Future Power Markets Forum

Redefining resource adequacy for a new era

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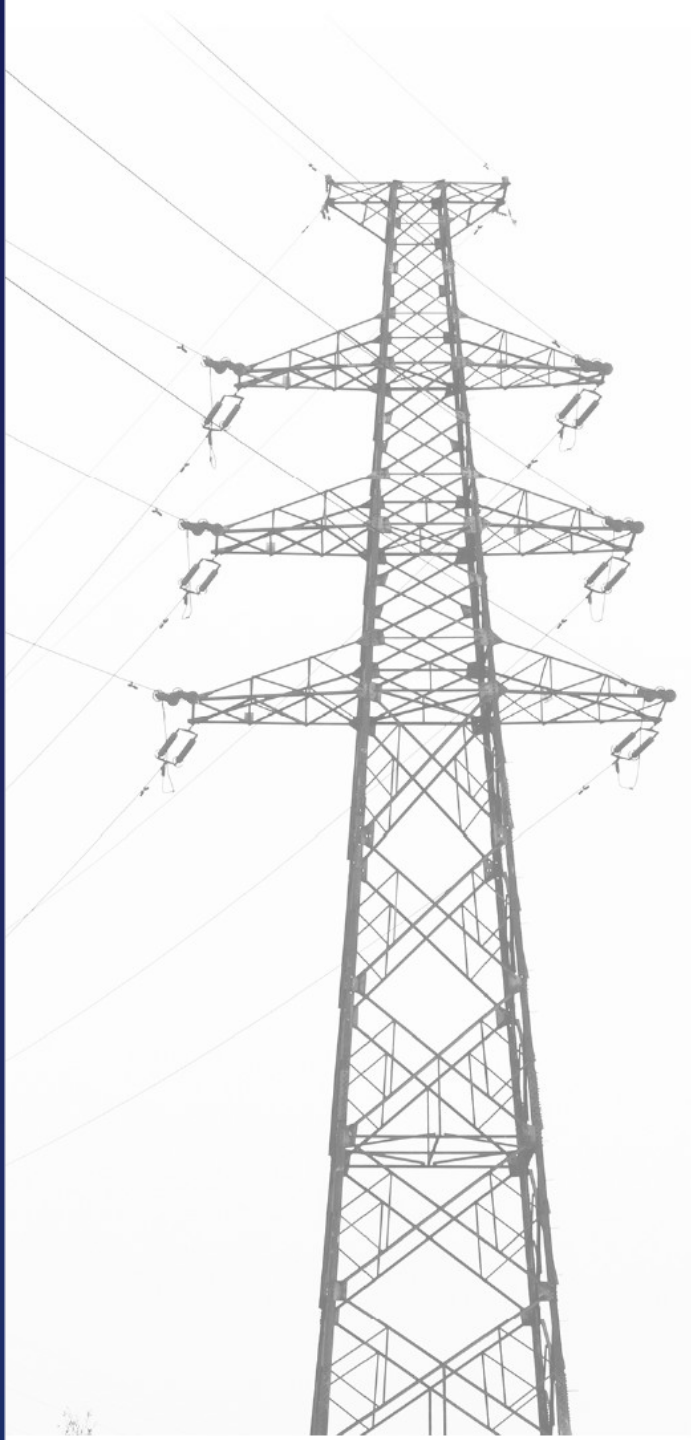

Thank You

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American Public Power Association

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Speakers

Featured Experts

Dr. Ben Hobbs
Johns Hopkins University

Mr. Derek Stenclik
Telos Energy

Mr. Jordan Bakke
MISO

Dr. Bethany Frew
NREL

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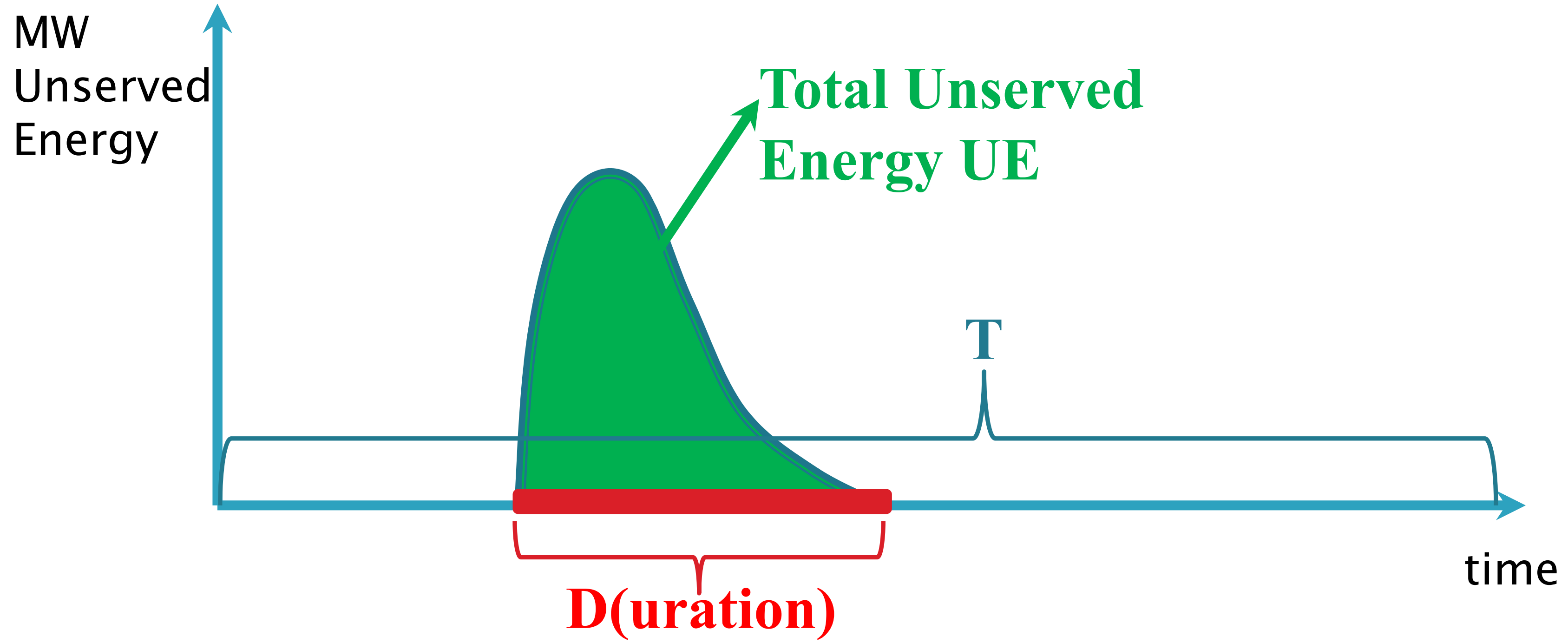
Engineer's Definition of Reliability & Resilience

(Billinton & Allan, *Reliability Analysis of Engineered Systems*)



- Reliability = P(UE>0) = 1−(**D**/**T**)
- Severity = **UE**/**T**
- Resilience = 1/**D**

Probabilistic Definition of Reliability & Resilience

(Billinton & Allan)

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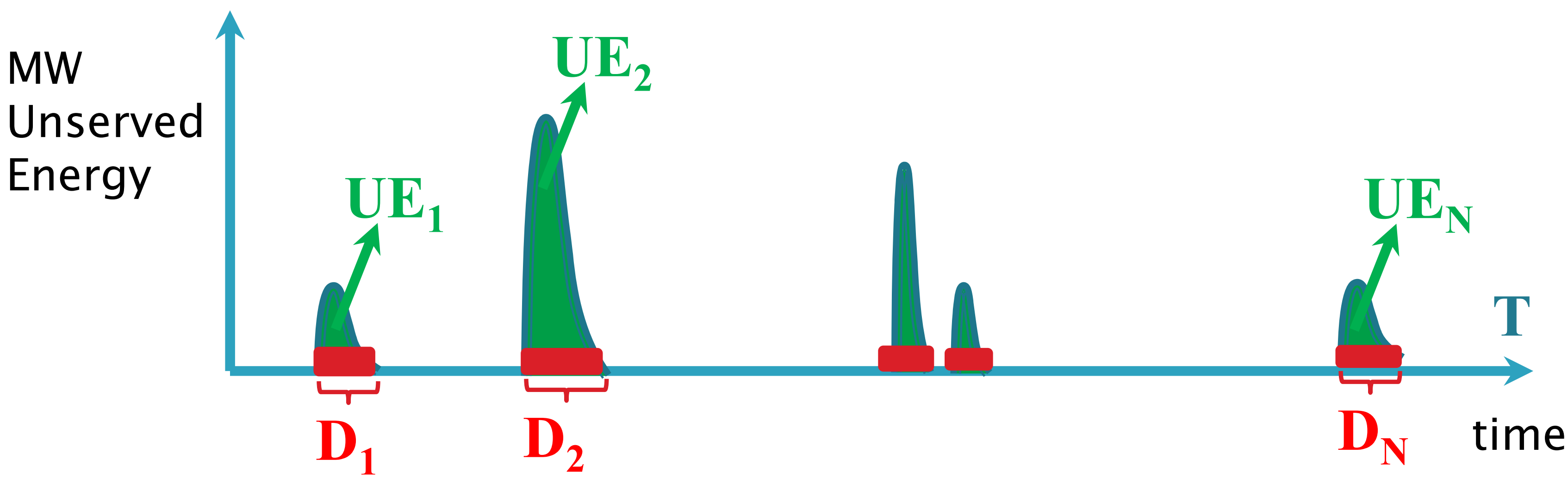
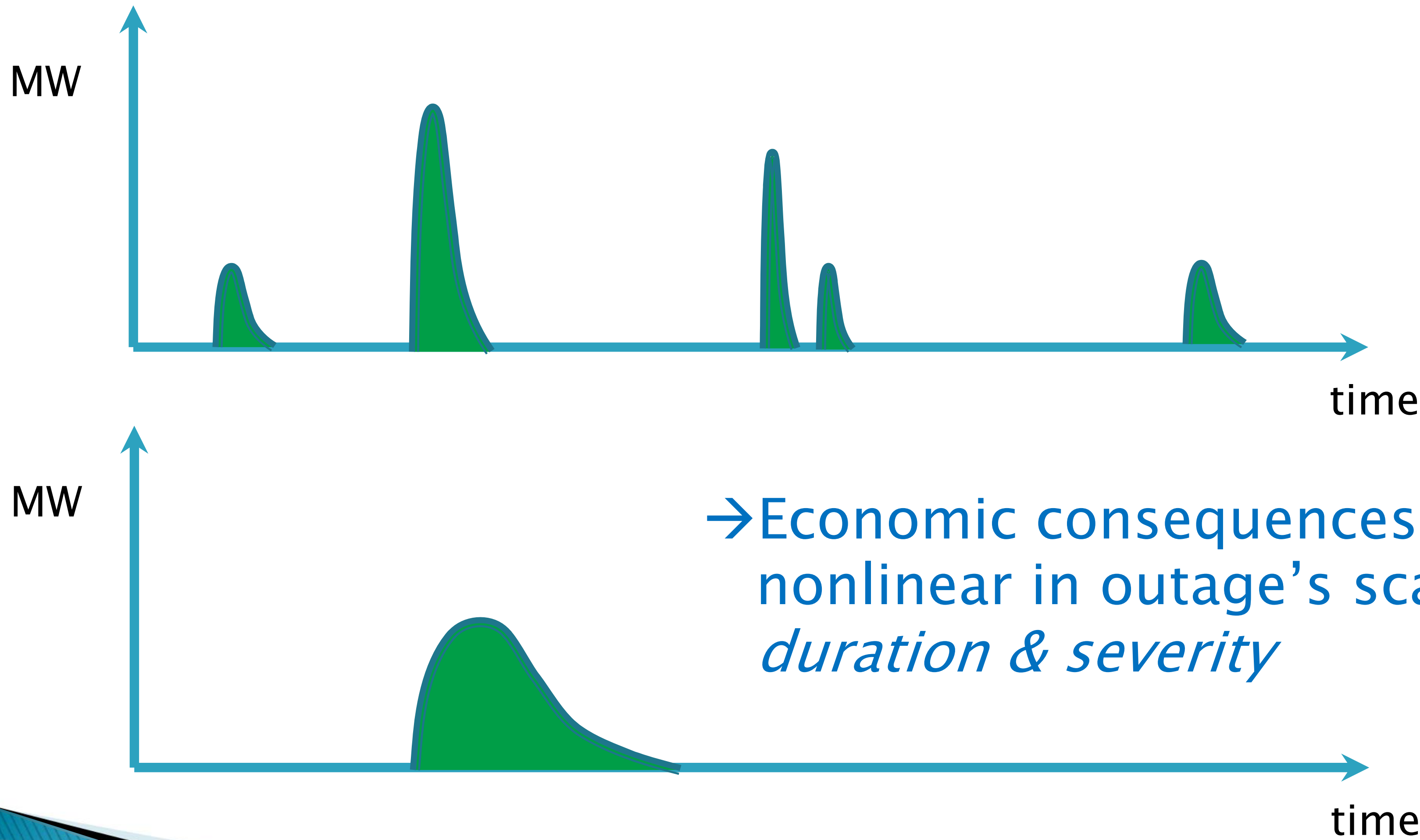


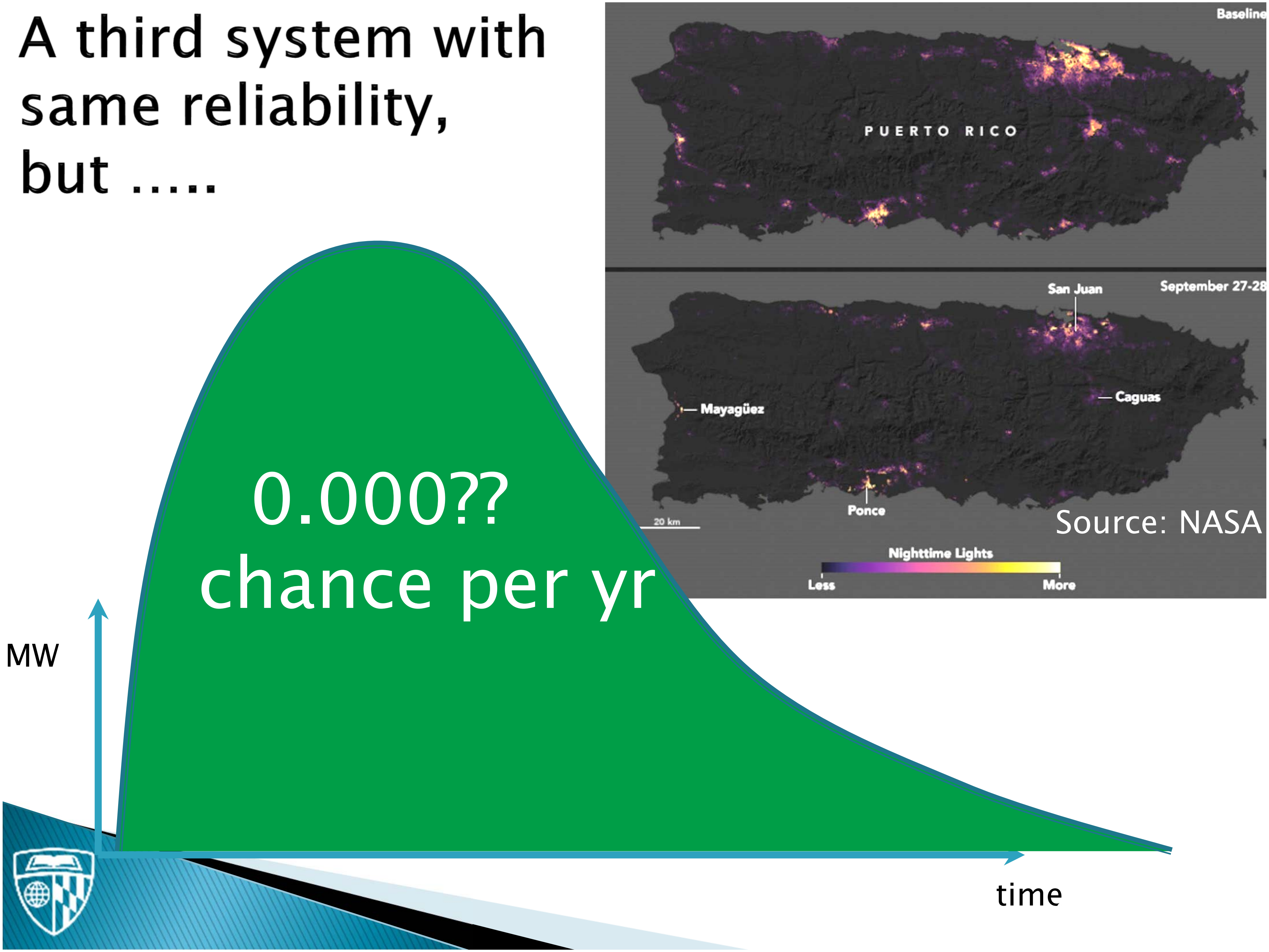
- Reliability = P(UE>0) = $1-(\Sigma_i D_i/T)$
- Severity = $\Sigma_i UE_i/T$
- Frequency (sometimes called LOLP) = N/T
- Average Resilience = 1 / (Average D_i)

Two Systems with *Same* Reliability, *Differing* Resilience



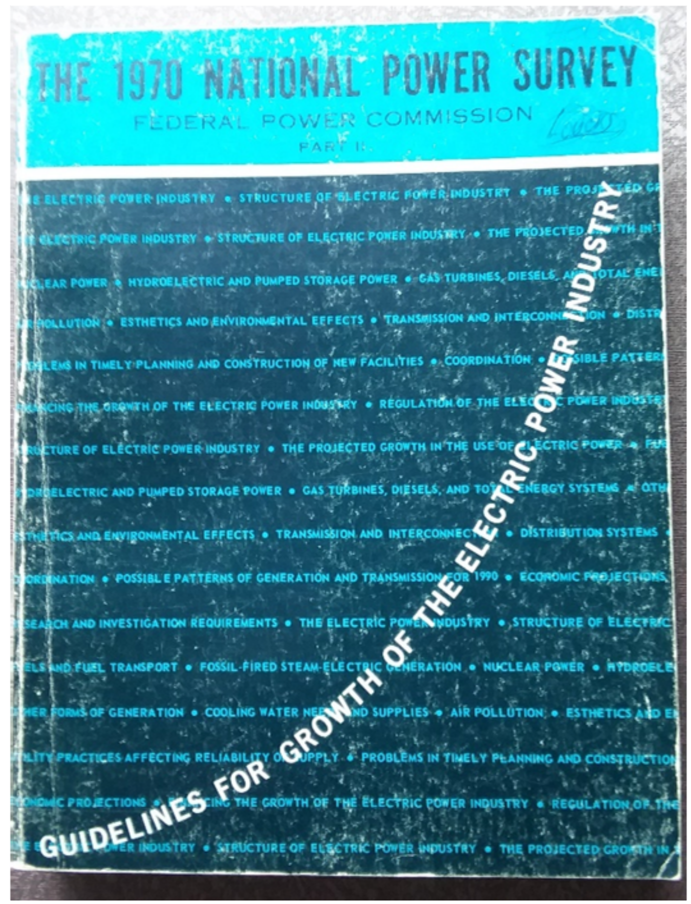
→Economic consequences are nonlinear in outage's scale: *duration & severity*

A third system with same reliability, but …..



Classical Generator Adequacy under Independent Events

- Assume:
  - Generator outages are random ..
  - ..and (conditionally) independent of each other and of load
- Classic engineering methods:
  - LOLP, EUE by convolution methods
    (Calabrese; Billinton/Allan)
- Time to give those methods a gold watch: need to deal with:
  - *operating complexities*
  - *correlated, common-mode failures*
    - "When sorrows come, they come not single spies. But in battalions." (King Claudius, Hamlet Act 4 Scene 5)



Redefining Resource Adequacy for Modern Power Systems

Future Power Markets Forum | 6/3/2021

TELOS ENERGY

Acknowledgements

This project is supported by the Energy Systems Integration Group (ESIG), as part of the **Redefining Resource Adequacy Task Force.** The contents of this presentation are solely the responsibility of the authors and do not necessarily represent the official views of ESIG or its members

The Redefining Resource Adequacy Task Force is collaborating closely with a project team made up of industry experts:

Aaron Bloom, Gord Stephen, **Wesley Cole**, **Armando Figueroa Acevedo, Chris Dent,** and **Aidan Touhy**.

I would like to acknowledge their valuable input and support regarding these First Principles and concepts.

Resource adequacy making the headlines

The California Event, August 2020

"There doesn't have to be a tradeoff between reliability and decarbonization... What caused the [August blackouts] was a lack of putting all the pieces together... You have to **rethink these old ways of doing things**, and I think that's what didn't happen."

"The resource adequacy program in California is now not matched up with the realities of working through a renewable-based system, and in a nutshell ... needs to be redesigned,"

-Steve Berberich, CAISO

Source: S&P Global, You have to rethink these old ways: Parting advice from CAISO's retiring CEO, September 25, 2020

Why is Resource Adequacy Broken?

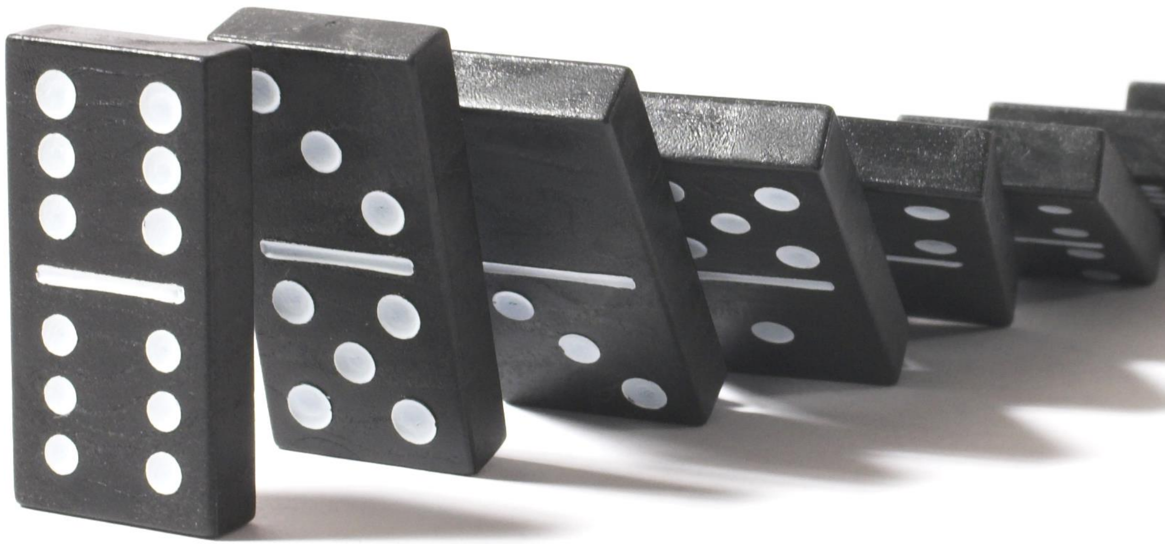
CHRONOLOGY + CORRELATION

CHRONOLOGY

- ✓ Variable Renewables
- ✓ Energy Storage
- ✓ Load Flexibility
- ✓ Hybrid resources

CORRELATION

- ✓ Weather
- ✓ Combined Outages
- ✓ Modular Technology
- ✓ Climate Trends



= fundamental need to rethink RA

Six principles of resource adequacy for modern power systems

1. Quantifying size, frequency and duration of outages is critical to finding the right resource solutions.
2. There is no such thing as perfect capacity.
3. Modeling chronological operations is essential for modern power systems.
4. Load participation fundamentally changes the resource adequacy construct.
5. Neighboring grids and transmission are a key part of the RA challenge
6. Reliability criterion should not be arbitrary, but transparent and economic.

Resource adequacy criteria are simply a "line in the sand"

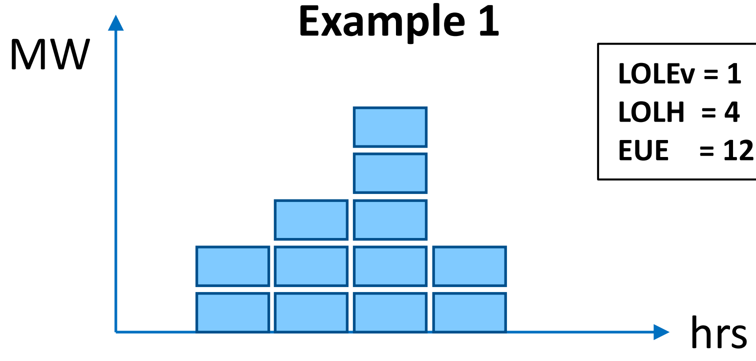
- 1 day in 10 years LOLE is arbitrary
- Criterion need to include an economic or financial consideration of reliability
- Grid planners and regulators should have a clear understanding of the costs associated with achieving reliability targets.

1

Quantifying size, frequency and duration of outages is critical to finding the right resource solutions

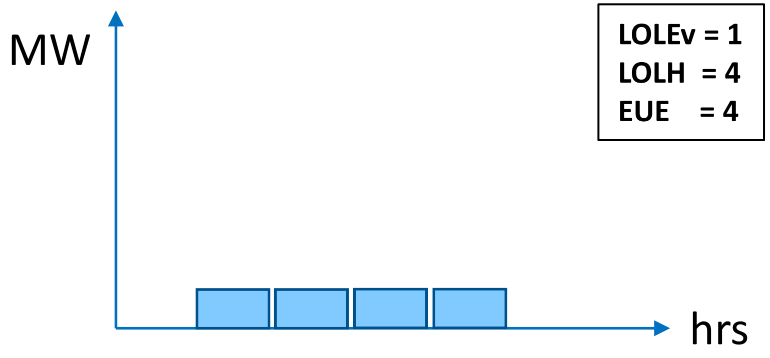
Same LOLEv and LOLH, but very different events

Example 1



LOLEv = 1
LOLH = 4
EUE = 12

Max MW = 5
Max MWh = 12
Duration = 4

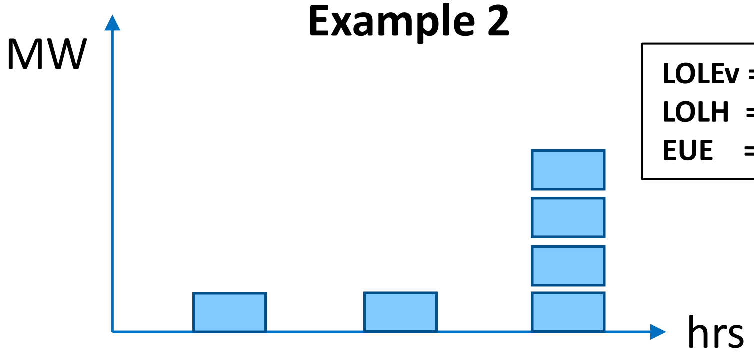


LOLEv = 1
LOLH = 4
EUE = 4

Max MW = 1
Max MWh = 4
Duration = 4

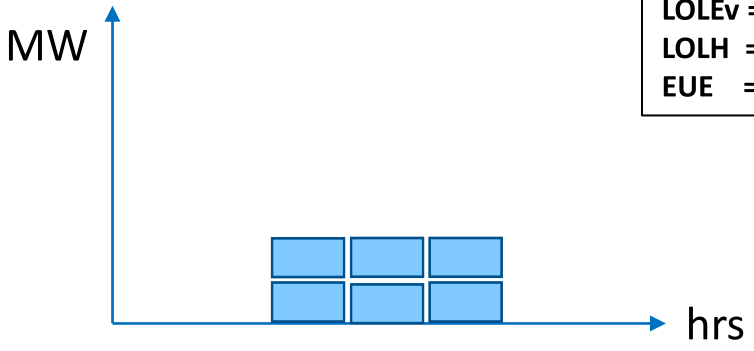
Same LOLH and EUE, but very different events

Example 2



LOLEv = 3
LOLH = 3
EUE = 6

Max MW = 4
Max MWh = 2
Duration = 1



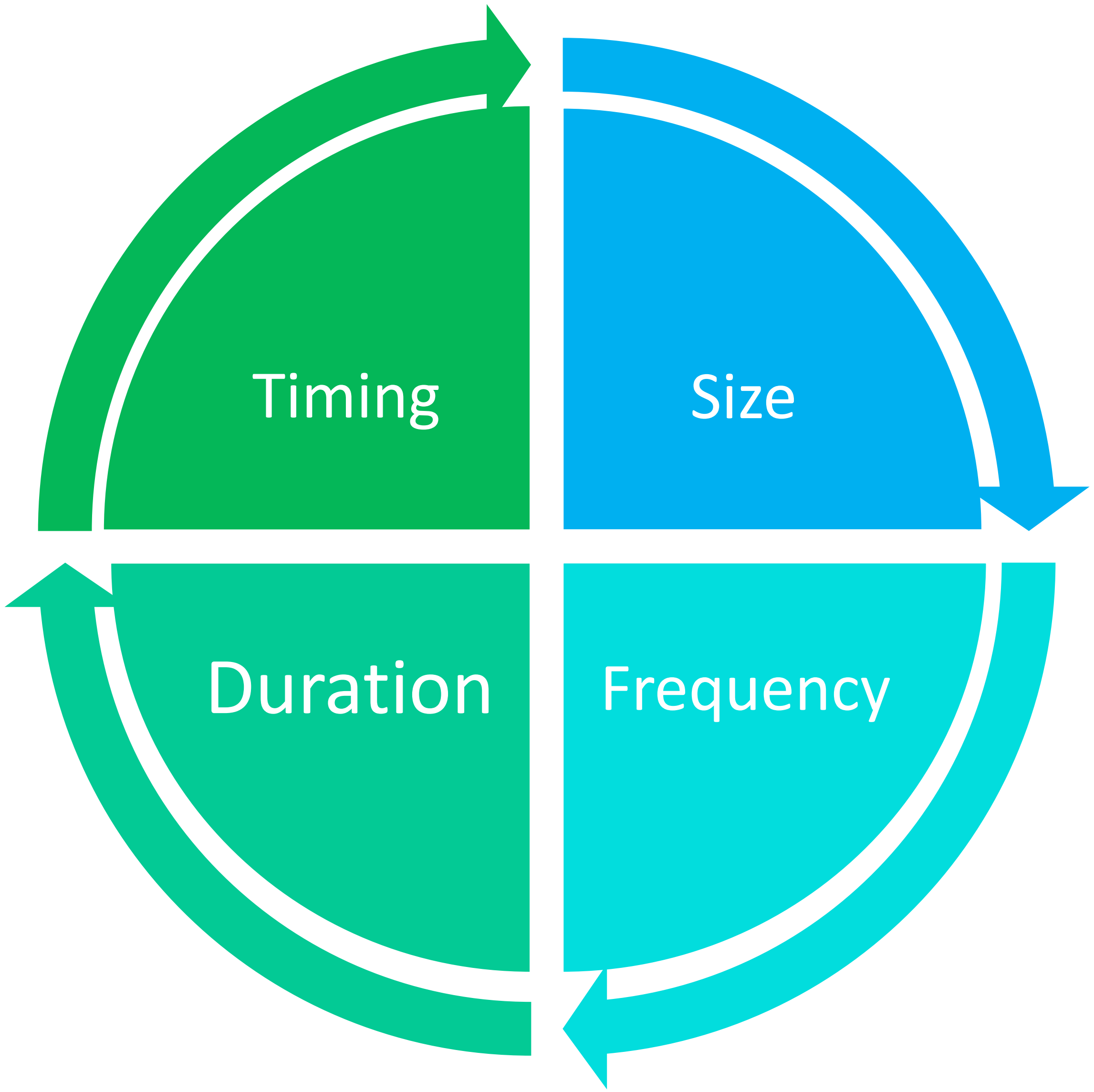
LOLEv = 1
LOLH = 3
EUE = 6

Max MW = 2
Max MWh = 6
Duration = 3

New & multiple metrics can better select and size appropriate mitigations (DR & BESS vs. thermal capacity)

Our metrics need to go further!

1. Place more emphasis on Expected Unserved Energy
2. Use a suite of reliability metrics, not just one
3. Move beyond expected values and consider tail events
4. Characterize size, frequency, duration, and timing of shortfall events



DER and storage can provide both power (MW) and energy (MWh) … how much is needed of each?

Larger Power Shortfalls (MW) →

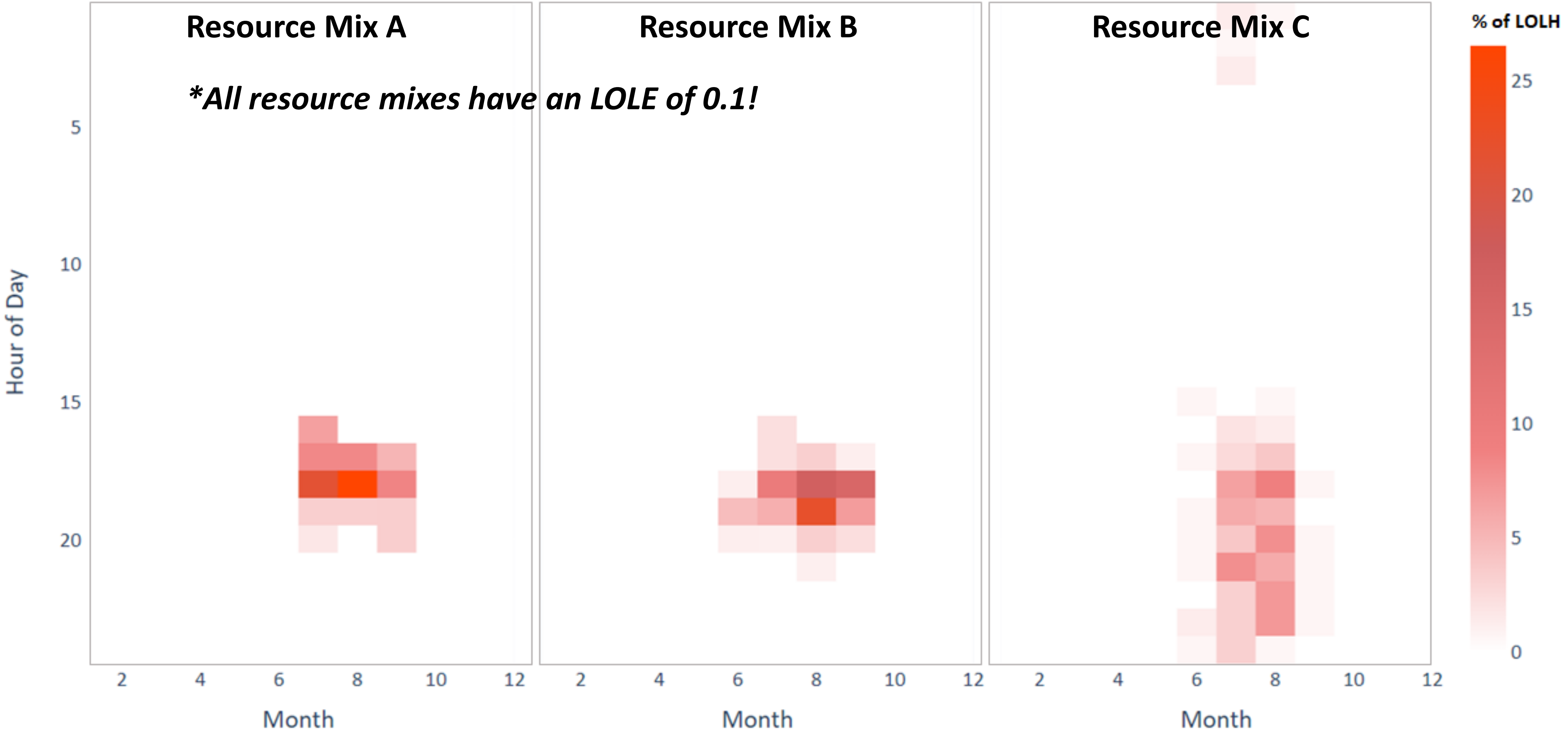
Larger Energy Shortfalls (MWh) ↓

Energy (MWh)	Max Size (MW) 10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	>=200	Total
20	19.9%	14.4%	5.31%																		39.6%
40		0.70%	6.02%	6.11%	1.41%																14.2%
60			0.61%	2.34%	3.90%	1.60%	0.26%														8.7%
80			0.03%	0.58%	1.89%	2.18%	1.41%	0.16%													6.2%
100			0.03%	0.06%	0.64%	1.63%	1.66%	0.90%	0.06%	0.13%	0.06%										5.2%
120					0.06%	0.42%	1.12%	1.47%	0.67%	0.16%	0.10%	0.03%									4.0%
140							0.51%	1.02%	0.74%	0.35%	0.06%										2.7%
160						0.06%	0.32%	0.80%	0.42%	0.48%	0.19%	0.03%	0.03%								2.3%
180					0.03%		0.10%	0.35%	0.38%	0.42%	0.32%	0.06%	0.06%								1.7%
200							0.10%	0.29%	0.42%	0.51%	0.42%	0.32%	0.06%	0.03%	0.03%						2.2%
220						0.03%		0.06%	0.42%	0.16%	0.35%	0.26%	0.10%	0.03%							1.4%
240								0.06%	0.10%	0.16%	0.16%	0.29%	0.19%								1.0%
260								0.06%	0.03%	0.19%	0.35%	0.16%	0.29%	0.10%	0.19%		0.03%				1.4%
280							0.03%	0.03%	0.03%	0.03%	0.19%	0.19%	0.22%	0.10%	0.19%		0.03%				1.1%
300								0.03%		0.03%	0.16%	0.13%	0.13%	0.10%	0.03%						0.6%
320										0.10%	0.06%	0.06%	0.22%	0.10%	0.16%			0.03%			0.7%
340											0.03%	0.03%	0.16%	0.06%	0.16%	0.03%					0.5%
360											0.03%	0.10%	0.19%	0.06%	0.29%	0.03%	0.06%				0.8%
380												0.06%	0.03%	0.06%	0.13%	0.13%	0.16%				0.6%
400												0.06%	0.03%	0.16%		0.10%	0.06%	0.06%			0.5%
>400											0.16%	0.10%	0.22%	0.16%	0.35%	0.74%	0.32%	0.51%	0.42%	1.60%	4.6%
Total	19.9%	15.1%	12.0%	9.1%	7.9%	5.9%	5.5%	5.2%	3.3%	2.7%	2.7%	1.9%	2.0%	1.0%	1.5%	1.0%	0.7%	0.6%	0.4%	1.6%	100%

70% of events covered by 60 MW 2HR resource

85% of events covered by 100 MW 2HR resource

Seasonal and Time of Day Risk is Uneven, useful information for identifying mitigations



Thank You!

Questions?

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Want to get involved in the ESIG Redefining Resource Adequacy Task Force? Reach Out!

Future of Resource Adequacy

Future Power Markets Forum

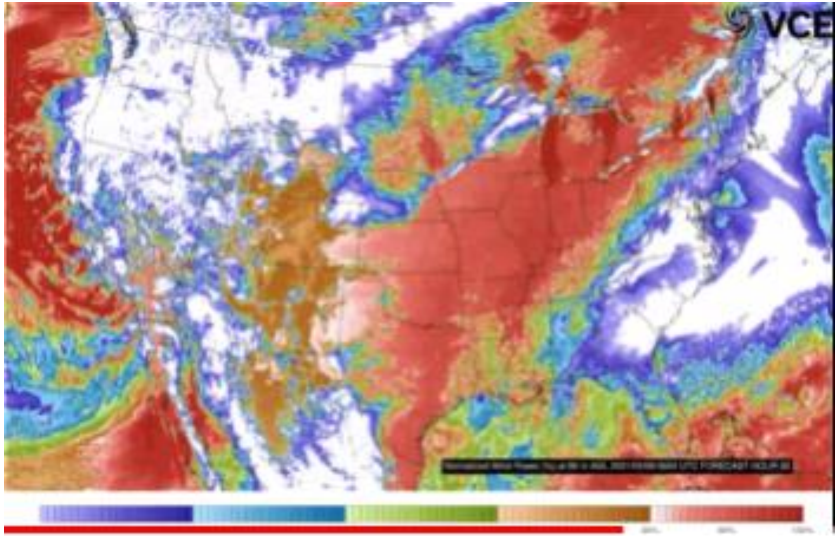
June 3, 2021

Redefinition of resource adequacy is needed due to the growing interconnectedness of the power system

- *Disclaimer: The views expressed are my own and not necessarily those of MISO*
- Resource Adequacy transformation is needed due to:
  - Increasingly coupled relationship of generator availability
  - Maximizing geographic diversity leading to increased deliverability challenges
  - Divergence of Resource Adequacy metrics from reliable outcomes

Renewable output and extreme temperature can be highly correlated across wide areas

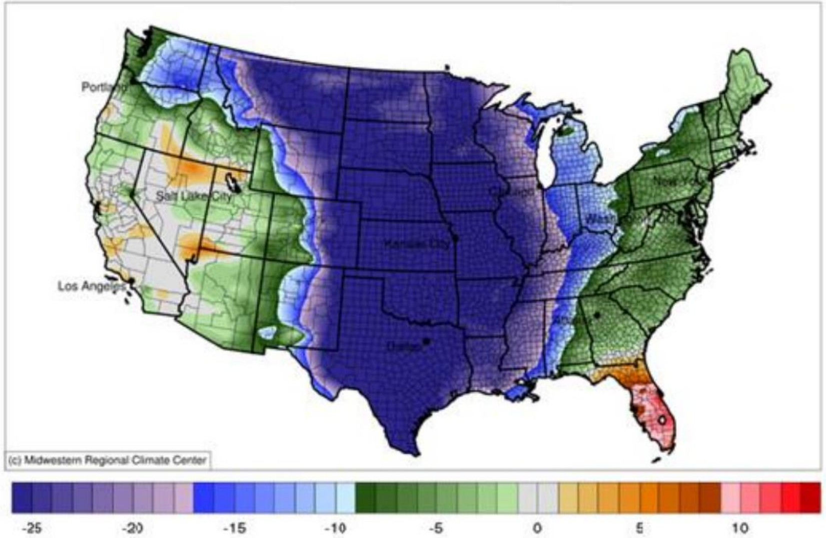
Wind Power Potential March 9, 2021
(Normalized wind power %)



Vibrant Clean Energy
https://www.youtube.com/watch?v=7RDrWOIUEHY

Average Temperature (°F): Departure from 1981-2010 Normals

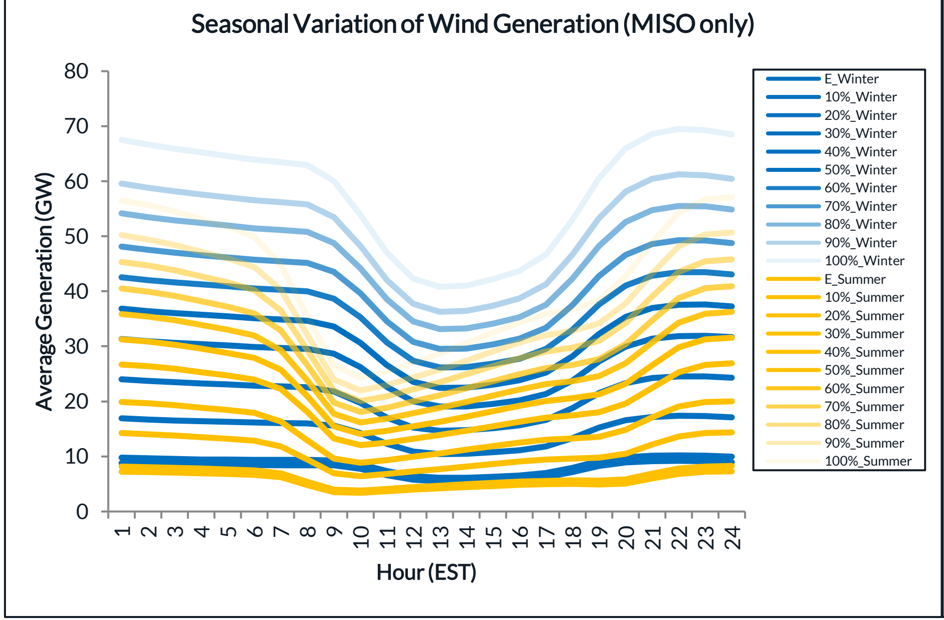
February 12, 2021 to February 18, 2021



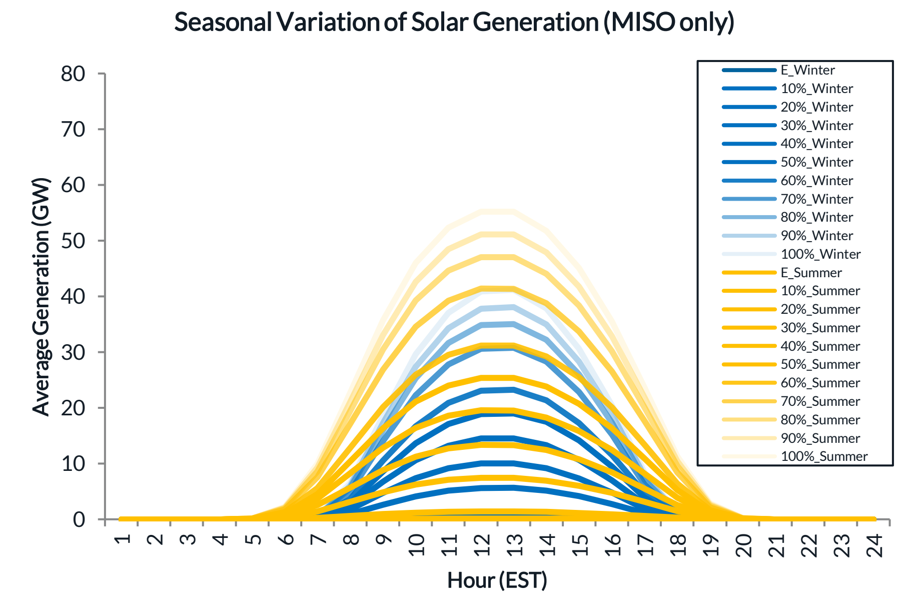
Stations from the following networks used: FAA, ICAO,
Midwestern Regional Climate Center
cli-MATE: MRCC Application Tools Environment

Availability of wind and solar is highly variable over time

Wind



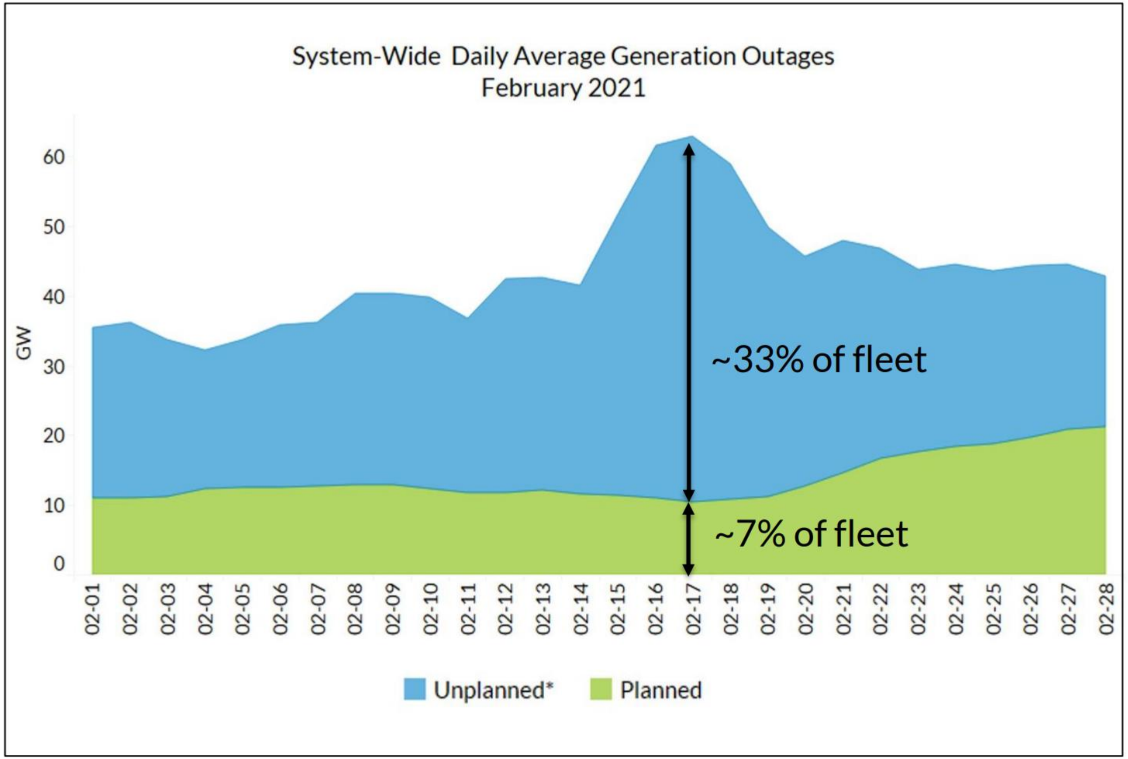
Solar

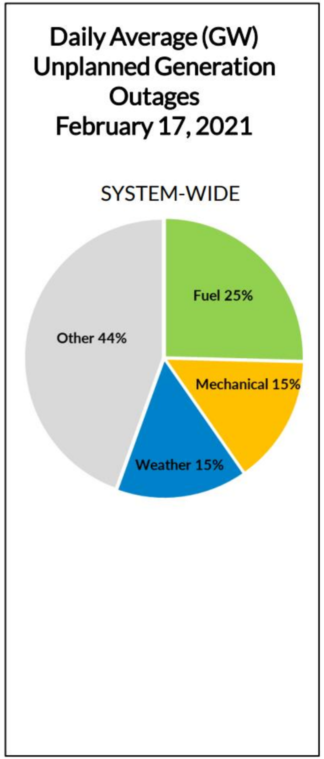


**Profile shapes represent seasonal hourly averages across the 6 study years.*
**Summer includes May, June, July, and August; Winter includes January, February, November, and December*

Renewable data from this presentation from the MISO Renewable Integration Impact Assessment (RIIA)
https://www.misoenergy.org/planning/policy-studies/Renewable-integration-impact-assessment/#nt=%2Friiatype%3AReport&t=10&p=0&s=Updated&sd=desc

Wide area low temperatures led to large deviations in expected generator outages



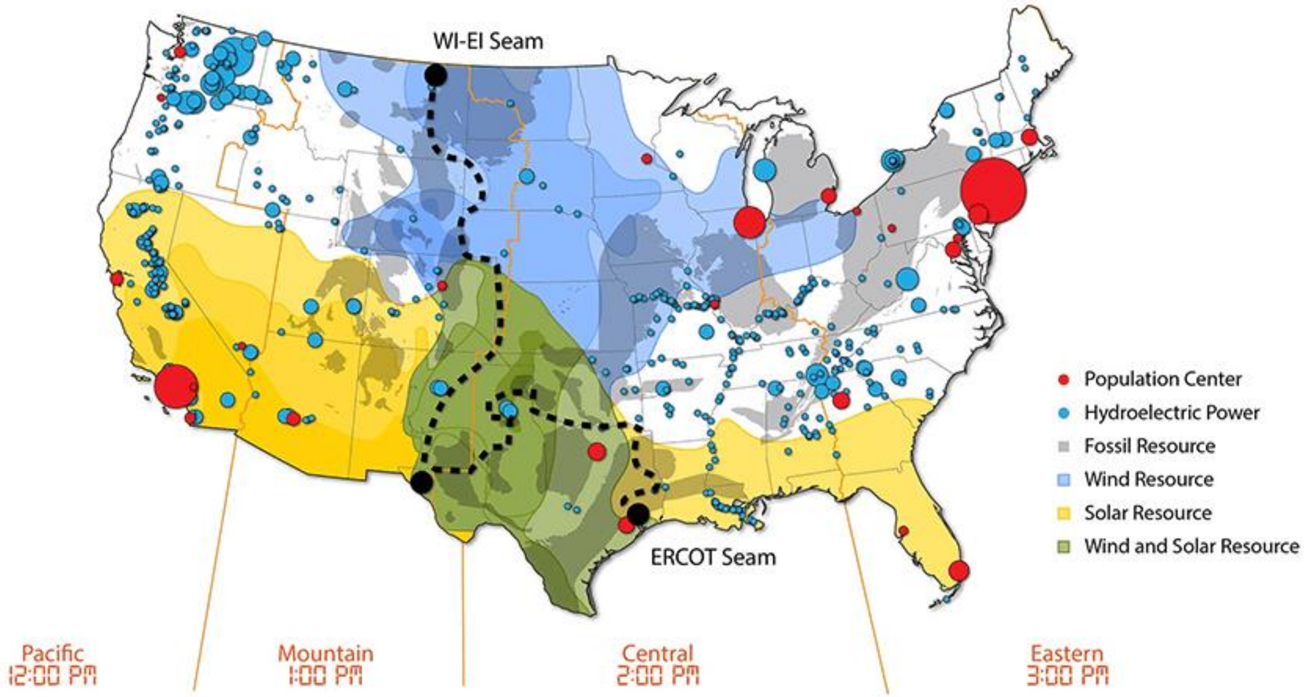


*Unplanned includes forced outages and derates
Data as of March 1, 2021 in CROW Outage system

MISO 2021 Arctic Event discussion
https://cdn.misoenergy.org/20210311%20MSC%20Item%2004%20Max%20Gen%20Feb%2015530356.pdf

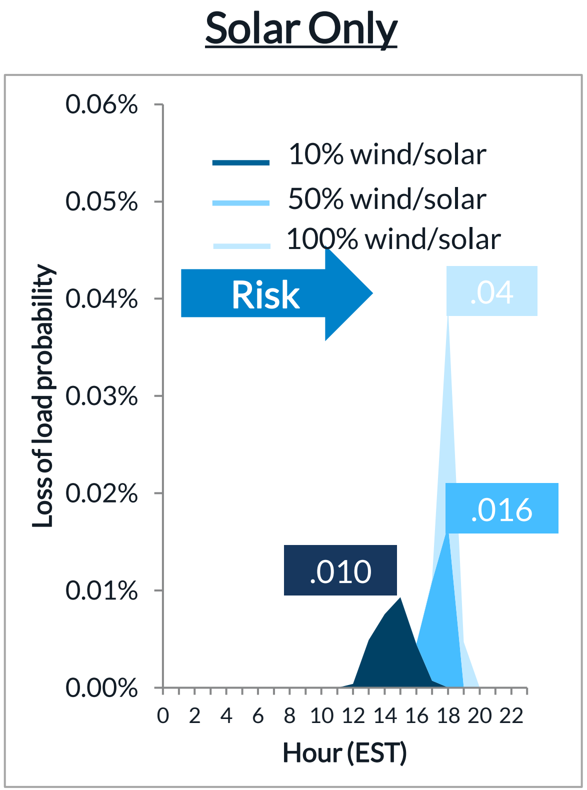
MISO 2021 Arctic Event Report
https://cdn.misoenergy.org/2021%20Arctic%20Event%20Report554429.pdf

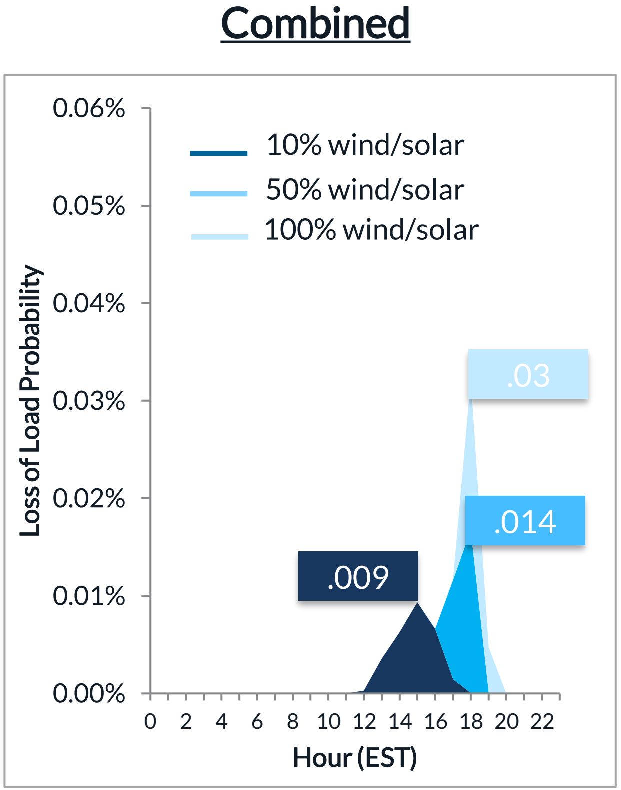
Available production of wind and solar resources are geographically constrained

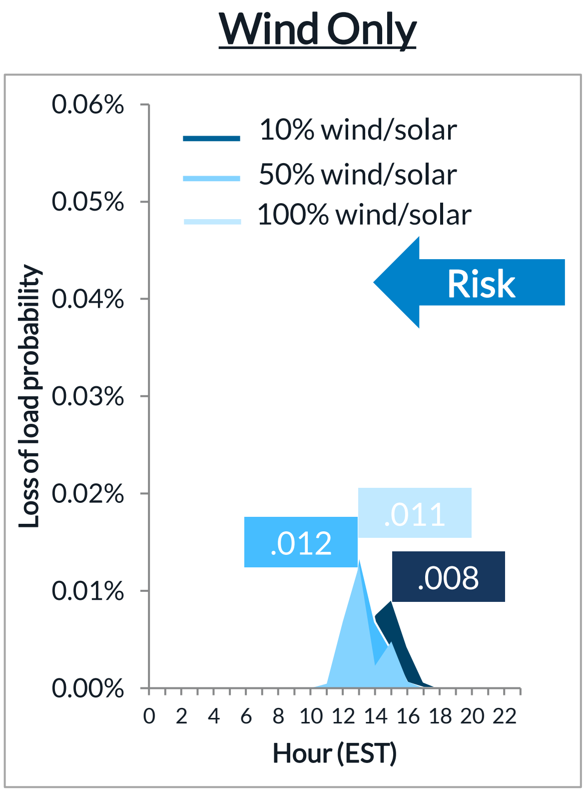


https://www.nrel.gov/analysis/seams.html

The combination of wind and solar decreases the probability of not serving load during periods of high risk

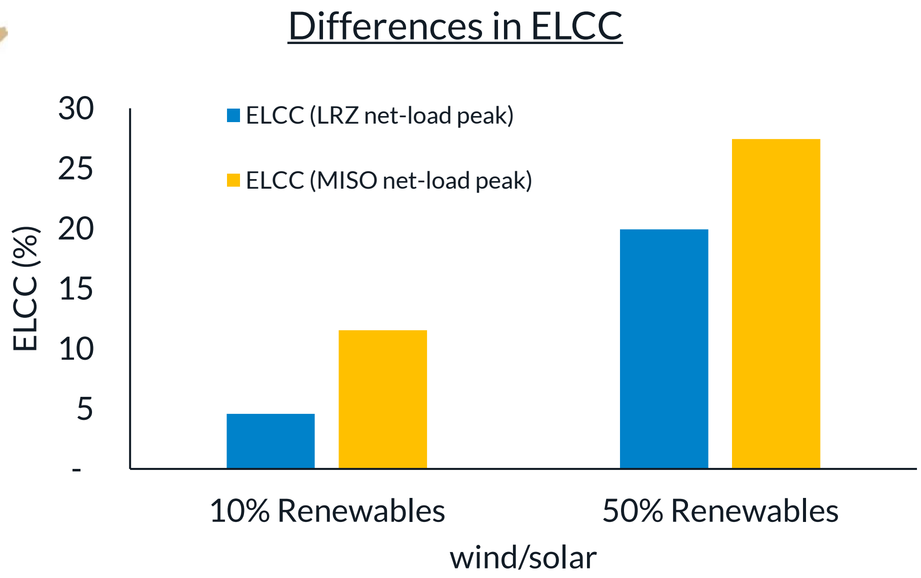






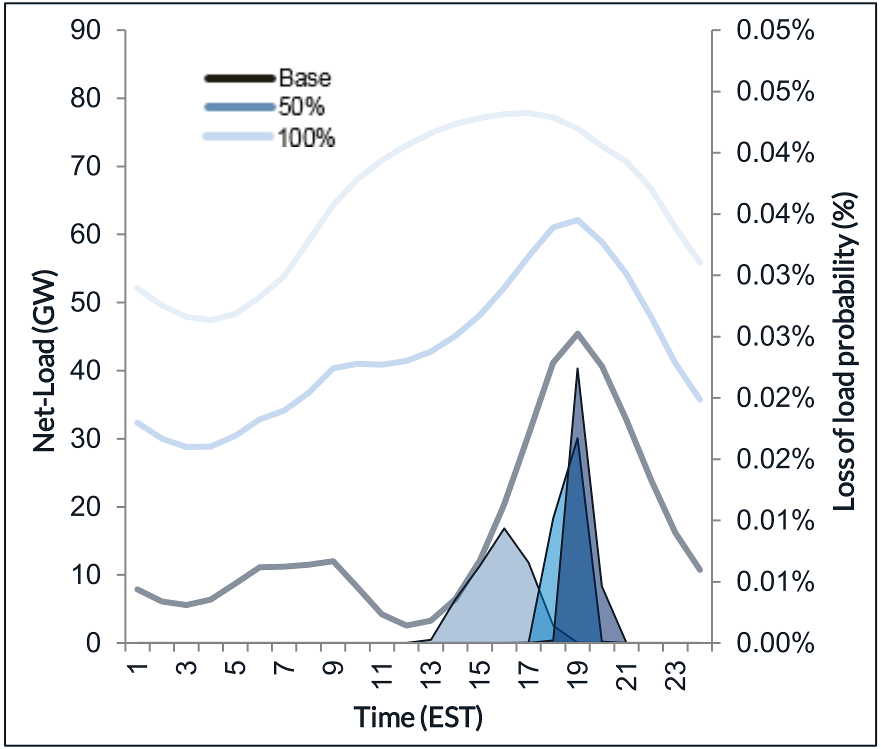
Renewable performance is significantly greater over larger geographic regions

Local Resource Zone	Local Balancing Authorities
1	DPC, GRE, MDU, MP, NSP, OTP, SMP
2	ALTE, MGE, MIUP, UPPC, WEC, WPS
3	ALTW, MEC, MPW
4	AMIL, CWLP, SIPC
5	AMMO, CWLD
6	BREC, CIN, HE, IPL, NIPSCO, SIGE
7	CONS, DECO
8	EAI
9	CLEC, EES, LAFA, LAGN, LEPA
10	EMBA, SME



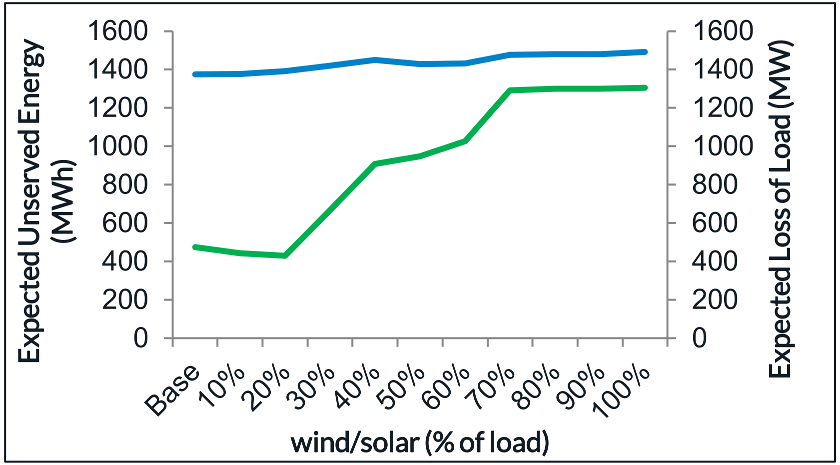
ELCC (LRZ net-load peak) represents the summation of ELCC (in MWs) from all 10 LRZs. Each LRZ was simulated as an isolated area.

As a result of the risk shift, the expected demand not served becomes a short-duration event with higher magnitude



Expected Loss of Load: It is determined by taking the total area where the demand is greater than the installed capacity.

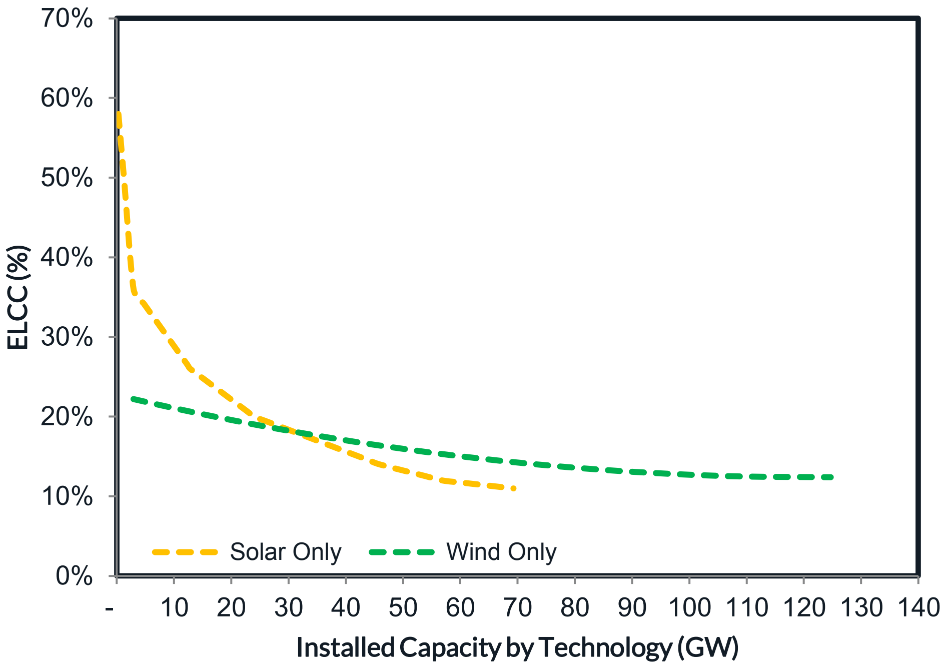
Expected Unserved Energy (EUE): It is the total amount of time multiplied by the expected demand not served.



RA indexes converge as renewable penetration increases

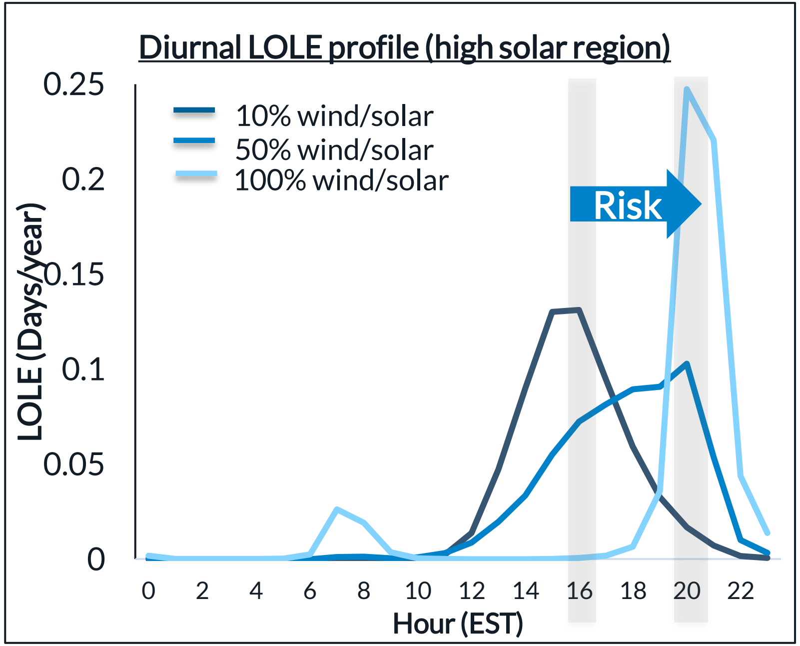
As a result of the shift in risk of losing load, the available energy from wind and solar during high-risk hours decreases

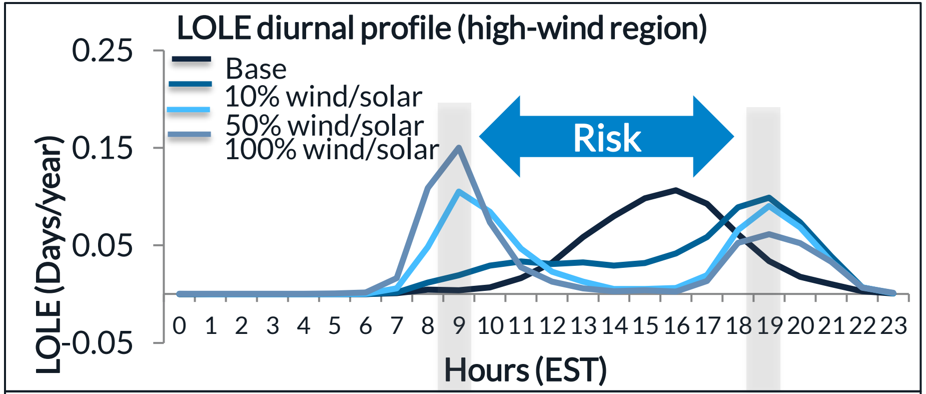
- As penetration levels increase and the net peak load timing shifts:
  - ELCC* for wind decreases slightly
  - ELCC for solar sees a steeper drop-off
- These values are reflective of average ELCC calculated separately for wind and solar to isolate the impacts of each technology.
- Values between wind/solar were interpolated

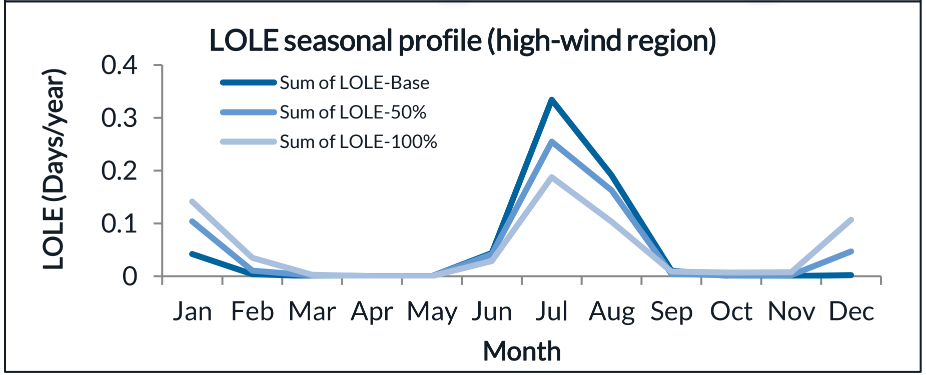


**Effective Load Carrying Capability (ELCC) is a measure of the additional load that the system can supply with the particular generator of interest, with no net change in reliability.*

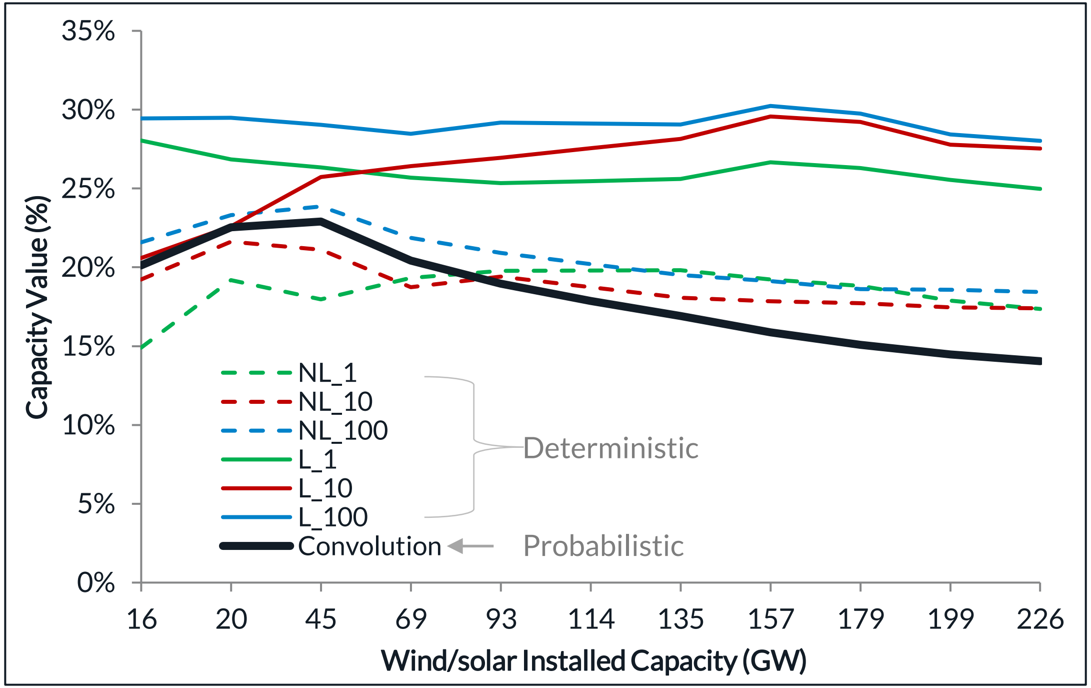
Wind and solar drive very different resource adequacy outcomes





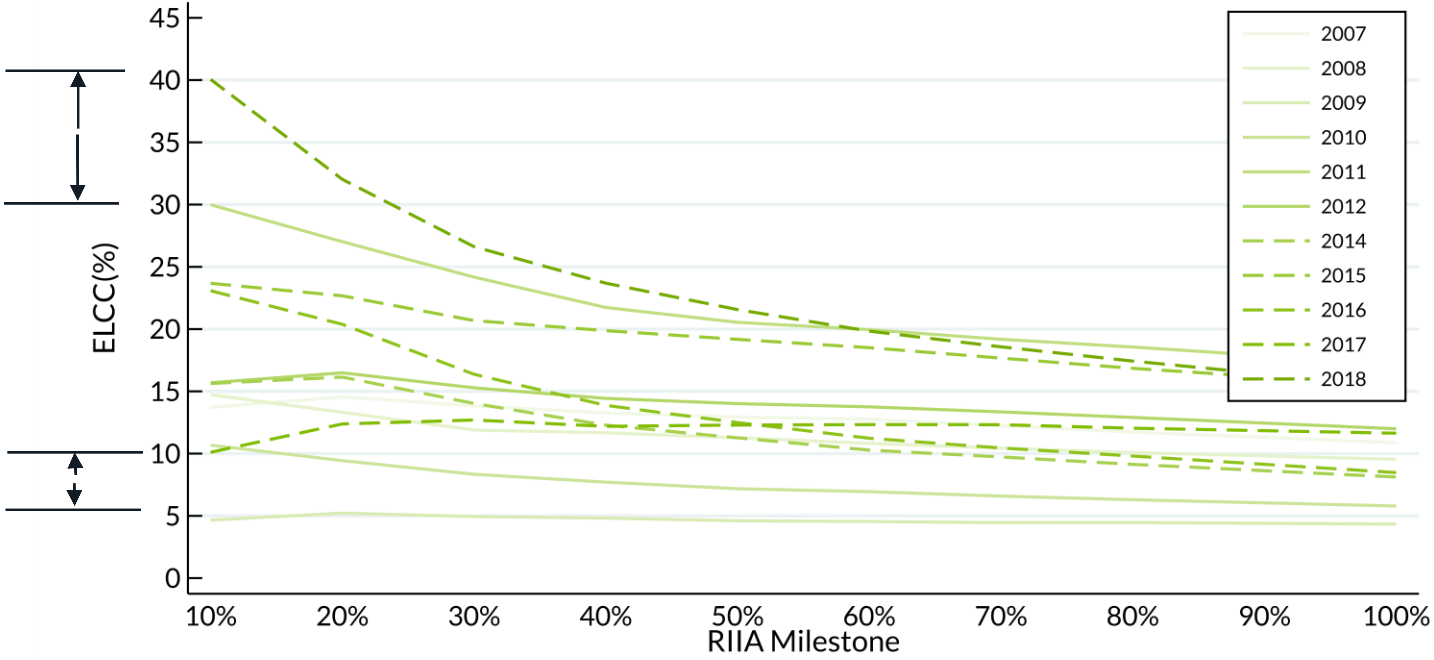


Deterministic and probabilistic (ELCC) approaches produce different capacity values



Deterministic Methods	Total number of samples averaged across all years
Peak Load (L_1)	Top 1 (peak load)
Peak Net Load (NL_1)	Top 1 (net peak load)
Peak Load (L_10)	Top 10 (peak load)
Peak Net Load (NL_10)	Top 10 (net peak load)
Peak Load (L_100)	Top 100 (peak load)
Peak Net Load (NL_100)	Top 100 (net peak load)

The additional number of weather years expands the upper bounds of wind's ELCC



Resource adequacy needs to become more locational, coordinated and comprehensive

- Resource adequacy analysis and requirements should
  - explicitly include locational constraints over all risk periods
  - be coordinated across connected areas of an interconnected system
  - be forecasted in detail into the future to inform resource planning
  - include as much weather data as possible to capture extreme periods, and forecast climate related future changes
  - be calculated based on comprehensive analysis of all hours and correlated events
  - be based on metrics that capture the timing and magnitude of risk and be consistently used across different planning areas (Example: Normalized Expected Unserved Energy NEUE)

Questions?

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Questions

1. Considering February's Texas events, can we quantify resource adequacy metrics and translate them into market concepts in ways that will mitigate future events?

2. Compare CAISO in August and ERCOT in Feb: what is the role of probabilistic adequacy metrics in understanding system preparedness, and what other tools are needed?

3. Historically, planning reserve margin was easy to understand & communicate-- how do we balance the need for transparency in adequacy criteria and market mechanisms, and the increased complexity of power system threats and vulnerability?

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