CLEAN ENERGY SOLUTIONS CENTER
ASSISTING COUNTRIES WITH CLEAN ENERGY POLICY
An Initiative of the Clean Energy Ministerial

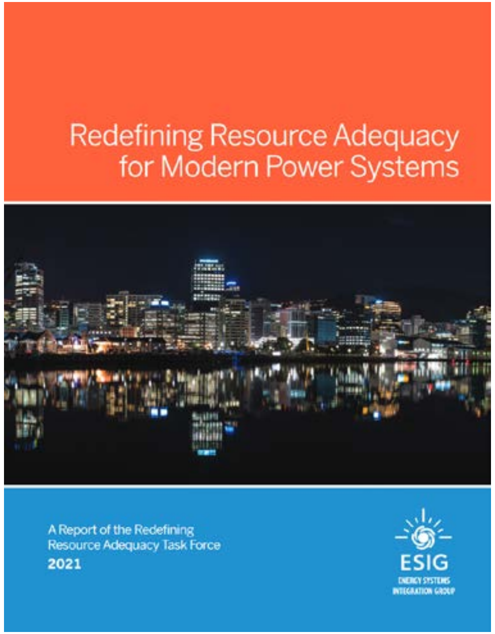
21st CENTURY POWER PARTNERSHIP
AN INITIATIVE OF THE CLEAN ENERGY MINISTERIAL

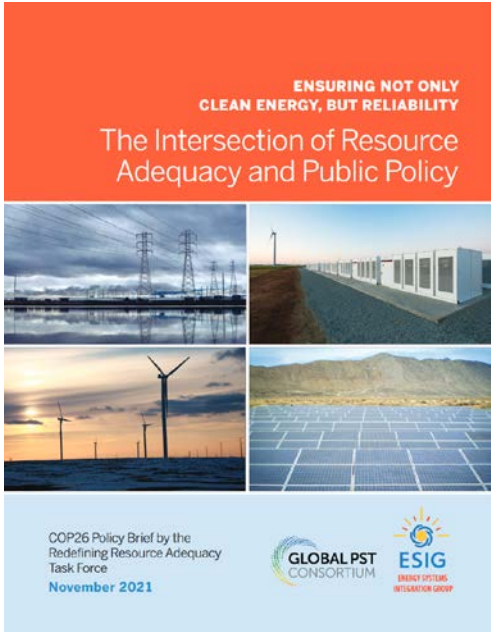
Resource Adequacy in Decarbonizing Power Systems

Gord Stephen
National Renewable Energy Laboratory (NREL)

May 24, 2023

Today’s content based on…





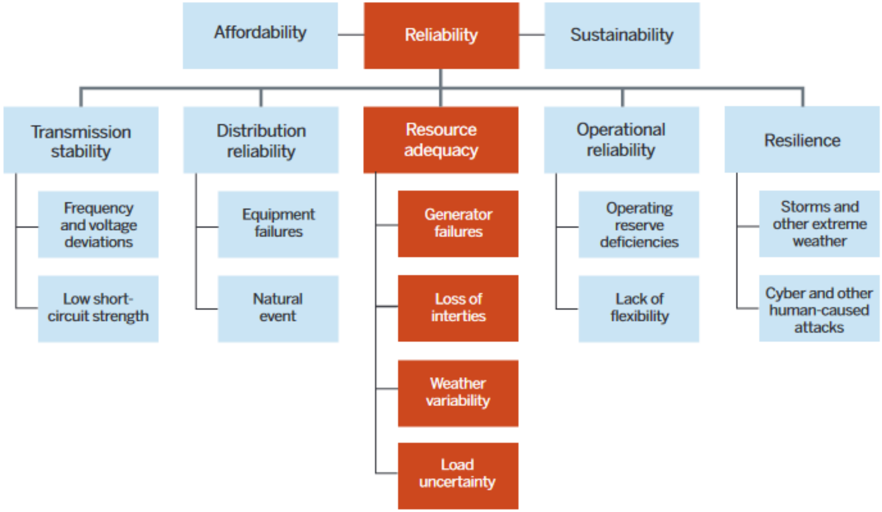
https://www.esig.energy/resource-adequacy-for-modern-power-systems/

What is resource adequacy?

“Resource adequacy (RA) studies assess whether a power system has an appropriate set of resources to maintain continuous service to demand, with a desired level of certainty”

Resource Adequacy for a Decarbonized Future: A Summary of Existing and Proposed Resource Adequacy Metrics, EPRI, April 2022

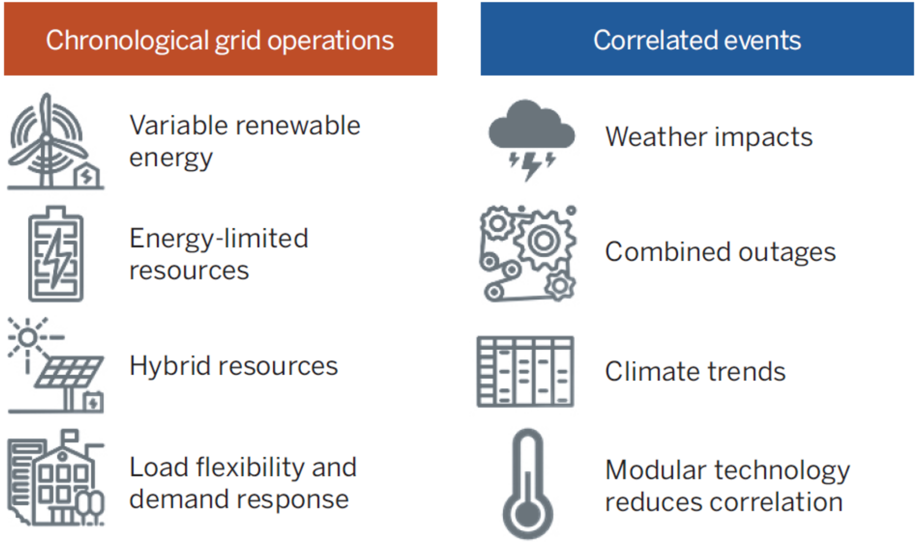
- RA is just one aspect of grid reliability and overall grid performance



Source: Energy Systems Integration Group.

Why modernize resource adequacy analysis?

- Historical adequacy assessment focused on independent mechanical outages of thermal generating units
- Resource interactions and risk drivers in modern power systems can look dramatically different



Source: Energy Systems Integration Group.

Six Principles for Resource Adequacy Analysis

Principle 1
Quantifying size, frequency, duration, and timing of capacity shortfalls is critical to finding the right resource solutions.

Principle 2
Chronological operations must be modeled across many weather years.

Principle 3
There is no such thing as perfect capacity.

Principle 4
Load participation fundamentally changes the resource adequacy construct.

Principle 5
Neighboring grids and transmission should be modeled as capacity resources.

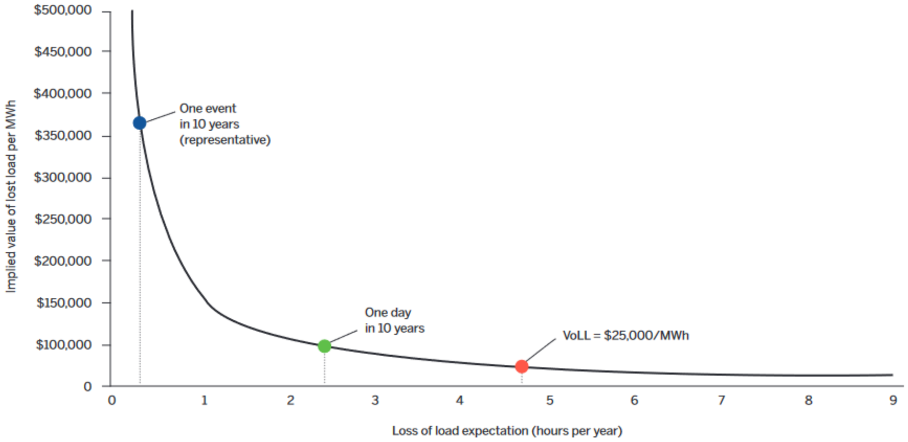
Principle 6
Reliability criteria should be transparent and economic.

Principle 6: How much adequacy do we need?

- Both technical and economic factors need to be considered when defining an “acceptable” adequacy level
- Electricity shortfalls are undesirable, but so are high system costs
- Need to find the balance that is appropriate for the specific system context

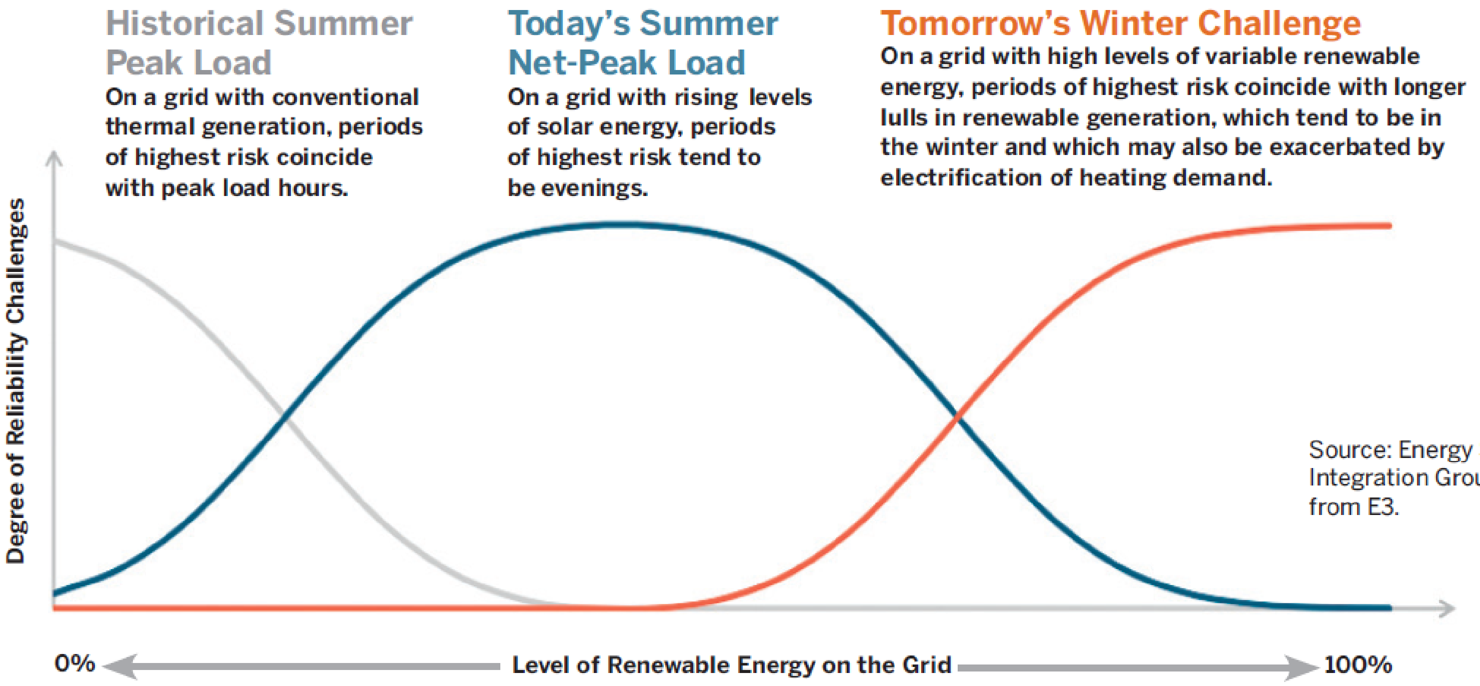
Benefit of reliability

Cost of reliability



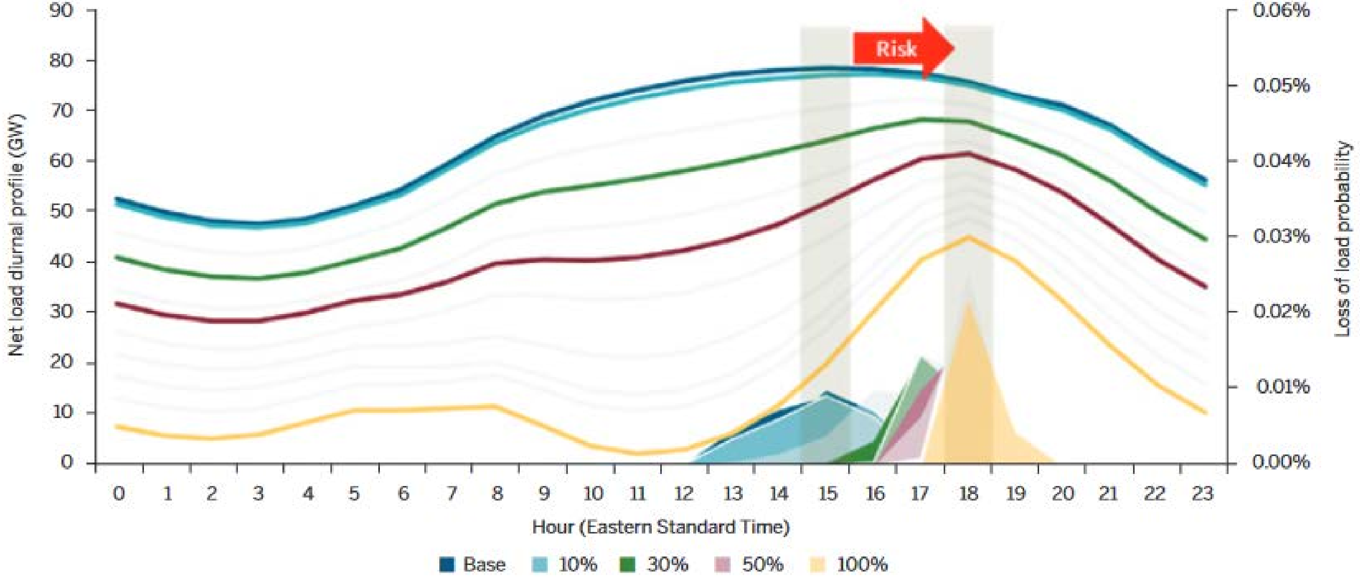
Source: Regulatory Assistance Project / Hogan and Littell (2020).

Principle 2: Study chronology and multiple weather years



Source: Energy Systems Integration Group, adapted from E3.

Principle 1: Identify specific risk characteristics

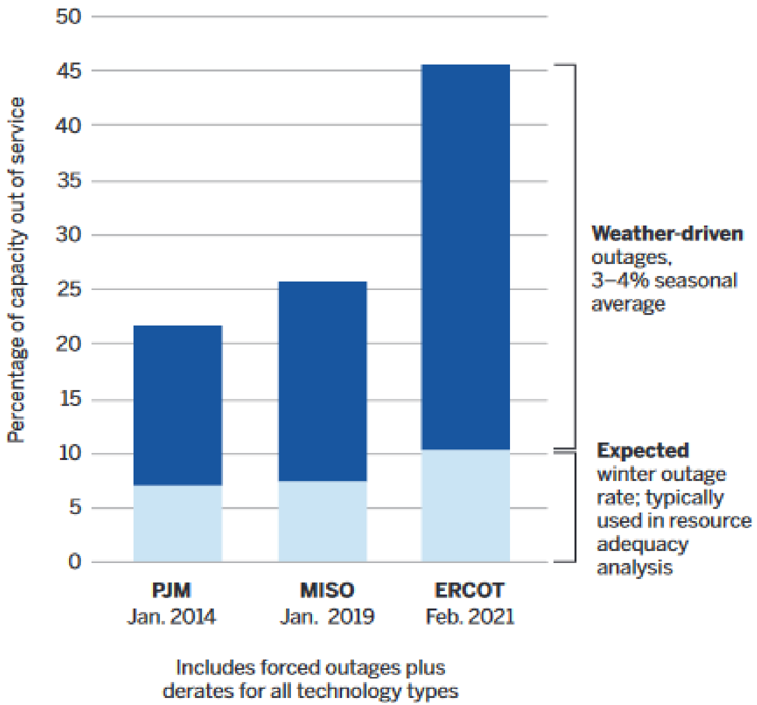


Source: Midcontinent Independent System Operator (2021).

Principle 3: No perfect capacity

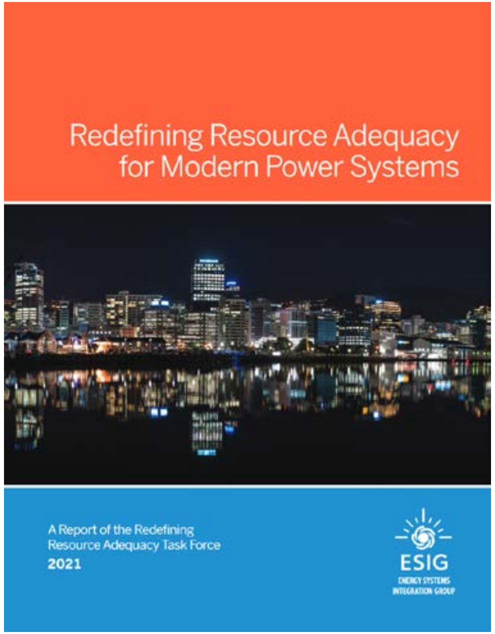
- All generating resources, including thermal generation, face unavailability risks

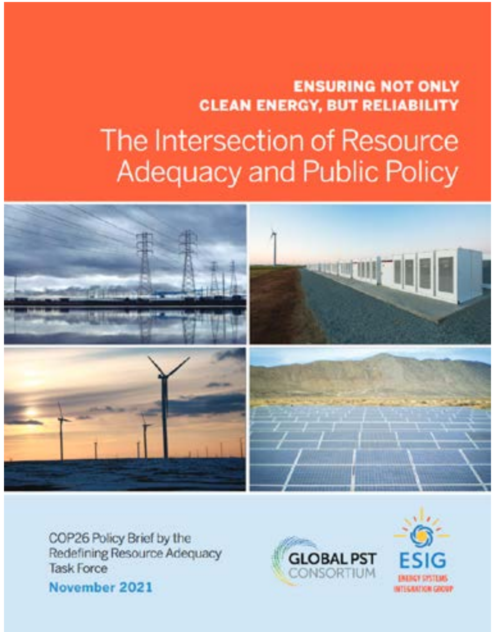
- Need to better capture this risk (including timing, outage correlation, and common-mode failures) when considering system adequacy and comparing potential adequacy investments



Source: Energy Systems Integration Group.

Full reports, executive summaries and fact sheets

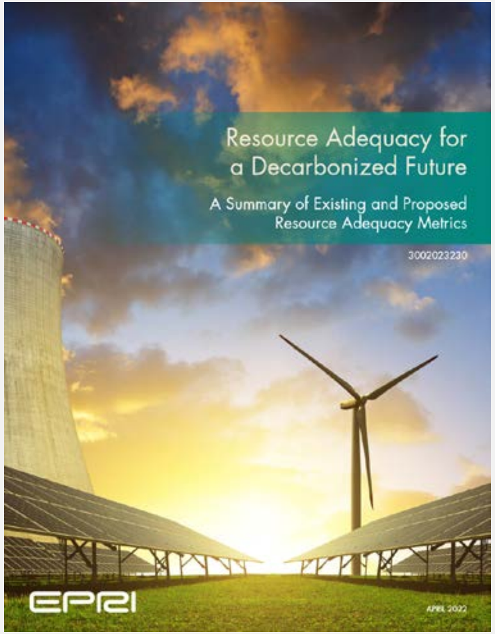




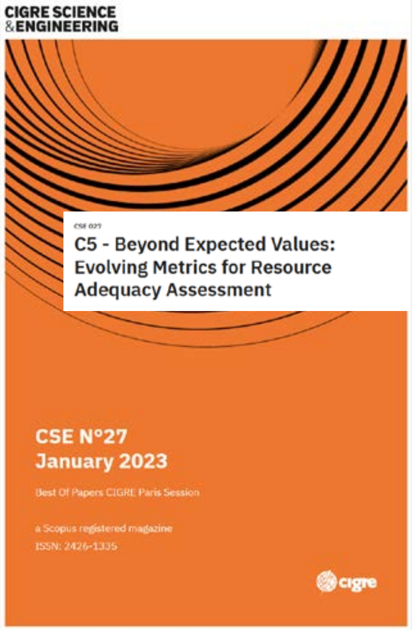
https://www.esig.energy/resource-adequacy-for-modern-power-systems/

Further resources

Adequacy Risk Metrics

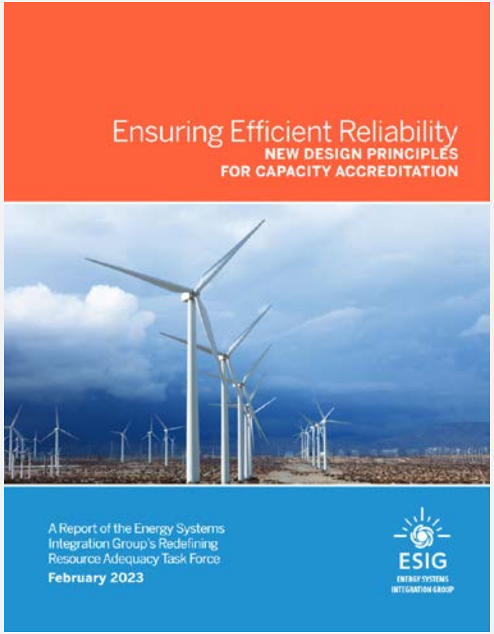


https://www.epri.com/research/products/000000003002023230



https://cse.cigre.org/cse-n027/c5-beyond-expected-values-evolving-metrics-for-resource-adequacy-assessment

Capacity Accreditation



https://www.esig.energy/new-design-principles-for-capacity-accreditation/

Further resources

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.

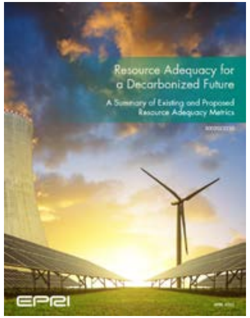
Method	Type	Computational Burden	Data Requirements
Effective Load Carrying Capability	Probabilistic	+++	+++
Equivalent Firm Capacity	Probabilistic	+++	+++
Equivalent Conventional Power	Probabilistic	+++	+++
Installed Capacity	Approximation	+	+
Unforced Capacity	Approximation	+	+
Generation Over Peak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

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

Country or Region	RA Metrics/Criteria	Entity Calculating RA Metric
North America [20,21]		
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		
NPCC-Québec		
PJM Interconnection		
SERC-C		
SERC-E		
SERC-FP		
SERC-SE		
SPP		
TRE-ERCOT[3]		
WECC-AB		
WECC-BC		
WECC-WPP-US & RMRG [22]		
WECC-SRSG		
WECC-CAMX [23]		
Hawaii [24]		

Country or Region	RA Metrics/Criteria	Entity Calculating RA Metric
Europe [18,25]		
Belgium [26]	LOLH ≤ 3 hours/year LOLH95[5] ≤ 20 hours/year	Elia Group
France [27]	LOLH ≤ 3 hours/year	RTE
Great Britain [28]	LOLH ≤ 3 hours/year	National Grid ESO
Ireland and Northern Ireland [29]	LOLH ≤ 8 hours/year (Ireland) LOLH ≤ 4.9 hours/year (Northern Ireland)	EirGrid and SONI
Netherlands [30]	LOLH ≤ 4 hours/year	TenneT
Poland [31]	LOLH ≤ 3 hours/year	PSE
Portugal [27]	LOLH ≤ 5 hours/year	REN
Spain [27,32]	PRM ≥ 10% (Mainland) LOL	REE
Oceania		
Australia-NEM [33]	NEU	
Australia-NT [34]	NEU	
Australia-WEM [35]	PRM NEU	
New Zealand [36,37]	WE WE WC	
Africa		
South Africa [38]	EUE OC Bas < 5	

Country or Region	RA Metrics/Criteria	Entity Calculating RA Metric
Asia		
India [39]	LOLP[9] ≤ 0.2% NEUE ≤ 0.05%	CEA
Indonesia [40]	PRM (2019–2028) ≥ 30% (National)	Ministry of Energy and Mineral Resources
Japan [41]	PRM (2020–2029) ≥ 8% per region	OCCTO
Laos [42]	PRM (2020–2030) ≥ 15%	Ministry of Energy and Mines
Malaysia [43]	LOLE ≤ 1 days/year	TNB
Philippines [44]	PRM (2017–2040) ≥ 25%	DOE
Singapore [45,46]	LOLH ≤ 3 hours/year	EMA
Thailand [47,48]	PRM (2015–2036) ≥ 15%	EGAT
Vietnam [49]	LOLH ≤ 12 hours/year per region	MOIT
Middle East		
Saudi Arabia [50]	PRM (2016) ≥ 8–10%	SEC
Oman [51]	LOLH ≤ 24 hours/year	OPWP
Qatar [52]	PRM (2019) ≥ 6%	KAHRAMAA



https://www.epri.com/research/products/000000003002023230

CLEAN ENERGY SOLUTIONS CENTER
ASSISTING COUNTRIES WITH CLEAN ENERGY POLICY
An Initiative of the Clean Energy Ministerial

21st CENTURY POWER PARTNERSHIP
AN INITIATIVE OF THE CLEAN ENERGY MINISTERIAL

Thank you!

Gord Stephen
National Renewable Energy Laboratory
gord.stephen@nrel.gov

NREL/PR-6A40-86365