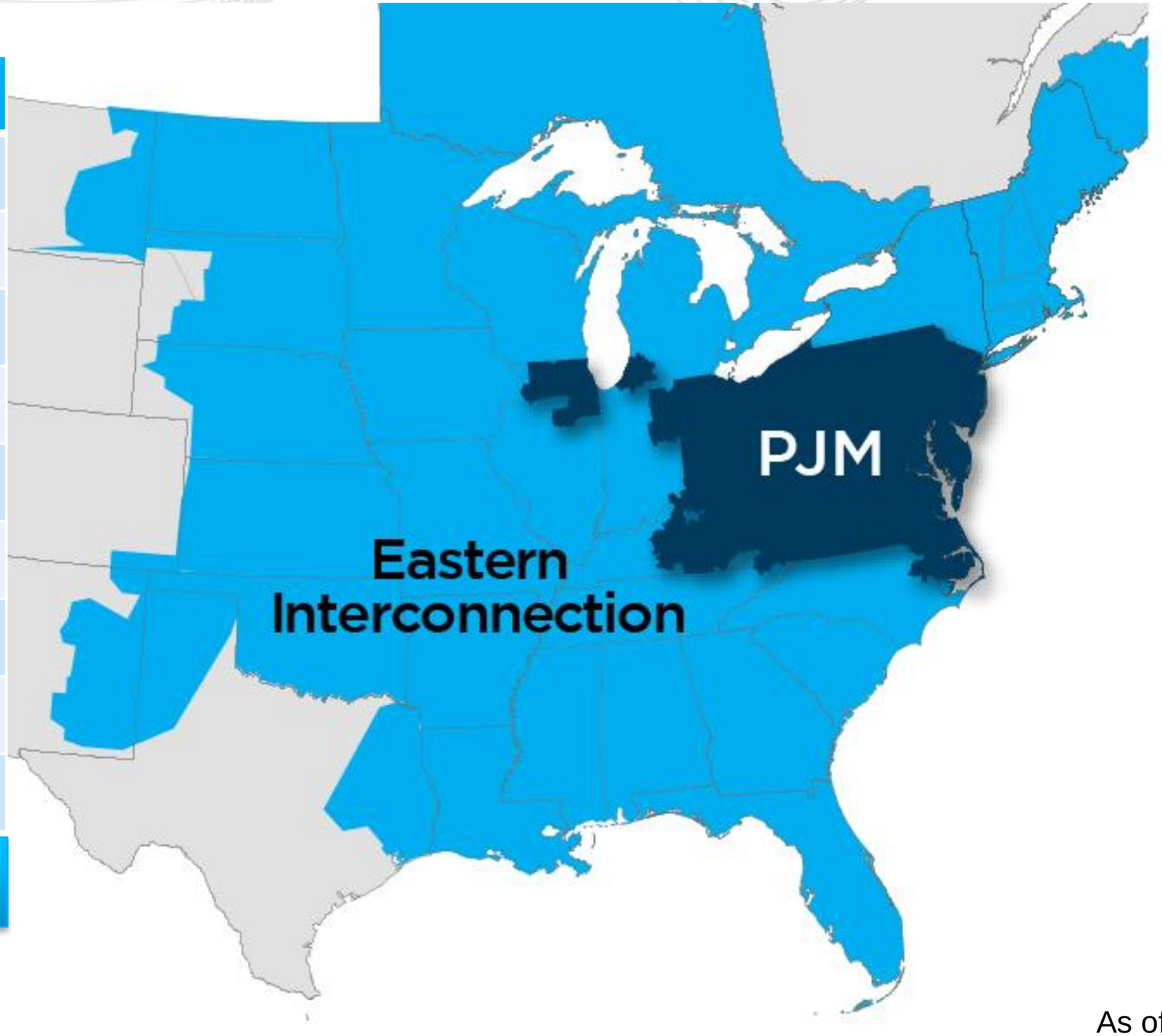
Patrick Bruno
Principal Market Design Specialist

IURC Technical Conference
June 6, 2024

PJM as Part of the Eastern Interconnection

Key Statistics	
Member companies	1,090
Millions of people served	65+
Peak load in megawatts	165,563
Megawatts of generating capacity	180,785
Miles of transmission lines	88,185
Gigawatt hours of annual energy	770
Generation sources	1,419
Square miles of territory	368,906
States served	13 + DC

21% of U.S. GDP produced in PJM



As of 2/2024

Resource Adequacy Analysis used in PJM

Reserve Requirement Study (RRS) *(also referred to as the Installed Reserve Margin or "IRM" study)*
PJM study to determine the amount of capacity resources necessary to maintain PJM's Loss of Load Expectation (LOLE) reliability criterion of one day in 10 years

Resource Accreditation – Effective Load Carrying Capability (ELCC) Analysis
PJM study to determine the capacity value, or reliability contribution, of different resource types and individual units

Capacity Emergency Transfer Objective (CETO) / Limit (CETL) Studies
Studies run by PJM to determine the capacity needs in constrained areas of the system (Locational Deliverability Areas, or LDAs) and the capability of the transmission system to import energy into those areas

Background: Procurement of Capacity in PJM

PJM Capacity Market

Forward procurement of capacity resources to meet RTO and LDA reliability requirements determined from the resource adequacy analyses for a future delivery year (June – May)

Two Procurement Approaches:

- **Reliability Pricing Model (RPM):** PJM procures capacity on behalf of Load Serving Entities (LSEs) to satisfy load capacity obligations through the conduct of RPM Auctions
- **Fixed Resource Requirement (FRR) Alternative:** Opt-out option for certain LSEs to secure their own resources to satisfy their capacity obligations and provide the resource plan to PJM

Recent Reforms to Resource Adequacy Studies

PJM recently worked with its stakeholders on an extensive set of reforms to the Capacity Market that made significant changes to resource adequacy studies and resource accreditation

- **Improved consistency and granularity in risk modeling:** RRS and ELCC studies are now both based on the same underlying loss-of-load probabilistic model ("RRS/ELCC Model") that evaluates resource adequacy risk across all 8,760 hours of the year
- **Explicitly models how generator forced outages and other de-rates vary with temperature** (increasing in extreme cold and hot) and are further **correlated across the fleet**
- **Expanded the weather history** used in the model to better capture potential for extreme outcomes
- **Uses a consistent accreditation methodology (ELCC analysis)** across resource types that accredits resources based on the **reliability contribution they provide to the system (reduction in Expected Unserved Energy, or EUE)**

Overview of ELCC/RRS Model

Model Inputs

Weather Scenarios
Historical weather patterns captured back to 1993 (30 years)

Load Scenarios
Hourly load profiles derived from PJM's Load Forecast model for each historical weather scenario

Weather patterns shifted +/- 6 days to account for day of the week / holiday variables

Projected Resource Mix and Performance
Unit, class, and fleet performance for thermal and variable generation modeled as a function of temperature by resampling against historical availability back to 2012 using a binning methodology

Dispatch of Demand Resources and Limited Duration Resources simulated in model

Loss-of-Load Risk Modeling
System simulated under thousands of alternative scenarios to capture a broad range of potential system conditions and reliability outcomes.

30 Alternative Weather Years
x 13 Alternative Load Scenarios
x 100 Alternative Resource Performance Draws
= **39,000 Simulated Years**

Patterns of Risk
LOLE vs LOLH vs EUE

Summer vs. winter?
Morning vs. evening?
Long vs. short events?
Deep vs. shallow?

Reserve Targets
At the loss-of-load criterion

ELCC Ratings
Measure of resources' contribution to reliability given patterns of loss-of-load risk

Projected Resource Mix used in the Model

The projected resource mix used in the ELCC/RRS risk modeling is based on:

1	**Existing Generation** Capacity Resources
2	**minus Generation Retirements** (based on submitted deactivation notices)
3	**plus Planned Generation Capacity Resources** (based on submitted notices to offer and FRR plans)
4	**plus DR Forecast** (based on projected DR deployment in Load Forecast model)

Resource Performance: Modeling Approach Overview

	Modeling Approach
Forced Outages and Ambient De-rates for Unlimited Resources	Historical weather and corresponding forced outages and ambient de-rates since June 1, 2012 used to characterize thermal outage rates as a function of weather based on a binning methodology
Variable Resource Availability	Historical weather and corresponding variable resource performance (actual and putative) since June 1, 2012 used to characterize performance as a function of weather based on a binning methodology
Planned & Maintenance Outages for Unlimited Resources	The amount (MW-weeks) of planned and maintenance outages per year based on historical data since June 1, 2012. Heuristic used to schedule planned and maintenance outages during periods of lower loads, except for small portion intentionally scheduled during high risk periods as observed since 2012.
Intermittent Hydro	Annual draw of performance since 2012 as a function of closest matching seasonal peak loads
Limited Duration Storage & Combination Resource	Simulated dispatch in the model that depends on other system conditions (e.g. load, other resources' performance, remaining storage) during the hour
Demand Resources	Simulated dispatch in the model where DR is deployed during hours within its defined performance windows when total available Unlimited and Variable Resources is less than the load

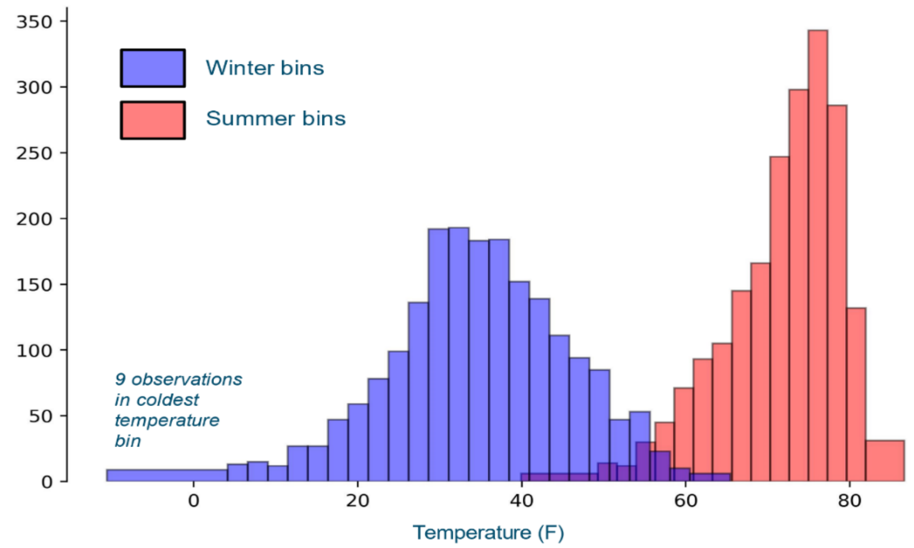
Resource Performance: Temperature Bins

A binning methodology is used as a means to mix and match (or “sample”) load and resource performance that occurred within similar weather conditions or “temperature bins.”

Temperature Binning Methodology

- Each historical day in the analysis is assigned to a temperature bin based on either (a) the minimum hourly RTO-wide THI for days in the winter, or (b) the maximum hourly RTO-wide THI for days in the summer
- The temperatures are grouped using binning methods (e.g. Freedman Diaconis Estimator method) employed in the development of histograms
- The historical days since June 1, 2012 and corresponding temperature bins form the “Resource Performance Bins” used to derive the 100 different resource performance patterns used in the analysis

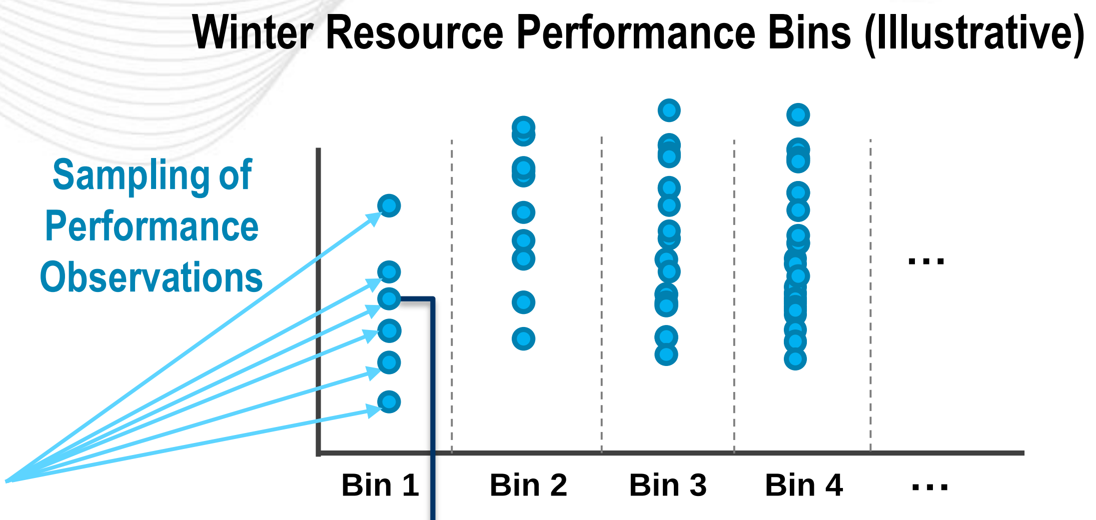
Number of historical days within each temperature bin of Resource Performance Bins

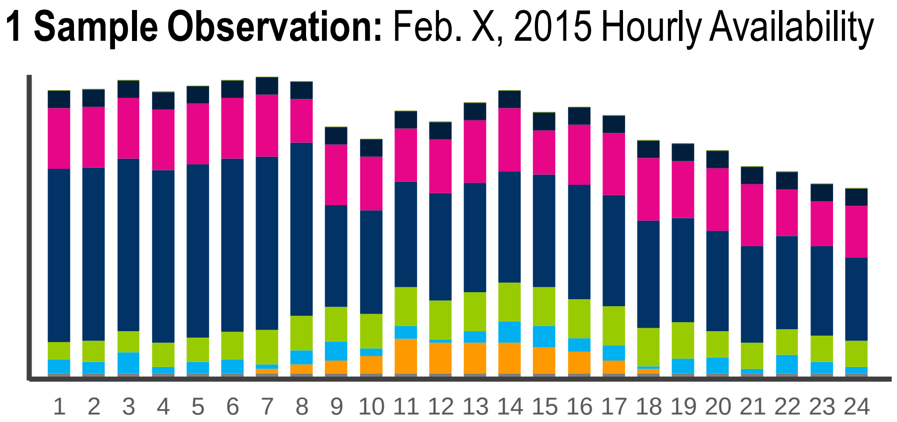


Resource Performance: Sampling from Temperature Bins

Weather Scenarios

Weather Year	Date	Season	Daily Temp.
197X	Jan. 1	Winter	4° (min)
197X	Jan. 2	Winter	8° (min)
197X	Jan. 3	Winter	7° (min)
	…	…	…
1994	Jan. X	Winter	-5° (min)
	…	…	…
2012	7/15/12	Summer	92° (max)
2012	7/16/22	Summer	89° (max)
	…	…	…
2022	Dec. 31	Winter	12° (min)





Resource Performance: Simulated Dispatch

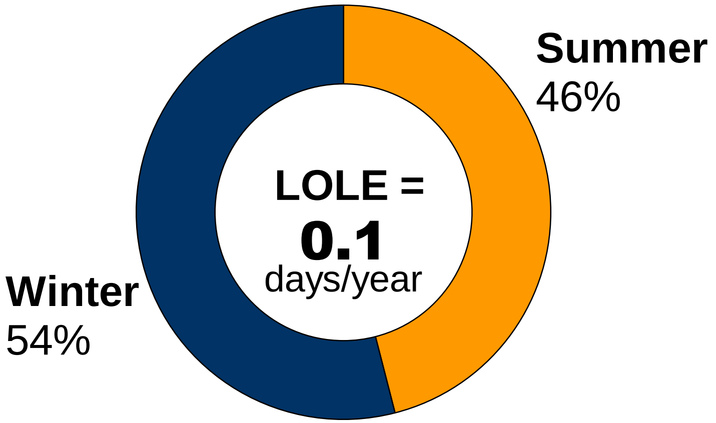
- Less available resources are dispatched after the more available resources to maximize the system reliability benefit
  - If during a certain hour early on in the emergency event PJM has to choose between serving load with a more available resource (e.g., Demand Resource available for more than 10 hours) and serving load with a less available resource (e.g., a four-hour Limited Duration resource), PJM will dispatch the more available resource first

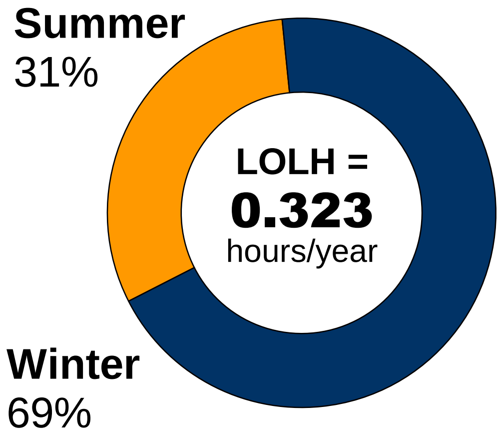
General Order of Dispatch in the Model:

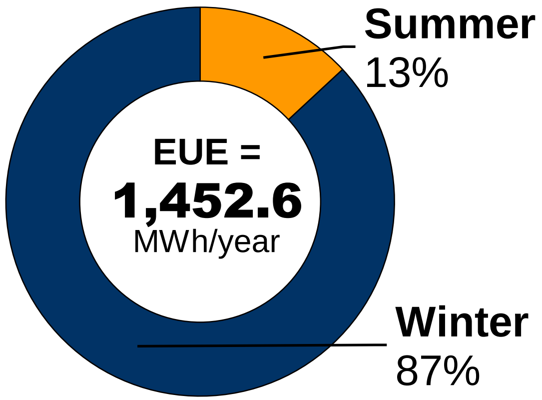
Unlimited and Variable Resources → Demand Resources → Limited Duration Resources

New Resource Adequacy Model Results: Seasonal Risk Patterns

2025/26 BRA
Seasonal
Share of:



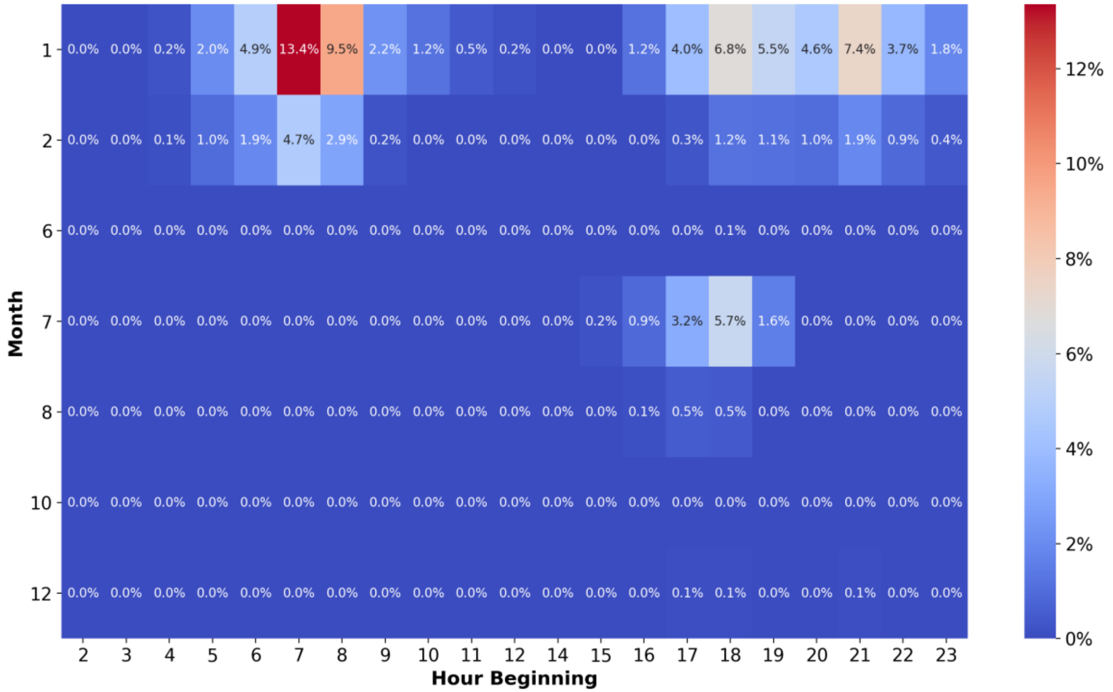




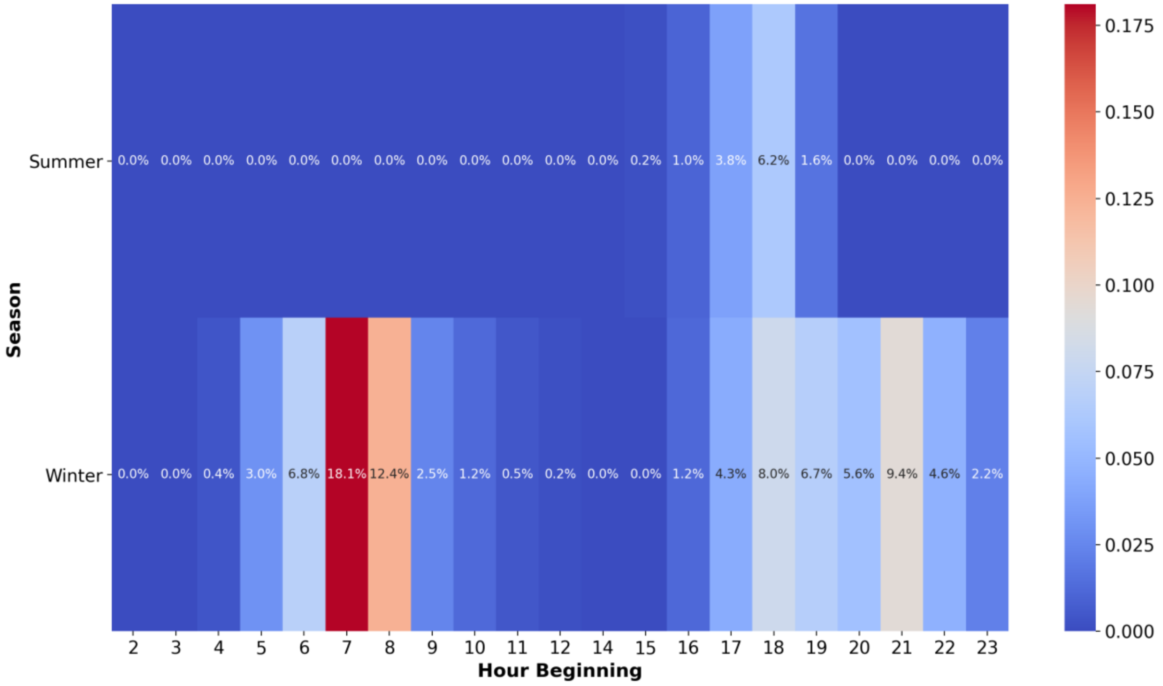
- **Significantly more reliability risk observed in the winter season under the new resource adequacy model**, where prior studies had shown nearly all LOLE risk during the summer peak
- Increased winter risk largely driven by the improvements in correlated resource outage/unavailability modeling and the expansion of weather history

New Resource Adequacy Model Results: Hourly Patterns of EUE Risk

Month/Hour EUE Heatmap



Season/Hour EUE Heatmap



Capacity Accreditation

Capacity accreditation is a way to measure the capacity value or reliability contribution of a resource (quantified in terms of “UCAP MW” in PJM)

Why is accreditation needed?

- Resources do not provide the same amount of reliability value per MW of installed capacity (ICAP)
  - e.g. 1,000 MW of installed wind capacity does not provide the same reliability value as 1,000 MW of installed nuclear capacity
- Accreditation provides a means to quantify the amount of capacity or reliability value provided by different resource classes and individual units
  - This can allow for a single, substitutable market product (i.e. “UCAP”) to be used across resources with disparate operating characteristics, where one MW of qualified UCAP can be exchanged for any other qualified UCAP MW while maintaining resource adequacy.
- It also sets the maximum amount of capacity a resource is eligible to sell, and is therefore commensurate to the compensation a resource can receive

Link Between Accreditation and Risk Patterns

- Accredited capacity, as a measure of a resource's contribution to system reliability, depends on the patterns of system risk
  - A solar resource provides more reliability value to a system that sees the majority of risk during summer afternoons than one with most risk in the evening or during winter peaks
- The reliability value (and accreditation) of resources change over time as the patterns of system risk evolve
- The patterns of system risk are, in part, driven by makeup of the resource fleet
  - Certain resources provide diminishing reliability value (e.g. as more and more solar comes online, the incremental reliability benefit of the solar declines as the risk shifts outside the daylight hours)
  - Resources can also provide synergistic benefits to other resource types (e.g. increased solar penetration can improve the reliability contribution of battery storage)

Capacity Accreditation in PJM: ELCC Analysis

The ELCC analysis uses the probabilistic risk model to measure the incremental reliability contribution provided by a resource or resource class (relative to that of “perfect” capacity)

Methodology		Example: Application to “Class 1”
1.	Start with the expected resource mix and system at the annual target reliability criteria in the ELCC model	
2.	Add an increment of “perfect” annual capacity	*Add 100 MW of 24x7 “perfect” capacity to the model*
3.	Run the risk model to determine reduction in EUE from adding the increment of “perfect” annual capacity	*Results show 50 MWh of EUE reduction*
4.	Replace the “perfect” capacity with the same amount of incremental capacity from the class under study	*Replace “perfect” capacity with equal ICAP of “Class 1”*
5.	Run the risk model and determine reduction in EUE from adding the increment of class capacity	*Results show 40 MWh of EUE reduction*
6.	Set the ELCC Class Rating based on the class EUE reduction relative to that of “perfect” capacity	*“Class 1” Rating = 40 MWh / 50 MWh =* ***80%*** *“Class 1” ELCC*

Accreditation: ELCC Class Ratings

	RATING 2025/26	RATING 2024/25	Change
Onshore Wind	35%	21%	+14%
Offshore Wind	60%	47%	+13%
Solar Fixed Panel	9%	33%	-24%
Solar Tracking Panel	14%	50%	-36%
Landfill Gas	54%	61%	-7%
Hydro Intermittent	37%	36%	+1%
4-hr Storage	59%	92%	-33%
6-hr Storage	67%	100%	-33%
8-hr Storage	68%	100%	-32%

	RATING 2025/26	RATING 2024/25	Change
10-hr Storage	78%	100%	-22%
DR	76%	109%	-33%
Nuclear	95%	99%	-4%
Coal	84%	88%	-4%
Gas CC	79%	96%	-17%
Gas CT	62%	90%	-28%
Gas CT Dual Fuel	79%	N/A	NA
Diesel	92%	93%	-1%
Steam	75%	88%	-13%

ELCC Resource Performance Adjustment and Accredited UCAP

Accredited UCAP: The capacity value of resources within an ELCC Class (e.g. Nuclear, Coal, Fixed/Tracking Solar, etc.) is based on the ELCC Class Rating and a Resource Performance Adjustment factor that provides individual units within the ELCC Class a capacity rating above or below the class average based on the individual unit's performance

ELCC Resource Performance Adjustment: Reflects each resources' average historically-observed performance, in those hours and weather conditions (temperature bins) in which the system experiences reliability risk, relative to class average historically-observed performance in those same hours and weather conditions

Details of Resource Performance Adjustment computation:

- For each temperature bin *(b)* and hour of day *(h)*:
  - Calculate unit's *(u)* average availability across all observations in that bin & hour: A_{ubh}
  - Calculate class's *(c)* average availability across all observations in that bin & hour: A_{cbh}
  - Calculate relative risk weighting of the bin & hour (as a share of total risk): R_{bh}
- Compute weighted average of unit availability across all bin/hour pairs: $A_u = \sum_{b,h} R_{bh} \cdot A_{ubh}$
- Compute weighted average of class availability across all bin/hour pairs: $A_c = \sum_{b,h} R_{bh} \cdot A_{cbh}$
- Compute Resource Performance Adjustment: $RPA_u = \frac{A_u}{A_c}$

Accreditation Examples

Nuclear Unit 1

Accredited UCAP = 1,000 MW ICAP * **95%** ELCC Class Rating * **1.02** Resource Performance Adjustment = **969 MW UCAP**

Solar Tracking 1

Accredited UCAP = 100 Nameplate MW * **14%** ELCC Class Rating * **0.95** Resource Performance Adjustment = **13.3 MW UCAP**

Onshore Wind 1

Accredited UCAP = 100 Nameplate MW * **35%** ELCC Class Rating * **1.0** Resource Performance Adjustment = **35 MW UCAP**

Accredited UCAP may be impacted by Capacity Interconnection Rights (CIRs) or studied deliverability

Reference Materials

- Effective Load Carrying Capability (ELCC) Webpage
  https://www.pjm.com/planning/resource-adequacy-planning/effective-load-carrying-capability

- ELCC Education:
  https://pjm.com/-/media/committees-groups/committees/pc/2024/20240221-special/elcc-education.ashx

- Manual 20A: Resource Adequacy Analysis (Draft)
  https://pjm.com/-/media/committees-groups/committees/mrc/2024/20240522/20240522-item-03b---4-manual-20a-revisions---clean.ashx

- Manual 21B: PJM Rules and Procedures for Determining Generating Capability (Draft)
  https://pjm.com/-/media/committees-groups/committees/mrc/2024/20240522/20240522-item-03b---5-manual-21b-revisions---clean.ashx

Contact Information

Pat Bruno,
Patrick.Bruno@pjm.com

Resource Adequacy and Capacity Accreditation in PJM

Member Hotline

(610) 666-8980

(866) 400-8980

custsvc@pjm.com