# CPQR Simulation Approach

RASTF

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# Competitive Offer

- **Unit specific competitive offer for a CP resource:**

$$p = Net\ ACR + Net\ (Expected\ Penalties - Expected\ Bonuses)$$

$$or, p = \begin{cases} Net\ ACR + CPBR \times H \times (\overline{B} - \overline{A}), & if\ \overline{B} < \overline{A} \\ Net\ ACR + PPR \times H \times (\overline{B} - \overline{A}), & if\ \overline{A} < \overline{B} \end{cases}$$

- **Where:**
  - Net ACR = Gross ACR − Net E&AS revenues
  - CPBR is the average bonus payment rate during PAI
  - PPR is the average nonperformance charge rate during PAI (tariff defined).
  - H is the expected number of PAI divided by 12
  - $\overline{A}$ is the expected unit performance during PAI
  - $\overline{B}$ is the expected balancing ratio during PAI

# CPQR

- **CPQR includes both the expected net nonperformance charges and the cost to mitigate the risk associated with the estimated net nonperformance charges.**
- **Net nonperformance charges can be simulated to account for uncertainty in the inputs to calculation (A, B, H).**
- **The MMU framework for evaluating the simulation approach was presented on March 24, 2022.**

# CPQR

***CPQR = E(net penalties) + Cost of mitigating risk***

***Where:***

- ***E(net penalties):*** **expected value (mean) from distribution of simulated outcome**
  - Can be positive, negative, or zero.
- ***Cost of mitigating risk=Risk Cost x (Extreme Value – Mean)***
- **Extreme Value: for example 30th percentile or 95th percentile of distribution of simulated outcomes.**
- **Risk Cost:**
  - Cost of incurring risk of nonperformance penalties
  - Affected by factors including portfolio

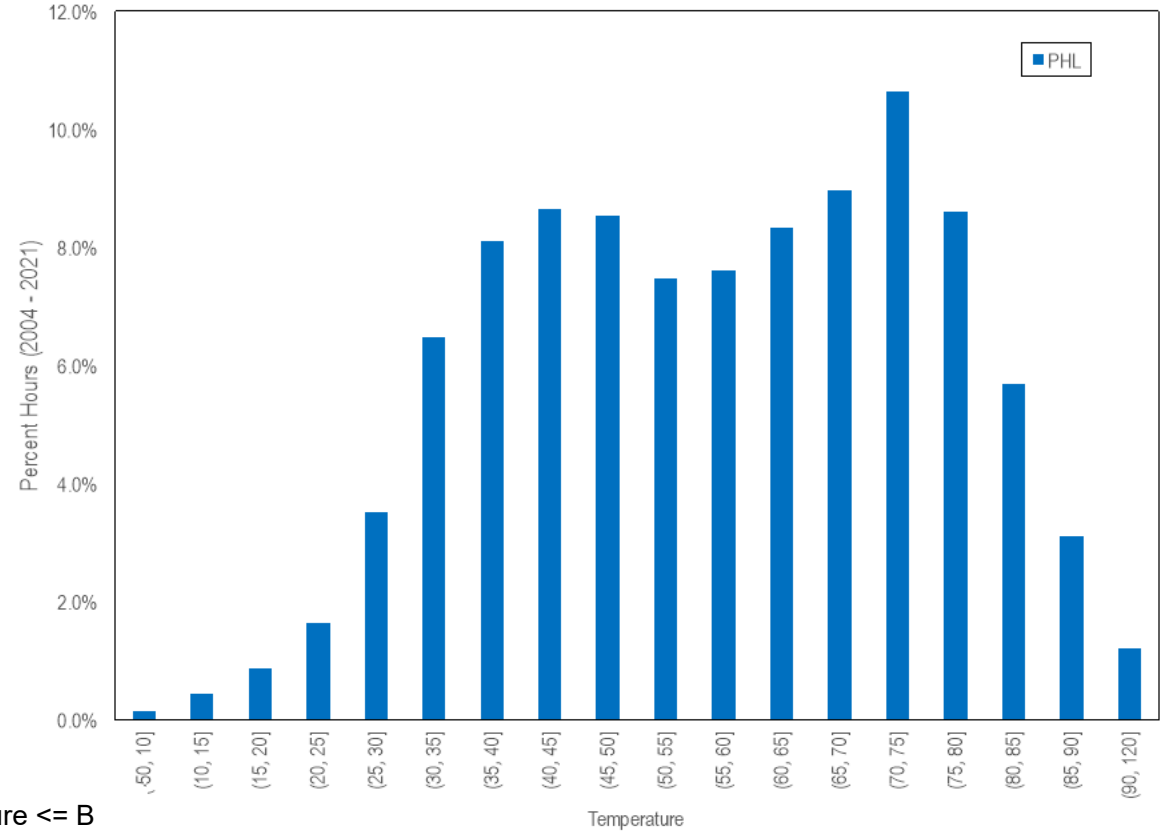
# Simulation Model

- Simulation of CP nonperformance charges and bonus payments.
- The key inputs are:
  - A: Unit specific performance during PAH
  - B: Balancing Ratio during PAH
  - H: Number of PAH
  - CPBR: Average bonus payment rate during PAI
  - PPR: Nonperformance charge rate during PAI for the unit's zone (PPR value in tariff)
  - Stop loss limit
  - Tax rate
  - Historical temperature data.

# Simulation Model – Stage 1

- Two stage simulation.
- First stage simulates future temperature outcomes based on history.
  - Location is a proxy weather station close to the unit. For this example, location is PHL.
  - Assumes temperature is a multinomial random variable with probability calculated empirically.
- 500 sample years generated using 18 years (2004 – 2021) of weather history.
  - Each sample distributes 8,760 hours into the specified temperature ranges.

# Example: PHL Temperature History




(A, B]: A < Temperature <= B



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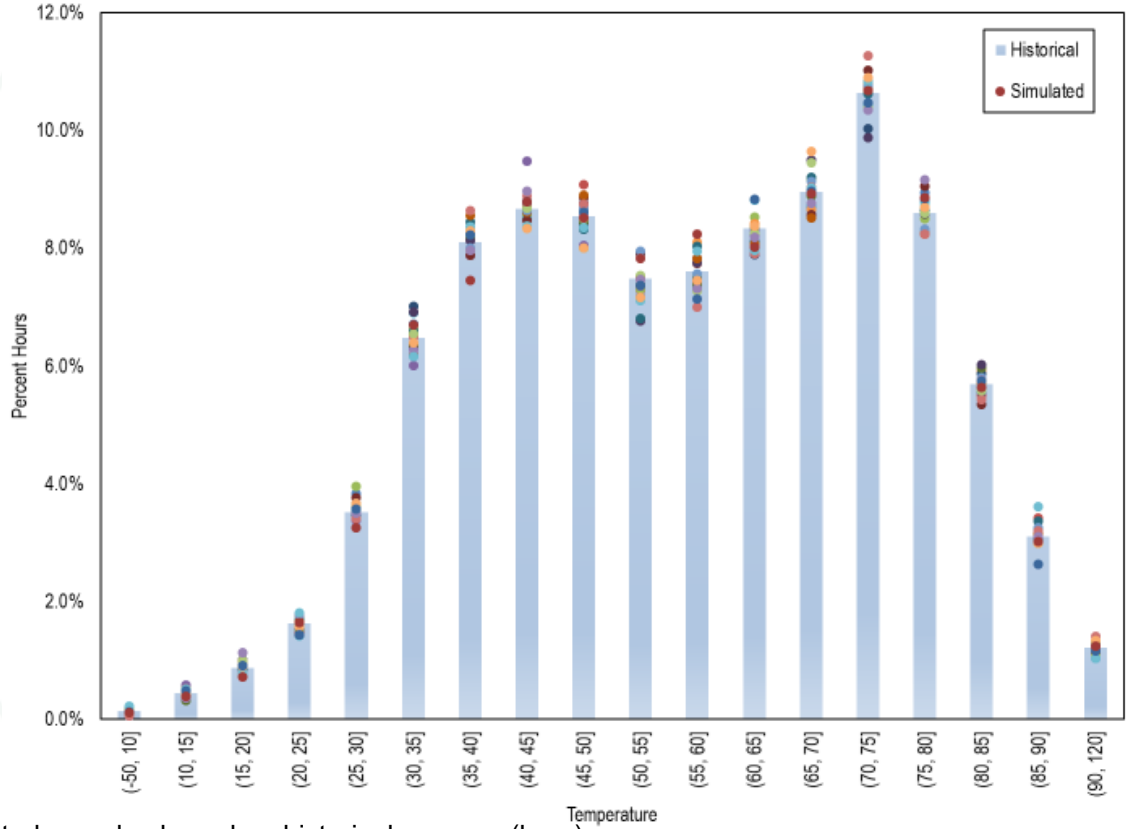
# Sample Simulated Temperature Distributions




Circles show 20 simulated samples based on historical average (bars)



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# Sample Simulated Temperature Distributions

- **Table shows number of hours out of 8,760 that fall into each temperature category from three sample simulated years.**

| $T_i$ | $N(T_i)$ | | |
|---|---|---|---|
| | Sample Year 1 | Sample Year 2 | Sample Year 3 |
| (-50, 10] | 9 | 8 | 11 |
| (10, 15] | 36 | 45 | 47 |
| (15, 20] | 79 | 87 | 66 |
| (20, 25] | 155 | 128 | 155 |
| (25, 30] | 335 | 304 | 346 |
| (30, 35] | 552 | 572 | 580 |
| (35, 40] | 721 | 714 | 718 |
| (40, 45] | 761 | 765 | 749 |
| (45, 50] | 759 | 795 | 701 |
| (50, 55] | 629 | 638 | 640 |
| (55, 60] | 640 | 651 | 659 |
| (60, 65] | 734 | 691 | 747 |
| (65, 70] | 758 | 762 | 802 |
| (70, 75] | 933 | 938 | 933 |
| (75, 80] | 783 | 773 | 745 |
| (80, 85] | 500 | 481 | 490 |
| (85, 90] | 280 | 299 | 268 |
| (90, 120] | 96 | 109 | 103 |
| **Total** | **8,760** | **8,760** | **8,760** |

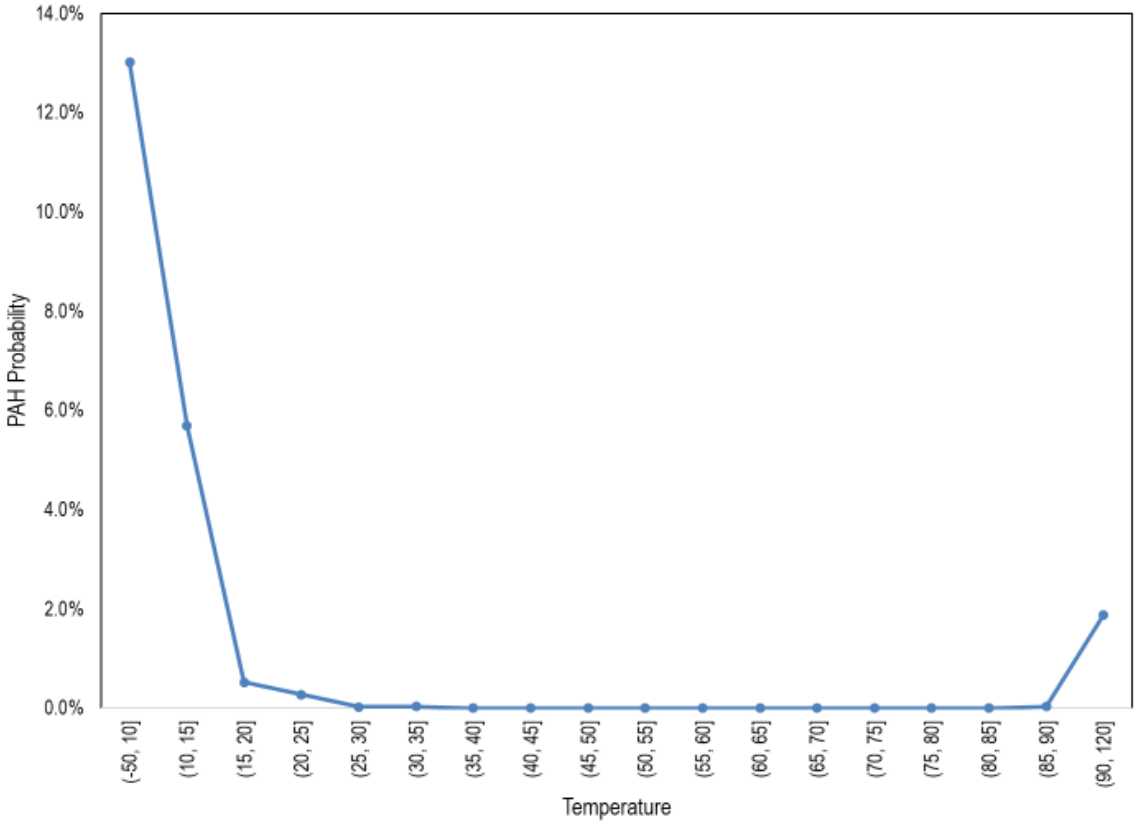
# Simulation Model – Stage 2

- **Second stage simulates:**
  - **conditional probability of PAH given temperature,**
  - **conditional probability of forced outage given temperature,**
  - **balancing ratio during PAH given temperature.**

# Simulation Model – Stage 2

- **Conditional probability of PAH given a temperature range is based on 10 year history of temperature and PAH or proxy.**
  - **PAH includes emergency actions that would have triggered PAH prior to Capacity Performance.**
  - **Temperature dependent PAH probabilities calculated for the zone where unit is located.**
- **Fewer emergencies since CP implemented.**
- **Ten year history overestimates emergencies.**

# PAH Conditional Probabilities




- **Data from 2012 through 2021.**
- **All emergency actions in eastern PJM included:**
  - **RTO**
  - **Mid-Atlantic Dominion**
  - **BGE & Pepco**



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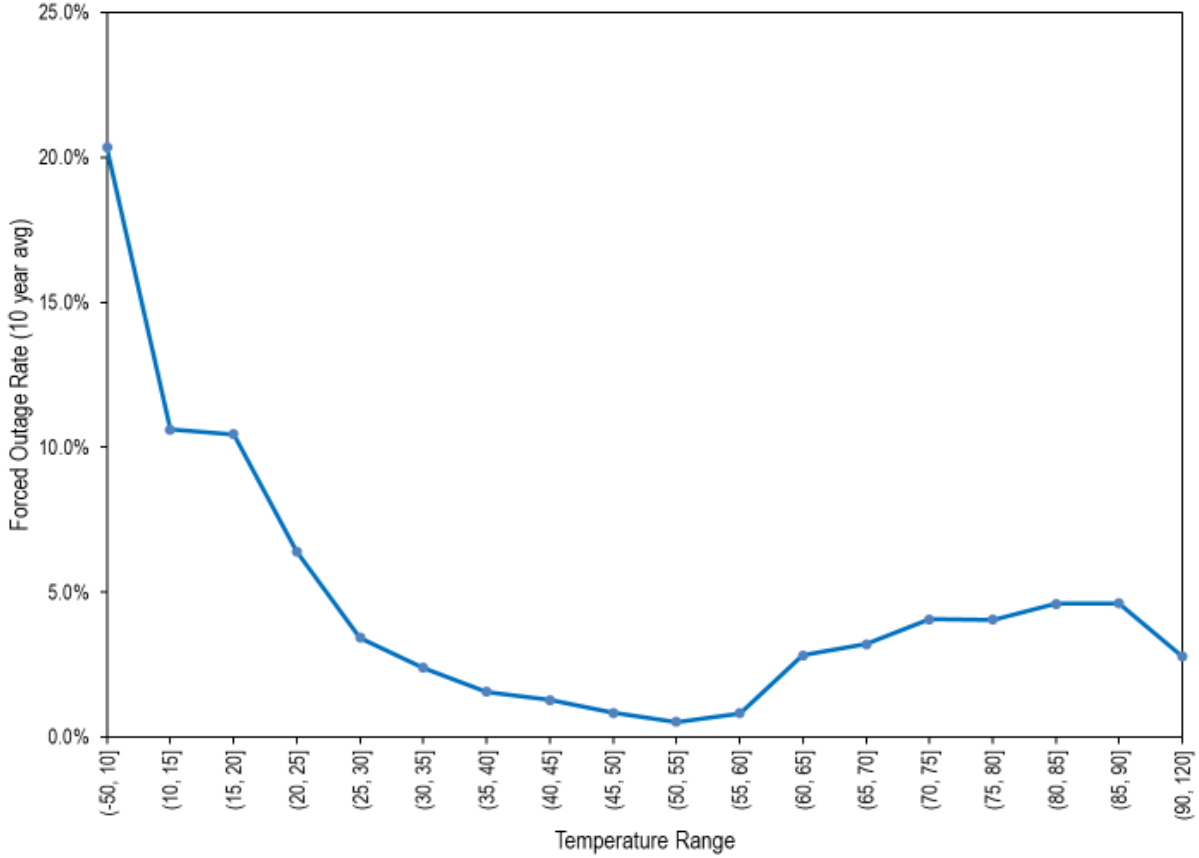
# Simulation Model – Stage 2

- **Conditional probability of unit forced outages given a temperature range is based on 10 year history of temperature and forced outages**
  - **Unit specific calculation based on GADS reported forced outages.**
  - **Equivalent forced outage rate calculated that includes both derates and full unit forced outages.**
- **Outage rates lower since CP implemented.**
- **Ten year history overestimates forced outage rates.**

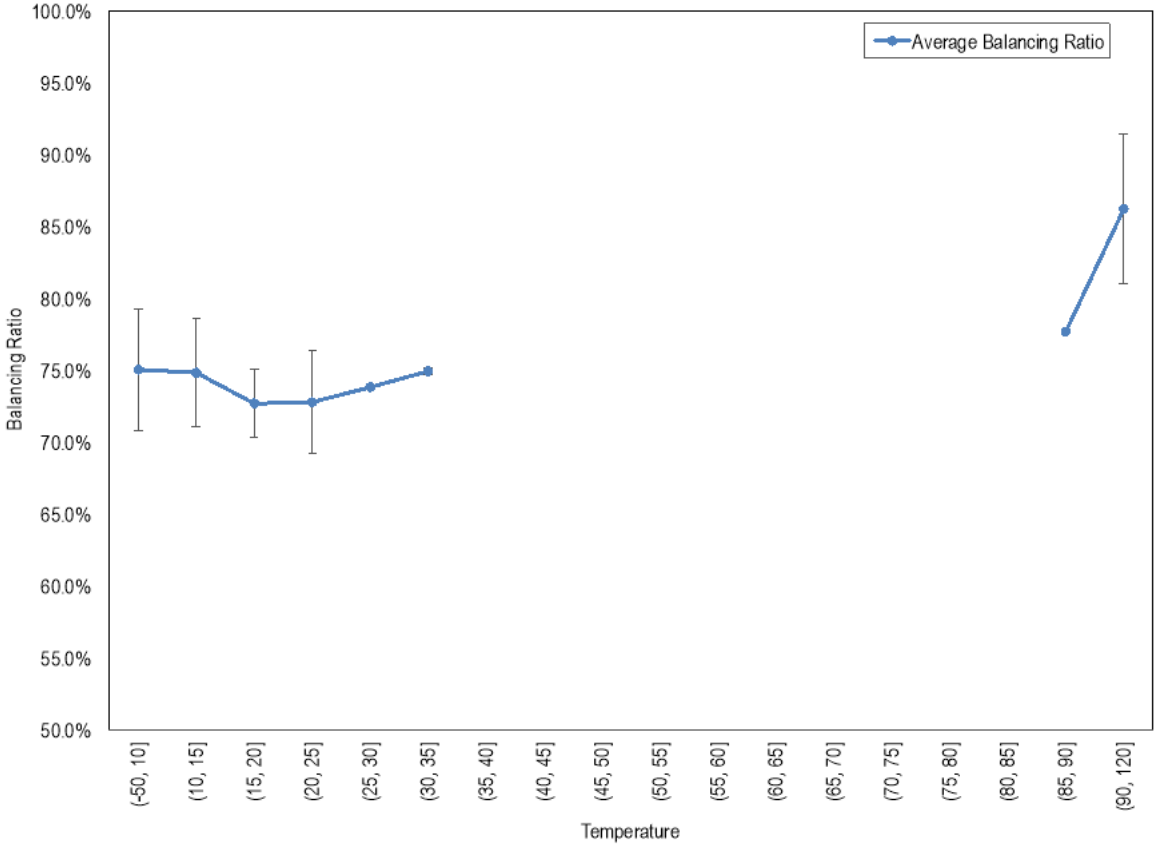
# Example Unit Forced Outage Probabilities



# Balancing Ratio (B)

- Conditional value of balancing ratio during a PAH, given a temperature range, is based on 10 year history of balancing ratios during PAH or proxy PAH.
- Balancing ratio is used to calculate expected performance for each resource during a PAI.
- B calculated for the RTO even if the emergency was regional. Same PAH as used in the PAH history.
  - RTO
  - Mid-Atlantic & Dominion
  - BGE & Pepco

# Balancing Ratio




- Balancing ratio exists only for categories with historical PAH or proxy PAH.
- Error bars show the standard deviation of balancing ratio for each temperature category.
- No error bars indicate very few PAH (1 or 2).



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# Simulating penalties and bonuses – Stage 2

- For each temperature range, conditional probabilities of PAH and unit forced outages are simulated as results of a binomial process (repeated Bernoulli trials).
- 1,000 Bernoulli trials:
  - PAH = 1 or 0, and FO = 1 or 0.
  - If PAH = 1 and FO = 1, then penalty.
  - If PAH = 1 and FO = 0 then bonus.
  - If PAH = 0, no penalty or bonus regardless of FO.
- For each temperature range, B is simulated as a normal random variable with the historical mean and standard deviation.

# Simulating penalties and bonuses – Stage 2

- Each binomial process generates conditional probabilities for a given temperature range, $i$:
  - $Probability\ of\ PAH,\ p(^{PAH}/_{T}) = \sum(PAH)/1{,}000$
  - $Probability\ of\ penalties, p(^{penalties}/_{T}) = \sum(PAH * FO)/1{,}000$
  - $Probability\ of\ bonuses, p(^{bonuses}/_{T}) = \sum(PAH * (1 - FO))/1{,}000$
- For each penalty or bonus hour, a unit would pay maximum nonperformance charges for MW = B*UCAP.
- Similarly, a unit is eligible for bonuses for MW = (1 – B)*UCAP.
- Incorporating the simulated B:
  - $Penalty\ probability\ P(^{pen}/_{T_i}) = \sum(PAH * FO * B_i)/1{,}000$
  - $Bonus\ probability\ P(^{bon}/_{T_i}) = \sum(PAH * (1 - FO) * (1 - B_i))/1{,}000$

# Net Penalty Probability – Stage 2

- 1,000 such conditional probabilities are generated for each temperature category.
- The net penalty probability for temperature category $i$ is calculated as:

$$p\left({}^{net}/_{T_i}\right) = P({}^{pen}/_{T_i}) - P({}^{bon}/_{T_i})$$

- Portion of underperformance can be excused.
  - Results in effective penalty rate lower than the tariff defined rate.
  - Results in bonus payment rate lower than penalty rate.

# Combining Stage 1 and Stage 2

- Each of the 1,000 stage 2 simulated outcomes is multiplied by the number of hours in that temperature category $N(T_i)$, for each of the 500 simulated years to get the net penalty hours.
- $(Net\ Penalty\ Hours)_i = N(T_i) * P(^{net}/_{T_i})$
- Total net penalty hours $= \sum_i (Net\ penalty\ hours)_i$
- Results in 500,000 possible outcomes for each unit for net non performance charges in a year.
  - Mean is the expected net penalty hours in a year.
  - Percentiles show the distribution of net penalty hours in a year.

# Sample Results: Net nonperformance charges

| Net Nonperformance Charges ($/MW-day) UCAP | |
|---|---|
| Mean (m) | -$7.7 |
| **Percentiles** | |
| p5 | -$11.2 |
| p10 | -$10.4 |
| p25 | -$9.1 |
| p50 | -$7.7 |
| p75 | -$6.3 |
| p90 | -$5.2 |
| p95 | -$4.4 |
| | |
| p95 - Mean (a) | $3.3 |
| Cost of Risk (b) | 10% |
| Risk Premium (c=a*b) | $0.33 |
| | |
| Mean + Risk Premium (m+c) | -$7.39 |

- **Using nonperformance charge rate = $3,366.27 per MWh (EMAAC, 2023/2024 BRA)**
- **Net nonperformance charges ($/MW-day) = Net penalty hours*Rate ($/MWh)/365.**

# Notes

- The simulation outcome is the $/MW-day UCAP value.
  - Auction EFORd needed to convert to $/MW-day ICAP terms.
- No GADS data for intermittent resources.
  - The source of risk is due to both intermittency and forced outages.
  - ELCC reduces committed UCAP, reduces risk of penalties.
- Newer units without long history need proxy outage rates if they have not operated under extreme temperatures.
  - Nonperformance risk is concentrated in extreme temperature ranges.

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