Redefining Resource Adequacy Metrics for Modern Power Systems

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EPRI Resource Adequacy Initiative

Address Industry Needs

RA Process

- **Recommended Metrics and Criteria**
- **Consistent Approach to Developing Scenarios**

Models and Data

- **Approaches to Modelling Power System Resources**
- **Developing Guidance on Data Requirements**

Analysis Tools

- **Understand Existing RA Tool Capabilities**
- **Application of New Approaches in Tools**

Case Studies

Develop evidence base for main questions through comparative case studies across multiple tools: ERCOT, North-East, South-East, Western Interconnect, SPP, MISO

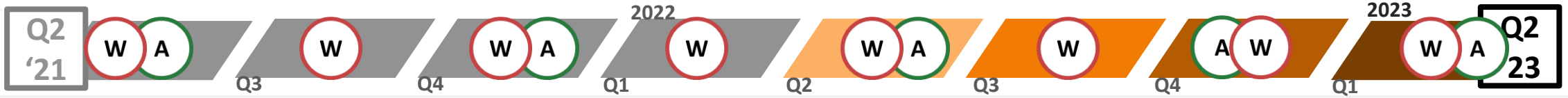
Engage

External Advisory group: NARUC, RROs, DOE, ESIG, EEI, ISO/RTOs, G-PST, et. al.
R&D Partners: Consultants, Universities

www.epri.com/resource-adequacy for more details

Timeline

W Workshop A Advisory Mtg.



Metrics and Criteria for Resource Adequacy

Motivation

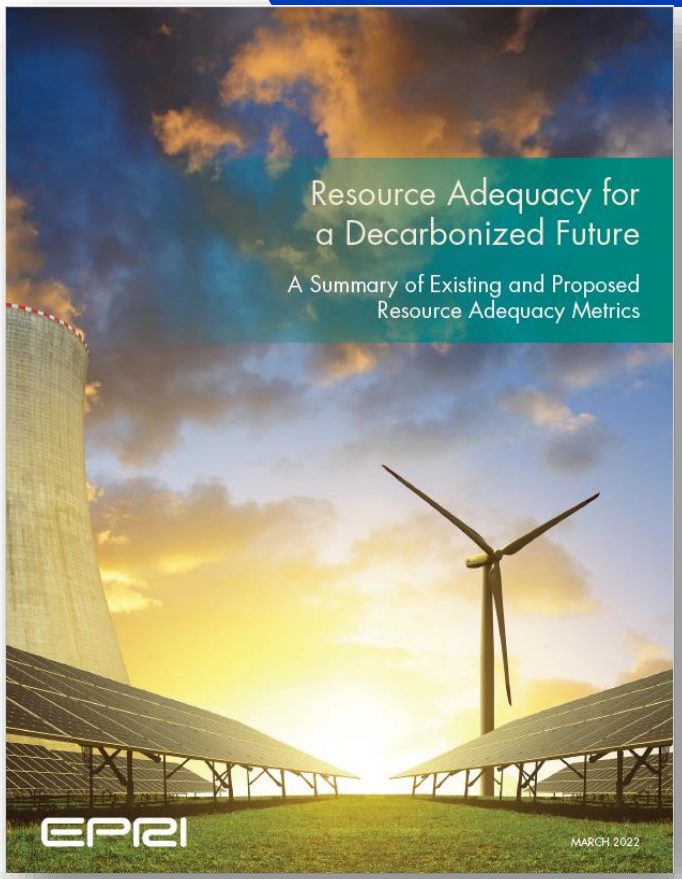
The metrics traditionally used to assess adequacy risk and the criteria established for planners to adhere to may not perform as expected in the future

Objective

Identify appropriate adequacy assessment metrics and minimum criteria for low carbon systems in changing climate/weather extremes.

Work to date

» White paper published in April 2022 summarizes existing and proposed RA metrics (visit https://www.epri.com/resource-adequacy to download)



Future work

» Complementary “Resource Adequacy Philosophy” document to be publicly released by EPRI team in Q4 2022

» A suite of RA risk and capacity valuation metrics to be evaluated through case studies

» A second white paper published in Q1 2023 will propose recommendations for metrics use and minimum criteria setting, based on system characteristics and intended study uses.

Survey of Existing and Proposed Metrics

- Categorizes as probabilistic and deterministic, with some additional indices that may be considered related to RA
  - Probabilistic tend to give the more detailed results
  - Deterministic used in resource planning or markets

- Metrics for resource contribution also important

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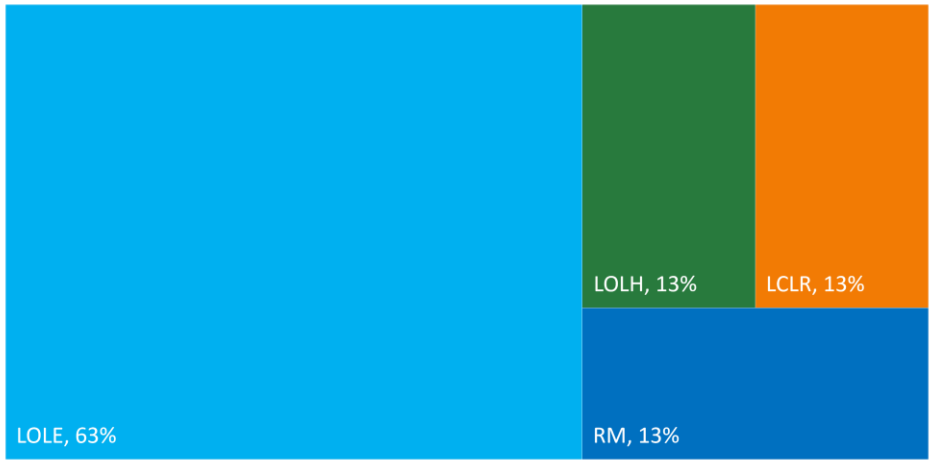
Metrics currently used for RA



- Survey of 20+ US utilities and ISOs

Metric	Abbreviation	Units	Definition
Loss-of-load expectation	LOLE	Time periods/year*	Average number of event-periods per year* across all of the random samples simulated. The LOLE metric can be applied to any time period length, and must be clearly defined by the user.
Loss-of-load hours	LOLH	Hours/year*	Average event-hours per year* across all of the random samples simulated.
Loss-of-load days	LOLD	Days/year*	Average event-days per year* across all of the random samples simulated.
Loss-of-load years	LOLY	Years/study horizon	Average event-years per study horizon across all of the random samples simulated.
Loss-of-Load probability	LOLP	%	Calculated as the total number of event-periods divided by the total number of time periods sampled. The LOLP metric can be applied to any time period length and study horizon, and must be clearly defined by the user.
Loss-of-load events	LOLEv	Events/year*	Average count of events per year* across all of the random samples simulated.
Expected unserved energy	EUE	MWh/year*	Average load not served per year* due to shortfall events across all of the random samples simulated.
Normalized expected unserved energy	nEUE	%	Average load not served per year* due to shortfall events across all of the random samples simulated, calculated as a percentage of system load.

*Alternative study horizons can be defined for this metric, although an annual study horizon is most common.

- **Many respondents indicated LOLE as their main metric**
- **Minimum reliability criteria varies, but 0.1 day per year is most common**

Also could have combination metrics, e.g. EUE/LOLH, full distribution of events and time of day/year

Resource Contribution Metrics

- Other approaches also being examined, including both retrospective and prospective analysis and looking at tight conditions

Method	Type	Computational Burden	Data Requirements
Effective Load Carrying Capability	Probabilistic	+++	+++
Equivalent Firm Capacity	Probabilistic	+++	+++
Equivalent Conventional Power	Probabilistic	+++	+++
Installed Capacity	Approximation	+	+
Unforced Capacity	Approximation	+	+
Generation Over Peak Load	Approximation	+	++
Generation Over Net Peak Road	Approximation	+	++
Generation Over Peak LOLP Hours	Approximation	++	++

+ = low, ++ = medium, +++ = high

Metrics in use around the world

Country or Region	Metrics/Criteria	Responsible Entity
North America [19] [20]		
MISO	LOLE ≤ 0.1 days/year	MISO
MRO-Manitoba Hydro	LOLE ≤ 0.1 days/year	Manitoba Public Utilities Board
NPCC-Maritimes	LOLE ≤ 0.1 days/year	Maritimes Sub-areas and NPCC
NPCC-New England	LOLE ≤ 0.1 days/year	ISO-NE and NPCC
NPCC-New York	LOLE ≤ 0.1 days/year	NYSRC and NPCC
NPCC-Ontario	LOLE ≤ 0.1 days/year	IESO and NPCC
NPCC-Québec	LOLE ≤ 0.1 days/year	Hydro-Québec and NPCC
PJM	LOLE ≤ 0.1 days/year	PJM Board of Managers
SERC-C	LOLE ≤ 0.1 days/year	Member Utilities
SERC-E	LOLE ≤ 0.1 days/year	Member Utilities
SERC-FP	LOLE ≤ 0.1 days/year	Florida Public Service Commission
SERC-SE	LOLE ≤ 0.1 days/year	Member Utilities
SPP	LOLE ≤ 0.1 days/year	SPP RTO Staff and Stakeholders
TRE-ERCOT[1]	LOLE ≤ 0.1 days/year	ERCOT Board of Directors
WECC-AB	LOLP[2] ≤ 0.02%	WECC
WECC-BC	LOLP[2] ≤ 0.02%	WECC
WECC-NWPP-US & RMRG [21]	LOLE ≤ 0.1 days/year	WECC
WECC-SRSG	LOLP[2] ≤ 0.02%	WECC
WECC-CAMX [22]	PRM ≥ 15%	WECC
Hawaii [23]	ERM ≥ 30% (3 islands), 60% (2 islands)	HECO

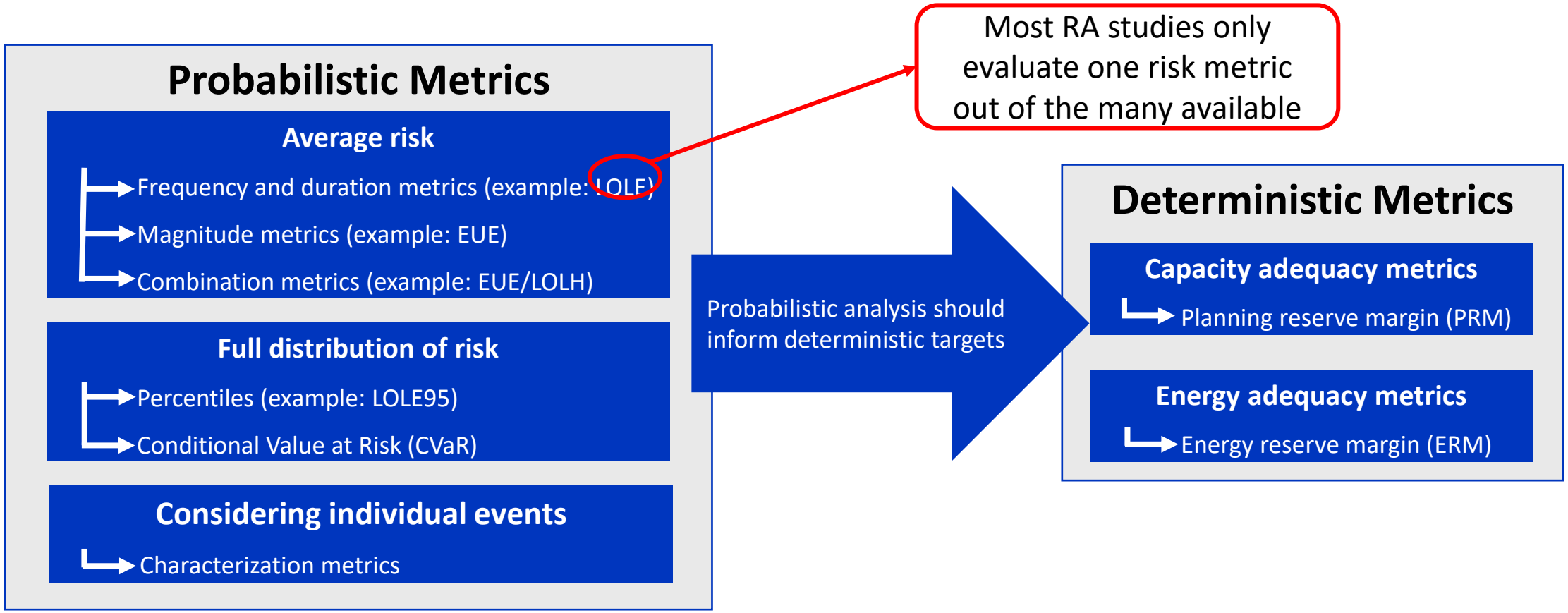
[1] LOLE is reported as a guideline metric not a requirement in the ERCOT system which relies on energy only and scarcity pricing to meet resource adequacy needs.
[2] The LOLP metric represents an event-period of 1 day and a horizon of 10 years.

Metrics in use around the world

Country or Region	Metrics/Criteria	Responsible Entity
Europe [17] [24]		
Belgium [25]	LOLH ≤ 3 hours/year; LOLH95 ≤ 20 hours/year	Elia Group
France [26]	LOLH ≤ 3 hours/year	RTE
Great Britain [27]	LOLH ≤ 3 hours/year	National Grid ESO
Ireland and Northern Ireland [28]	LOLH ≤ 8 hours/year (Ireland) LOLH ≤ 4.9 hours/year (Northern Ireland)	EirGrid and SONI
Netherlands [29]	LOLH ≤ 4 hours/year	TenneT
Poland [30]	LOLH ≤ 3 hours/year	PSE
Portugal [26]	LOLH ≤ 5 hours/year	REN
Spain [26] [31]	PRM ≥ 10% (Mainland); LOLE ≤ 1 day in 10 years (Island grids)	REE
Oceania		
Australia-NEM [32]	NEUE ≤ 0.002% per region	AEMO
Australia-NT [33]	NEUE ≤ 0.002%	AEMO
Australia-WEM [34]	PRM ≥ WEM metric; NEUE ≤ 0.002%	AEMO
New Zealand [35] [36]	WEM ≥ 14-16% (New Zealand); WEM ≥ 25.5-30% (South Island); WCM ≥ 630-780 MW (North Island)	Transpower
Africa		
South Africa [37]	EUE < 20 GWh/year; OCGT capacity factor < 6%/year; Baseload stations capacity factor < 50%/year	Eskom
Asia		
India [38]	LOLP ≤ 0.2%; NEUE ≤ 0.05%	CEA
Indonesia [39]	PRM (2019-2028) ≥ 30% (National)	Ministry of Energy and Mineral Resources
Japan [40]	PRM (2020-2029) ≥ 8% per region	OCCTO
Laos [41]	PRM (2020-2030) ≥ 15%	Ministry of Energy and Mines
Malaysia [42]	LOLE ≤ 1 days/year	TNB
Philippines [43]	PRM (2017-2040) ≥ 25%	DOE
Singapore [44] [45]	LOLH ≤ 3 hours/year	EMA
Thailand [46] [47]	PRM (2015-2036) ≥ 15%	EGAT
Vietnam [48]	LOLH ≤ 12 hours/year per region	MOIT
Middle East		
Saudi Arabia [49]	PRM (2016) ≥ 8-10%	SEC
Oman [50]	LOLH ≤ 24 hours/year	OPWP
Qatar [51]	PRM (2019) ≥ 6%	KAHRAMAA

Metrics and Criteria for RA – Key Insights

1. Avoid relying on a single metric
2. Better leverage existing metrics
3. Ensure metrics are appropriate for intended uses and systems studied



Avoid relying on a single metric

Example from ERCOT case study
Draft results, likely to change,
for illustration only

	Samples	Shortfall	LOLE	LOLEv	LOLH	LOLP	EUE	NEUE	EUE/LOLE	LOLH/LOLE
	Years	Days	Days/yr	Events/yr	Hours/yr	% of Days	MWh/yr	ppm*	MWh/event	Hours/event
2023	600	57	0.095	0.098	0.34	0.03%	526	1.3	5,539	3.6
2026	600	56	0.093	0.120	0.31	0.03%	502	1.1	5,379	3.3
2030	600	60	0.100	0.117	0.38	0.03%	701	1.4	7,010	3.8

frequency | size | duration

*ppm = parts per million,
Also expressed as 0.0001%
For reference, AEMO RA criteria = 0.002%

- Three future portfolios were developed to bring the system to a ~0.1 days/year LOLE criteria
  - Note: ERCOT does not have a stated reliability criterion
  - Allows different portfolios to be compared against one another consistently
  - 2023 had lower than 0.1 days/year LOLE, additional 684 MW was retired
  - 2026 and 2030 were higher than 0.1 days/year, so additional firm capacity was added (700 MW, and 2250 MW respectively)
- 2030 portfolio has slightly higher EUE, suggesting larger event sizes
- Normalized EUE ~1.1 – 1.4 ppm, or 0.0001%

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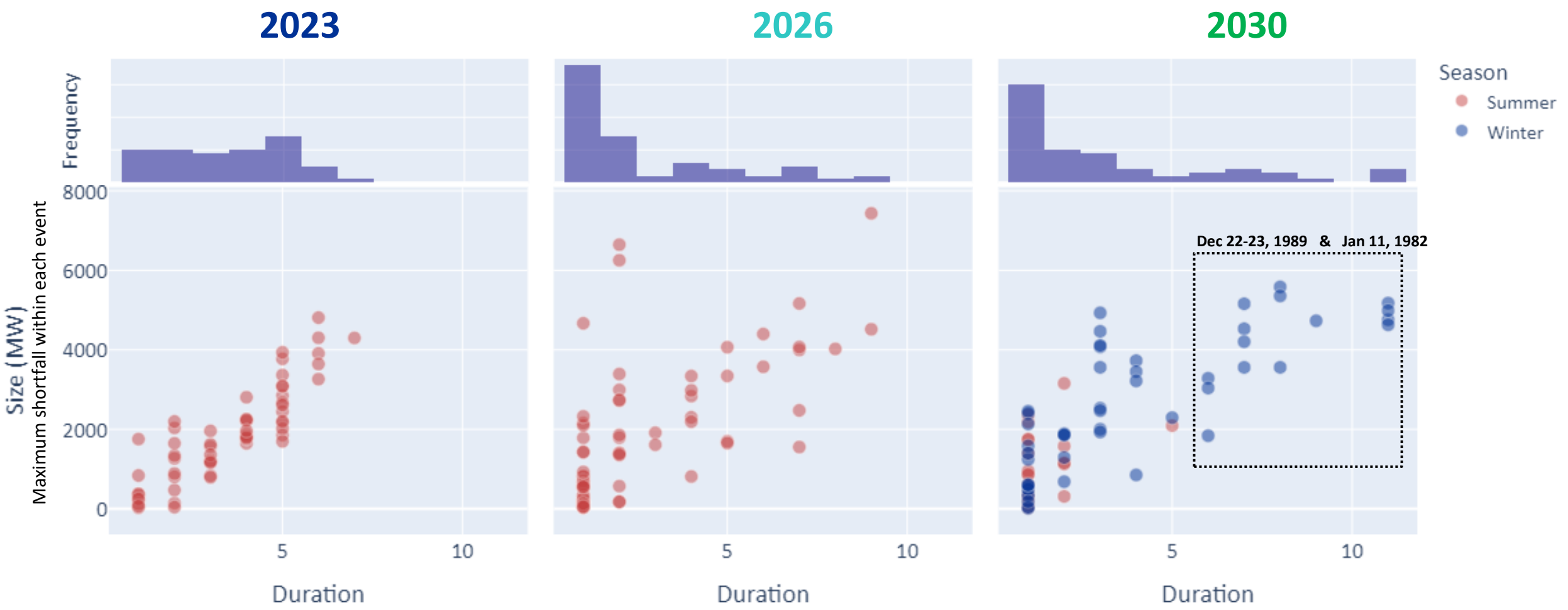
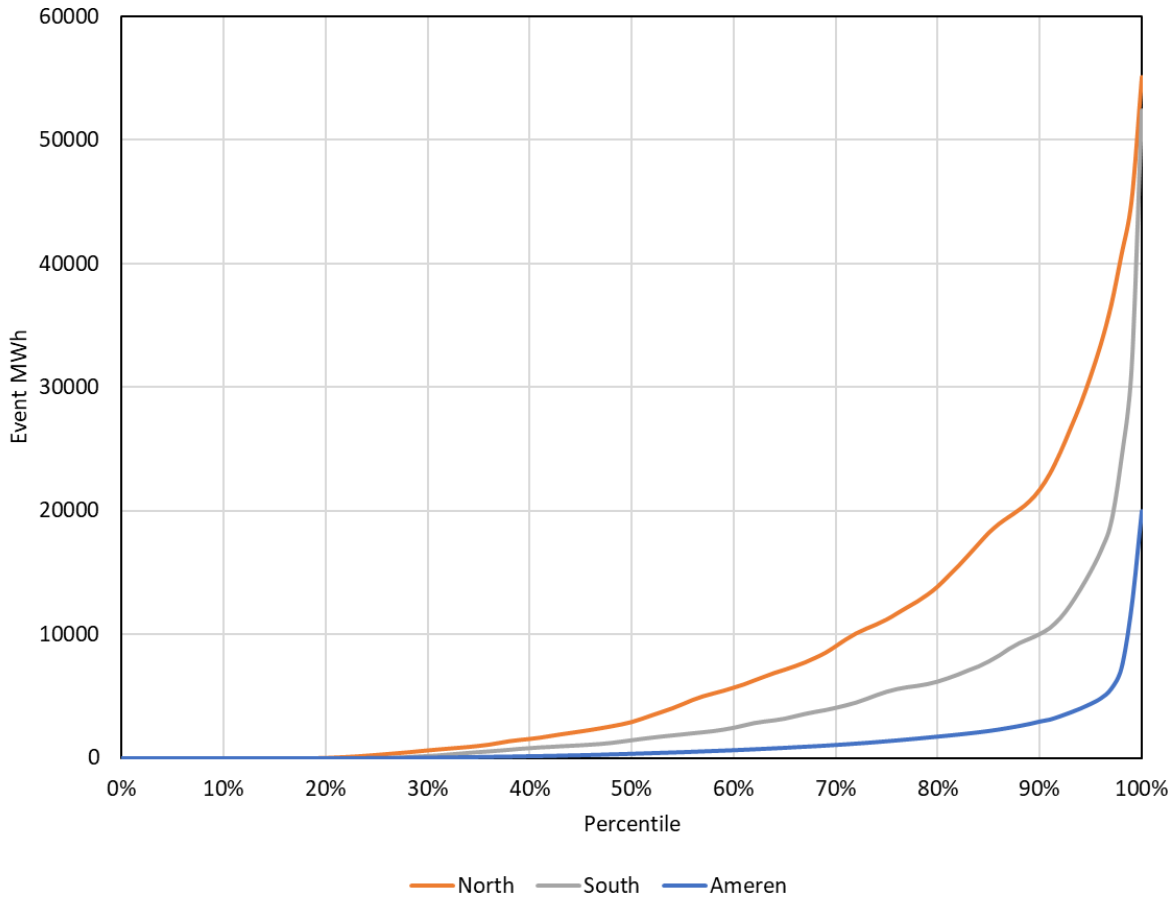
Better leverage exiting metrics



30% of events occur on June 25-26, Weather Year 2012

47% of events occur on Dec 22-23, Weather Year 1989 & Jan 11, Weather Year 1982

May need to think about extremes and what happens there



Region	MWh Shed		Multiplier (99th/50th)
	Median	99th Percentile	
North	2,940	45,119	15
South	1,469	15,132	21
Single zone	396	4,862	50

Example from MISO case study
Draft results, likely to change, for illustration only

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Ongoing work – case studies

Risk Metric	Definition	Calculated in case studies
LOLE (days/year)	Average number of event-days per year across all of the random samples simulated	Calculated in all regions, often by month/weather year, zone and at different percentiles
LOLP (%)	Defined as LOLE/365	Calculated for some regions and in some level of detail (weather year, zone, etc.)
LOLH (hours/year)	Average number of event-hours per year across all of the random samples simulated	Calculated in most regions, often by month/weather year, zone and at different percentiles
LOLEv (events/year)	Average count of events per year across all of the random samples simulated	Calculated for some regions and in some level of detail (weather year, zone, etc.)
EUE (MWh/year)	Average load not served per year due to shortfall events across all of the random samples simulated	Calculated in all regions, often by month/weather year, zone and at different percentiles
NEUE (%)	Average load not served per year due to shortfall events across the random samples simulated, calculated as a percentage of system load	Calculated for some regions and in some level of detail (weather year, zone, etc.)
LOLH/LOLE (hours/day)	average number of unserved load hours per loss-of-load day across all of the random samples simulated	Calculated for some regions for expected values
average event duration (hours)	average duration of a loss of load event across all of the random samples simulated	Calculated for some regions for expected values
histogram of shortfall events by duration	across all random samples simulated, events are categorized into buckets based on the duration of the shortfall event (e.g., x shortfall events between 0-1 hr duration, y shortfall events between 1-2 hour duration, etc)	Calculated for some regions for expected values
histogram of shortfall events by magnitude	across all random samples simulated, events are categorized into buckets based on the magnitude of the shortfall event (e.g., x shortfall events between 0-50 MWh magnitude, y shortfall events between 50-100 MWh magnitude, etc)	Calculated for some regions for expected values

Challenges and Next Steps

- Which metrics provide a complete picture of the risk profile?
- Are metrics straightforward to use and understand?
- How to capture high-impact low probability events?
- What counts as a loss of load event?
- Do metrics appropriately capture insufficiencies in capacity, energy and flexibility?
- Are accreditation metrics coherent between one another and appropriate to the nature of the resources dispatched?
- How to set minimum reliability criteria based on economic considerations?

- Next Steps
- Recommendations on what metrics are best to use (individual or combination), as well as how to set criteria
- Visualization tools developed to illustrate different type of metrics and how they can be calculated
- www.epri.com/resource-adequacy for more details