NERC Evaluating Resource Contributions for Reliability and Capacity Supply Workshop

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June 5-6, 2025

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  - Aidan Tuohy, Director, Transmission Operations and Planning, EPRI
  - Derek Stenclik, Founding Partner, Telos Energy
  - Duane Highley, Chief Executive Officer, Tri-State Generation and Transmission
  - Arne Olson, Senior Partner, Energy and Environmental Economics, Inc.
  - Samuel A. Newell, Ph.D., Principal, The Brattle Group
  - Zach Smith, Senior Vice President, System & Resource Planning, New York ISO
  - Savannah Miller, Advisor, Resource Adequacy Planning, Midcontinent ISO
  - Marianne Perben, Director of Planning Services, ISO New England

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Evaluating Resource Contributions for Reliability and Capacity Supply Workshop

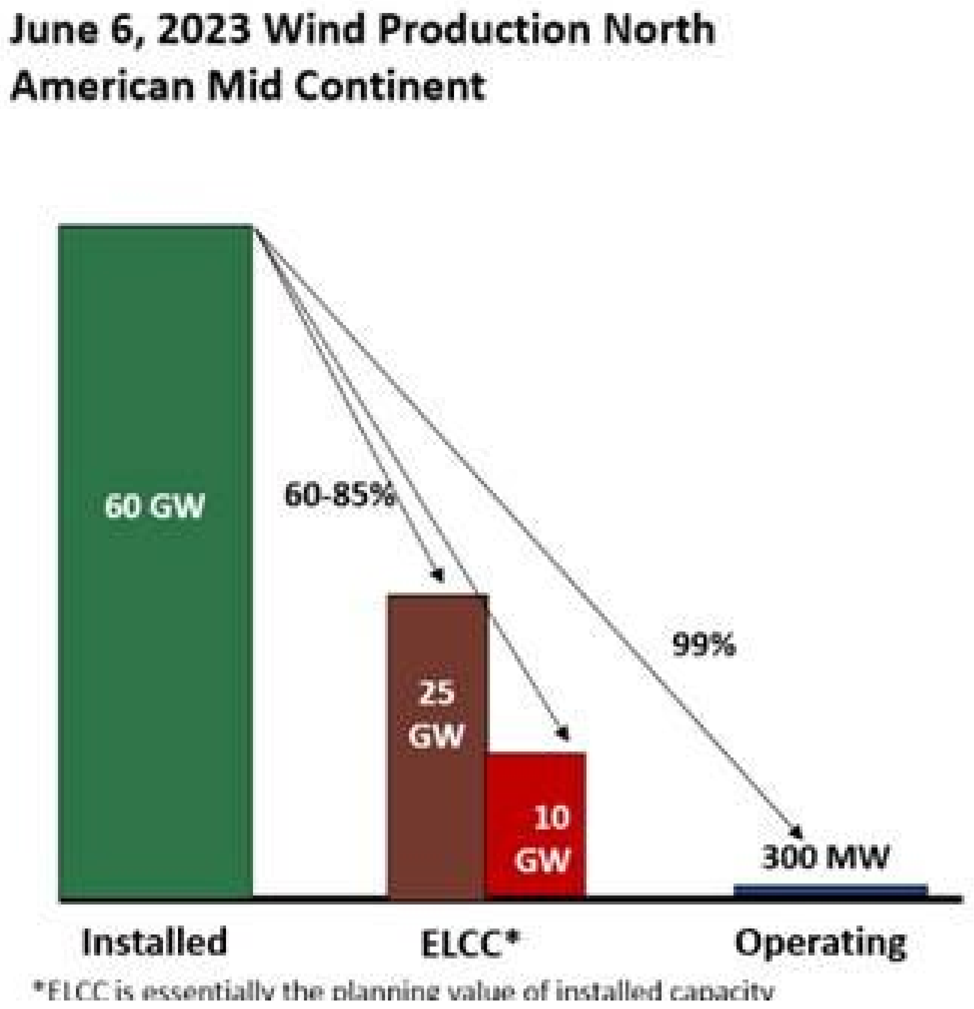
John Moura, Director Reliability Assessments and Performance Analysis, NERC
June 5, 2025

ELCC Description

- Effective Load Carrying Capability (ELCC) is a statistical approximation—a marginal reliability contribution of a resource relative to a benchmark technology like a firm gas plant.
- It is not a physical property of the generator. It’s a system-dependent metric, sensitive to the load shape, portfolio mix, geographic diversity, and risk tolerance.
- ELCC doesn’t reflect true dispatchable capability or performance under duress, especially during extreme events.

Misinterpretations and Risks

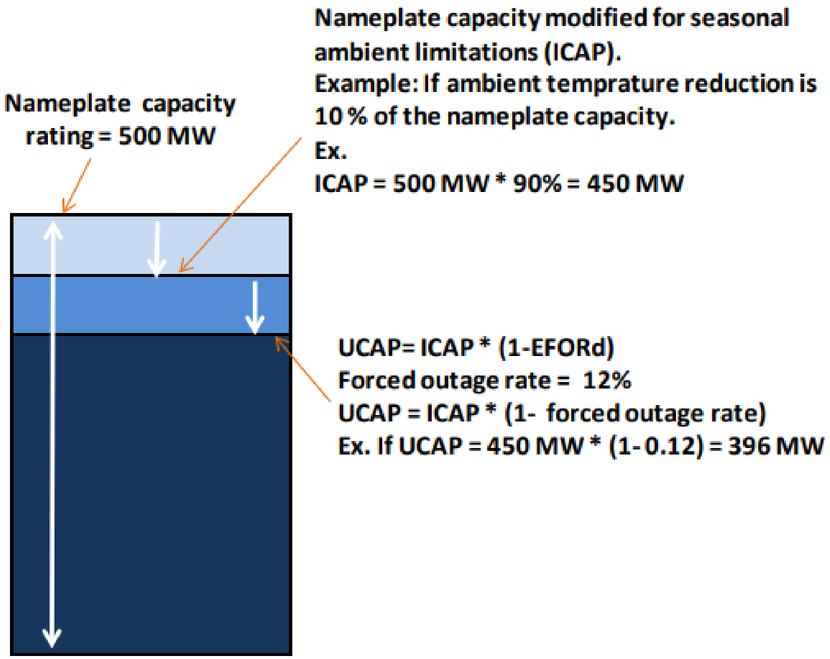
- ELCC can be easily misunderstood as a fixed or intrinsic rating.
- In markets, ELCC is sometimes deployed as a way to “credit” resources—this can lead to illusionary adequacy if reliability risk isn’t modeled deeply.
- ELCC values used for long-term planning are not fixed and will adjust as the resource and load mix change.
- Mistake: Thinking that a wind fleet with a 20% ELCC is “firm” like a generator with a 95% Unforced Capacity (UCAP).



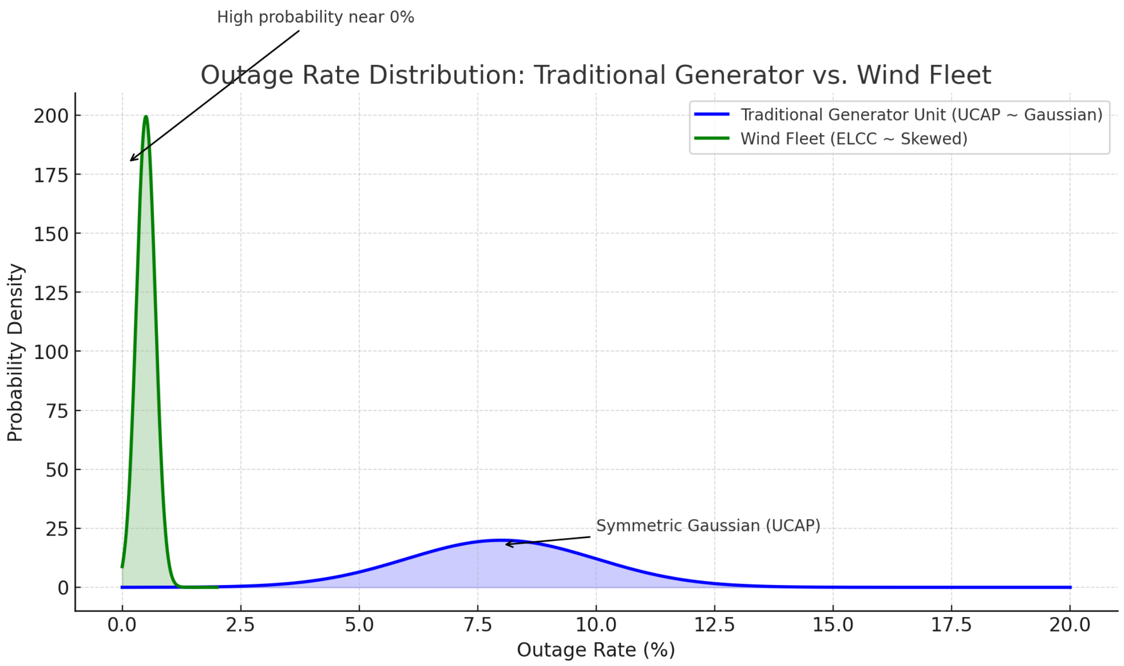
Why It's Not Equivalent to UCAP or Forced Outage Derating

- Unlike a traditional capacity rating, which is derated for a known forced outage rate, ELCC is based on probabilistic modeling of loss-of-load events.
- This means two resources with identical capacity factors or outage statistics could have different ELCCs, depending on the portfolio they're in.

Traditional Dispatchable Resource



Outage Probability Distribution



How Should We Think About Resource Contributions (From a Reliability Perspective)

- Conservative by design—planning approaches that are resilient to uncertainty and extreme events.
- Mistake: Assuming ELCC is stable across seasons or conditions.
- Instead of relying solely on ELCC:
  - Use multi-metric planning, combining ELCC with firm capacity, seasonal risk assessments, and resource availability curves.
  - Perform scenario-based stress testing under extreme weather, fuel disruptions, and correlated outages and constrain contributions as appropriate.
  - Evaluate stability, not just adequacy—can the resource follow ramps, respond to contingencies, provide inertia or voltage support?

The Right Questions to Ask in Resource Adequacy Today

- Is this resource available when risk is highest?
- Does it reduce net load uncertainty, or add to it?
- What is its performance record during extreme system conditions?
- What is its dependence on infrastructure or assumptions (e.g., transmission availability, fuel delivery, storage duration)?

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Ideas for Discussion: Reliability Lens

- With higher penetration of energy-limited and/or variable resources, capacity planning using only the Planning Reserve Margin is insufficient
- Resource adequacy assessments requires all time periods to be evaluated
- ELCC is a clever approach and technically sound using probabilistic
- To unify ELCC, conforming underlying probabilistic resource adequacy assessments are needed
- But capacity planning is still important, particularly in markets, and by incorporating energy considerations using a unified and risk adverse approach, adequate capacity supply can be planned

Questions and Answers

LCOE

LEVELIZED COST OF ELECTRICITY

BUILDING A BETTER NARRATIVE

Karl Hausker, Ph.D.
Senior Fellow
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June 2025

TOPICS

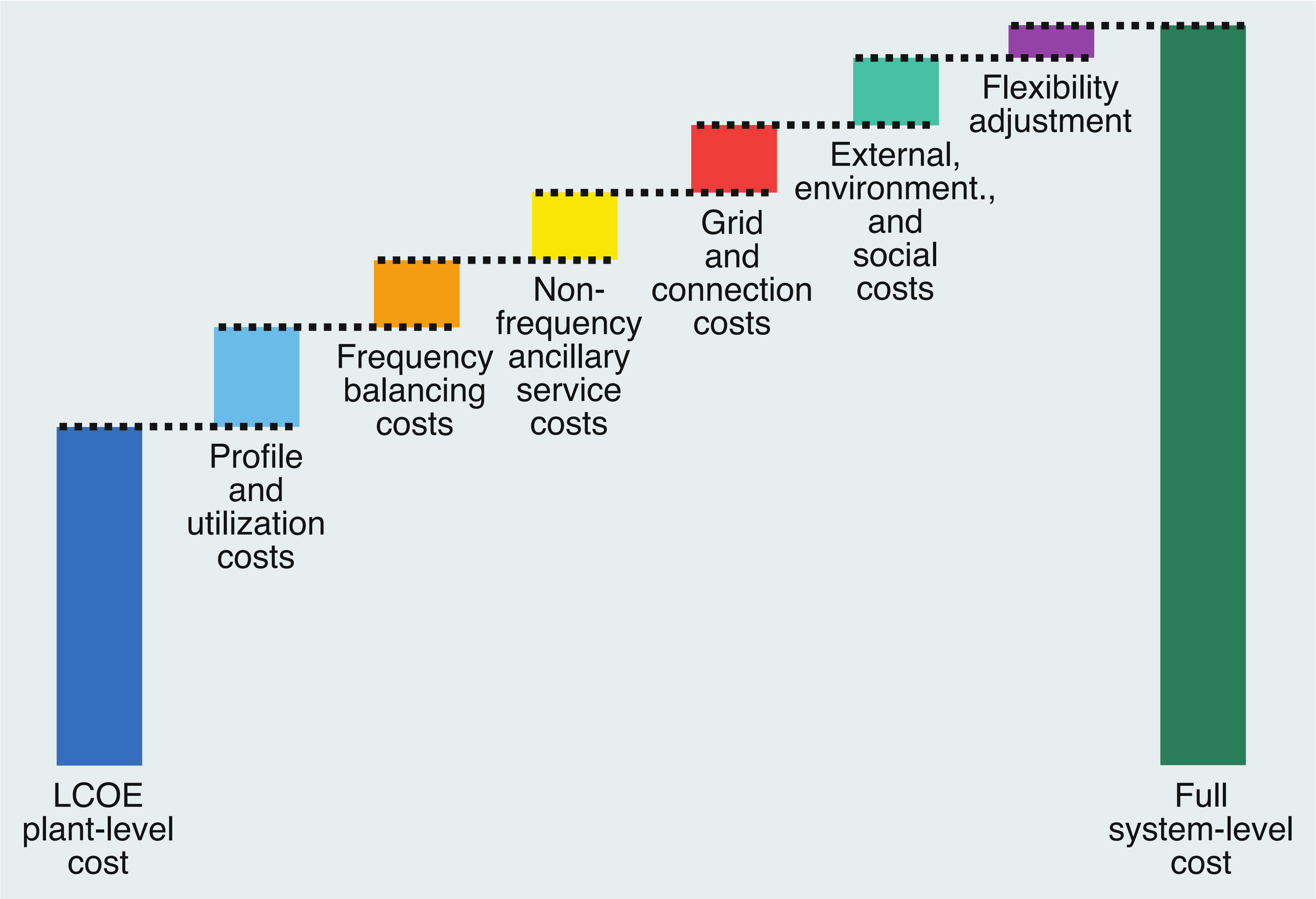
- Preview of upcoming study on *"Understanding the Full System Costs of the Electricity System"*
  - Commissioned by the United Nations Economic Commission for Europe (UNECE) and World Nuclear Association (WNA)
  - Jim Robb (NERC) and I serve on Advisory Group
  - Addresses issues related to
    - LCOE and variations on LCOE
    - Framing of issues of resource adequacy, reliability, robustness, and resiliency
    - How these challenges should push us to further improve our models of electricity systems – to inform decision-making
- Personal views on LCOE, and the need to change the narrative on LCOE
- 'Preaching to the choir' but aiming for practical advice

UNECE/WNA STUDY REVIEW LCOE AND LCOE VARIANTS

- LCOE and its limitations
- Variants
  - LFSCOE – Levelized Full System Cost of Electricity (Idel) – assumes a single technology serves the grid
  - VALCOE – Value-Adjust Levelized Cost of Electricity (IEA) – adjust LCOE up or down to reflect some time dimensions of production, ability to meet peak demand, and flexibility
  - LACE – Levelized Avoided Cost of Electricity (EIA) – what cost is avoided by addition of a plant to a grid (i.e., a measure of value)
    - Ask: Is LACE > LCOE?

STUDY PROPOSES NEW LCOE VARIANT

- **“Full system-level cost”**
- **Aims at more complex set of adjustments to LCOE**
  - **Profile and utilization (time dimension)**
  - **Frequency balancing**
  - **Non-frequency ancillary services**
  - **Grid and connection**
  - **External environment and social costs**
  - **Flexibility adjustment**



PERSONAL VIEWS ON LCOE AND LCOE VARIANTS

- Improvements for LCOE have been proposed for years but get no traction
- All LCOE variants are more complex and require assumptions on the grid that a plant would feed into
  - Which makes the LCOE variant estimate ‘grid-specific’
  - Which makes the LCOE variant more ‘realistic’
  - Which makes it less ‘general’ and ‘widely applicable’….
- No proposed LCOE variant can be decision-making metric for a utility, grid operator or IPP
- So where do we go from here?....

CAUTIONS ON USE OF LCOE

INSIDER: Not All Electricity Is Equal—Uses and Misuses of Levelized Cost of Electricity (LCOE)

WORLD RESOURCES INSTITUTE

August 1, 2019 By **Laura Malaguzzi Valeri**

Competitiveness Metrics for Electricity System Technologies

Trieu Mai,[1] Matthew Mowers,[2] and Kelly Eurek[1]

[1] *National Renewable Energy Laboratory*
[2] *Independent Contractor*

NREL

Levelized Costs of New Generation Resources in the Annual Energy Outlook 2023

"Direct comparisons of LCOE or LCOS across technologies are misleading as a method to assess economic competitiveness"
-- *EIA, AEO 2023*

HOW SHOULD LCOE BE USED?

Competitiveness Metrics for Electricity System Technologies, *T. Mai et al, 2021*

"LCOE is an incomplete metric… LCOE is not designed to capture a technology's full economic value to the system..." [p.vi]

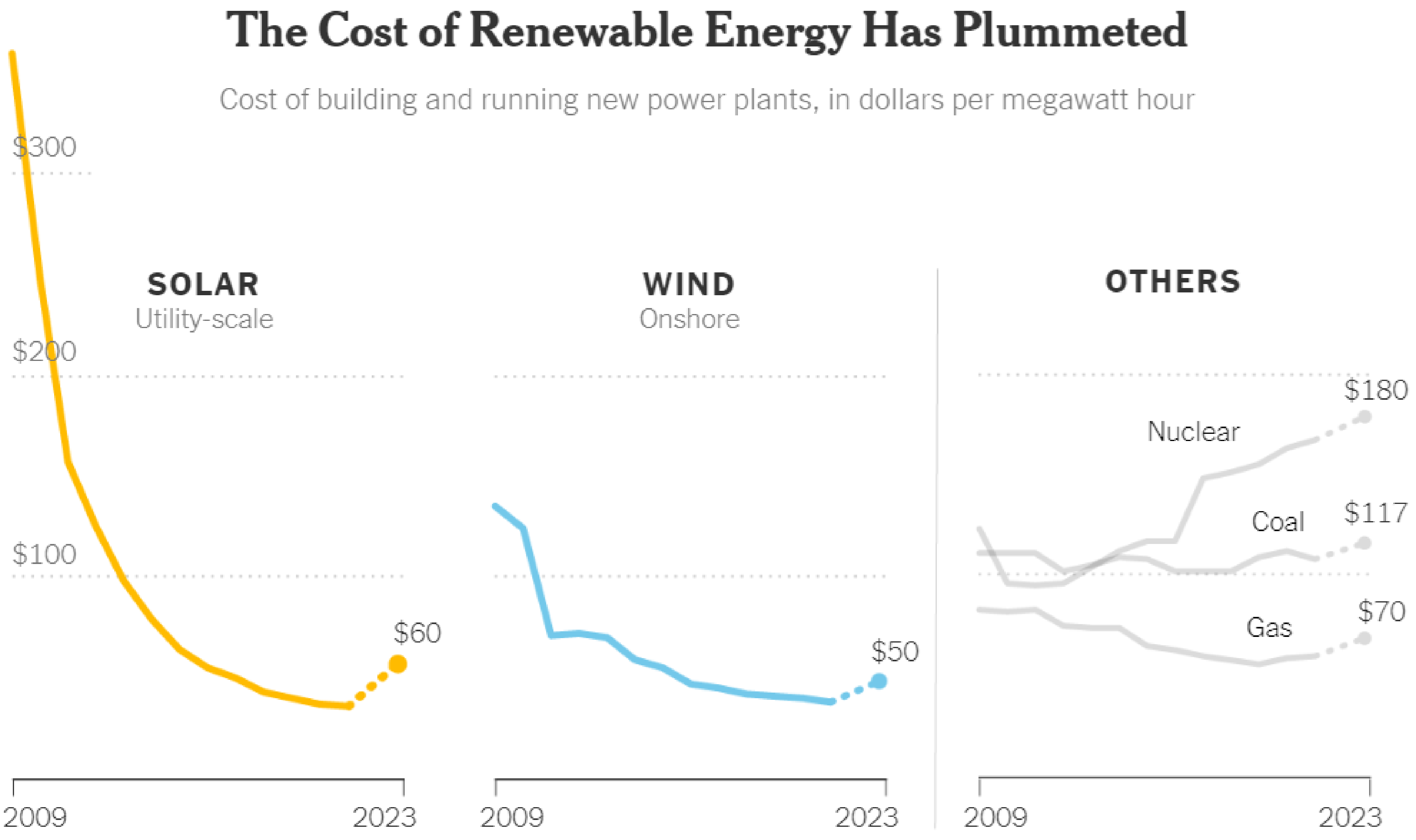
"LCOE is commonly used to communicate technology comparisons. This use can be appropriate to track

- **the cost and performance progress of a single technology over time**
- **or to compare technologies that operate similarly and that primarily provide energy services." [p.14]**

TYPICAL MEDIA COVERAGE OF COST OF ELECTRICITY

"Today, solar and wind power are the least expensive new sources of electricity in many markets…"

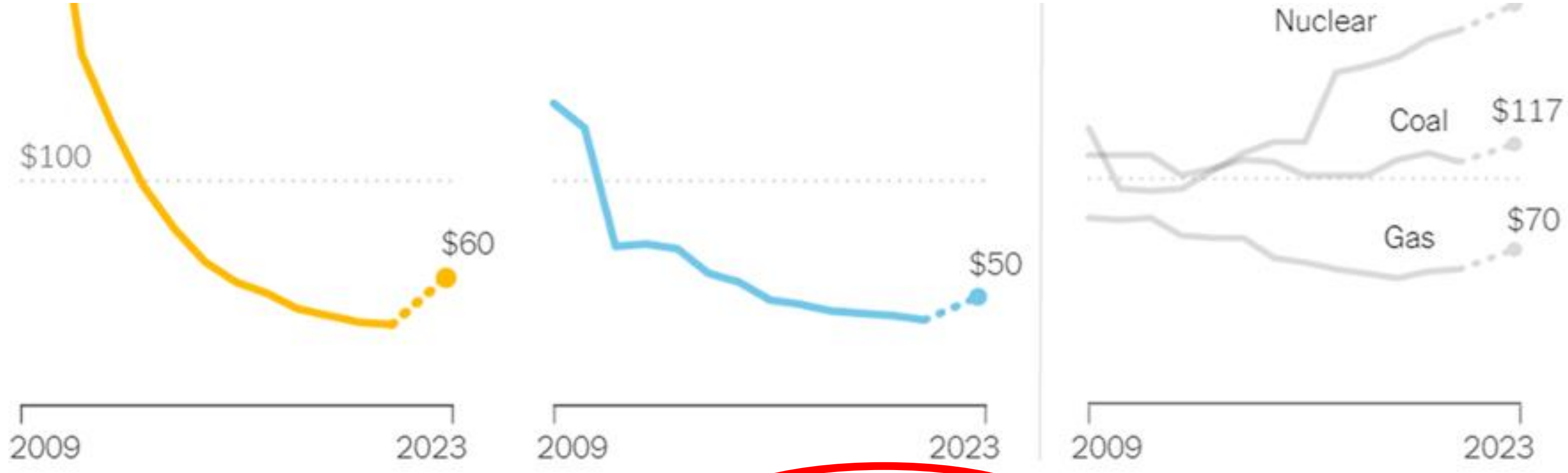
- NY Times, 2023



Source: Lazard • Notes: Charts reflect the mean levelized cost of energy, which captures the price of building and running new power plants but excludes other electrical system costs. Lazard did not release data for 2022. In 2023, costs rose because of supply-chain problems, inflation and other issues. • By The New York Times

WHAT IS CHEAPEST SOURCE OF ELECTRICITY?

- **WRONG QUESTION!**
- **A myth has been constructed: *"Renewables are cheapest"* – end of story.**
- **The truth is more complicated…**



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The myth rests on a measure of cost called "Levelized Cost of Energy" or LCOE.
All credible experts acknowledge that this measure is simplistic, and risks comparing "apples to oranges."
BTW-- Pet peeve: it's "Electricity", not Energy"

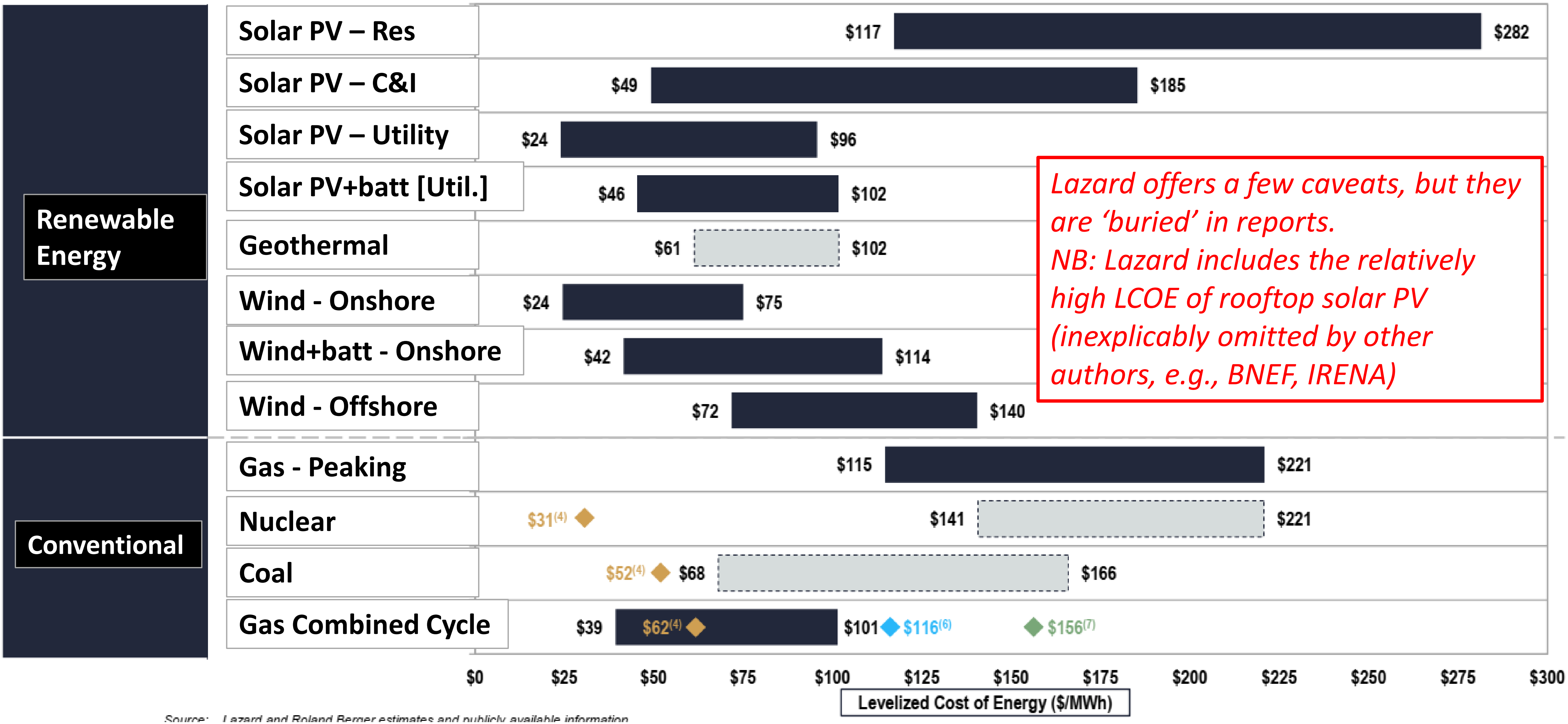
See for example: [Not All Electricity Is Equal—Uses and Misuses of Levelized Cost of Electricity (LCOE)]

WORLD RESOURCES INSTITUTE

Levelized Cost of Energy Comparison—Unsubsidized Analysis

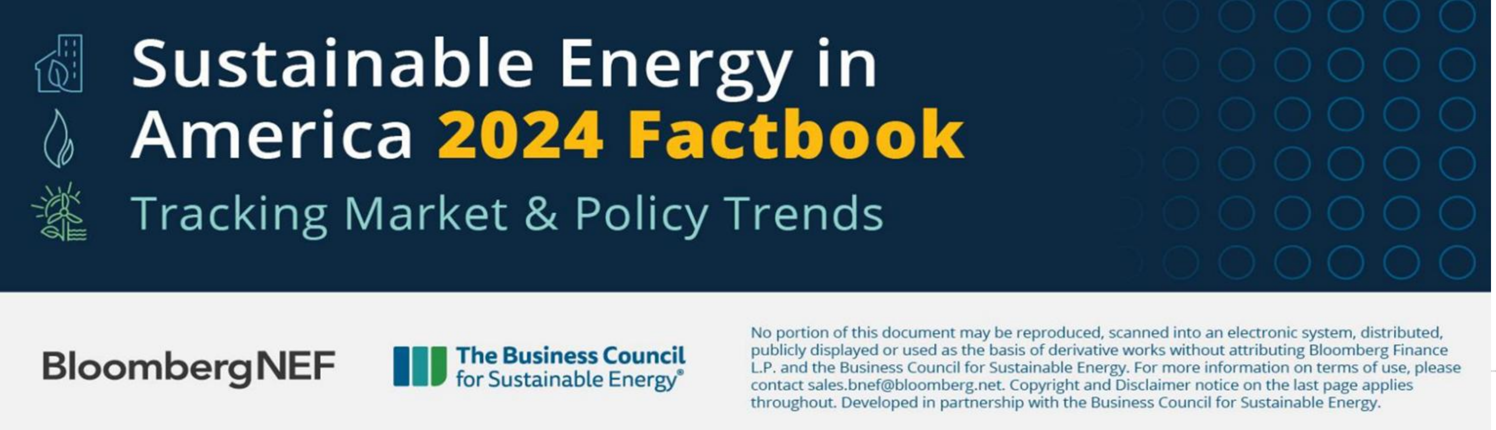
LAZARD

Selected renewable energy generation technologies are cost-competitive with conventional generation technologies under certain circumstances



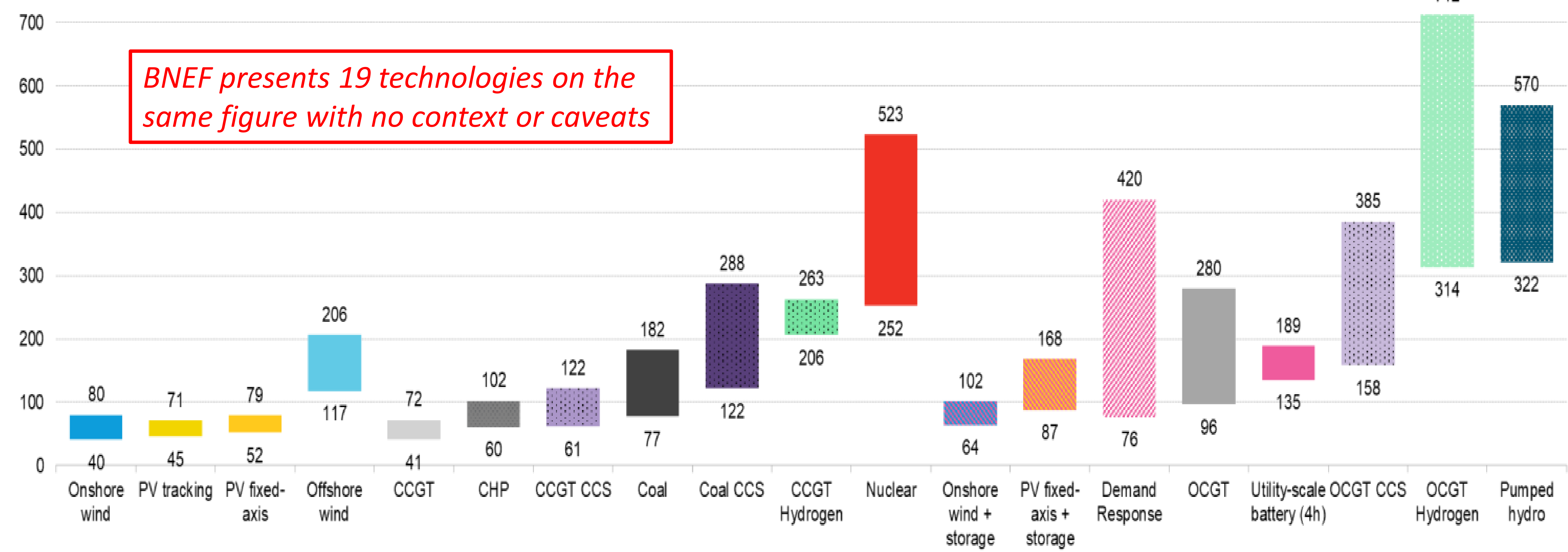
Lazard offers a few caveats, but they are 'buried' in reports.
NB: Lazard includes the relatively high LCOE of rooftop solar PV (inexplicably omitted by other authors, e.g., BNEF, IRENA)

Source: Lazard and Roland Berger estimates and publicly available information



"Tax credits help new-build renewables remain cheaper than unsubsidized new gas-fired plants for bulk generation in many areas of the US, except for offshore wind."

BNEF presents 19 technologies on the same figure with no context or caveats



THE NARRATIVE: 'RENEWABLES ARE CHEAPEST'

EDITORS' PICK | INNOVATION > SUSTAINABILITY

81% Of Renewables Offer Cheaper Energy Than Fossil Fuels, Report Says

Forbes

By Jeff McMahon, Senior Contributor. ⓘ Reporting from Europe, Jeff McMah...

Published Sep 26, 2024, 09:00am EDT, Updated Sep 26, 2024, 12:04pm EDT

- **Clean Technica June 2024: "Utility-scale solar power and onshore wind power are by far the cheapest sources for new electricity generation."** ***Citing Lazard.***
- **Wood MacKenzie, Oct 2024: "Across regions, the cost competitiveness of these technologies shows significant variation, but overall, renewables are on a steady path towards outcompeting traditional fossil fuel sources,"**

THE NARRATIVE: ‘RENEWABLES ARE CHEAPEST’

Record Growth Drives Cost Advantage of Renewable Power

24 September 2024 | **Press Releases**

iea

“Onshore wind and solar PV are cheaper today than new fossil fuel plants almost everywhere and cheaper than existing fossil fuel plants in most countries.”
- Fatih Birol
Executive Director, 2024

IRENA
International Renewable Energy Agency

“Renewable power generation has become the default source of least-cost new power generation…”

- LCOE of solar PV is 56% less than average fossil plants
- LCOE of new onshore wind projects is 67% less than average fossil plant.

-- *September 2024*

[Record Growth Drives Cost Advantage of Renewable Power (irena.org)](https://www.irena.org)
https://www.iea.org/news/massive-expansion-of-renewable-power-opens-door-to-achieving-global-tripling-goal-set-at-cop28

BUILDING A BETTER NARRATIVE

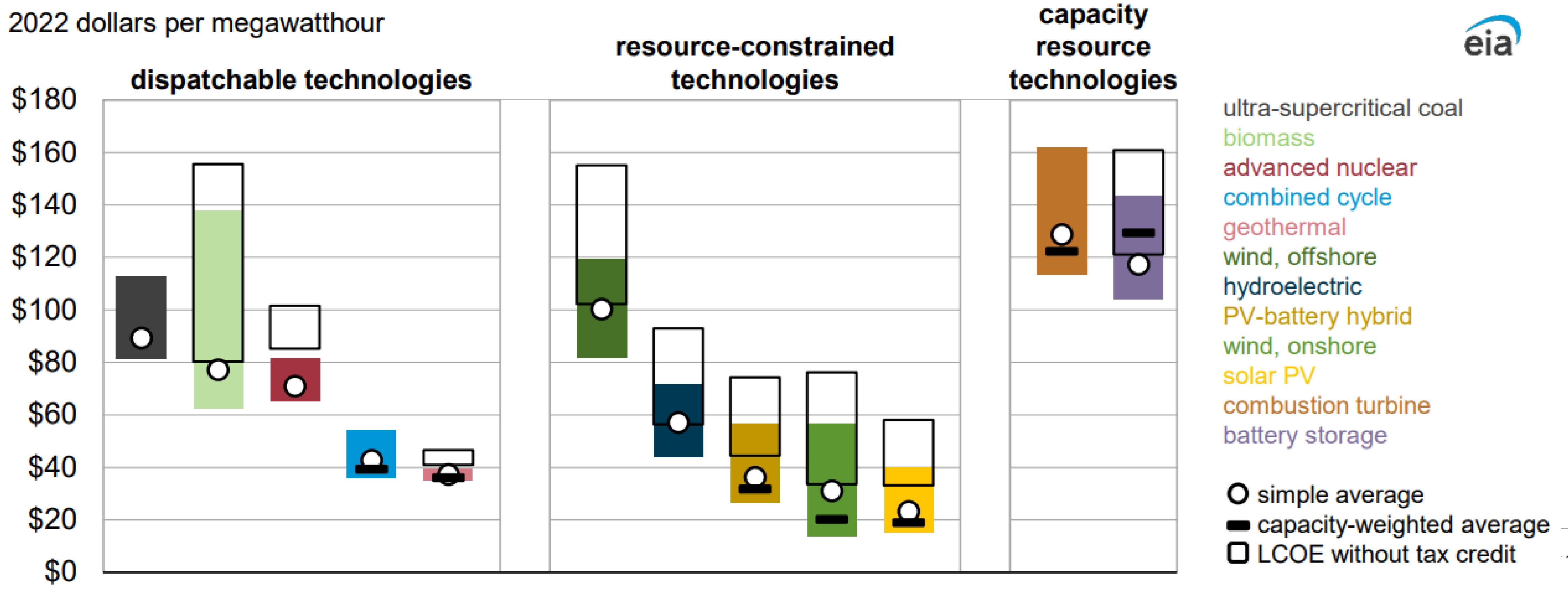
- **Simplistic LCOE comparisons feed a simplistic narrative:**
  - ***'Renewable electricity is cheapest. The competition is over. Don't build anything else.'***
- **A better narrative: move away from asking 'What is cheapest?' and from the notion of 'who wins' a competition among technologies.**
  - **REALITY: We need a team of complementary technologies to achieve zero-carbon grids that are reliable and affordable.**
- **Possible top-line messaging --**
  - **"Low-cost renewables complemented by clean firm power can achieve zero-carbon grids."**
  - **"Zero-carbon grids are possible with low-cost renewables, batteries, expanded transmission, demand-side management, and clean firm power."**
    (i.e., invoke all 4 integration strategies)

BETTER DEPICTIONS OF LCOE

- EIA was the first source of LCOE estimates to present technologies in categories to assist the reader in understanding their different roles and values.

Levelized Costs of New Generation Resources in the Annual Energy Outlook 2023

Regional variation in levelized cost of electricity (LCOE) and levelized cost of storage (LCOS) for new resources entering service in 2028 by technology, AEO2023 Reference case



POSSIBLE CATEGORIES AND LABELS FOR LCOE ESTIMATES

Technologies	EIA labels	Jesse Jenkins labels	Other labels
Solar, wind	"Resource-constrained"	"Fuel saving"	Variable, intermittent, weather-dependent
Geothermal, nuclear, fossil, fossil w/ CCS, bioenergy, hydro	"Dispatchable"	"Firm low-carbon"	Firm
Short-duration batteries, DSM, gas CT, hydrogen CT	"Capacity resource"	"Fast burst"	Balancing resources

<u>Option for Four Categories:</u>

1. Non-Dispatchable (solar/wind)

2. Dispatchable - Diurnal (solar/wind+storage)

3. Fully Dispatchable *(LDES fits best here)*

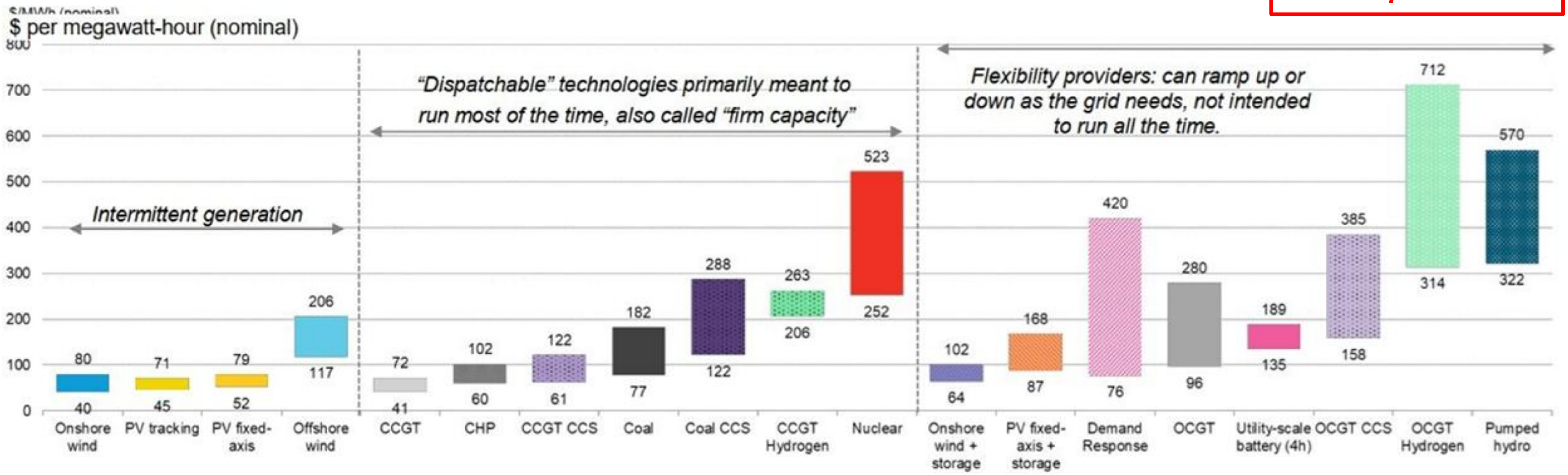
4. Balancing (LI batteries, DSM, CTs)

TOWARD A BETTER NARRATIVE: CATEGORIZATION

Sustainable Energy in America 2025 Factbook

- **Intermittent (solar, wind)**
- **Dispatchable, firm (gas, coal, nuclear)**
- **Flexibility providers (peaking plants, batteries, demand response, etc)**

Stop asking: "What is the cheapest source of electricity? And ask: "What team of sources delivers lowest system cost?"



https://bcse.org/market-trends/

BloombergNEF The Business Council for Sustainable Energy®

SUPPLEMENTAL SLIDES

LCOE IS A METRIC OF "AVERAGE COST per MWH" --

sum of all costs *(discounted)* divided by the sum of all MWh generated *(also discounted)*

$$\mathrm{LCOE} = \frac{\text{sum of costs over lifetime}}{\text{sum of electrical energy produced over lifetime}} = \frac{\sum_{t=1}^{n} \frac{I_t+M_t+F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

I_t	:	investment expenditures in the year *t*
M_t	:	operations and maintenance expenditures in the year *t*
F_t	:	fuel expenditures in the year *t*
E_t	:	electrical energy generated in the year *t*
r	:	discount rate
n	:	expected lifetime of system or power station

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- **Simple sum of annual MWh takes no account of the <u>value</u> of the MWh generated**

‘ALL MEGAWATT-HOURS ARE *NOT* CREATED EQUAL’

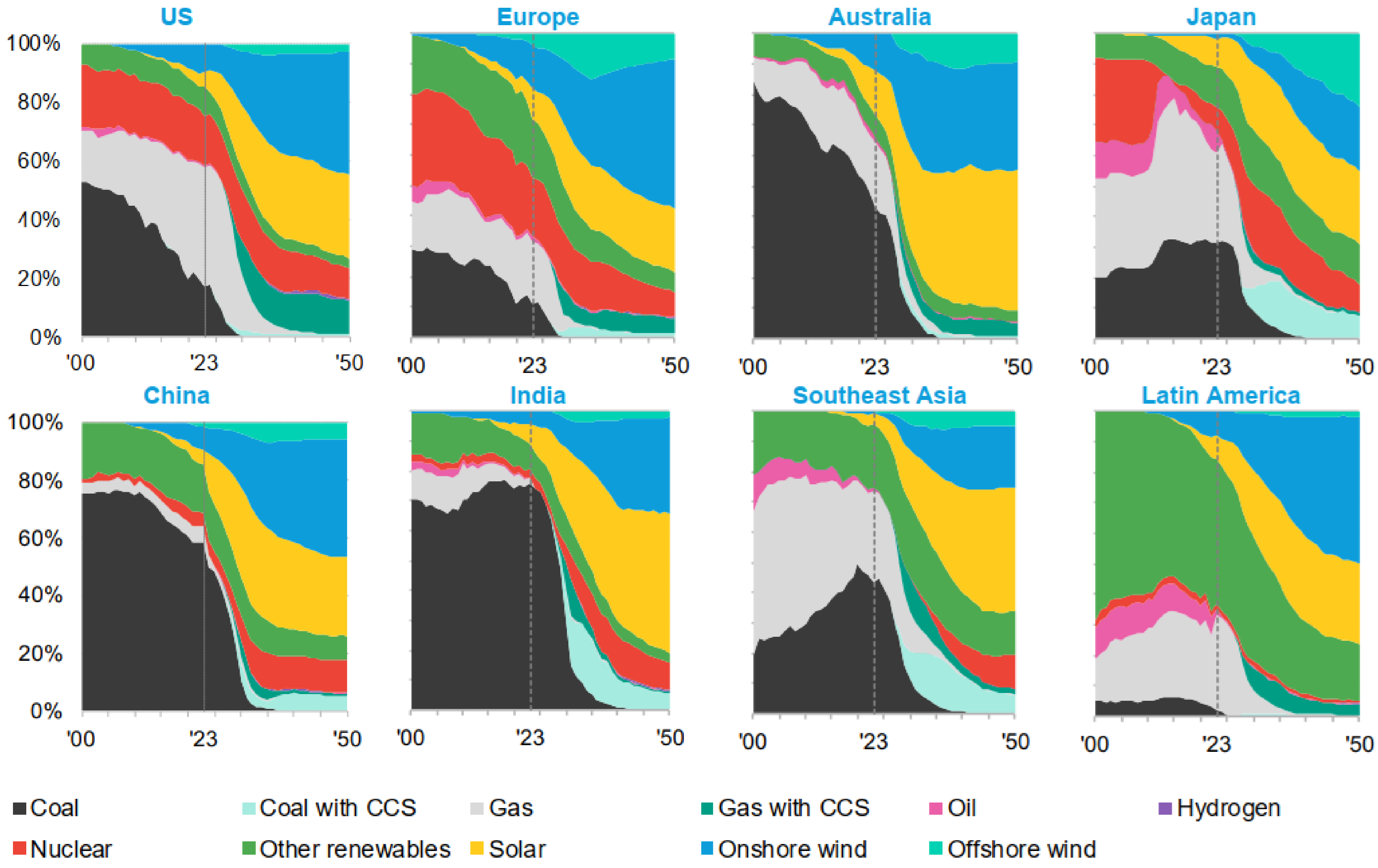
- Value of a MWh depends its time and location
  - Value varies by time of day and season
  - Value varies by location (congested vs. uncongested T&D lines, need for new T&D lines)
- Value of a MWH depends on whether it is firm or weather-dependent
  - Value depends on ancillary services that maintain reliability: regulation services, spinning and non-spinning reserves, black start services
- Value of a MWh depends on how a power plant interacts with the power system as a whole and the roles it plays.
- But: LCOE treats a power plant as standing alone, isolated, and unconnected to a power system.

ILLUSTRATE THE TEAM CONCEPT

In BNEF Net Zero:

- **Total TWh triples.**
- **In all cases, high solar/wind penetration complemented by clean firm power** (nuclear, CCS, hydro, geothermal, bioenergy, etc.).
- **Consistent with IPCC AR6, and global modeling by IEA, IRENA, etc.**

Figure 10: Electricity generation by source under the Net Zero Scenario, by country/region, 2000-2050



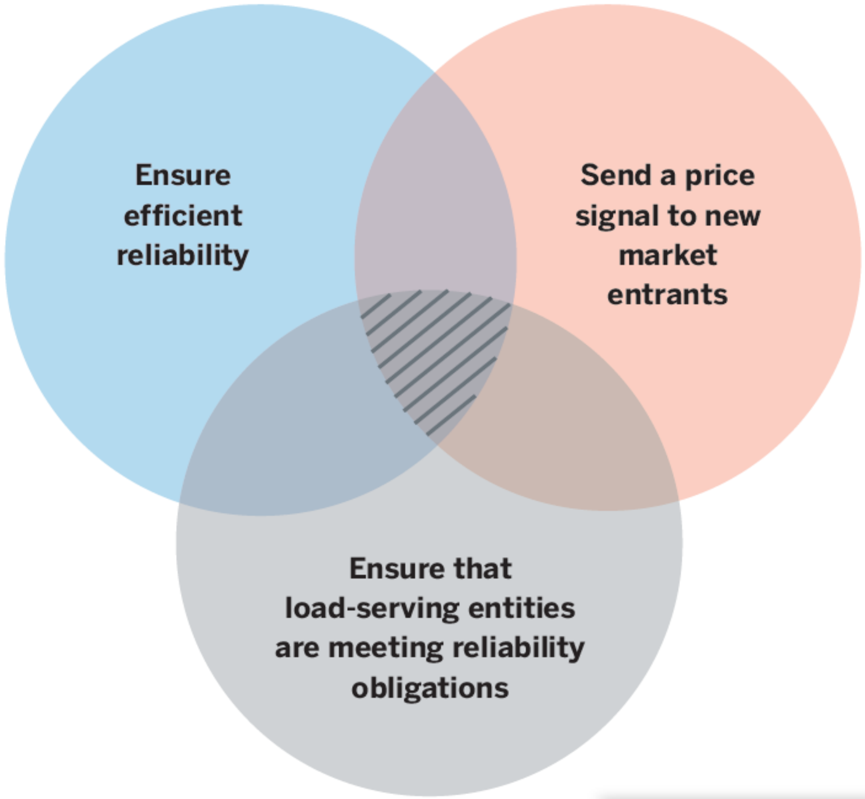
Source: BloombergNEF. Note: '00' is 2000, '23' is 2023, '50' is 2050. Includes electricity generation needed for hydrogen production via electrolysis. 'Other renewables' includes all other non-combustible renewable energy in electricity generation, such as hydro, geothermal and solar thermal. CCS is carbon capture and storage

Capacity Accreditation

Metrics, Link with Reliability, and Resource Expansion

Aidan Tuohy,
Contributions from Genevieve de Mijolla
NERC ELCC Workshop
June 5/6, 2025

Motivation for Capacity Accreditation



Source: Energy Systems Integration Group.

Applications for Resource Accreditation

Resource adequacy assessments:

- Is the system going to meet its reliability targets?
- How do different resources support meeting reliability of the system?

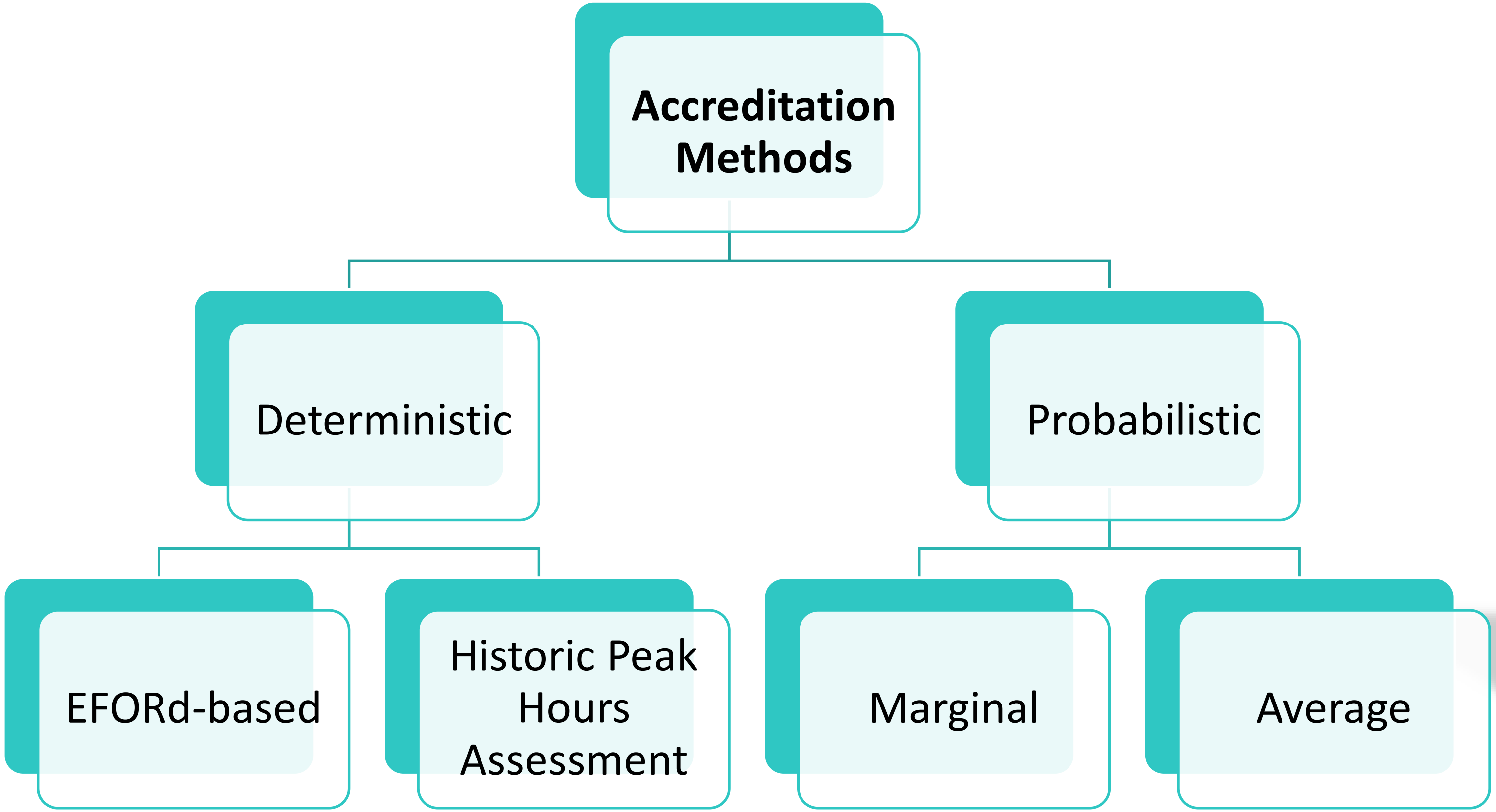
Long-range supply resource expansion planning, such as integrated resource plans (IRPs):

- Capacity accreditation as an input to the optimization

Electricity markets:

- Where capacity auctions exist, resources are assigned an accreditation value, which is then used within auction algorithms

Probabilistic vs. Deterministic and Methods vs. Metrics



ELCC: method or metric?

In the historical use of the term, ELCC has been used to refer to both a method and a metric. It is still sometimes (erroneously) used as a global term to refer to all methods to calculate a range of probabilistic capacity accreditation metrics. **The use of the term *ELCC* is recommended to refer specifically to the ELCC metric, while using "ELCC method" for calculating the ELCC metric in the common way it is calculated.**

Different Flavors of Capacity Accreditation Methods

Many different options to consider when selecting a capacity accreditation method:

- Deterministic vs. Probabilistic
- Marginal vs. Average
- Prospective vs. Retrospective

Many different variations are available even within a same method:

- Choice of risk metric (LOLE, EUE, etc)
- Perturbation method
- Choice of resource adequacy target
- Method to bring the system up to target
- …

ACCREDITATION METRIC	PERTURBATION	VALUE
ELCC marginal	Increase resource capacity; then increase load	Δload @ constant LOLE
ELCC average	Increase resource class capacity; then increase load	Δload @ constant LOLE *(resource capacity/resource class capacity)
Effective Firm Capacity	Decrease resource capacity; then increase perfect supply	Δsupply @ constant LOLE
Marginal Reliability Improvement	Increase resource capacity	ΔLOLE/ΔLOLE(perfect resource)
Direct Loss of Load	N/A	(Weighted) Availability during critical hours

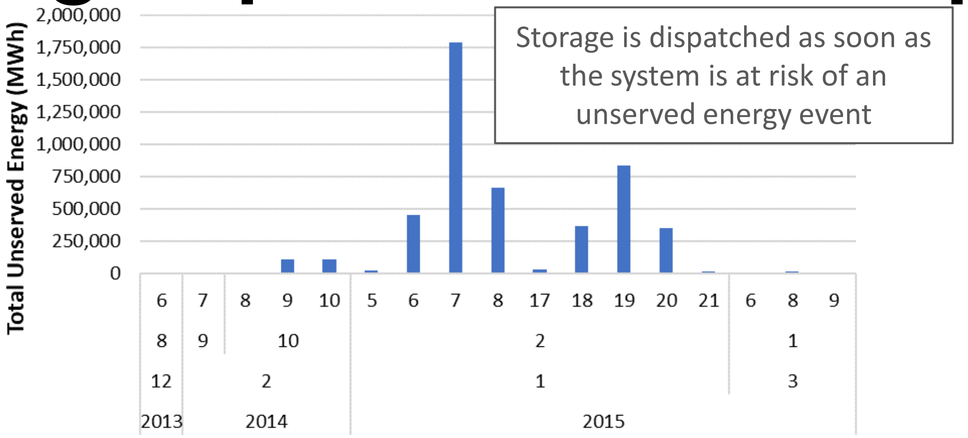
Impact of Resource Adequacy Tool and Data on Adequacy and Accreditation

Unit commitment	Objective function	Temporal Granularity
Locational granularity (system, zonal, nodal)	Short-term forecast error and multi-stage operation	Ramp rates and start-up times
Interchange	Energy storage state-of-charge	Combined cycle modes

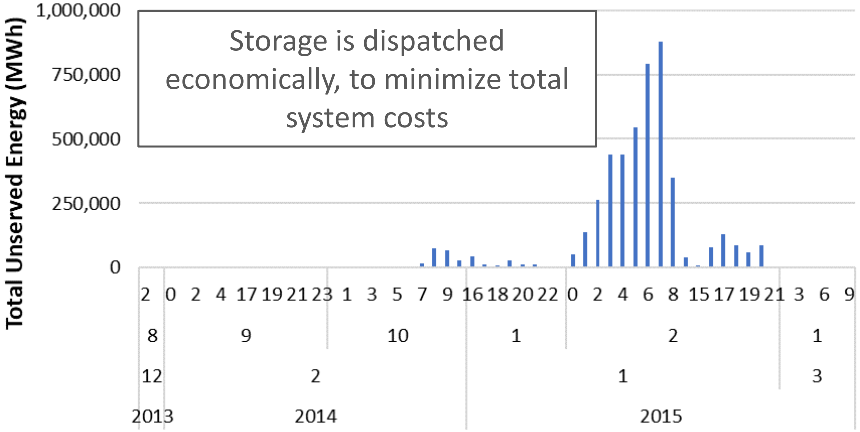
The impact and choice of tools and data used can possibly have a larger impact on accreditation value differences than would using different accreditation methods entirely.

Storage operational assumptions matter….

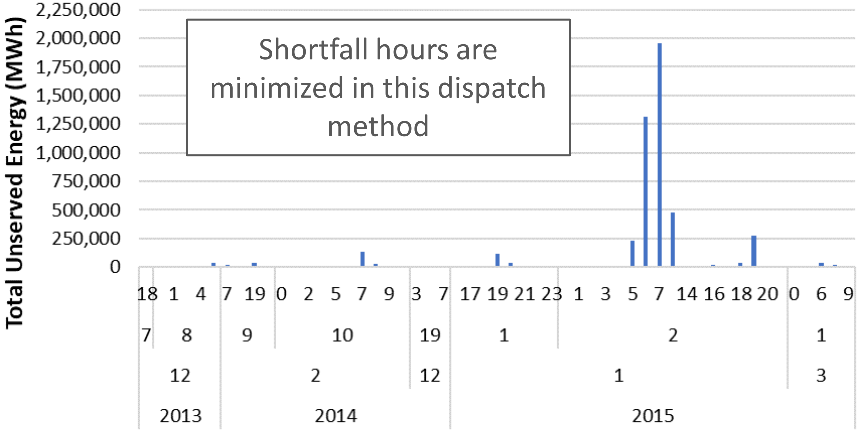
Recent DOE-funded study



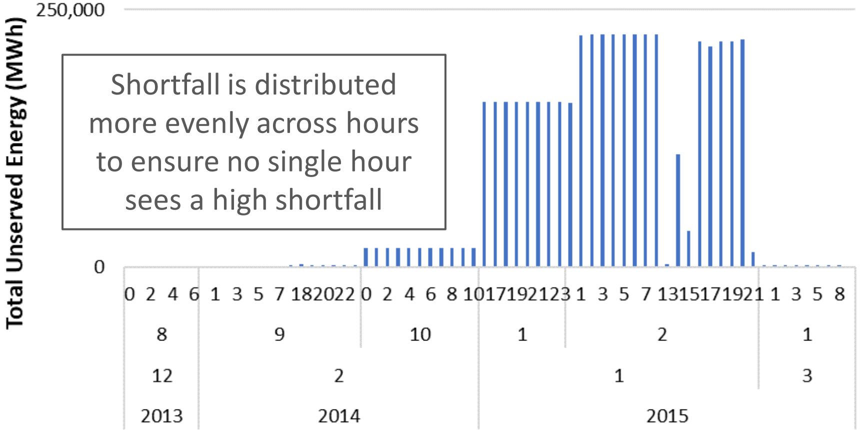
Unserved energy by weather year and hour of year for the 'greedy' storage strategy



Unserved energy by weather year and hour of year for the cost minimization storage strategy



Unserved energy by weather year and hour of year for the 'min LOLE' storage strategy



Unserved energy by weather year and hour of year for the 'min residual shortfall' storage strategy

Storage Dispatch Method	EUE (MWh/year)	LOLE (days/year)	LOLH (hours/year)
Greedy response	3,518	0.1999	0.74
Cost minimization	3,511	0.231	1.02
Min LOLE	3,599	0.300	0.66
Min residual shortfall	3,518	0.316	3.60

While EUE across storage dispatch strategies is stable, LOLE and LOLH vary quite significantly from one method to the other. The greedy response was chosen for future runs, as it allows for a more intuitive storage behavior that is easier to track and more closely resembles market operations.

Contribution varies by metric and method…

Recent DOE-funded study
Wind capacity value

		LOLE	EUE	LOLH
LOLP Capacity Factor	At criterion	11%		
	Original	14%		
Marginal Reliability Improvement (MRI)	At criterion	26%	22%	21%
	Original	9%	14%	9%
Effective Load Carrying Capability (ELCC)	At criterion	7%	15%	7%
	Original	14%	14%	10%
Equivalent Firm Capacity (EFC)	At criterion	16%	15%	15%
	Original	5%	12%	5%

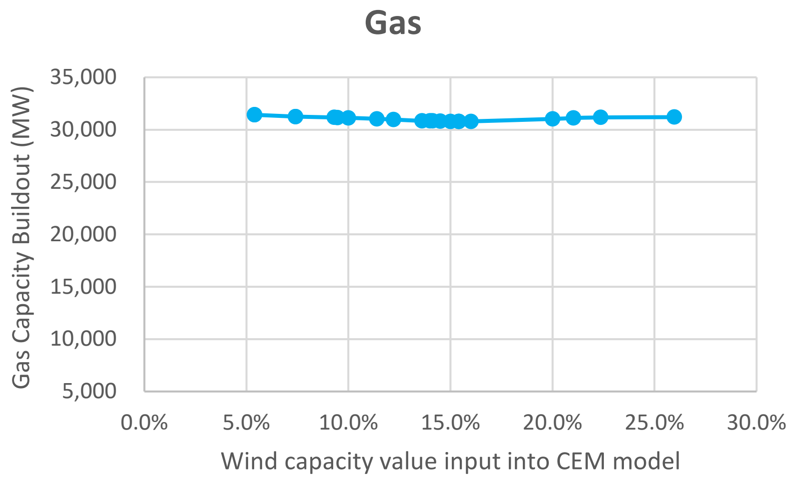
All MRI, EFC, and ELCC cases were brought to criterion using a 500 MW marginal unit size.

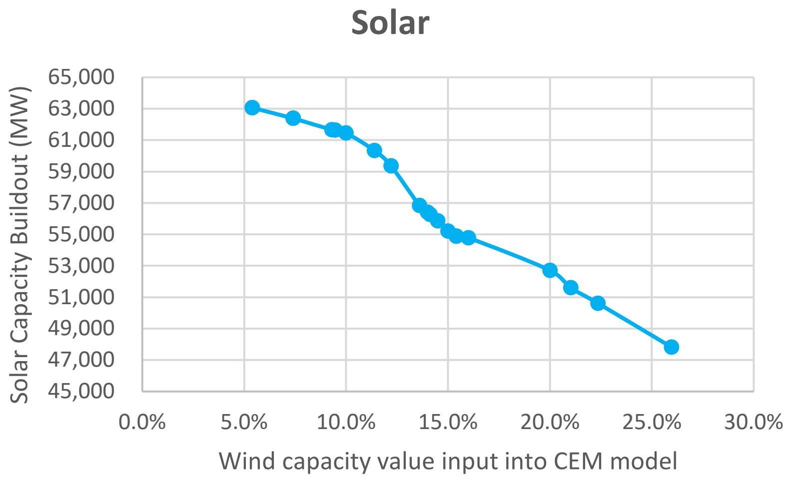
Wind capacity accreditation values vary considerably from one methodology to the next (anywhere from 5% to 26%) and are impacted by which underlying risk metric is used and whether the case was brought to a 0.1 days/year reliability criterion first.

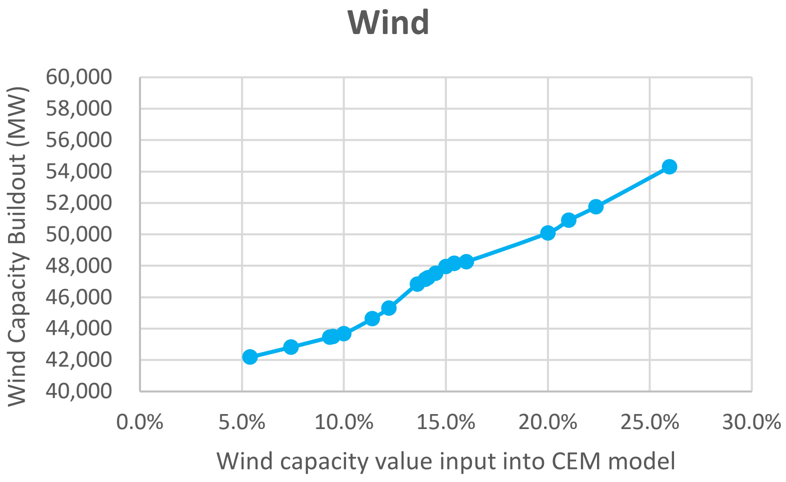
In general, capacity accreditation values calculated using the EUE metric appear more stable than the ones calculated using the LOLE or LOLH metrics.

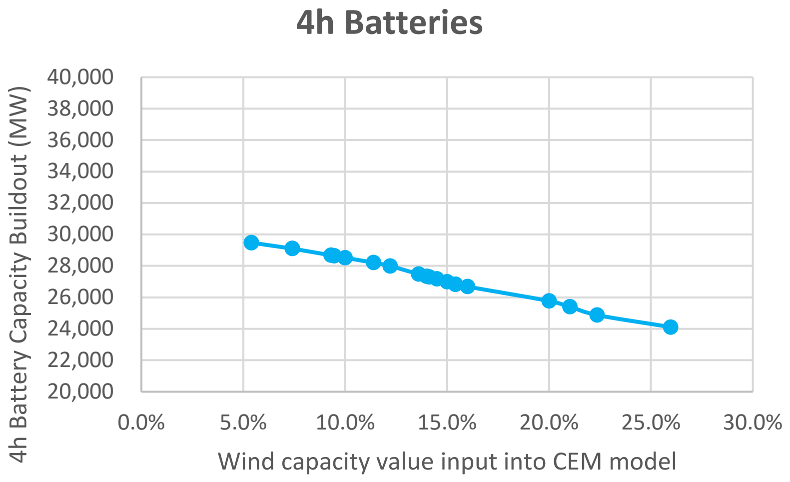
Capacity expansion buildouts

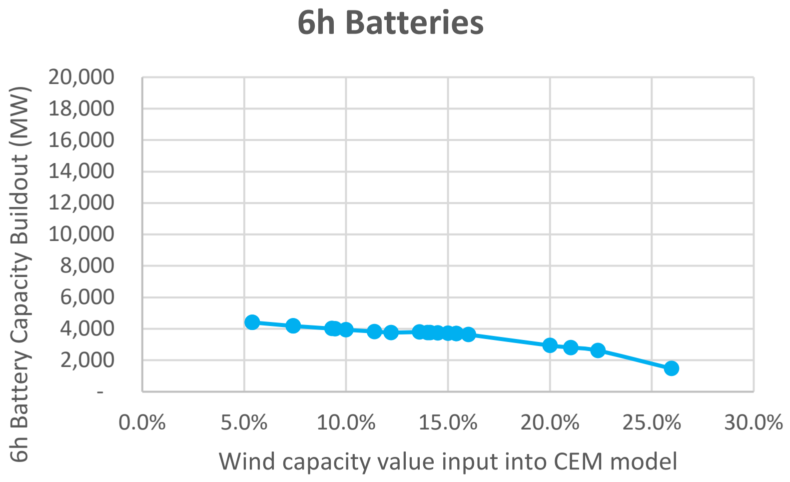
Recent DOE-funded study
Impact of wind capacity value







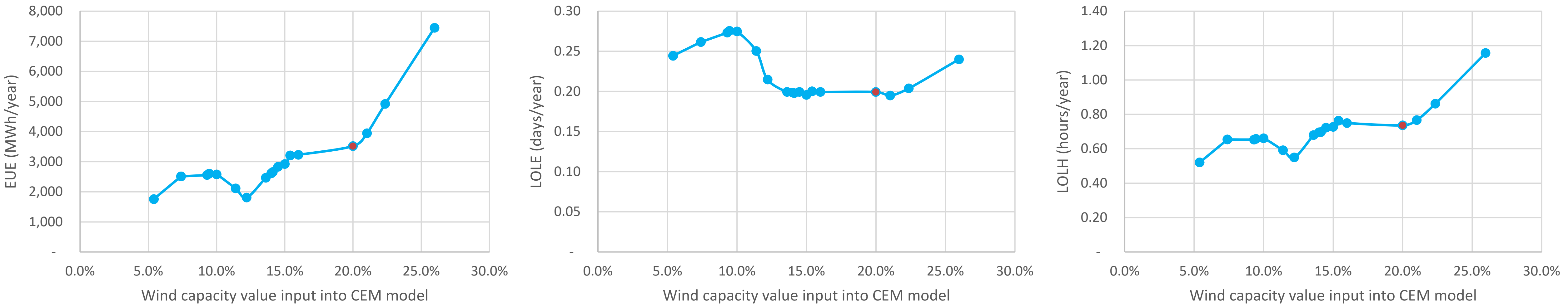




The higher the wind capacity value input into the CEM model, the more wind gets built, as you would expect.

A higher amount of wind built corresponds to a lower amount of solar and batteries built, and a fairly constant amount of gas built.

Adequacy of varying capacity buildouts



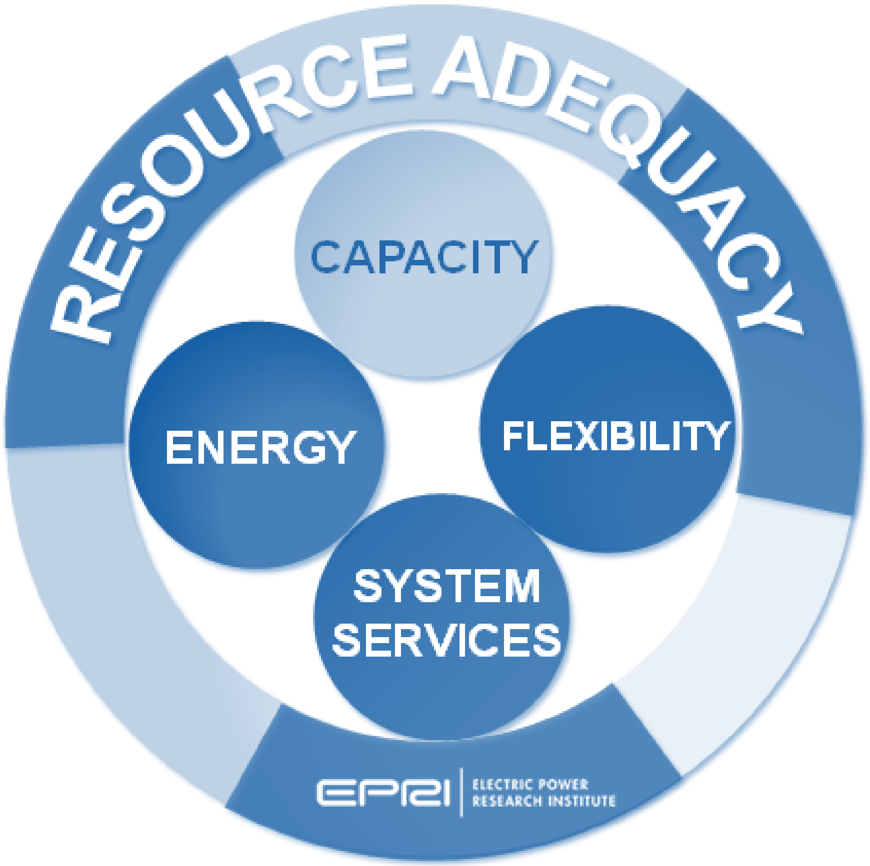
Small changes in inputs to capacity expansion models can lead to large differences in CEM results

Capacity expansion models are greatly simplified and as such don't explicitly plan for the highest risk periods of the system, leading to a linkage between CEM and RA models that isn't as strong as might be desired.

A method that directly models high risk adequacy periods within the capacity expansion modeling framework may be a more effective approach than a CEM/RA round-trip approach as illustrated here.

Operational Features in RA and Impacts on Accreditation

- How much operational detailed should be included in RA?
- Should flexibility needs be part of RA assessments?
- Should system services be represented in detail in RA assessments?
- **All the above will have a material impact on resource accreditation**
- EPRI has conducted work on the above and will continue to explore the above questions in 2025



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The reliability impacts of accreditation of generation and transmission

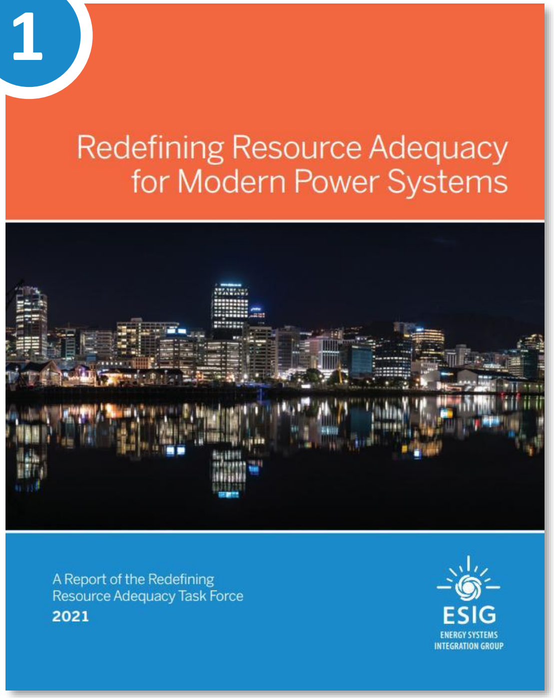
NERC Resource Contributions for Reliability Workshop

Derek Stenclik
June 2025

TELOS ENERGY

ESIG Redefining Resource Adequacy Task Force

1



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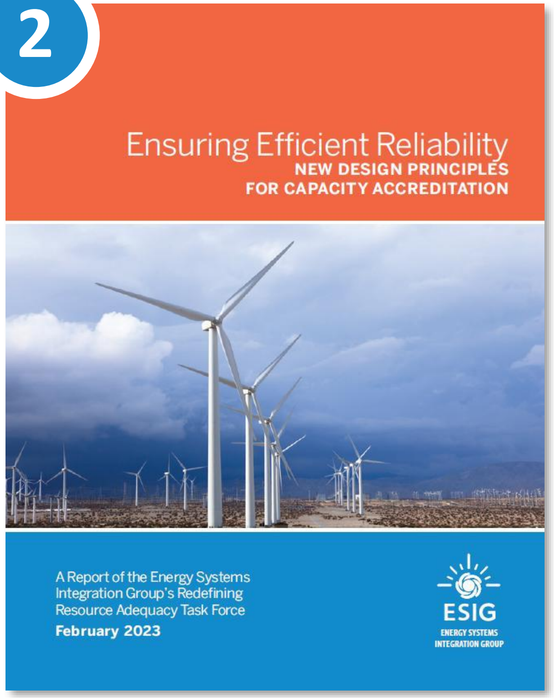

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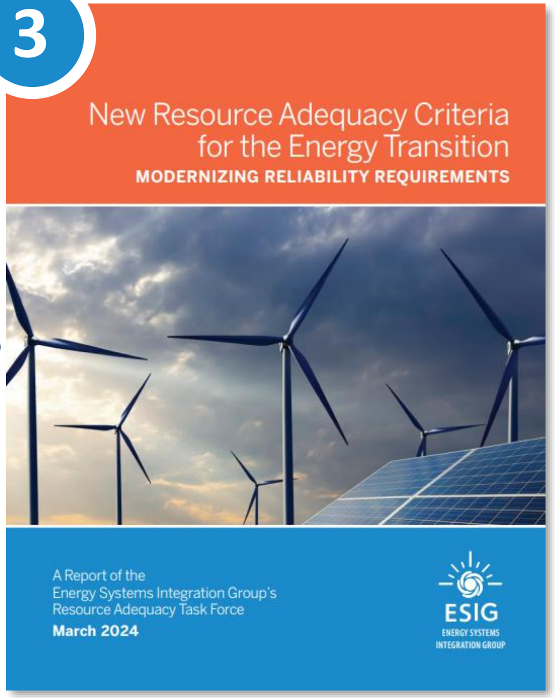

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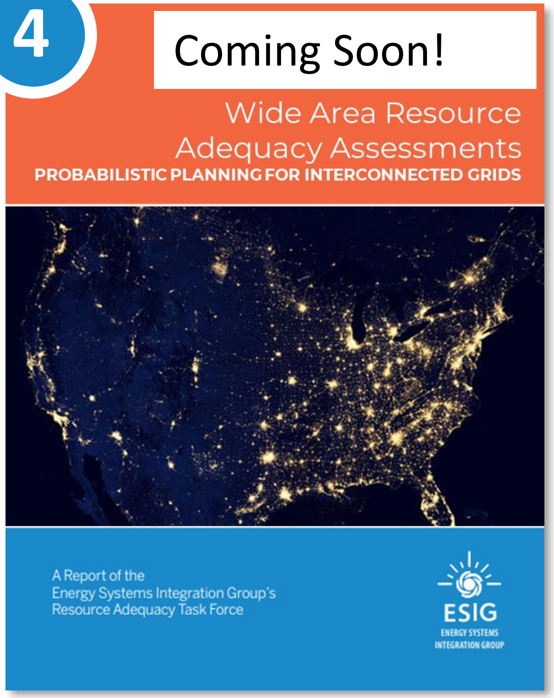


Probabilistic Analysis & First Principles

Chronology & Correlation

Capacity Accreditation and Procurement

Capacity accreditation for all resources

New Reliability Criteria & Capacity Needs

Moving beyond 1-day-in-10 LOLE

Wide Area Resource Adequacy Assessments

Interregional coordination and transmission

Capacity accreditation in the energy transition

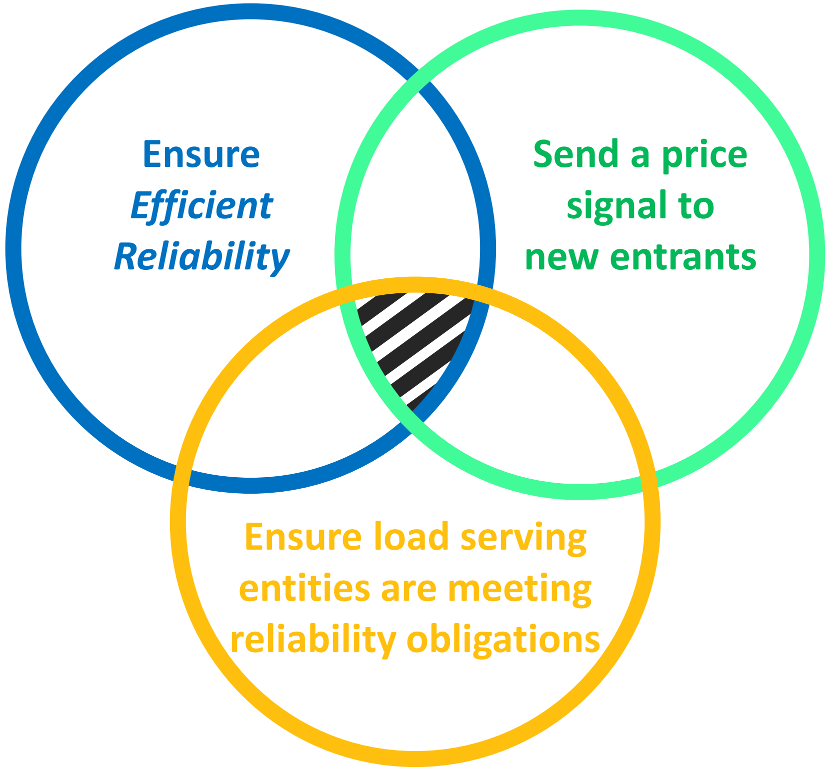
Accreditation: Measures the ability of a resource to be available ***when, where*** and for ***how long*** it is needed for to support resource adequacy.

Increasing shares of variable renewables and energy-limited resources

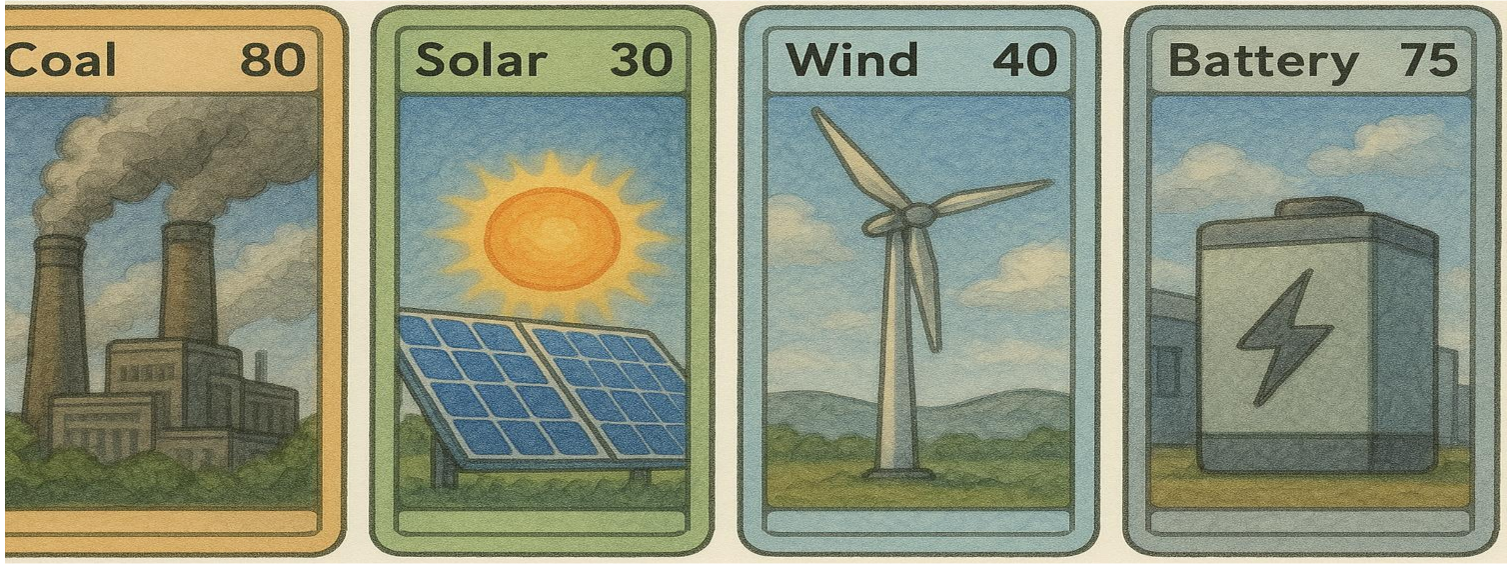
1. Nameplate capacity of resources
2. Expected capacity available at the time of peak load
3. Expected capacity available at the time of peak net load
4. Expected capacity available at the time of high risk
5. Expected capacity and energy available from resources during periods of high risk

Source: Energy Systems Integration Group, Ensuring Efficient Reliability: New Design Principles for Capacity Accreditation

Why do we accredit resources?



- **Enable efficient markets** and fostering reliability
- Makes capacity a fungible commodity
- To enable **trading of capacity,**
  "Pokémon cards of the energy transition"

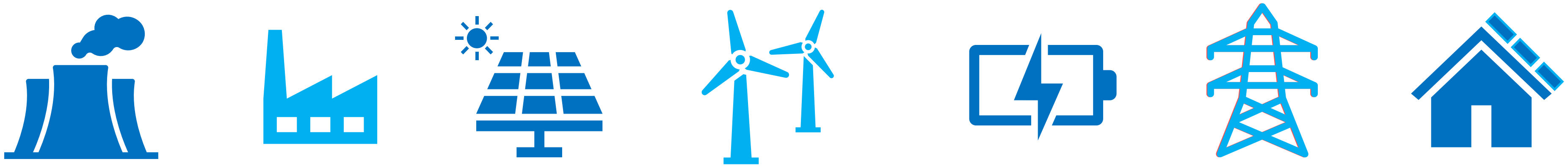


NOT! for measuring system reliability nor necessary for long-term planning

Source: Energy Systems Integration Group, [Ensuring Efficient Reliability: New Design Principles for Capacity Accreditation]

Harmonizing capacity accreditation

consistent methods applied to all resource types



ALL resources provide some "firm" capacity

But NONE of them provide perfect capacity

Accreditation for transmission

If batteries shift energy across time to ***when*** it is needed most, transmission shifts energy across space to ***where*** it is needed.

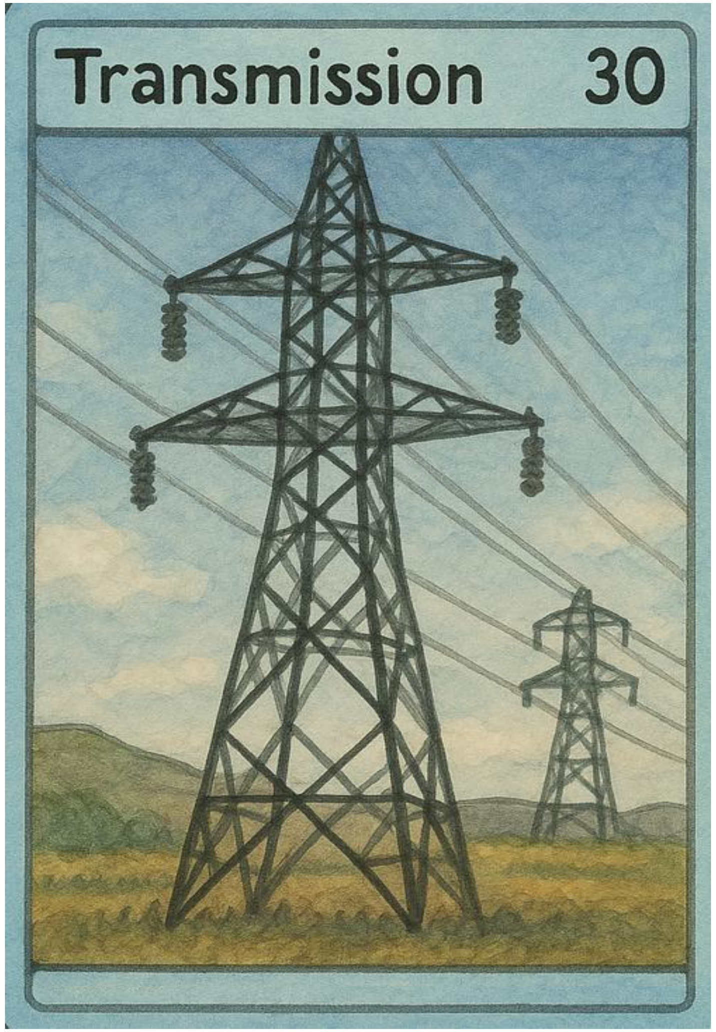
- **Standardize accreditation across all resources:** No different than generation, HVDC is controllable and measurable at the POI, technically no different than other inverter-based resources

- **Alternate participation model:** Procurement of transmission directly into capacity markets and IRP all-source procurements

- **Easier to monetize:** accreditation privatizes RA benefits, rather than socializing it across the load

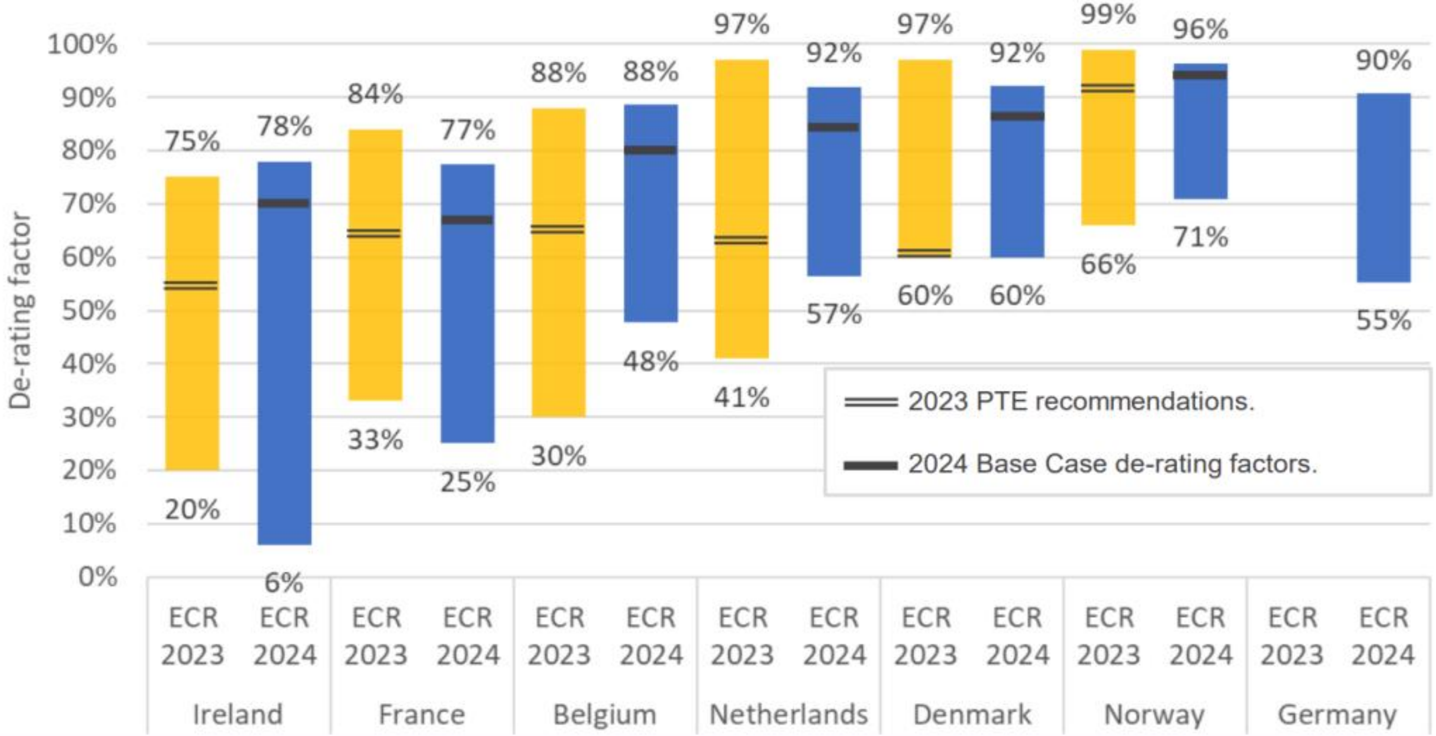
- **Pay for performance:** transfers risk to owner rather than ratepayer

- **Wide-area adequacy assessments** required for interregional Tx



https://www.telos.energy/post/transmission-as-a-capacity-resource

Lessons from Europe, Intertie Accreditation in the UK



Legend	Ireland	France	Belgium	Netherlands	Denmark	Norway	Germany
—	70%	67%	80%	84%	86%	94%	(1)
═	55%	65%	65%	62%	60%	91%	(2)

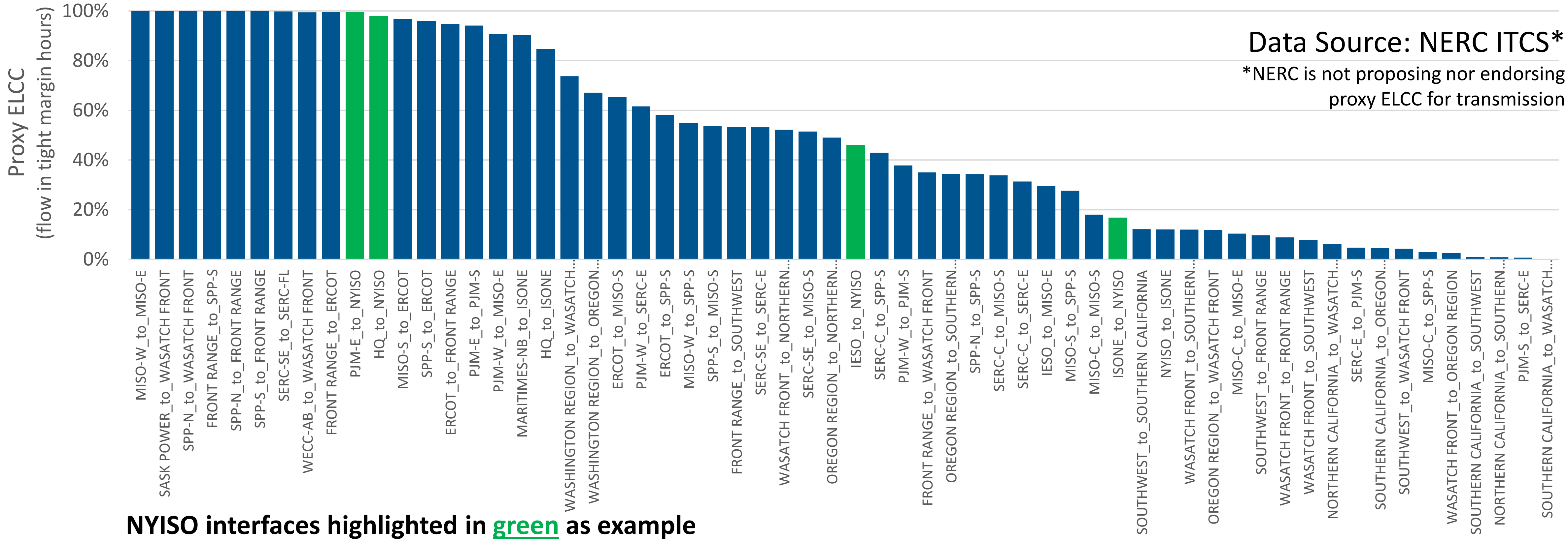
National Energy System Operator (NESO) includes intertie accreditation for capacity market participation, *without contracted capacity* in Continental Europe

Transmission can and should compete with generation in capacity markets

Source: NESO, Electricity Capacity Report 2024

Reliability benefits of interregional transmission

- "Proxy ELCC" measures the average flow during **tight margin hours** on the receiving end (<10% margin)
- Hours when a region would have imported more, but there was (1) insufficient transfer capability, (2) insufficient resources on the sending end, and/or (3) total import constraint was binding
- Useful for ***relative prioritization*** of transfer capability for RA benefits, but not true accreditation



NYISO interfaces highlighted in green as example

Thank You!

Questions?

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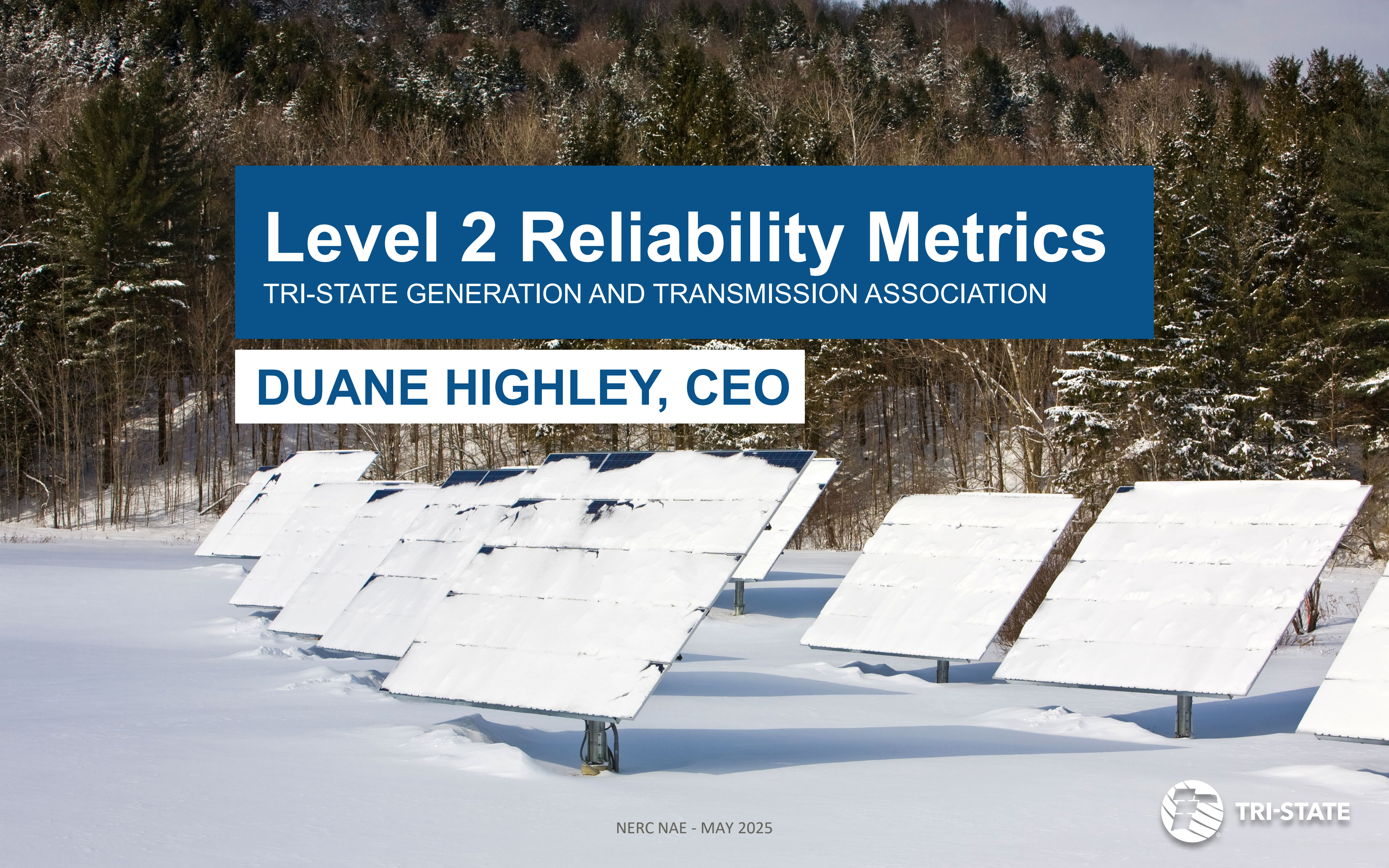
TELOS ENERGY



Level 2 Reliability Metrics

TRI-STATE GENERATION AND TRANSMISSION ASSOCIATION

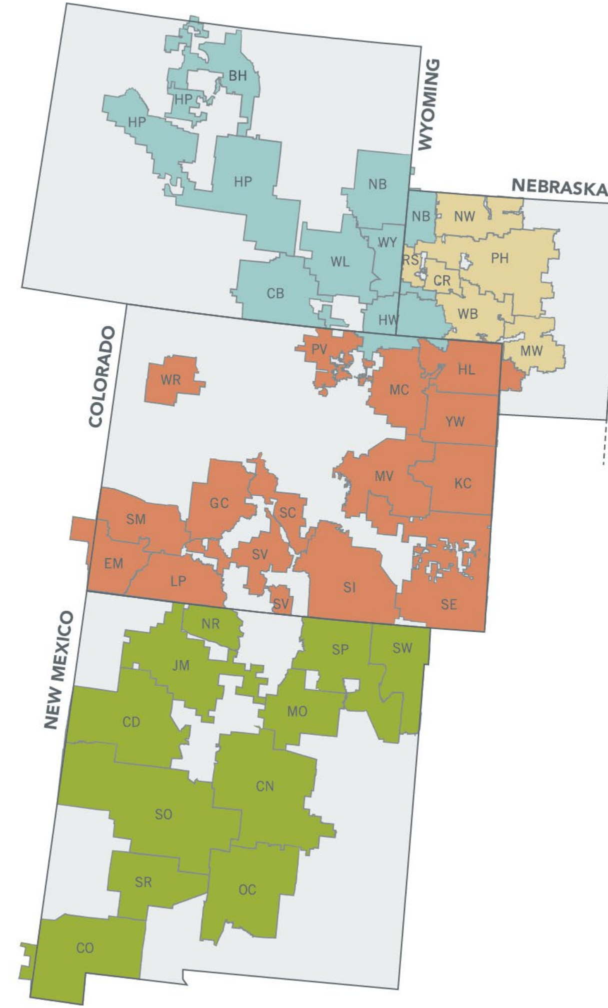
DUANE HIGHLEY, CEO

NERC NAE - MAY 2025

TRI-STATE

Who is Tri-State?

- Not-for-profit co-op association of 43 members
- Board of Directors comprised of representatives from our utility members
- Engaged in rapid energy transition
  - By 2030:
    - 70% non-emitting (wind/solar/hydro/geothermal)
    - In Colorado, 80% GHG reduction (2005 baseline)
    - Reliability and affordability maintained!



Our ***Resource Inadequacy*** Experience

- Storm Uri and Storm Elliot
  - Broad regional wind droughts for multiple consecutive days
  - Little to no solar generation on-peak
  - Limited ability to import from neighbors (they were hurting too)
- State-by-State Resource Adequacy management has limitations
  - Resource Adequacy is often regulated by the states, **each state has independent criteria**
  - Sometimes Resource Adequacy is **not regulated by anyone!** (non-regulated marketers)
  - **Over-reliance and double-counting of imports** from neighbors (typically assume some import capability)
  - Wind generation isn't usually broadly correlated, ***but sometimes it is! (Multi-state wind droughts)***
- Wyoming co-ops worried about Colorado PUC Resource Planning process
- Conventional reliability measures (PRM, LOLE, LOLP) ***don't assure reliability*** with non-dispatchable resources
  - Even with consideration of ELCC (effective load-carrying capability)

Our Methodology

MODELING

- Astrape performed modeling
- "Extreme Weather Event" (worst winter and summer week)
  - Stressed transmission availability, power and gas pricing, market availability (depth and timing), thermal resources, intermittent resources, and load (based on historical events)
  - Intermittent resources are additionally stressed for 72 hours over the peak
- Assume extremely low or **no wind** (winter and summer peak)
- Assume **no solar** (winter peak)
- Assume **no imports** from neighbors for capacity

OUR METRIC

- ≤ 12 loss-of-load hours during study period (10 years)
- ≤3 loss-of-load hours in any one year
- Expected unserved energy ≤20% of total load in any one hour
- Cannot rely on market purchases to meet load during critical peak

RESULTS

- Gas/oil plant is required for reliability, **30.5% PRM!**
- Endorsed by Colorado PUC and 28 stakeholders in our ERP

TRI-STATE

To follow up, contact:

DUANE.HIGHLEY@TRISTATEGT.ORG

LISA.TIFFIN@TRISTATEGT.ORG

WHATEVER THE FUTURE HOLDS,
WE'LL POWER IT.

A “Critical Periods” Reliability Framework

North American Electric Reliability Corporation

Evaluating Resource Contributions for Reliability and Capacity Supply Workshop

Washington, DC

June 5, 2025

Energy+Environmental Economics

Arne Olson, Senior Partner

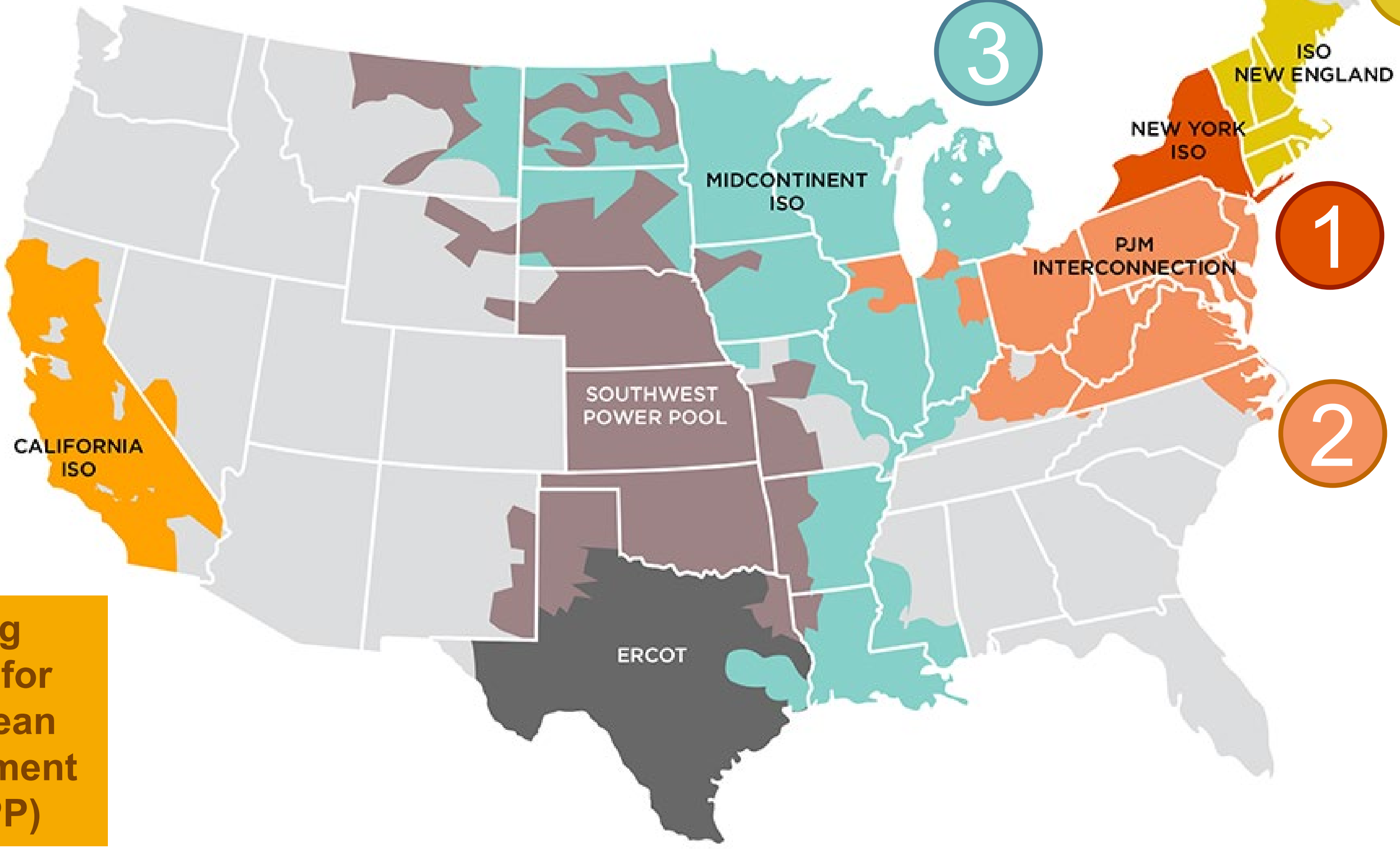
The resource adequacy “externality”

- **Resource adequacy is an “externality” that must be remedied with actions outside the hourly electricity market because of structural barriers that prevent the market from clearing at a societally optimal reliability level**
  - Price caps on hourly electric energy markets are below many customers’ value of lost load (VOLL)
  - Most retail customers are not exposed to varying wholesale electricity prices and have no ability or incentive to reduce load during critical periods, resulting in a vertical demand curve
  - Market operators lack the ability to target individual customers during a supply shortfall event based on their specific VOLL
- **ISOs run resource adequacy markets that remedy the externality by imposing a requirement on load-serving entities to forward-procure resource adequacy capacity**
- **Resource adequacy need determination, need allocation, and resource accreditation must be modernized to more accurately measure the contributions of resources and loads to resource adequacy needs**

The industry is moving toward a "Critical Periods" framework for need determination, need allocation, and resource accreditation

3 FERC approved MISO's Direct Loss-of-Load (DLOL) framework in 2024

4 ISO-NE currently proposing marginal ELCC approach



1 FERC approved NYISO move to marginal capacity accreditation in late 2022

2 PJM filed to FERC for marginal capacity accreditation Oct 2023 and received approval in 2024

5 CPUC proposing marginal ELCC for Reliable and Clean Power Procurement Program (RCPPP)

Key elements of the Critical Periods framework

1. **Determine Total Reliability Need (TRN)** based on quantity of equivalent perfect capacity needed to meet the specified reliability standard, and calibrate LOLP model of the power system to meet TRN

2. **Determine Marginal ELCCs** of individual resource types based on their marginal contribution toward the TRN, or equivalently their expected performance during Critical Periods

3. **Determine Total Procurement Need (TPN)** as the sum of Marginal ELCCs of individual resources in a "tuned" portfolio, or equivalently the expected load during Critical Periods

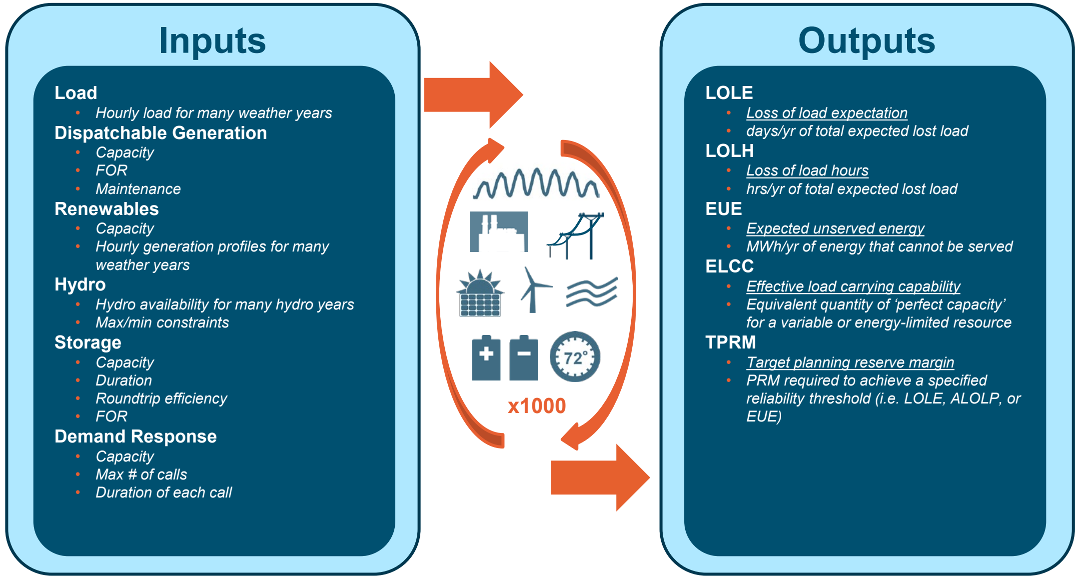
4. **Allocate TPN to Load-Serving Entities** based on their expected contribution to the need for capacity, i.e., their expected load during Critical Periods

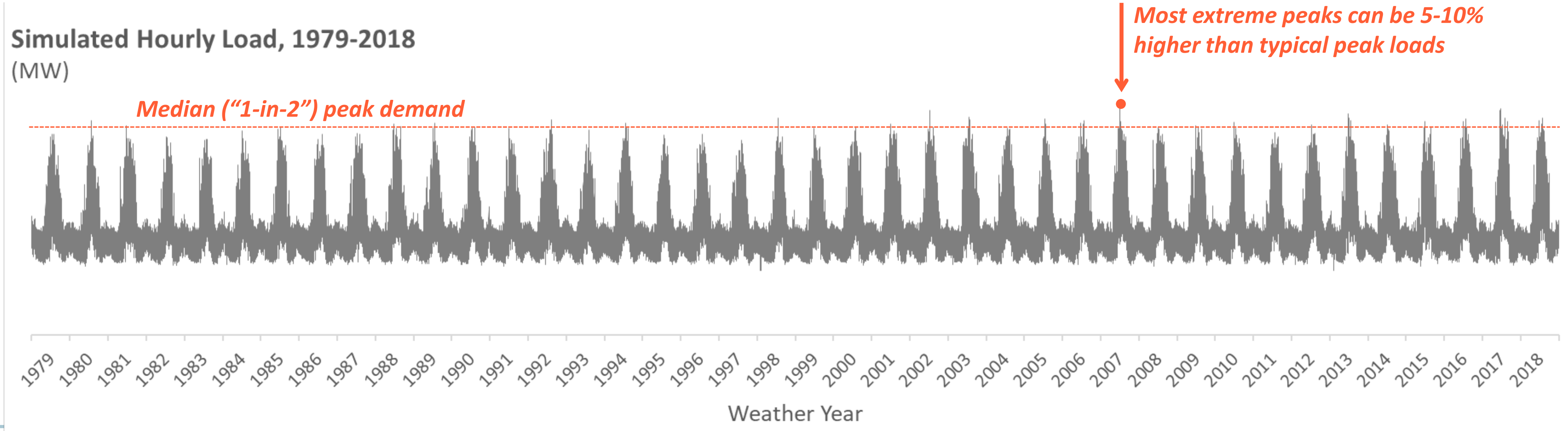
Resource Adequacy for the Energy Transition: A Critical Periods Reliability Framework and its Applications in Planning and Markets
E3 white paper describing the theoretical basis and practical applications of this framework in wholesale markets and system planning

Loss of load probability modeling is the foundation for understanding resource adequacy needs

+ **LOLP modeling can be thought of as an organized way to analyze the potential for extreme weather and other events to cause a supply shortfall**

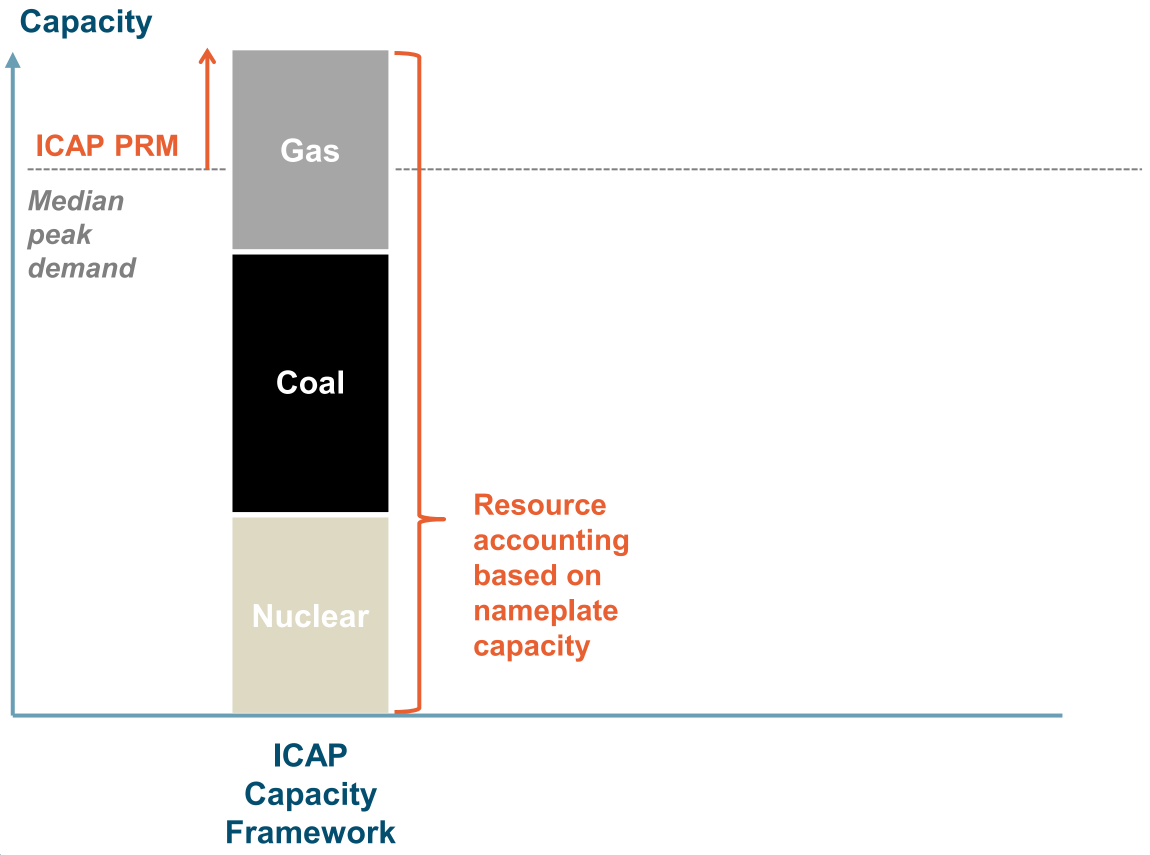
+ **LOLP can capture factors that matter for reliability such as:**
  - High loads due to extreme weather
  - Correlations between load and renewable conditions
  - Energy and capacity limitations
  - Dispatch behavior of energy-limited resources such as energy storage, demand response and hydro





The conventional framework rests on simplifying assumptions that are increasingly inaccurate

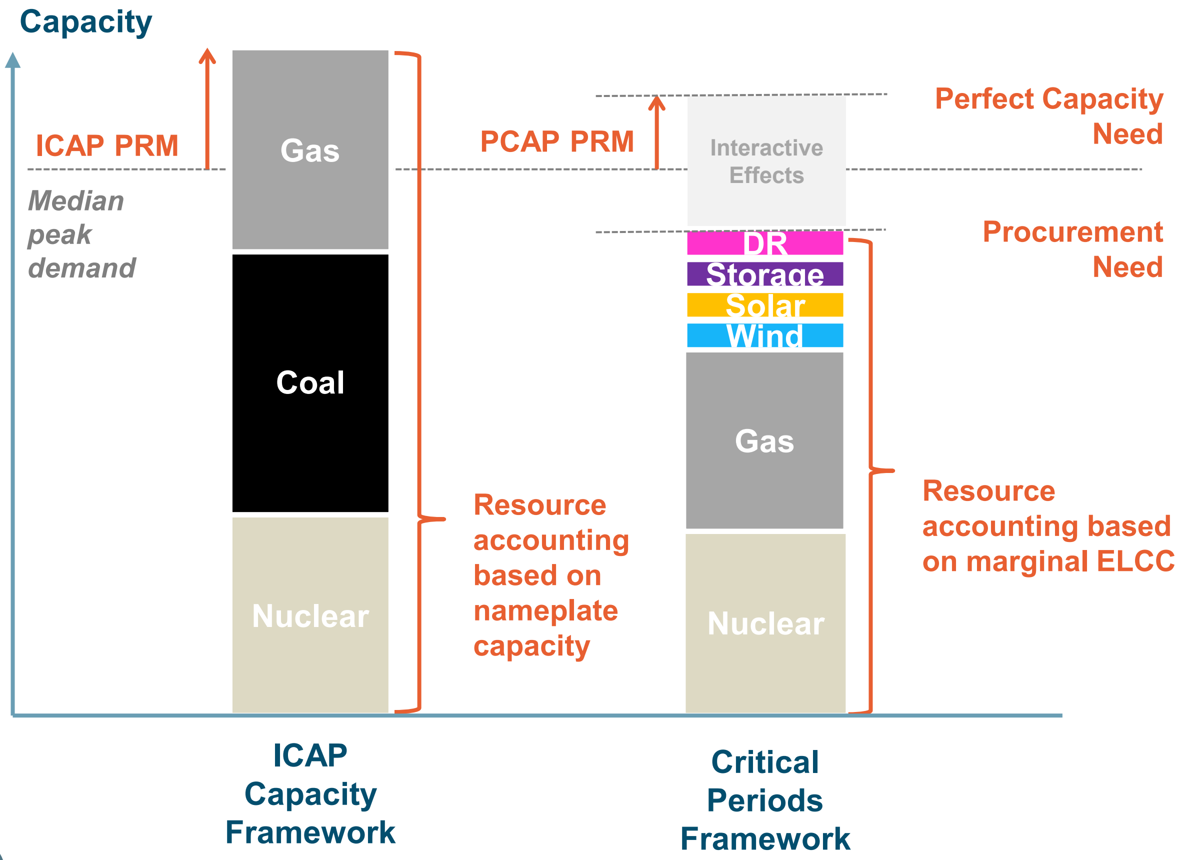
+ **PRM defined based on Installed Capacity method (ICAP)**
  - Covers annual peak load variation, operating reserve requirements, and thermal resource forced outages
+ **Individual resources accredited based on nameplate capacity**
  - Small differences in forced outage rates
  - No interactions among resources
  - Forced outages also incorporated through performance penalties



$$Installed\ Capacity = \sum_{i=1}^{n} G_i$$

The Critical Periods framework is more accurate and more adaptable for a diverse resource mix

- **PRM defined based on need for Equivalent Perfect Capacity (PCAP)**
  - Covers annual peak load variation and operating reserves only; forced outages addressed in resource accreditation
- **Individual resources accredited based on Marginal ELCC**
  - Large differences in availability during key hours
  - Significant interactions among resources
  - ELCC values are dynamic based on resource portfolio



$$Portfolio\ ELCC = f(G_1, G_2, \ldots, G_n)$$

Measuring ELCC of a portfolio and individual resources

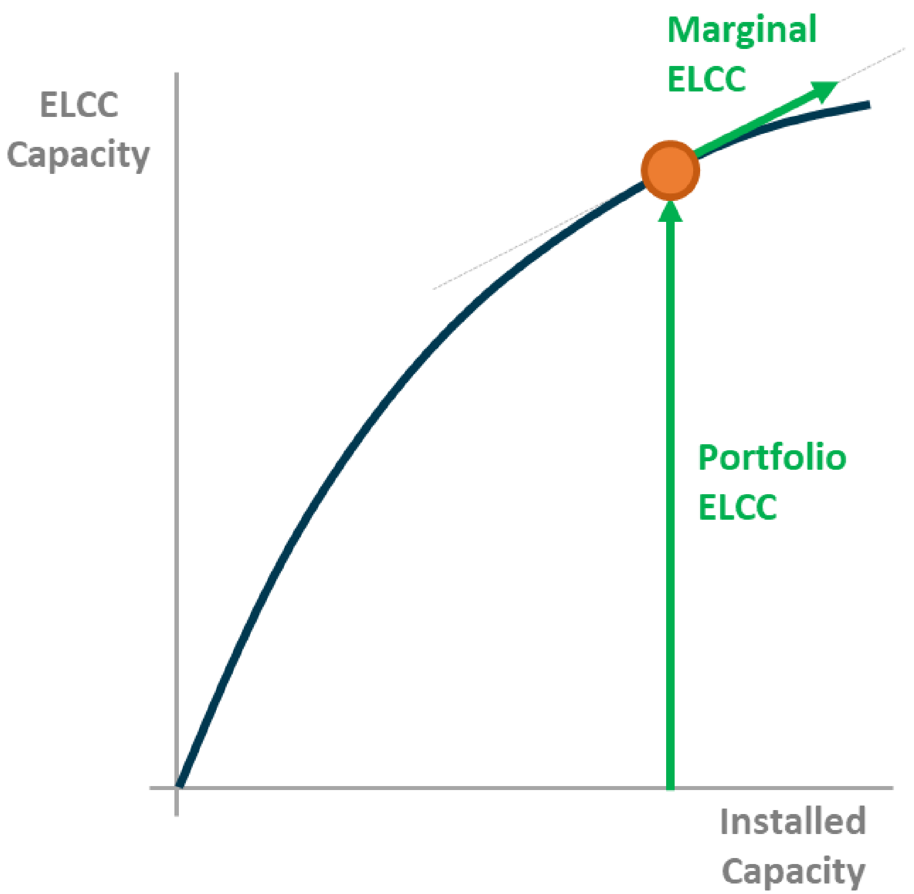
- **ELCC is a function of the portfolio of resources**
  - The function is a surface in multiple dimensions
  - The Portfolio ELCC is the height of the surface at the point representing the total portfolio

$$Portfolio\ ELCC = f(G_1, G_2, \ldots, G_n)\ (MW)$$

  - The Marginal ELCC of any individual resource is the gradient (or slope) of the surface along a single dimension – mathematically, the partial derivative of the surface with respect to that resource

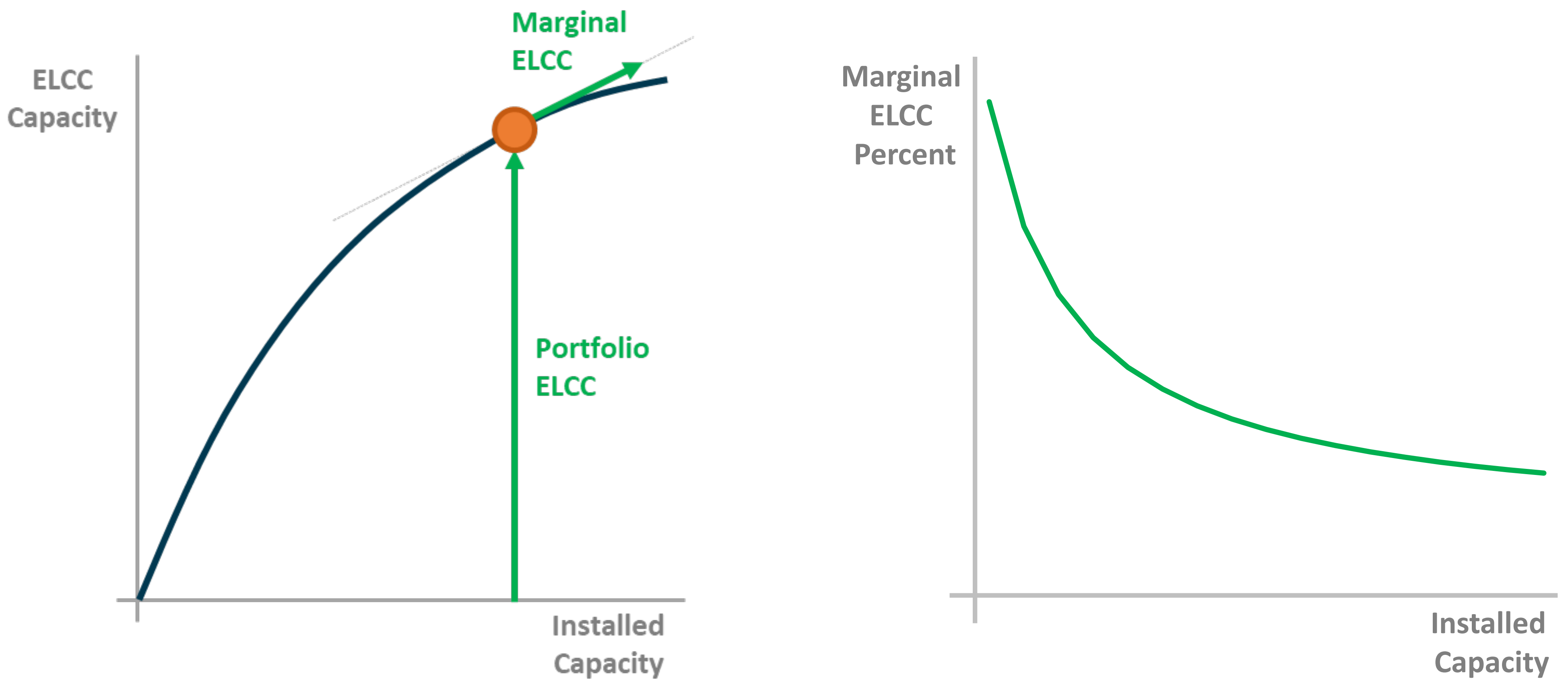
$$Marginal\ ELCC_{G_1} = \frac{\partial f}{\partial G_1}(G_1, G_2, \ldots G_n)\ (\%)$$

- **The functional form of the surface is unknowable**
  - Marginal ELCC calculations give us measurements of the contours of the surface at specific points
  - It is impractical to map out the entire surface



The Portfolio ELCC function is concave across multiple dimensions

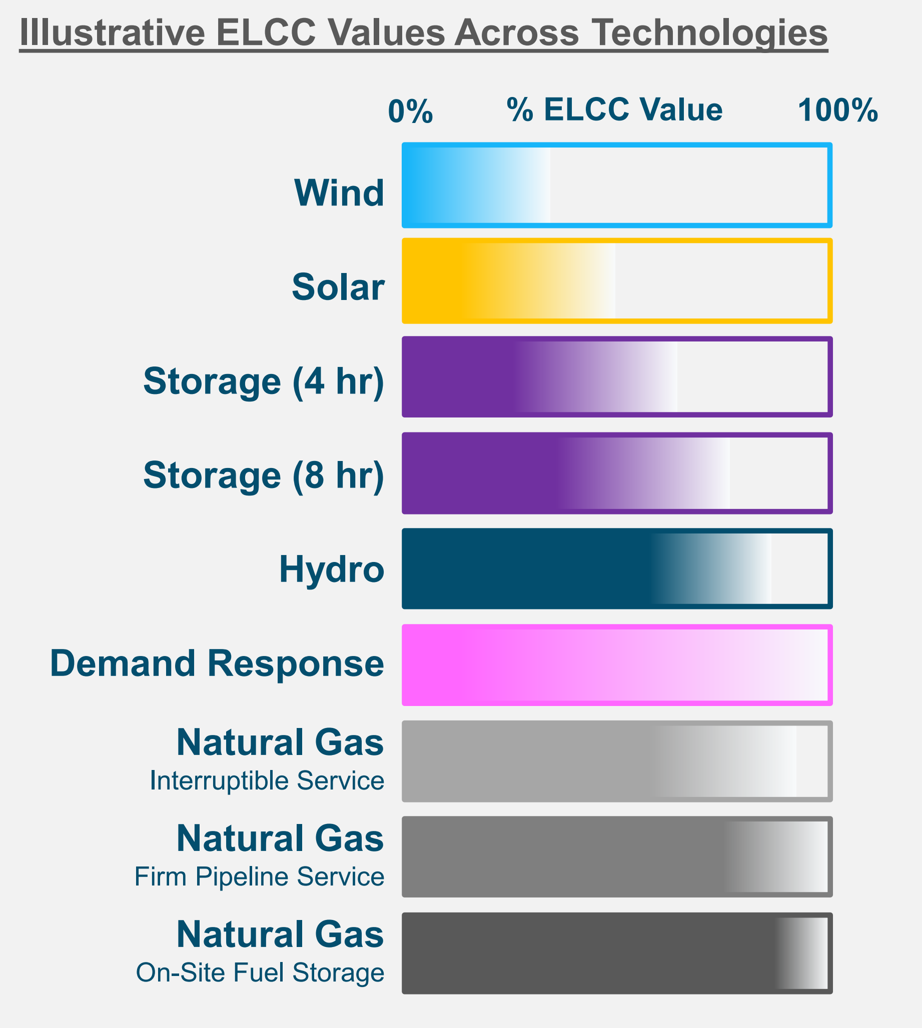
+ Marginal ELCCs are monotonically decreasing
+ The shape the surface is a function of the characteristics of a system's loads and resources



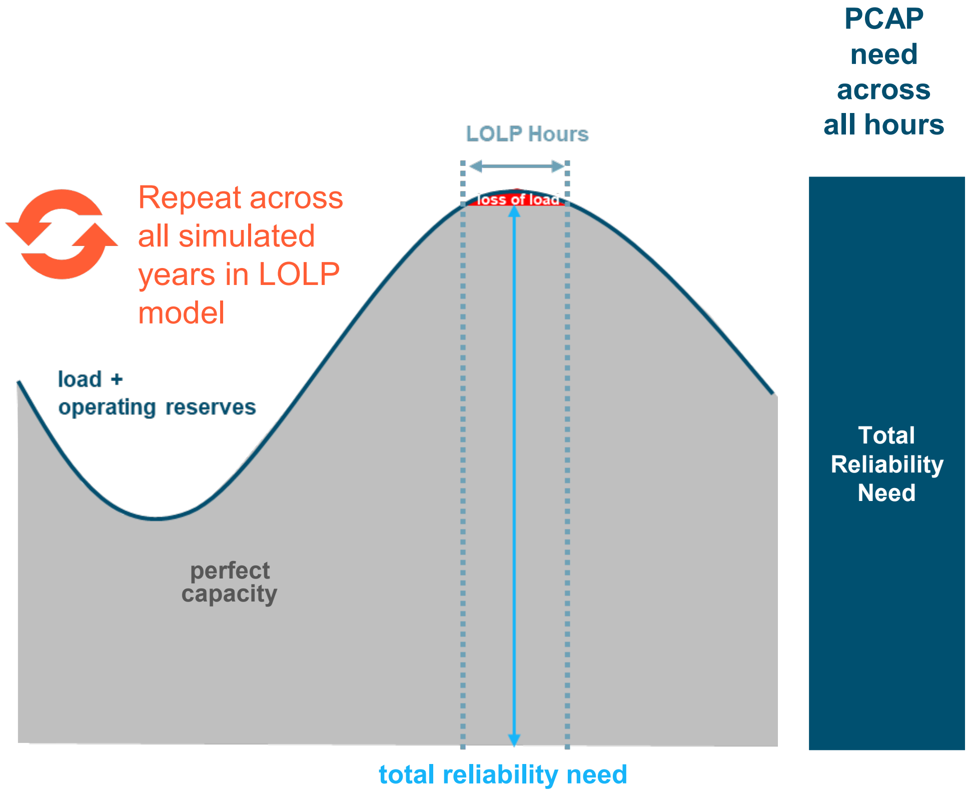
No resource is "perfect" – Marginal ELCC is applied to all resources in the Critical Periods framework

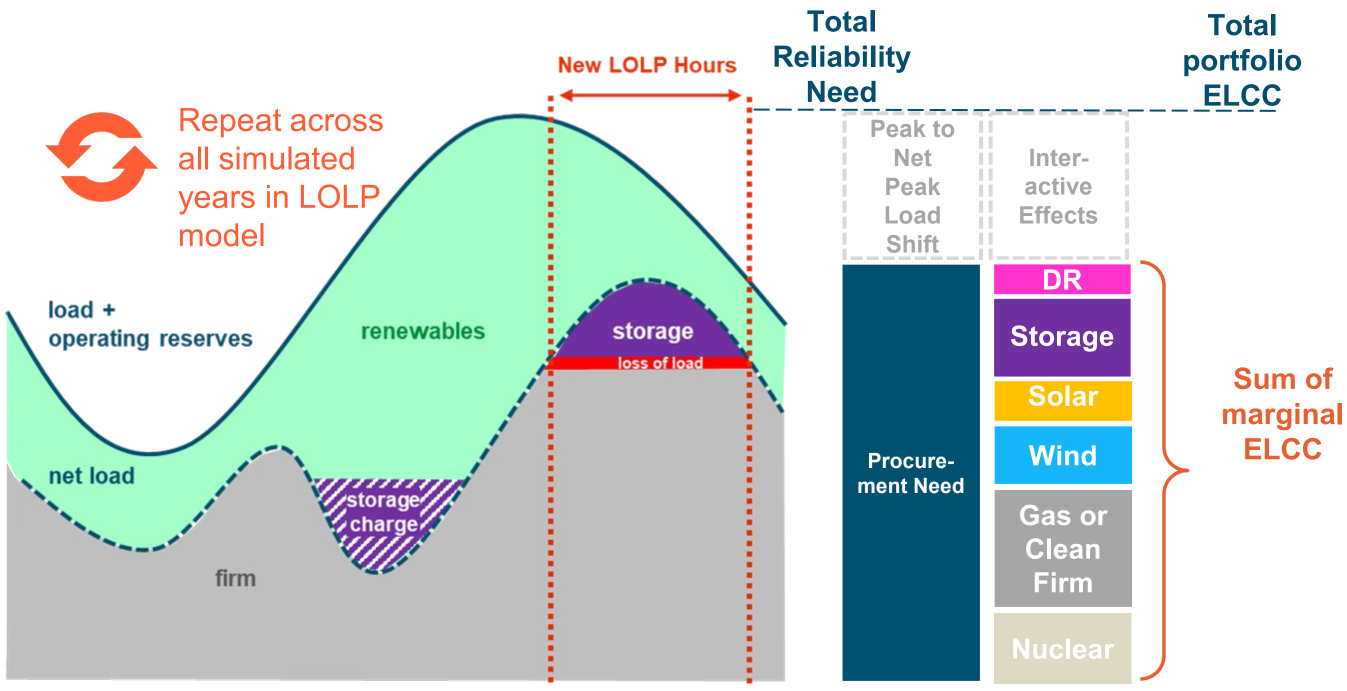
+ **Marginal ELCC creates level playing field by measuring all resources against perfect capacity**
+ **Accounts for all factors that can limit availability:**
  - Energy availability
  - Hourly variability in output
  - Duration and/or use limitations
  - Temperature-related de-rates and outage rates
  - Correlated outage risk
+ **Interactive effects in the portfolio cannot be uniquely attributed to individual resources**

$$\mathit{Portfolio}\ \mathrm{ELCC} = \sum_{i=1}^{n} \mathit{MELCC}_i + \mathit{Interactive\ Effects}$$



Procurement need and accreditations evolve with the portfolio, continually providing efficient entry signals





Conventional System with Firm Capacity

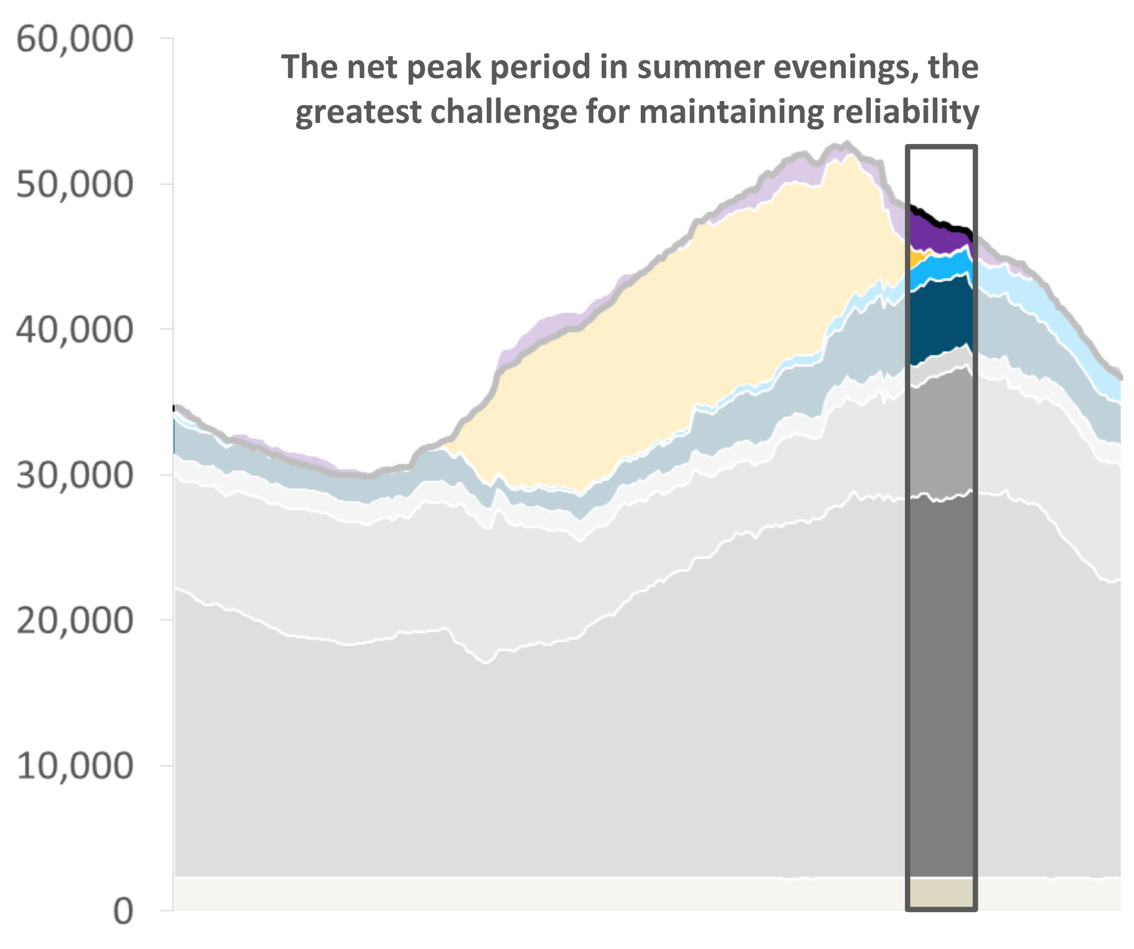
- Critical Hours ≈ Peak Load Hours
- No interactive effects among resource types
- Accreditation using ICAP or UCAP

System with High Solar Penetration

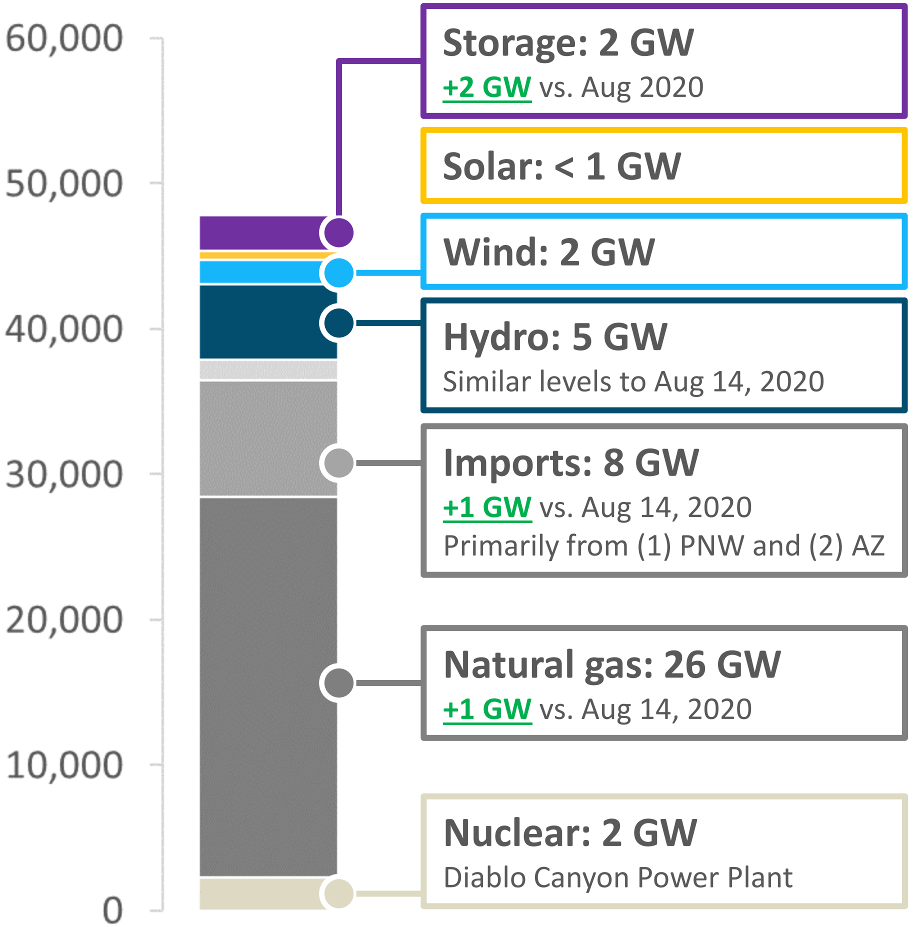
- Critical Hours ≈ Net Peak Load Hours
- Large interactive effects among resources
- Accreditation based on Marginal ELCC ≈ performance during critical hours

Recent events demonstrate the practical applicability of the Critical Periods framework

CAISO System Operations on September 6, 2022
(MW)



Generation During Hour of Highest Net Load
(MW)

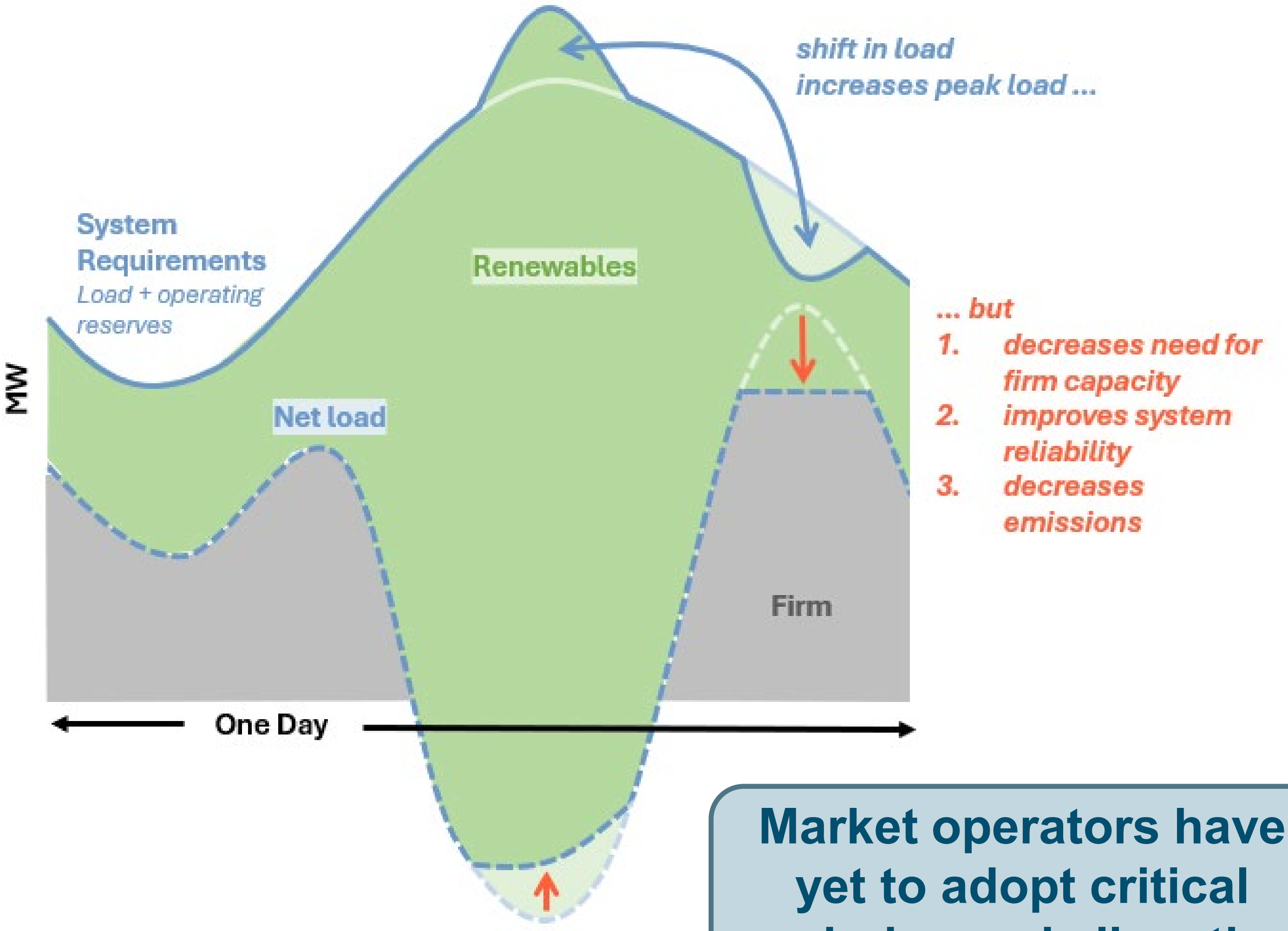


Resource adequacy capacity is one of several capacity reservations with physical accreditation requirements

Capacity Reservation Type	Description	Accreditation
Resource adequacy capacity	Physical option held by the system operator to call on energy production **during periods with critical supply shortfalls**	Marginal ELCC
Contingency reserves	Physical options held by the system operator to call on energy production in response to the **sudden loss of large generation or transmission facilities**	Synchronized and respond within 10 minutes (spin) Respond within 30 minutes (non-spin)
Flexibility reserves	Physical options held by the system operator to call on energy production in response to net load forecast error or large-timescale **(5-120 minute) net load fluctuations**	Ramp rate requirement (MW/min)
Regulation reserves	Physical options held by the system operator to call on energy production in response to small-timescale **(<5 minute) net load fluctuations**	Automated generation control (AGC) or governor response

Allocating need based on load during critical periods is important to encourage load participation

- **Aligns need allocation method with periods of expected scarcity**
- **Encourages load reduction during critical hours**
  - Reducing consumption during high load but not critical periods is harmful to reliability by making loads less likely to respond when needed
  - Demand-side measures such as daytime EV charging are disincentivized by allocating need based on peak load
- **Aligns incentives for "event-based" and "price-based" DR**



Market operators have yet to adopt critical periods need allocation

Thank you!

Arne Olson, Senior Partner, arne@ethree.com

Energy+Environmental Economics

Developments in Capacity Accreditation

BY:

SAM NEWELL (PRESENTING)
ANDREW LEVITT
RAGINI SREENATH

PRESENTED TO:

NERC "EVALUATING RESOURCE CONTRIBUTIONS FOR RELIABILITY AND CAPACITY SUPPLY" WORKSHOP

JUNE 5, 2025

Brattle

Recap: Principles of Accreditation

Why is Accreditation Needed?

- We need accurate supply-demand accounting to track meeting the resource adequacy standard of having sufficient reserve margin going into each planning period to support, e.g., 1-in-10 LOLE in expectations.

What Accurate Accreditation Involves

- Each resource has its own challenges, and yet the value of each resource (and discounts for the challenges) depends on how its capability correlates with those of other resources in the fleet, and with load, through time variables and fluctuating weather variables.
- To accredit resources according to their contribution to resource adequacy, system operators simulate and/or observe how the fleet and individual resources perform throughout the year, accounting for correlations, limited durations, etc.

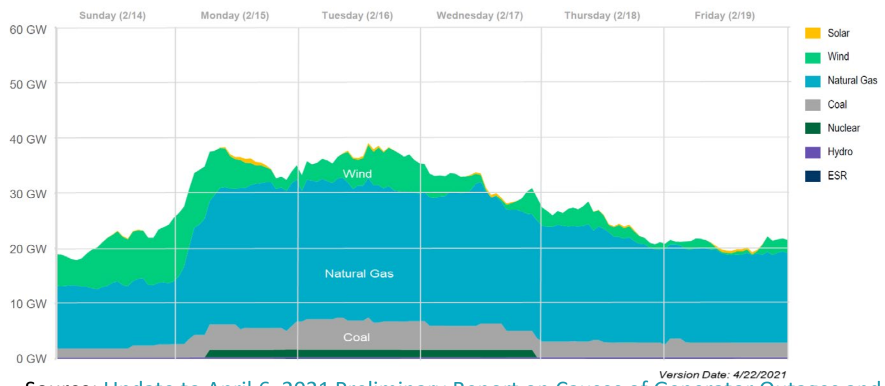
Why Only Marginal Accreditation Can Guide Efficient Investment Decisions

- Adding or removing a resource has a marginal effect on the fleet each year over the rest of its life; investment decisions can optimize total economic value by considering the marginal value provided, and the net costs.
- (Demand must be defined consistently with accreditation that does not recognize non-marginal value, e.g., mid-day solar helping to meet the afternoon peak when net peak has shifted to the evening. Demand corresponds roughly to demand plus reserve margin in the projected hours with highest risk.)

Recap: Why Accreditation is Becoming More Interesting

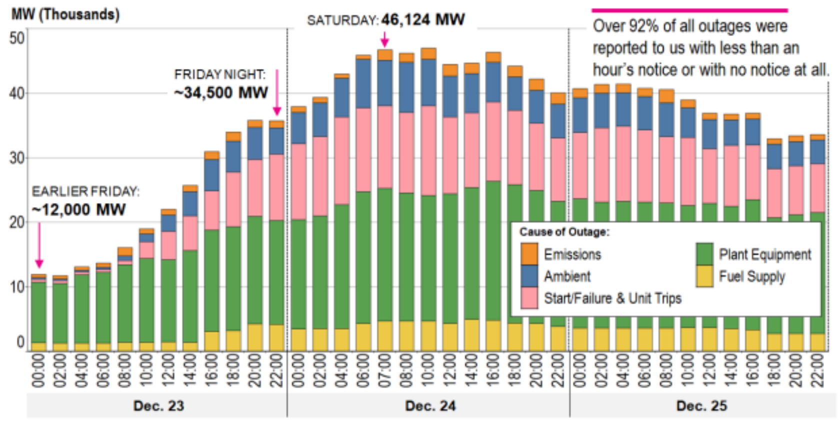
The biggest recent events have been from correlated thermal outages

Net Generator Outages and Derates by Fuel Type (MW)



Source: Update to April 6, 2021 Preliminary Report on Causes of Generator Outages and Derates during the February 2021 Extreme Cold Weather Event," ERCOT, April 27, 2021.

Figure 12. Forced Outages by Cause



Source: Winter Storm Elliott – Event Analysis and Recommendation Report, PJM, July 17, 2023.

As wind and solar increase, the nature of risks will shift… and will require retaining/adding dispatchable as backup

FIGURE 13: TOP 100 RESOURCE ADEQUACY RISK HOURS BY MONTH (SCENARIO B2)

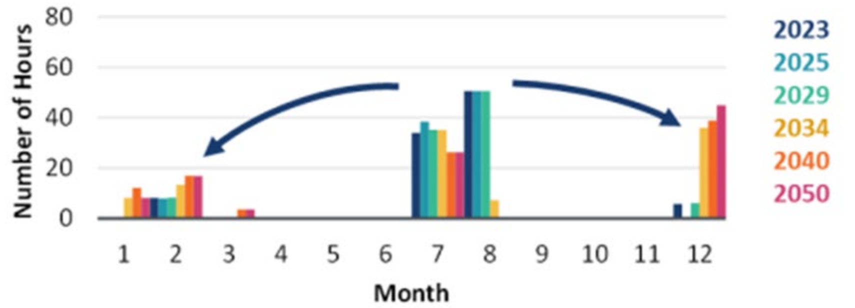
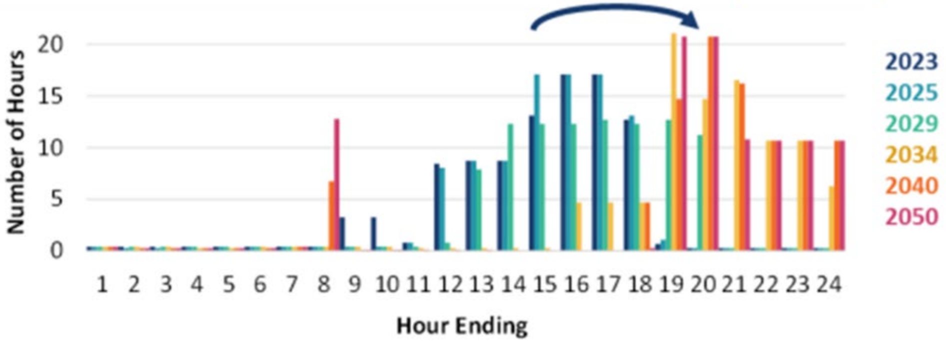


FIGURE 14: TOP 100 RESOURCE ADEQUACY RISK HOURS BY HOUR (SCENARIO B2)



Source: SPP Future Energy & Resource Needs Study (FERNS), Feb 2025.

In the Past ~3 Years, RTOs and Utilities Have Improved or Announced Improvements to their Capacity Accreditation

Previously

High gross peak load used as primary indicator of risk hour

Simple EFORd deratings w/o correlated outages of thermal units; derating of wind/solar to output in peak periods

Capacity ratings based on **average value**

Today

Modeling **full range of risk hours** across the year (and many years)

Weather-correlated risk analysis: correlated thermal fleet outages; modeling wind, solar, storage, DR

Ratings at **marginal value**

Examples include:

- **MISO** – DLOL Approach
- **PJM** – Marginal ELCC
- **NYISO** – Marginal Reliability Improvement
- **CAISO** – Slice-Of-Day Framework

Yet Accreditation Continues to Evolve

Previously

High gross peak load used as primary indicator of risk hour

Simple EFORd deratings w/o correlated outages of thermal units; derating of wind/solar to output in peak periods

Capacity ratings based on **average value**

Today

Modeling **full range of risk hours** across the year (and many years)

Weather-correlated risk analysis: correlated thermal fleet outages; modeling wind, solar, storage, DR

Ratings at **marginal value**

Future Improvements

1. Re-accrediting **upgraded** thermal generators
2. Considering **climate change**
3. Improving **forecastability**

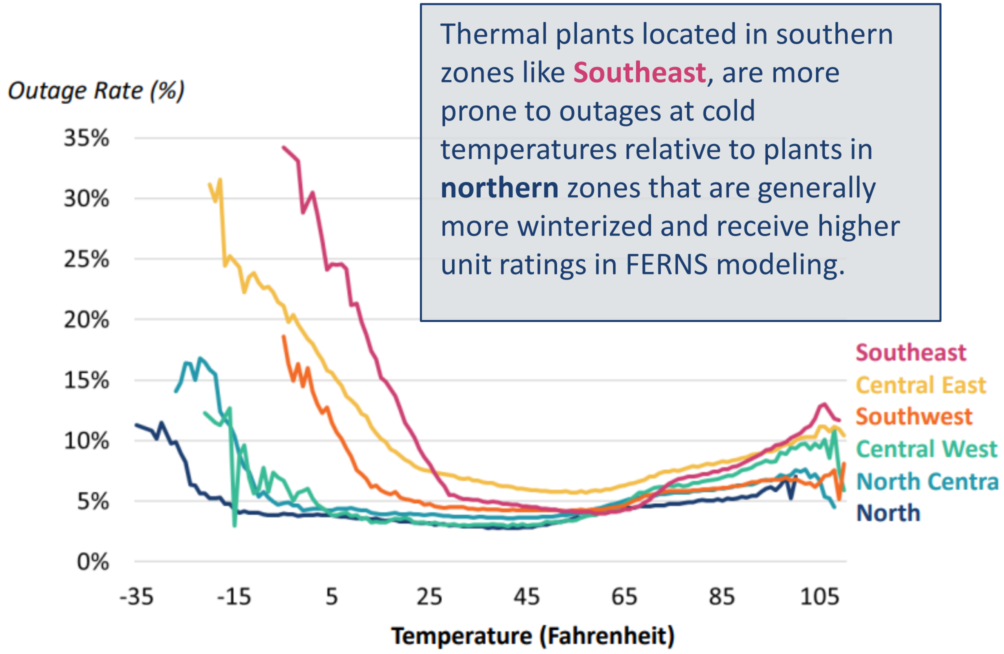
1. Re-Accrediting **Upgraded** Thermal Generators

- **Issue**: Unit-specific ELCC adjustments use historical performance from infrequent, extreme events. If a generator subsequently improves its winterization & fuel firming, its rating may not improve until demonstrated in future rare events. Yet such improvements are highly valuable so should be recognized (see right).
- **Potential Solution**: Introduce re-characterization of types, or unit-specific adjustments based on demonstrated enhancements.
- **Challenges**: Difficult to determine the effectiveness of improvements.

State of Play

- MISO has a short 3-year lookback, allowing unit-specific accreditations to update more quickly (but not as reflective of performance in extremes).
- PJM recognizes that its longer individual history lags incorporating improvements and is reviewing adjustments needed to fix it.
- ISO-NE, PJM, and MISO have special categories for dual-fuel units to recognize their higher capacity value.

Thermal Temperature based outages in SPP, by Zone



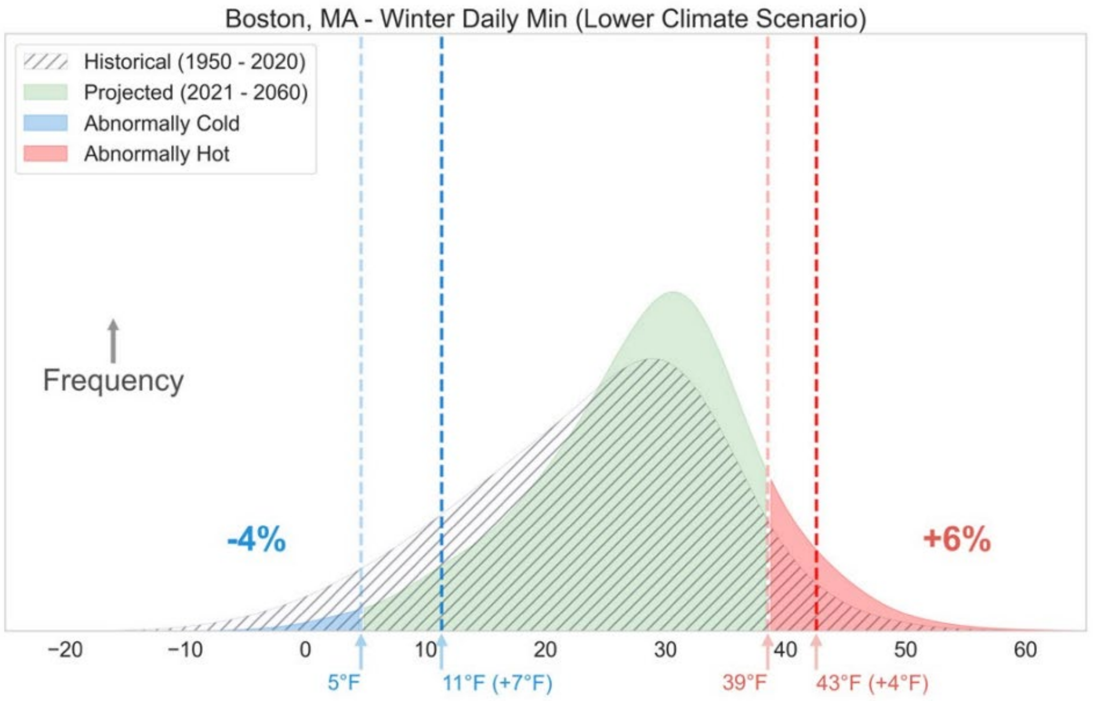
Source: SPP Future Energy & Resource Needs Study (FERNS), Feb 2025.

2. Considering **Climate Change Impacts**

- **Issue**: While using longer weather history has helped capture a broader range of conditions, that historical data reflects a different climate from today's (not to mention that of the future).
- **Potential Solution**: Consider weighting recent years more or adjusting historical data using long-term trends.
- **Challenges**: Would have to engage climate experts to develop appropriate region-specific adjustments especially for extremes.

State of Play

- **PJM** has considered adjusting weather variables in its reliability modeling of ELCCs and reserve requirements to account for long-term trends in average and extreme temperatures.
- **ISO-NE** developed a Probabilistic Energy Adequacy Tool to assess adequacy during extreme weather events, to inform the Regional Energy Shortfall Threshold intervention by exception.
- **California** is looking into adjusting demand forecasts to account for climate change impacts.



Source: ISO-NE Operational Impact of Extreme Weather Events.

3. Improving **Forecastability**

- **Issue**: Complexity of new methods combined with uncertainties about the future fleet has made it more complicated for resource owners to project future accreditations relevant to investment decisions.
- **Solution**: Develop tools or studies that provide stakeholders indicators of future ratings.
- **Challenges**: Developing future scenarios (including expansion modeling with endogenous builds and accreditations); the possibility of future refinements to accreditation.

State of Play		
	Available Previously	**Updates**
PJM	PJM published preliminary ELCC ratings for 9 future delivery years, with resource mix based on a vendor's forecast on future deployment levels by resource type.	PJM has introduced an ELCC calculator, allowing users to estimate ELCC class ratings for delivery years 2026-38, specifying different future deployment levels by resource type.
MISO	MISO published the RIIA report to help stakeholders understand the declining ELCC value of renewables with increasing penetration; 2022 RRA also began including 2031 picture of resource adequacy.	MISO is redesigning its Futures study and will develop consistent DLOL accreditation and expansion results using a calibration process and a dynamic function estimating DLOL as a function of ICAP.

Presenter Bio

Samuel Newell

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Dr. Newell leads Brattle's electricity practice in analyzing critical economic questions around the industry's energy transition.

His 25 years of consulting experience centers on electricity wholesale markets, market design, resource valuation, transmission planning, integrated resource planning, and policy analysis. Dr. Newell conducts studies and prepares testimony on behalf of independent system operators (ISOs), state energy agencies, infrastructure investors, and wholesale market participants.

The views expressed in this presentation are strictly those of the presenter and do not necessarily reflect the views of The Brattle Group or its clients.

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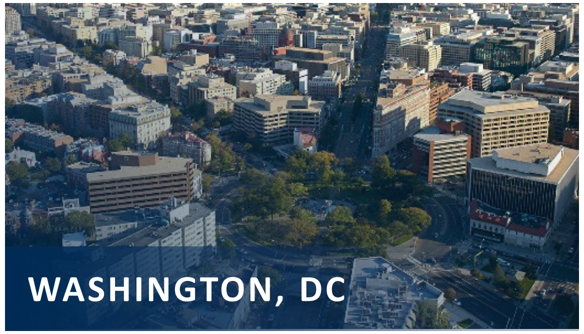


Brattle

Our Practices and Industries

TOP 25 PRACTICES

- Accounting
- Alternative Investments
- Antitrust & Competition
- Bankruptcy & Restructuring
- Broker-Dealers & Financial Services
- Consumer Protection & Product Liability
- Credit, Derivatives & Structured Products
- Cryptocurrency & Digital Assets
- Electricity Litigation & Regulatory Disputes
- Electricity Wholesale Markets & Planning
- Environment & Natural Resources
- Financial Institutions
- Healthcare & Life Sciences
- Infrastructure
- Intellectual Property
- International Arbitration
- M&A Litigation
- Oil & Gas
- Regulatory Economics, Finance & Rates
- Regulatory Investigations & Enforcement
- Securities Class Actions
- Tax Controversy & Transfer Pricing
- Technology
- Telecommunications, Media & Entertainment
- White Collar Investigations & Litigation

Clarity in the face of complexity

Brattle

New York ISO
Independent System Operator

Resource Adequacy's Role in New York's Capacity Market

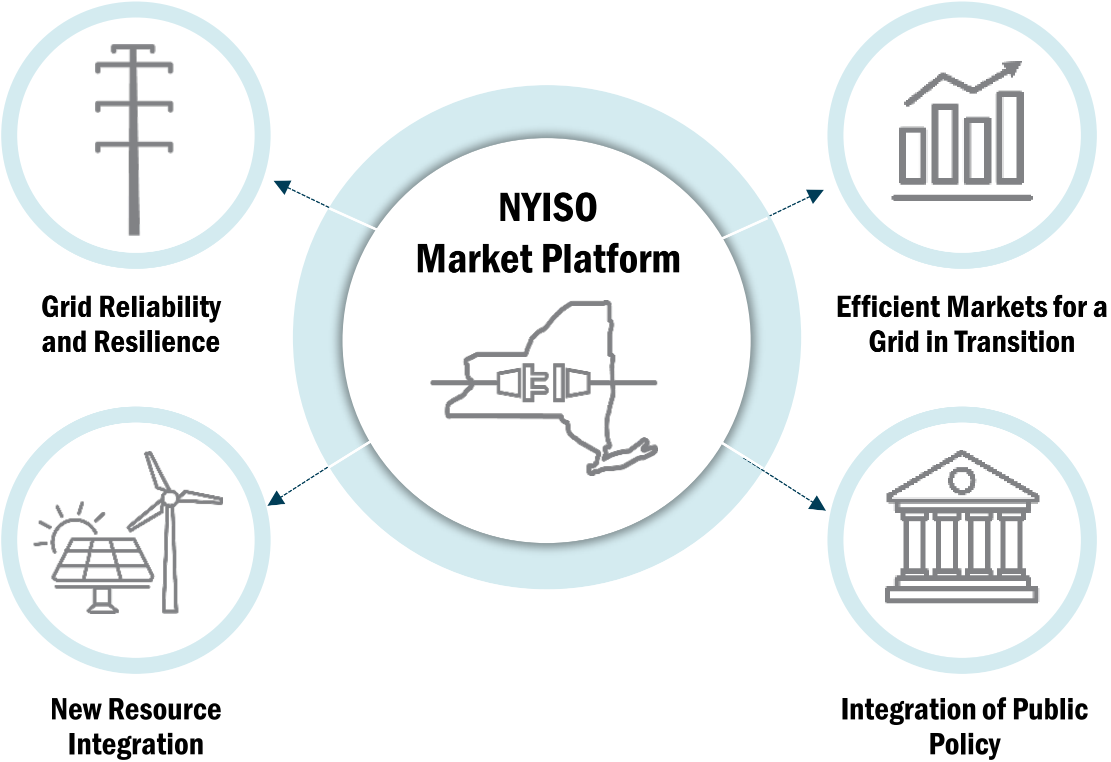
Zach Smith

Senior Vice President, System & Resource Planning

NERC Workshop

June 5, 2025

Enhancing Wholesale Electricity Markets to Meet Changing Needs



System Needs for a Grid in Transition

- **Dispatchability to address intermittent renewable balancing**
  - Dispatchable: Resources that can follow instructions to increase or decrease output on a minute-to-minute basis
  - Short Notification: Resources that can start quickly (<10 minutes)
  - Zero/Minimal Downtime: Resources that can cycle often with minimal to zero downtime
- **Flexibility to address renewable uncertainty**
  - Fast ramping: Resources that can quickly follow net load to manage ACE (Area Control Error – which measures regional generation to load balance) on a second-to-second basis
  - Energy Secure: Resources that can provide energy for multiple hours and days regardless of weather, storage, or fuel constraints
- **Support Power System Stability, Strength, and Minimize Operational Risk**
  - Resources that can hold their bus voltage regardless of topology or resource commitment
  - Resources sized to avoid extreme contingency scenarios, where contingency reserves may be expensive or unavailable and loss of generation does not contribute to LOLE/EUE

New York ISO

Role of Energy and Capacity Markets

Energy and Ancillary Services Market

- Aligned to the physics of the power system operations
- Prices for real-time energy and ancillary service needs aligned with reliability
- Provides infra-marginal and shortage pricing revenues for recovering investment costs
- Prices and cost recovery can be volatile

Role of the Capacity Market

- Procures enough Capacity to meet System Planning Criterion related to load losses
- Provides fixed cost recovery for investments
- Acts as a call option on future energy and as a hedge on extreme volatility that energy-only markets are susceptible to

NYISO is taking a comprehensive approach to Energy, Ancillary, and Capacity Market enhancements to attract and retain resources with the reliability characteristics the grid of the future will need.

Resource Adequacy

- **In New York's Capacity Market, resource adequacy studies are used to:**
  - Establish the amount of capacity the NYCA and its Localities must procure monthly
  - Determine the seasonal shaping of the reference point prices of the ICAP Demand Curves.
  - Assess the capacity value of resources based on their contribution to meeting resource adequacy requirements
  - Determine annual import right limits
  - Establish Peak Load Windows

Capacity Accreditation

Capacity Accreditation

- **Capacity Accreditation Factors (CAFs) reflect the marginal reliability contribution of the ICAP Suppliers within each Capacity Accreditation Resource Class (CARC) toward meeting NYSRC resource adequacy requirements for the upcoming Capability Year.[1]**
  - A CARC is a defined set of Resources and/or Aggregations with similar technologies and/or operating characteristics which are expected to have similar marginal reliability contributions toward meeting NYSRC resource adequacy requirements for the upcoming Capability Year.
  - CAFs are calculated using the Locational Capacity Requirements (LCR) model that is used to calculate the LCRs for the upcoming capability year.
- **In general, according to ISO Procedures:**
  - UCAP = Adjusted ICAP x (1 – Derating Factor)
  - Adjusted ICAP = Available ICAP x Capacity Accreditation Factor (CAF)

[1] NYISO's FERC Filing for Adopting a Marginal Capacity Accreditation Market Design

[2] UCAP is "the measure by which Installed Capacity Suppliers will be rated, in accordance with formulae set forth in the ISO Procedures, to quantify the extent of their contribution to satisfy the NYCA Installed Capacity Requirement, and which will be used to measure the portion of that NYCA Installed Capacity Requirement for which each LSE is responsible"

New York ISO

Relationship between the LOLE Risk Profile and CAFs

- **The LOLE risk profile impacts CAF values**
  - CAF values are calculated based on how effective a CARC is at addressing LOLE risk compared to “perfect capacity”
- **As the LOLE risk profile changes, a CARC’s ability to address LOLE risk can also change, leading to changes in CAF values**
  - For example, if the LOLE risk profile shifts to later in the day, a solar resource is less effective at addressing such later occurring LOLE risk; therefore, the CAF for a solar resource is likely to be lower

Capacity Accreditation

- Utilizing the LCR model, NYISO annually calculates each CAF for each CARC using the Marginal Reliability Improvement (MRI) technique[1], as follows:

$$CAF_{ca} = \frac{LOLE_i - LOLE_{mca}}{LOLE_i - LOLE_{pa}}$$

Where:

CAF_{ca} = the Capacity Accreditation Factor for the upcoming Capability Year for the capacity zone a of the evaluated Capacity Accreditation Resource Class c

$LOLE_i$ = the starting loss of load expectation of the LCR model

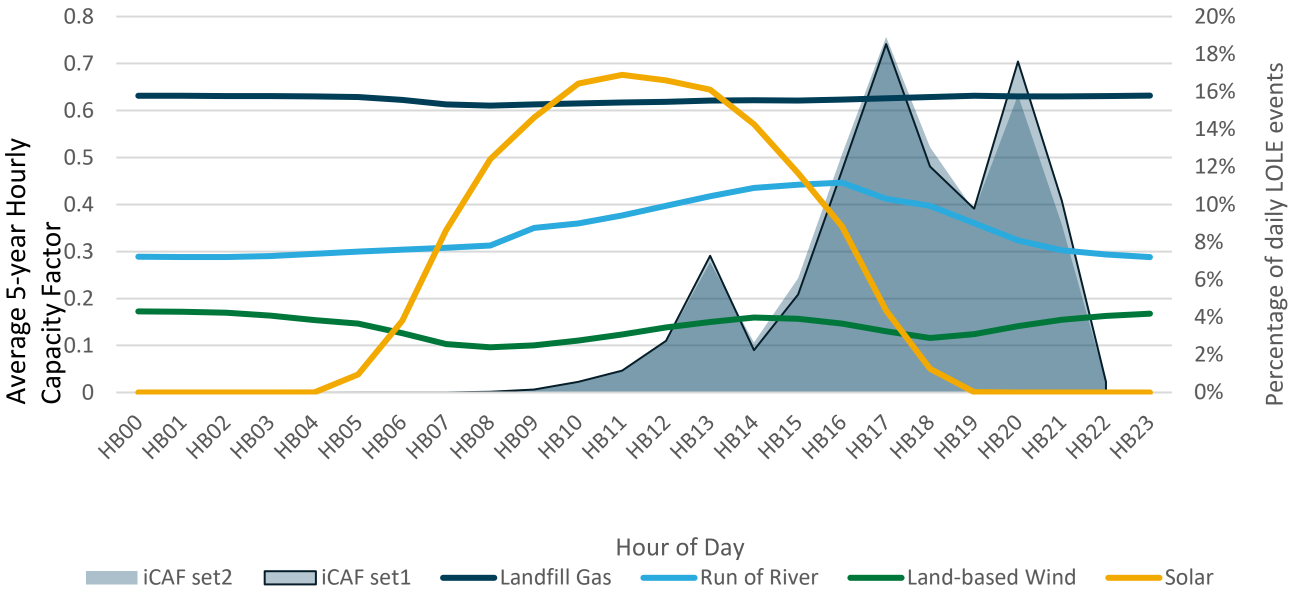
$LOLE_{mca}$ = the loss of load expectation of the LCR model with the addition of a 100 MW representative unit of the evaluated Capacity Accreditation Resource Class c to the modeling zone that corresponds to capacity zone a

$LOLE_{pa}$ = the loss of load expectation of the LCR model with the addition of 100 MWs of perfect capacity to the modeling zone that corresponds to capacity zone a

[1]The methodology for calculating CAFS as outlined in Section 7.2.1 of the ICAP Manual

New York ISO

Illustration: Average Shape-Based Unit Profiles vs. LOLE Risk Profile in Rest of State in July



- **The figure is for illustrative purposes, comparing the average hourly profiles of shape-based units with hourly LOLE distribution**
  - It represents an average only for July and specific circumstances during each GE MARS simulation that may be different than this illustrative depiction
- **The hourly resource profiles are based on five years of historical production data for July (July 2019–July 2023)**

New York ISO

Capacity Accreditation

2025-2026 Final CAFs

CARCs	Rest of State	GHI	NYC	LI
Special Case Resource (SCR)	77.21%	76.88%	68.31%	74.43%
2-Hour Energy Duration Limited	74.32%	73.97%	64.94%	52.68%
4-Hour Energy Duration Limited	78.91%	78.60%	78.53%	87.10%
6-Hour Energy Duration Limited	87.24%	87.16%	85.90%	94.59%
8-Hour Energy Duration Limited	96.77%	96.40%	96.12%	98.96%
Landfill Gas	63.95%	63.87%	64.04%	65.68%
Solar	12.24%	12.33%	12.03%	10.05%
Offshore Wind	-	-	-	35.79%
Land-based Wind	16.84%	16.61%	16.69%	18.20%
Limited Control Run of River	38.44%	41.44%	-	-
Large Hydro	100.00%	100.00%	100.00%	100.00%
Large Hydro with partial Pump Storage	100.00%	-	-	-
Generator	100.00%	100.00%	100.00%	100.00%

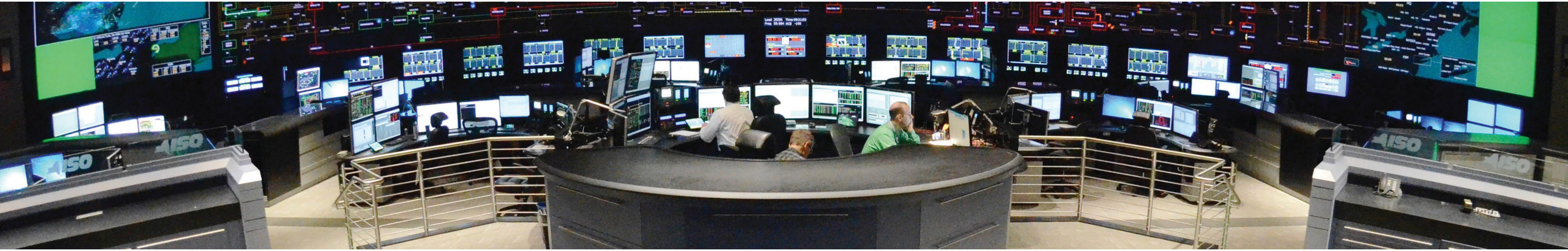
New York ISO

Questions?

Our Mission and Vision

Mission
Ensure power system reliability and competitive markets for New York in a clean energy future

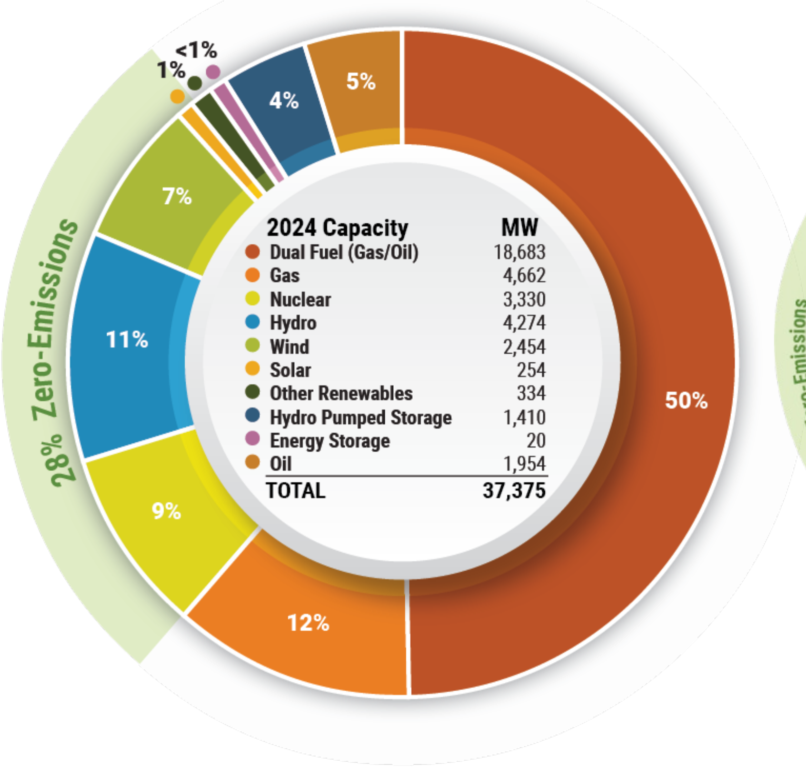
Vision
Working together with stakeholders to build the cleanest, most reliable electric system in the nation



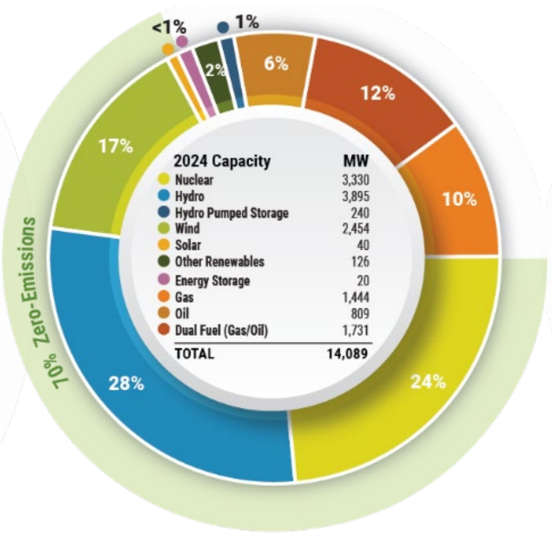
Appendix

Generating Capacity by Fuel Source: 2024

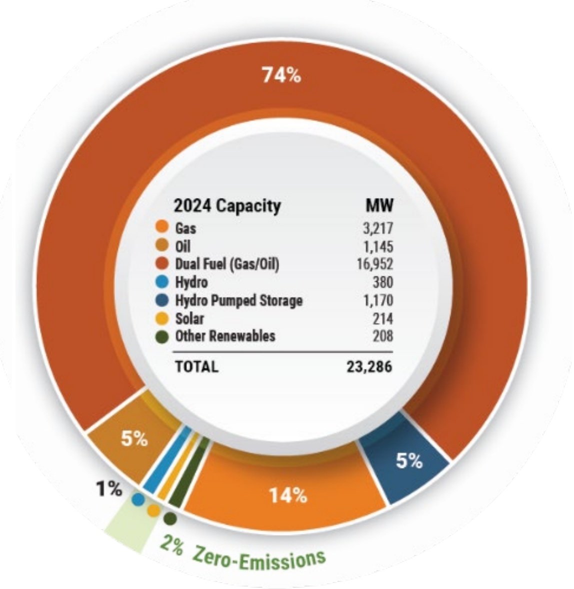
NYCA



Upstate (Zones A-E)



Downstate (Zones F-K)



Generating Capacity is the maximum electric output a generator can produce

New York ISO

New York Capacity Requirements

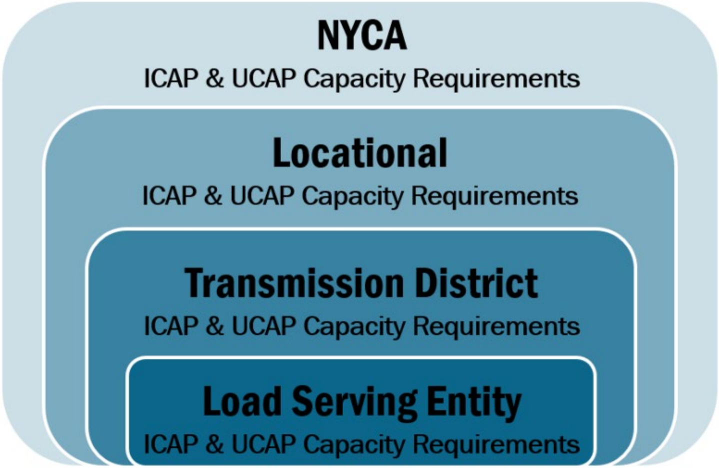
New York ISO

Role of the NYISO Capacity Market

- **Ensures Resource Adequacy**
  - Ensures the New York Control Area (NYCA) has enough supply to meet expected peak load plus an Installed Reserve Margin (IRM).
  - Sets Locational Minimum Installed Capacity Requirements (LCRs) to ensure Localities have enough internal supply to maintain resource adequacy given transmission limitations.
- **Provides a mechanism for Suppliers to recover costs not otherwise covered by the energy and ancillary services markets**
- **Supports market signals for investment.**
  - Sends locational signals for resource entry and exit.

New York Capacity Requirements

- **The NYCA and Locality capacity requirements, established through the IRM and LCRs, are used to determine the corresponding Unforced Capacity (UCAP) requirements for each Capability Period.**
  - These requirements also form the basis for calculating each Load Serving Entity's (LSE's) UCAP purchase obligation, based on its share of load within each Transmission District.



New York ISO

New York Capacity Requirements

- **IRM**
  - Established annually by the New York State Reliability Council (NYSRC) for the upcoming Capability Year.[1]
    - May 1 – April 30
  - Used to derive the amount of capacity that must be available to the NYCA to ensure the Northeast Power Coordinating Council (NPCC) resource adequacy standard is met.
    - The standard requires that Loss of Load Expectation (LOLE) due to resource deficiency on the NYCA system is no more than once in 10 years (0.1).
  - Calculated using GE MARS, which probabilistically models LOLE based on assumptions about load, transmission, and available capacity.
- **LCR**
  - The NYISO is responsible for calculating and establishing LCRs for each NYCA locality, using a separate process informed by the NYSRC-approved IRM.[2]
  - LCRs are determined using an economic optimization in conjunction with GE MARS that sets locality-specific requirements based on the relative cost of capacity across zones.

[1] 2025-2026 NYSRC IRM Report
[2] 2025-2026 NYISO LCR Report

New York ISO

DRAFT – FOR DISCUSSION PURPOSES ONLY

Direct Loss of Load (DLOL) Accreditation Reform Overview

NERC ELCC Workshop

June 5, 2025

MISO is transitioning its capacity accreditation, to a new methodology that will become effective in Planning Year 2028-2029

- Currently, MISO's approach utilizes a mix of accreditation methods for different classes
  - Non-intermittent/non-emergency (mostly thermal) resource classes are accredited through historical operational data during resource adequacy hours and other operation hours
  - Wind generators are accredited through average ELCC
  - Solar is accredited through average performance during peak load hours
- The new accreditation approach will provide a single accreditation approach for all classes, except LMR and external resources
  - Combines resource class performance in the LOLE model and during critical operational hours
  - FERC approved MISO's Direct Loss of Load filing in October 2024

MISO

Currently, MISO uses an average ELCC method to determine resource accreditation for wind resources

1. **System-wide Seasonal ELCC**
   Calculated within the probabilistic model during all hours
2. **Evaluate Wind Performance on Peak**
   Deliverable + Curtailed during the top eight peaks for each season
3. **Individual Capacity Credits**
   ELCC distributed across all wind CPNodes
4. **Following Year LOLE Study Inputs**
   Wind units modeled at nameplate and tied to hourly profiles for each LRZ

- Effective Load Carrying Capability (ELCC) is defined as the amount of incremental load a resource can dependably and reliably serve
- Today, ELCC values for wind resources are determined through MISO’s probabilistic model and are used in Planning Reserve Margin (PRM) calculations and in resource accreditation

Top 8 unique-day historical coincident seasonal peaks from the most recent 3 Planning Years are sampled, for a total of 24 sample points for each seasonal allocation lookback period

Average ELCC Calculation Methodology in Probabilistic Model

Step 1

Without the New Resources

Base System

LOLE = 0.15 days/yr
(1.5 days in 10 yrs)

With the New Resources

Base System

+

New Resource (Wind)

LOLE = 0.08 days/yr
(0.8 days in 10 yrs)

Step 2

Without the New Resources and Solved to Criteria

Decreased Load
-200 MW

Base System

LOLE = 0.1 days/yr (1 day in 10 yrs)

With the New Resources and Solved to Criteria

Base System

+

Load Increase
+100 MW

New Resource (Wind)
1,000 MW Nameplate

LOLE = 0.1 days/yr (1 day in 10 yrs)

ELCC = 300 MW or 30%

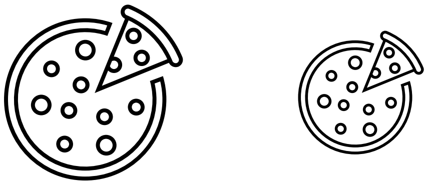
- The difference between the adjustments is the amount of ELCC expressed in load or megawatts
- ELCC can be expressed as a percentage by dividing by the total RMax (Registered Maximum) of wind resources

Recent Wind ELCC Values

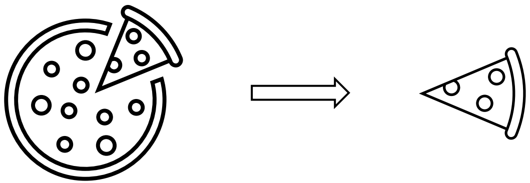
Planning Year	Summer	Fall	Winter	Spring
2025-2026	21%	31%	29%	25%
2028-2029	22%	29%	29%	29%
2030-2031	21%	29%	29%	28%

MISO’s DLOL accreditation methodology measures resource availability during periods of elevated reliability risk in a two primary steps

Class-Level (Prospective/Probabilistic)	Resource-Level (Retrospective/Deterministic)
Direct Loss of Load (DLOL) Method Availability within probabilistic model during simulated Critical Hours	**Schedule 53A Method** Based on actual performance with historical high-risk hours weighted more heavily



Step 1: Determining class-level accreditation



Step 2: Allocating class-level accreditation to each resource within a class

DLOL was approved by FERC in October 2024 with an implementation date of Planning Year 2028-2029.

MISO defined thirteen resource classes to which the DLOL accreditation methodology will be applied

Resource Class	Summer	Fall	Winter	Spring
Biomass	52%	47%	51%	49%
Coal	89%	85%	76%	72%
Combined Cycle	95%	92%	77%	78%
Dual Fuel Oil/Gas	87%	84%	79%	77%
Gas	88%	85%	64%	68%
Nuclear	94%	91%	90%	81%
Oil	77%	75%	74%	73%
Pumped Storage	98%	93%	77%	66%
Reservoir Hydro	89%	82%	76%	70%
Run-of-River Hydro	62%	52%	58%	63%
Solar	45%	28%	19%	28%
Storage	61%	88%	85%	90%
Wind	8%	15%	23%	15%

- MISO will produce indicative DLOL accreditation results every year leading up to the Planning Year 2028-2029 implementation date.
- Class-level indicative DLOL results will be shared publicly while resource-level results will be shared in a confidential manner with MISO's Market Participants.
- All resources participating in the MISO Planning Resource Auction, with the exception of external and emergency-only resources, will be assigned to a resource class.
- Resource classes are defined in Schedule 53A of MISO's Tariff and subject to change through future filings.

Indicative DLOL accreditation results were produced using MISO's most recent Planning Year 2025-2026 probabilistic model.

Recent and near-term Resource Adequacy enhancements

- MISO's FERC-approved **Direct Loss of Load (DLOL) accreditation reform** will be implemented starting with the Planning Year 2028-2029 Planning Resource Auction.

- In April 2025, MISO concluded its first Planning Resource Auction utilizing the **Reliability Based Demand Curve (RBDC)** methodology to produce probabilistically-derived sloped demand curves for use in the auction clearing engine.

- In collaboration with stakeholders and MISO's Independent Market Monitor, MISO developed separate **accreditation reforms for demand response and emergency resources** that was filed with FERC in April 2025.

- MISO is actively evaluating several potential options for the **application of deliverability** in resource accreditation to account for the new DLOL process.

Contact Info

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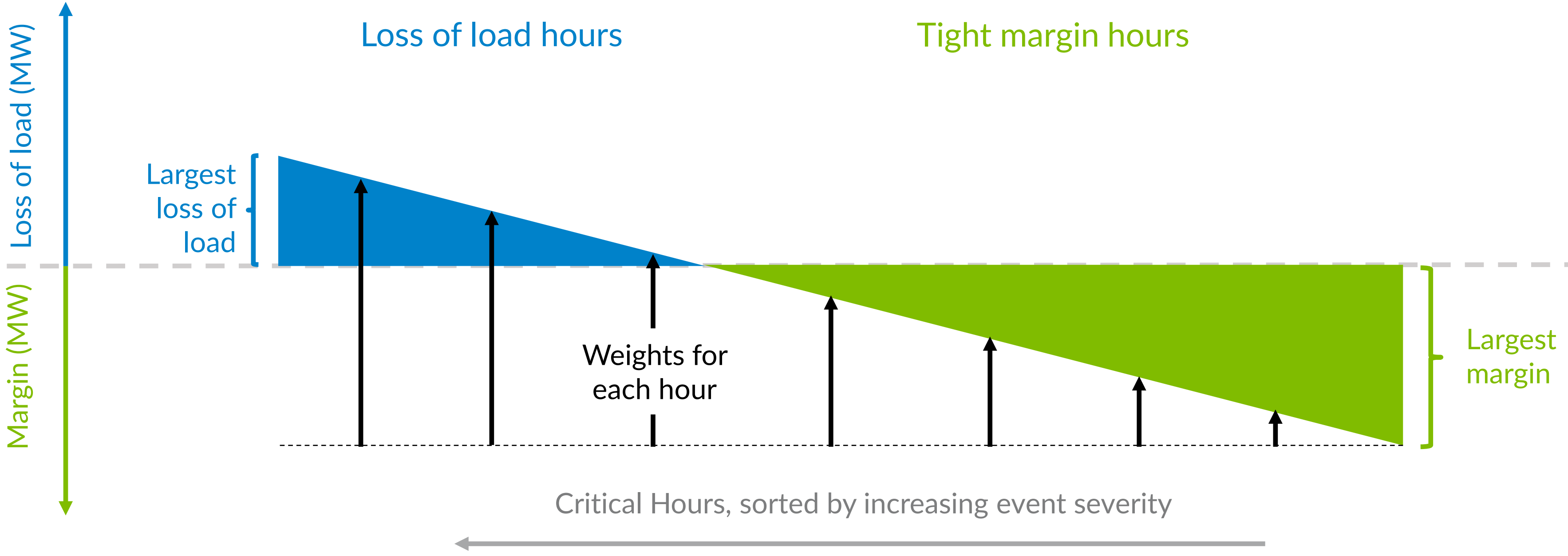
Appendix

For calculating class-level accreditation, Critical Hours with more loss of load or tighter margins are weighted higher in the DLOL method



Critical Hours includes all loss of load hours and any hours where available generation in excess of load is less than or equal to 3% of load in that hour.

Evaluation Criteria Comparison of DLOL to Current Methods

Method	Class & Unit Levels	Impact	Flexibility	Feasibility	Stability
MISO's Current Wind Method	**Class:** Average Individual-Load Carrying Capability (ELCC) **Unit:** Performance during peak hours	Aligns availability with current risk but is disconnected from future risk	Extending to many other resource types misses synergistic effects	Computationally difficult and hard to understand as method scales	Results averaged over a range; doesn't inform the future well
MISO's Current Solar Method	**Class:** N/A **Unit:** Performance during peak hours	Doesn't align changing needs with availability	Easily extendable to other resource types	Computationally efficient and easy to administer	Easy to predict but doesn't reflect changing conditions
Direct Loss of Load Method	**Class:** Availability during critical hours **Unit:** Seasonal Tier 1 and Tier 2 RA hours	Direct alignment between availability and reserve requirements: Account of probabilistic and realized risk, compensation for desired behavior	Easily extendable to other resource types, accounts for synergistic effects	Computationally efficient and easy to administer	Results dependent on resource mix; informs the future well

JUNE 5-6, 2025 | WASHINGTON D.C.

Resource Contributions for Reliability and Capacity Supply

New England's Perspective

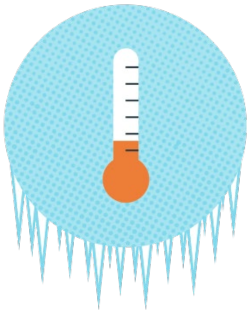
Marianne Perben

DIRECTOR, PLANNING SERVICES

ISO-NE's Capacity Auction Reforms (CAR)

Effective Load Carrying Capability (ELCC) considerations in New England

- CAR seeks to align resources' compensation with their contribution to meeting "one-in-ten" resource adequacy criterion while accounting for resources' energy limitations during cold winter periods
  - Considering a marginal ELCC accreditation framework
  - Pursuing resource adequacy modeling enhancements to improve the representation of system supply and demand conditions with greater accuracy and granularity
- Prompt, seasonal market will help facilitate the development of a market constraint that represents the region's gas infrastructure for the winter months
  - Under CAR, a new constraint will reflect limited available natural gas during cold winter periods, consistent with region's fuel infrastructure



For more details, see the ISO-NE Capacity Auction Reforms Key Project page on the ISO New England website.

Use of Marginal Resource Accreditation

ELCC considerations in New England, cont.

- Marginal Reliability Impact (MRI) based resource accreditation (equivalent to marginal ELCC accreditation)
  - Align individual resource's accreditation to their reliability contribution during the times reliability concerns arise
  - MRI calculated based on the impact an incremental increase in a resource's capacity and energy has on reducing system's expected unserved energy (Expected Unserved Energy (EUE)-based ELCC)
  - Consistent with MRI and EUE-based demand curve design
- Accreditation value is substitutable
  - One MW of accredited capacity from different resources has the same reliability impact
  - Technology neutral
- Advantages over average ELCC accreditation
  - Provide accurate and dynamic entry/exit signals based on current resource mix
  - Allow for procuring resources in most cost-effective manner through capacity market to meet resource adequacy objectives

Resource Adequacy Modeling Enhancements

ELCC considerations in New England, cont.

- Hourly demand forecasts incorporate a broader range of climate-adjusted weather scenarios, calendar effects, and load component impacts (e.g., behind-the-meter PV, electric vehicles, heat pumps)
- Recognize individual resource's supply capability and limitations in serving the system demand
  - Availability and performance (e.g., forced/maintenance outages)
  - Output variability (e.g., intermittent power resources)
  - Fuel/energy constraints (e.g., gas/oil energy constraints during winter)
- Modeling also incorporates correlations among resource types and between supply and demand, such as:
  - Negative correlation between gas supply and load during winter
  - Positive correlation between PV output and mid-day load during summer
  - Geographic correlation among PV and wind resources

Modeling of Gas Constraints

ELCC considerations in New England, cont.

- CAR includes design elements in response to long-standing winter reliability challenges in the region
  - Seasonal market design allows for reflecting resource adequacy risks specific to the winter season, e.g.
    - Pipeline infrastructure in the region has been built primarily to support firm gas demand from local distribution companies; as a result, during periods of cold weather the amount of gas available for power generation is limited
  - Prompt market design better aligns with time frame for operational decisions that affect resource capability, particularly winter fuel arrangements
  - Market constraint design for gas resource accreditation
    - Exemption for gas resources with firm gas contracts
    - Non-exempt gas resources to compete to provide capacity within the limitations of the gas constraint

Reliance on Tie Benefits and Imports

- ISO-NE's resource adequacy framework recognizes reliability benefits from external ties through use of tie benefits
  - Reliance on external ties reduces the quantity of required resources the region needs to procure to meet resource adequacy objectives
  - Tie benefits are quantified through a probabilistic analysis, assuming New England and its neighbors are all at the design condition (each area at a LOLE of 0.1 days/year)
  - Reliance is rooted in NPCC's planning standards and formal Coordination Agreements between ISO-NE and each of its neighbors

- Beyond tie benefits, import resources also participate in ISO-NE's capacity market
  - Import resources are procured from surplus resources above neighboring areas' required levels to meet their resource adequacy objectives
  - The total amount is subject to remaining headroom of the external tie line capabilities after tie benefits

- Consistent modeling and accreditation across interconnected regions is important
  - Consistent modeling captures the correlated/marginal contribution of resources across regions so that one region does not over-rely on other regions' assistance for tie benefits
  - Consistent accreditation across regions is important for quantifying the level of surplus capacity available in each region to support exports to other regions
  - This is another reason for NERC to standardize modeling and a marginal ELCC methodology

For more information, see the Tie Benefits Study Results for 2027-2028 Capacity Commitment Period on the ISO New England website.

Factoring in Extreme Conditions

Use of energy adequacy analysis to complement resource adequacy

- **Probabilistic Energy Adequacy Tool (PEAT)** introduces an innovative approach to quantitatively and probabilistically evaluate energy adequacy risk under extreme conditions within an operational timeframe
  - ISO-NE collaborated with EPRI and developed PEAT for assessing energy adequacy risks and system resilience
  - Initial studies using PEAT focused on 2027 and 2032 study years, providing insights on the regional energy shortfall risks as climate projections and resource mix evolve
- ISO-NE is in the process of establishing a **Regional Energy Shortfall Threshold (REST)** to reflect the region's risk tolerance with respect to energy shortfalls during extreme conditions
  - Energy adequacy studies using PEAT play an important role in informing the development of the REST
  - REST will be complementary to the 1-day-in-10 standard
  - Current thinking is that REST will consist of distinct duration and magnitude metrics

For more details about PEAT and REST, see the Operational Impacts of Extreme Weather Events Key Project page on the ISO New England website.

Questions

Thank You

We appreciate your engagement in this important discussion.

[Agenda]

[Workshop Proposal]