NATIONAL RENEWABLE ENERGY LABORATORY

Probabilistic Assessment of High-Renewables Power Systems: Current Work and Future Directions

Gord Stephen

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1. Probabilistic Assessment in NREL Long-Term Studies
2. Looking Ahead: Characterizing Future Power Systems
3. Looking Ahead: Future Sources of Resource Adequacy Risk
4. Looking Ahead: Probabilistic Planning Models

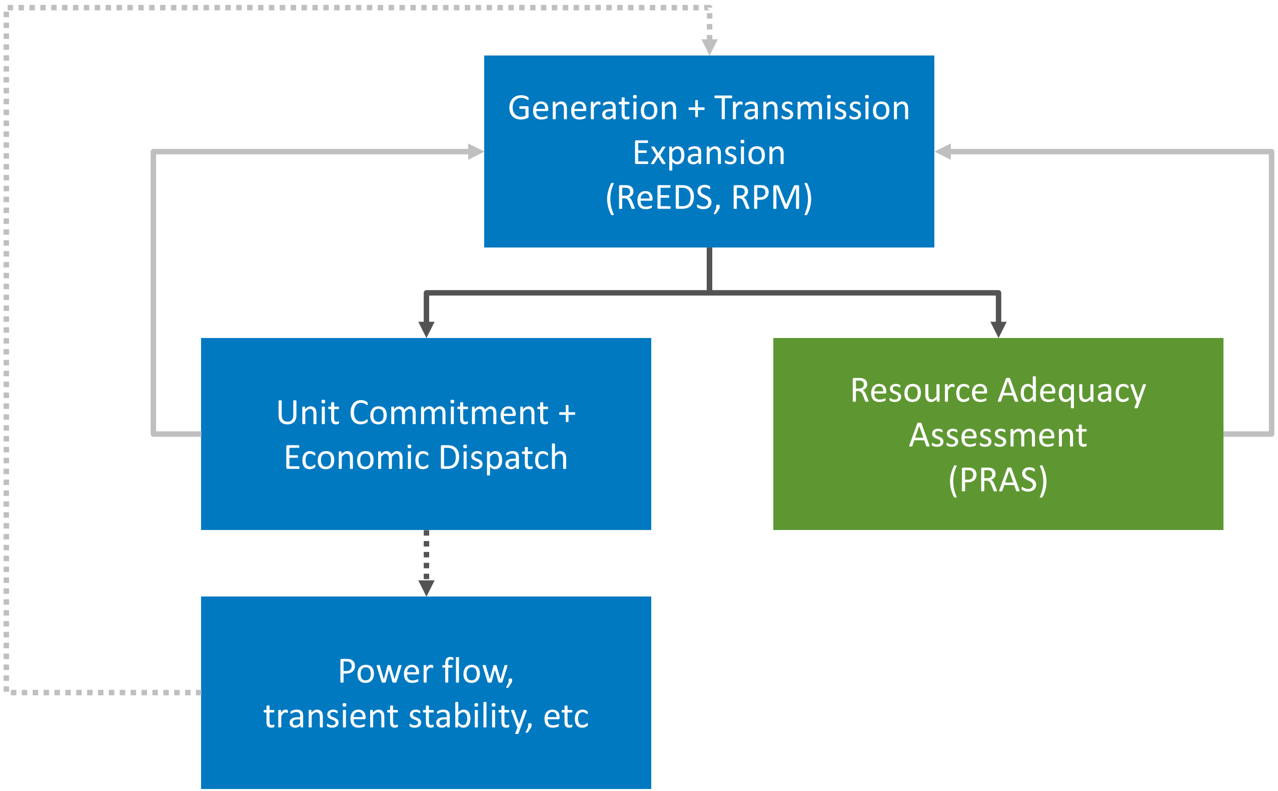
1 **Probabilistic Assessment in NREL Long-Term Studies**

2 Looking Ahead: Characterizing Future Power Systems

3 Looking Ahead: Future Sources of Resource Adequacy Risk

4 Looking Ahead: Probabilistic Planning Models

Typical NREL Long-Term Study Workflow



What is PRAS?

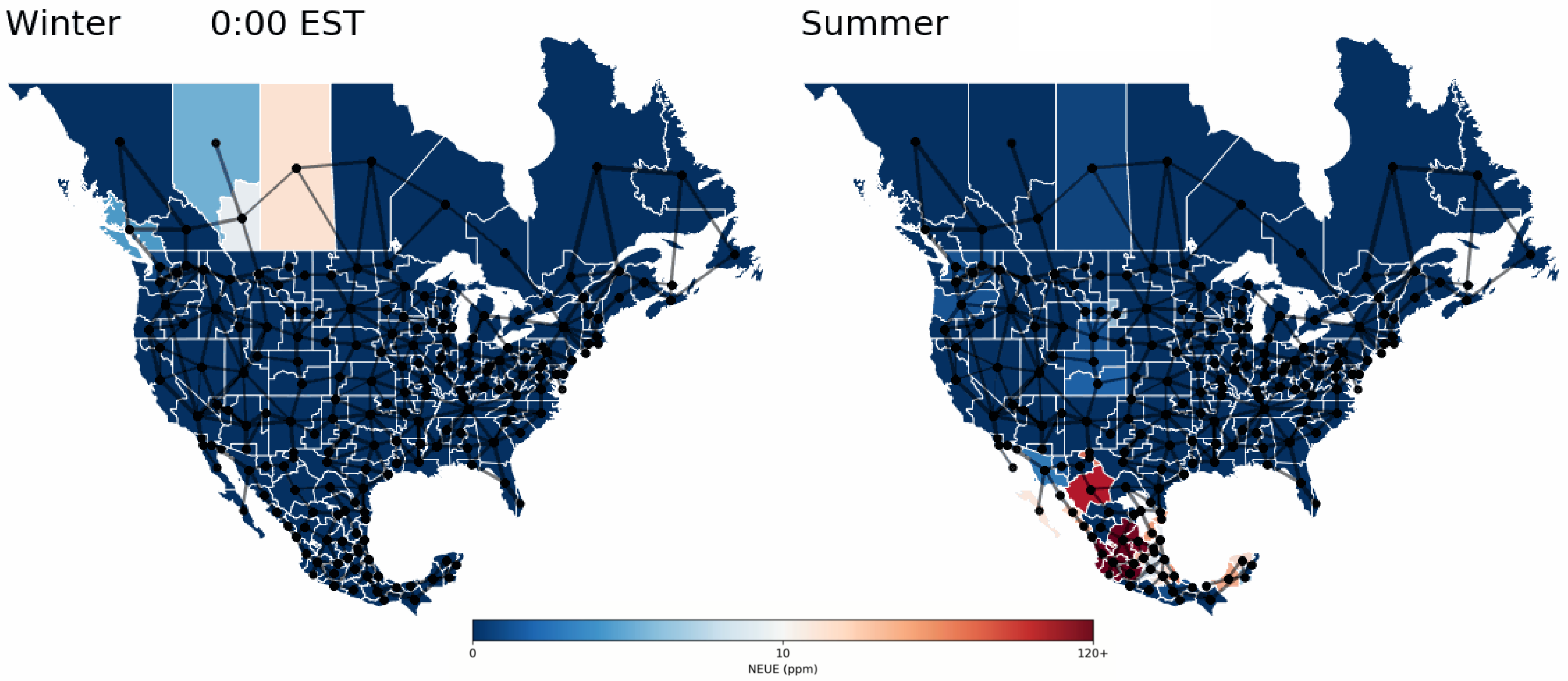
Probabilistic Resource Adequacy Suite: NREL's collection of tools for studying unserved energy risk in electric power systems, across space and time

Resource adequacy assessment: Quantifies shortfall risk using standard probabilistic metrics such as Loss-of-Load Probability (LOLP), Loss-of-Load Expectation (LOLE), Expected Unserved Energy (EUE), Normalized Expected Unserved Energy (NEUE)

Capacity credit calculation: Determines resource adequacy-based capacity credit metrics such as Equivalent Firm Capacity (EFC) and Equivalent Load Carrying Capability (ELCC) of individual resources

Free and open-source software: Get it now at nrel.github.io/PRAS

What can you do with PRAS?



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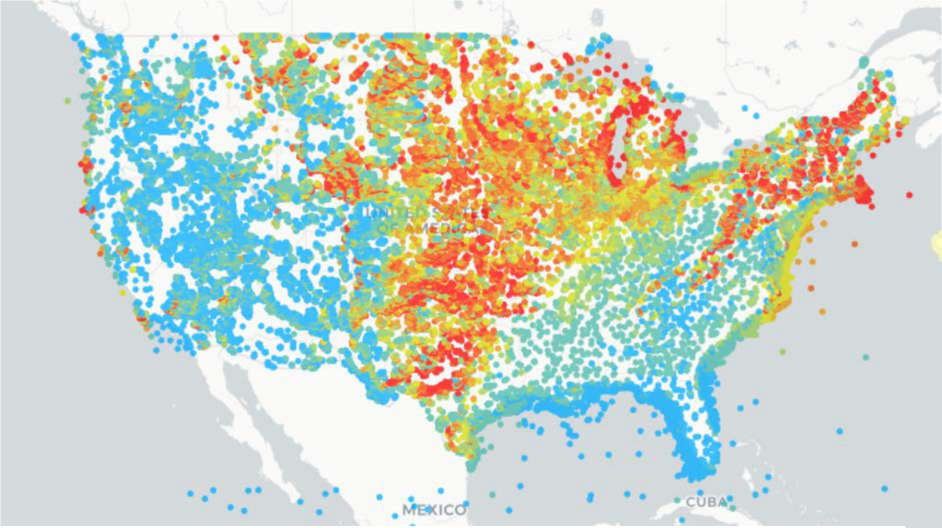
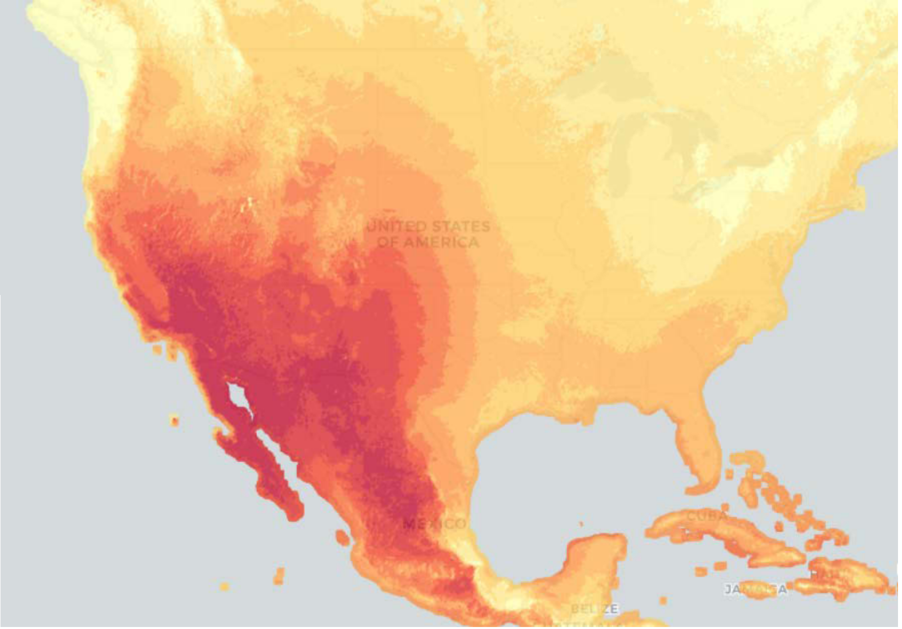
We have lots of historical data…



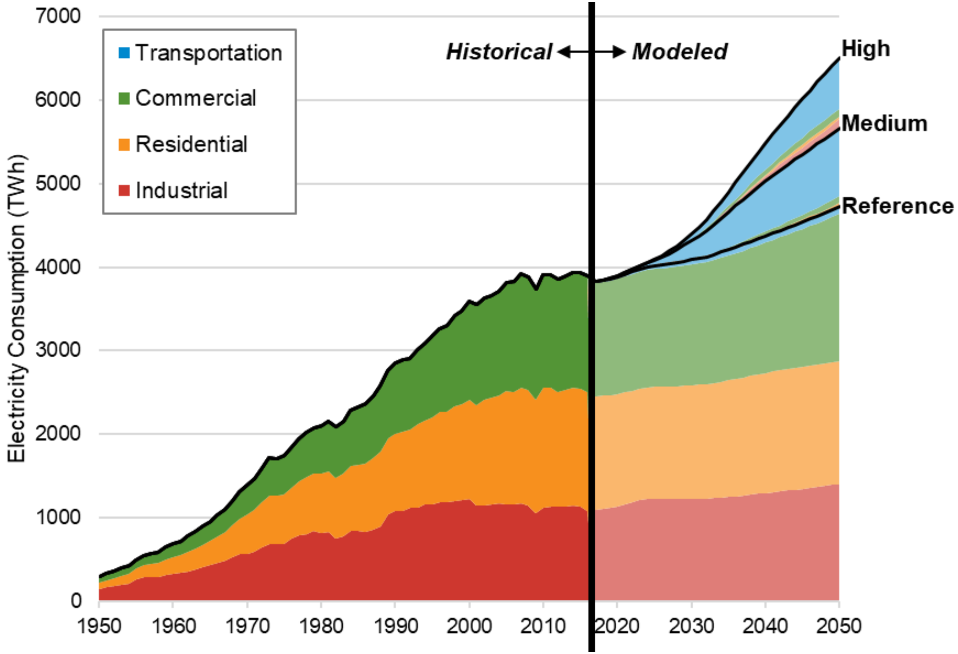
WIND Toolkit (2007-2013)

National Solar Radiation Database (1998-2017)



Historical hourly load (2007-2013)

…but does the future look like the past?



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LETTER

Effects on power system operations of potential changes in wind and solar generation potential under climate change

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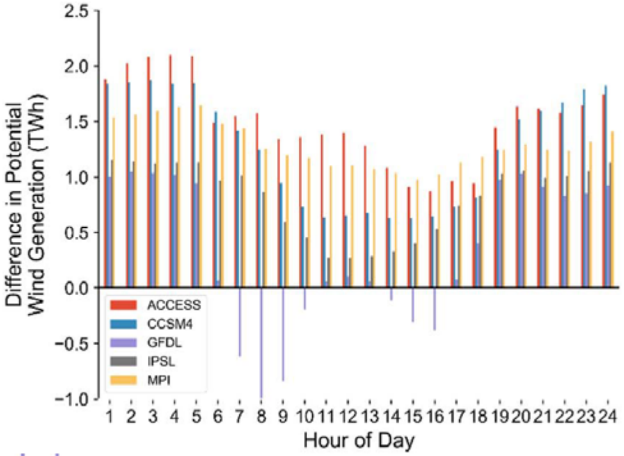
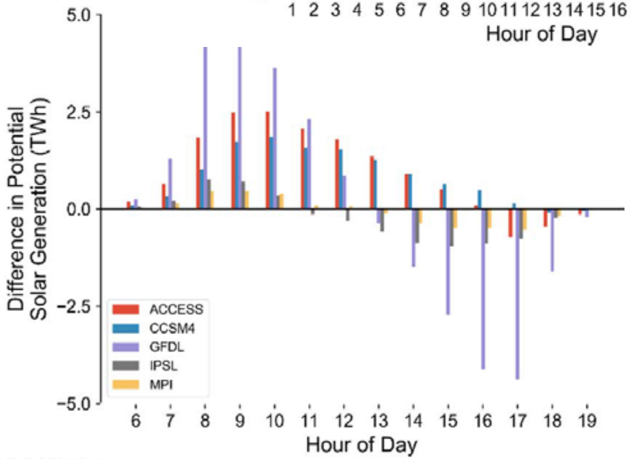
Keywords: climate change, power system operations, wind power, solar power

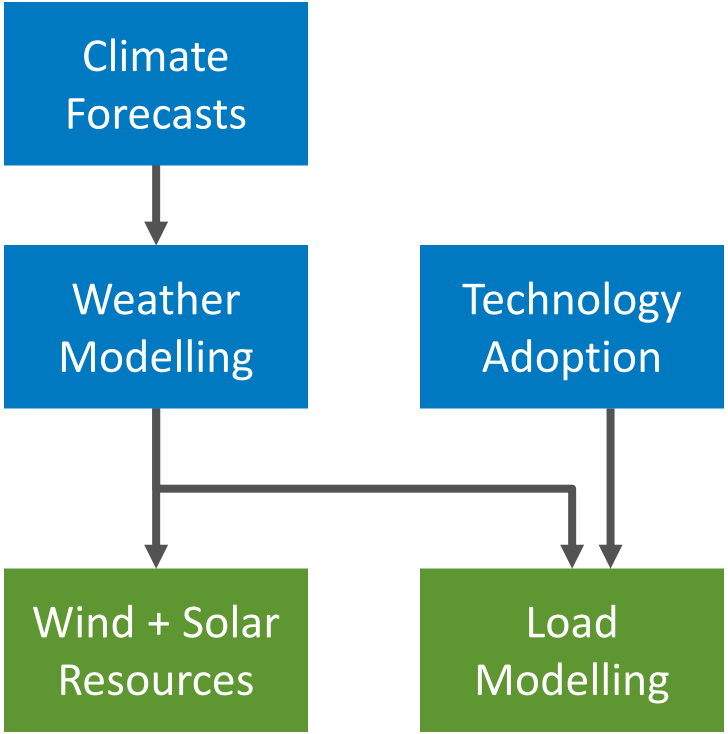
Supplementary material for this article is available online

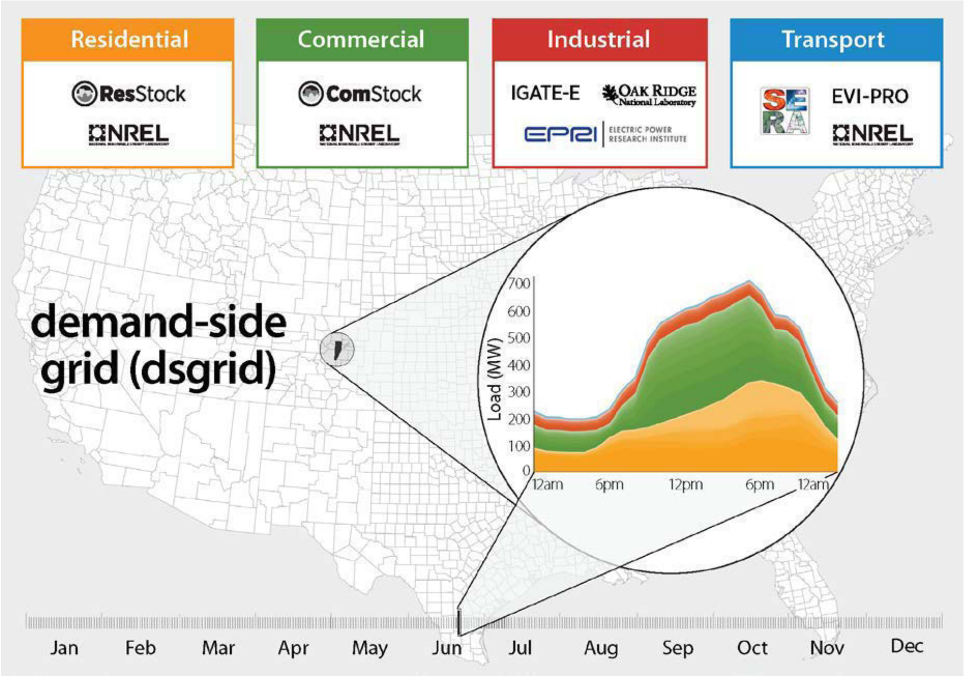
Abstract
Climate change will likely impact wind and solar resources. As power systems increasingly sl
wind and solar power, these resource changes will increasingly impact power system operati
assess how power system operations will be affected by climate change impacts on wind and
resources by generating wind and solar generation profiles for a reference period and five cli
projections. We then run a unit commitment and economic dispatch model to dispatch a hi
renewable generator fleet with these profiles. For climate change projections, we use 2041–2
from five global climate models (GCMs) for Representative Concentration Pathway 8.5 for
study system. All five GCMs indicate increased wind generation potential by 1%–4% under
change in Texas, while three and two GCMs indicate increased and decreased solar generation potentia





Probably not. Potential remedies?





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Where's the uncertainty in resource adequacy?

Uncertainty	Historical Case	High Renewables Case
Mechanical reliability	MTTF/MTTR as dominant factor	Shorter average thermal run-times: startup failure rates may dominate long-run MTTF
Weather variability / forecast errors	Reduced impact	Significant impact (dominant factor?)
Risk correlation	Independent failure assumptions common	Risk drivers (wind, solar, load) nontrivially correlated

Tractable theoretical foundations: traditional reliability focus

Mathematically messy / data-driven / simulation-based: increasingly relevant

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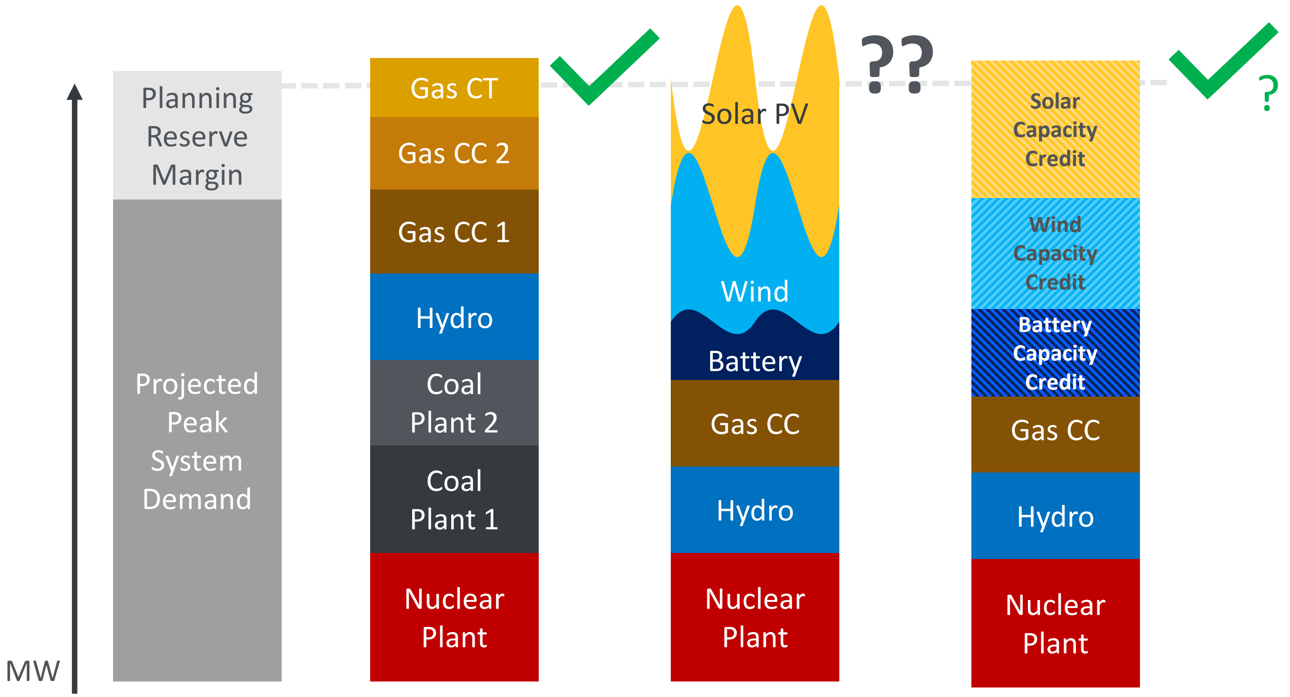
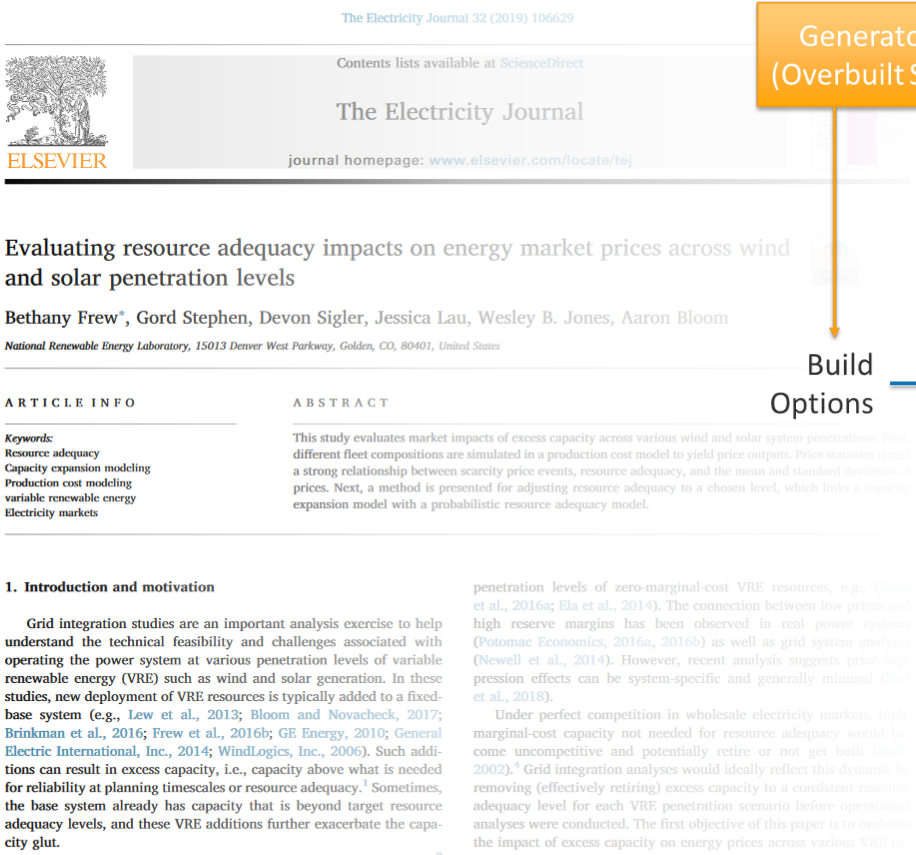
Expansion Models and Planning Reserve Margins



Closing the feedback loop?



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Evaluating resource adequacy impacts on energy market prices across wind and solar penetration levels

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ARTICLE INFO

Keywords:
Resource adequacy
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ABSTRACT

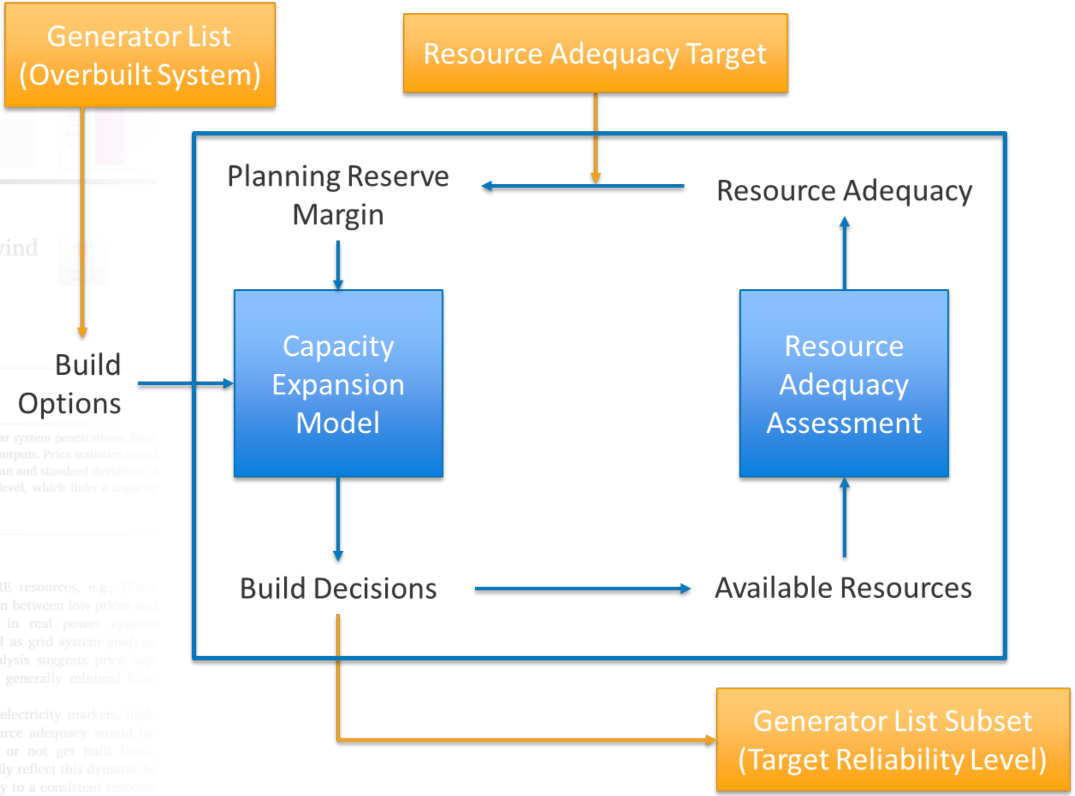
This study evaluates market impacts of excess capacity across various wind and solar system penetrations. First, different fleet compositions are simulated in a production cost model to yield price outputs. Price statistics reveal a strong relationship between scarcity price events, resource adequacy, and the mean and standard deviation of prices. Next, a method is presented for adjusting resource adequacy to a chosen level, which links a capacity expansion model with a probabilistic resource adequacy model.

1. Introduction and motivation

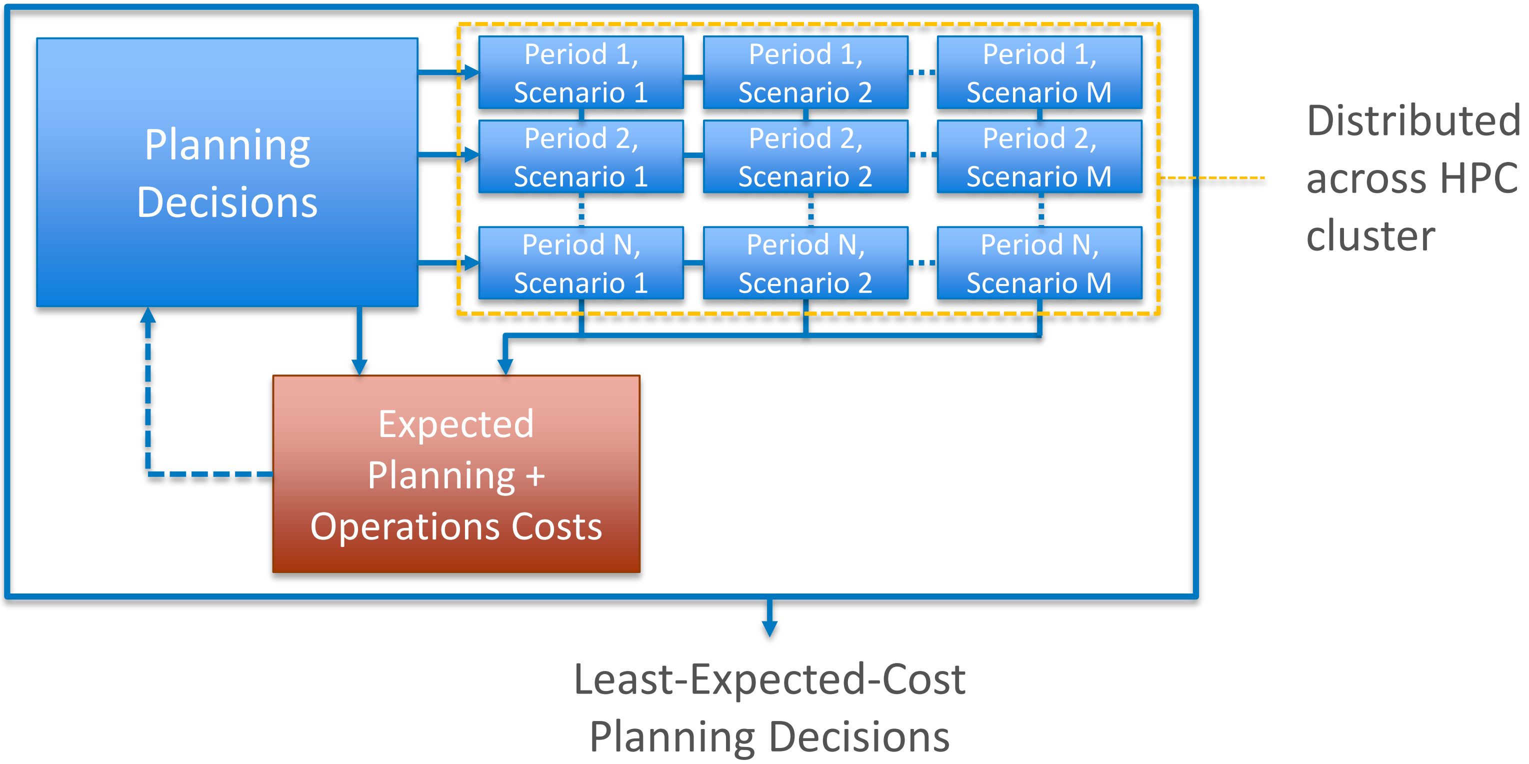
Grid integration studies are an important analysis exercise to help understand the technical feasibility and challenges associated with operating the power system at various penetration levels of variable renewable energy (VRE) such as wind and solar generation. In these studies, new deployment of VRE resources is typically added to a fixed-base system (e.g., Lew et al., 2013; Bloom and Novacheck, 2017; Brinkman et al., 2016; Frew et al., 2016b; GE Energy, 2010; General Electric International, Inc., 2014; WindLogics, Inc., 2006). Such additions can result in excess capacity, i.e., capacity above what is needed for reliability at planning timescales or resource adequacy.[1] Sometimes, the base system already has capacity that is beyond target resource adequacy levels, and these VRE additions further exacerbate the capacity glut.

penetration levels of zero-marginal-cost VRE resources, e.g., (Frew et al., 2016a; Ela et al., 2014). The connection between low prices and high reserve margins has been observed in real power systems (Potomac Economics, 2016a, 2016b) as well as grid system analyses (Newell et al., 2014). However, recent analysis suggests price suppression effects can be system-specific and generally minimal (Seel et al., 2018).

Under perfect competition in wholesale electricity markets, high-marginal-cost capacity not needed for resource adequacy would become uncompetitive and potentially retire or not get built (Stoft, 2002).[4] Grid integration analyses would ideally reflect this dynamic by removing (effectively retiring) excess capacity to a consistent resource adequacy level for each VRE penetration scenario before operational analyses were conducted. The first objective of this paper is to evaluate the impact of excess capacity on energy prices across various VRE pe-



Closing the feedback loop?



Keep in touch!

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PRAS: nrel.github.io/PRAS

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