Solar and Storage Integration in the U.S. Southeast: Implications for Resource Adequacy

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Project overview

Objective: Understand changes in electricity system economics, reliability, resource adequacy, and operations in the U.S. Southeast with higher levels of solar and storage and with different levels of regional coordination

Project consists of three studies:

- **Solar-storage integration study (Phase 1)**: How do higher levels of solar and storage impact economics, reliability, and operations, with different levels of regional coordination?
- **Solar forecasting and storage study (Phase 2)**: How will better solar forecasting change operations? How should storage be optimally operated and modeled incorporating solar forecast uncertainty?
- **Resource adequacy in energy-limited systems study (Phase 3)**: How do higher levels of solar and storage impact resource adequacy and the value of demand-side resources in providing resource adequacy?

Focus of this presentation

Study is research focused and is not responding to active regulatory proceedings or intended to make specific policy recommendations.

Motivation: the need for new approaches to resource adequacy

Resource adequacy (RA) = having enough power system resources to meet demand at all times

Traditional RA methods often rely on assessing the contribution of resources during stress hours, often peak net load or specific periods

- Resource contribution quantified as its **capacity credit**

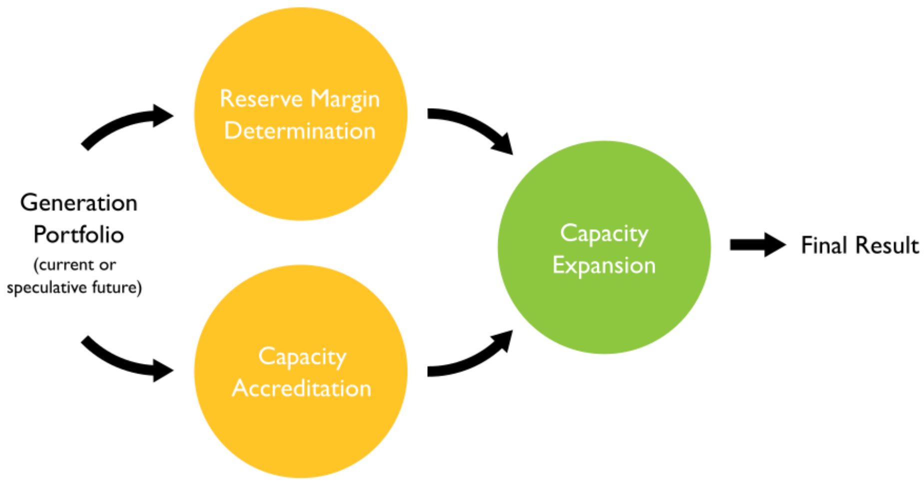
Systems with higher shares of weather-dependent resources likely to require **more advanced RA approaches**, with features such as:

- hourly, chronological grid operations
- correlated outages
- multiple years of weather data

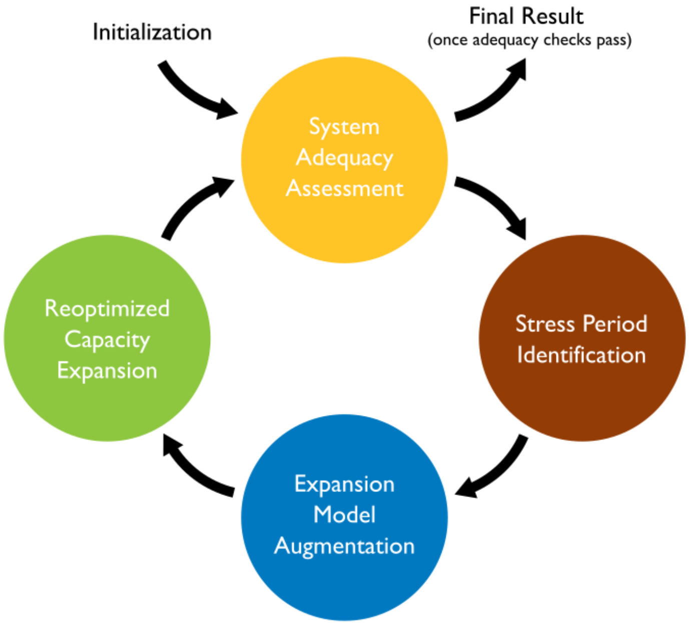
Stenclik, D., Bloom, A., Cole, W., Acevedo, A., Stephen, G., & Tuohy, A. (2021). *Redefining Resource Adequacy for Modern Power Systems: A Report of the Redefining Resource Adequacy Task Force* https://doi.org/10.2172/1961567

Motivation: the need for new approaches to resource adequacy

Traditional approach



Iterative approach



Kuna, J., Stephen, G., & Mai, T. (2024). *Beyond Capacity Credits: Adaptive Stress Period Planning for Evolving Power Systems* https://doi.org/10.2172/2368579

Detailed research questions

How does **integrating a capacity portfolio planning tool with a probabilistic resource adequacy model** help address challenges for planning systems with higher amounts of solar?

What are some of **the drivers of unserved energy** when using existing resource adequacy methods for higher levels of solar?

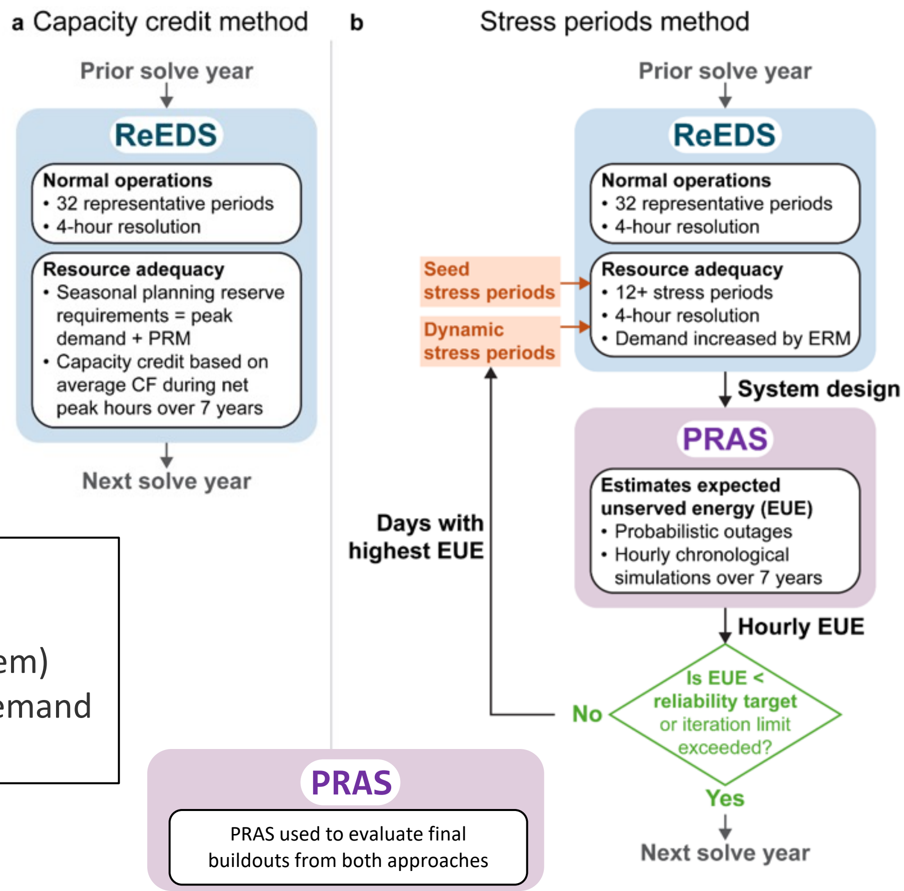
How are results with the integrated planning approach affected by key sensitivities related **to load, weather years, and regional coordination**?

Integrating planning and adequacy tools

Analysis relies on two open-source tools:

Capacity expansion: Regional Energy Deployment System (ReEDS) (https://github.com/NREL/ReEDS-2.0)

Resource adequacy assessment: Probabilistic Resource Adequacy Suite (PRAS) (https://github.com/NREL/PRAS)



Key assumptions:

- Planning/energy reserve margin = 12%
- Number of Monte Carlo samples = 10 (50 for final system)
- Expected Unserved Energy (EUE) target = 10 ppm of demand
- Iteration limit = 5

Mai, T., Brown, P. R., Lavin, L., Dhulipala, S. C., & Kuna, J. (2024). *Incorporating Stressful Grid Conditions for Reliable and Cost-Effective Electricity System Planning* https://doi.org/10.2139/ssrn.4841668

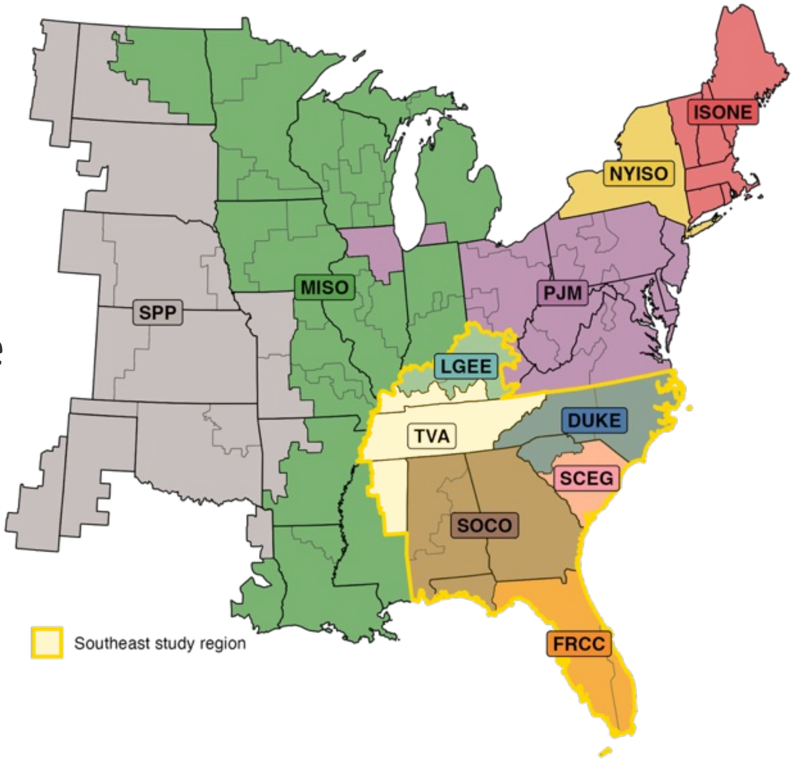
Modeling assumptions (I)

ReEDS run for Eastern Interconnection through 2050 with 3-year steps

Southeast balancing areas run as "porous islands"

- Energy trade allowed, but with hurdle rate of 10 $/MWh [2024$]
- No firm capacity trade

Cost assumptions derived from NREL's Annual Technology Baseline (ATB)



Modeling assumptions (II)

Dispatch in ReEDS performed using **representative days**

- 36 days selected using 2012 weather profile
- Each day modeled using **4-hour chunks**

Capacity credit / stress periods rely on **7 years of hourly data**

- Default relies on 2007-2013

Scenarios comparing integrated stress periods to capacity credit approach

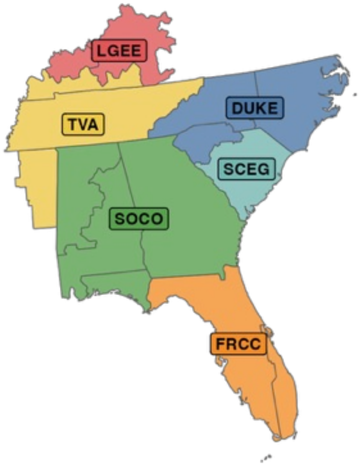
		Solar deployment	
		Business-as-usual (BAU)	**High solar deployment (High PV)**
Resource adequacy approach	**Capacity credit (CC)**	BAU CC	High PV CC
	Stress periods (SP)	BAU SP	High PV SP
	Solar share in 2050: (% of ann. generation)	*32%*	*45%*

High PV scenario generated using Annual Technology Baseline "advanced" solar and storage costs trajectories (BAU uses "moderate")

Sensitivities evaluating the stress period method

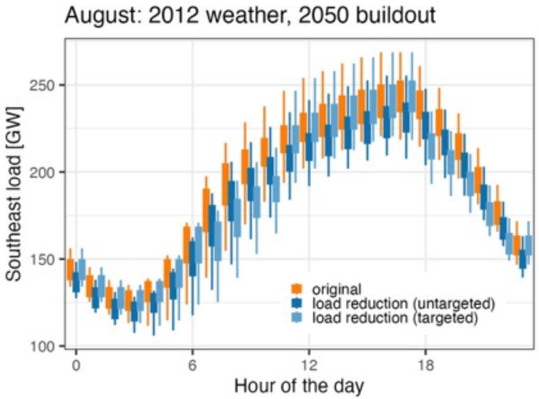
Regional coordination

- Zero hurdle rates
- Allow firm capacity trade between BAs



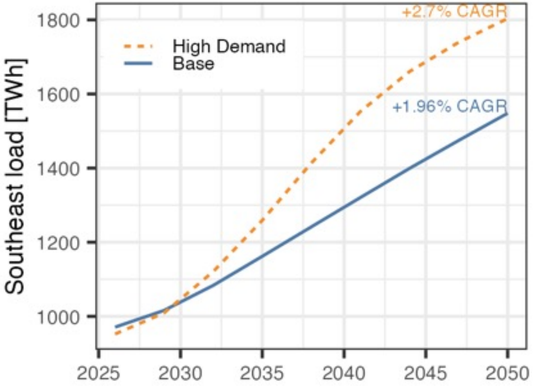
Load reduction strategies

- **Untargeted**: 5% reduction in all hours
- **Targeted**: 10% reduction in solar ramp hours



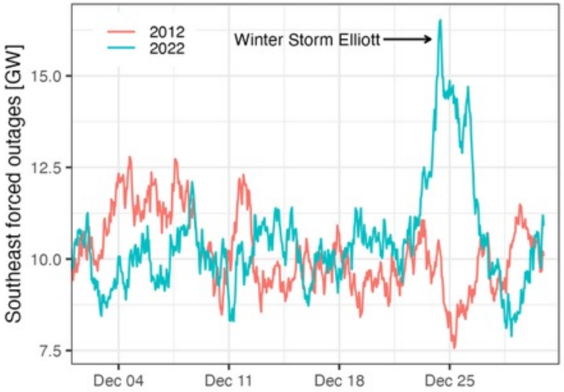
Higher demand growth

- Based on high electrification pathway from Evolved Energy Research



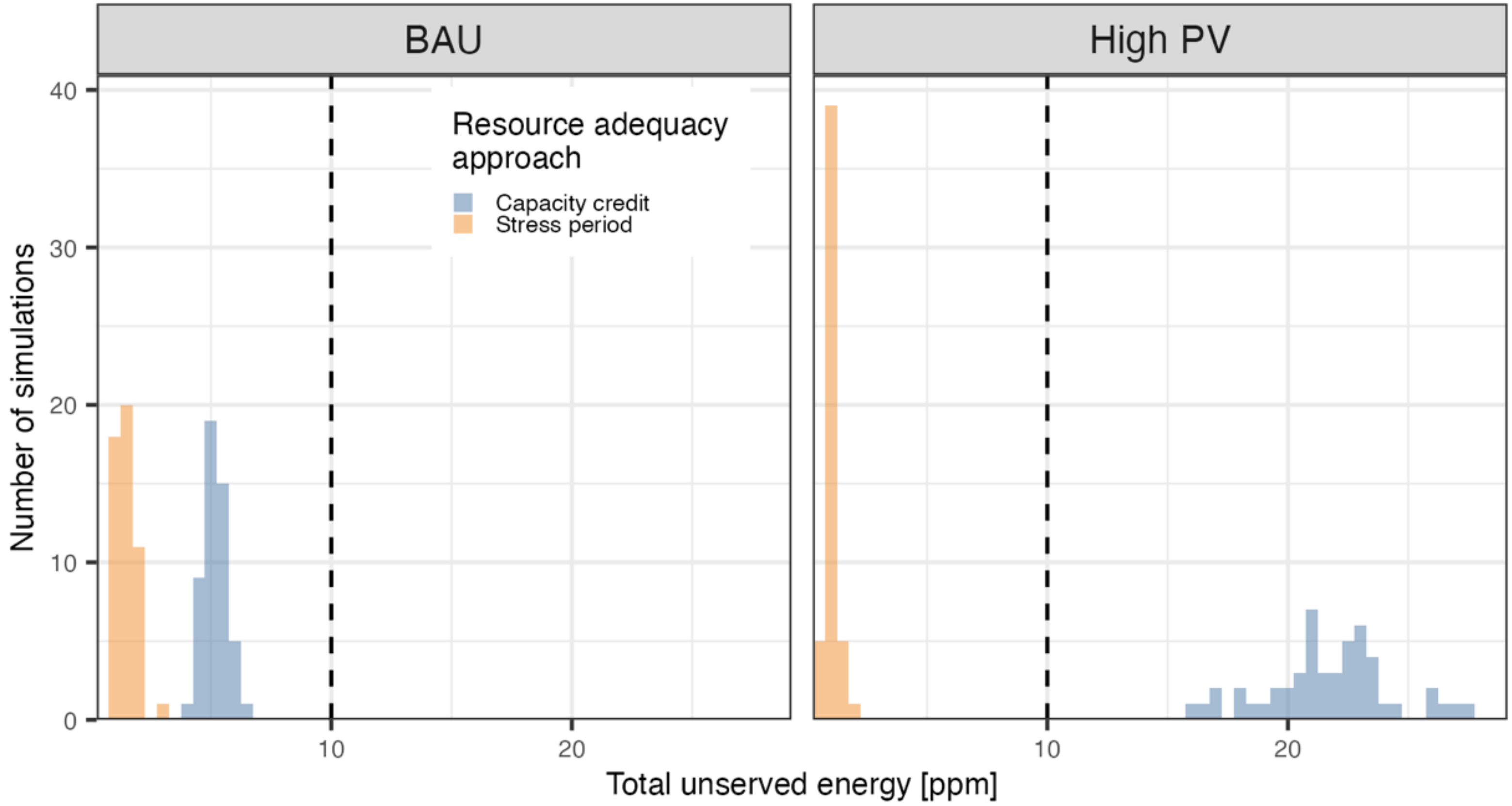
Additional weather years

- 2016-2022 for PRAS
- Rep days using 2022
- Also tested with higher demand

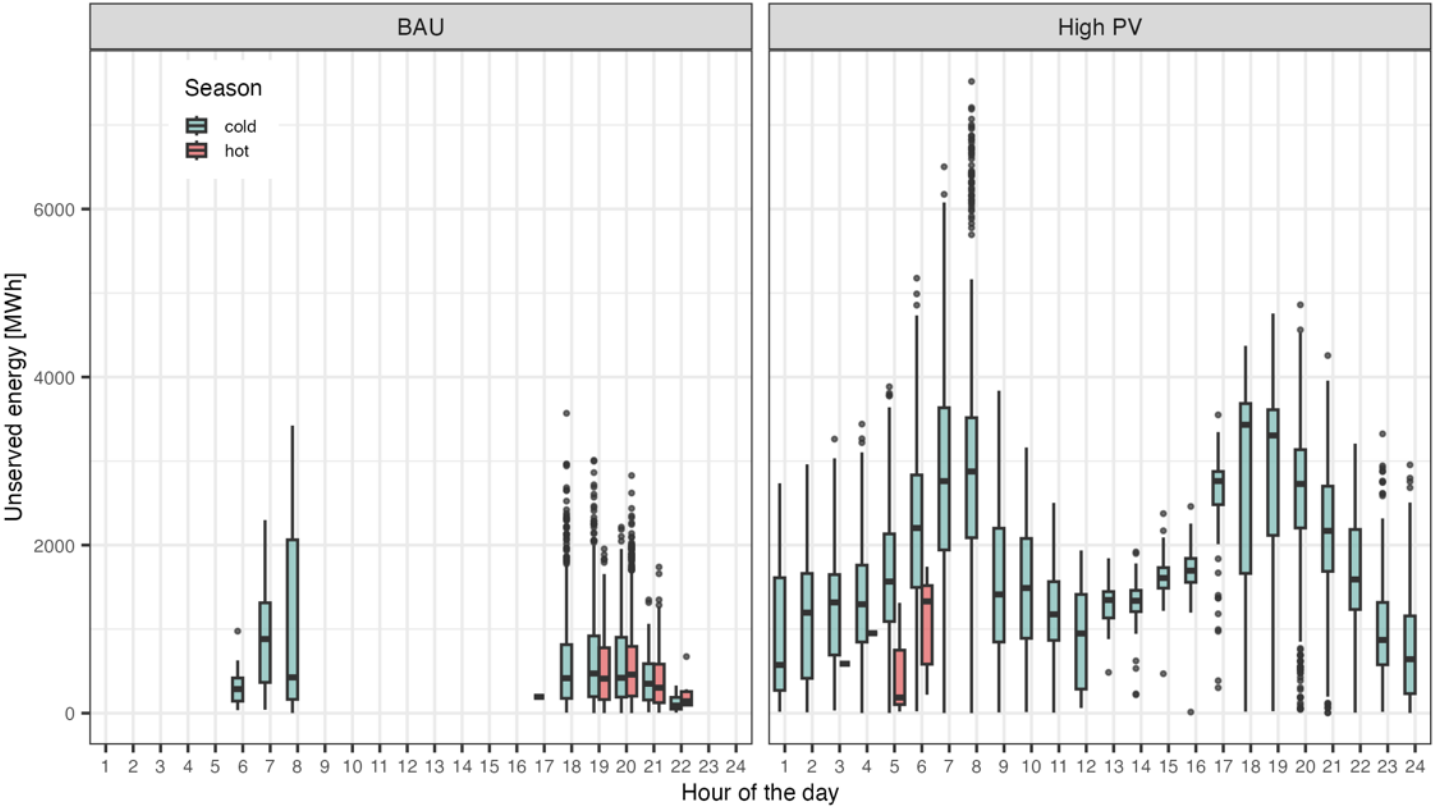


Results: ReEDS/PRAS integration

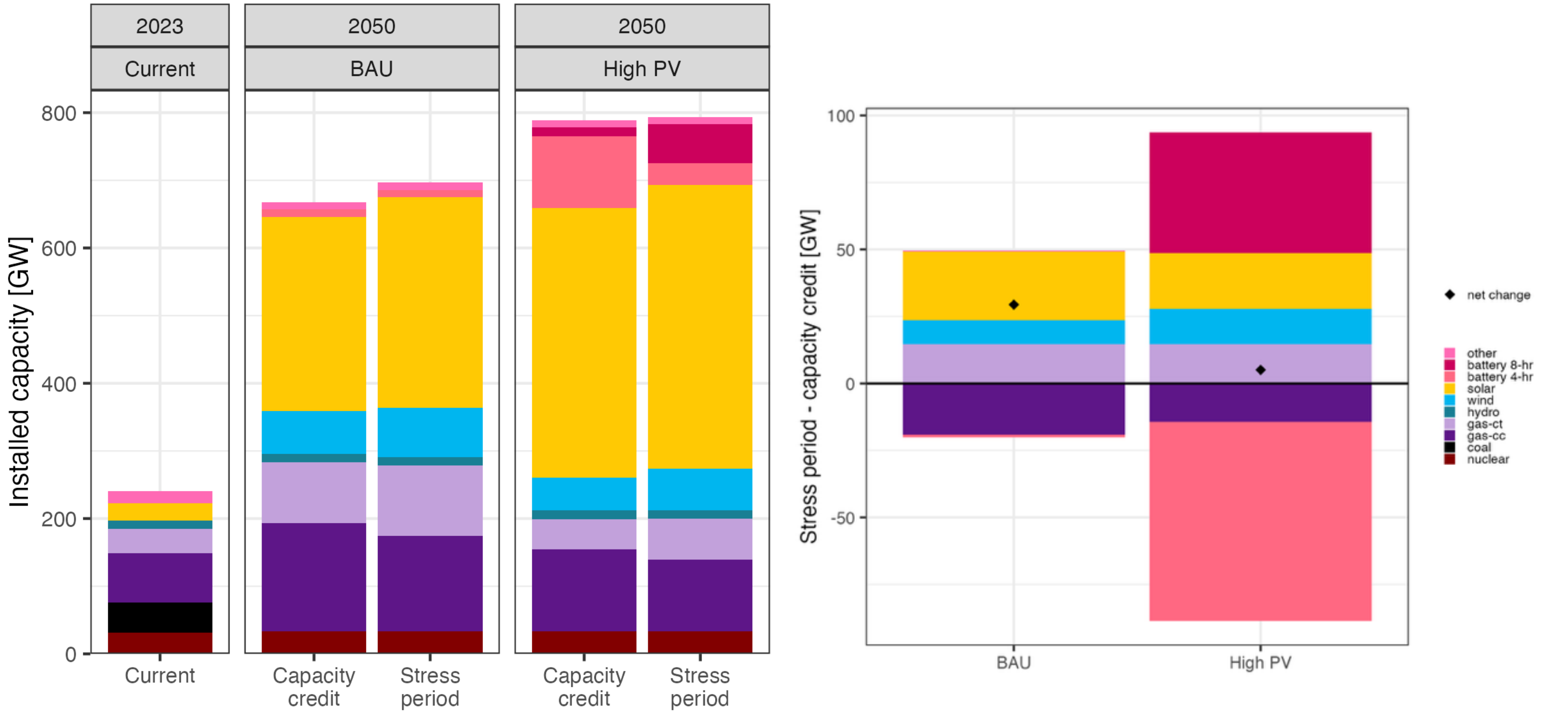
Both methods meet RA criteria in BAU scenario, but capacity credit exceeds criteria in High PV scenario



High PV system sees more challenges throughout the day during winter with capacity credit approach

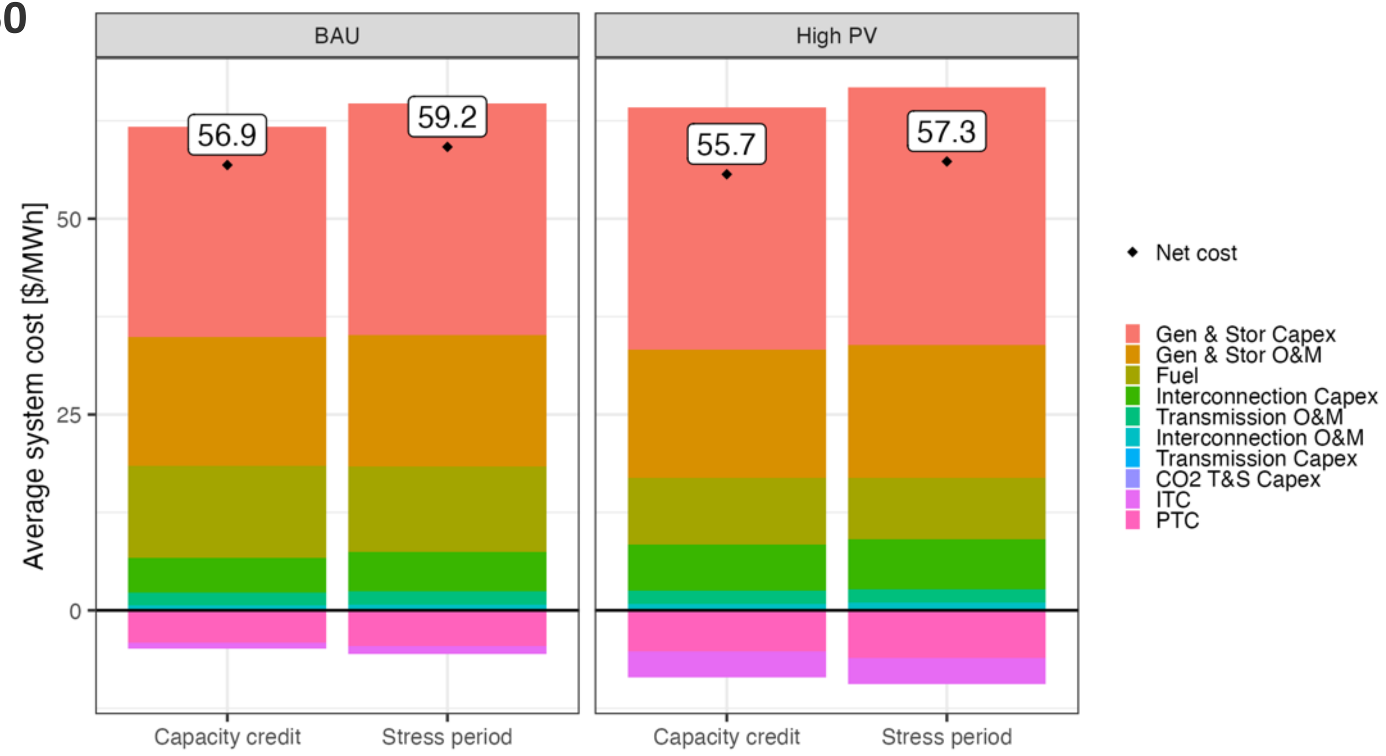


Stress period approach addresses shortfall in High PV scenario by increasing storage duration



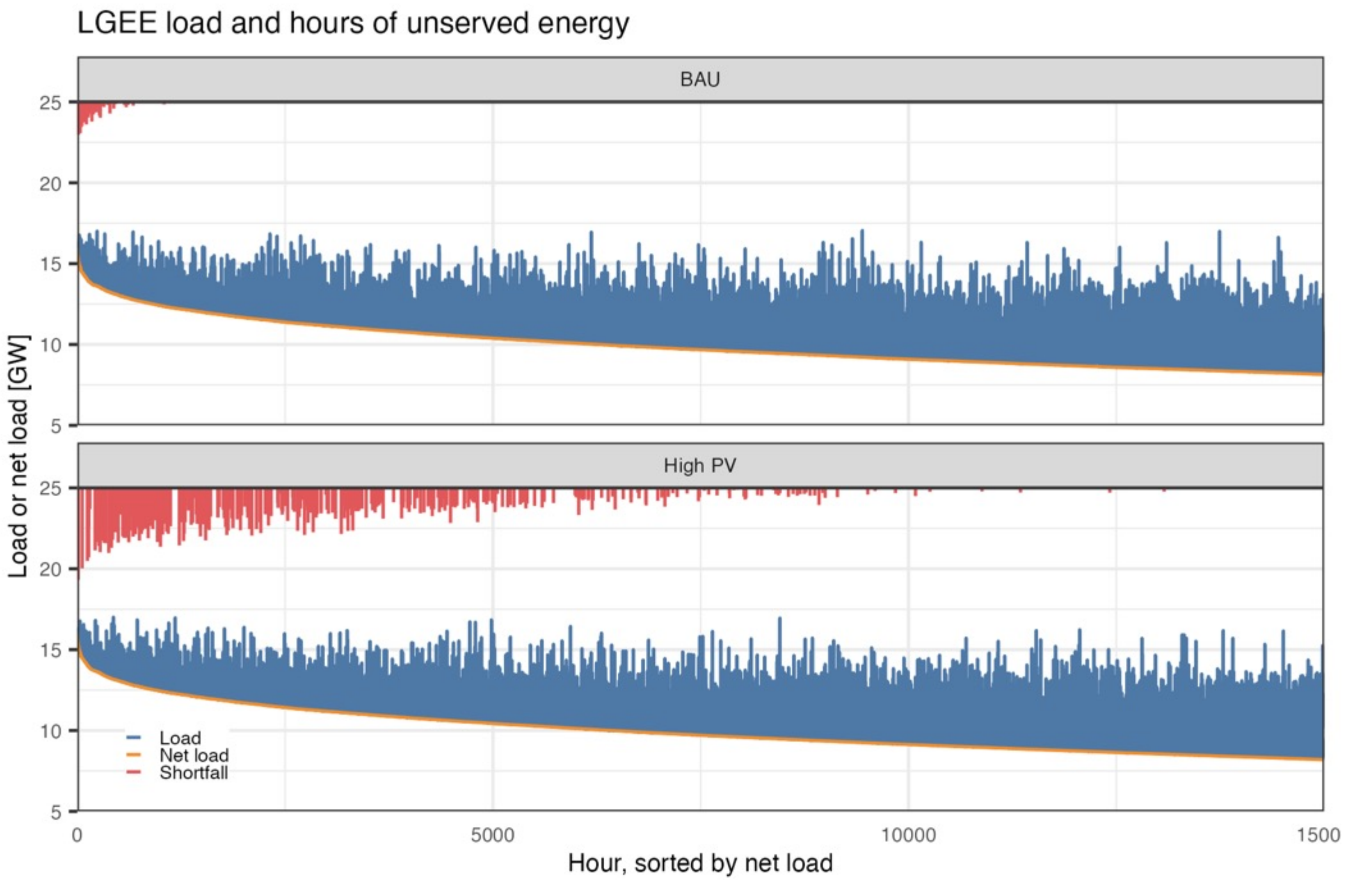
Stress period approach increases costs, but improves reliability

Average wholesale electricity costs in 2050

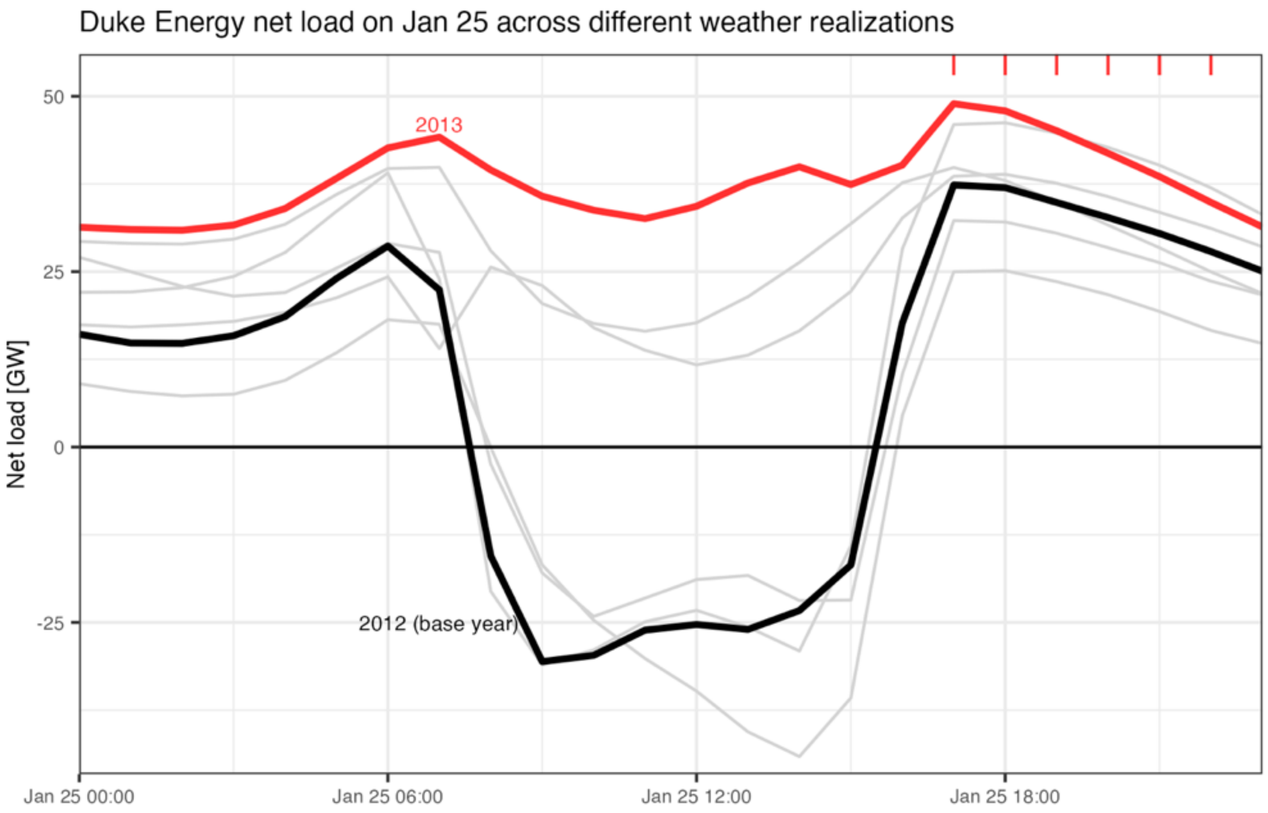


Results: What drives unserved energy in the capacity credit approach?

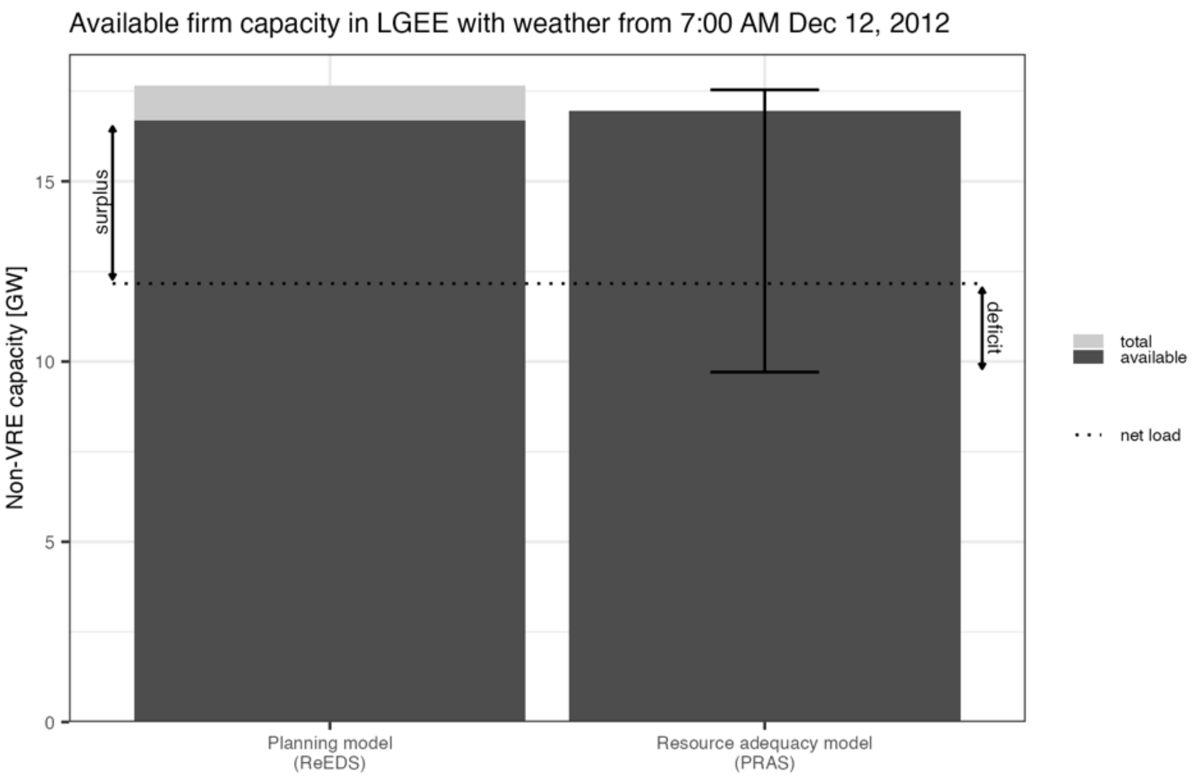
At higher PV levels, unserved energy hours are less concentrated on peak net load hours



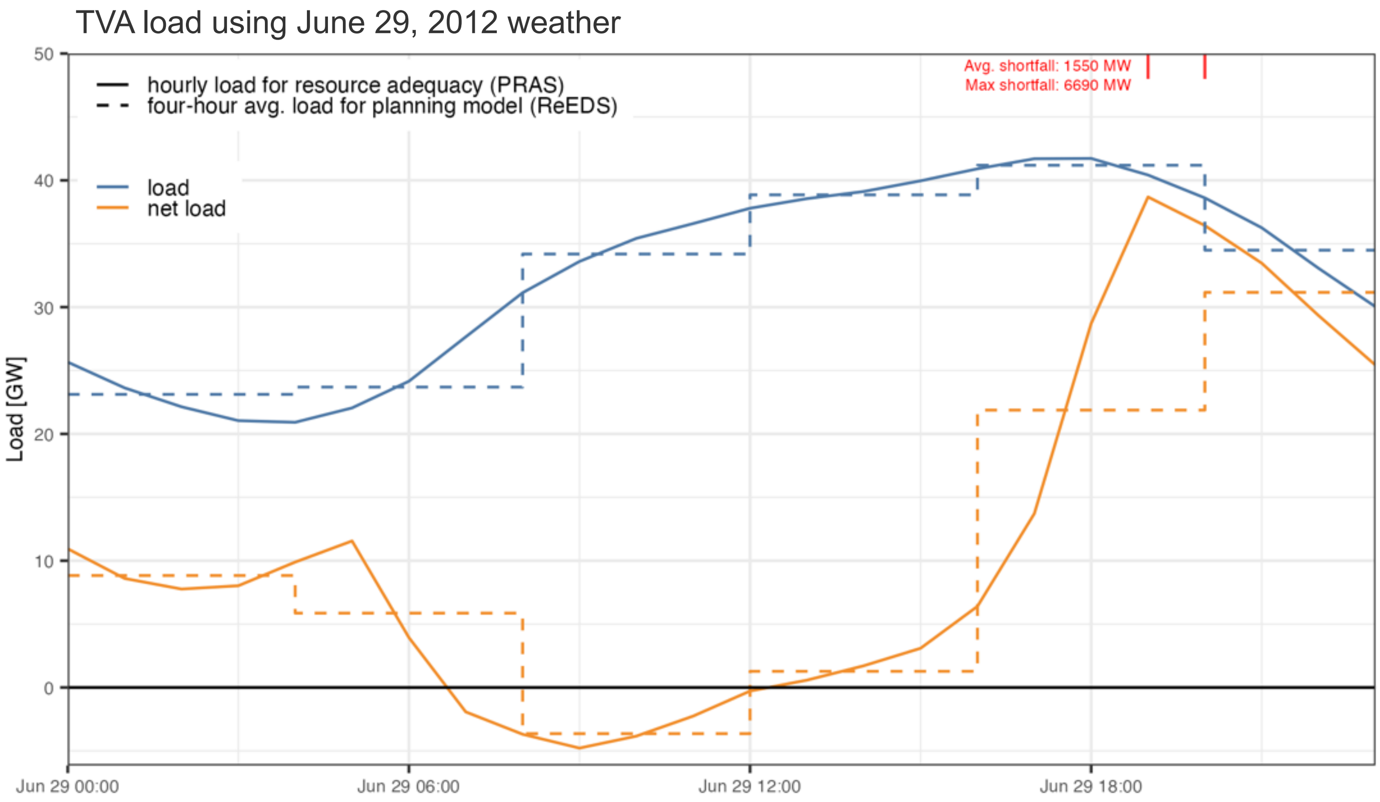
Unseen weather realizations outside top net load hours can lead to shortfall



Average derates can miss potential for low probability, high impact outage events

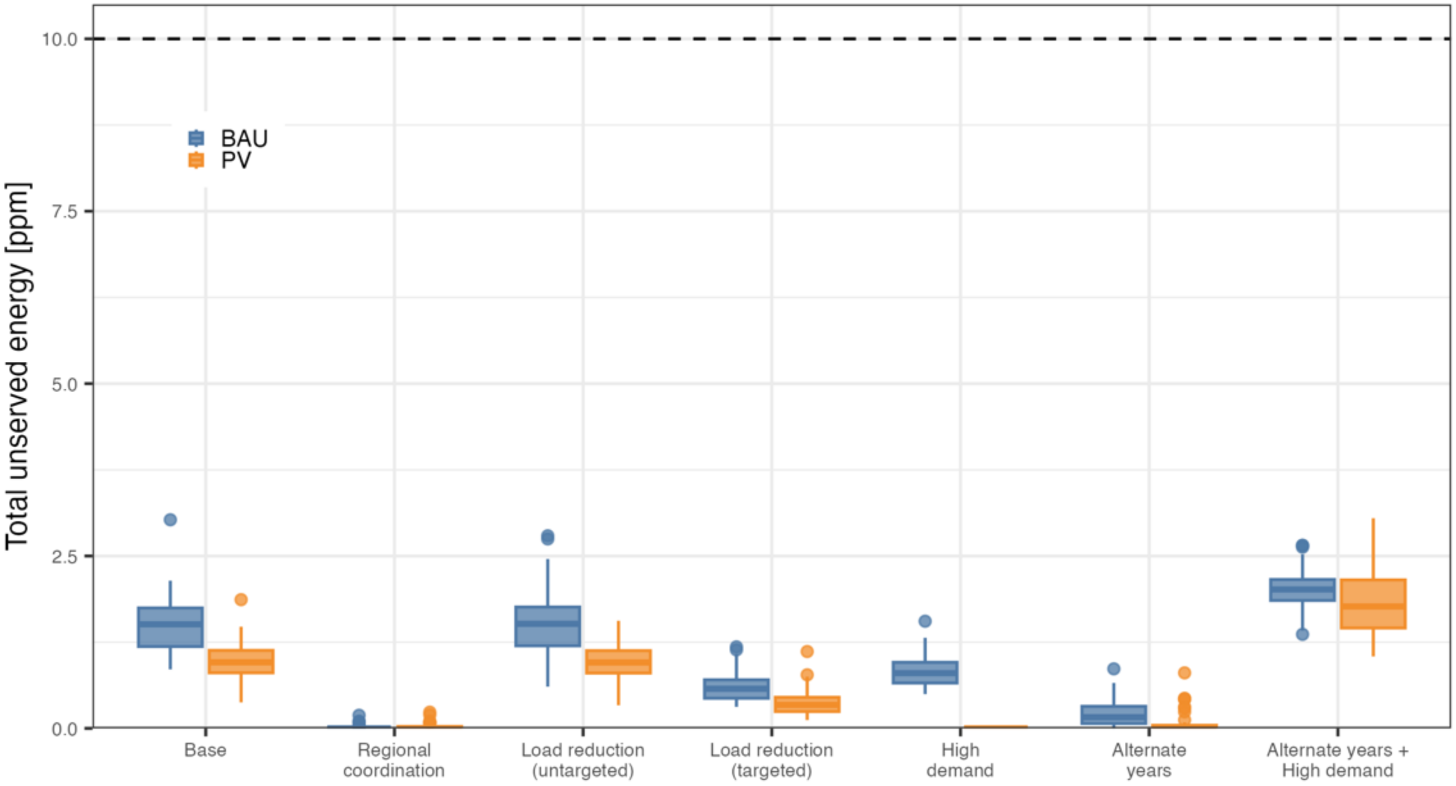


Fine temporal resolution more critical for capturing solar and net load ramping in High PV scenario

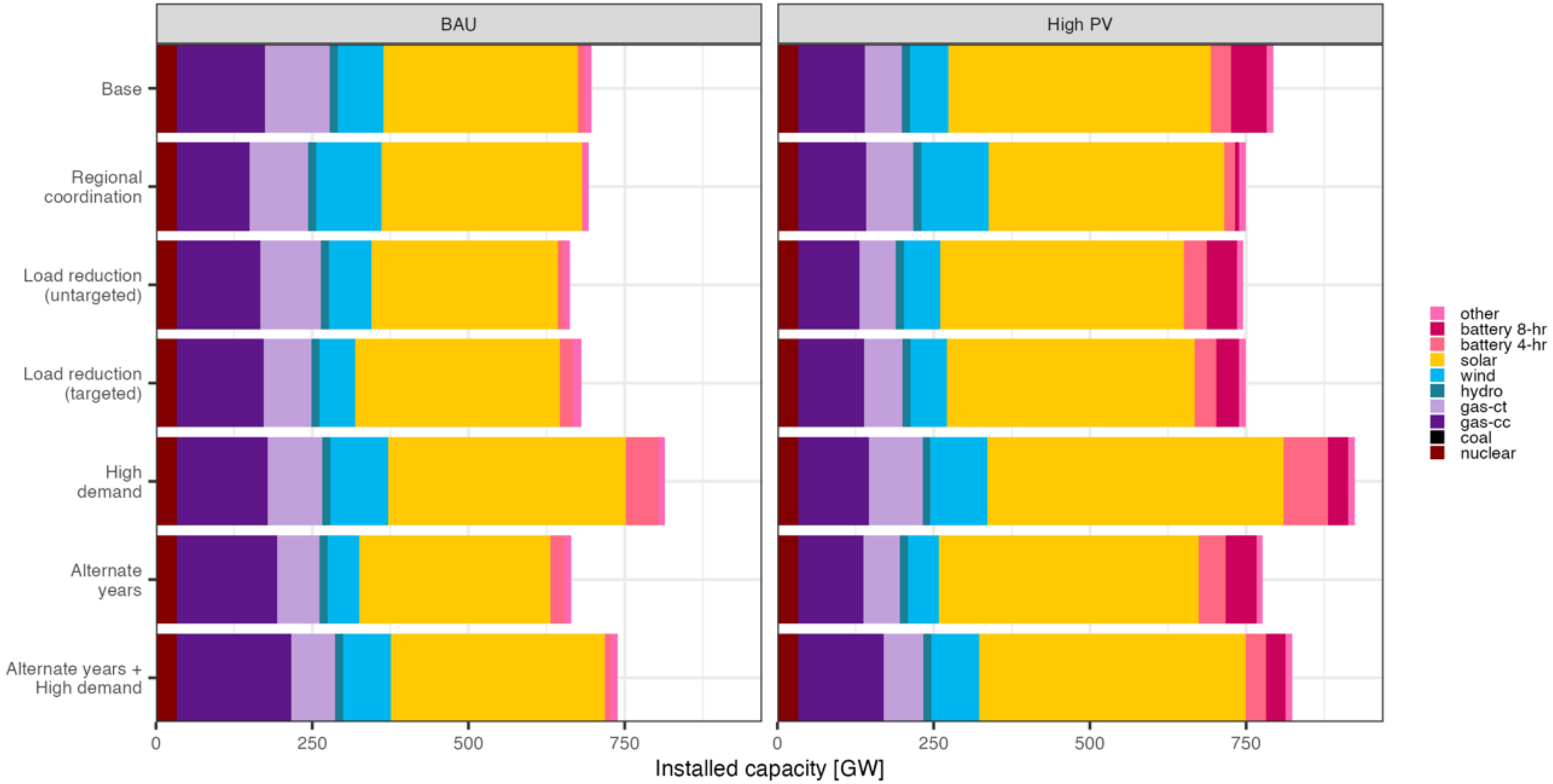


Results: stress test sensitivities

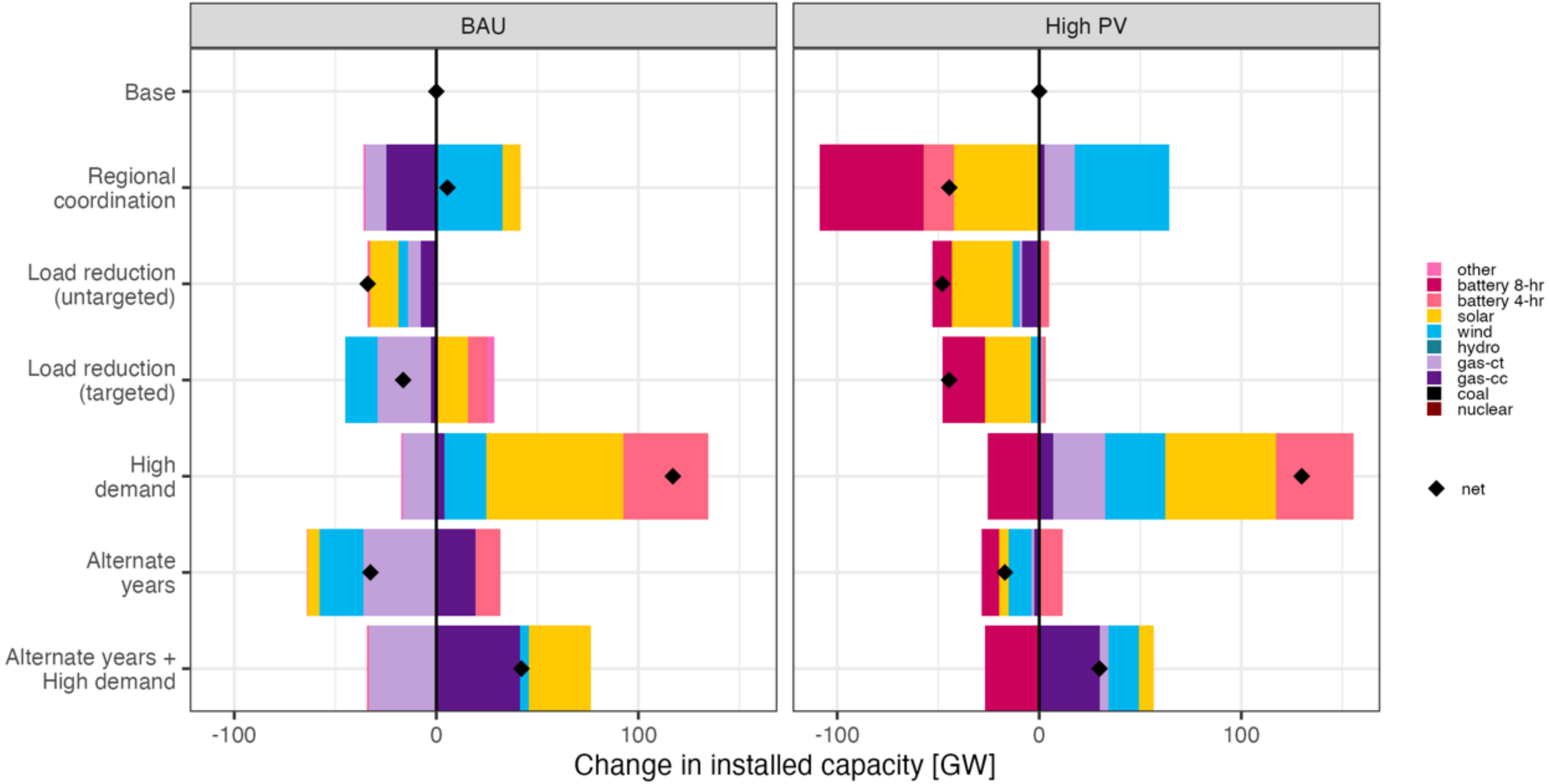
Stress period approach yields systems that meet reliability target across a range of conditions



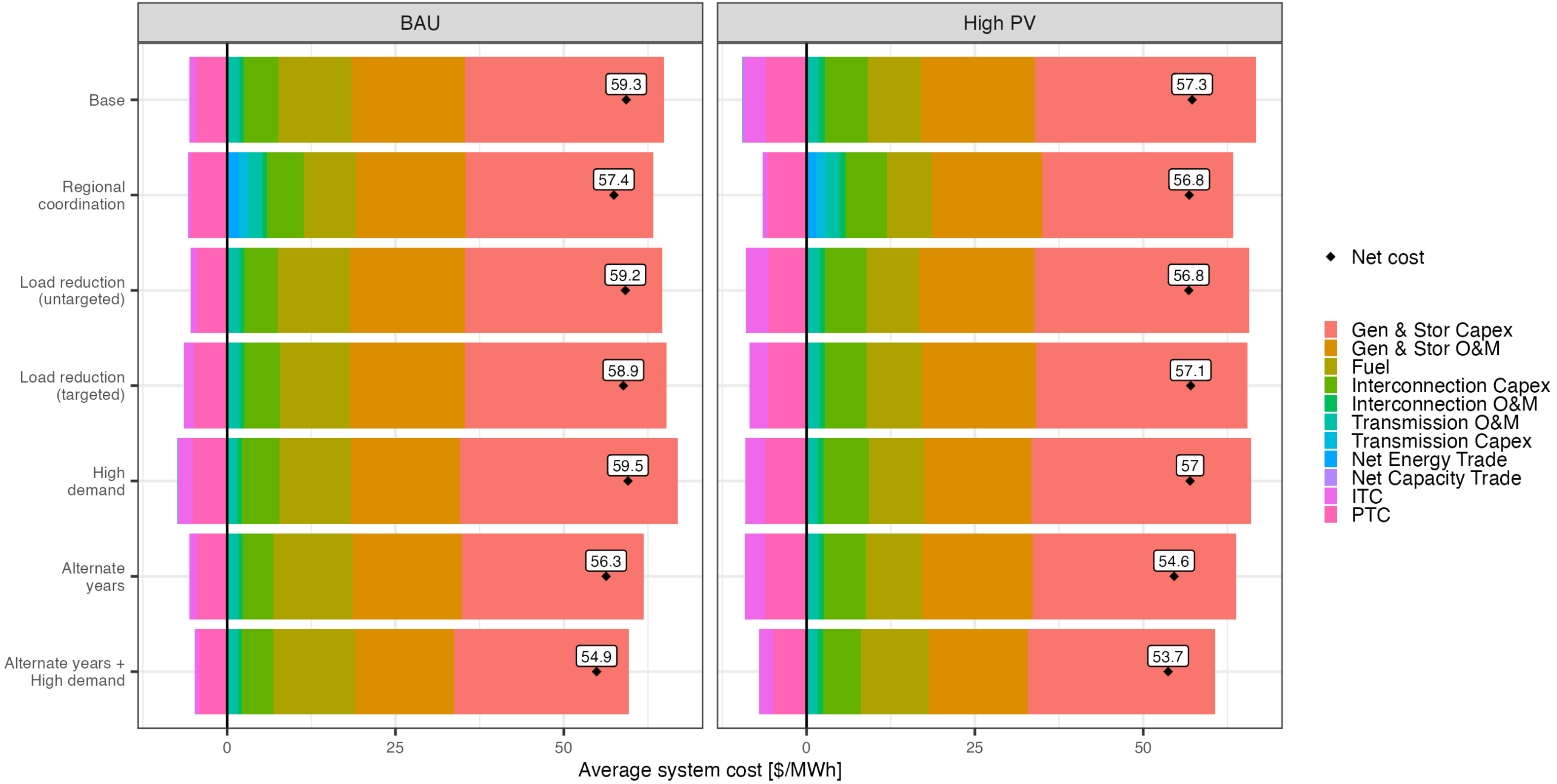
Total capacity and mix of resources for Southeast varies across sensitivities



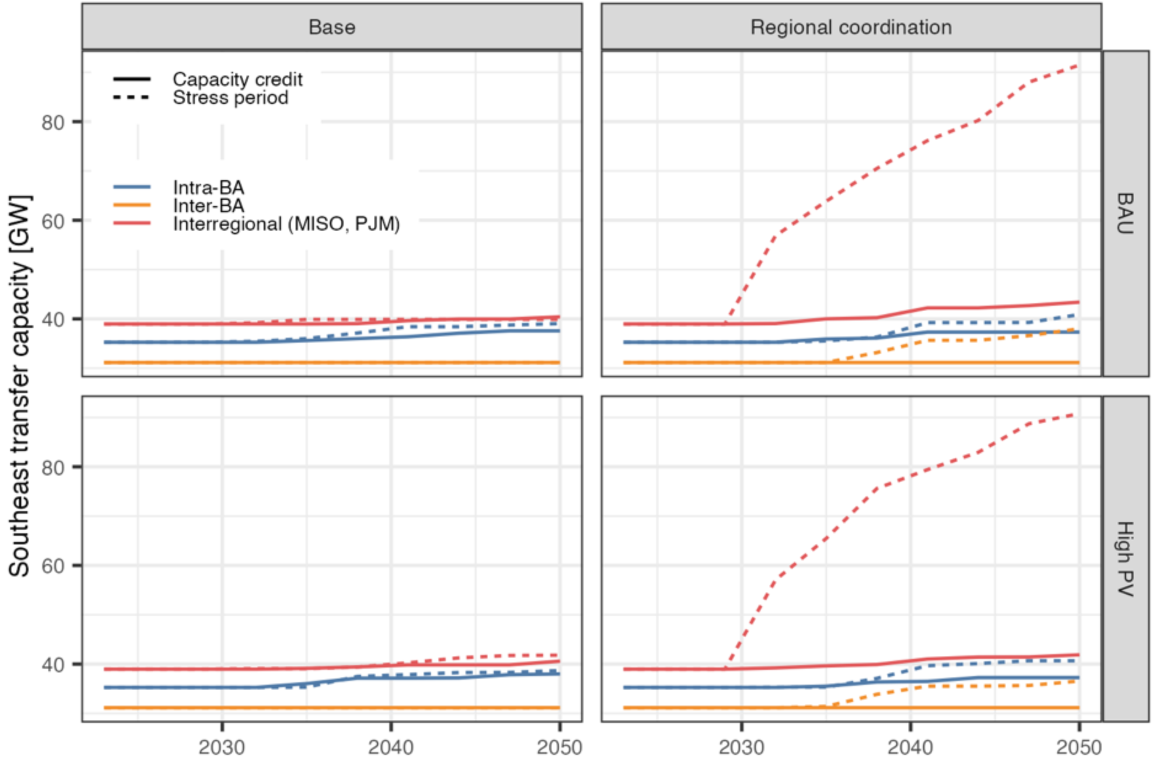
Total capacity and mix of resources for Southeast varies across sensitivities



Regional coordination and load reduction strategies offer options to reduce costs



Regional coordination can reduce costs and improve reliability, but requires new transmission



Benefits of regional coordination only captured using stress period method

Conclusions

Although it performs well in today's system, **capacity credit approximation may face challenges** modeling systems with higher levels of solar and storage.

Integrating planning and resource adequacy models can address some of these gaps, helping planners deliver more reliable systems.

- In this study, the integrated approach addresses shortfall risk by adding longer-duration storage and a diverse mix of new capacity.
- Higher reliability achieved but with 3-4% increase in 2050 average system costs; also imposes additional computational burden.
- The integrated approach handles a range of sensitivities, including capturing the benefits of regional coordination from resource diversity that are not well characterized by the capacity credit approach.

Questions?

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