PJM Capacity Market Reforms

PJM Resource Adequacy Senior Task Force (RASTF)

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Energy+Environmental Economics

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E3 was retained by Calpine to review the current design of the PJM capacity market to evaluate its performance along several key objectives (shown right)

E3 has identified:

- Several areas for market improvement
- Several recommendations to better achieve key market design objectives

Key Market Design Objectives

1 Reliability
Does the design support sufficient pricing to retain and/or incentivize new capacity to meet the long-run reliability standard?

2 Cost
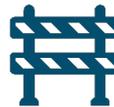Does the design minimize the cost of capacity to society, subject to external constraints (such as clean energy standard)?

3 Competition
Does the design fairly and non-discriminatorily compensate resources for the value they provide to the system?

4 Implementable
Is the design tractable and understandable?

Areas for PJM Market Improvement

E3 has identified three key areas for market improvement

1. **Market is not appropriately valuing resources for their contribution to system reliability**

   - If the market does not consider all reliability risks, the system is less reliable than stated (artificial abundance)

   - If the market procures resources that do not provide the reliability they purport, customers bear costs without commensurate reliability benefits. Additionally, price suppression due to artificial abundance could drive existing resources out of the market and require costly new entry

   - If resources with different reliability benefits are valued identically, this creates inequity and stifles competition. Additionally, artificial abundance suppresses prices, impacting competition

   Does not meet objectives of
   - Reliability
   - Cost
   - Competition

2. **Market does not ensure resources are actually capable of performing consistently with their accredited reliability value**

   - Same reasons as #1 – a resource that cannot perform consistently with its accredited reliability value creates same issues as a resource that is not appropriately valued

   Does not meet objectives of
   - Reliability
   - Cost
   - Competition

3. **Market does not allow existing resources to bid full costs into market (go-forward + risk + opportunity costs)**

   - Over-mitigation of resources will cause existing resources to inefficiently exit the market, thus requiring new entry and increasing costs

   Does not meet objectives of
   - Cost

Key Recommendations

E3 has identified three key recommendations that correspond to the prior areas for market improvement

Each is described more fully in the rest of the presentation

Timeframe

Key Recommendation 1: Use an ELCC framework for all resources in order to capture additional key reliability risks

Long-Term
- ELCC analysis should specifically be expanded to include:
  - Extreme weather correlated outages
  - Fuel supply/security correlated outages
  - Use limitations
  - Planned outages

Med-Term
- Transition from average to marginal ELCC

Key Recommendation 2: Ensure performance assessment holds resources accountable to their accredited capacity

Med-Term
- Increase frequency of performance assessment hours (PAH) through a yearly PAH floor to ensure consistency with performance penalty price

Near-Term
- Remove planned outages as a performance assessment exemption

Near-Term
- Measure performance of resources relative to UCAP (i.e., balancing ratio = 100%)
  - This will reduce revenue neutrality feature of the current CP program and result in partial refund of capacity payments to load for underperforming resources

Key Recommendation 3: Ensure market seller offer cap (MSOC) captures full costs of being a capacity resource

Near-Term
- Default MSOC should include a positive cost of fully eliminating penalty risk

Near-Term
- Default MSOC should be the higher of
  - ACR – E&AS + Penalty Performance Risk
  - Penalty Performance Risk + Opportunity Cost

If recommendations 2 is implemented, *recommendation 3 must be implemented as well* to ensure internal consistency

# Key Recommendation 1: Use an ELCC framework for all resources to capture additional key reliability risks

- **ELCC provides a technology-neutral mechanism to value full reliability risks across all resources on an apples-to-apples basis**

- **ELCC is already used in PJM to value wind, solar, storage, and hydro**

- **ELCC can be extended to thermal resources to capture four key additional factors**

  1) Extreme weather correlated outages

  2) Fuel supply/security correlated outages

  3) Use limitations

  4) Planned outages

     – Planned outages are already modeled in PJM loss-of-load-probability modeling and thus will inherently be captured in ELCC calculations

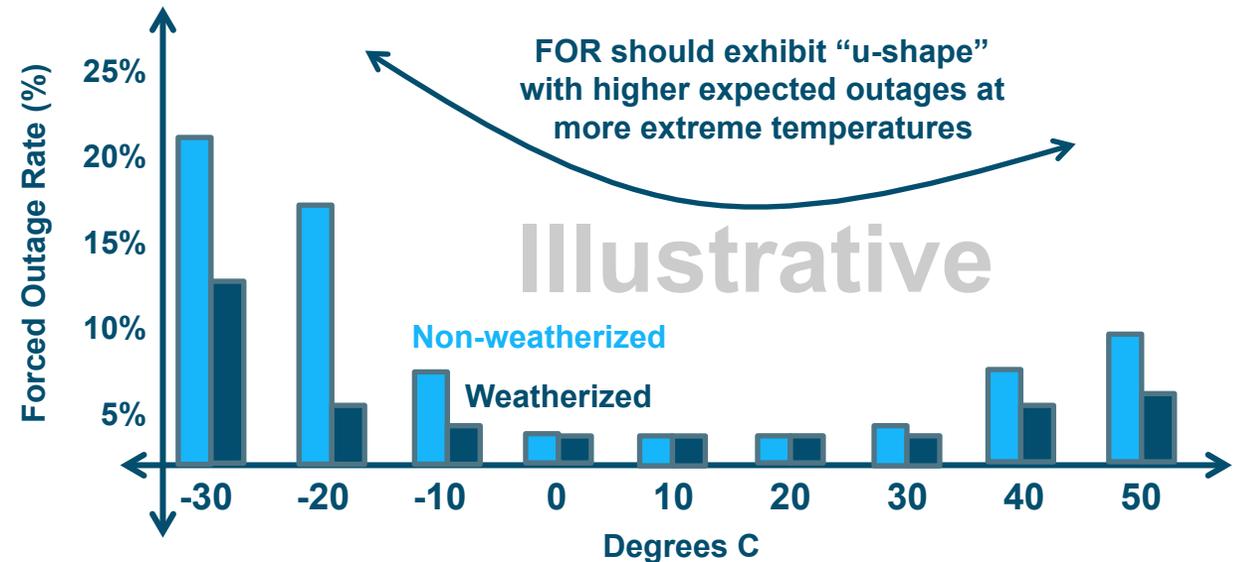- **Factors 1-3 are described in the subsequent slides**

Illustrative ELCC Values
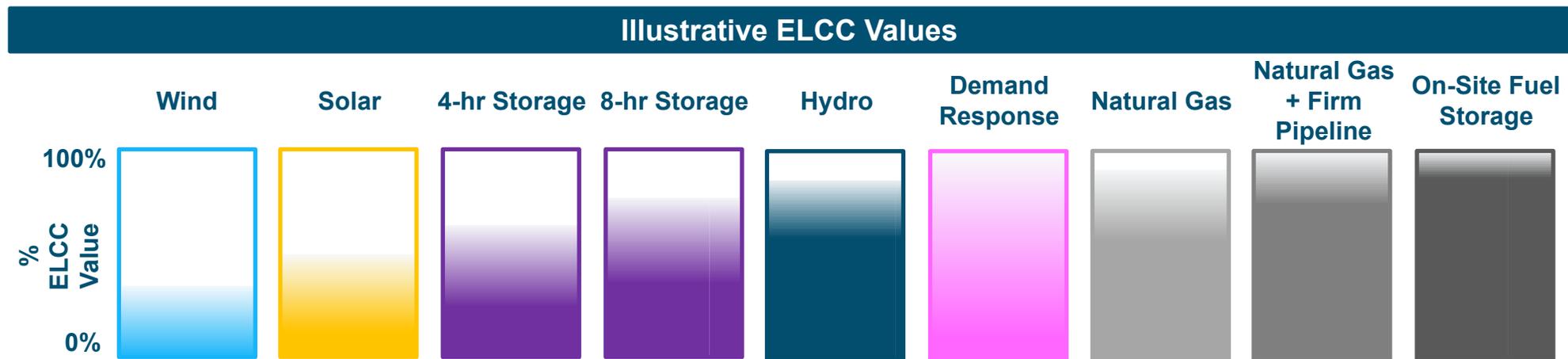
Extreme Weather Correlated Outages

- **PJM current approach to UCAP accreditation assumes outages are independent**

- **Research and experience has shown that availability of conventional generation is a function of temperature**

- **Accrediting conventional generating using an ELCC approach with a dynamic forced outage rate (FOR) that is a function of temperature can capture key correlated outage risk at extreme temperatures**

- **Dynamic FOR should account for key resource-specific differentiators, namely weatherization and other resiliency attributes**
  - PJM should conduct study and analyze historical data to develop dynamic FOR factors

- **Important to differentiate between resources with different characteristics (e.g. weatherized vs. non-weatherized)**

(Note reduced availability at both cold and hot temperatures)
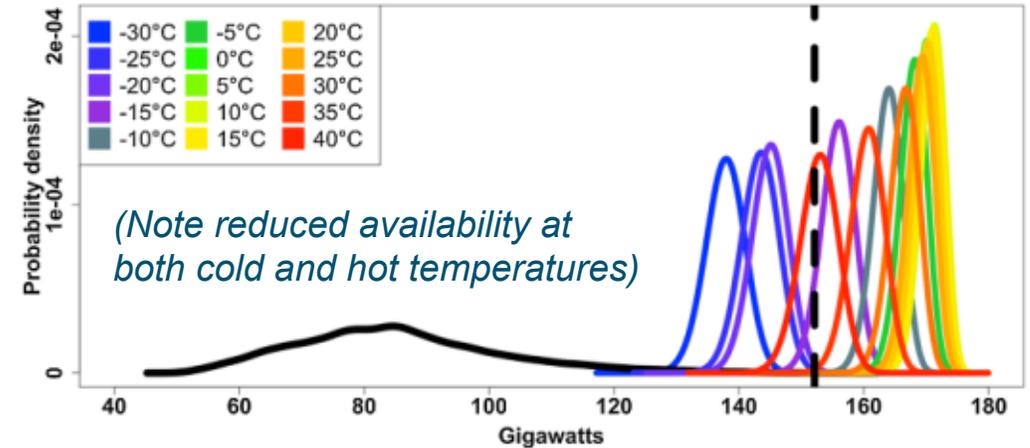
Source: *Resource adequacy implications of temperature-dependent electric generator availability*

FOR should exhibit "u-shape" with higher expected outages at more extreme temperatures

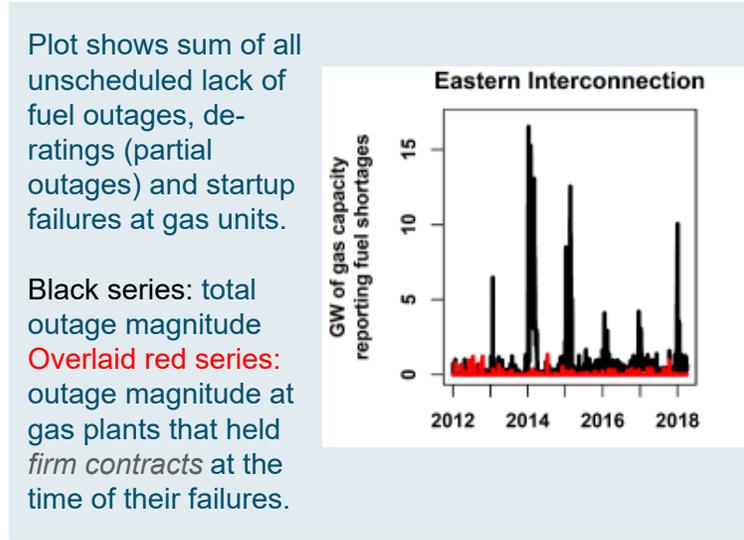Illustrative

Non-weatherized

Weatherized

Fuel Supply/Security Correlated Outages

- **Fuel supply/security is an emergent consideration in utility reliability planning, particularly as more resources (natural gas) have become more dependent upon "just in time" fuel**

- **Root causes of fuel supply/security can be accounted for in an ELCC resource accreditation framework**
  - Natural gas wellhead freeze-offs and pipeline constraints
    - ELCC framework can capture key systemic fuel supply risks by imposing additional "system-wide" forced outage rate to all exposed resources or "maximum output" from all exposed resources to capture the maximum gas deliverability capability during extreme weather conditions
  - Coal pile freeze-offs
    - Can be accounted for in correlated forced outages

- **Resources with secure fuel supplies will be modeled as such**
  - On-site fuel storage
    - Highly secure supply of fuel that is resilient to nearly all fuel supply disruptions
  - Firm pipeline gas contracts
    - Significantly beneficial in systems with constrained gas pipelines during extreme winter weather (i.e. New England) but not resilient to natural gas wellhead freeze-offs (such as in Texas)

- **Incorporating fuel supply/security factors into a full ELCC modeling framework allows system planners to capture key interactive effects with other resources – for example it will have interactions with required levels of storage duration for full capacity value**

- **Acquiring rigorous information on fuel supply availability will be a key challenge**

In January 2014 Northeast cold snap, PJM experienced *9,300 MW (>13%of total operable fleet) of forced outages* due to natural gas shortages.

Plot shows sum of all unscheduled lack of fuel outages, de-ratings (partial outages) and startup failures at gas units.

Black series: total outage magnitude
Overlaid red series: outage magnitude at gas plants that held *firm contracts* at the time of their failures.

Source: What causes natural gas fuel shortages at U.S. power plants?

Use Limitations

- **System planners have long considered resources with use limitations in reliability analysis, namely hydro**
  - A use-limited resource is one that is constrained by both maximum capacity output *and* energy generation
- **Many conventional resources are also use-limited or may increasingly become so**
  - **Local air pollution:** run-time limitations from resources in urban areas due to local air pollution restrictions may limit ELCC
  - **Carbon constraints:** A system with high clean energy targets or significant carbon constraints may limit energy generation from carbon-emitting resources
- **Extending existing ELCC hydro modeling techniques to carbon-emitting resources with use limitations should provide a robust estimate of capacity value for conventional generation**
- **Incorporating use limitations natural extends to a low or zero carbon system – a resource that cannot generate any energy will have zero ELCC**
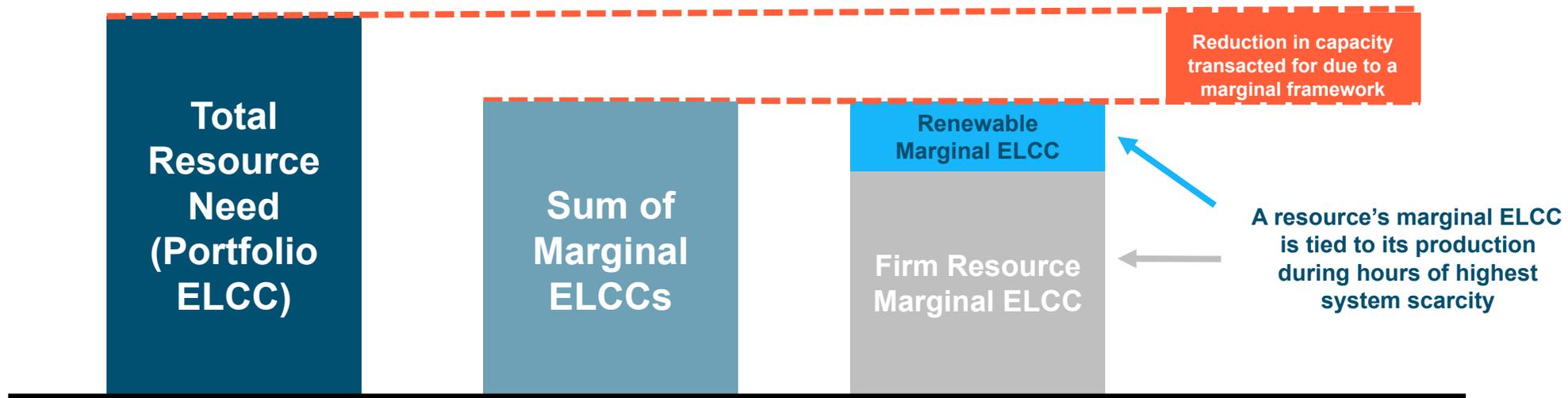

http://encyclopedia.che.engin.umich.edu/Images/TransportStorage/Turbines/hyd-equ.JPG
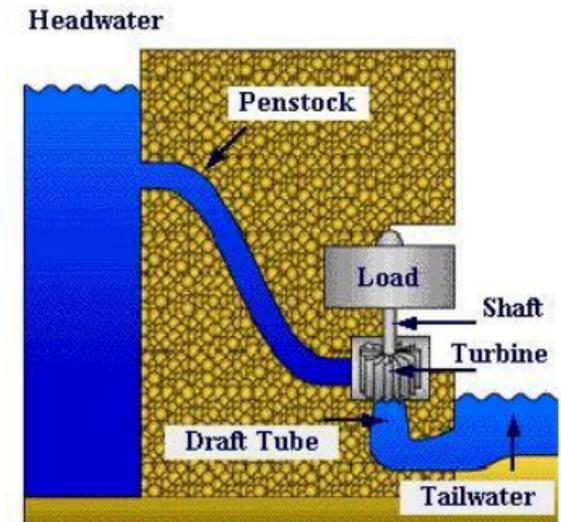
Marginal ELCC

- **A marginal ELCC framework values resources based on their production during hours of highest system scarcity (i.e. peak net load not peak gross load)**

- **Transitioning from average ELCC to marginal ELCC will improve economic efficiency and incentivize the development of resources that decrease reliability costs**
  - Current PJM average ELCC approach uses the delta method – while E3 believes that the delta method is the best average method, marginal has advantages over average

- **A marginal ELCC framework will reduce the capacity procurement target (or equivalently provide a "free" resource of interactive effects**
  - Load benefits from a marginal ELCC framework since it does not have to procure as much capacity

- **Marginal ELCC accreditation is consistent with a capacity performance construct that assesses resource performance during the hours of highest system scarcity**

Total Resource Need (Portfolio ELCC)

Sum of Marginal ELCCs

Renewable Marginal ELCC

Firm Resource Marginal ELCC

Reduction in capacity transacted for due to a marginal framework

A resource's marginal ELCC is tied to its production during hours of highest system scarcity

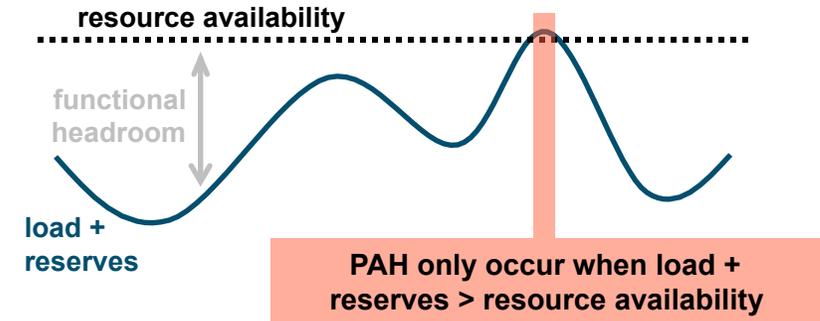# Key Recommendation 2: Ensure perf. assessment holds resources accountable to their accredited capacity

- **Ensuring resources perform in accordance with their accredited value requires a strong, consistent capacity performance (CP) construct**

- **Current frequency of performance assessment hours (PAH) is not significant enough recoup revenues from resources that do not / can not perform in accordance with their accredited capacity value**

  - Zero events in 2015-2017; 10 minutes of localized events in 2018; two hours in 2019

  - This is not wholly unexpected from a reliable system that is planed to a (better than) 1-in-10-year standard

- **E3 proposes three key reforms to the CP construct**

  1. Increase frequency of performance assessment hours (PAH) in order to ensure consistency with performance penalty price

  2. Remove planned outages as a performance assessment exemption

  3. Measure performance of resources relative to UCAP (i.e., balancing ratio = 100%)

     – This will reduce revenue neutrality feature of the current CP program and result in partial refund of capacity payments to load for underperforming resources

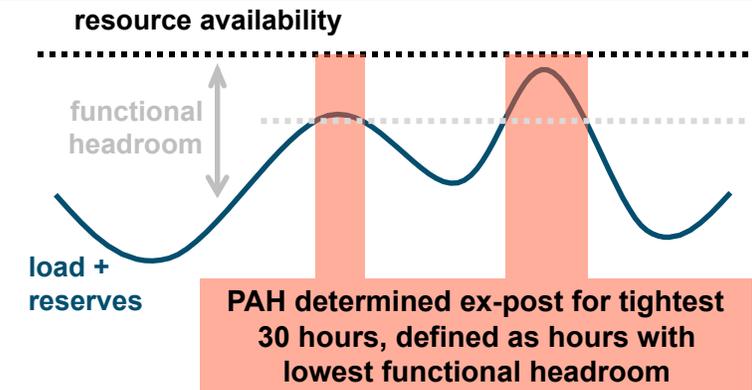- **Proposals 1 and 3 are described in more detail in subsequent slides**

Increasing Frequency of PAH

PJM should increase the frequency and consistency of PAH in a manner consistent with capacity market framework

- Increasing frequency of PAH ensures annual exposure to penalties is consistent with annual revenues

- Capacity market pricing is predicated on predictable, consistent compensation (opposite for example of energy scarcity pricing in other markets)

Threshold for PAH should be increased to target 30 hours per year based on functional head room

- *Difference between maximum and current output level of online resources + maximum of offline resources that can be started in a designated amount of time[1]*

- By design, resource penalties and bonuses will need to be based on availability, not generation

PJM should ensure a floor of 30 PAH/year in order to provide stability and certainty in capacity market

- <u>Floor:</u> By end of year, if fewer than 30 hours fall within functional headroom threshold, PJM should determine on an ex-post the tightest 30 hours of the prior year and assess bonuses/penalties in these hours

- <u>Additional PAH:</u> PAH can exceed 30 if there are more than 30 hours where functional headroom is less than the new threshold (scarcity hour)

Existing PAH Determination

resource availability

functional headroom

load + reserves

PAH only occur when load + reserves > resource availability

Proposed PAH Determination

resource availability

functional headroom

load + reserves

PAH determined ex-post for tightest 30 hours, defined as hours with lowest functional headroom

[1]*Language from Potomac Economics comments on proposed MISO resource adequacy requirements, FERC Docket ER22-495-000*

Measure Performance Relative to UCAP by Eliminating Balancing Ratio

↳ **Current CP construct measures performance of a resource relative to its UCAP * Balancing Ratio**

- Balancing ratio = total available capacity in the PAH / total committed capacity

- The balancing ratio exists to send an economic signal to generate without imposing an aggregate cost on generators (all penalties from underperforming generators are paid to overperforming generators)

↳ **However, resources have sold their full UCAP to load and should be held accountable to deliver the full value of what they sold forward**

- *Therefore, CP should measure performance relative to UCAP only*

↳ **This modification will remove the revenue neutrality aspect of the CP program and could likely result in aggregate penalty $ collections that can then be refunded to load (since they didn't receive the full capacity they paid for)**

↳ **Renewable and storage resources will be assessed relative to their marginal ELCC, which is consistent with their expected performance during scarcity hours**
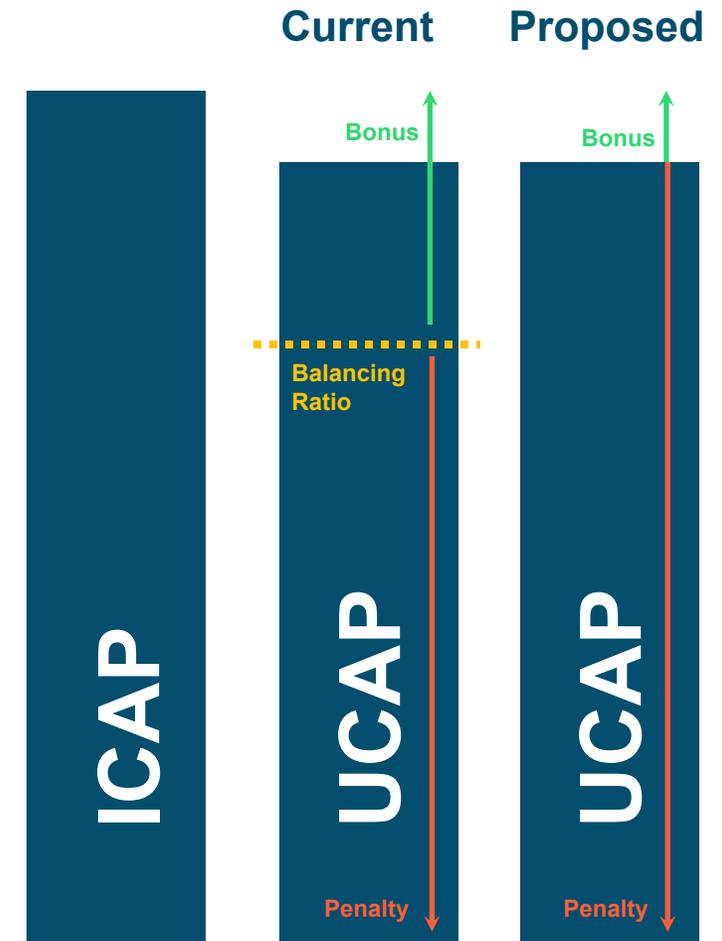
Current   **Proposed**

ICAP

UCAP
Bonus
Balancing Ratio
Penalty

UCAP
Bonus
Penalty

- **The current MSOC is based on gross avoidable cost rate (ACR) less energy and ancillary service (E&AS) net revenues**
  - Unit-specific ACR represents fixed annual costs that would not be incurred if a resource were not a capacity resource for a year less energy and ancillary service revenues
  - Adopted by FERC in Sep 2021

- **This is a departure from the prior MSOC that was based on the opportunity cost of foregone bonus payments associated with being a capacity resource**
  - Rationale is that the embedded assumption of 30 hours/year of performance assessment was higher than the actual number of expected hours, leading to complaints this MSOC was too high
  - Was ruled unjust and unreasonable by FERC in 2021

- **Resources with high expected E&AS net revenues cannot capture full costs of the risk and/or opportunity cost of being a capacity resource**

- **An MSOC that allows resources to bid full cost of risk and opportunity should be set as the highest of:**

$$\text{Avoidable Cost Rate} = [\text{Adjustment Factor} * (AOML + AAE + AFAE + AME + AVE + ATFI + ACC + ACLE) + ARPIR + APIR + CPQR]$$

- Adjustment factor
- Avoidable Operations and Maintenance labor
- Avoidable Administrative Expenses
- Avoidable fuel availability expenses
- Avoidable maintenance expenses
- Avoidable variable expenses
- Avoidable taxes, fees, and insurance
- Avoidable carrying charges
- Avoidable corporate level expenses
- Capacity performance quantifiable risk
- Avoidable project investment recovery rate

https://www.pjm.com/-/media/committees-groups/committees/mic/2021/20210210/20210210-item-05d-tariff-attachment-dd-section-6-8-redline.ashx

$$\frac{Net\ CONE}{Penalty\ PAI} * B * H = Net\ CONE * B$$

Proposed MSOC = Max (Gross ACR Including Risk – E&AS , Risk + Opportunity Cost[1])

- **It is expected that proposed changes to performance assessment construct will have significant impacts to the risks faced by a resource – it is critical that the MSOC adjust accordingly to reflect these risks**

[1]Assumes by convention cost of risk and opportunity cost are both positive values

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Appendix

Interim Proposal While Thermal ELCC Is Developed

- **One interim solution while thermal ELCC is being implemented is a less complex heuristic that could closely approximate a resource's ability to avoid loss of load**

- **MISO has actively explored metrics to approximate availability during the tightest system hours, including:**
  - Available Capacity (ACAP) – shown to right
  - Seasonal Accredited Capacity (SAC) – shown below

- **"Tight" hours defined as margin (%) e.g. effective headroom**

Available Capacity (ACAP)

Current Annual Construct	Initial Sub-annual Construct Proposal
MISO accredits conventional resources annually based on a 3-year XEFORd excluding planned outages.	MISO will accredit by season based on resource's availability (ACAP) during the tightest operating conditions including planned outages and utilize a UCAP/ACAP conversion ratio to align PRM and accreditation.

Resource Accreditation

Source: RAN Reliability Requirements and Sub-annual Construct

Seasonal Accredited Capacity (SAC)

$$Margin\ (\%)_j = \frac{Online\ margin\ (MW)_j + offline\ margin\ (12-hour\ lead\ time)(MW)_j}{Real\ Time\ (RT)\ Load\ (MW)_j}; \text{in which}$$

$Online\ margin\ (MW)_j = \sum_{unit\ i\ in\ region\ j}(EmergencyMax_i - Energy\ MW_i - cleared\ operating\ reserve_i)$

if a generation unit is online and under normal dispatch control

$Offline\ margin\ (MW)_j = \sum_{unit\ i\ in\ region\ j} Emergency\ Max_i - $
$cleared\ offline\ supplemental\ reserve(MW)_j$

if (i) a generation unit is offline; (ii) it's cold-start lead-time is less than or equal to 12 hours; and (iii) is not on outage

High

Reliability Risks

Low

Tier 2 Tight Hours — 80%

Tier 1 Non-Tight Hours — 20%
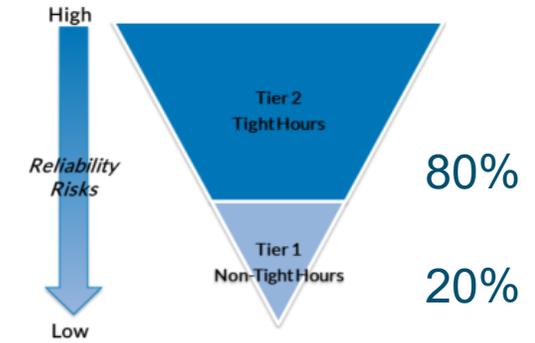
Balancing Ratio Numerical Examples

Overperforming Generator (Actual Performance > UCAP)

	Exemptions[1]	Balancing Ratio[2]	Bonus Rate $/MWh[3]	UCAP[4]	Actual Performance[5]	Total Bonus $/MW-yr[6]
Option 1: Status Quo	50%	70%	$1,700	90%	100%	$18,870
Option 2: Exemptions Excluded in Balancing Ratio	50%	85%	$3,400	90%	100%	$23,970
Option 3: Balancing Ratio = 100% (i.e. UCAP)	50%	100%	$3,400	90%	100%	$10,200

✎ **Key Takeaways**

- A higher balancing ratio will cause an overperforming generator to benefit from a higher bonus rate but lower bonus MW

- Option 2: Will cause total bonus to increase if actual performance > UCAP (i.e. when higher bonus rate outweighs lower bonus MW) and vice versa

- Option 3: Will cause total bonus to increase if original balancing ratio is high (i.e. minimal reduction in bonus MW but high gains in bonus rate) and vice versa

Underperforming Generator

	Exemptions[1]	Balancing Ratio[2]	Penalty Rate $/MWh[3]	UCAP[4]	Actual Performance[5]	Total Penalty $/MW-yr[6]
Option 1: Status Quo	50%	70%	$3,400	90%	0%	$64,260
Option 2: Exemptions Excluded in Balancing Ratio	50%	85%	$3,400	90%	0%	$78,030
Option 3: Balancing Ratio = 100% (i.e. UCAP)	50%	100%	$3,400	90%	0%	$91,800

✎ **Key Takeaway**

- A higher balancing ratio will always increase total penalties since penalty MW will increase but penalty rate is held constant

[1] Illustrative assumption
[2] Option 1 = illustrative assumption; Option 2 = 50% of balancing ratio reduction has been reduced (70% + [100%-70%*50%]); Option 3 = 100% by definition
[3] Option 1 = $3,400 * (1 - Exemption %); Option 2 = $3,400 by design since balancing ratio has increased; Option 3 = $3,400 by definition
[4] Illustrative assumption
[5] Illustrative assumption
[6] (Actual Performance % – UCAP % * Balancing Ratio %) * $/MWh Bonus/Penalty Rate * 30 Performance Hrs/Yr = Total Bonus Penalty $/MW-yr

MSOC Numerical Examples

All units in $/kW-yr	Costs		Benefits					
Scenario	Gross ACR	Risk	E&AS	Opportunity Cost	**Net Revenues** if doesn't clear capacity market	**Net Revenues** if clears capacity market	Required Minimum Capacity Bid	
		Only applies if resource clears the capacity market		*Only applies if resource doesn't clear capacity market*	*Gross ACR + E&AS + Opportunity Cost*	*Gross ACR + E&AS + Risk*		
1: Low E&AS Low Opportunity Cost	($110)	($10)	$30	$0	($80)	($90)	$90	*Resource requires $90/kW-yr to clear capacity market or it will mothball/retire*
2: High E&AS Low Opportunity Cost	($110)	($10)	$130	$0	$20	$10	$10	*Resource requires $10/kW-yr to be as well off as if it didn't clear capacity market*
3: Low E&AS High Opportunity Cost	($110)	($10)	$30	$20	($60)	($90)	$90	*Resource requires $90/kW-yr to clear capacity market or it will mothball/retire*
4: High E&AS High Opportunity Cost	($110)	($10)	$130	$20	$40	$10	$30	*Resource requires $30/kW-yr to be as well off as if it didn't clear capacity market*

Risk Aversion

- **It is well established that risk-averse actors prefer a lower certain value to an uncertain higher expected value**
  - For example, someone might prefer guaranteed $40 above a 50% chance at $100
  - This is similar to saying that someone might prefer to pay $10 rather than face an uncertainty with 50% probability of losing $50 and 50% of making $50

- **The current CP construct is revenue neutral, which means all generators in aggregate have an expected value of $0, but with individual uncertain outcomes**
  - *Risk averse generators will pay to mitigate this risk*
  - Whether or not generators buy insurance to cover this risk is influenced by the price of insurance relative to how they value the risk themselves

- **The price of insurance is based on the broader market's willingness to take on non-diversifiable risk**

risk-neutral preference | expected value