ESIG
ENERGY SYSTEMS
INTEGRATION GROUP

ESIG REPORT

New Resource Adequacy Criteria for the Energy Transition

MODERNIZING RELIABILITY REQUIREMENTS

EXECUTIVE SUMMARY

The transition toward a cleaner and more weather-dependent power system brings with it unprecedented challenges and opportunities for maintaining resource adequacy—namely, a future that includes rapid load growth, plant retirements, and a shift toward variable and energy-limited resources. Resource adequacy analyses, capacity accreditation, and the resource adequacy planning criteria are becoming increasingly important for power system planning and investment decisions.

While previous ESIG reports—*Redefining Resource Adequacy for Modern Power Systems* and *Ensuring Efficient Reliability: New Design Principles for Capacity Accreditation*—evaluated the changing resource adequacy risks and planning practices created by the energy transition, neither specifically examined potential changes to the resource adequacy criterion used for planning. The resource adequacy criterion sets the level of supply- and demand-side resources that are required for a given power system to meet reliability objectives. It is a pivotal standard that influences billions of dollars of investment decisions.

Limitations of the Current Resource Adequacy Criterion

The most common resource adequacy criterion is the loss-of-load expectation (LOLE), and is colloquially referred to as the 1-day-in-10 LOLE criterion across much of North America. The LOLE criterion has been the lynchpin of power system planning for decades. But resource adequacy criteria now need to do more—being not only about capacity shortfalls at any one point in time, but also about energy constraints that arise from variable renewables, increasing battery storage, and limited fuel supplies. Damages from outages increase at a nonlinear rate as events increase in duration and size, so it is important to differentiate between large or long-lasting outages versus short ones, and consider tail risks associated with high-impact, low-probability events.

The LOLE criterion has several limitations. First, it is treated as an arbitrary line in the sand rather than articulating resource adequacy as a continuum and a trade-off between cost and reliability. Second, it does not differentiate types of shortfalls, but rather treats risks associated with longer-duration or larger outages as equal to shorter, less severe outages. Third, it is a static criterion which in many regions has not changed in decades, despite rapid changes to the power system resource mix and electrification of new sectors. Lastly, the minimum threshold for the criterion is often set without considering the trade-off between cost and reliability.

There is a need to move beyond a single, one-size-fits-all resource adequacy criterion and move toward multi-metric criteria.

These limitations highlight a need to move beyond a single, one-size-fits-all resource adequacy criterion and augment it with multi-metric criteria. The ESIG Resource Adequacy Task Force identified the following critical features for a new resource adequacy criteria:

- Measures the magnitude (maximum MW and total MWh) of energy shortfalls and not just the number of times that shortfalls occur (their frequency)
- Captures tail risks and outlier events
- Explicitly considers the inherent trade-off between cost and reliability

See the full report:
New Resource Adequacy Criteria for the Energy Transition—Modernizing Reliability Requirements

Transitioning to Multi-metric Criteria

Loss-of-load expectation as the sole resource adequacy criterion represents only a single dimension of risk. It needs to be supplemented. A significant limitation of the single criterion approach is its failure to differentiate among the size, frequency, duration, and timing of shortfalls. This is a critical omission, as damages associated with power system shortfalls are nonlinear. Longer and larger disruptions lead to disproportionately greater damages, yet the LOLE metric treats all resource adequacy shortfalls equally. This equal weighting does not accurately reflect the real-world impacts of loss of load, which vary greatly in severity and consequences. Tail events—those which may occur seldomly but have disproportionately high impacts and costs—require additional focus. Using resource adequacy criteria that explicitly differentiate between resource adequacy shortfalls is beneficial.

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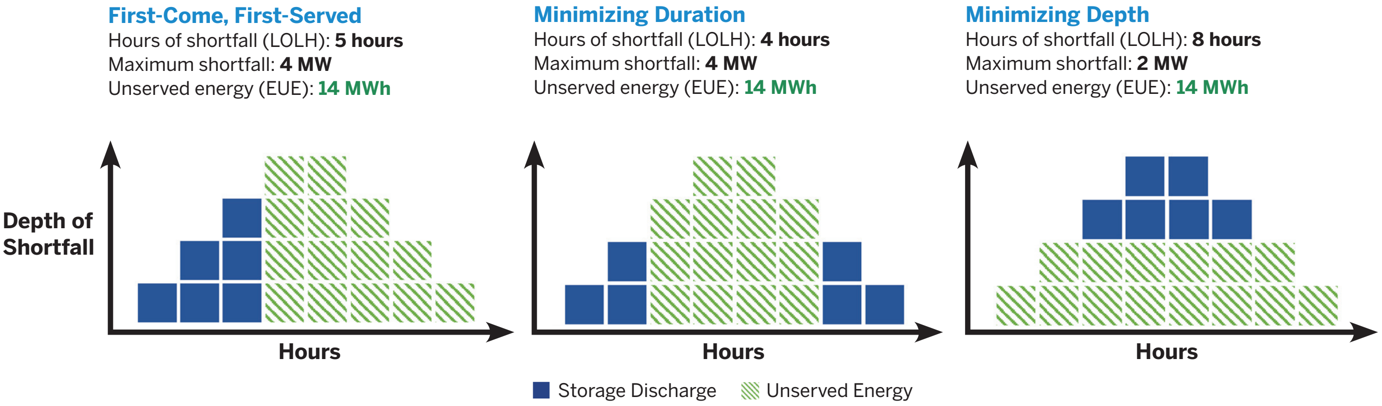
Expected unserved energy (EUE) is a preferred addition to incorporate size of shortfalls, especially as the system moves toward energy limitations. A first step to better differentiating resource adequacy shortfalls is adding EUE as a resource adequacy criterion. EUE measures the expected (i.e., average) amount of unserved energy per year, averaged across all resource adequacy simulations. A first benefit is that, all other things equal, EUE places a greater emphasis on larger, more disruptive events, a critical consideration in differentiating shortfalls. A second benefit of EUE is that it explicitly measures power system energy limitations—an important consideration as the system becomes more energy-constrained (due to increased storage and load flexibility) and is not just capacity-constrained. In energy-limited systems, the way in which storage or load flexibility is utilized can greatly impact resource adequacy metrics. For example, when a system with short-duration storage capability faces a longer-duration shortfall, it has several options as to how it can deploy its stored energy, each of which yields a different residual shortfall. Operators can choose to use economic criteria to determine dispatch profile, deplete the storage energy as soon as a resource adequacy event starts (“first come, first served”),

FIGURE ES-1

Energy-Limited Resource Scheduling During a Loss-of-Load Event



The figure illustrates how battery storage scheduling can influence resource adequacy metrics. In each case, the total battery storage available is equal to 6 units (blue), and the total unserved energy is equal to 14 units (green). However, decisions of the battery storage scheduling can change LOLE, LOLH, and event characteristics.

Source: Energy Systems Integration Group, adapted from Dent (2019).

decrease the duration of the event ("minimize duration"), or decrease the maximum size of the event ("minimize shortfall") (Figure ES-1, p. 2). EUE also aligns well with economic metrics, as the value of lost load (VoLL) and other cost metrics are often expressed as $/MWh, facilitating a more straightforward translation between reliability and cost objectives.

No one metric is the solution; a multi-metric framework is needed to consider size, frequency, and duration of shortfalls. Given the evolving dynamics in resource adequacy analysis, the changing energy resource mix, and consumer preferences for reliability, adopting a multi-metric criteria approach may be prudent because it provides a more comprehensive assessment of the size, frequency, and duration of shortfalls; explicitly considers tail risks; and can stress-test extreme events that may fall outside historical records.

A multi-metric framework allows planners and regulators to embrace a flexible, multi-dimensional approach that adapts as the risks of the system change. It can also help identify and limit the most impactful risks for a given system and inform stakeholders of the potential size, frequency, duration, and timing of shortfalls.

Specifically Considering Extreme Events

Not all resource adequacy loss-of-load events are the same. Tail risks can have a disproportionate impact on reliability and costs and should be quantified in resource adequacy criteria. While traditional resource adequacy studies considered the probability of independent outages occurring at the same time, power system regulators and planners are increasingly concerned about the correlated risk of multiple stressors occurring simultaneously due to underlying weather conditions. These drivers could create tail risks—which are included in resource adequacy analyses, but may occur so seldom that they do not materially influence the average adequacy metrics. However, though they are rare, they are large enough to warrant further analysis and potential investment.

Such events are akin to a "100-year flood," which is statistically rare but can cause devastating and

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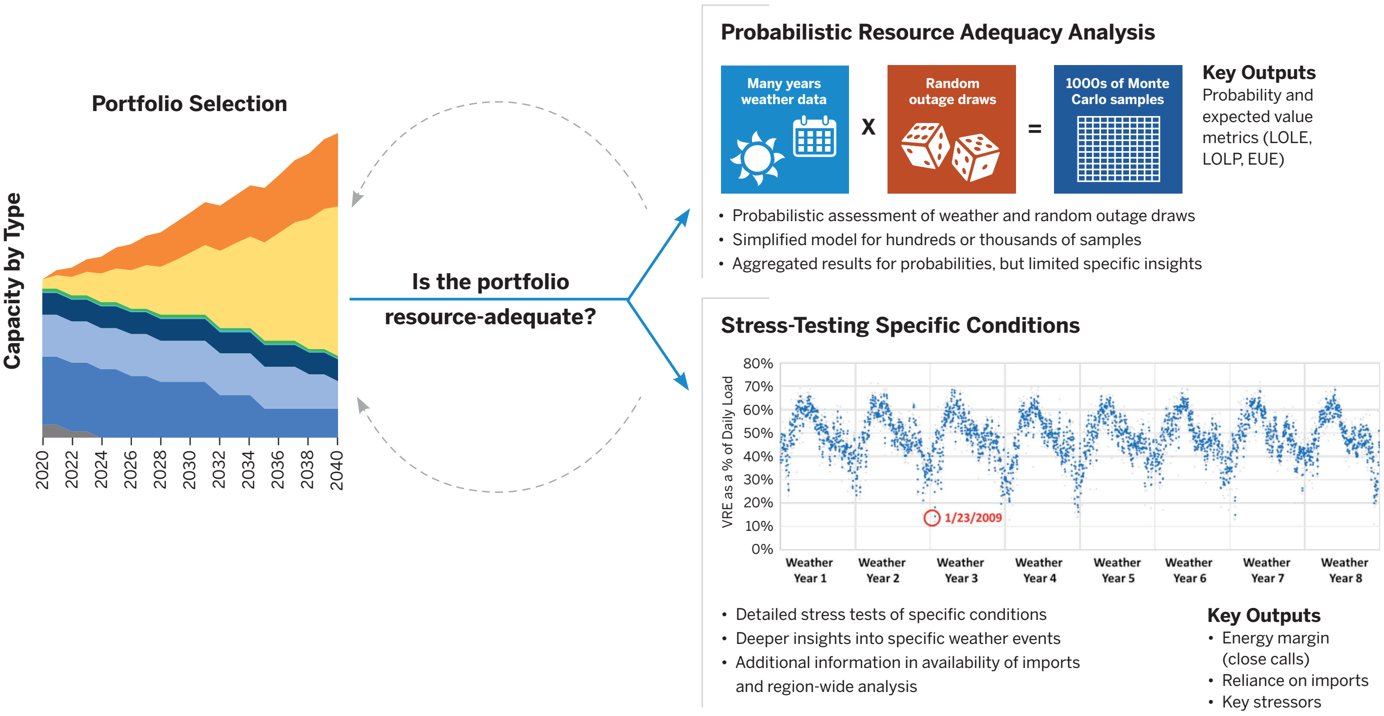
widespread damage. The cost of damages is often a highly nonlinear function of the size of a power system shortage. For example, a summer evening heat wave causing a shortfall for two to four hours might be far less damaging than a winter event of the same duration or an event of the same duration but much larger in scale.

Limited data are available to confidently determine the probability of extreme events. This reality may require discrete analysis or "stress testing" rather than a statistical measure. In some cases, the limited availability of data to confidently determine the probability of extreme events necessitates discrete analysis, or stress testing, rather than relying solely on statistical measures. The inclusion of probabilistic metrics in the planning criteria (like value at risk (VaR) or conditional value at risk (CvaR)), while important, may not be sufficient to ensure system adequacy against rare, high-impact, low-probability events (see Figure ES-2). Deterministic stress-testing evaluates the power system's resilience in specific scenarios, such as a wide-area heat wave, a winter cold snap with limited gas supplies, or a multi-day renewable drought. These events can be explicitly modeled, allowing planners and regulators to understand system risks and prioritize mitigations beyond simply adding new capacity, and offering insights into system vulnerabilities that probabilistic resource adequacy assessments might overlook.

> **Extreme events, such as a wide-area heat wave, a winter cold snap with limited gas supplies, or a multi-day renewable drought, can be explicitly modeled, allowing planners and regulators to understand system risks and prioritize mitigations beyond simply adding new capacity.**

FIGURE ES-2

Combining Probabilistic Resource Adequacy Analysis with Stress Testing



The figure illustrates the two-pronged approach of determining resource adequacy of a resource portfolio, one that includes probabilistic resource adequacy analysis and one that selects challenging time periods for a deterministic stress-testing approach.

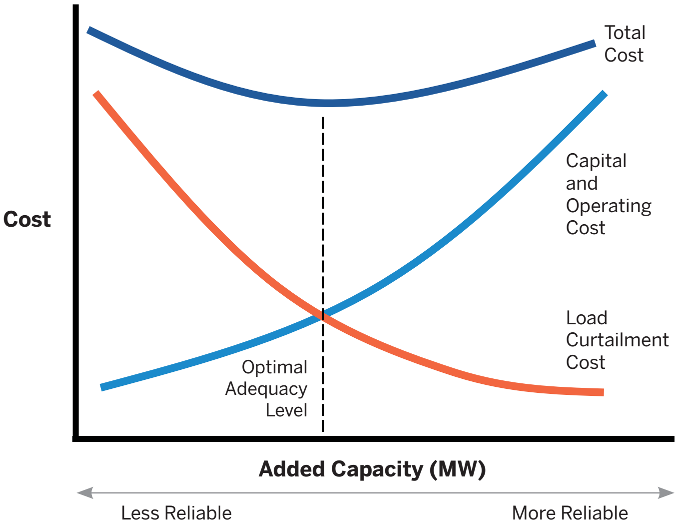
Source: GridLab (2022).

Incorporating Economics

The resource adequacy threshold should be used to establish the appropriate trade-off between reliability and cost. Cost and reliability are intrinsically linked, and this trade-off should be clear. Establishing the appropriate level of power system adequacy is not a straightforward task; it requires a collective judgment call involving planners, regulators, customers, and other stakeholders. Resource adequacy in power systems should not be viewed as black and white or a line in the sand. The objective of resource adequacy criteria is to strike the right balance between reliability and cost.

FIGURE ES-3

Optimal Adequacy Level as a Function of Investment Cost and Load Curtailment Damages



The figure illustrates the trade-off between resource adequacy as a function of added capacity (x-axis) and cost (y-axis). As capacity is added to the system, cost (damages) from load curtailment decreases, but the capital and operating costs increase. The optimum level of reliability is where the sum of the two costs, representing total costs, is minimized.

Source: Energy Systems Integration Group.

Setting the criteria too high can lead to prohibitively high investment costs, while setting the threshold too low risks diminished reliability and the potential for significant economic damages (Figure ES-3). It's crucial that this intrinsic link between cost and reliability is transparent and well understood by all involved parties.

Implementing changes to the reliability standard in the power system requires a broad consensus among various stakeholders. The utilities and grid operators—in consultation with stakeholders—can lead this reform and be the ones to establish the resource adequacy framework, the analytical methods, and metrics used to measure adequacy. They are also responsible for devising specific plans or markets to meet these standards at reasonable costs.

However, the responsibility for determining the level, or minimum threshold, of the resource adequacy criteria ultimately falls on regulators—not the utility or power system planners. They play a crucial role in ensuring that the trade-off between risk and economic factors is appropriately balanced, as this is ultimately a societal and equity decision. This division of responsibilities ensures that while the regulatory bodies establish the criteria, the actual implementation is carried out effectively by those managing the power system.

There are multiple ways to accomplish these goals. To effectively navigate the energy transition, new resource adequacy criteria must encompass, at a minimum, a multi-metric approach, including both LOLE and EUE. Additionally, indicators should capture tail risks, and the framework must be more transparent about providing an economic justification for the chosen reliability level. This comprehensive approach, though challenging, is crucial for ensuring the reliability of our current, and evolving, power systems.

New Resource Adequacy Criteria for the Energy Transition: Modernizing Reliability Requirements, by the Energy Systems Integration Group's Resource Adequacy Task Force, is available at https://www.esig.energy/new-resource-adequacy-criteria.

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The Energy Systems Integration Group is a nonprofit organization that marshals the expertise of the electricity industry's technical community to support grid transformation and energy systems integration and operation. https://www.esig.energy.