Incorporating Stressful Grid Conditions for Reliable and Cost-Effective Electricity System Planning

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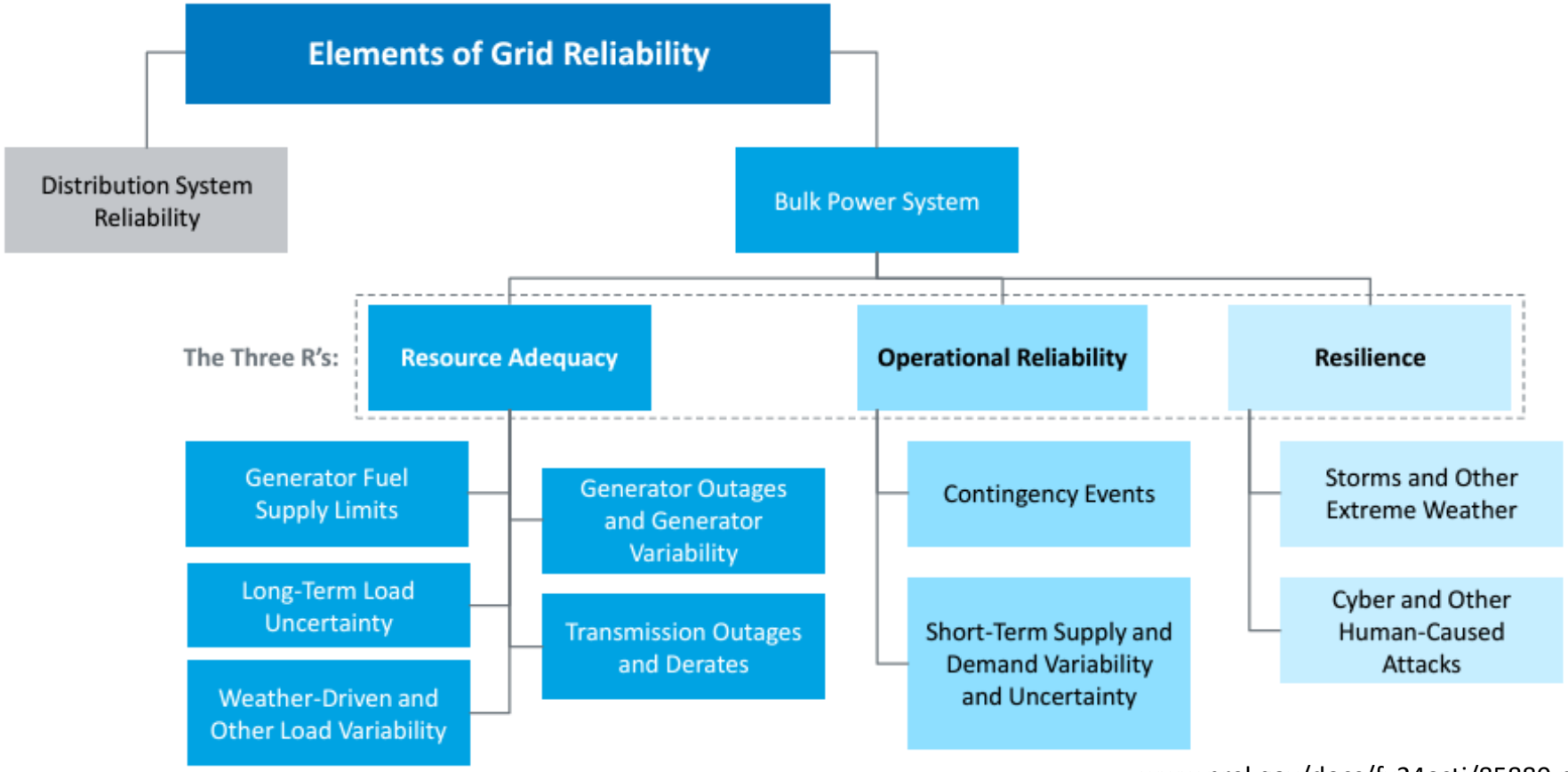
ESIG Spring Technical Workshop

Material includes unpublished preliminary data and analysis that is subject to change

Resource Adequacy (RA) is a component of grid reliability

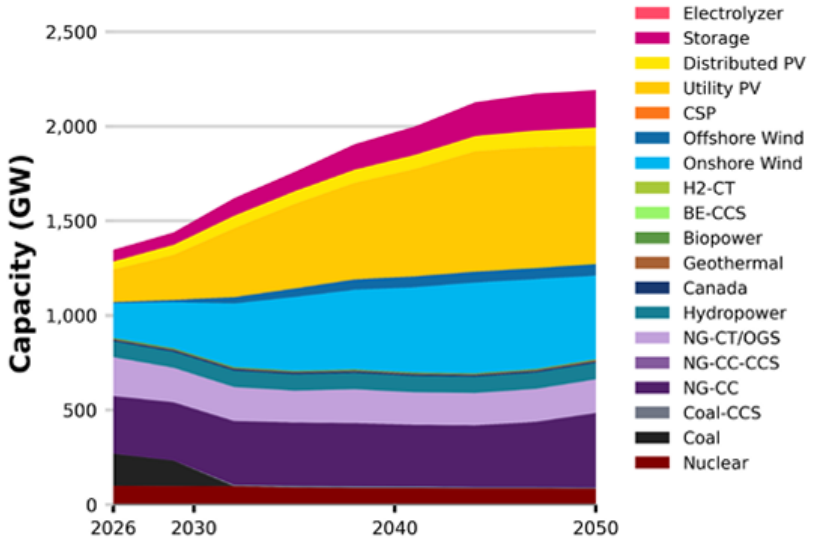


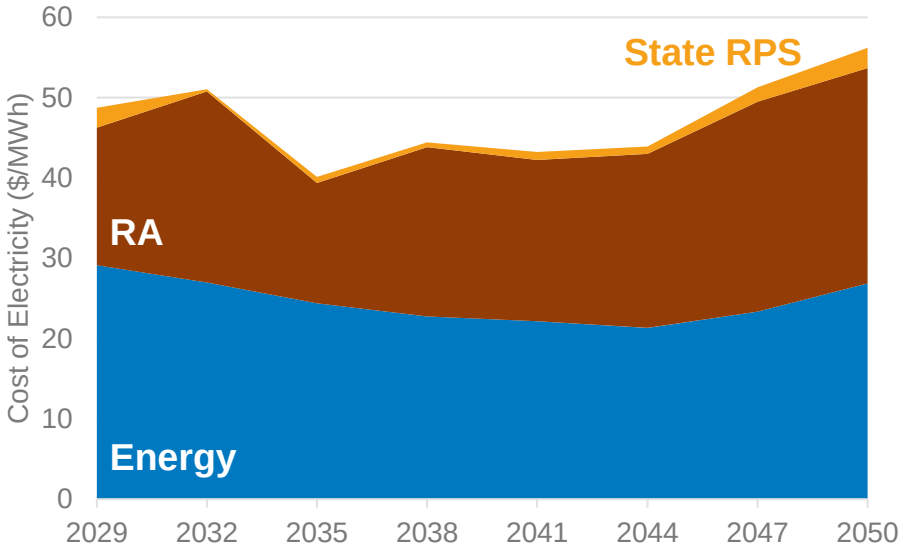
www.nrel.gov/docs/fy24osti/85880.pdf

"[t]he ability of the electric system to supply the aggregate electric power and energy requirements of electricity consumers at all times while taking into account scheduled and reasonably expected unscheduled outages of system components"

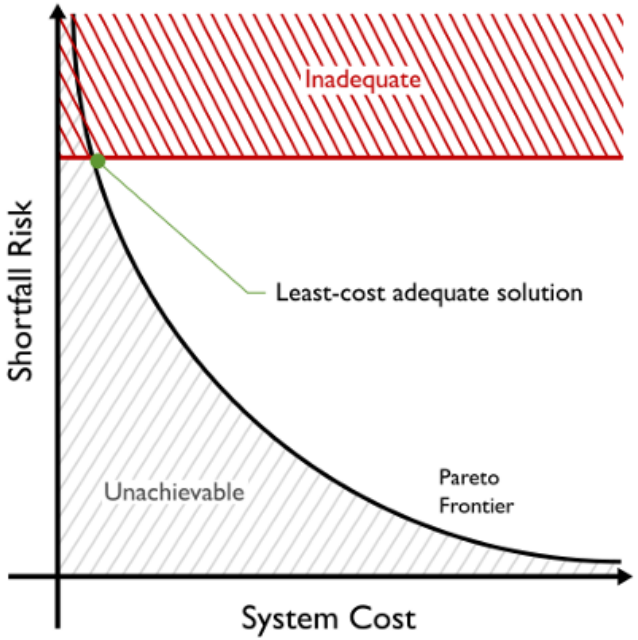
NERC "2022 State of Reliability"

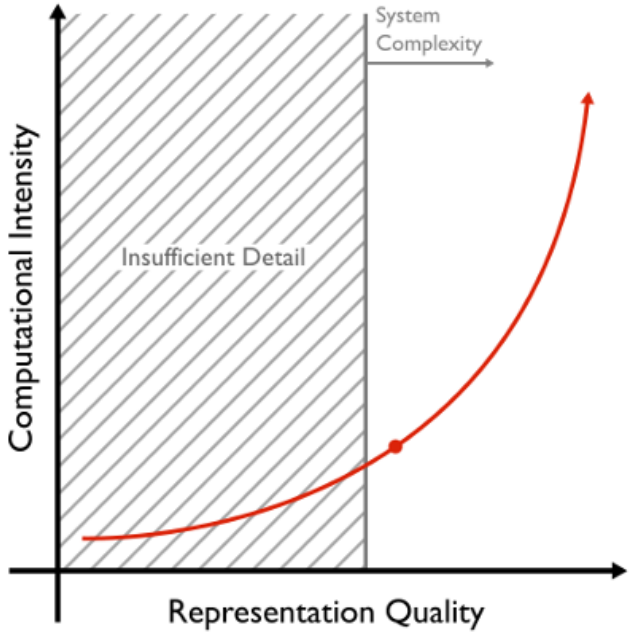
RA is the primary reliability component driving capacity expansion models





Low Demand – Current Policies Scenario from Standard Scenarios 2024
https://www.nrel.gov/docs/fy25osti/92256.pdf





Challenge is to find the **lowest cost** resource adequate system, but **computational** constraints apply

Kuna et al. 2024. https://www.nrel.gov/docs/fy24osti/89386.pdf

RA and CEM methods need to advance as the resource mix evolves

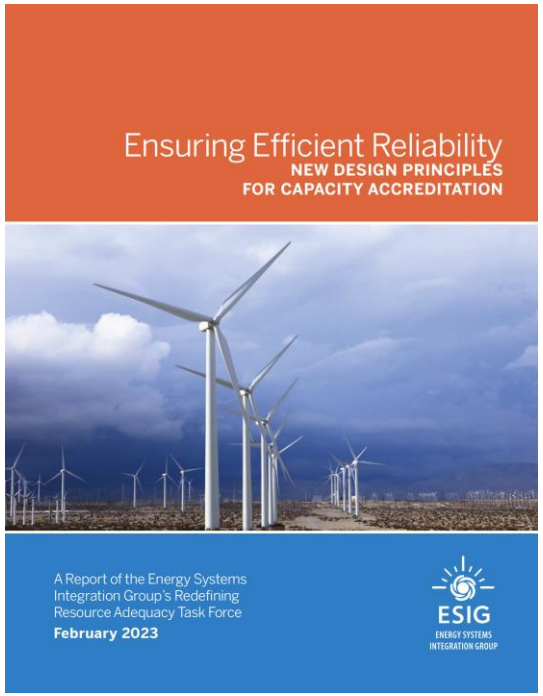


FIGURE 4

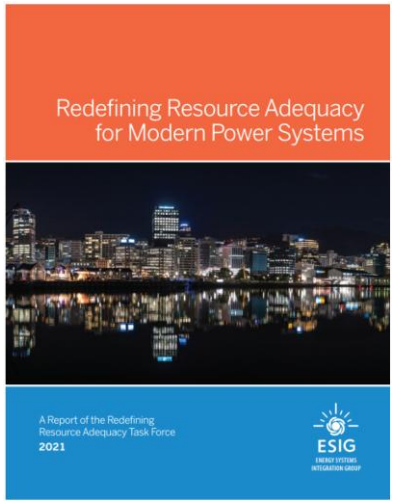
Transition of Capacity Accreditation Methods

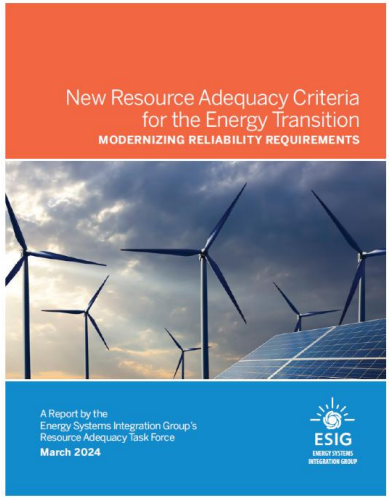
Increasing shares of variable renewables and energy-limited resources

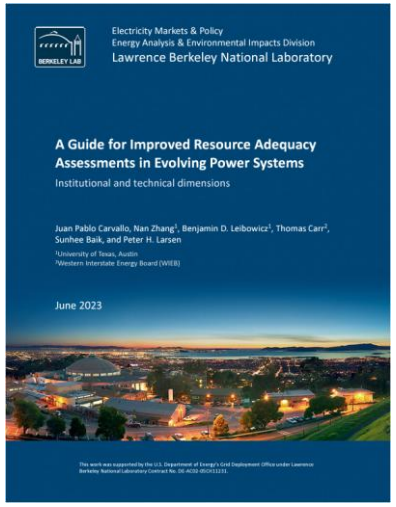
1. Nameplate capacity of resources
2. Expected capacity available at the time of peak load
3. Expected capacity available at the time of peak net load
4. Expected capacity available at the time of high risk
5. Expected capacity and energy available from resources during periods of high risk

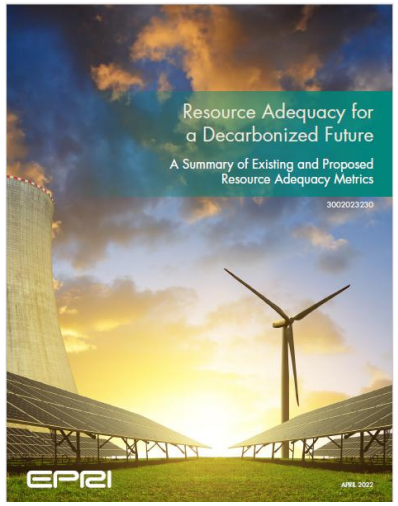
Source: Energy Systems Integration Group.

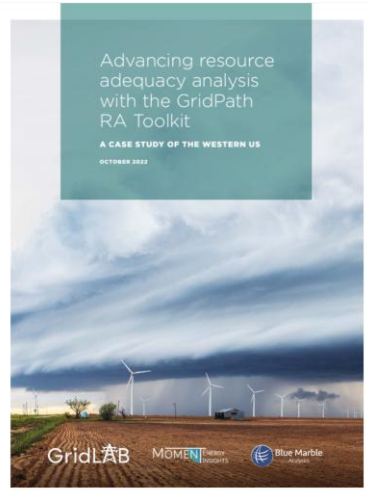
https://www.esig.energy/new-design-principles-for-capacity-accreditation/

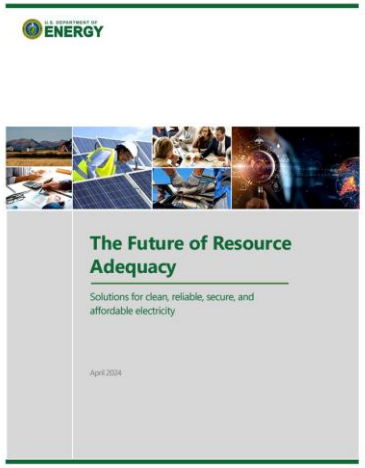








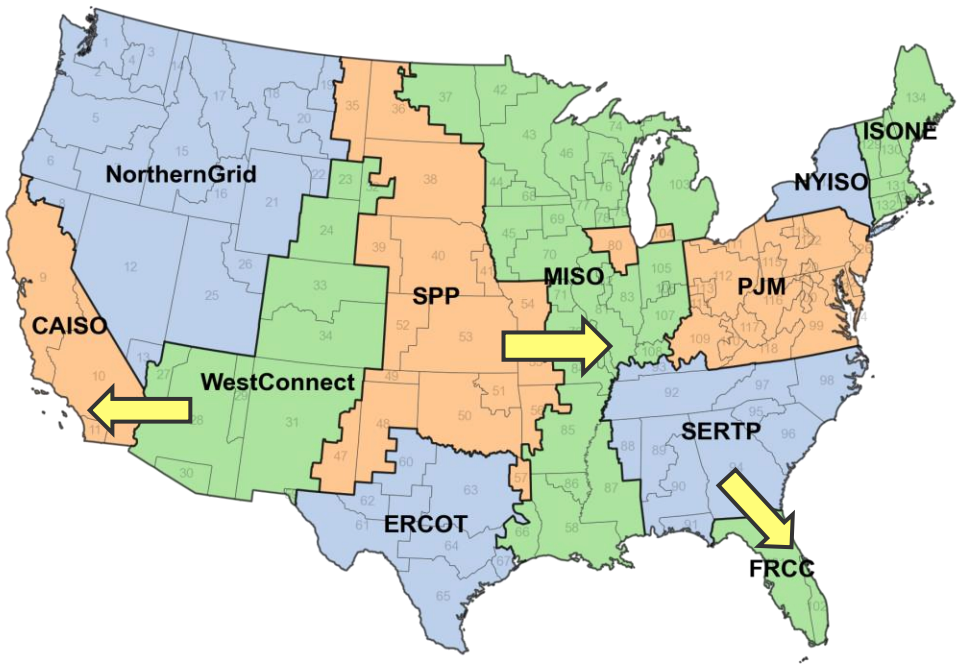




+ many more

What's the matter with capacity credit?

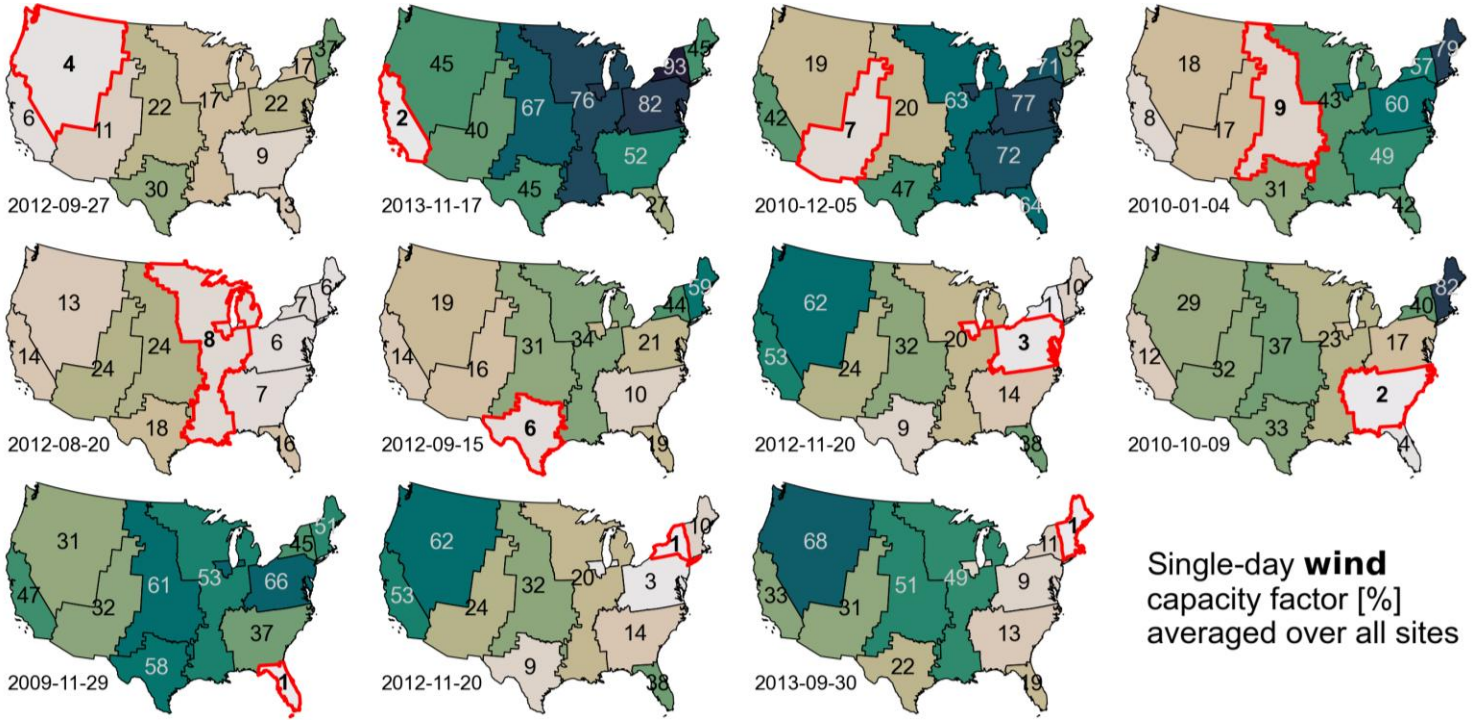
1. Capacity credit is assessed in the planning region where a resource is **sited**, even if it is used to meet RA needs in a **different** planning region



2. "Peak load" or "peak net load" may not be the **most stressful period**

3. Capacity credit does not account for **resource complementarity** or **load diversity**

Take the least-**windy** day in each region.
How windy are other regions **on that day**?



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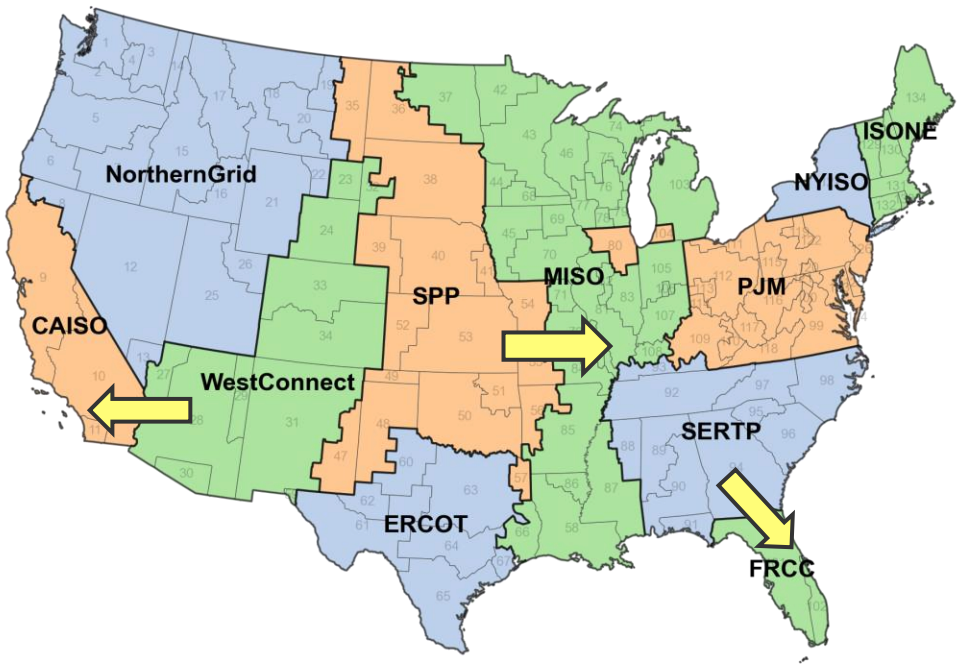
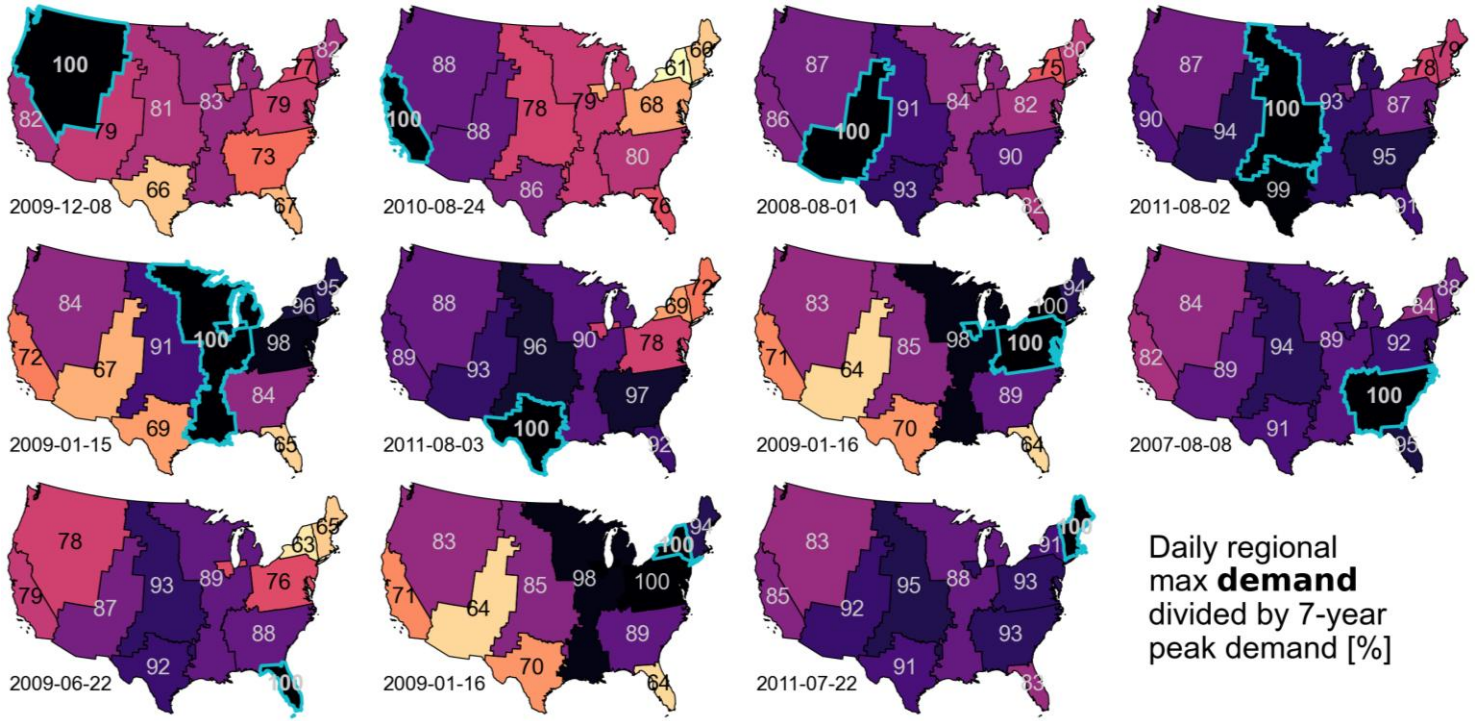


2. "Peak load" or "peak net load" may not be the **most stressful period**

3. Capacity credit does not account for **resource complementarity** or **load diversity**

Take the **peak demand** day in each region.
How close are other regions to their peak **on that day**?

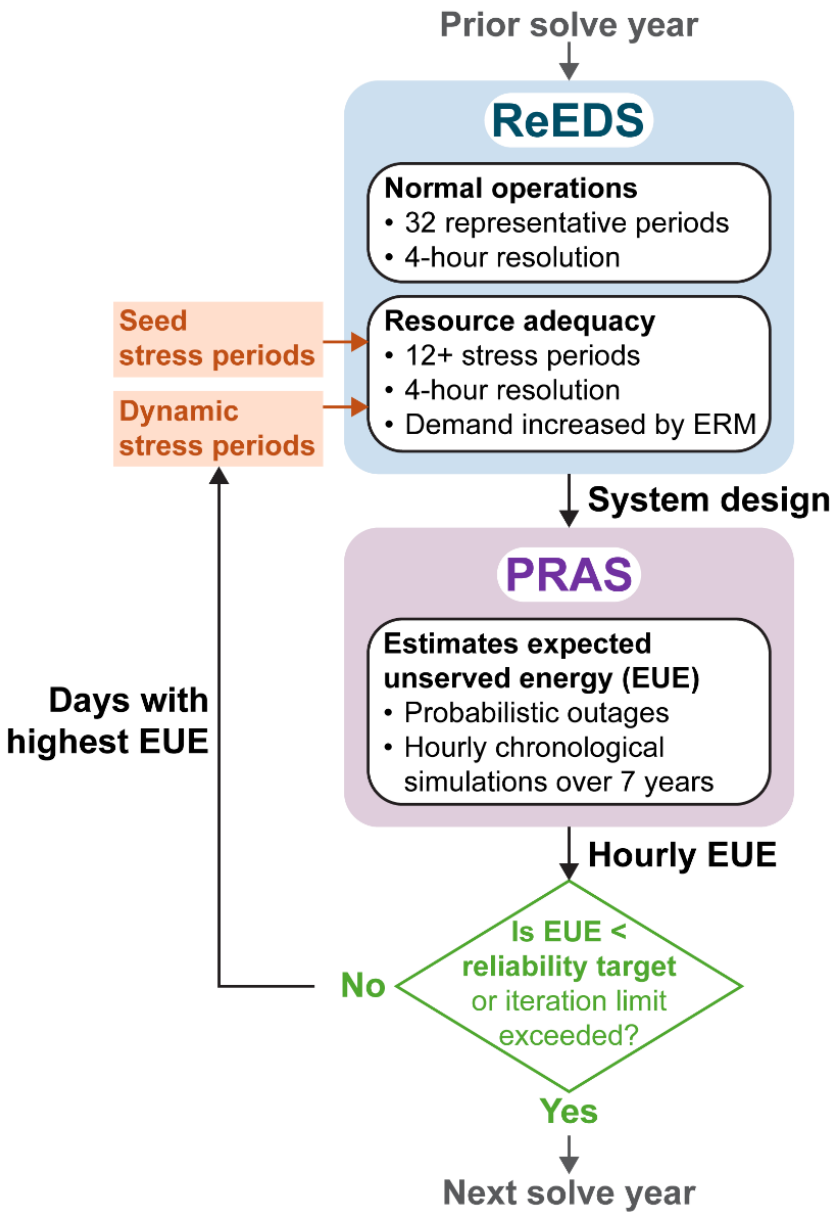


4. Requires additional verification to assess whether the intended **reliability target (LOLE, NEUE) has been met**; capacity credit and planning reserves are reliability proxies

New “Stress Periods” Method

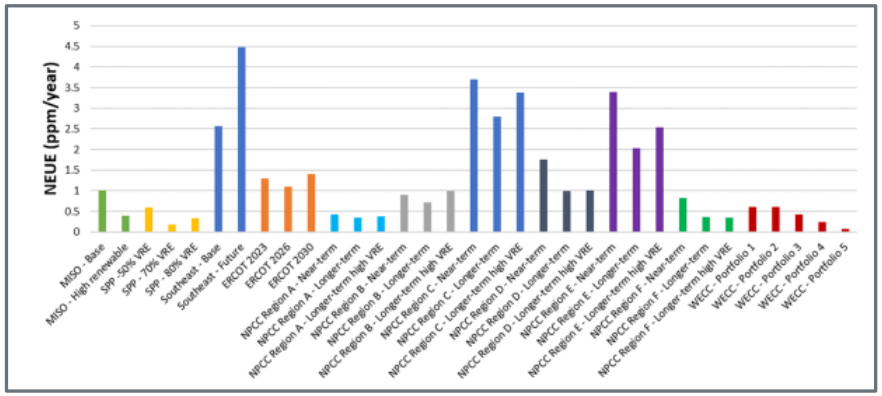
1. Identify days with highest risk of unserved energy for all regions (“stress periods”)
2. Include stress periods for each region and model them coincidently for U.S. wide capacity expansion
3. Iterate until reliability target is achieved for all regions

Overview of the Stress Periods Method



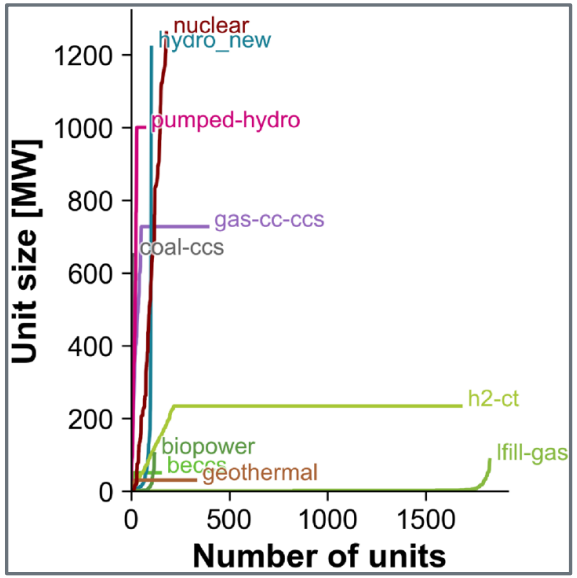
Implementation details (customizable)

User-specified reliability target

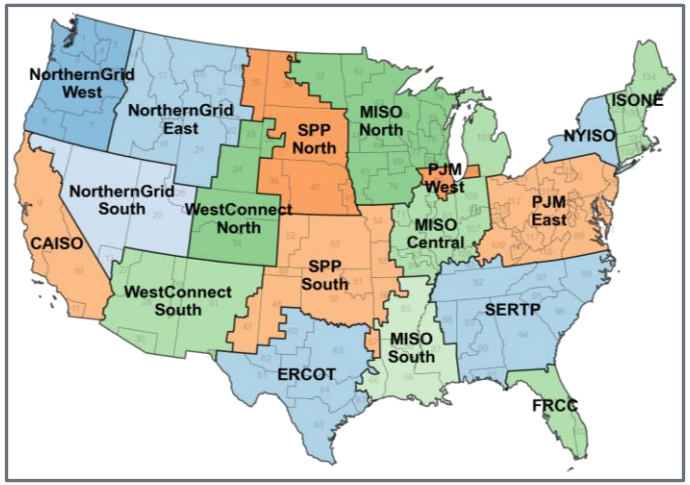


EPRI 2024. https://www.epri.com/research/products/000000003002030638

Disaggregation to individual units

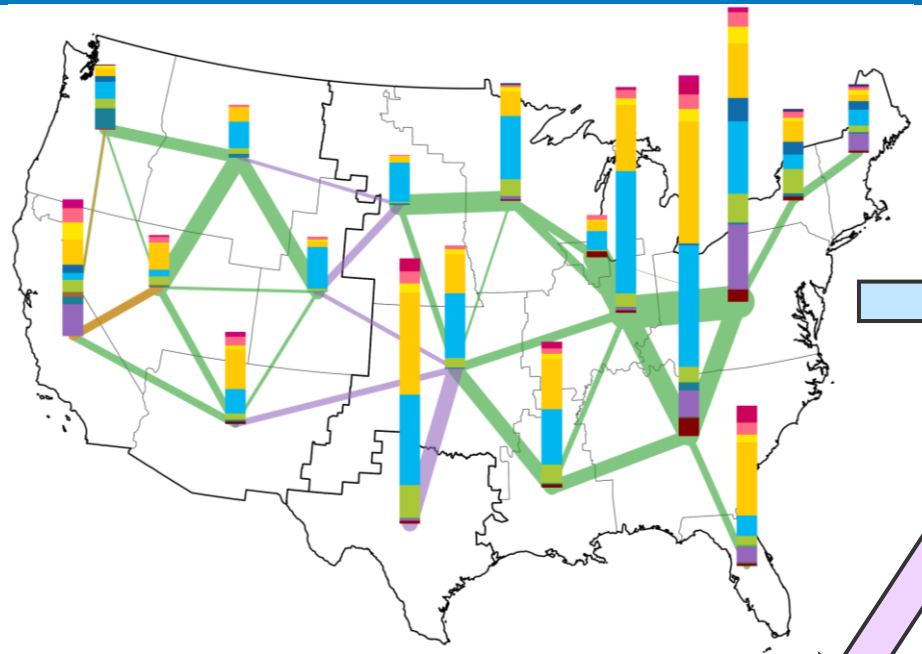


Target applied to 18 planning regions



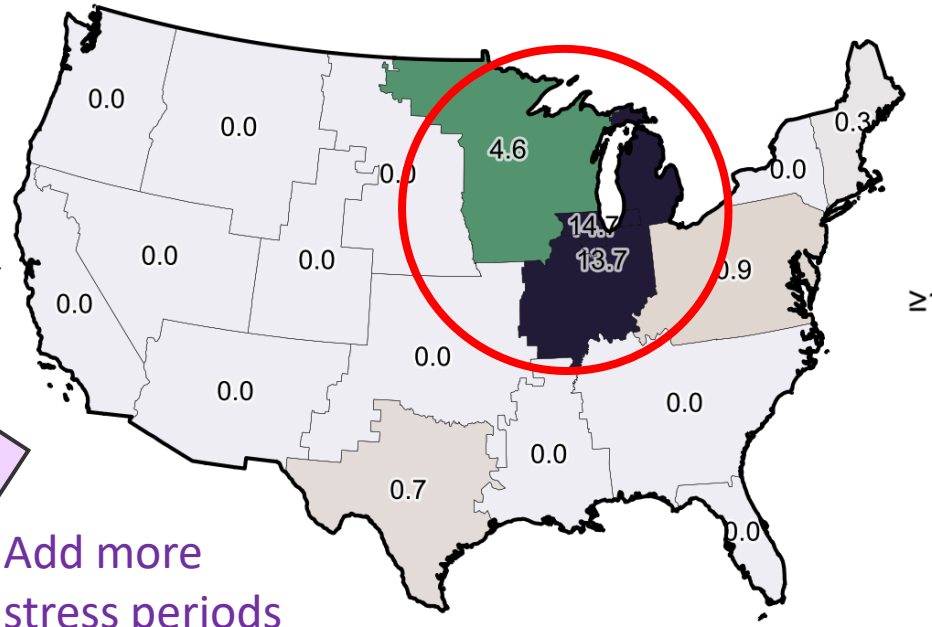
Example iteration between capacity expansion & RA

Illustrative Results



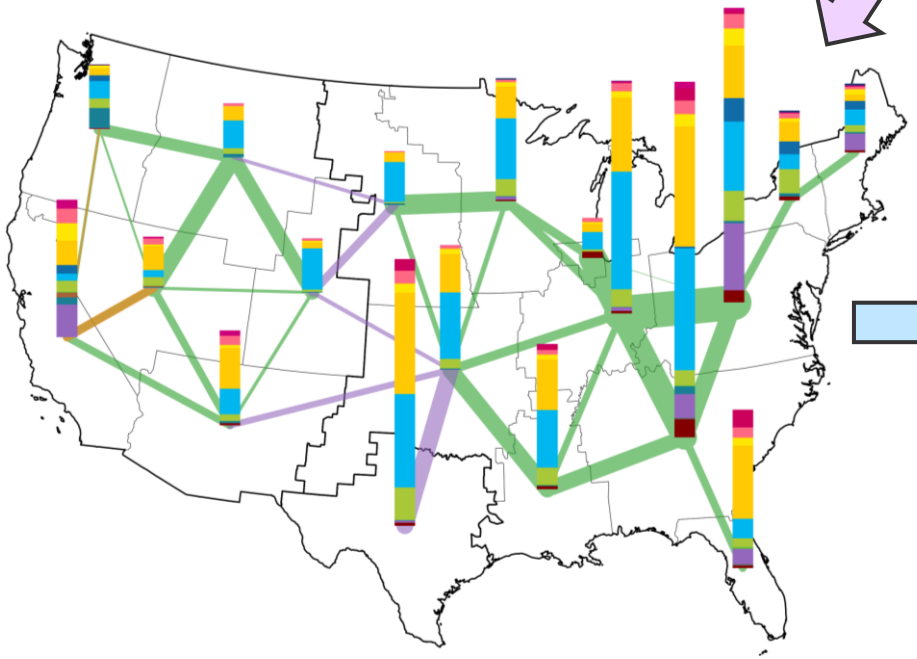
Generation capacity

- Storage
- PV
- CSP
- Offshore wind
- Land-based wind
- H2 turbine
- BECCS
- Gas+CCS
- Gas
- Coal+CCS
- Coal
- Nuclear
- Hydro/Geo/Bio
- Imports



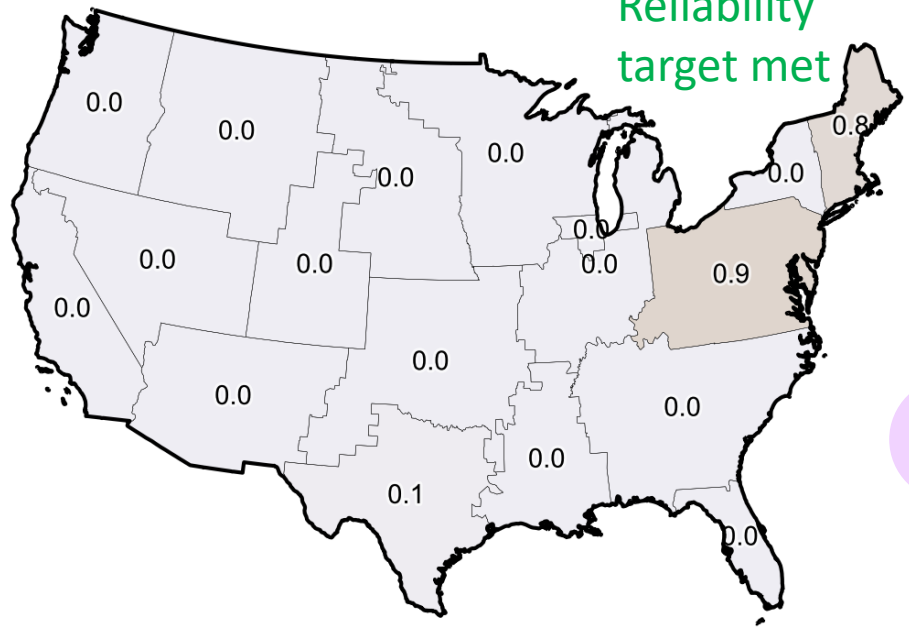
Reliability target **not** met

Add more stress periods

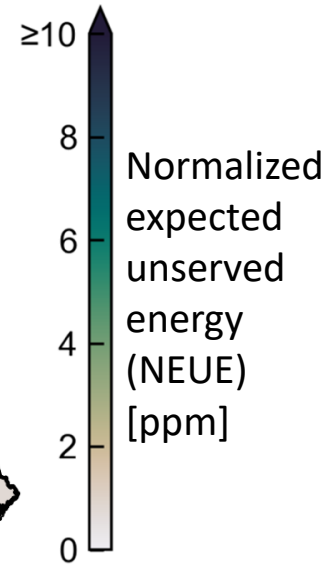


Capacity expansion model

ReEDS



Reliability target met

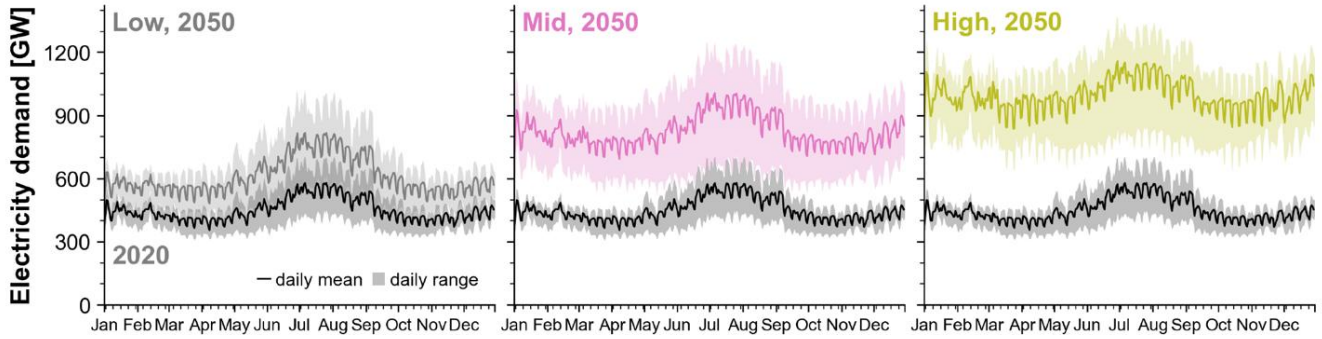


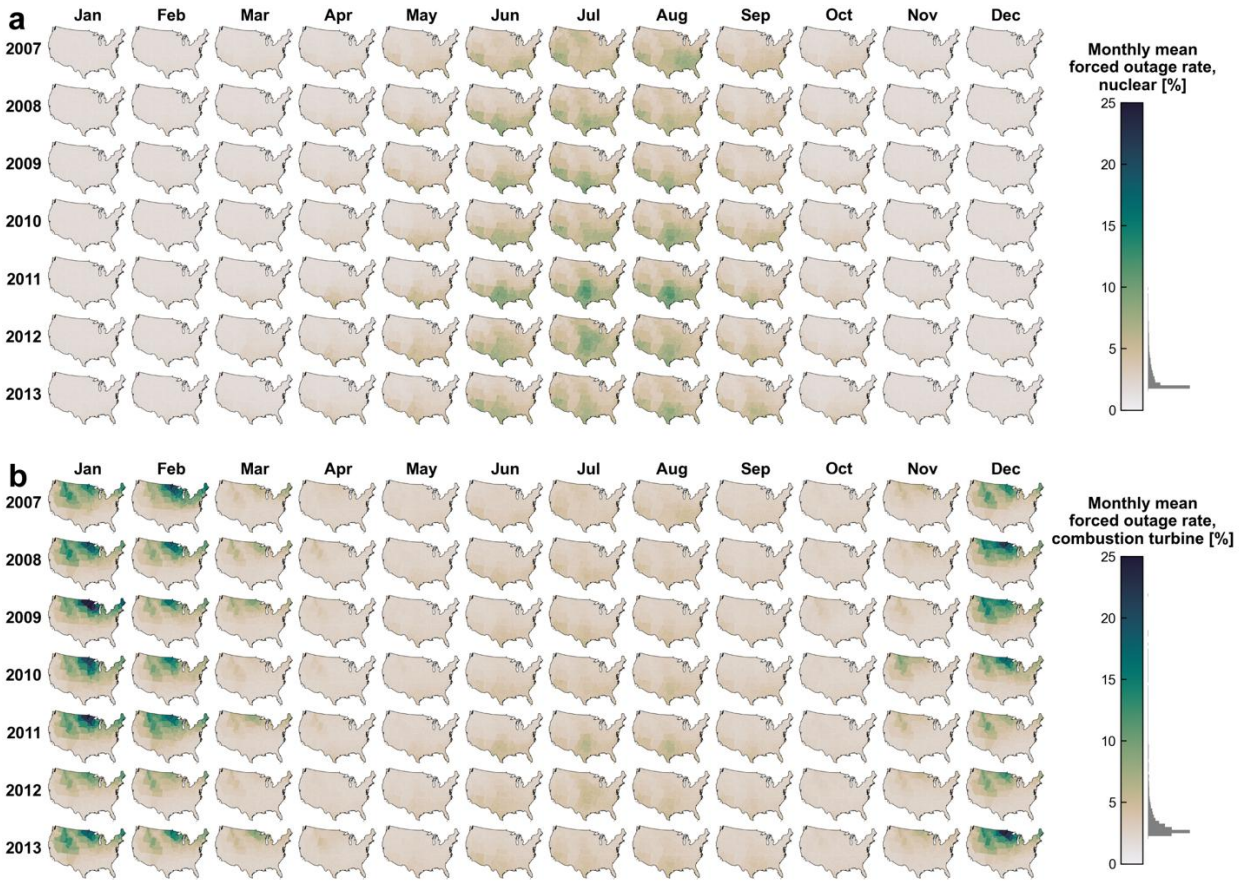
Resource adequacy model

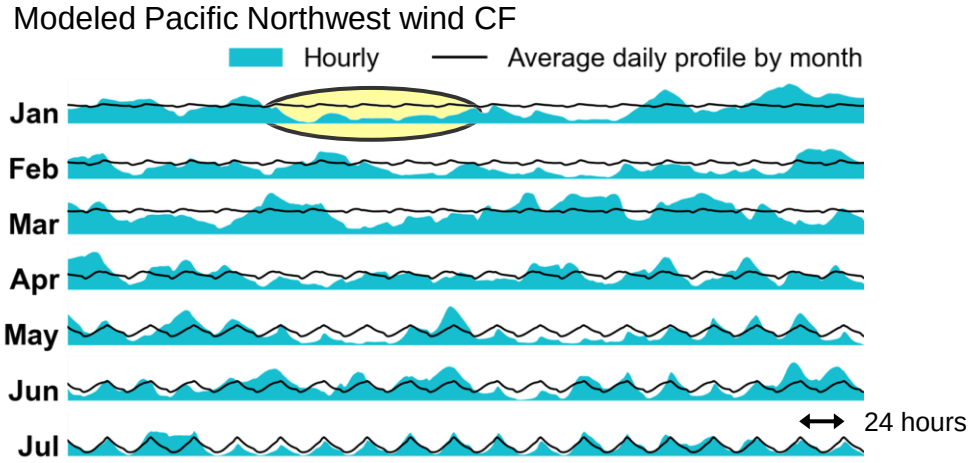
PRAS

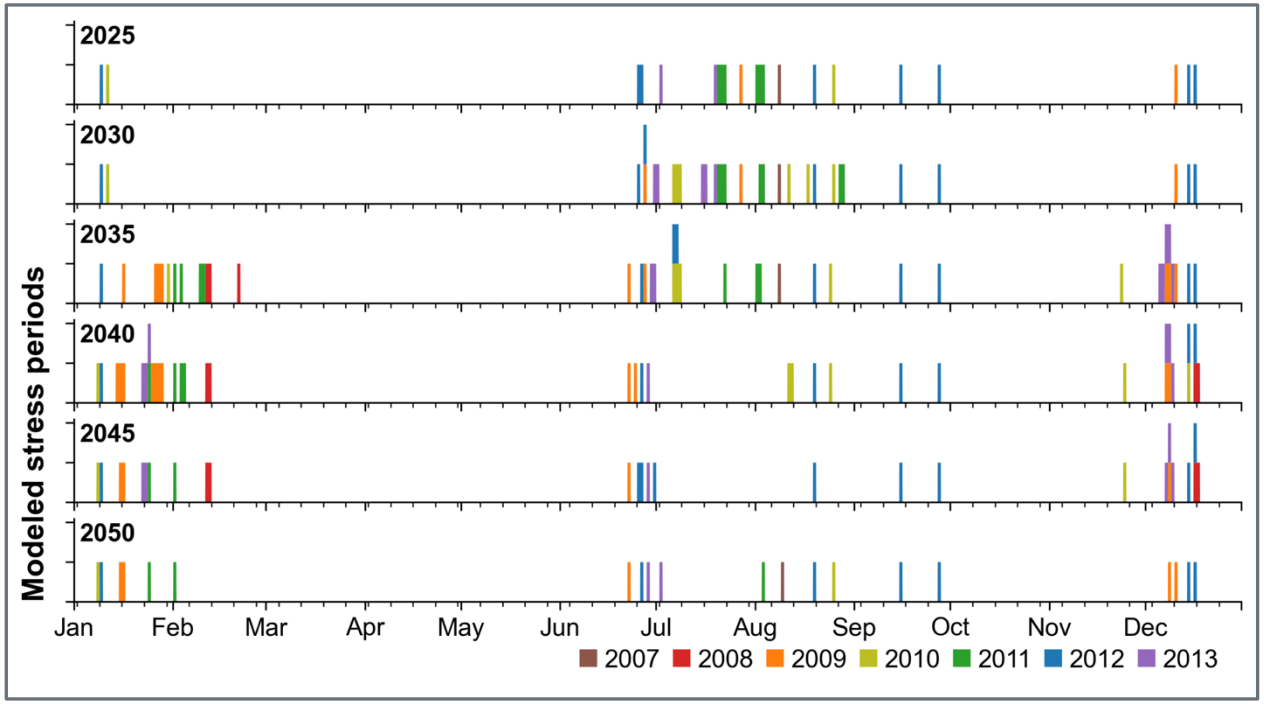
7y × 8760h × *N* samples

Considers multiple sources of grid stress and their changes over time





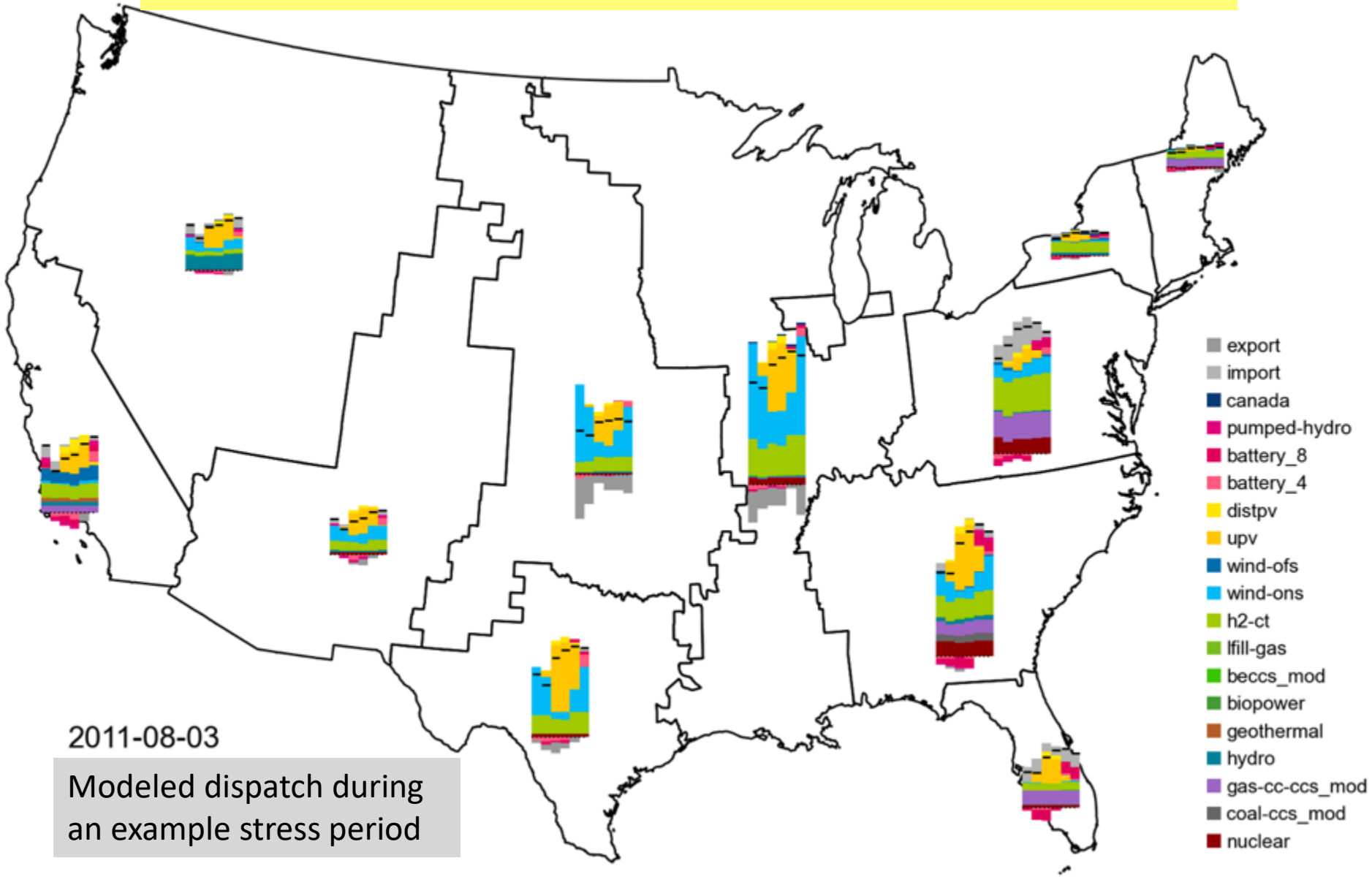




Illustrative Results

And finds the optimal solutions* to meet the stresses

* Solutions chosen from multiple combinations of **resources** and **regions**

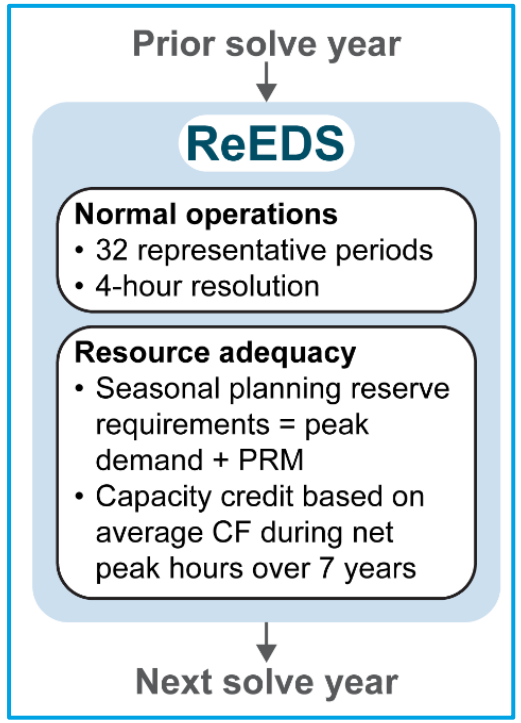


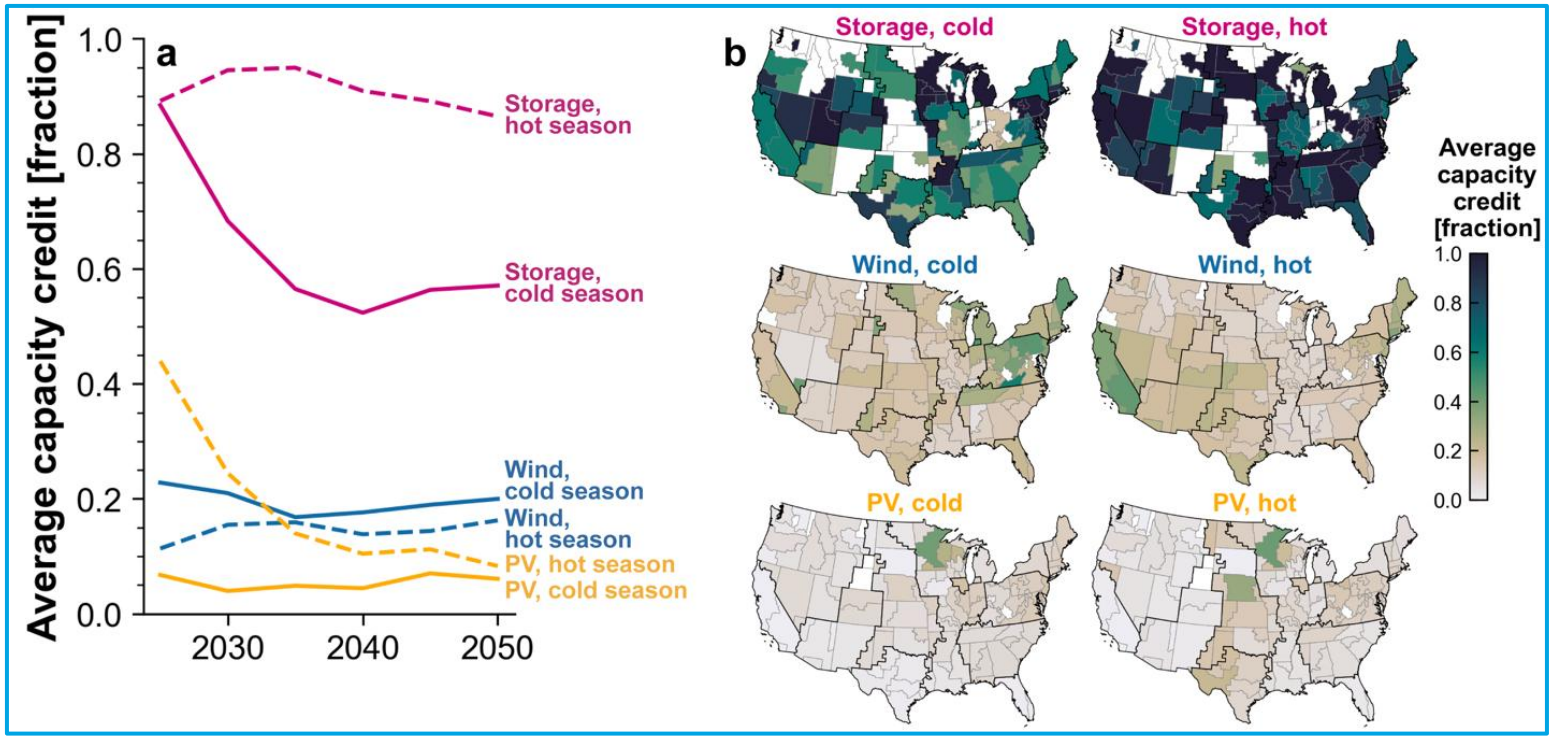
Modeled dispatch during an example stress period

Illustrative Results

How much does the choice of RA method matter?

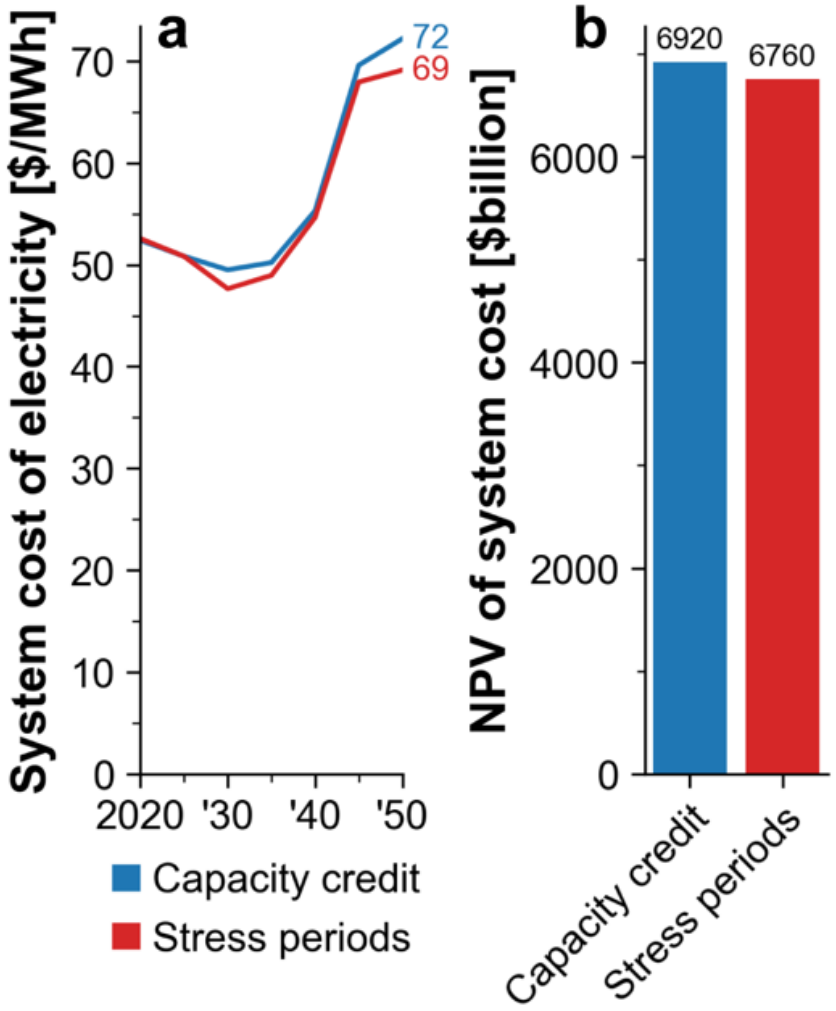
Compare cost and reliability of portfolios designed using the Stress Periods method vs. a traditional **Capacity Credit** method





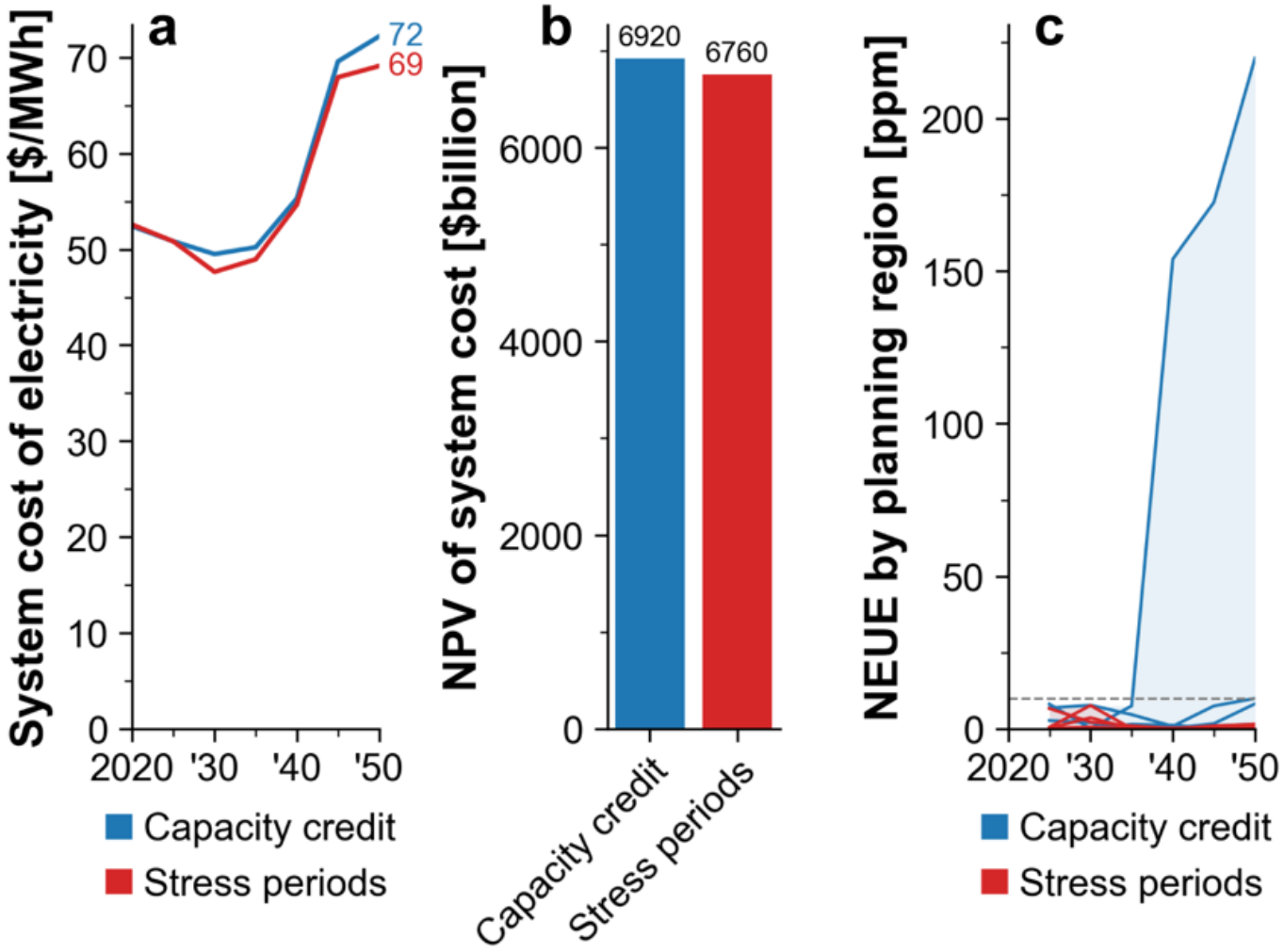
Preliminary

The Stress periods method results in **lower costs**



Preliminary

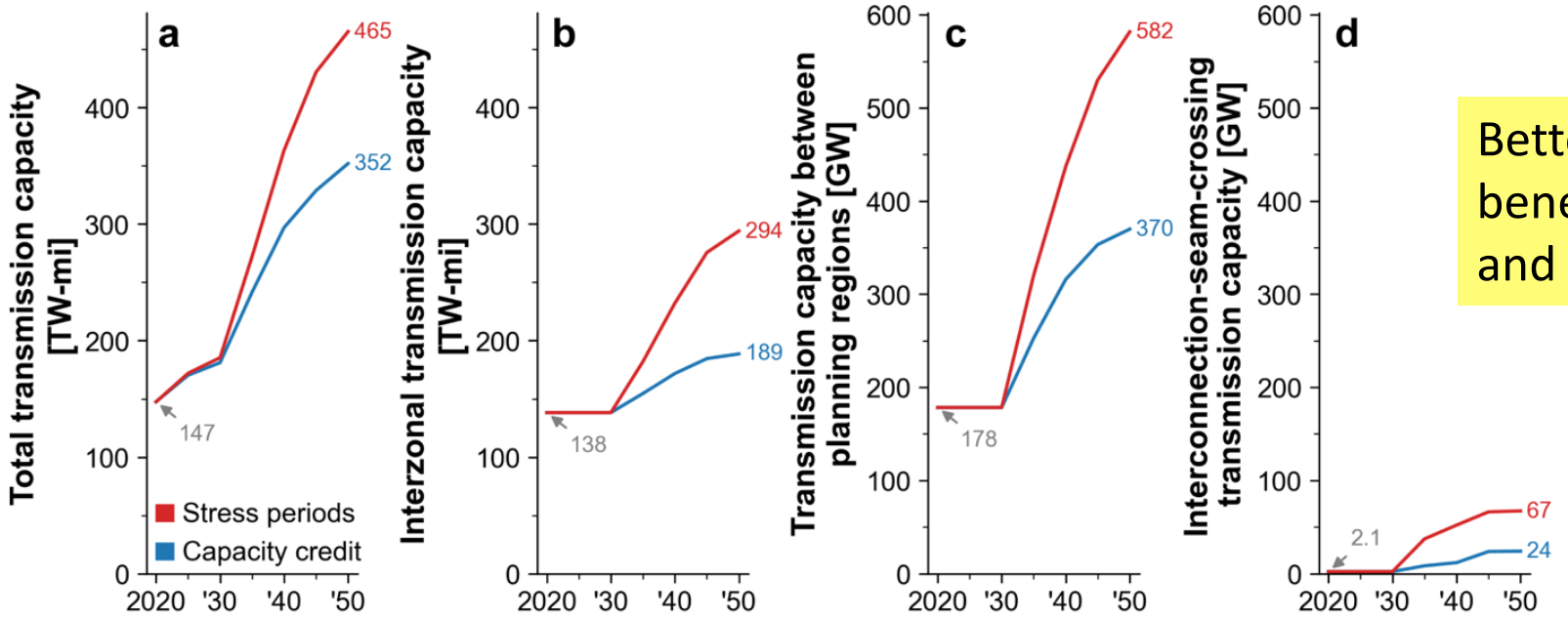
The Stress periods method results in lower costs and **greater reliability**



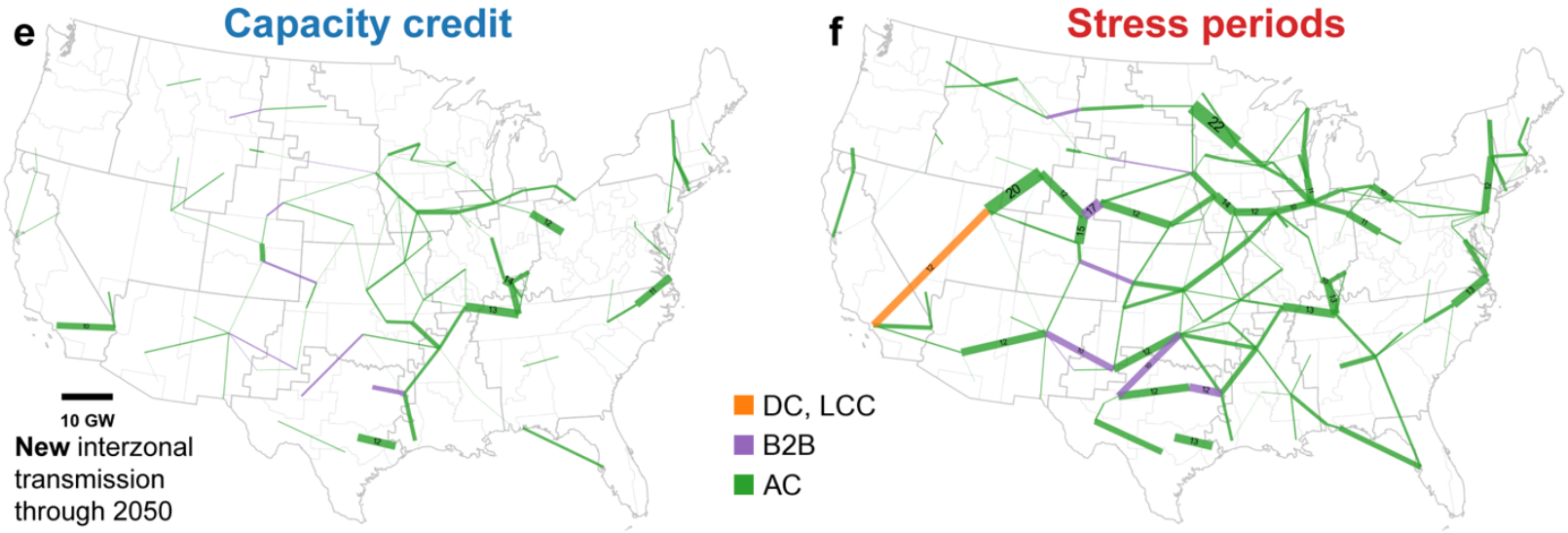
Benefits are achieved through reducing “overbuilds” and finding a more-optimal resource mix

Preliminary

Stress periods method results in greater transmission expansion, especially interregional transmission



Better captures transmission's benefit to **geographic diversity** and **resource sharing**



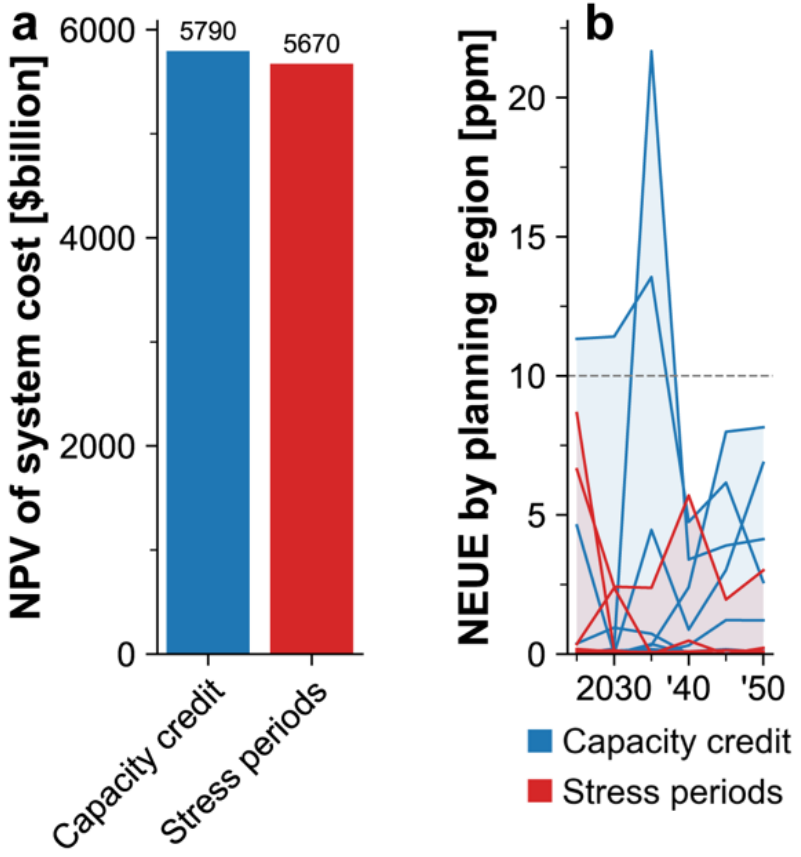
But requires **interregional coordination** in planning and operations.

The method can be used to quantify the benefits of coordination (e.g., National Transmission Planning Study)

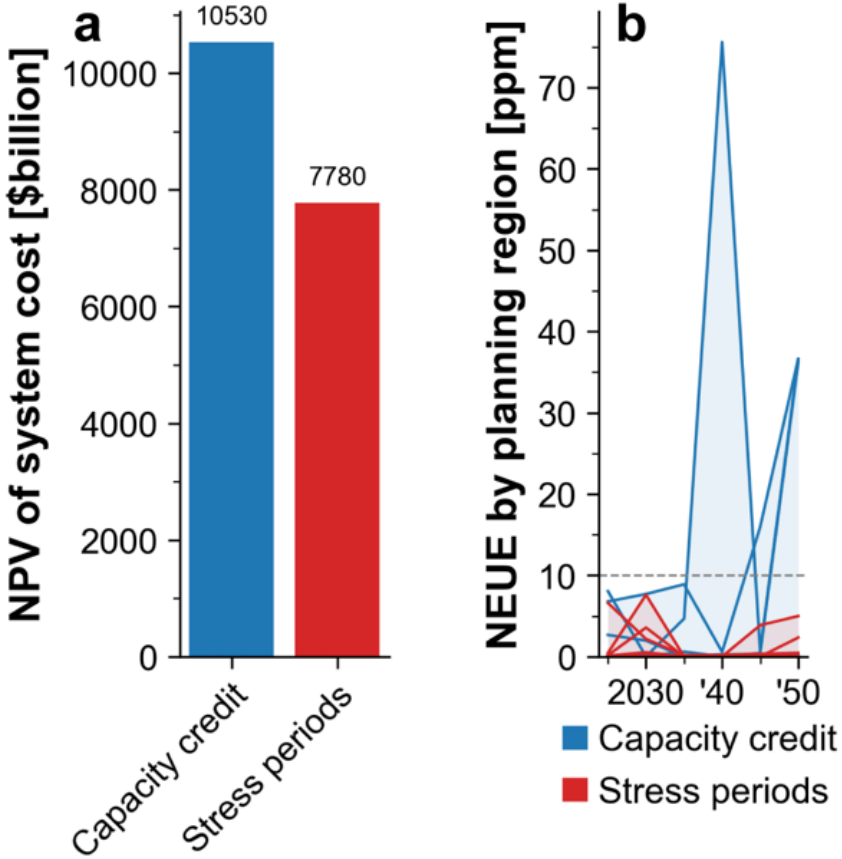
Preliminary

Advantages of the Stress periods method exist across a range of conditions

Existing policies → lower RE



Limited technologies → higher RE



The choice of RA method is more important when there is greater reliance on **weather-dependent resources**, with more **interregional coordination**, and for **larger systems sizes**

Preliminary

Conclusions

- Introduced a (computationally manageable) planning method that integrates probabilistic RA modeling to identify and model **grid stressful periods** directly for capacity expansion decisions
- The stress periods method results in systems that are both **lower cost and more reliable** compared to a traditional capacity credit-based approach
- How RA is considered in capacity expansion becomes more important with **greater weather-dependent resources** and **interregional coordination**
- The method is straightforwardly extendable: more **weather conditions**, wider range of **outages**, multiple **reliability metrics**, and more

Preliminary

Thank you

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www.nrel.gov

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