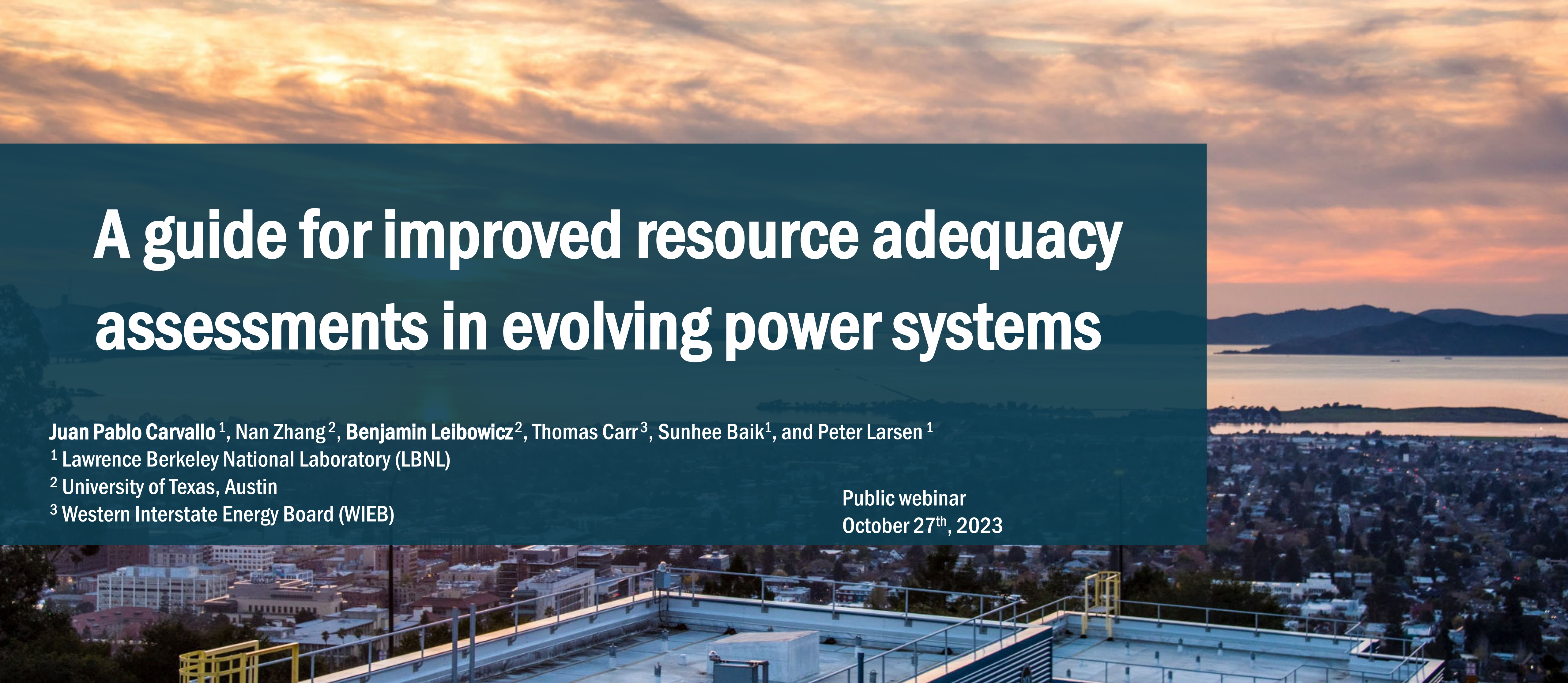

A guide for improved resource adequacy assessments in evolving power systems

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What is resource adequacy (RA)?

Resource adequacy (RA) refers to the ability of an electric power system to meet demands for electricity using its supply-side and demand-side resources (NERC, 2011)

Resource adequacy gaining prominence ....

LOCAL NEWS ›

California ISO warns of possible flex alerts during heat wave

CBS NEWS LOS ANGELES

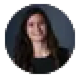
BY CBSLA STAFF

AUGUST 30, 2022 / 7:44 PM / CBS LOS ANGELES

CLIMATE

California avoids widespread rolling blackouts as heat strains power grid

PUBLISHED WED, SEP 7 2022•10:43 AM EDT



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INFRASTRUCTURE

Continued Instability In State Power Grid A Colossal Risk To Texas, U.S.

BY DAVE MANNING - SEPTEMBER 26, 2022

Ian batters Florida: 'Some fatalities' and widespread power outages reported

09/29/2022 11:09 AM EDT

WINTER STORM 2021

2 million Texas households without power as massive winter storm drives demand for electricity

> Some utility companies that deliver electricity to Texans are telling customers to expect power outages through Monday night and potentially into Tuesday.

https://www.reformaustin.org/infrastructure/continued-instability-in-state-power-grid-a-colossal-risk-to-texas-us/

https://www.politico.com/video/2022/09/29/ian-batters-florida-some-fatalities-and-widespread-power-outages-reported-717386

https://www.texastribune.org/2021/02/15/rolling-blackouts-texas/

Three potential issues with RA outcomes

Metrics

- Insufficient metrics **may not reveal certain RA outcomes** that are not measured in RA assessment processes

Load and weather data

- If metrics are correct, it is possible that **load and weather data do not properly reflect current power system conditions**.

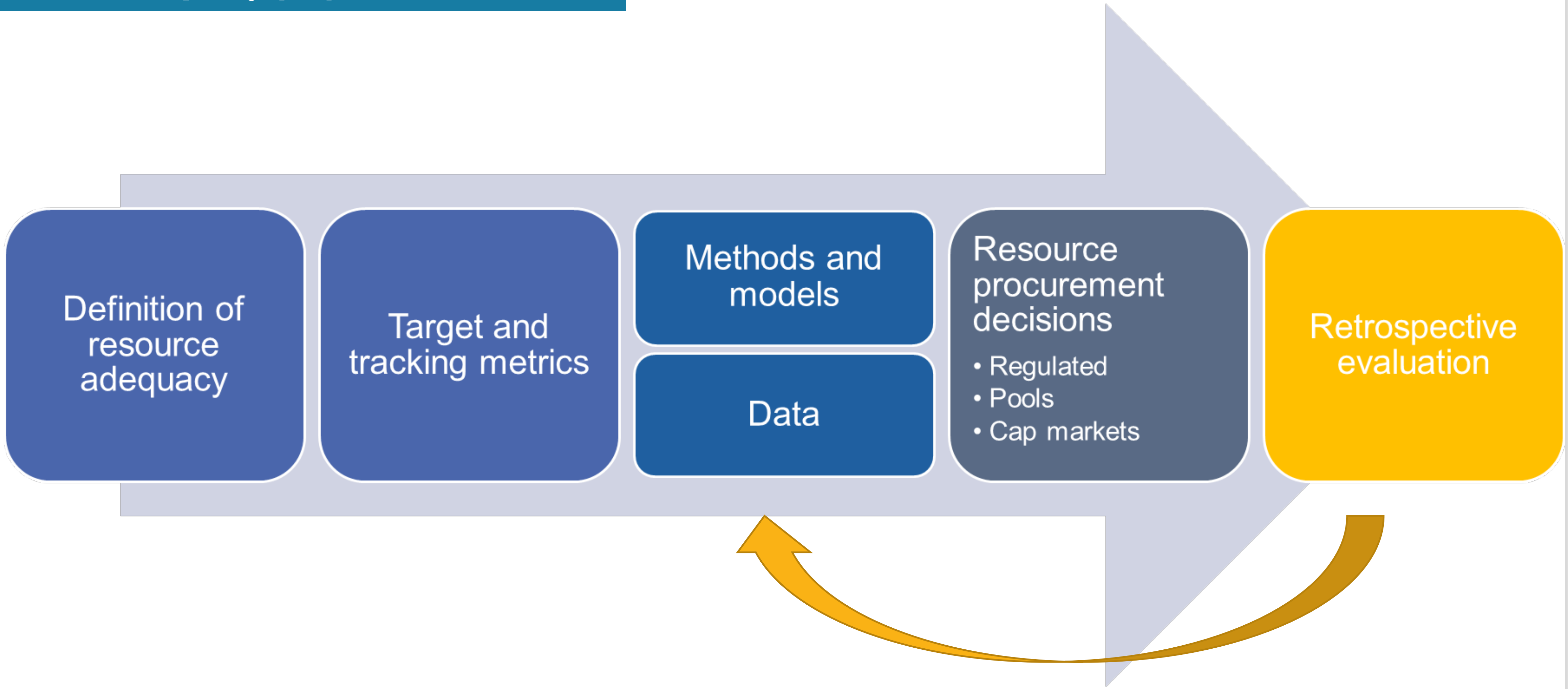
Resource performance

- If metrics and data are correct, **performance of actual procured resources may not match that of simulated resources**

Emerging challenges to traditional RA assessments

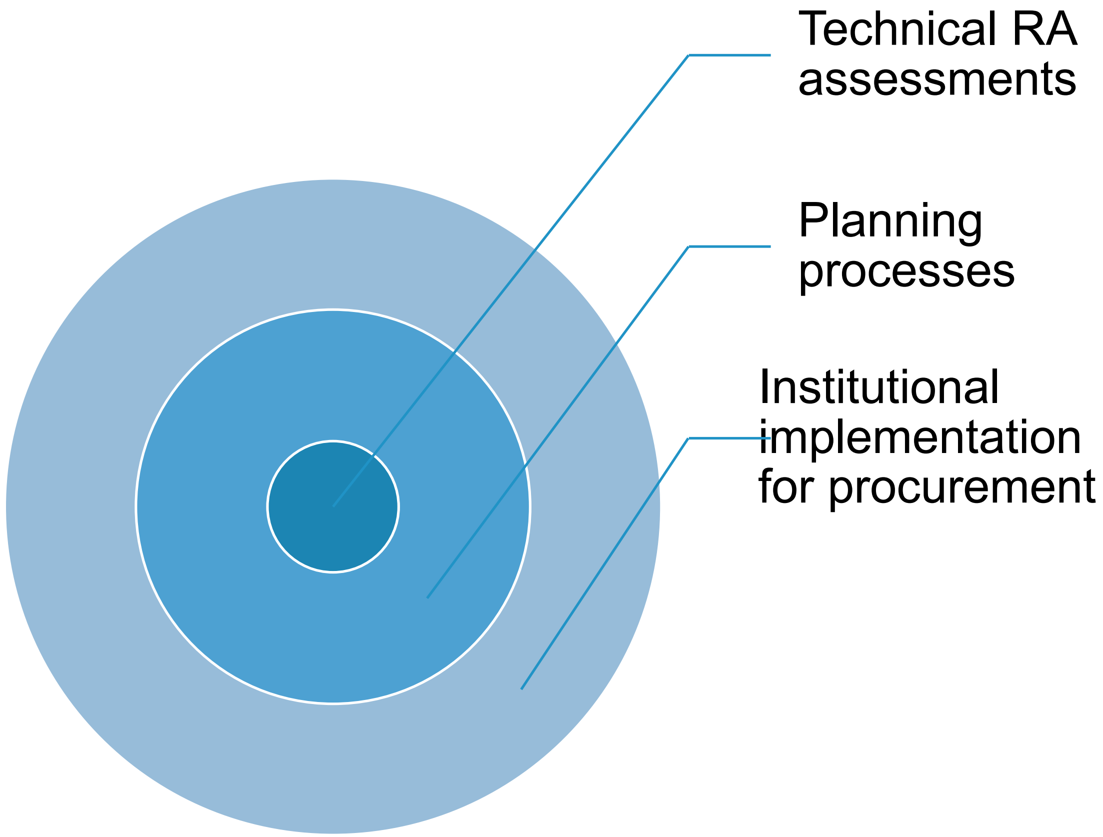
Traditionally, RA assessments …	Emerging challenge …
Resources are predominantly **dispatchable** and available to the operator based on their forced and planned outage rate	Resources are predominantly **non-dispatchable** (variable renewable resources, VRE) and their availability and contribution to RA is stochastic
Present state of most dispatchable resources **does not depend significantly on past state** and does not require chronological simulation	Present state of storage **resources depend on past states** and requires chronological simulation
Described the system's high risk conditions with the **peak demand** hour or few top hours reasonably well	The system's high risk condition **may not occur during gross or net peak demand**, but during other hours in the year
Characterized stress conditions using **historical data**	Increase in extreme weather events and VRE adoption makes **historical data less relevant** and creates challenges related to how to characterize possible reliability and resilience events
Assumed that **outage or failure events were uncorrelated** to each other and randomly occurring	Evidence show **large correlation of failures within technologies** and across infrastructure systems (e.g. natural gas and electricity)

Components of a comprehensive resource adequacy (RA) framework



Key questions guiding current work

- Given power system evolution, what changes are needed in **technical RA assessments**?
- What are **best practices** in RA planning and procurement **to follow innovations in technical assessments**?
- What are **frontier practices** to meet decarbonization challenges?



Topics covered in paper

1. Introduce **challenges with current RA assessments**; present RA framework
2. **RA definition**, and the need to move away from "peak hour"
   – How may resilience be incorporated as part of RA assessments?
3. **Institutional analysis**
   – How may existing Integrated Resource Plans (IRP) and market design structures be affected by the evolving definition of RA and the technical innovations needed?
   – What are minimum and best practices for RA assessments? What are frontier practices?
4. **Technical aspects of RA**
   – Review of technical recommendations for enhanced RA assessments
   – The impact of incorporating operational detail into RA assessments

2 | Resilience and resource adequacy

- Resilience is a **relatively new concept** in power systems that has gained prominence associated with climate change impacts
- As opposed to reliability, there is **no shared definition of resilience.** Should it be part of RA assessments?

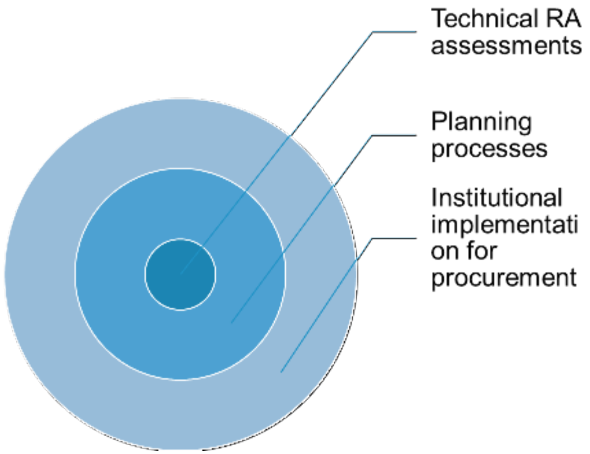
Yes: It is the **only probabilistic assessment** in bulk power system planning	**No:** It deals with high impact, low frequency **events that are hard to characterize**
Yes: Examine the **tails of the shortfalls** and look for particularly large events, and how to avoid them	**No**: It has operational/ dynamic components (e.g. withstanding events) that are **outside of the scope of RA**

2 | Resilience and resource adequacy

- We reviewed 13 integrated resource plans and RA assessments for six ISO/RTO or regional organizations
- Findings:
  - There's a **qualitative awareness of the importance of resilience**, with an identification of resources that increase resilience (e.g. microgrid projects or transmission expansions)
  - **No monetization of resilience costs or benefits**, and **no clear metrics** to quantify baseline or changes in resilience
  - ISO/RTO highlight the impending changes in the power system and opportunities to enhance resilience with new technologies, but it is **unclear how these would be built in RA assessments or transmission planning processes**

3 | Institutional implications

- RA assessments do not occur in a vacuum: they are **part of broader regulatory or market processes**
- This section investigates the **ripple effects that changes in RA definition**, metrics, methods, data, and results may have on **existing processes** that rely on resource adequacy verifications.
- We review current RA practices for six LSE and four ISO/RTO
- Make our recommendations actionable by clustering them:
  - Insufficient/minimum
  - Best practice
  - Frontier practice



3 Roadmap to incorporate best practices for RA assessment into planning processes

Planning Element	Insufficient Practice	Minimum Practice
Temporal resolution for RA	Meet single peak hour load	Meet load in a fraction of the top peak net load hours of the year
RA metrics and targets	Administratively set PRM	Single metric (e.g. planning reserve margin) driven by a maximum LOLP (not by the 1-in-10 rule of thumb)
Weather data		A few years of historical weather data with daily maximums/minimums
Load forecasting for resource adequacy	Rely on a few years of historical load data	Rely on several years of historical load data
VRE characterization	Single year, single site (not multi location) profiles	Historical wind/solar performance for several years
Transmission and market transactions	Assume market is deeply available at historical hub prices; transmission limits ignored	Basic modeling of firm capacity and available exchanges
RA modeling and integration with planning process	Deterministic and non-chronological models	Basic chronological Monte Carlo LOLP analysis; simplified storage representation
Capacity credit	Administratively set VRE capacity contribution based on peak hour of year	ELCC for renewables

3 Roadmap to incorporate best practices for RA assessment into planning processes

Planning Element	Current Best Practice	Frontier Practice
Temporal resolution for RA	Meet load on an 8,760 hour basis	Sub-hourly analysis to meet load and ramping requirements
RA metrics and targets	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
Weather data	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
Load forecasting for resource adequacy	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
VRE characterization	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
Transmission and market transactions	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
RA modeling and integration with planning process	Iterative LOLP-CEM approach; model chronological storage operations	Stochastic CEM that internally assesses and ensures RA; include unit commitment and operational details
Capacity credit	ELCC for all resources, analyzed from individual and portfolio perspectives	Energy adequacy analysis; portfolio-based ELCC accounting for interactive effects

Load forecasting for RA

Minimum	Best	Frontier
• Use several years of historical load data • Capture seasonal and inter-annual load patterns	• Explicitly capture sensitivity of load to weather • Use bottom-up engineering models to predict load levels as a function of weather variables, among others	• Pair weather-sensitive load models with forward-looking climate change-based weather models • Consider the use of different load composition scenarios that may result in drastically different demand profiles

Extra: do not include DER in load forecasts → DER stochastic behavior may be quite different

VRE characterization

Minimum	Best	Frontier
• Use historical data available to characterize resources at the technology-level	• Develop simulated or synthetic hourly profiles for wind and solar • Combine historical resource characterization with technology representation to reflect improvements in performance	• Use synthetic models with downscaled climate change-based weather profiles and weather-sensitive outage rates • Move from technology-level to project (or project cluster) level representations that capture spatial diversity in resource characteristic

Extra: single entity to collect, curate, and manage weather datasets for consistent regional assessments

Integration of RA and planning

Minimum	Best	Frontier
• Limited representation of system operation • RA deficiencies are assumed to be cured with natural gas peakers or storage with "perfect capacity"	• Chronological MC that reflects system dispatch for energy-limited resources • Iterate least-cost portfolios and RA assessment (e.g. LOLP) using technology-level ELCC	• Represent unit commitment decisions for supply-side and transmission resources • Develop models that produce resource adequate least-cost portfolios by integrating capacity expansion and probabilistic assessment

Extra: develop methods to ground-truth RA assessments with empirical system performance

4 | Technical analysis: guiding research questions

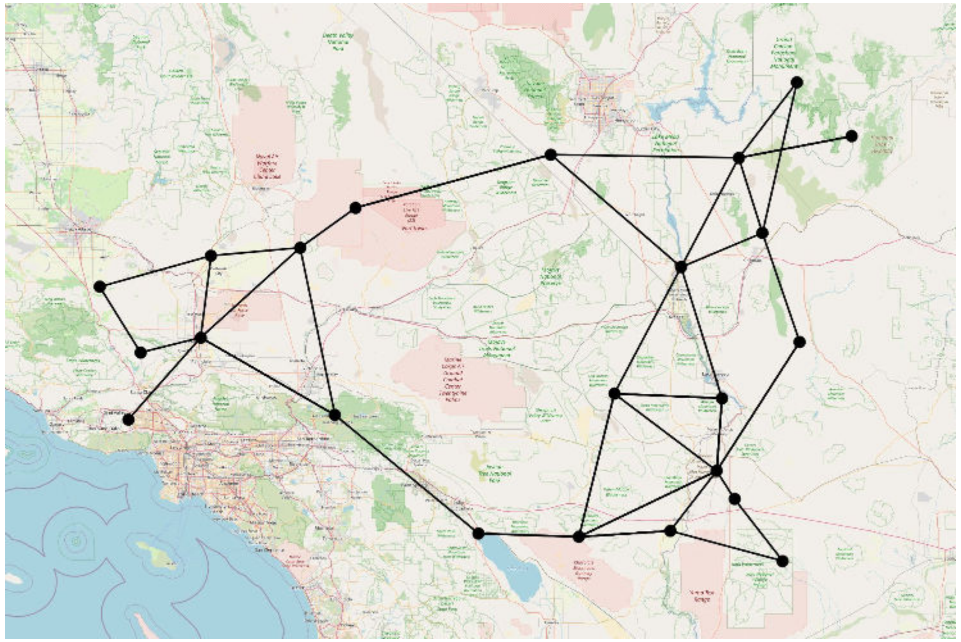
- In reality, the real-time state of the system is contingent on dispatch decisions for thermal, storage, and transmission assets that follow economic and technical criteria.
- **What operational details of power systems are important to include in a probabilistic RA assessment in order to accurately compute RA metrics?**
  - This is important because more detail → higher computational burden
- We explore several types of choices about how to model power system operations:

1. Economic considerations
   - What is the impact of using economic vs. non-economic dispatch strategies to assess the RA of a system?
2. Dispatch strategies
   - How do different power dispatch strategies affect outcomes of RA assessments?
3. System representation/details
   - What are the impacts of different modeling assumptions on RA assessments, and can these impacts be fully captured by traditional RA metrics?

4 | Technical analysis: approach and findings

- Modify Prescient production cost model to run quickly in a Monte Carlo RA simulation
- Apply model to modified IEEE RTS-GMLC
- High-level summary of findings on the impacts of six operational details we analyzed:

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



Simplified transmission network for our case study based on the IEEE RTS-GMLC system

4 | Technical analysis: sample result #1

- **Question:** How important is it to incorporate economic dispatch?
- **Scenario Comparison:**
  - *RADp-4*: a reliability-focused dispatch RA model; generators are dispatched in order of reliability and storage units are dispatched to meet predetermined states of charge
  - *EcDp*: an economic dispatch RA model; least-cost thermal dispatch that reflects the operational principles of real-world power systems

Scenario	LOLE (days/year)	LOLP	LOLEV (events/year)	EUE (MWh/year)	Production cost (M$)
RADp-4	0.286	24.6%	0.288	41.92	96.3
EcDp	0.294	25.2%	0.296	43.25	76.9

- **Takeaway:** It is possible to estimate probabilistic RA metrics accurately without incorporating economic dispatch as long as assets are coordinated with reasonable and detailed operational strategies

4 | Technical analysis: sample result #2

- **Question:** How important is it to represent transmission limits instead of assuming a "copper plate" model in which power flows freely throughout the whole region?

- **Scenario Comparison:**
  - *RADp-4*: a reliability-focused dispatch RA model; generators are dispatched in order of reliability and storage units are dispatched to meet predetermined states of charge
  - *TxFr*: a transmission-free case that is the same as *RADp-4* except transmission limits are omitted

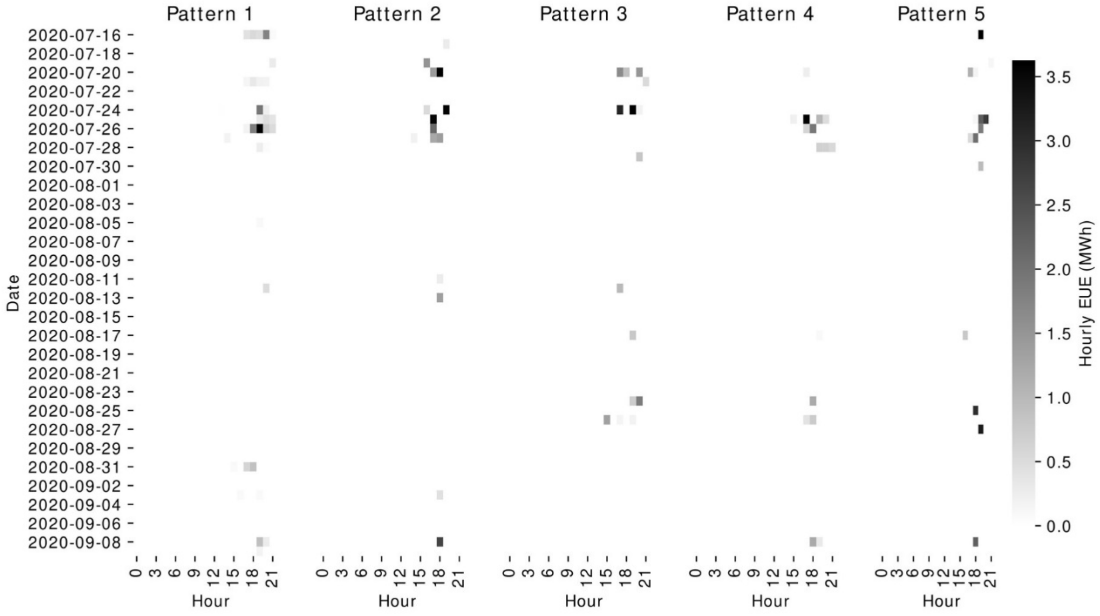
Scenario	LOLE (days/year)	LOLP	EUE (MWh/year)
RADp-4	0.286	24.6%	41.92
TxFr	0.220	19.0%	36.49

- **Takeaway:** Omitting transmission limits can make the power system seem more resource adequate than it actually is, so transmission is important to represent in probabilistic RA analysis

4 | Technical analysis: sample result #3

- **Question:** How important is it to incorporate multiple years of weather data for solar generation, wind generation, and load time series?

Hourly EUE in the *RADp-4* scenario for simulation instances with 5 different weather patterns



- **Takeaway:** While the expected-value-based RA metrics have similar values across the 5 weather patterns, the characteristics of shortfalls (timing, magnitude, duration) can be quite different

4 | Technical analysis: summary of findings

- **Non-economic dispatch schemes** that ignore economic objectives can lead **to fairly accurate RA assessments** when coordinated with detailed operational strategies.
- Representing the **detailed chronological operations** of thermal generators and storage units is essential for accurate RA assessments
  - Simplified dispatch models can be used as screening tools due to their low computational complexity.
- Multi-year data is important to capture **inter-annual variations** in system conditions.
- **Neglecting to incorporate transmission limits into RA assessment could lead to substantial underestimation of traditional "expected value" RA metrics.**
  - However, experiments with alternate metrics that focus on individual event characteristics show that **neglecting transmission limits will not mask the most critical shortfall events.**
- New RA metrics that **capture event-specific shortfall characteristics** should be used as supplements to traditional metrics.

Some remaining challenges and questions

- **Planning**
  - How can we **validate that the LOLP or EUE** calculated for a given system is consistent with the empirical evidence? How do we anchor RA assessments with reality when there are few contingency and actual interruption events?
  - If we use multiple metrics, **how do we choose the benchmark or threshold for them**? How do we integrate these metrics into portfolio selection processes?
- **Procurement**
  - There is **no rigorous method to identify a specific technology** that cures the shortfalls from RA assessment
    - What shortfalls should be cured? How to ensure cost-effectiveness?
  - Need to **include the economics of reliability and resilience** in RA assessments. Is a 1-day-in-10-years socially optimal? Are some users willing to pay more, or less? If so, how should the system accommodate?

Contact information

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For more http://emp.lbl.gov

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