PJM RESOURCE ADEQUACY METRICS

AND ACCREDITATION

April 11, 2022

About LS Power

LS Power is a development, investment and operating company focused on the North American power and energy infrastructure sector

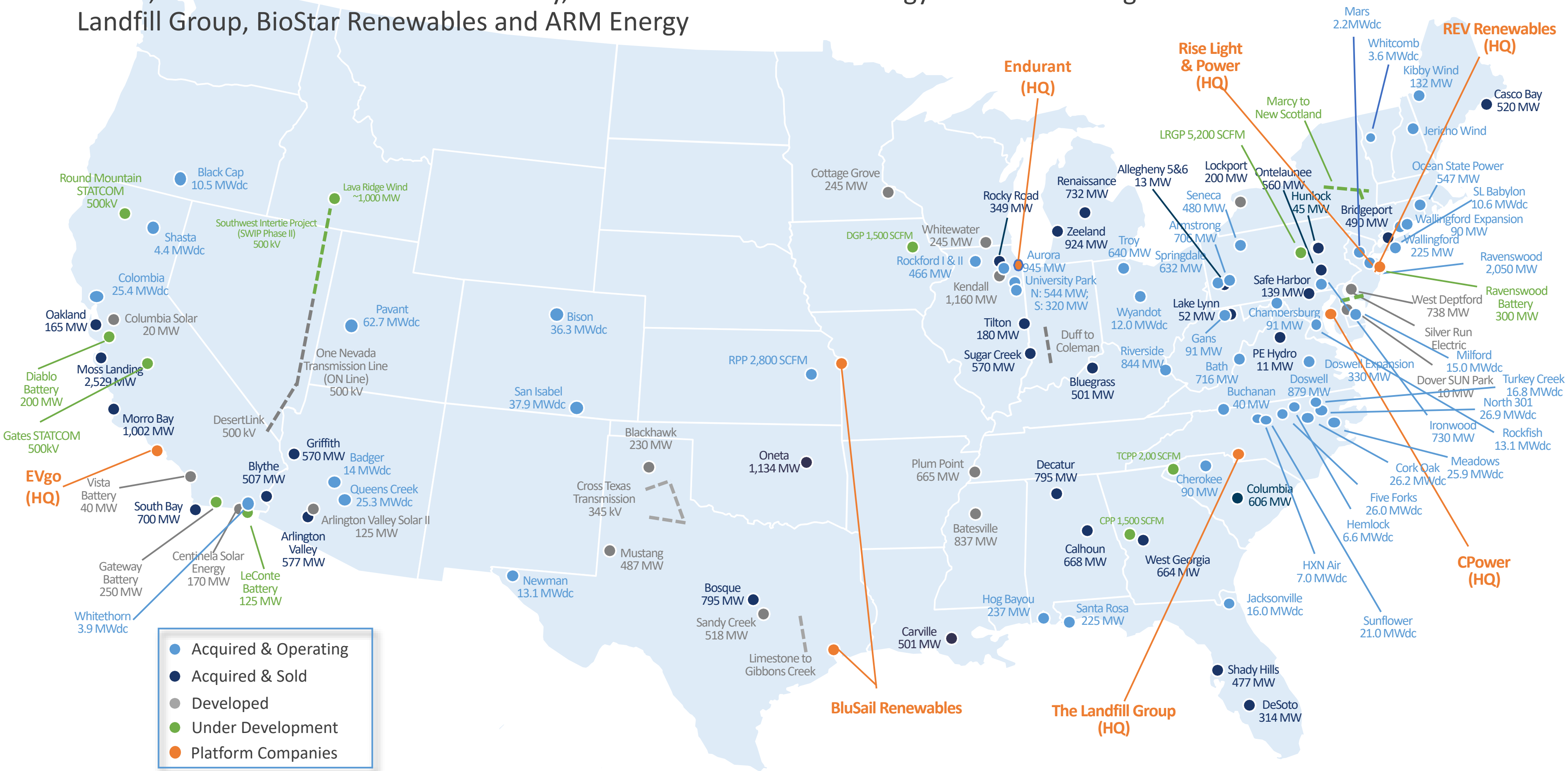
- Founded in 1990, LS Power has 280 employees across its principal and affiliate offices in New York, New Jersey, Missouri, Texas and California
- LS Power is at the leading edge of the industry's transition to low-carbon energy by commercializing new technologies and developing new markets.
  - **Utility-scale power projects across multiple fuel and technology types**, such as pumped storage hydro, wind, solar and natural gas-fired generation
  - **Battery energy storage**, market-leading utility-scale solutions that complement weather dependent renewables like wind and solar energy
  - **High voltage electric transmission infrastructure**, which is key to increasing grid reliability and efficiency, as well as carrying renewable energy from remote locations to population centers
  - **EVgo, the nation's largest public fast charging platform for electric vehicles** and first platform to be 100% powered by renewable energy
  - **CPower Energy Management**, the largest demand response provider in the country that is dedicated solely to the commercial and industrial sector
- Since inception, LS Power has developed, constructed, managed and acquired competitive power generation and transmission infrastructure, for which **we have raised over $47 billion in debt and equity financing.**
  - **Developed over 11,000 MW of power generation** (both conventional and renewable) across the United States
  - **Acquired over 34,000 MW of power generation assets** (both conventional and renewable)
  - **Developed over 660 miles of high voltage transmission**, with ~400 miles of additional transmission under development

Utilize deep industry expertise as owner/operator

LS Power Project Portfolio

Extensive development/operating experience across multiple markets and technologies

- With over $47 billion in equity and debt raised, LS Power has developed and acquired 120 Power Generation projects (renewable and conventional generation), 7 Transmission projects, and 5 Battery Energy Storage projects
- LS Power's Energy Transition Platforms includes CPower Energy Management, Endurant Energy, EVgo, Rise Light & Power, and REV Renewables. Additionally, LS Power has Waste to Energy initiatives through its Joint Ventures with the Landfill Group, BioStar Renewables and ARM Energy



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Motivation for This Presentation

- KWA #2 is to determine the types of reliability risks and risk drivers to be considered by the capacity market and how they should be accounted for
- As a part of KWA #2, stakeholders have identified concerns, which LS Power (LSP) largely share, with the existing accreditation methodology for conventional resources; and
- There's a need for better price signals to incent unit-specific investment in reliability regardless of fuel source.

LS Power Shares Enel's Concerns Around Market Design

STUDIES RAISE CRITICAL QUESTIONS FOR PJM RELIABILITY AND MARKETS

- How can we ensure that consumers are paying for resources that can **deliver** when needed?
- Is the market sending accurate price signals to appropriately **value** and **differentiate** thermal resources?
- How can markets best send exit signals to unreliable MW and entry /retention signals to **reliable** MWs?

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Source: 2/28 Enel presentation to the RASTF

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Position Summary

- Thermal resources are not all the same.
  - Thermal reliability is driven primarily by economic decisions, not external or uncontrollable factors.
  - Significant variability within and among thermal resource types.
- Proposals to apply ELCC to thermal resources will obscure economic choices and may solidify the status quo by muting price signals.
- **Instead of developing an assumption-driven ELCC for thermal, it is preferable to refine the unit-specific "UCAP" concept and better align it with the treatment of intermittent resources.**

ELCC works for intermittent resources because performance is mostly determined by factors outside their control.

- ELCC for intermittents is intended to predict expected output, coincident with system demand, in stressed hours.
- Reliability value is driven by fuel availability – wind or solar radiance – and load.
- Once a resource has been built, there is little that it can do to improve its performance.
  - There will be some natural variability performance within a class and this is covered with the ELCC Resource Performance Adjustment.
- The only way a resource can "secure" more wind or sun is through new construction or repowering.
  - A solar developer can elect to build a tracking array instead of a fixed.
  - A wind developer can repower an existing farm with taller turbines or better power curves.

ELCC doesn't work for thermal because performance primarily depends on individual unit operations and economic choices.

- Many factors influence reliability for thermal resources, and these factors are largely economic in nature.
  - **Investment to improve reliability is highly fact-specific** and is influenced by many variables (e.g., weatherization, type and duration of dual-fuel capacity, reinforcing single points of equipment failure, age of existing equipment).
  - **Gas availability is highly fact-specific** based on a number of economic considerations (e.g., plant heat rate, gas interconnection arrangements, etc.).
- An existing thermal resource can improve its reliability by improving its weatherization, changing its fueling arrangements, modifying its maintenance practices, changing its air permit restrictions, and so on.
- ELCC class-average approaches lumps good and bad performers into one class, which discourages generators from taking proactive steps to improve/maintain reliability because non-performance risk is socialized across the whole class.
- While a "perfect" ELCC might yield accurate accreditations, it is unlikely that any modeling exercise can capture the nuances of thermal operation.

Current Unit-Specific Accreditation Approaches Are Not Sufficient

- UCAP-based thermal resource accreditation in PJM, based on EFORd, does not distinguish between outages when the system is stressed and outages when system is unstressed.
  - A failed start on a mild April morning is fundamentally different than a failed start on the summer peak hour.
- UCAP-based accreditation does not account for *any* correlated risk (e.g. temperature dependence)
- UCAP-based accreditation incorrectly allocates outage variability to load.
  - Under UCAP, system planners embed thermal correlated outage in the demand-side Reliability Requirement.
  - Under class-based ELCC, this risk is allocated back to the suppliers.

1. Astrape Consulting, *Accrediting Resource Adequacy Value to Thermal Generators,* March 2022, https://www.aee.net/aee-reports/getting-capacity-right-how-current-methods-overvalue-conventional-power-sources

Proposed Design Principles

For **enhanced accreditation for thermal resources**, a design should:

1. Weight system stressed hours more heavily;
2. Avoid diluting stand-alone performance (or non-performance);
3. Ensure sufficient forward-looking market signals are created to incent investment in reliability;
4. Ensure price signals for actual and expected non-performance would drive to a market exit; and
5. Use class-average approaches to augment unit-specific metrics only when unit-specific metrics are inadequate.

- Enhanced accreditation must be aligned with **performance incentives** to ensure that expected resource performance is "trued-up" with actual performance in operational timeframe.

Conclusions

- Thermal resources are not all the same.
  - Thermal reliability is driven primarily by economic decisions, not external or uncontrollable factors.
  - Significant variability within and between thermal resource types.
- Proposals to apply ELCC to thermal resources will obscure economic choices and may solidify the status quo by muting price signals.
- LSP suggests that resource accreditation should:
  - Incent investment in reliability;
  - Create market exit signals; and
  - Better aligns with the needs of the future grid.
- **Instead of developing an assumption-driven ELCC for thermal, it is preferable to refine the unit-specific "UCAP" concept and better align it with the treatment of intermittent resources.**

Comments on the AEE / Astrape Report

AEE's thermal accreditation work offers an interesting concept that suffers from methodological flaws & unit allocation inefficiencies.

Report implicitly highlights the difficulty of extending ELCC to conventional generators.

- Recent work sponsored by AEE contemplates extending ELCC-type techniques to thermal resources.
  - Considers system four kinds of new risks over and above to current accreditation including **(1)** outage asymmetry, **(2)** common mode failures, **(3)** weather dependent outages, and **(4)** fuel availability outages.
  - When all correlated outages are considered, **AEE suggests winter de-rates in excess of 20%,** despite a 5% forced outage rate.
- Report is an interesting thought piece but highlights the difficulties of extending market-based ELCC to thermal because:
  - Common-mode and fuel-supply outages are highly fact specific and not generalizable.
  - Weather dependent outages are highly variable on a unit-level.
  - Even if a high-quality class ELCC can be developed (uncertain), no obvious method to allocate class results to specific resources.

Thermal Generator SUMMER	Outage Factor	Accreditation Impact (Incremental)	Capacity Credit (Cumulative)
Standard Practice	Forced Outage Rate	5.0%	95.0%
Proposed Additional Factors	Outage Variability	4.6%	90.4%
	Common Mode Outage	N/A	
	Weather Dependent Outage	5.6%	84.7%
	Fuel Supply Outages	N/A	
Adjusted Summer Thermal Capacity Credit:		84.7%	

SOURCE: Astrapé Consulting, "Accrediting Resource Adequacy Value to Thermal Generation," March 2022

Thermal Generator WINTER	Outage Factor	Accreditation Impact (Incremental)	Capacity Credit (Cumulative)
Standard Practice	Forced Outage Rate	5.0%	95.0%
Proposed Additional Factors	Outage Variability	2.7%	92.3%
	Common Mode Outage	2.3%	90.0%
	Weather Dependent Outage	10.0%	82.3%
	Fuel Supply Outages	6.2%	76.1
Adjusted Winter Thermal Capacity Credit:		76.1%	

1. Astrape Consulting, *Accrediting Resource Adequacy Value to Thermal Generators,* March 2022, https://www.aee.net/aee-reports/getting-capacity-right-how-current-methods-overvalue-conventional-power-sources

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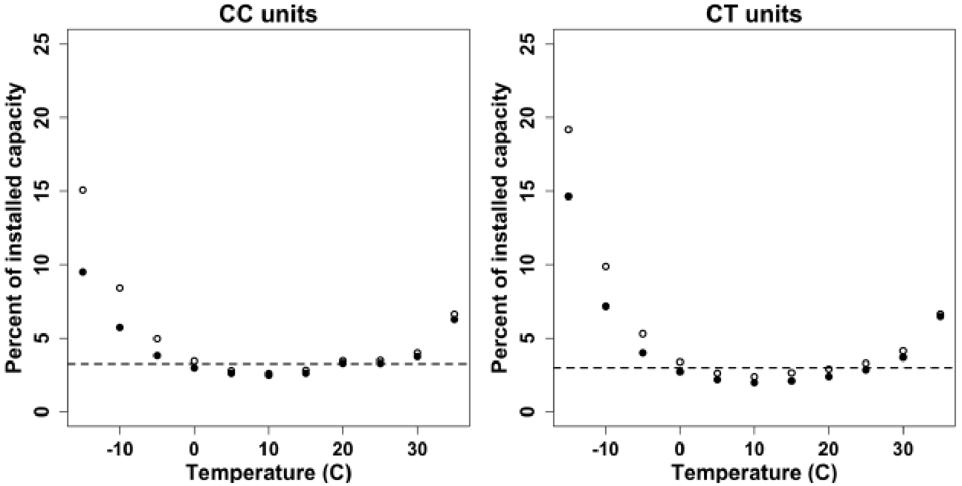
Concern #1: Astrape double-counts fuel supply constraints

Murphy (2019)'s cold-weather outage estimates already included fuel unavailability.

- Astrape report speculates that **weather-dependent outages** are separate and distinct from **fuel-supply outages.** [Report at 16]
  - "The weather dependent outages identified in the Sinnott Murphy report appears to only be identifying outage correlations with extreme hot and cold temperatures. However, during extreme cold weather events, there is an additional impact on the availability of fuel itself…" (Report at 34).
- But, the Murphy study *already* included fuel-supply outages as part of its overall temperature dependent outage estimates.
  - Per correspondence with Murphy, about 40% of cold-weather outage is due to fuel unavailability.
- So, by layering fuel constraints on top of the weather-dependent outage estimates, **Astrape is double counting fuel supply constraints (in part or whole).**



Murphy Fig. 6. Sensitivity: *Expected levels of unavailable capacity as a function of temperature, with and without fuel supply outages.*

- Hollow circles are presented in the main report and *include* all outages, including fuel unavailability events.
- Solid circles *exclude* fuel unavailability events.

Fuel unavailability events defined using three GADS codes (9130, 9131, 9134) which relate to physical fuel supply disruptions or fuel conservation, not fuel system mechanical issues.

Sinnott Murphy, Fallaw Sowell, Jay Apt, *A time-dependent model of generator failures and recoveries captures correlated events and quantifies temperature dependence,* Applied Energy, Volume 253, 2019, https://doi.org/10.1016/j.apenergy.2019.113513.

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Concern #2: Astrape extrapolates temperature dependent outages far beyond the research it is based on.

- Astrape estimates **weather-dependent outages** down to -15 Deg F (Report at 14)
  - Starts with estimates from Murphy (2019), which estimates down to -15 Deg C (5 Deg F).
  - Then, Astrape extrapolates outage rates down linearly to -15 Deg F
- **Extrapolation inflates maximum outage rate for CTs from 16% to 28% and CCs from 11% to 19%.**
- Astrape does not justify their extrapolation.
- Murphy cautions that there is very little outage data below 5 Deg F, so colder estimates are mostly parametric extrapolation, not physical observations.
- **Astrape's extrapolated region *also* implicitly includes significant fuel-related outage rates.**

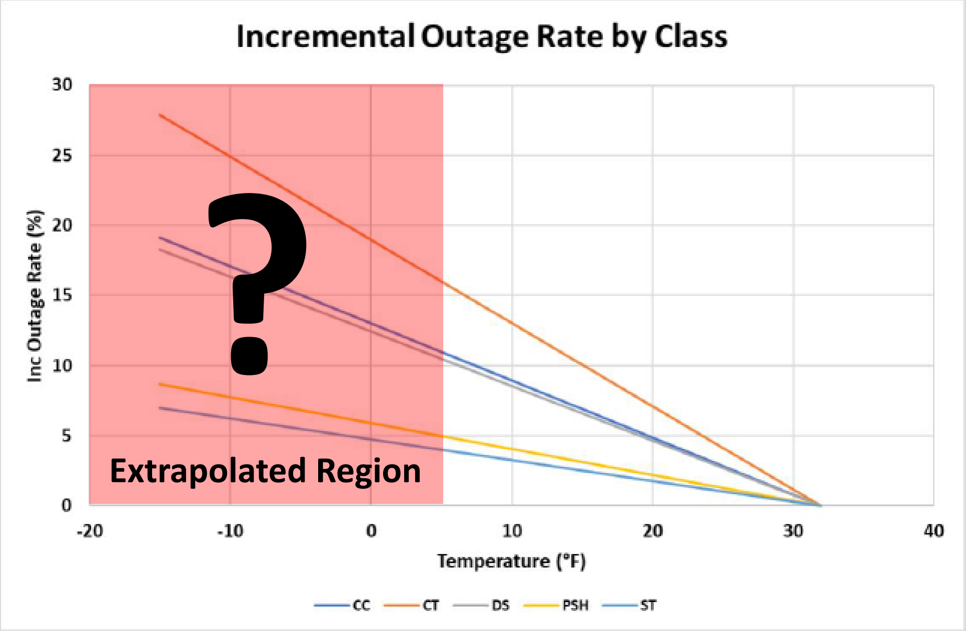

Figure ES3. Cold Weather Outage Assumptions

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Concern #3: Astrape elides significant intra-class variability

- Astrape indicates that class-level adjustments can be applied directly to resources within each class.
  - For example, Astrape indicates that weather-dependent outages should reduce portfolio accreditation by 12.7%
  - Astrape *also* indicates that a specific unit, the Hopewell CC, should be reduced by the same 12.7% to account for weather-dependent outages. (Report at 40).
- Murphy (2019) – on which these values are based – found that there is significant variance in unit reliability (i.e., a few were very unreliable and many were very reliable); see chart to the right.
- **Does not make sense to apply a fixed / average derate to all resources in a class given significant variability between resources.**
  - If thermal ELCC pursued, more work needed to develop high quality class-unit allocators.

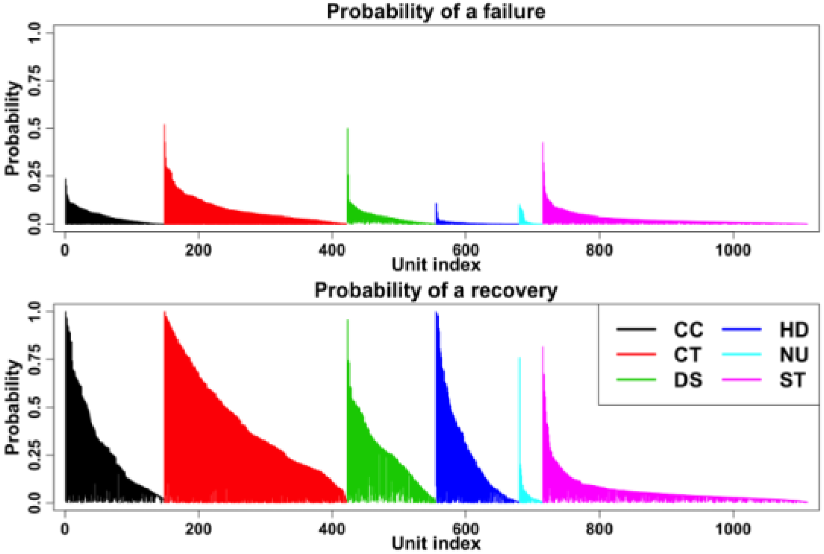

Figure A.12: Summarizing the empirical range of hourly transition probabilities (1995-2018 model fits). *Plots include 1,111 generators with at least 10 failure and recovery events per statistically significant model parameter. Each generator is represented as a vertical line at an integer index (1 to 1,111). In each plot, generators are sorted by generator type and maximum experienced transition probability. Black is combined cycle gas (CC), red is simple cycle gas (CT), green is diesel (DS), blue is hydroelectric (HD), cyan is nuclear (NU), magenta is steam turbine (ST).*

1. Sinnott Murphy, Fallaw Sowell, Jay Apt, *A time-dependent model of generator failures and recoveries captures correlated events and quantifies temperature dependence,* Applied Energy, Volume 253, 2019, Supplementary Materials, https://ars.els-cdn.com/content/image/1-s2.0-S0306261919311870-mmc1.pdf

Appendix: Rationale for Proposed Design Principles

Design Principle #1: Weight System Stressed Hours

- ELCC accredits resources based on an expectation of performance with an emphasis on when system conditions are stressed (i.e., performance in non-stressed hours does not have a material impact on accreditation);
- An analogous approach to *incent* dispatchable resources to invest in reliability would be to create forward-looking expected costs of non-performance that increase as system conditions tighten;
  - System stressed hours are expected to occur more randomly as the penetration of intermittent resources increases
- Assuming system stress is highly correlated with extreme temperature conditions, it creates significant costs of non-performance during the periods of greatest need and should incent investment in reliability under these conditions.

Design Principle #2: Avoid Diluting Standalone Performance

- Aggregate trends show correlated outage risk, but this does not support a causal relationship (i.e., some generators appear to be very reliable under extreme hot and cold conditions);
- Our experience is that performance for thermal units during extreme temperatures is largely an economic choice, and reliability can be improved with proper market signals;
- Socializing performance into class averages shields non-performers and incents good performers to not invest in reliability (i.e., adverse selection problem); and
- To maximize the distinction between good and bad performers and drive investment in reliability, performance must be remain at the unit level.

Design Principle #3: Create Forward-looking Price Signals

- Thermal resources can improve their reliability through capital investments;
- Investment decisions are not made based on sunk costs but based on expected future revenues and costs; and
- Investment is driven by the ability of generators to calculate expected future costs and revenues under different scenarios with and without risk-mitigating investment.

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Design Principle #4: Create Sufficient Exit Signals

- If non-performance occurs during stressed hours, the future reduction in accreditation will place additional financial stress on all non-performing generators;
- Generators that are otherwise inframarginal and have expectations of future reliable performance will survive (i.e., treatment of the non-performance event as a sunk cost);
- Non-performing marginal generators that avoided reliability investment will be financially challenged in the short-term and may re-evaluate their expected long-term cash flows based on a heightened sensitivity to the risk of non-performance; and
- Selecting an averaging period that balances the need o provide strong, near-term exit signals and not excessively penalizing inframarginal generators requires careful consideration.

Design Principle #5: Use Class-averages Only When Unit-specific Measures Fail

- As previously described, asymmetric outage risk is a component that is currently calculated by PJM system planners and added to the IRM quantity to be procured by demand;
- To align with the approach used for intermittents, this risk component could be added to the unit-specific measurement; and
- While pipeline gas availability has been suggested as an area ripe for ELCC, there is no known dataset on gas supply and demand correlated with temperature that is robust enough for such a model and how pipeline gas, when scarce, would be allocated to gas-only generators has not been debated.