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A Guide for Improved Resource Adequacy Assessments in Evolving Power Systems

Executive Summary

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Executive Summary

Major weather events have caused widespread interruptions across vast regions in the U.S. In many cases, the power system did not have enough resources – including reserves – to meet demand due to a mix of higher than expected generation and transmission outages or deviations in short-term load or variable energy resources (VRE) generation forecasts. The ability of an electric power system to meet demands for electricity using its supply-side and demand-side resources is known as **resource adequacy (RA)** (NERC, 2011). The energy transition to highly decarbonized and electrified power systems with large penetration of VRE is requiring a revision of resource adequacy assessments to ensure the grid remains reliable, and potentially new types of assessment to ensure its resilience.

This paper identifies and evaluates issues in traditional resource adequacy assessment practices, and how adjusting these practices may depend on existing institutional arrangements for planning and procurement. The paper concludes by proposing a technical-institutional roadmap that would allow regulators in vertically-integrated jurisdictions and system planners and operators in restructured jurisdictions to revise resource adequacy practices across a range of components. More specifically, this paper provides answers to the following questions:

1. Who is the intended audience for this paper?
2. What are the key components of resource adequacy?
3. What are the emerging challenges with traditional RA assessments?
4. Should resilience be part of resource adequacy assessments?
5. What are key modeling practices that may improve RA assessments?
6. How may these technical changes in RA assessments affect other processes?
7. What are best practices for RA in planning processes?

Who is the intended audience for this paper?

This work caters to two distinct audiences:

- Regulators, policy-makers, and market designers will learn how the evolving power grid is prompting a need to review fundamental aspects of resource adequacy. The summary of recent developments in Section 3 should be accessible to understand the basic technical challenges, and Section 5 should provide insights on how the required changes will interact with existing planning processes developed in IRP and by ISO/RTO. These stakeholders may also be interested in latest developments in the treatment of resilience in planning processes, described in Section 2.
- System planners, researchers, analysts, and other stakeholders with a technical leaning may benefit from the organizational framework and discussion of adequacy provided in this Sections 1 and 2. The technical analysis in Section 4 and Appendix A should be relevant for these

audiences to learn about the benefits in complexity and accuracy of more detailed RA assessment models. These stakeholders may also benefit from reviewing Section 5, where the integration of RA assessment outcomes into planning and procurement practices raises new challenges.

What are the key components of RA?

Resource adequacy is a property of a power system, but the term is also used to refer to the process of tracking, assessing, and achieving adequacy. We propose decomposing adequacy in five key components or activities given the lack of an existing organizational framework (see Figure ES-1).

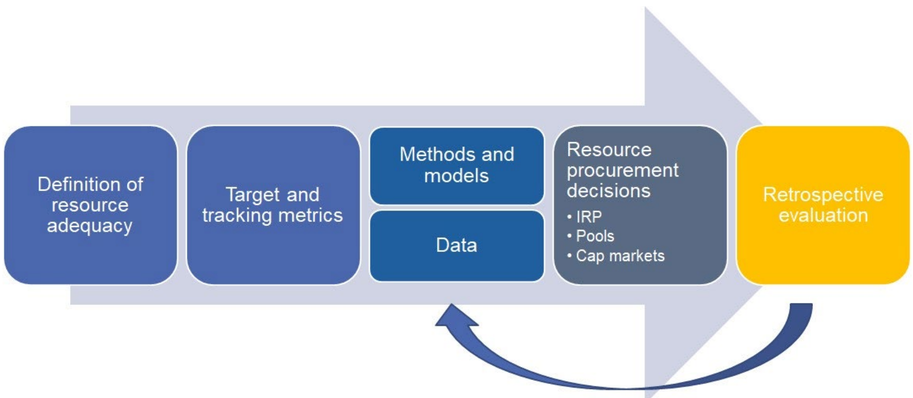

Figure ES-1 Resource adequacy framework developed in this paper

The first three components are technical in nature. How adequacy is defined; the metrics used to track adequacy and set targets; and the data, methods, and models employed have been the focus of recent research. The way adequacy assessments are translated into procurement decisions – and the potential role that this translation has in actual RA performance – has received less attention. This paper explores some aspects of this assessment-to-procurement process. Finally, the proposed RA framework offers a fifth new component focused on a retrospective evaluation of the adequacy performance of procured resources to inform their capacity accreditation, underlying data needs, and modeling approaches. RA processes in regulated jurisdictions and organized markets would benefit from this "anchoring" of the modeling process to the reality of resource performance under extreme weather events, cyberattacks, and other threats, as well as regular operational challenges.

What are the emerging challenges with traditional RA assessments?

Table ES-1 shows a sample of emerging challenges in traditional RA assessments resulting from (i) the evolution of the power systems towards decarbonization and (ii) climate change-induced extreme weather events.

Table ES-1 Emerging challenges with traditional resource adequacy assessments

Traditionally, RA assessments …	Emerging challenge …
Resources are predominantly **dispatchable**	Resources are becoming predominantly **non-dispatchable** (variable renewable resources, VRE)
The present state of most dispatchable resources **does not depend significantly on the past** and does not require chronological simulation	The present state of storage and load flexibility **resources depends on past states** and requires chronological simulation
Describe the system's high-risk conditions during the **peak demand** hour or a few top hours reasonably well	The system's high-risk conditions **may not occur during peak demand periods**, but during other hours in the year
Characterize stress conditions using **historical data**	Increases in extreme weather events, VRE adoption, and impending electrification of end uses makes **historical data less relevant** and creates challenges related to how to characterize possible reliability and resilience events
Assume that **outage events are uncorrelated** with each other and occur randomly	Evidence shows **high correlations of failures** within a class of power system assets and across infrastructure systems (e.g. natural gas and electricity)

We compile a critical review of current RA assessment practices (Section 3) based on (1) interviews with RA practitioners and (2) a review of recent technical literature. We find that:

- RA may need to **expand beyond capacity adequacy** to ensure energy adequacy – relevant for energy-limited resources such as storage – as well as ancillary service adequacy (e.g. enough ramping-up and ramping-down capability in the system). There is general agreement to include energy adequacy jointly with capacity adequacy, but it is not clear whether other system needs' assessments should be performed within the RA assessment or as separate processes.
- All studies and interviewees agreed that **basing RA assessments on the peak hour of the year or season, or on a few select top load hours, is insufficient** as peak demand may no longer predict the times when the power system is most stressed. Chronological hourly simulations are the current best practice.
- **Traditional metrics such as the Loss of Load Expectation (LOLE), Loss of Load Hours (LOLH), Loss of Load Events (LOLEv), and Loss of Load Probability (LOLP) are criticized** due to their "expected-value" nature, their focus on a single characteristic of a shortfall, and the coarse spatial resolution in their typical applications.
- An important shortcoming of current resource adequacy practices is that the **metrics and models used do not reflect economic criteria in system operation and loss of load**. Observers agree, however, that introducing economic criteria to determine adequacy levels introduces significant challenges related to valuing the loss of load for different customers, seasons, and end uses.

- There is a need to **improve representation of weather dependencies and weather data**, attending to a number of shortcomings of current practices that may hinder appropriate RA assessments under high wind and solar futures and climate change.

Should resilience be part of resource adequacy assessments?

A generally accepted definition of resilience is "the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions. Resilience includes the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents" (EOP, 2013) Planning processes in power systems are beginning to grapple with the **need to develop metrics and methods to assess power system resilience**. We establish that from an organizational framework perspective, **resource adequacy assessments could feasibly be expanded to include resilience.** Alternatively, **a resilience-specific assessment could be developed using the same basic framework used by RA assessments**, provided that commonly-accepted resilience metrics become available. In either case, resilience assessments should complement existing resource adequacy assessments to ensure holistic power system reliability and resilience.

We review planning and RA reports for several private and public entities that plan generation and/or transmission infrastructure in the continental U.S. to look for existing practices involving resilience assessments (Section 2). We find **no systematic treatment of the costs of extreme weather and other hazards, the benefits of resilience, and resilience metrics in planning analyses** and no systematic treatment of resilience metrics, methods, and outcomes for resource adequacy purposes.

What are key modeling practices that may improve RA assessments?

This paper analyzes the effects of RA modeling choices on estimated RA outcomes to provide high-level and conceptual insights to regulators and planners on what power system operational details are important to include in a model-based RA assessment (Section 4 and Appendix A). We find that **the use of multiple years of weather and VRE performance data, the enforcement of transmission constraints, and the modeling of short-duration storage dispatch have a high impact on the accuracy of RA assessments** (Table ES-2). We develop a simplified representation of the economic operation of the grid and compare whether an RA assessment using this representation is more accurate than when utilizing non-economic dispatch assumptions in traditional RA assessments. We find that non-economic dispatch schemes that ignore economic objectives for power system operation can lead to fairly accurate RA assessments when enhanced with detailed operational strategies. This means that **current approaches that do not represent economic dispatch of power systems may still be sufficient to represent resources for RA assessments providing they implement sufficient operational data to characterize system performance**.

Table ES-2 Impacts of operational details on RA assessments

Operational or simulation characteristic	Impacts on RA assessment accuracy	Level of effort to represent in models
Multi-year data	High	Medium
Transmission limits	High	Medium
Storage dispatch	High	Medium (short duration) High (long duration)
Non-economic thermal dispatch	Medium	Low
Operational cost	Medium	High
Short-term forecast error	Low	High

In addition, we find that new **RA metrics that capture event-specific shortfall characteristics should be used as supplements to traditional metrics** to better capture the impacts of different modeling assumptions on RA outcomes, as well as to better describe the ability of the system to prevent specific high-impact shortfalls. More generally, **categorizing shortfalls based on their duration, season, and magnitude may be a promising area of RA assessment improvement**.

How may these technical changes in RA assessments affect other processes?

RA assessments are usually embedded within broader planning processes developed by utilities and system operators. In turn, planning processes are part of a set of regulatory and/or market designs that support procurement practices to ensure that the power system remains affordable, reliable, resilient, and sustainable – typically competing priorities. The mutual dependencies that arise from these relationships prompt the question: how would technical changes in resource adequacy assessments – including metrics, data, models, and methods – impact planning processes and broader institutional contexts.

It is important to know that the technical changes in resource adequacy that are suggested by recent work (i) may require upstream changes in planning and procurement practices for their successful implementation and (ii) may create opportunities to enhance planning processes due to availability of high resolution weather, load, and generator performance data, in addition to higher resolution representation of the transmission system. Section 5 presents changes required and opportunities for improvement of RA assessments and planning practices.

What are best practices for RA in planning processes?

We examine integrated resource planning (IRP) reports as well as Independent System Operator and Regional Transmission Organization (ISO/RTO) RA assessments. We use this information to propose a roadmap of evolving industry standards for resource adequacy assessments in resource planning and transmission planning (Table ES-3). The roadmap is based on three benchmarks applicable to key components of RA assessments:

- The first benchmark identifies the **bare minimum** of essential steps that entities need to implement in a reliability assessment.
- The second proposed benchmark corresponds to current **best practices** in the industry.
- The third proposed benchmark adopts a forward-looking perspective to identify RA assessment **frontier practices** that few, if any, entities are currently implementing.

The roadmap describes the potential challenges in implementing best or frontier practices. For example, the use of multiple adequacy metrics would require new methods to select portfolios that meet all, or some, of the targets set for each metric. Similarly, the use of forward-looking downscaled weather data that reflects climate change scenarios would require a parallel development of models that allow load and renewable resources to respond to these weather profiles, rather than relying on historical values. This more holistic representation of loads and resources would have repercussions on integrated resource and transmission planning processes for vertically-integrated and ISO/RTO jurisdictions, respectively.

Table ES-3 Roadmap to incorporate best practices for RA assessment into planning process

		Benchmarks		
Components of RA Framework	**Planning Element**	**Minimum Practice**	**Current Best Practice**	**Frontier Practice**
Definition of RA	Temporal resolution for RA	Meet load in a fraction of the top peak net load hours of the year	Meet load on an 8,760 hour basis	Sub-hourly analysis to meet load and ramping requirements
RA metrics and targets	RA metrics and targets	Single metric (e.g. planning reserve margin) driven by a maximum LOLP (not by the 1-in-10 rule of thumb)	Develop and explore multiple metrics produced by stochastic models that track shortfall magnitudes, frequencies, and durations	Use multiple metrics that track magnitudes, frequencies, and durations; consider full probability distributions of metrics and economic metrics
Data	Weather data	A few years of historical weather data with daily maximums/minimums	Several decades of historical weather data with variables at an hourly temporal resolution	Combine historical data with climate model data for forward-looking hourly weather forecasts
Data	Load forecasting for resource adequacy	Rely on several years of historical load data	Develop econometric or engineering-based load models that explicitly capture the dependence of load on weather	Pair weather-sensitive load models with forward-looking climate change-based weather patterns
Data	VRE characterization	Historical wind/solar performance for several years	Forward-looking wind/solar data for new sites, informed by historical empirical profiles	Climate change-induced wind/solar profiles based on downscaled climate model output
Models	Transmission and market transactions	Basic modeling of firm capacity and available exchanges	Regional simulation to accurately account for the availability of imported resources and market depth uncertainty; locational reliability analysis.	Enhanced modeling of transmission line derates; strengthen integration between generation and transmission expansion
Models	RA modeling and integration with planning process	Basic chronological Monte Carlo LOLP analysis; simplified storage representation	Iterative LOLP-CEM approach; model chronological storage operations	Stochastic CEM that internally assesses and ensures RA; include unit commitment and operational details
Procurement	Capacity credit	ELCC for renewables	ELCC for all resources, analyzed from individual and portfolio perspectives	Energy adequacy analysis; portfolio-based ELCC accounting for interactive effects