Redefining Resource Adequacy for Modern Power Systems

NARUC Training Session | 5/6/2021

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Acknowledgements

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

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

I would like to acknowledge their valuable input and support regarding these First Principles and the forthcoming modeling efforts.

Agenda

- Lessons Learned the California and Texas events
- Two driving factors requiring us to rethink resource adequacy
- Six first principles for resource adequacy for modern power systems
- Four recommendations for improved use of RA metrics

Objective

Frame the issues on why a decarbonizing energy mix changes the way we need to think about resource adequacy…

… I can't provide the answers, but hopefully can help you ask the right questions

Resource adequacy making the headlines

What happened in California and Texas?

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The California Case Study

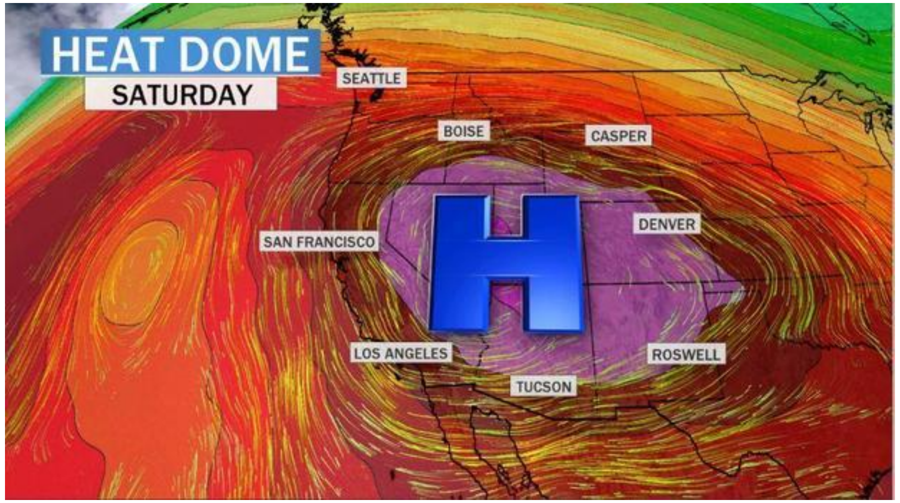
"There doesn't have to be a tradeoff between reliability and decarbonization… What caused the [August blackouts] was a lack of putting all the pieces together... You have to **rethink these old ways of doing things**, and I think that's what didn't happen."

"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

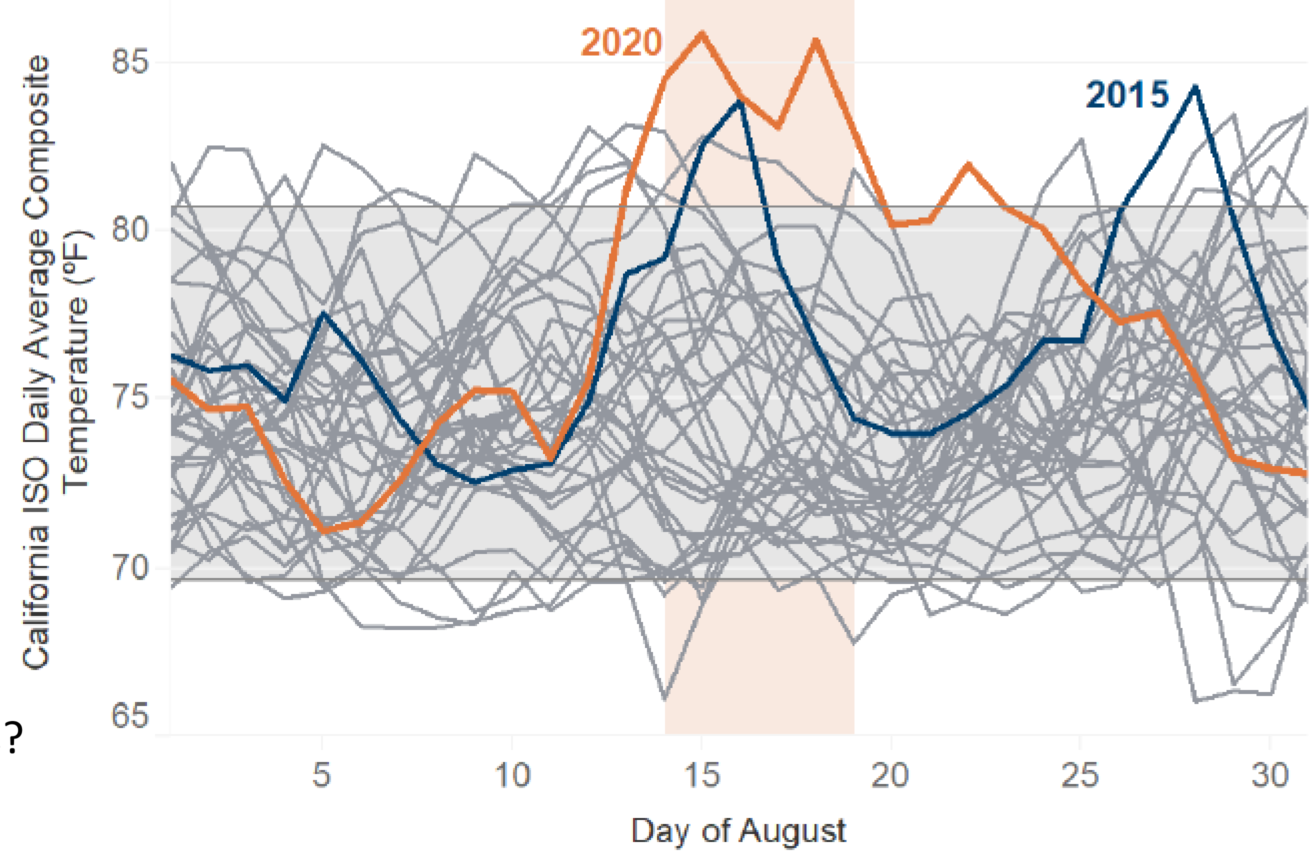
Source: S&P Global, You have to rethink these old ways: Parting advice from CAISO's retiring CEO, September 25, 2020

What Happened in California?



- Record breaking temperatures across the West
- *Regional* event… entire West was challenged
- Is a 1-in-30 year event reasonable to plan for?
- Should RA analysis take into account climate trends?
- Should we design our grid to withstand a 1-in-30 year event?

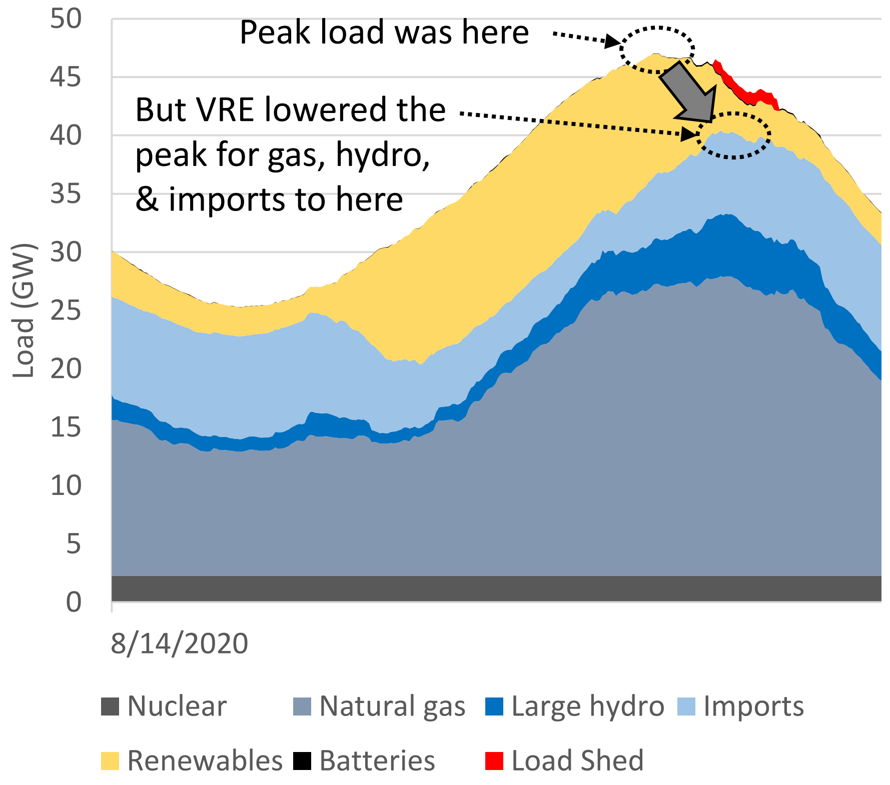
A 1-in-30 year event?



Source: CEC Weather Data/CEC Analysis, reported in CAISO Preliminary Root Cause Analysis

What Happened in California?

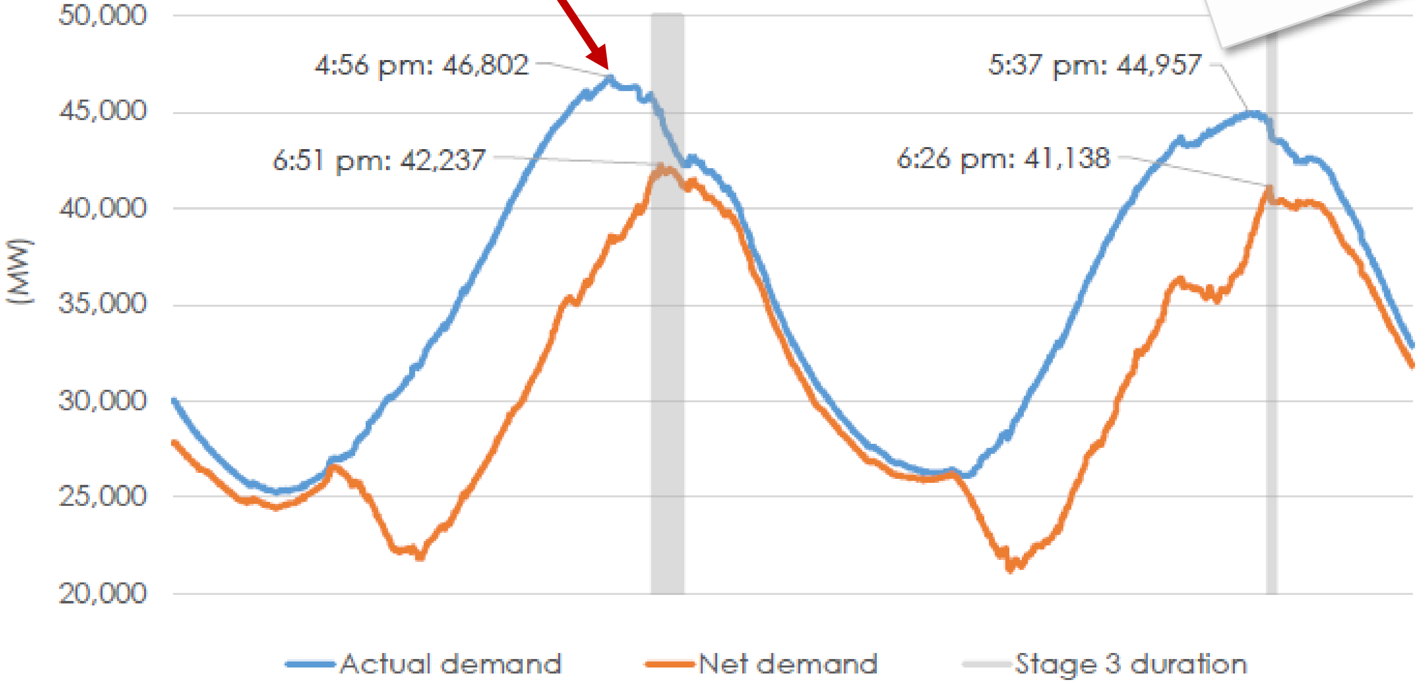
Preliminary Root Cause Analysis
Mid-August 2020 Heat Storm
October 6, 2020



Peak load was here

But VRE lowered the peak for gas, hydro, & imports to here

California's Planning Reserve Margin (115%) is based off of this peak



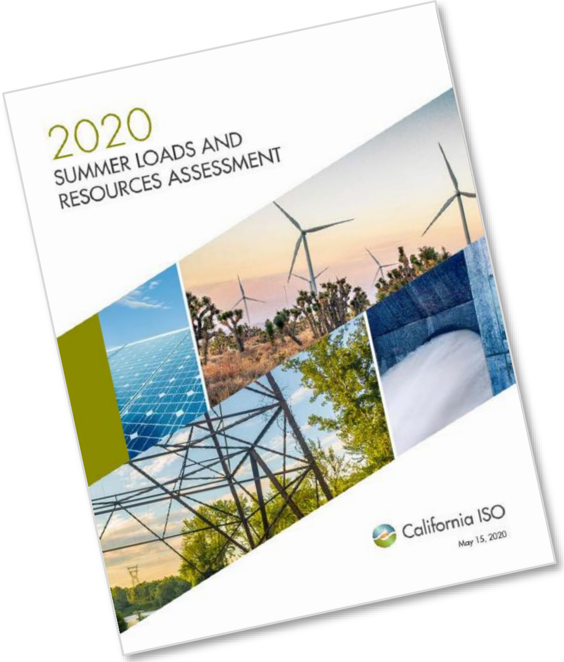
Source: CAISO Preliminary Root Cause Analysis

Growing disconnect between planning reserve margin and reliability… all hours, multiple weather years and chronological operations matter

What Happened…
Could this have been predicted?

“ The base case results show that the CAISO has a low probability of experiencing operating conditions that would lead to shedding firm load in summer 2020. However, if summer conditions are less favorable, resulting in **lower levels of imports as assumed** in the sensitivity case, the probability of shedding firm load will increase. The risk in 2020 primarily stems from less than average hydro conditions resulting in reduced energy from hydro resources across the summer, but particularly **impactful in late summer**. Furthermore, the CAISO daily peak period has shifted to **later in the day when solar generation is near or at zero levels,** resulting in the CAISO’s highest demand levels being supplied by the remaining non-solar fleet. With lower than normal hydro conditions, the CAISO may have to rely more heavily on imports from neighboring BAs during the CAISO summer peak hours. However, **if a heat wave occurs that impacts a broader area than the CAISO, the availability of surplus energy to import into the CAISO could be diminished**. ”

-CAISO Summer Loads and Resource Assessment, **May 15, 2020**



What can we learn from California?

PV and wind output was ~10 GW during peak load

- lowered and shortened the peak
- provided capacity value, things could have been much worse

ELCC correctly quantifies the ***average*** amount of risk PV avoids, but average doesn't matter

- For example, if PV has a 50% ELCC, we know for certain that it will provide 0% of its capacity at 9 PM
- Planning reserve margin method completely misses this obvious point!

ELCC is useful for showing the average capacity value of a resource. Good for capacity accreditation ($$$), but cannot be relied on in isolation for system planning

Planning Reserve Margin requires planners to know the time periods of system stress and likelihood of VRE to be available

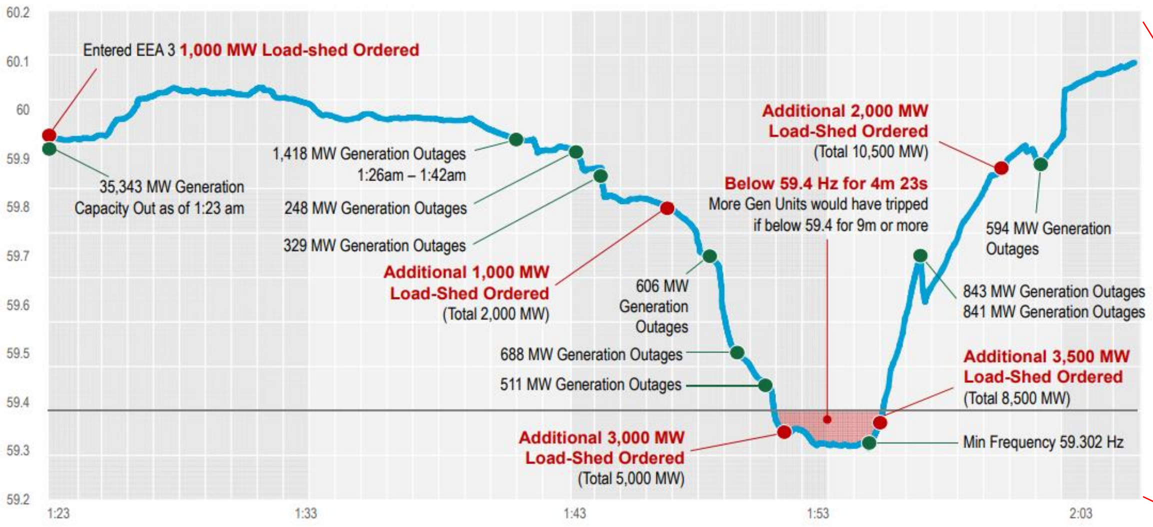
The California event was not a renewables problem, but a planning failure

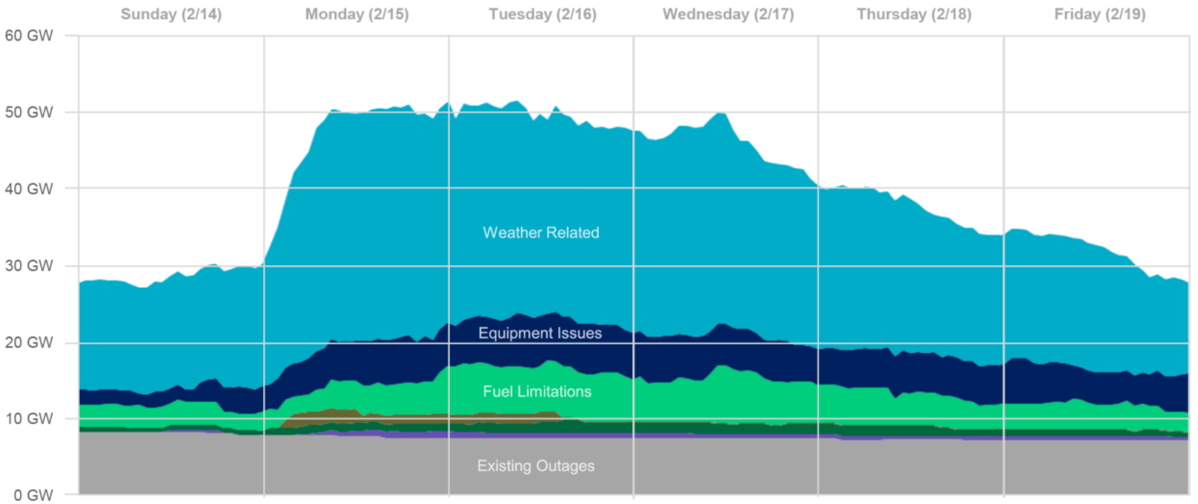
What Happened in Texas?

Cold weather conditions forced additional generation offline:

- ~20 GW of thermal generation (e.g. Natural Gas, Coal)
- Several thousand GW of wind generation due to icing

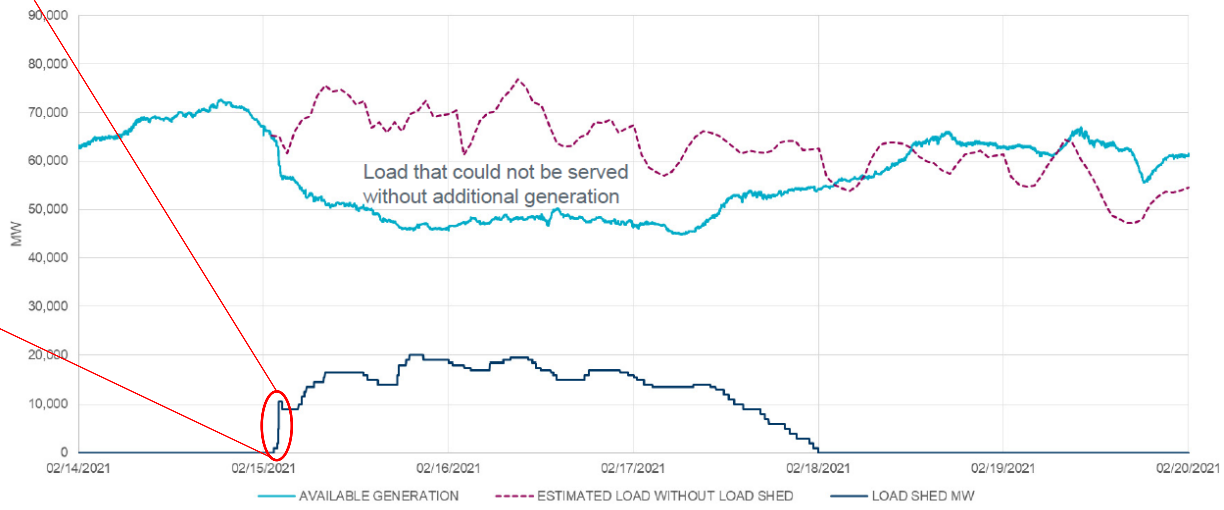
Deterministic studies missed the reconstituted peak load and did not account for the coincident generator outages





Version Date: 4/1/2021

Available Generation and Estimated Load without Load Shed

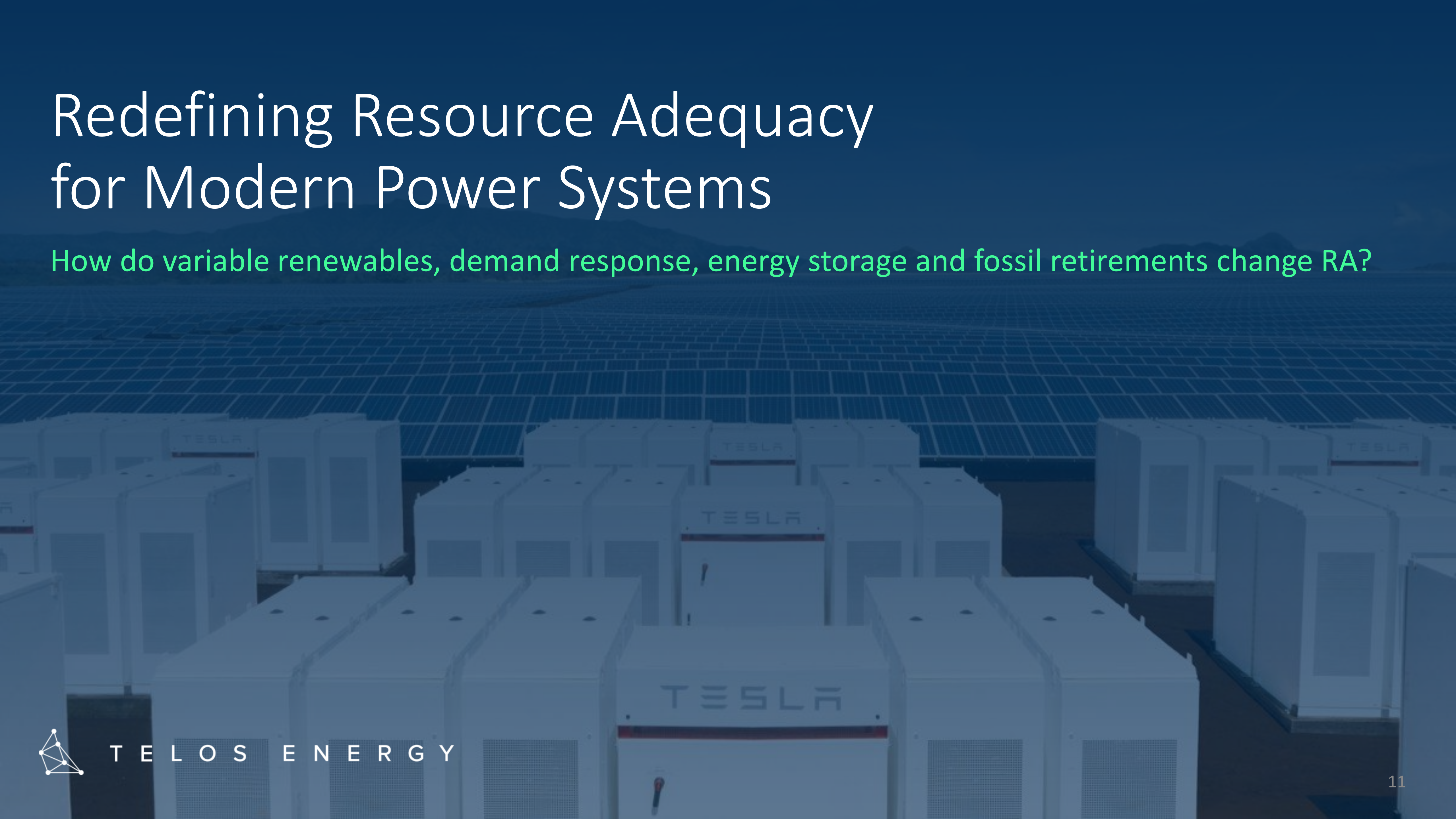


Sources:

- ERCOT Preliminary Report on Causes of Generator Outages and Derates For Operating Days February 14 – 19, 2021 Extreme Cold Weather Event
- Review of February 2021 Extreme Cold Weather Event

Redefining Resource Adequacy for Modern Power Systems

How do variable renewables, demand response, energy storage and fossil retirements change RA?



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Two Driving Factors requiring new RA methods

1) Chronological Grid Operations

- **Variable renewable** energy fluctuates hour-by hour
- **Energy limited resource** availability in one-hour depends on previous and following hours
- **Hybrids** may have competing objectives
- **Load Flexibility** is a growing tool

+

2) Correlated Events

- **Weather** underpins renewables, load, and generator outages
- **Combined outages** cause failures
- **Modular technology** reduces importance of random outage modeling
- **Climate** change trends

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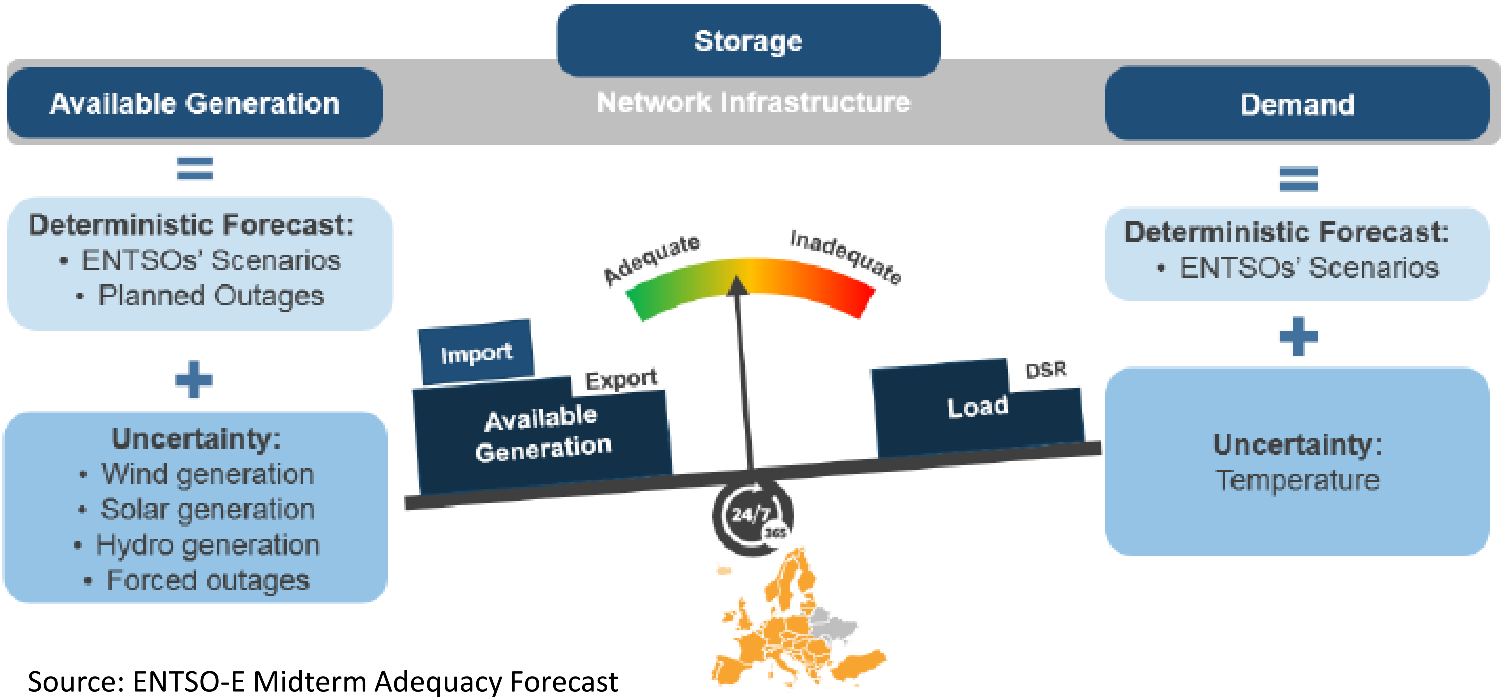
A fundamental need to rethink the way we approach resource adequacy analysis

How is resource adequacy changing?



Source: ENTSO-E Midterm Adequacy Forecast

Are there enough resources to serve load when it is needed?

Historical Perspective

1. Uncertainty in load
2. Uncertainty in supply (generator outages)

Some recognition that weather effects both

A new paradigm for resource adequacy is emerging…

1. Variable Renewables
2. Energy Limited Resources
3. Modular Technology
4. Load Flexibility
5. Correlated Events

Resource adequacy… starting from a blank canvas

We asked ourselves a few simple questions…

1. If we started from scratch, how would we evaluate resource adequacy for modern power systems?

2. Is there a better way to evaluate risk and reliability in a power system with increasing wind, solar, storage, and load flexibility?

3. What are the first principles that ensure enough resources are available for modern power systems, regardless of the technologies at play?

Objective: clearly articulate these evolving concepts to regulators and policy makers

The result: **SIX** principles of resource adequacy for modern power systems:

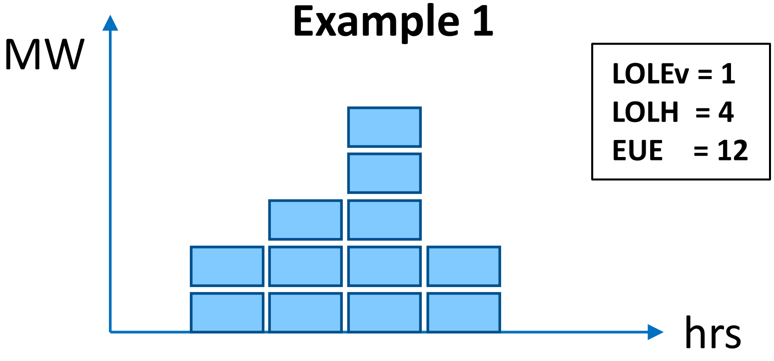
1. Quantifying size, frequency and duration of outages is critical to finding the right resource solutions.
2. There is no such thing as perfect capacity.
3. Modeling chronological operations is essential for modern power systems.
4. Load participation fundamentally changes the resource adequacy construct.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

1

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

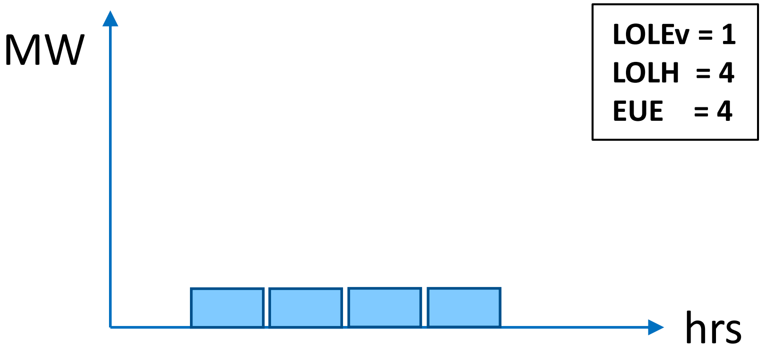
Same LOLEv and LOLH, but very different events

Example 1



LOLEv = 1
LOLH = 4
EUE = 12

Max MW = 5
Max MWh = 12
Duration = 4

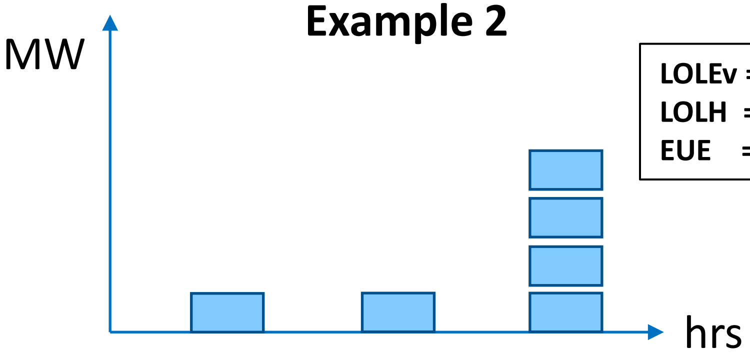


LOLEv = 1
LOLH = 4
EUE = 4

Max MW = 1
Max MWh = 4
Duration = 4

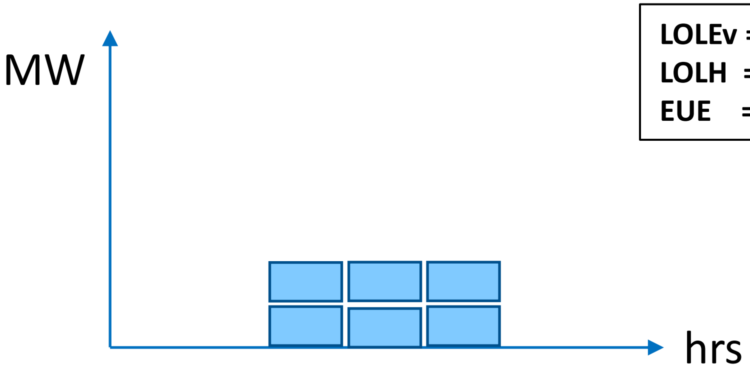
Same LOLH and EUE, but very different events

Example 2



LOLEv = 3
LOLH = 3
EUE = 6

Max MW = 4
Max MWh = 2
Duration = 1



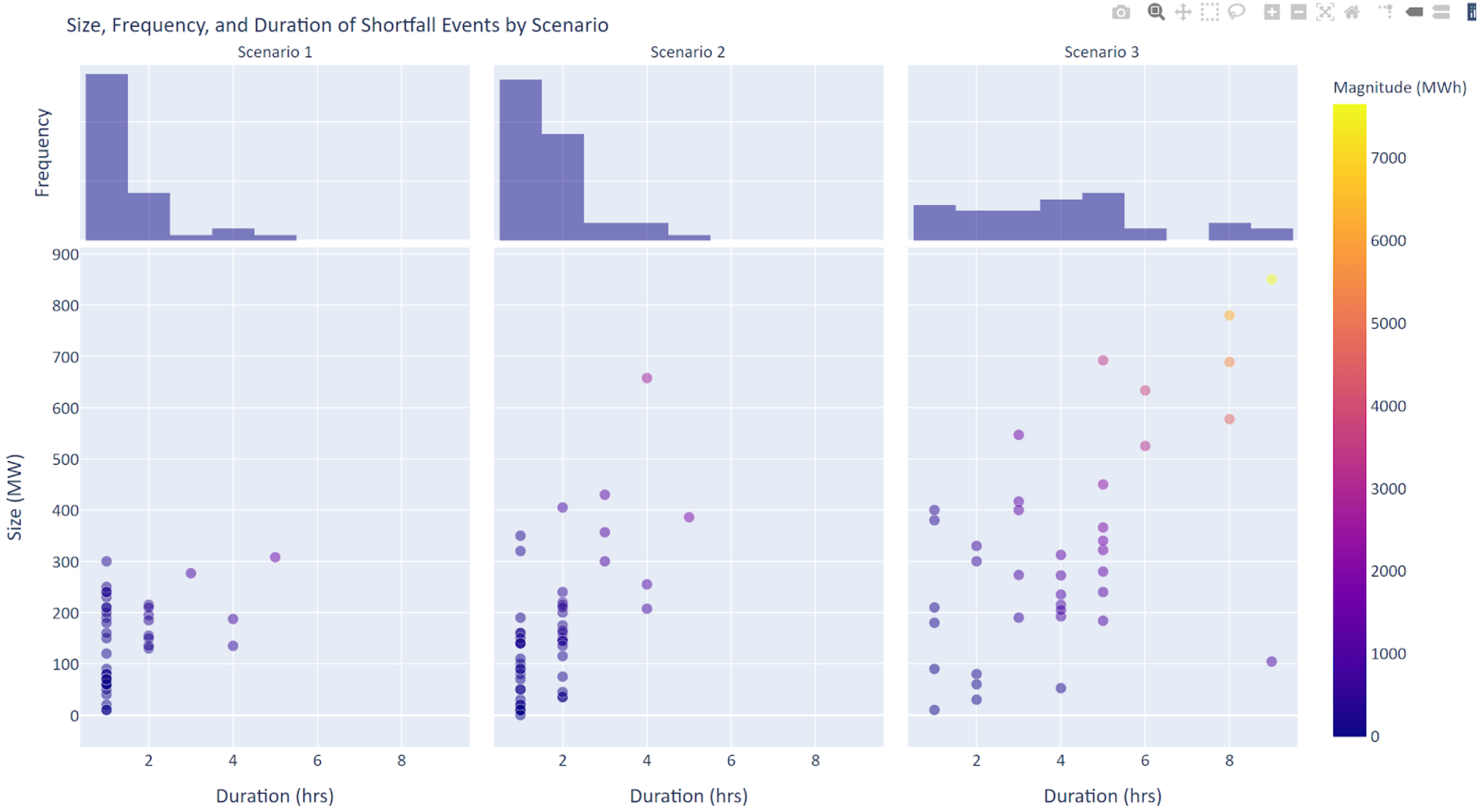
LOLEv = 1
LOLH = 3
EUE = 6

Max MW = 2
Max MWh = 6
Duration = 3

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

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

If there is an event… what does it look like?



We need move beyond expected values and provide information on the distribution of events, to provide emphasis on individual, rather than aggregate, event characteristics.

LOLE is an opaque metric when utilized in isolation.

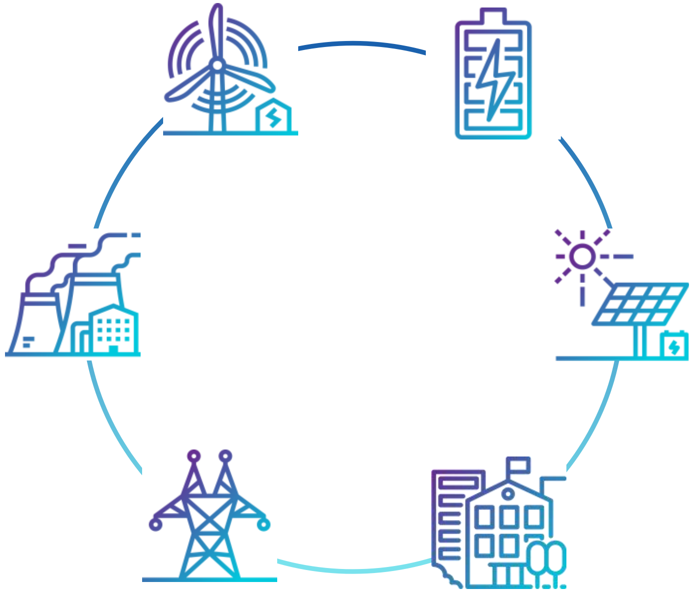
Does not characterize the magnitude or duration of specific outage events, nor their frequency of occurrence.

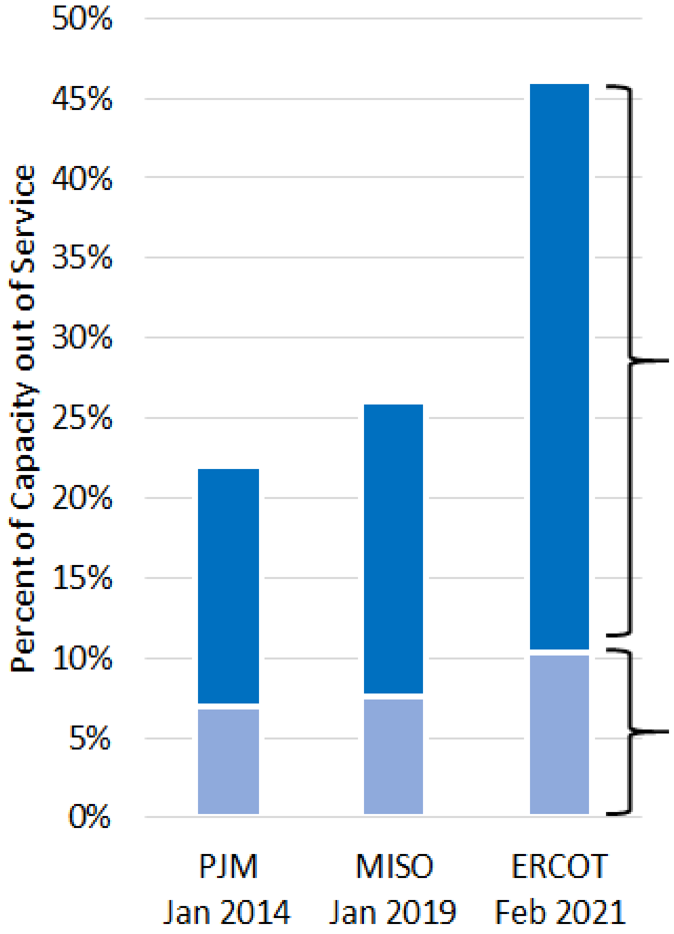
EUE is an improvement, but it mixes all three dimensions together

2

There is no such thing as perfect capacity

- All resources have limitations based on weather, outages, flexibility constraints, and common points of failure.
- Different resources bring different capabilities.
- Some capacity shortfalls may be made up of frequent but short-duration events, others may be infrequent but long-duration events.
- Mitigations should be specified accordingly.





Weather driven **outages; 3-4x seasonal average**

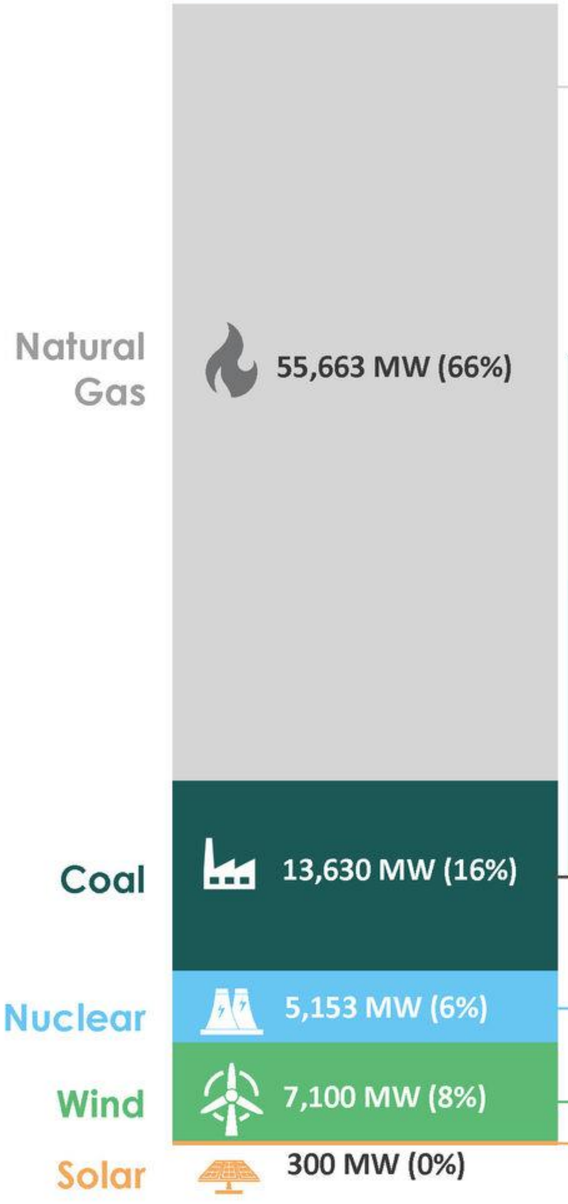
Expected **winter outage rate; typically used in RA analysis**

*Includes forced outages plus derates for all technology types

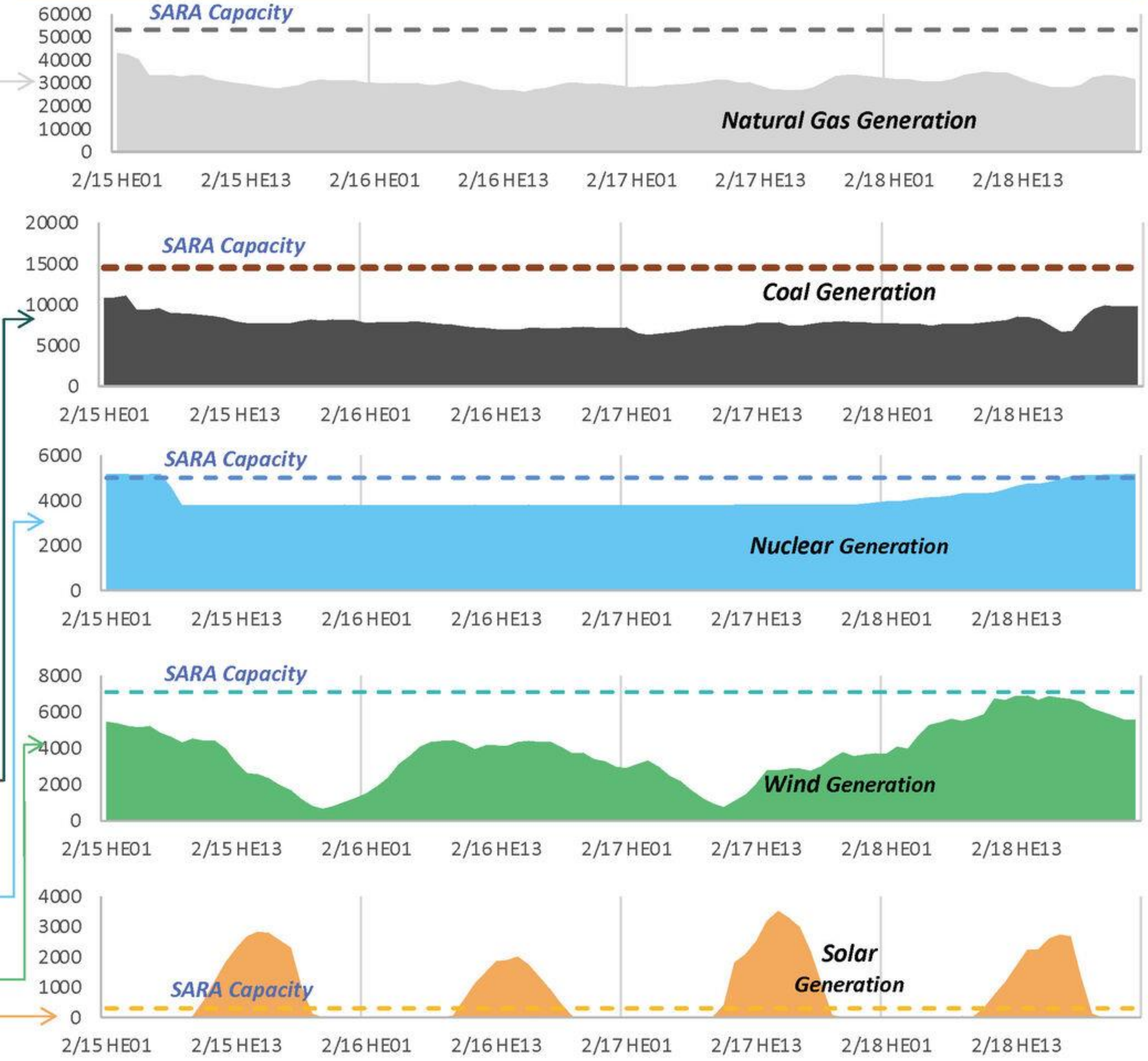
ERCOT Electricity Generation vs. Seasonal Expected Availability

Feb. 15-18

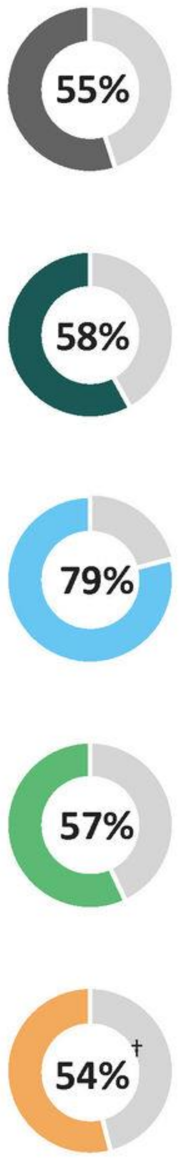
2021 Winter SARA



Seasonal Assessment of Resource Adequacy* (SARA) vs. Actual Generation



Performance vs. SARA



*ERCOT's Seasonal Assessment of Resource Adequacy (SARA) attributes an expected available capacity to each generation type, considering seasonal factors.

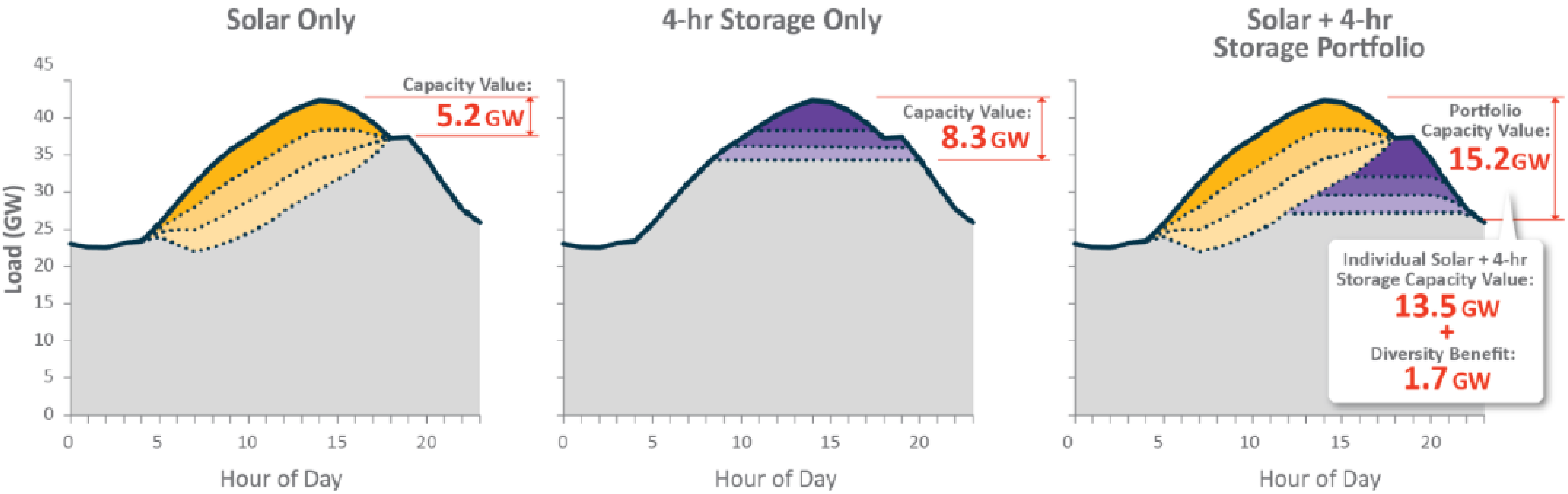
Data Sources:

Winter '21 SARA

Daily Balancing Authority Report

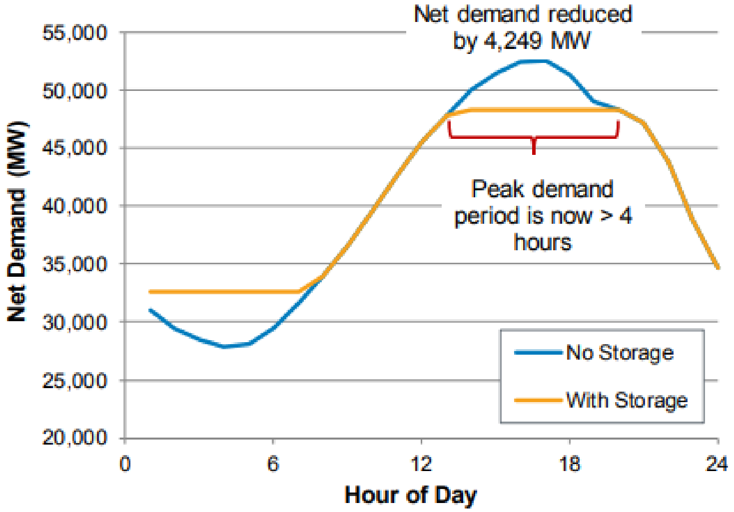
†During peak demand (18-23h)
Over all hours: 259%

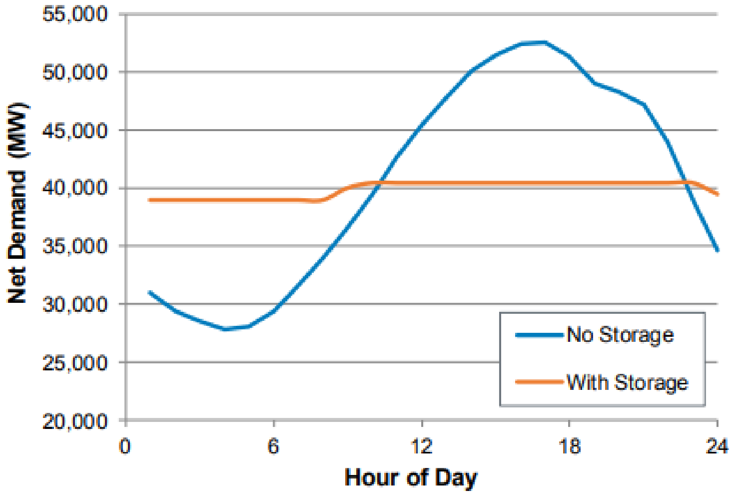
Capacity accreditation of one resources depends on others… the overall system mix matters



Modeling chronological operations is essential for modern power systems

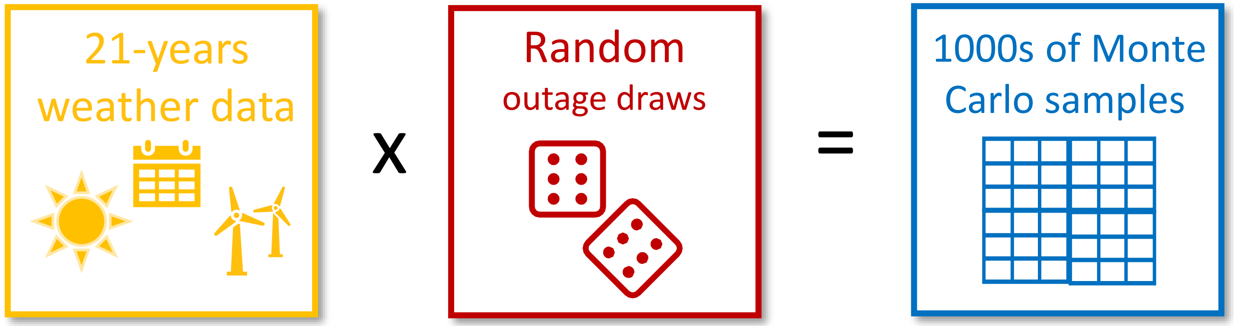
- Historically, resource adequacy analysis had a relatively simple task: ensure there is enough capacity installed to meet **peak** load
- VRE and energy-limited resources are changing this construct
- Periods of risk are not necessarily periods of high load.
- All intervals matter for resource adequacy analysis
- Chronological operations and scheduling ensure energy storage and demand response will be around long enough, and can fully recharge, to get the system through reliability challenges





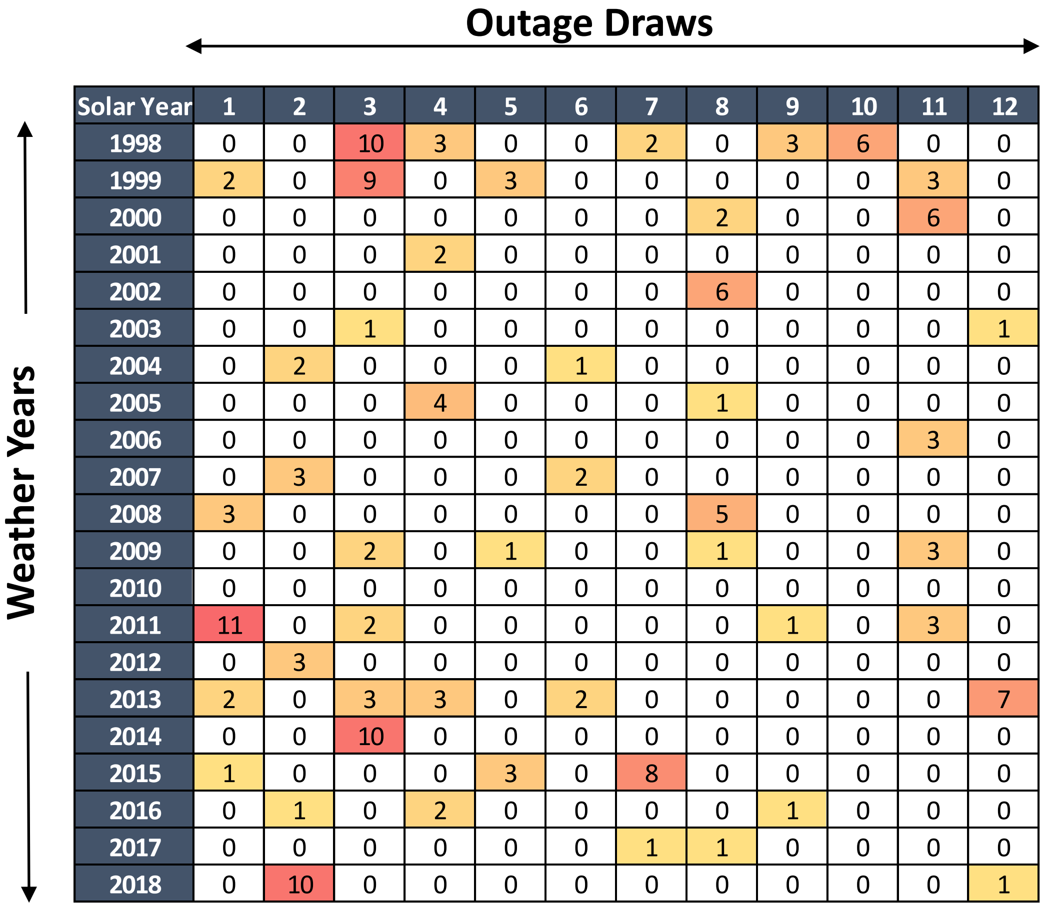
Source: Denholm & Margolis, "Potential for Energy Storage to Provide Peaking Capacity in California," NREL, 2018

How to model weather and generator uncertainty?


21-years weather data × Random outage draws = 1000s of Monte Carlo samples

- Historical inter-annual solar variability applied to future grid
- Uncertainty and timing of generator outages considered
- Each analysis evaluates capacity shortage across millions of hours of possible operation.
- Methodology allows detailed month-by-month, hour-by-hour characterization of loss of load events
- Monte Carlo production cost modeling tools useful for stochastic simulations

Example Loss of Load Hours by Sample

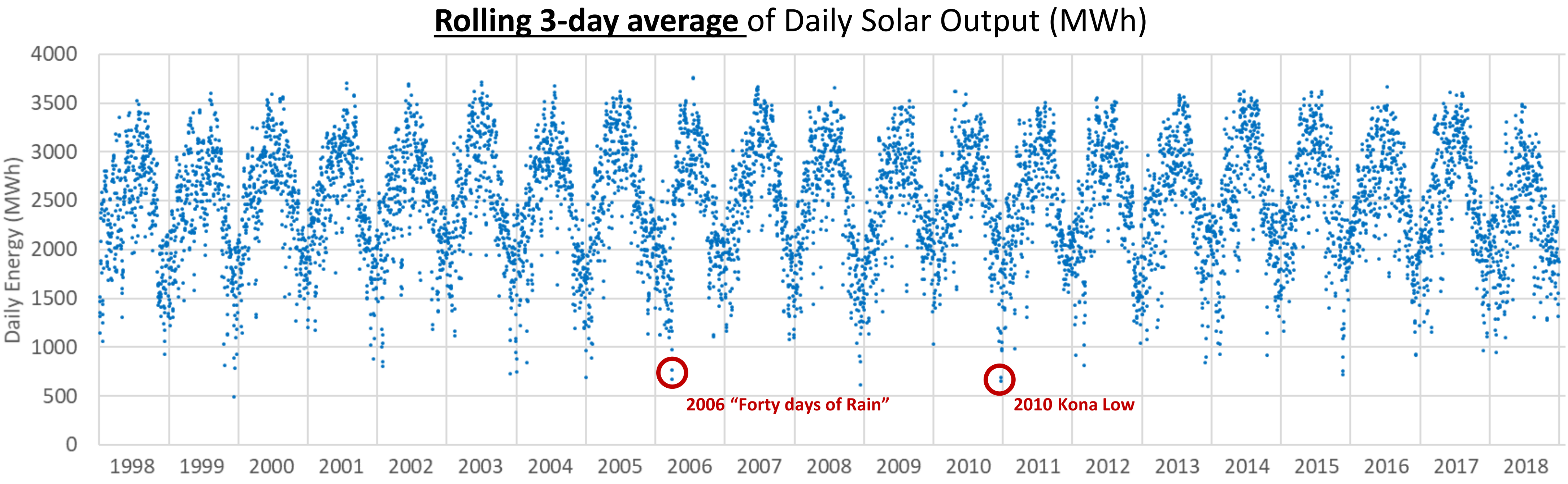


Solar Year	1	2	3	4	5	6	7	8	9	10	11	12
1998	0	0	10	3	0	0	2	0	3	6	0	0
1999	2	0	9	0	3	0	0	0	0	0	3	0
2000	0	0	0	0	0	0	0	2	0	0	6	0
2001	0	0	0	2	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	0	6	0	0	0	0
2003	0	0	1	0	0	0	0	0	0	0	0	1
2004	0	2	0	0	0	1	0	0	0	0	0	0
2005	0	0	0	4	0	0	0	1	0	0	0	0
2006	0	0	0	0	0	0	0	0	0	0	3	0
2007	0	3	0	0	0	2	0	0	0	0	0	0
2008	3	0	0	0	0	0	0	5	0	0	0	0
2009	0	0	2	0	1	0	0	1	0	0	3	0
2010	0	0	0	0	0	0	0	0	0	0	0	0
2011	11	0	2	0	0	0	0	0	1	0	3	0
2012	0	3	0	0	0	0	0	0	0	0	0	0
2013	2	0	3	3	0	2	0	0	0	0	0	7
2014	0	0	10	0	0	0	0	0	0	0	0	0
2015	1	0	0	0	3	0	8	0	0	0	0	0
2016	0	1	0	2	0	0	0	0	1	0	0	0
2017	0	0	0	0	0	0	1	1	0	0	0	0
2018	0	10	0	0	0	0	0	0	0	0	0	1

For Example, average across 1000 simulations yields LOLE for one specified grid conditions

~8.8 million hours of simulation per case

Long-term record of weather and its impact on load, solar, wind, hydro, etc.



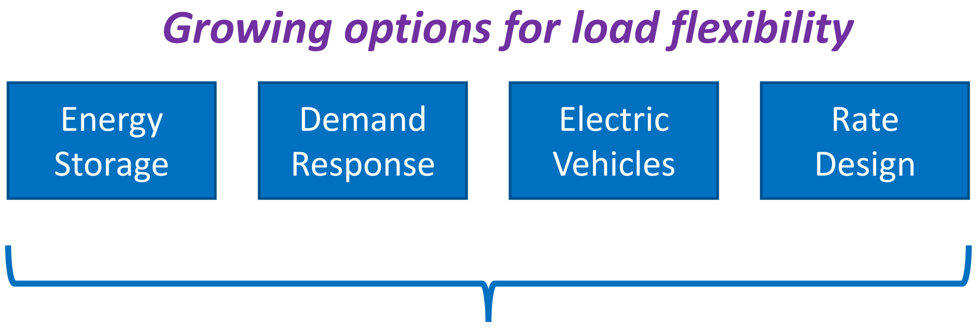
Source: Hawaii Natural Energy Institute & Telos Energy

What do you do with limited data?

4

Load participation fundamentally changes the resource adequacy construct

- Having enough generation capacity to meet a static load is no longer relevant.
- Load flexibility shifts the RA challenge toward economic considerations
- Customers can determine and differentiate which loads matter most.



Growing options for load flexibility

Energy Storage

Demand Response

Electric Vehicles

Rate Design

Need to be evaluated in a similar context as generating resources…

- ✓ **Unavailability**
- ✓ **Uncertainty**
- ✓ **Scheduling Constraints**

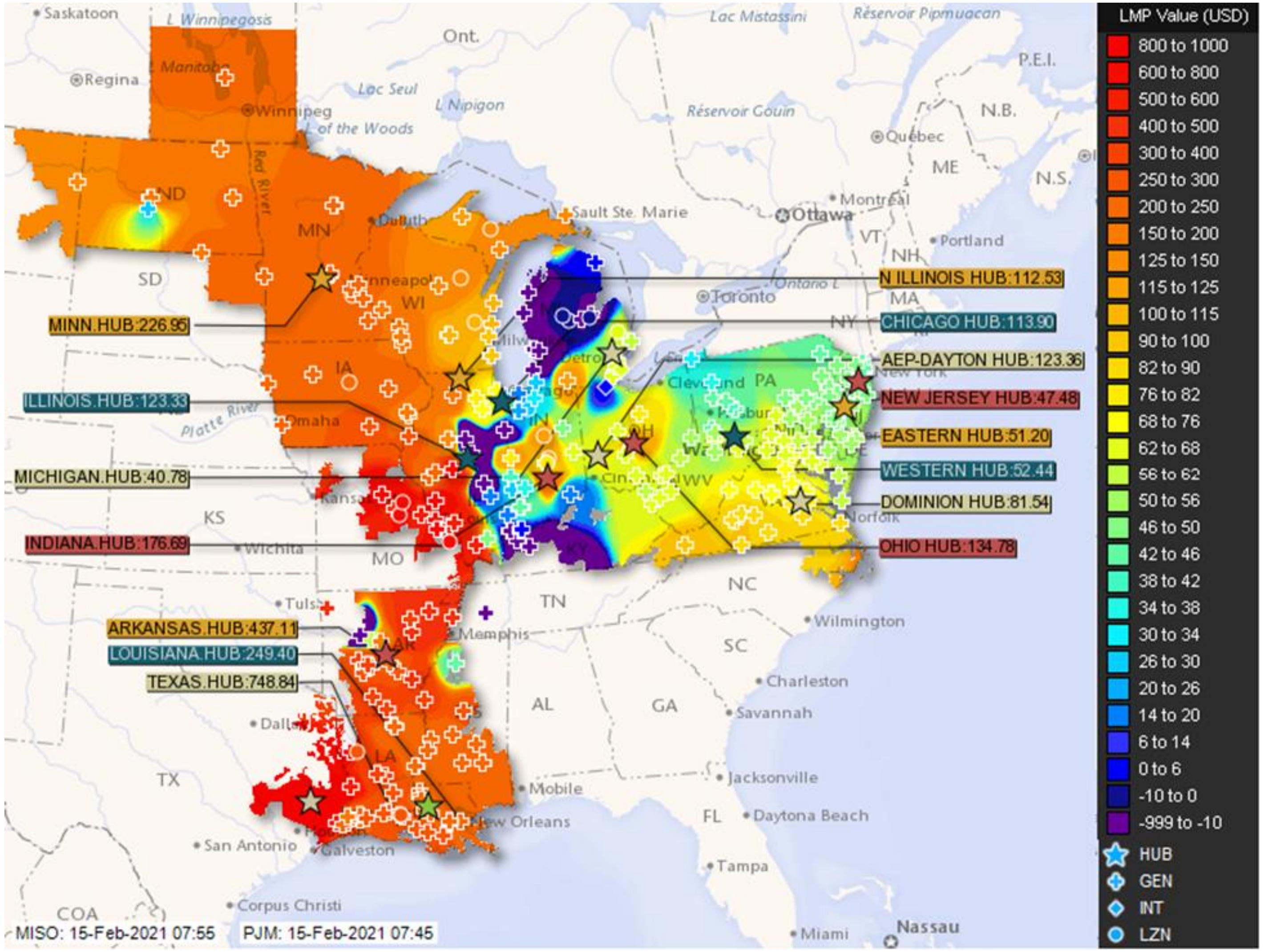
5

Neighboring grids and transmission are a key part of the RA challenge

- Conventional RA analysis generally does a poor job at modeling neighboring systems
- Reliability is a sensitive topic, you don't want to be reliant on your neighbors… but…

- Capacity sharing can be a large, low-cost alternative to procuring new resources
- Extreme weather can't happen everywhere at the same time
- Increased geographic diversity smooths out variability in wind/solar/load/temperature

Transmission can be a capacity resource!



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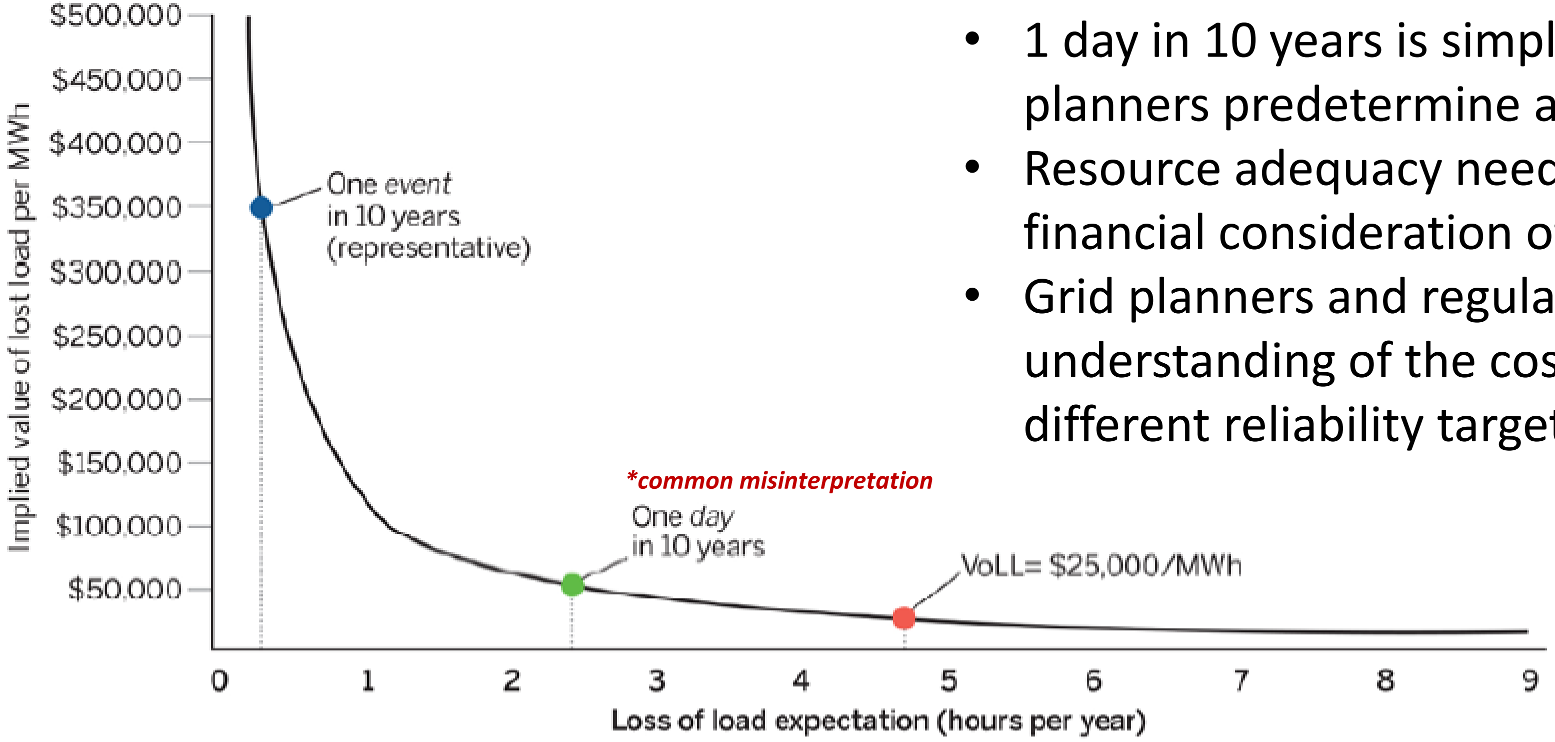
Reliability criterion should not be arbitrary, but transparent and economic

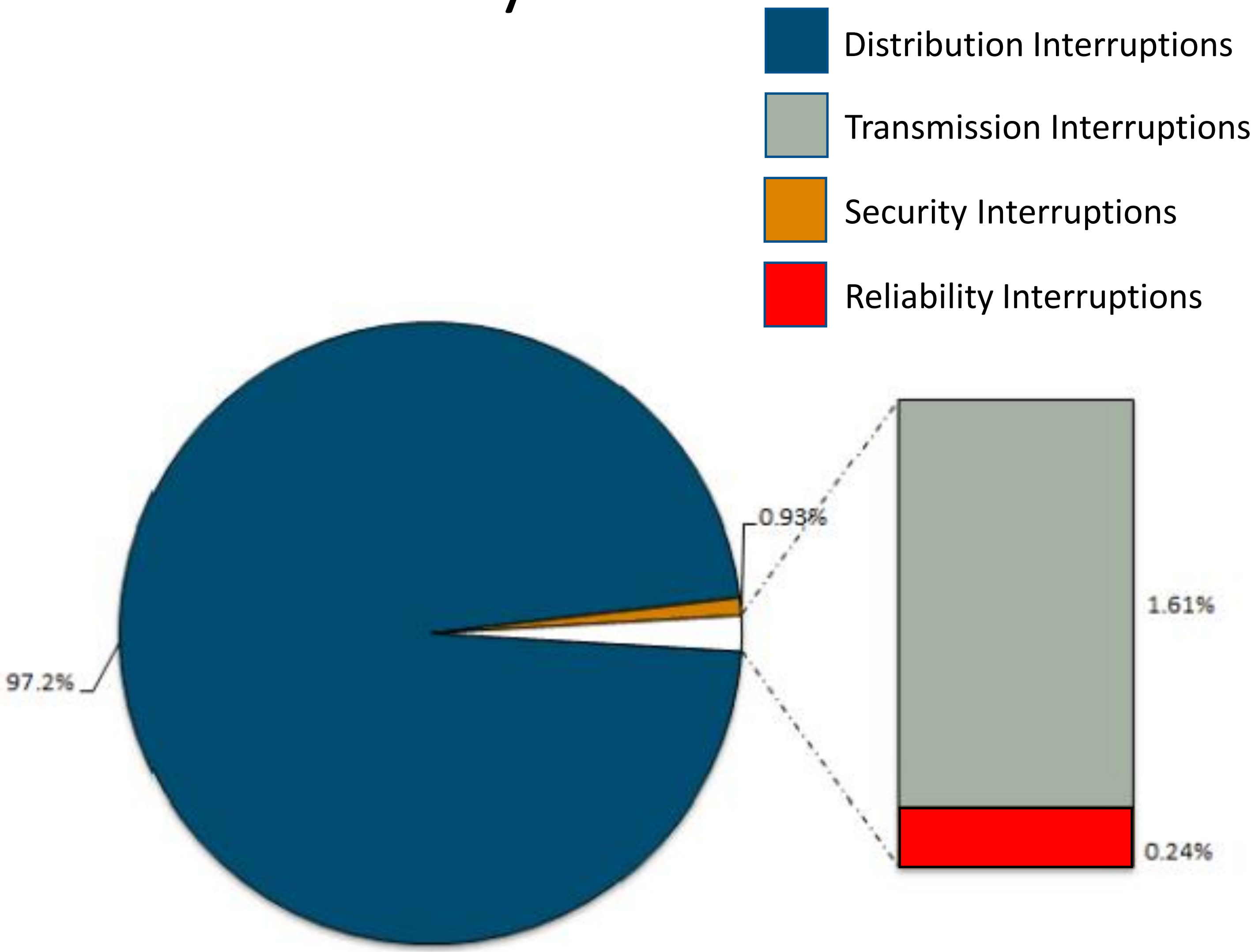


Source: Hogan & Littell, "Get What You Need: Reclaiming Consumer-Centric Resource Adequacy," Regulatory Assistance Project (RAP), June 2020

- 1 day in 10 years is simply a "line in the sand" that grid planners predetermine as the threshold.
- Resource adequacy needs to include an economic or financial consideration of the reliability criterion.
- Grid planners and regulators should have a clear understanding of the costs associated with achieving different reliability targets.

Resource Adequacy is not the only type of reliability risk

- How do we know if we are allocating our reliability dollars efficiently?
- Ultimately the customer doesn’t distinguish between the cause of outages.
- How does resiliency differ from resource adequacy?
- Transparent costs of incremental reliability help determine these tradeoffs



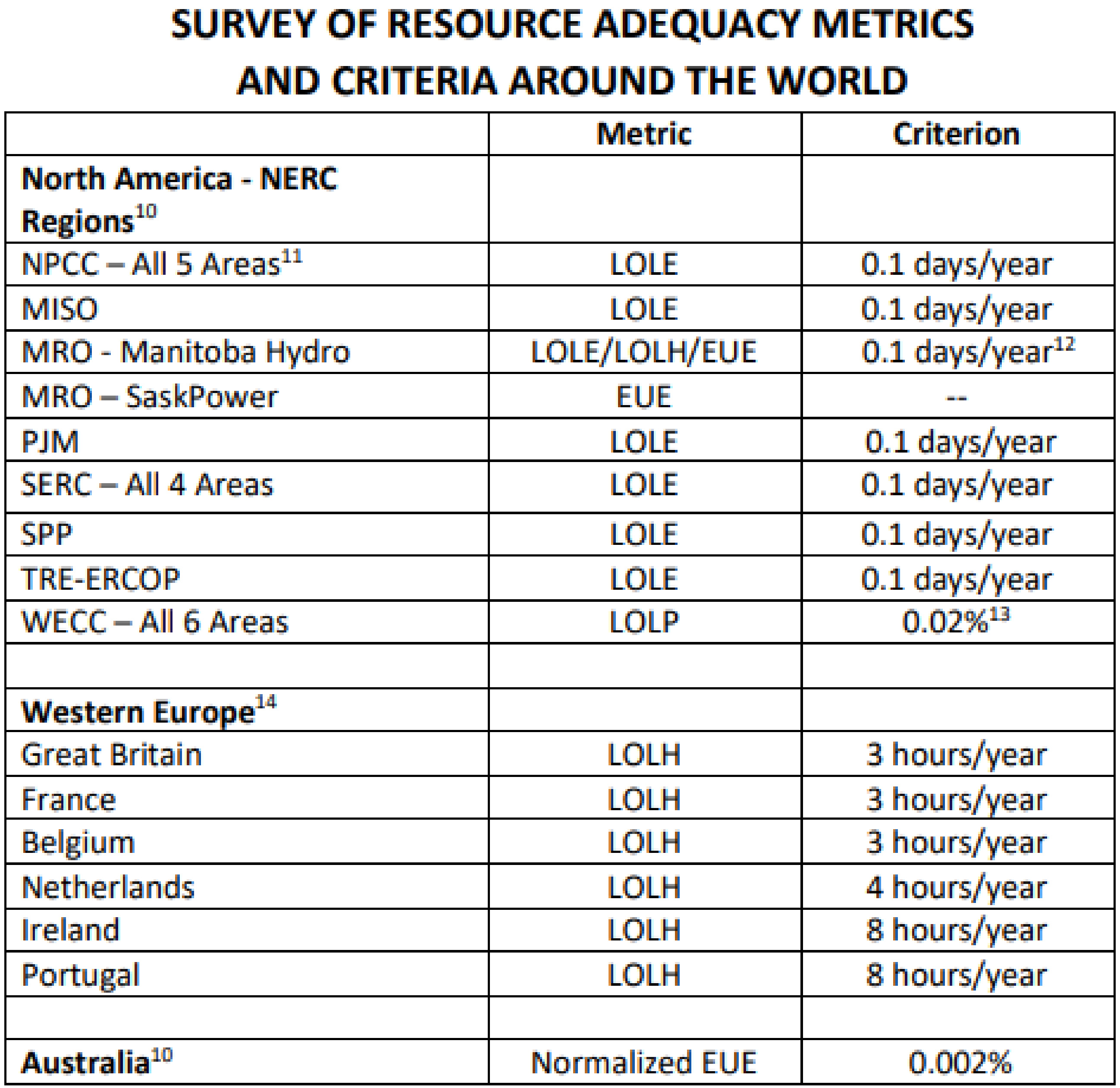
Source: AEMC Market Performance Report

New Metrics for Resource Adequacy

New metrics or deeper metrics? How to measure RA.

Where are we today with RA metrics?

- Most regions in North America use a 0.1 days/year LOLE metric as the reliability criteria
- "Line in the Sand Syndrome"
- Little understanding / transparency into why, or the costs of achieving reliability
- Other RA metrics rarely reported and deemphasized
- May have been appropriate for historic grid, where risk was largely driven by random generator outages and load variability



SURVEY OF RESOURCE ADEQUACY METRICS AND CRITERIA AROUND THE WORLD

	Metric	Criterion
North America - NERC Regions[10]		
NPCC – All 5 Areas[11]	LOLE	0.1 days/year
MISO	LOLE	0.1 days/year
MRO - Manitoba Hydro	LOLE/LOLH/EUE	0.1 days/year[12]
MRO – SaskPower	EUE	--
PJM	LOLE	0.1 days/year
SERC – All 4 Areas	LOLE	0.1 days/year
SPP	LOLE	0.1 days/year
TRE-ERCOP	LOLE	0.1 days/year
WECC – All 6 Areas	LOLP	0.02%[13]
Western Europe[14]		
Great Britain	LOLH	3 hours/year
France	LOLH	3 hours/year
Belgium	LOLH	3 hours/year
Netherlands	LOLH	4 hours/year
Ireland	LOLH	8 hours/year
Portugal	LOLH	8 hours/year
Australia[10]	Normalized EUE	0.002%

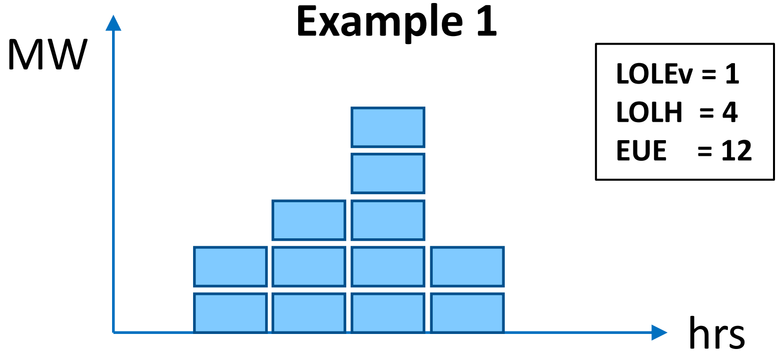
Refresher on Existing RA Metrics

Metric	Description	Limitations
Loss of Load Expectation (LOLE) days/year	Counts the number of loss of load **days** across all the random samples simulated. The total number of days with a shortfall is then divided by the number of samples to give an average days per year with a shortfall.	Quantifies the frequency of shortfalls, but does not provide information of size, duration or timing.
Loss of Load Events (LOLEv) events/year	Counts the number of loss of load **events** each year. Where an event is characterized as consecutive hours of a shortfall. Where one day may have multiple events, or one event may span multiple days.	Evaluates shortfall events based on consecutive duration, but does not provide information of size, duration or timing.
Loss of Load Hours (LOLH) hours/year	Counts the number of loss of load **hours** across all of the random samples simulated. The total number of hours with a shortfall is then divided by the number of samples to give an average hours per year with a shortfall.	Provides some insight into duration when combined with LOLE (LOLH/LOLE = hours/day) but does not provide insight into size of events.
Loss of Load Probability (LOLP) % of Days	Calculates a **probability** of a shortfall loss of load event occurring, between 0 and 1, often calculated as the number of days with a shortfall, divided by the total number of days sampled.	Similar to LOLE.
Expected Unserved Energy (EUE) MWh/year	Calculated the average amount of unserved **energy**, in MWh, in a given year. Unserved energy can be calculated as either the number of operating reserves not provided, or involuntary curtailed load.	Quantifies the size (magnitude) of loss of load, but does not provide information on the frequency or duration of the events.
Normalized Expected Unserved Energy (NEUE) % of load/year	Provides the same information as expected unserved energy but reports shortfalls as a percentage of system load as opposed to MWh to provide a relative risk level across different systems or load years.	Similar to EUE.

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



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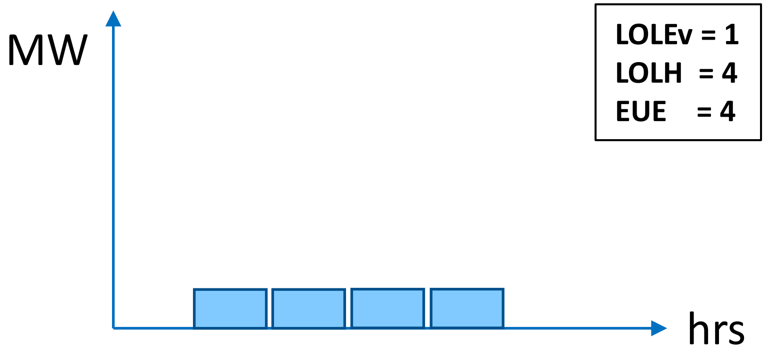
Max MWh = 12
Duration = 4

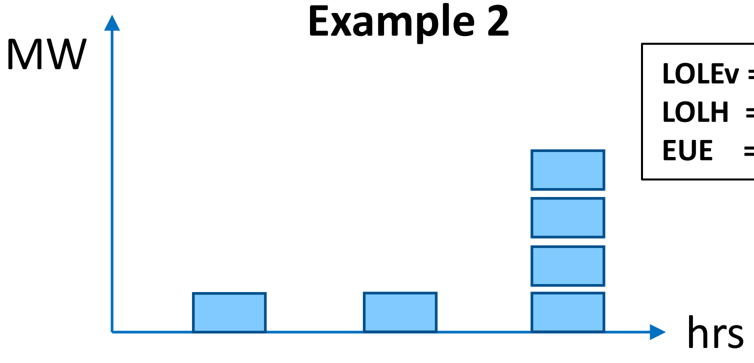


LOLEv = 1
LOLH = 4
EUE = 4

Max MW = 1
Max MWh = 4
Duration = 4

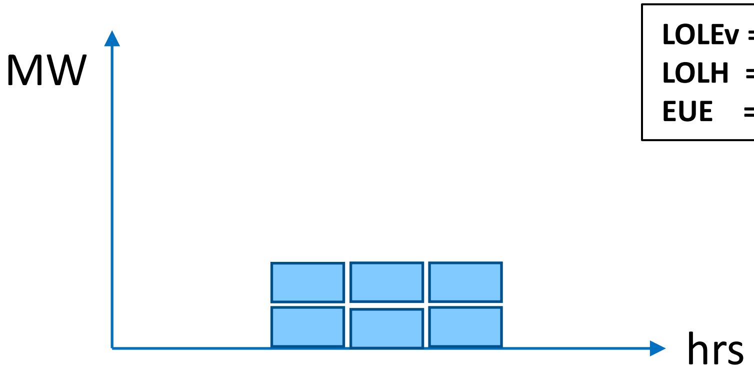
Same LOLH and EUE, but very different events

Example 2



LOLEv = 3
LOLH = 3
EUE = 6

Max MW = 4
Max MWh = 2
Duration = 1



LOLEv = 1
LOLH = 3
EUE = 6

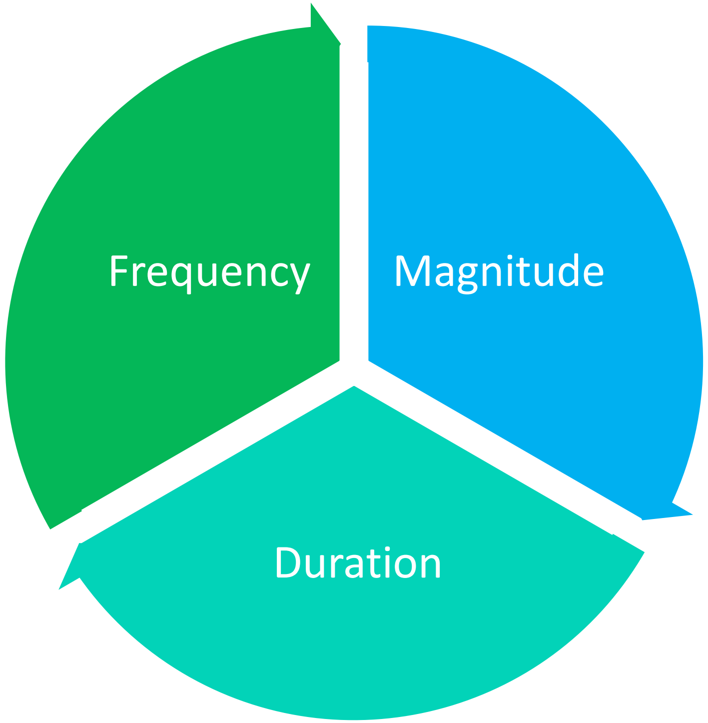
Max MW = 2
Max MWh = 6
Duration = 3

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

New metrics, more metrics, or deeper metrics? … what needs to change?

Existing metrics:

- Loss of Load Expectation (LOLE) & Loss of Load Hours (LOLH) quantify *frequency* of shortfalls, but not magnitude or duration
  … but the industry is well accustomed to "1 day in 10" RA criteria
- Expected Unserved Energy (EUE) quantifies the *magnitude* of shortfalls, but not frequency or duration
  … starting to be recognized as a preferred metric, but lacks common criteria (Normalized EUE getting traction)



A ***combination*** of these metrics can help provide insight into shortfall events… but they all still evaluate ***expected values***

Four Recommendations for Improved Use of RA Metrics

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

1

Place more emphasis on Expected Unserved Energy

- LOLE does not capture the magnitude of events when they occur
- Misses a potentially large measure of reliability as compared to a metric such as EUE.
- EUE captures the total quantity of energy that is expected to go unserved each year.
- While this metric is not perfect, it is likely the most robust metric in terms of measuring the true reliability of an electric system,
- Particularly useful in a system that is energy-constrained.
- But, EUE is not commonly used as a reliability metric in the industry today.

Source: E3, "Resource Adequacy in the Pacific Northwest"

Source: Dent, et al.

- Shape over time of shortfall
- Energy limited storage minimises duration of shortfall by doing this
- Minimises maximum shortfall depth by doing this

Benefits and Limitations of Using EUE

Benefits of EUE as an RA Metric
Measures size and duration of shortfall events
Evaluates risk across all hours of the year and not just on peak load periods
Places higher weight on large, disruptive, and catastrophic shortfall events
Easier to translate to an economic value by assigning a value of lost load (VoLL)
Better accounts for energy limitations of storage and load flexibility resources
Can provide more insights into timing of shortfall events (hour of day, day of week, month, season, etc.)

Limitations of EUE as an RA Metric
Does not explicitly capture the *frequency* of shortfalls
Requires more sophisticated statistical analysis and is more computationally intensive
Can overlook frequent, but small events that may be inconvenient to customers or politically damaging
Normalized EUE (nEUE) relative to system load can be difficult to interpret
Limited experience in setting EUE-based reliability criterion
More difficult to understand than a “1 day every 10 year” metric

2

Use a suite of reliability metrics, not just one

Event Characteristic	Metric Affected	California Aug 2020	Texas Feb 2021	Difference
Number of Events	**LOLEv**	**2 events**	**1 event**	**-50%**
Number of Days	**LOLE**	**2 days**	**3 days**	**+50%**
Number of Hours	**LOLH**	**6 hours**	**71 hours**	**+1,083%**
Unserved Energy	**EUE**	**2,700 MWh**	**990,000 MWh**	**+36,567%**
Max Shortfall	**-**	**1,072**	**20,000+**	**+1,766%**

"It would be helpful when assessing resource adequacy, particularly of a system with a high percentage of intermittent energy-limited resource capacity, that the values for all three metrics, LOLH and EUE, as well as LOLE, be calculated. The Working Group therefore recommends that the NYISO and the NYSRC consider whether the 2021 IRM Study should calculate all three metrics and report them to the Executive Committee." -New York State Reliability Council

3

Move beyond expected values

Average of ***all*** samples

Quantifying only samples with shortfall events

SCENARIO 1		Average	Average if…	25th percentile	Median	75th percentile	95th percentile	Max
LOLE	Days per year	0.10	1.38	1	1	2	2	3
LOLH	Hours per year	0.15	2.07	1	1	2	5	11
EUE	MWh per year	25	342	73	228	391	912	2,348

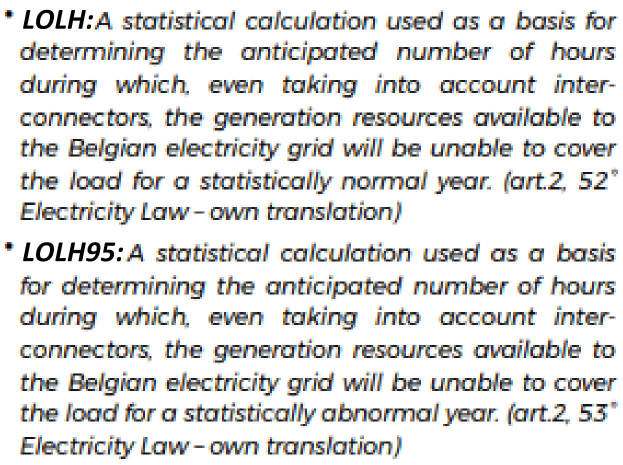
Same LOLE expected value

Very different extreme events

SCENARIO 2		Average	Average if…	25th percentile	Median	75th percentile	95th percentile	Max
LOLE	Days per year	0.10	1.31	1	1	1	3	6
LOLH	Hours per year	0.39	5.28	2	4	5	14	34
EUE	MWh per year	154	2088	405	918	2,249	6,792	16,563

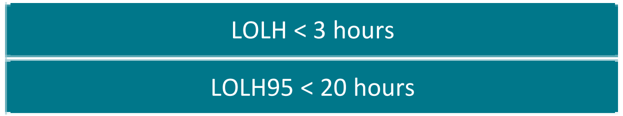
Belgium’s Dual RA Criterion

- There is precedent for using a dual RA criterion
- Belgium uses an *average* LOLH and a P95 *tail-end* LOLH



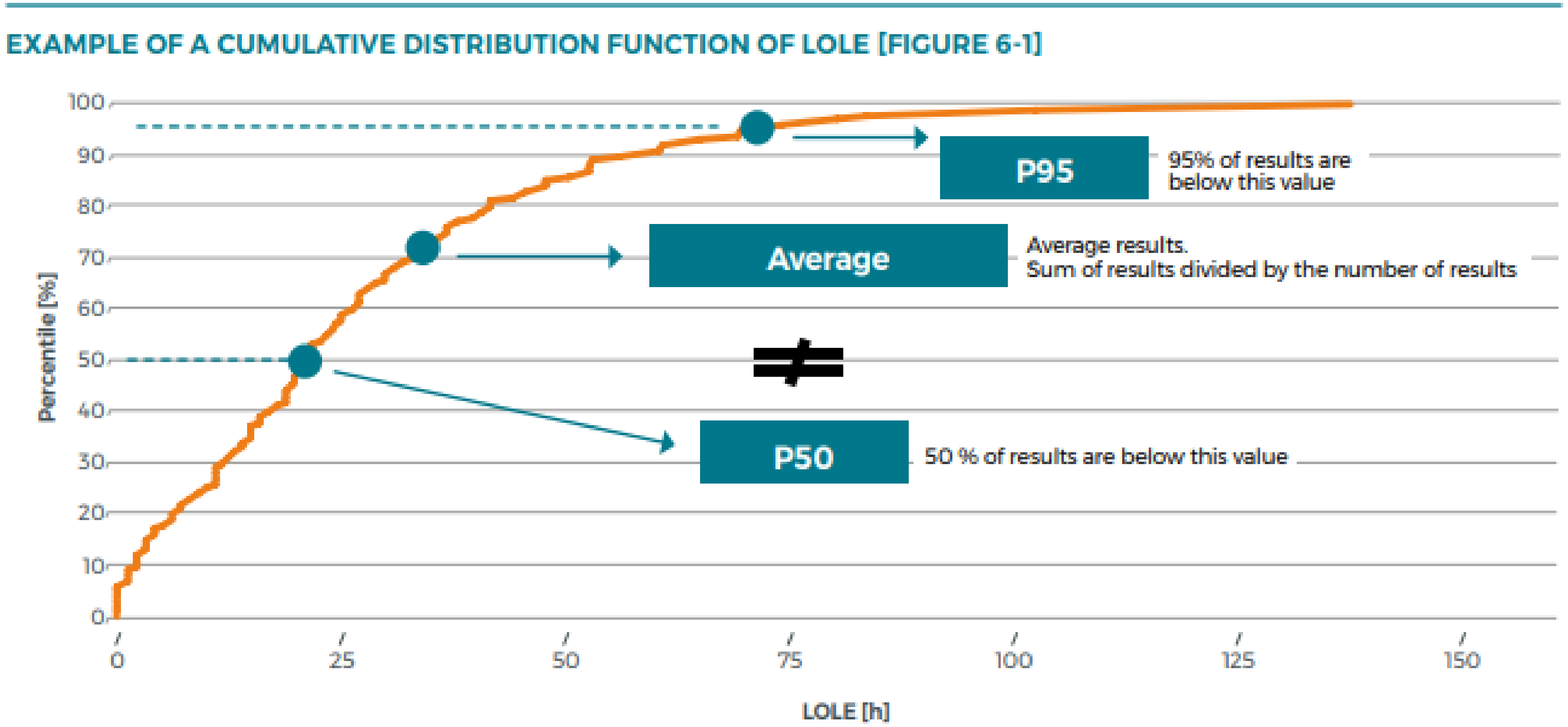
- ***LOLH:*** *A statistical calculation used as a basis for determining the anticipated number of hours during which, even taking into account inter-connectors, the generation resources available to the Belgian electricity grid will be unable to cover the load for a statistically normal year. (art.2, 52° Electricity Law – own translation)*
- ***LOLH95:*** *A statistical calculation used as a basis for determining the anticipated number of hours during which, even taking into account inter-connectors, the generation resources available to the Belgian electricity grid will be unable to cover the load for a statistically abnormal year. (art.2, 53° Electricity Law – own translation)*

ADEQUACY CRITERIA [FIGURE 1-1]



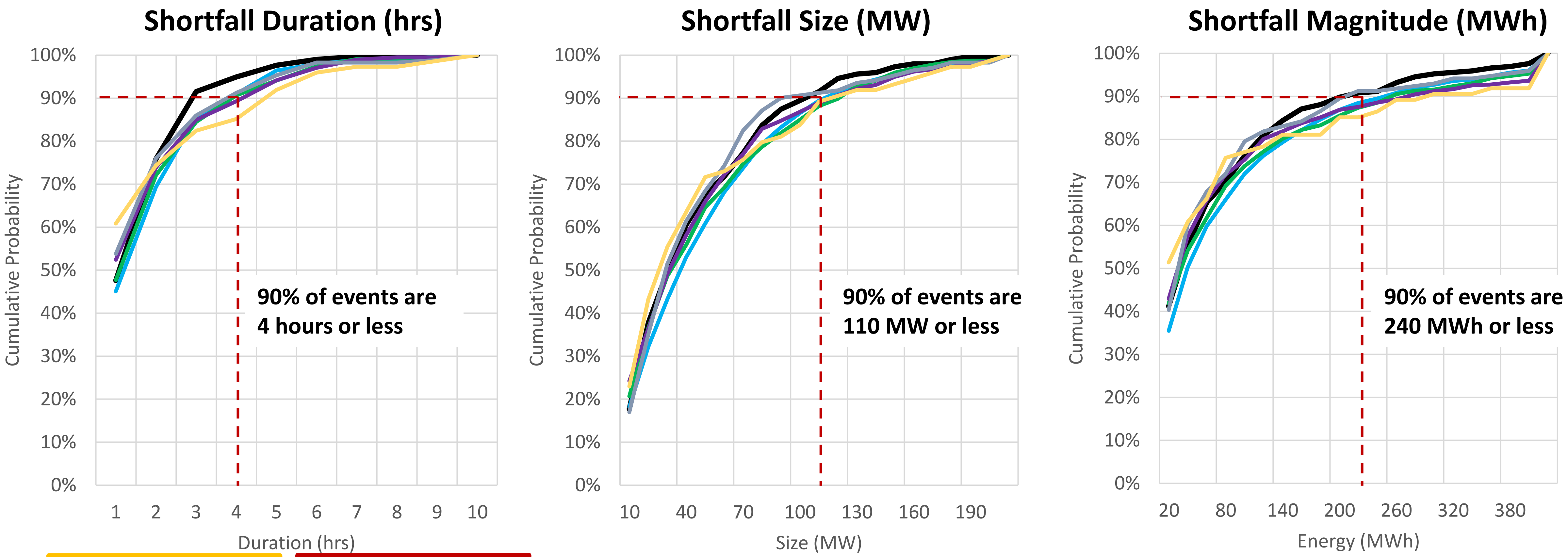
LOLH < 3 hours
LOLH95 < 20 hours

EXAMPLE OF A CUMULATIVE DISTRIBUTION FUNCTION OF LOLE [FIGURE 6-1]



Source: Elia, Adequacy and flexibility study for Belgium 2020 - 2030

4 Characterize size, frequency, duration, and timing of shortfall events


Shortfall Duration (hrs)

90% of events are 4 hours or less

Shortfall Size (MW)

90% of events are 110 MW or less

Shortfall Magnitude (MWh)

90% of events are 240 MWh or less

70% of events covered by 60 MW 2HR resource

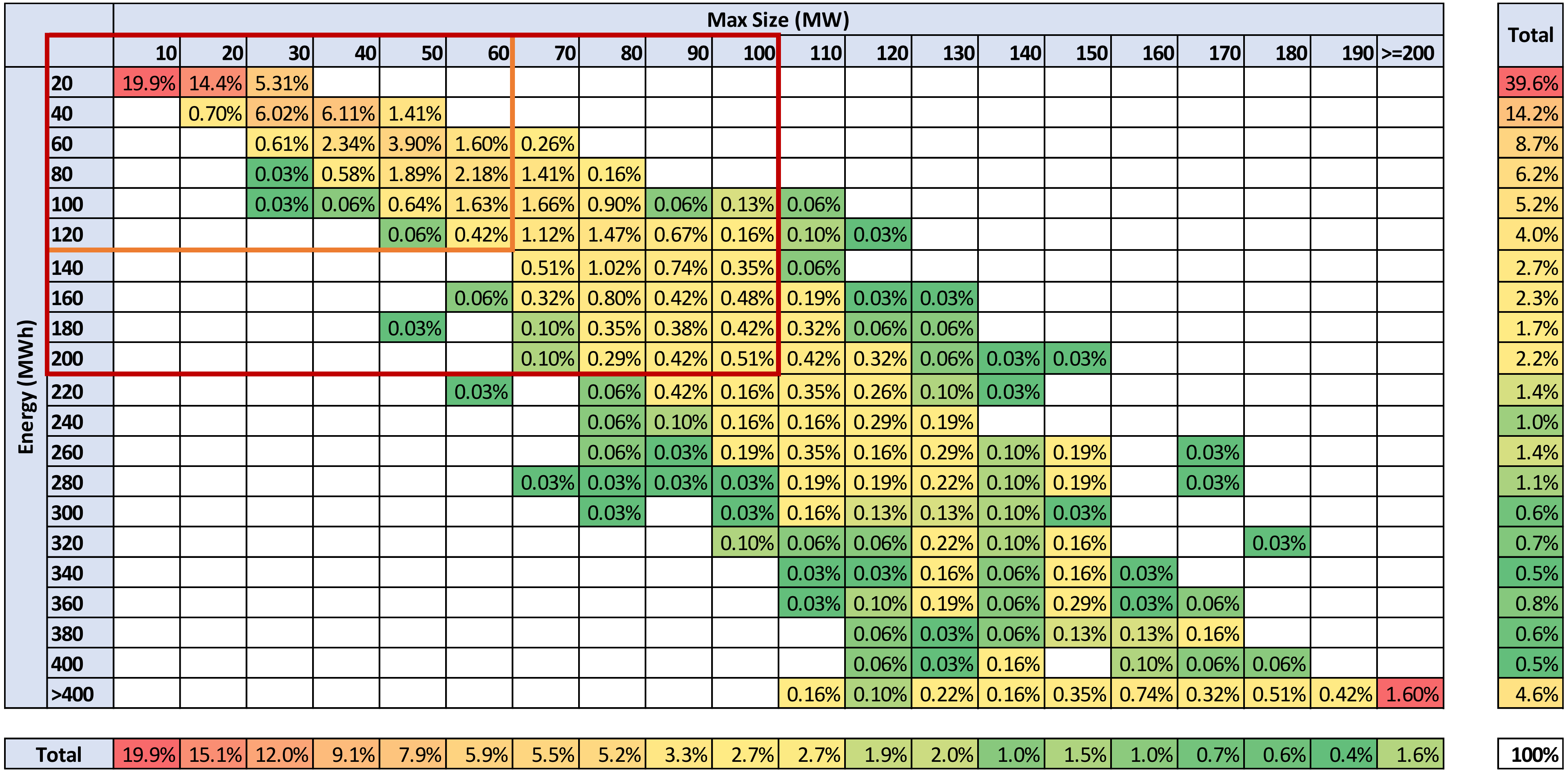
85% of events covered by 100 MW 2HR resource

**Assumes shortfall events after reserves are deployed.*

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)

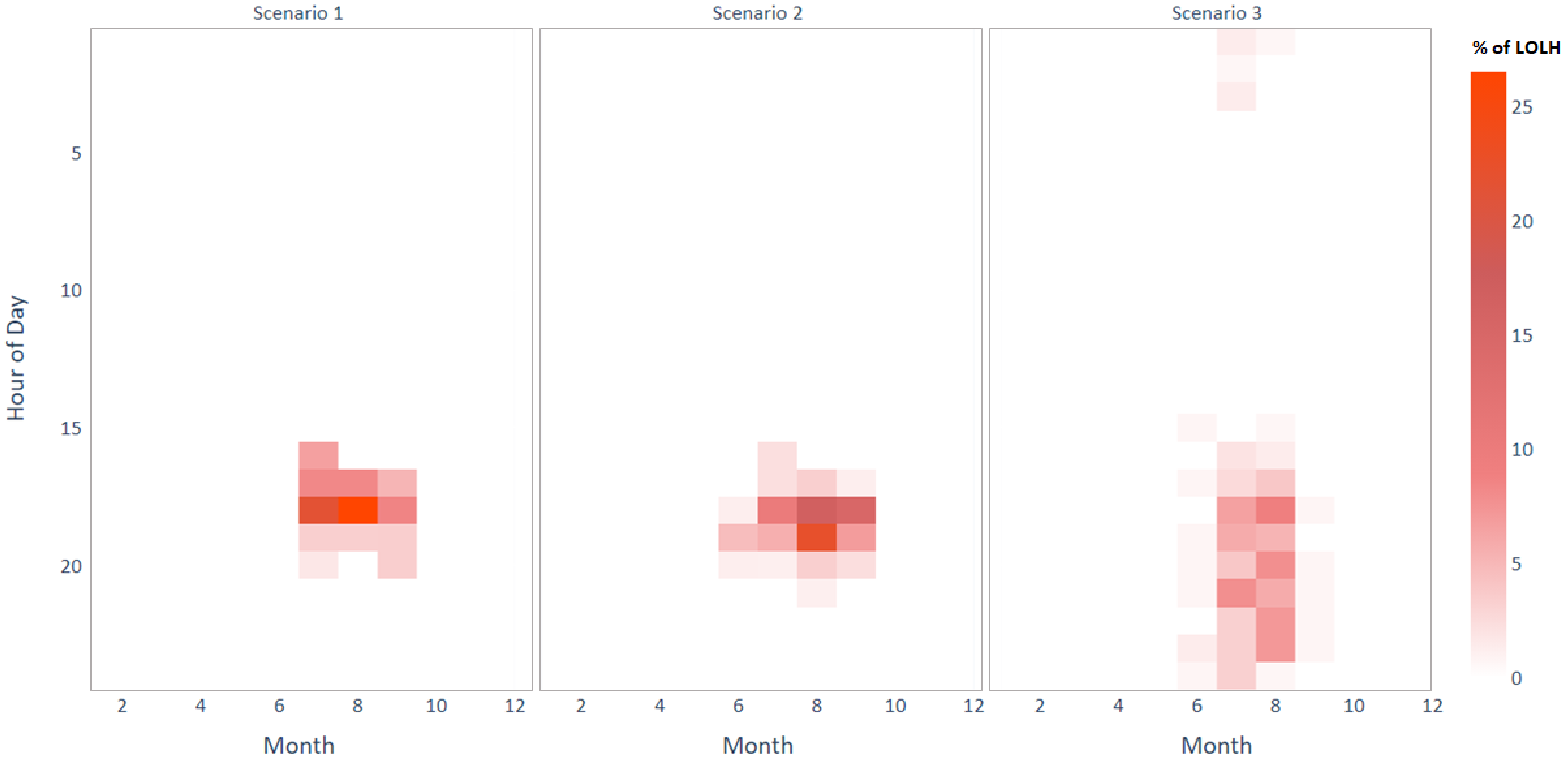


Energy (MWh)	Max Size (MW)																				Total
	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	>=200	
20	19.9%	14.4%	5.31%																		39.6%
40		0.70%	6.02%	6.11%	1.41%																14.2%
60			0.61%	2.34%	3.90%	1.60%	0.26%														8.7%
80			0.03%	0.58%	1.89%	2.18%	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



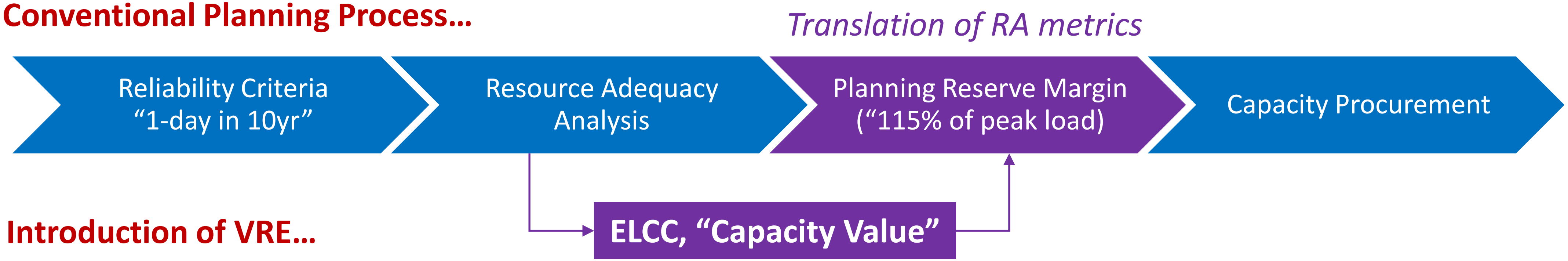
Planning Reserve Margin… what comes next?

Using RA Analysis for Investment Decisions

TELOS ENERGY

Where does the current planning process break down?

Conventional Planning Process…



Translation of RA metrics

Reliability Criteria
“1-day in 10yr”

Resource Adequacy
Analysis

Planning Reserve Margin
(“115% of peak load)

Capacity Procurement

ELCC, “Capacity Value”

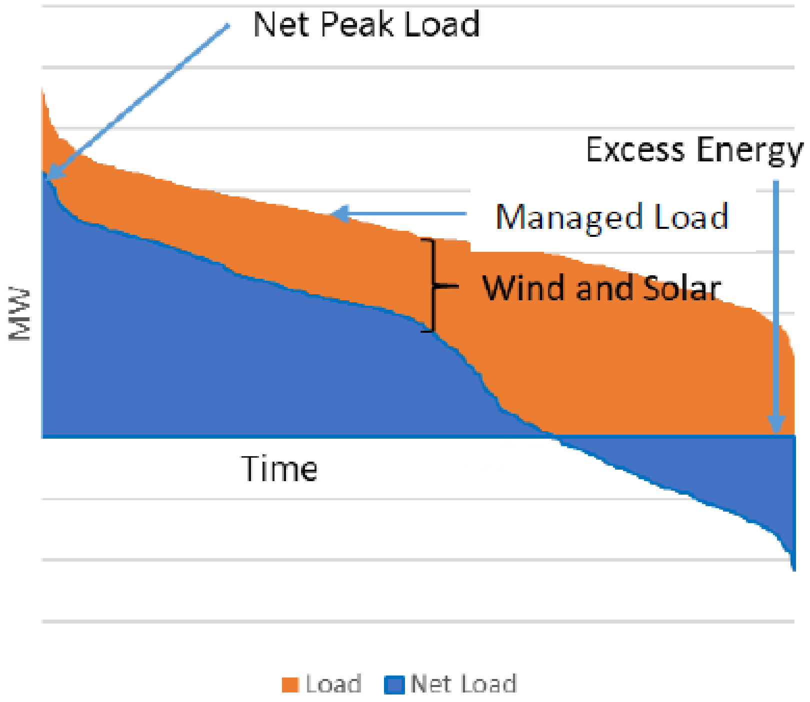
Introduction of VRE…

ELCC was quick-fix

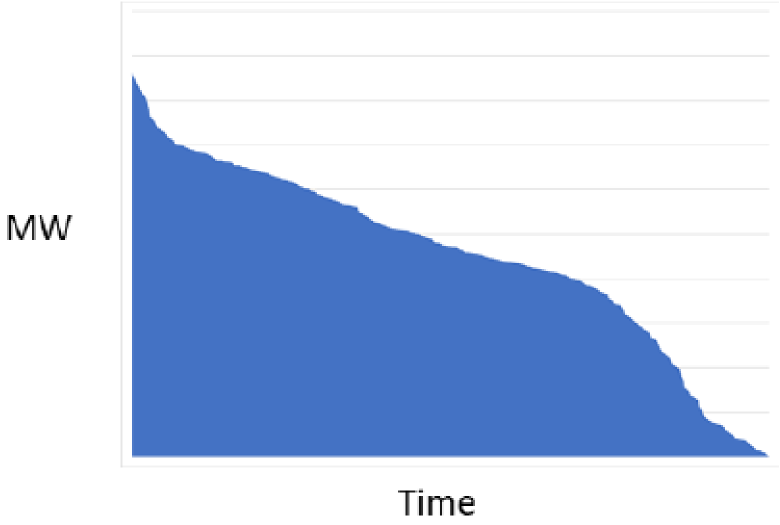
Limitations for future use…

- Planning reserve margin looks at peak load only, and requires accurate ELCC assumptions across the horizon
- ELCC is an *expected value only,* and is an average across all hours, seasons, and does not differentiate
- ELCC for storage and energy limited resources is highly dependent on the rest of the system
- In order to be useful, ELCC calculations must be routinely updated across the planning horizon and resource mixes

SCE’s Net Load Duration Curve Methodology



Capacity Requirement:
Monthly Net Load Peak



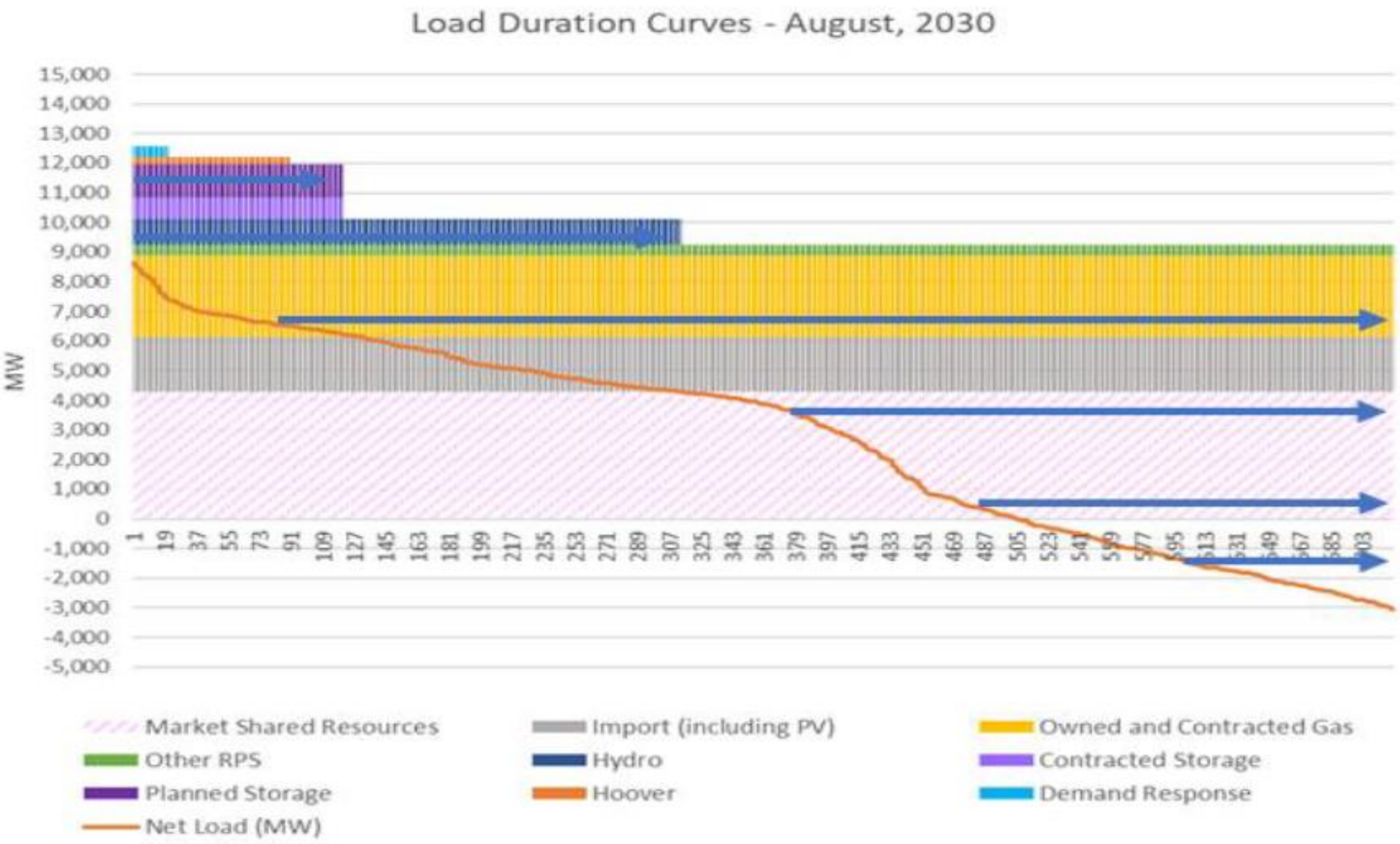
Energy Requirement:
Sum of Positive Monthly Net Energy

- Addresses energy attributes and reliance on resource use limitations
- Forward energy requirement construct).
- Conducted on a monthly basis to capture seasonal changes
- Unclear how multiple years of weather will be handled
- Does not consider chronology well

Source: SCE-CalCCA Track 3B2 RA Reform Proposal Workshop Slides February 9, 2021 CPUC RA Reform Workshop, R.19-11-009

SCE's Net Load Duration Curve Methodology

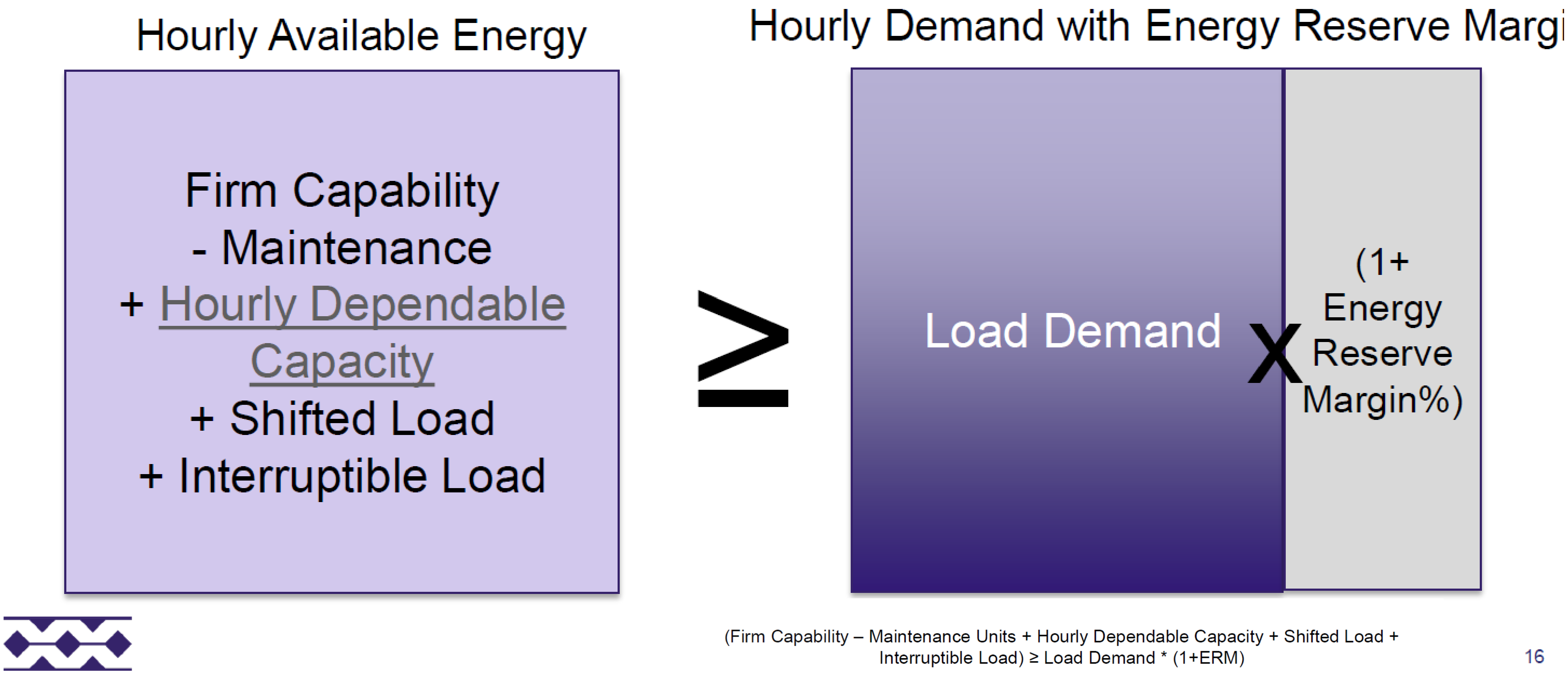
Compliance Example



Simplified example of monthly compliance for August 2030.

- Net load reflects netted solar and wind resources (not shown).
- Blue arrows reflect excess energy available for storage charging requirement.

HECO’s Energy Reserve Margin Methodology



Hourly Available Energy

Firm Capability
- Maintenance
+ Hourly Dependable Capacity
+ Shifted Load
+ Interruptible Load

≥

Hourly Demand with Energy Reserve Margi

Load Demand X (1+ Energy Reserve Margin%)

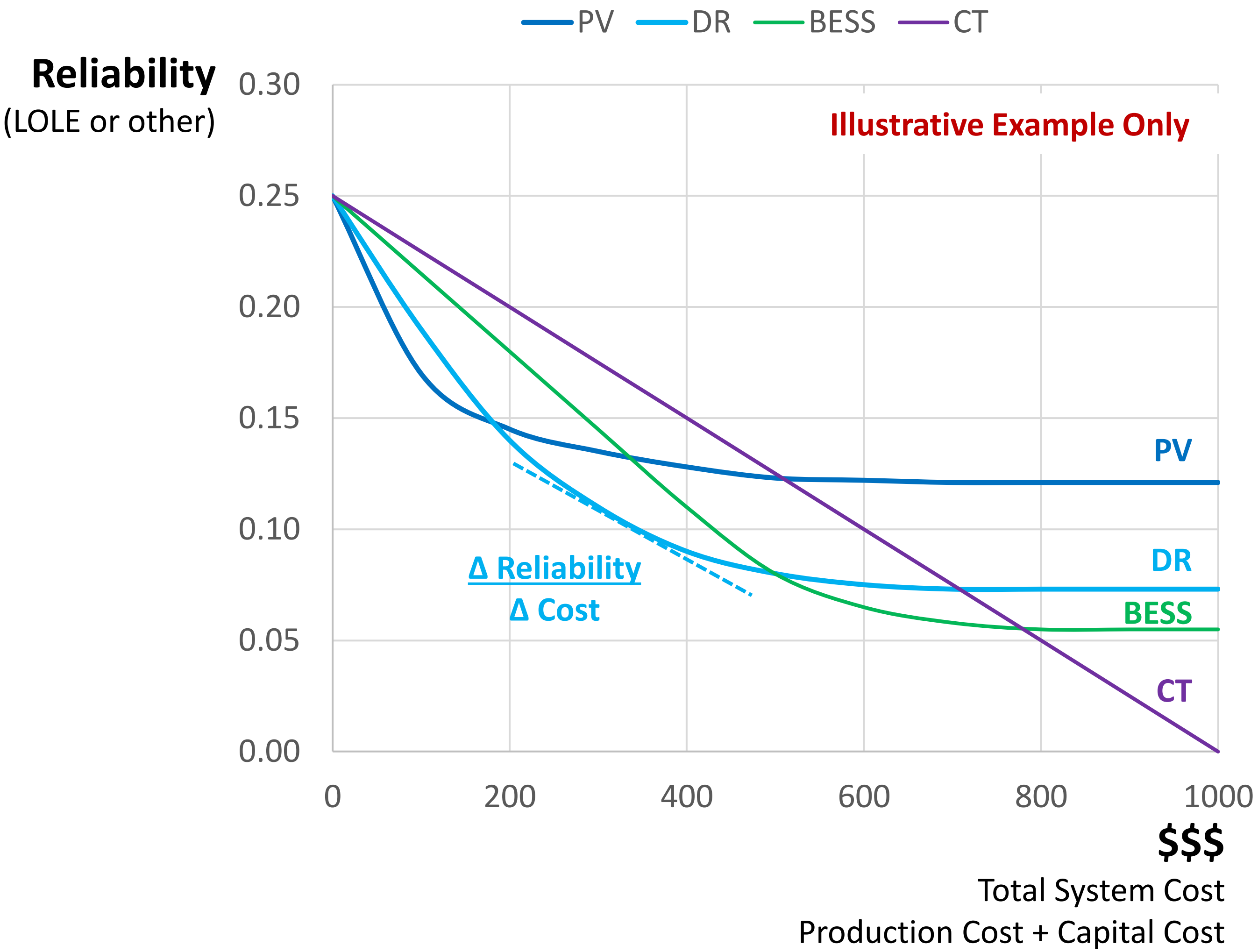
(Firm Capability – Maintenance Units + Hourly Dependable Capacity + Shifted Load + Interruptible Load) ≥ Load Demand * (1+ERM)

16

- Available energy is compared to the load on an hourly basis.
- An hour in which the energy reserve margin is not satisfied is considered at-risk and may result in unserved energy.

What if we cut out the “middle man” of PRM?

- Can we have a planning process that does not require the translation of resource adequacy metrics into a PRM?
- ELCC can continue to be used for accreditation and valuation
- Resource adequacy metrics could be used directly in the capacity procurement process
- Quantify a resource’s reliability benefits relative to system cost
- Stochastic capacity expansion planning someday?



Thank You!

Questions?

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Telos Energy

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