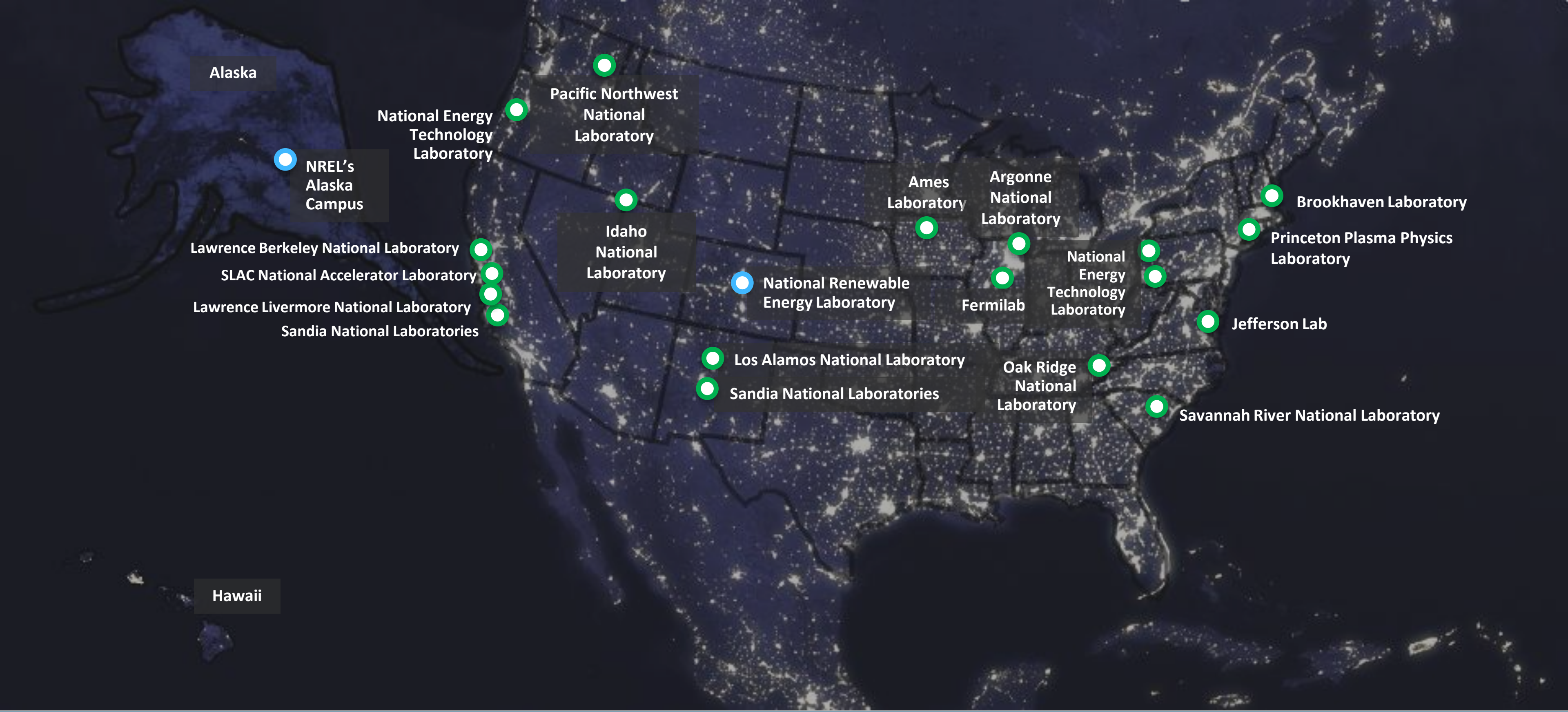
Overview of NREL's Regional Energy Deployment System (ReEDS) Planning Model

Trieu Mai
MCCC Energy Resilience & Efficiency WG
June 18, 2024

Photo by Dennis Schroeder, NREL 46840



National Renewable Energy Laboratory (NREL)

One of 17 national laboratories. Dedicated to renewable energy research and analysis.

Outline

1 Background

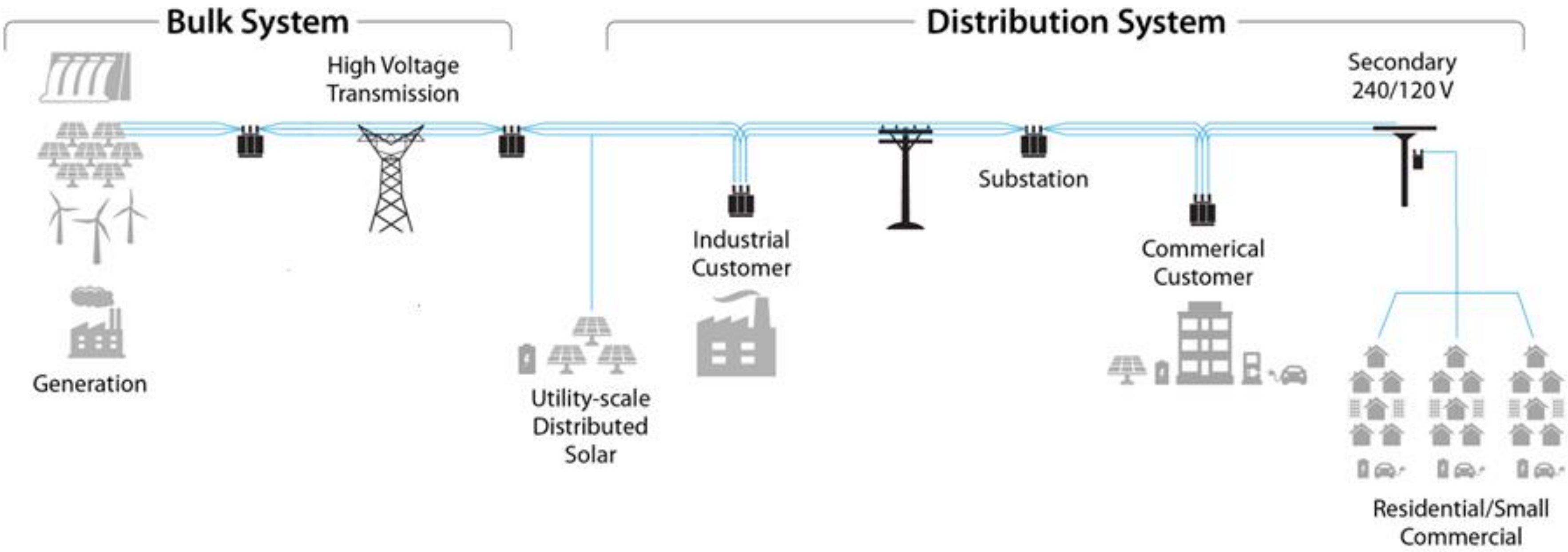
2 Regional Energy Deployment System (ReEDS)

3 The Electrification Futures Study

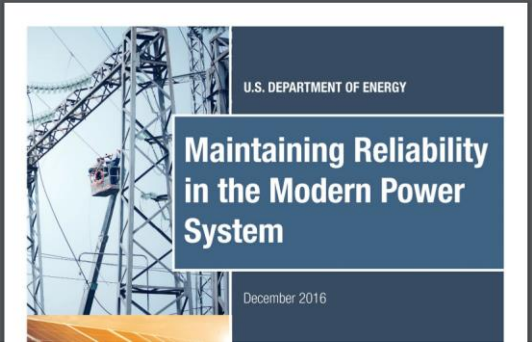
4 Q&A

Background

Focus: “Bulk” transmission and generation system

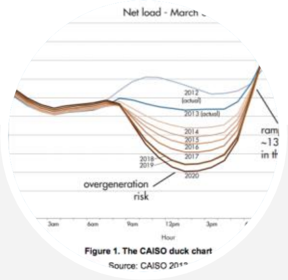


Four Pillars of Power System Reliability



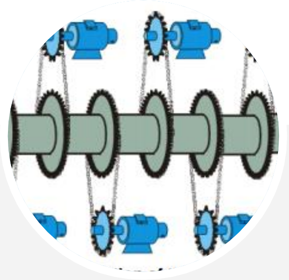
Capacity

Power generation and transmission capacity must be sufficient to meet peak demand for electricity.



Flexibility

Power systems must have adequate flexibility to address variability and uncertainty in demand (load) and generation resources.



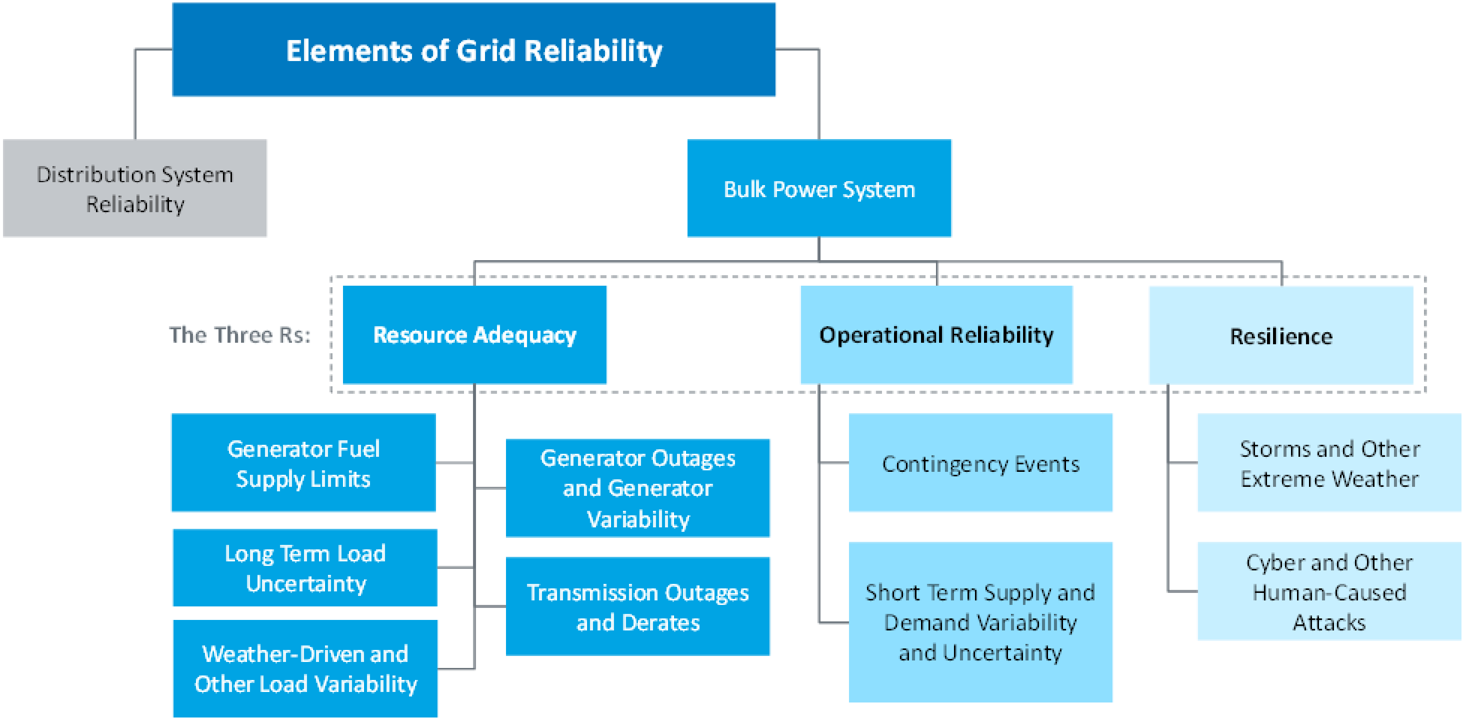
Frequency

Power systems must be able to maintain steady frequency.

Voltage

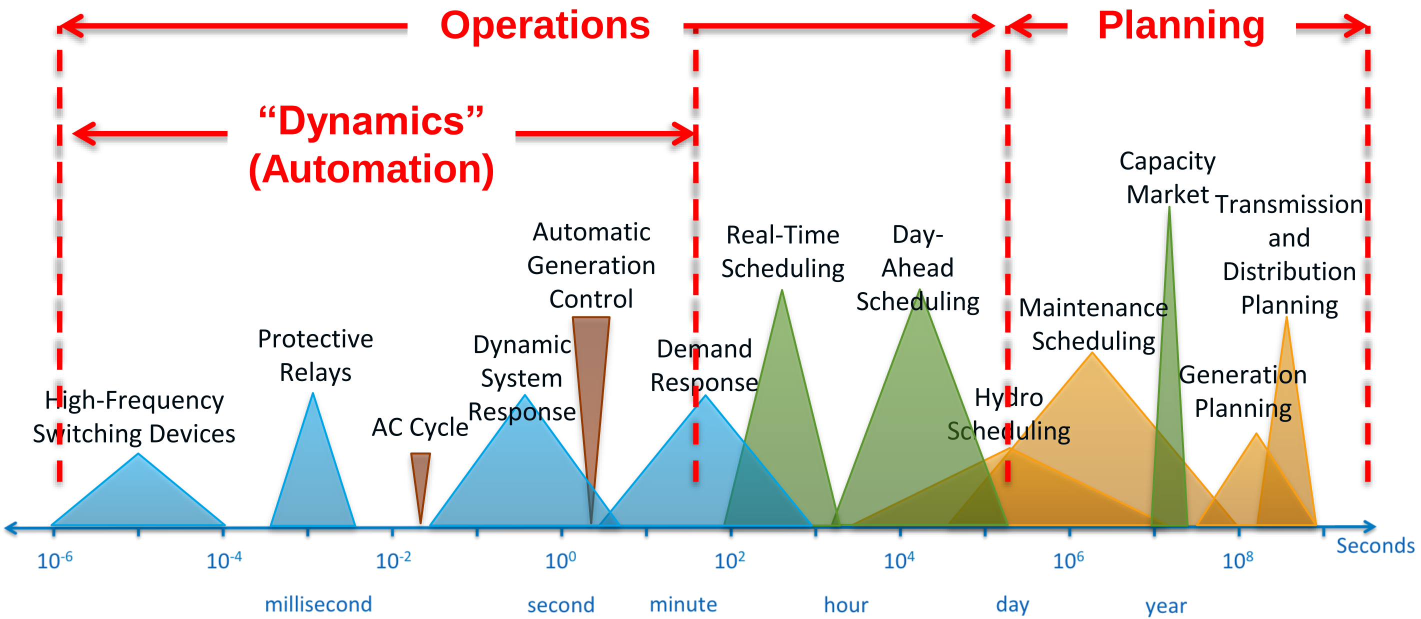
Power systems must be able to maintain voltage within an acceptable range.

Many elements of grid reliability



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

Relevant grid decision timescales span 15 orders of magnitude



Adapted from A. Von Meier

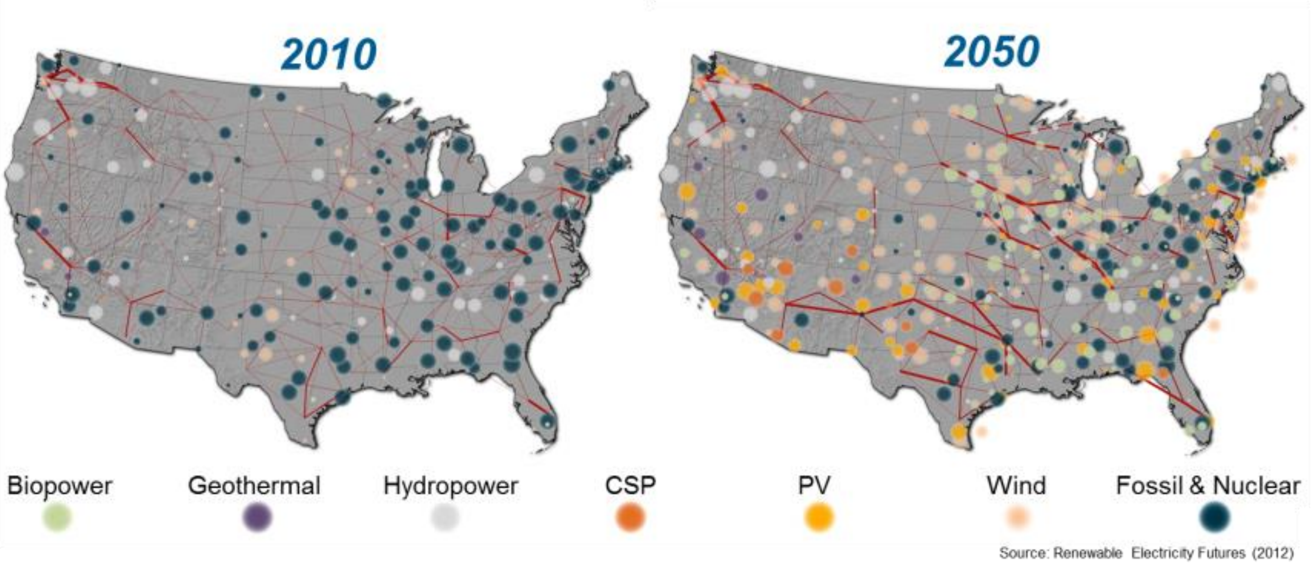
This presentation focuses on resource planning

Regional Energy Deployment System

www.nrel.gov/analysis/reeds

ReEDS

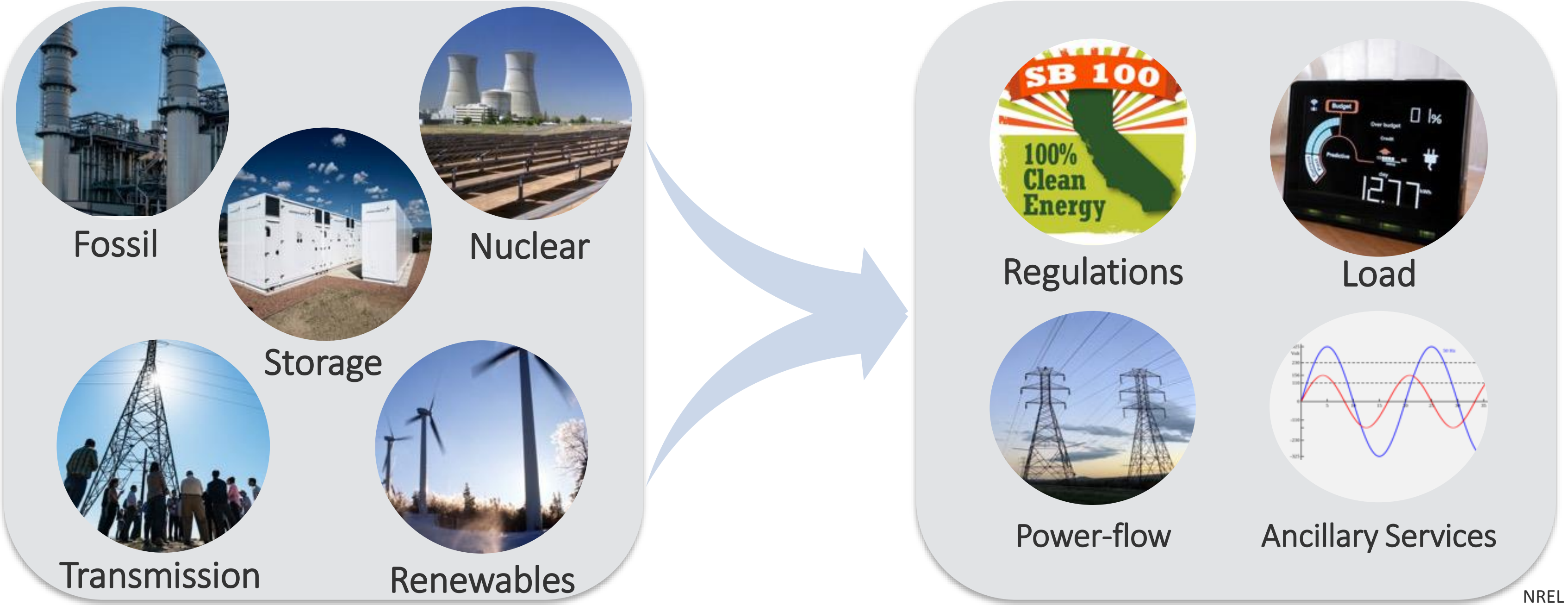
What does ReEDS do?



Given a set of input assumptions, ReEDS simulates the evolution and operation of US generation, storage, transmission, and some carbon mitigation technologies

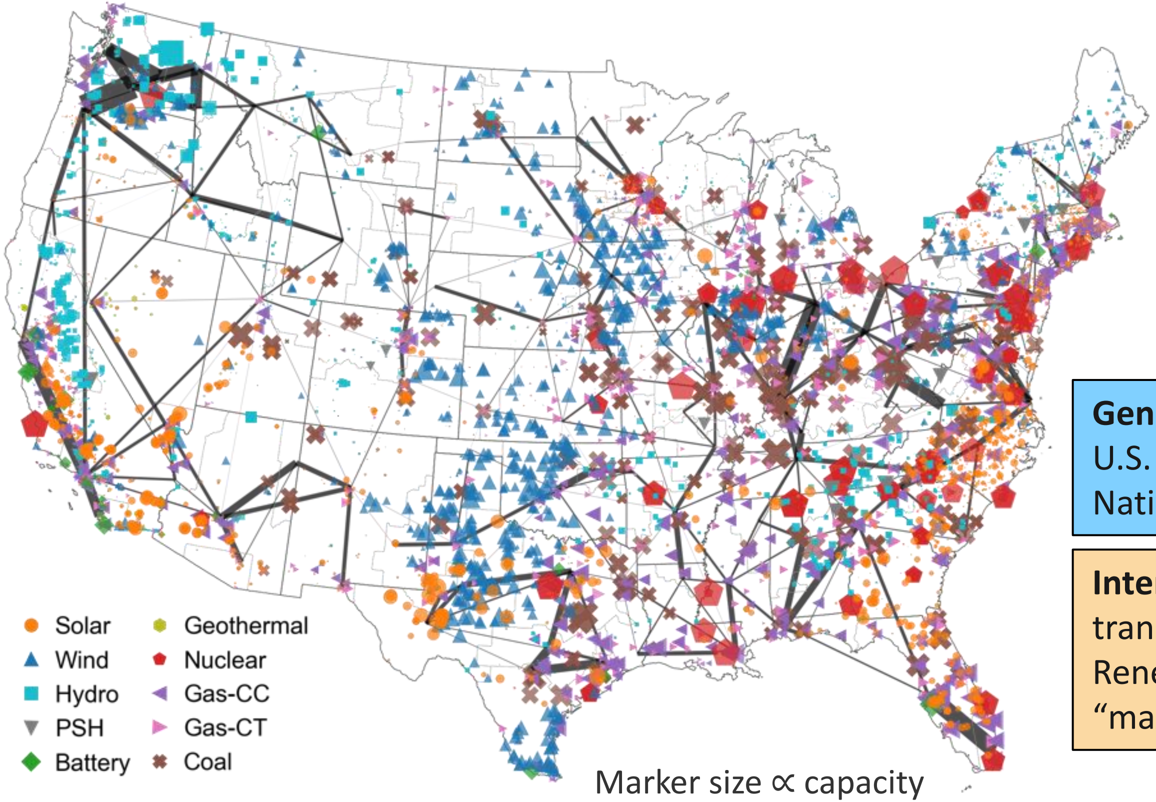
How does ReEDS work?

ReEDS uses **optimization** to identify the **least cost investment and operation** of grid assets that simultaneously meets load, all other electricity service requirements, and other physical, environmental, or policy constraints.



The starting point: Existing and Planned Capacity

2022 Generation and Transmission Capacity



U.S. Energy Information Administration

https://www.eia.gov/outlooks/aeo/

Generation capacity based on data from the U.S. Energy Information Administration (EIA) National Energy Modeling System (NEMS)

Interface transmission limits derived from transmission data from The North American Renewable Integration Study (NARIS) using a "maximum potential flow" optimization

ReEDS: Nationwide capacity expansion modeling

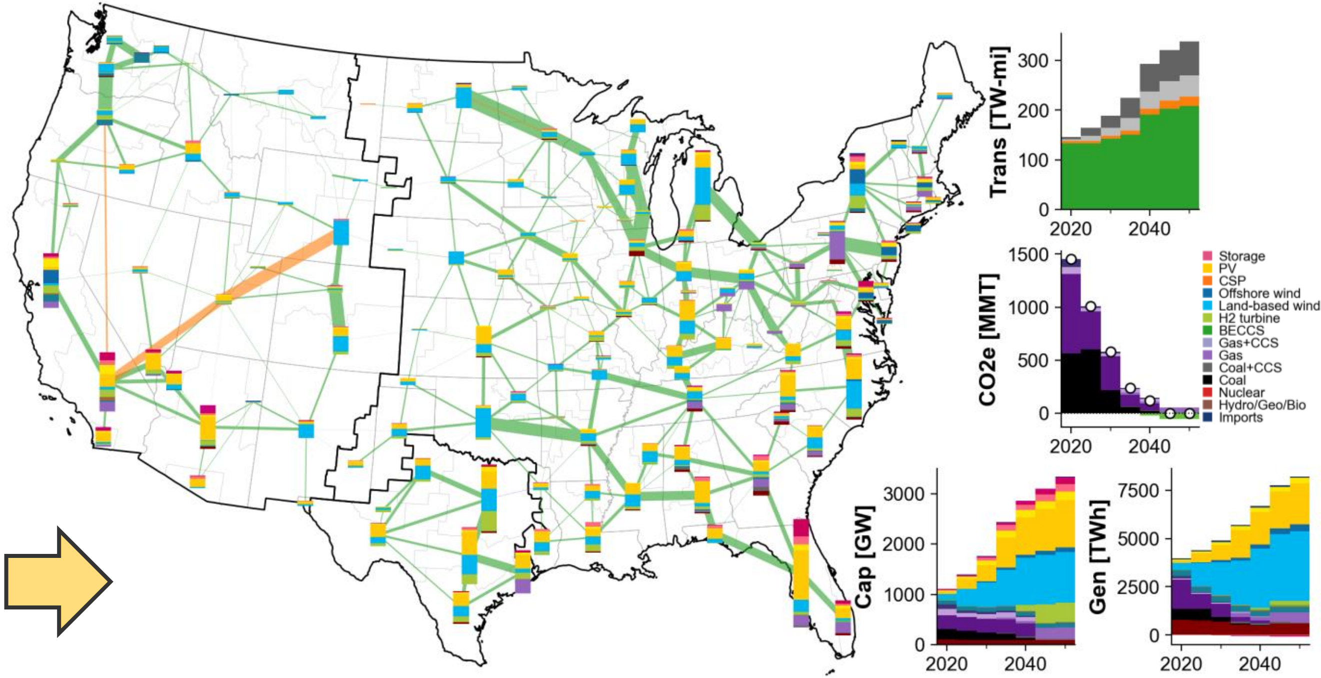
ReEDS **co-optimizes** generation, **transmission**, and storage **capacity & operations** to meet demand at **least possible cost** under many policy and physical **constraints**

Inputs

- RE **resource** and land availability
- **Demand** (hourly) projections
- **Technology** availability
- **Cost** projections
- Federal and state **policies**
- **Transmission** representation

ReEDS

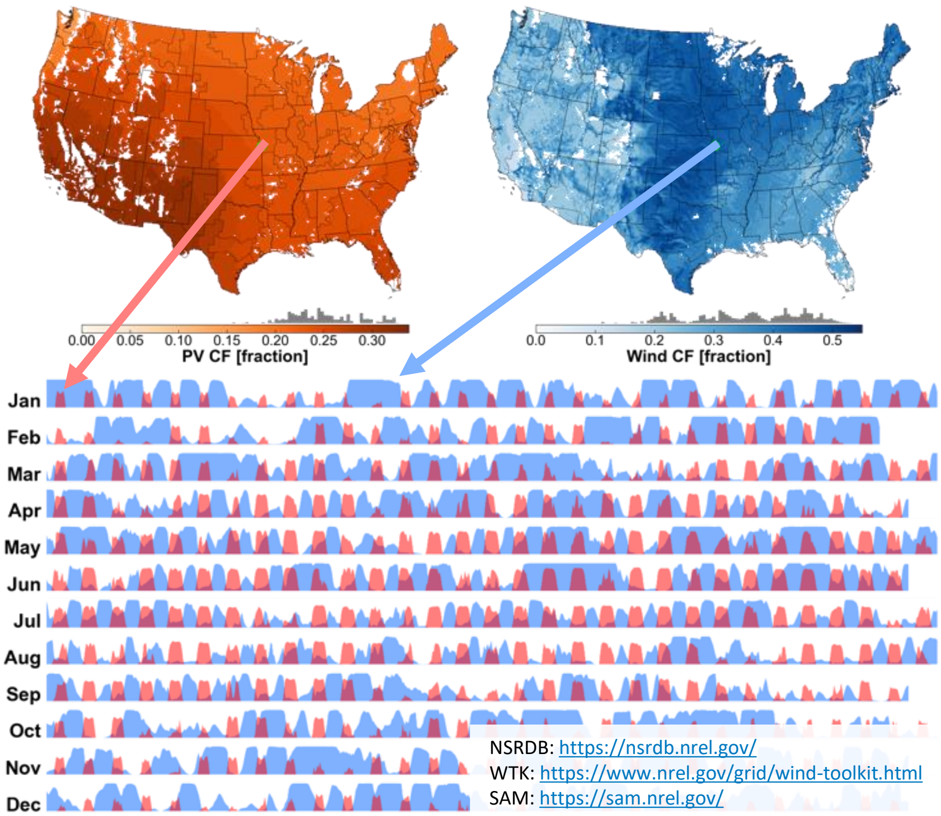
Outputs



Key inputs: Renewable Resource Availability

https://github.com/NREL/reV

Temporal availability



NSRDB: https://nsrdb.nrel.gov/
WTK: https://www.nrel.gov/grid/wind-toolkit.html
SAM: https://sam.nrel.gov/

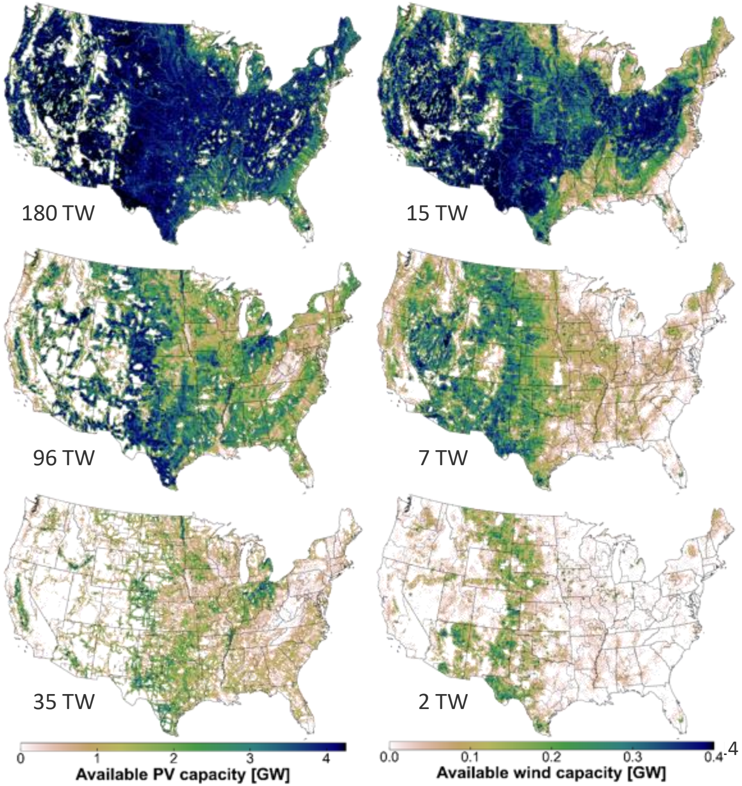
Spatial availability

Utility-scale PV | Land-based wind

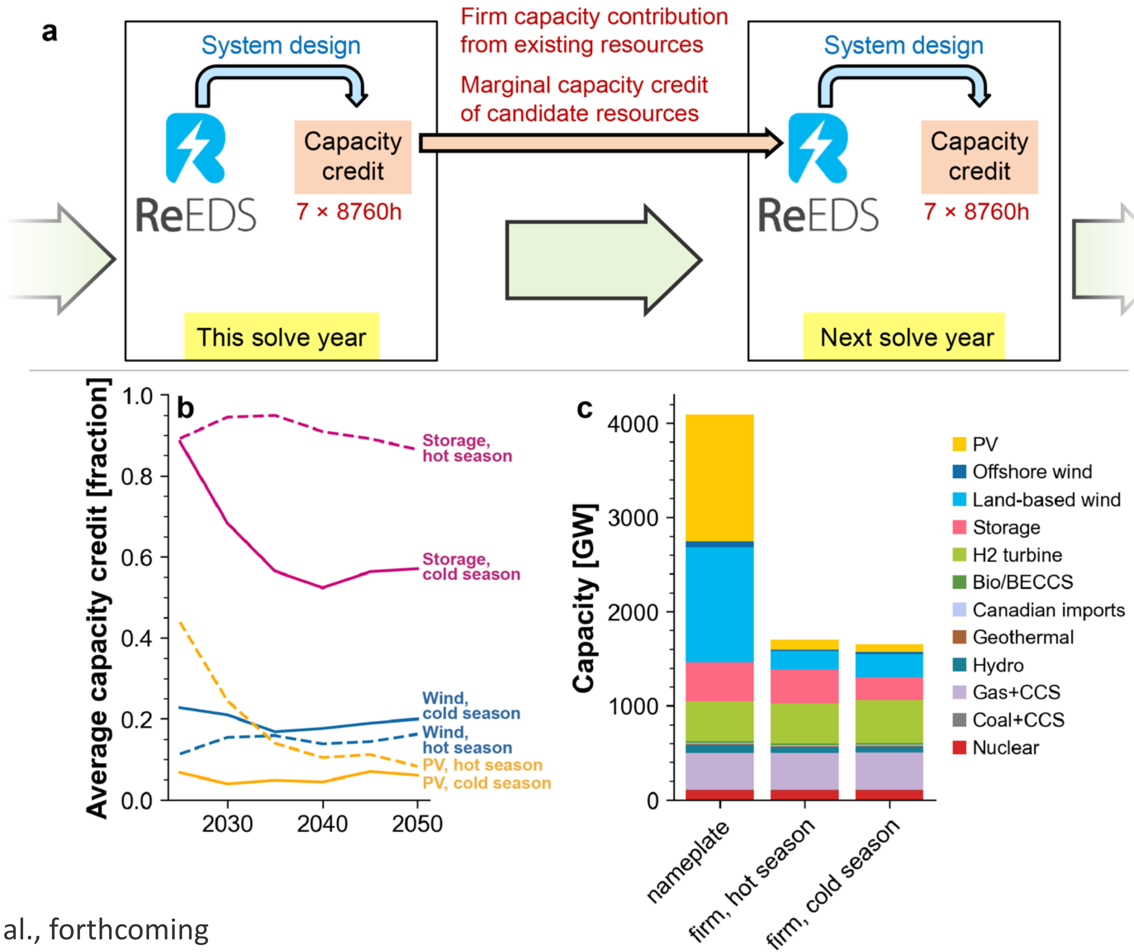
Open access

Reference access

Limited access



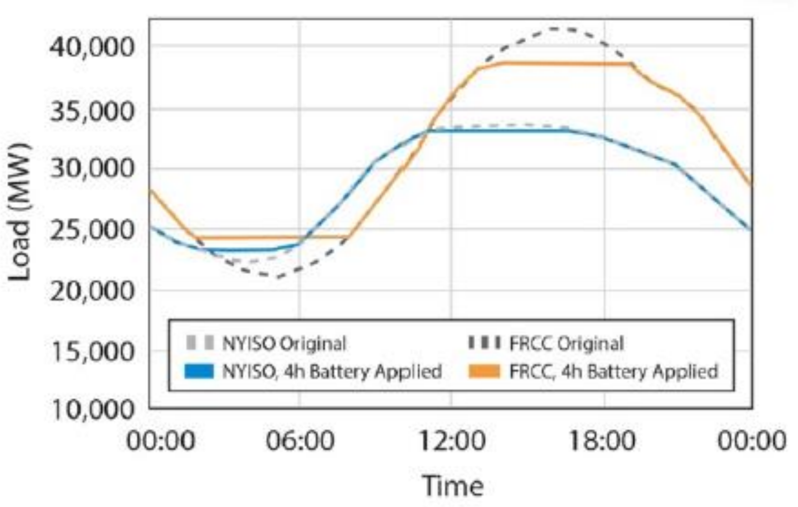
Extra attention to Resource Adequacy



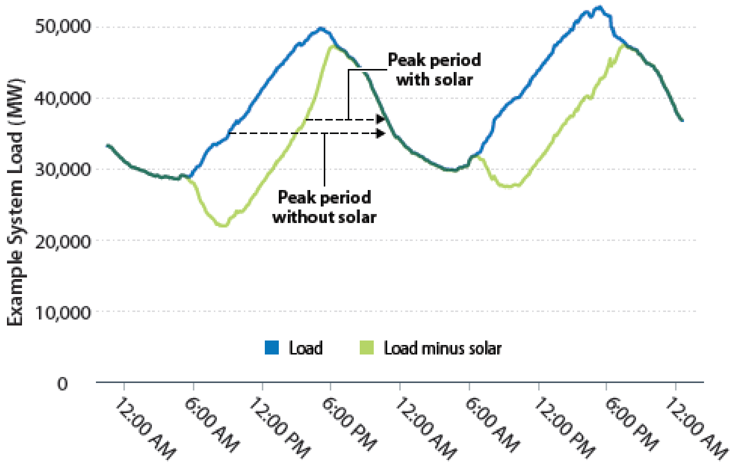
+ integration with [Probabilistic Resource Adequacy Suite (PRAS)]

Mai et al., forthcoming

Account for dynamically changing and complex relationships between technologies and demand



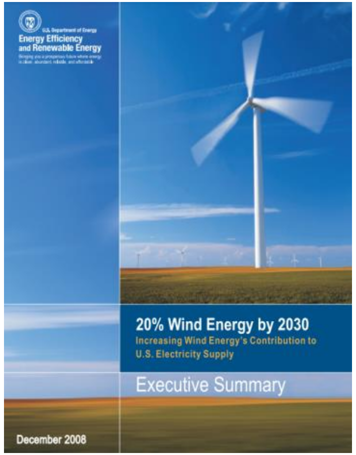
Denholm et al. 2019, https://www.nrel.gov/docs/fy19osti/74184.pdf



NREL 2024, https://www.nrel.gov/docs/fy24osti/87298.pdf

Identifying decarbonization pathways for the electric sector

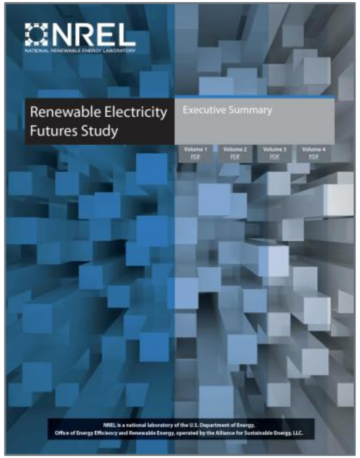
20% wind by 2030



20% Wind Study (2008)

https://www.nrel.gov/docs/fy08osti/41869.pdf

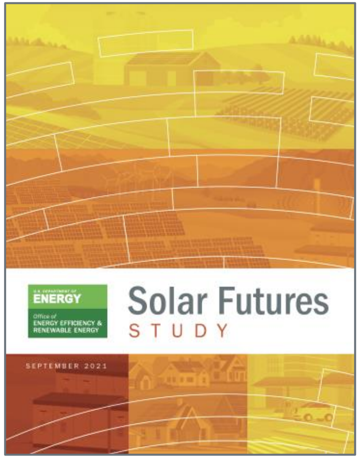
80% renewable by 2050



Renewable Electricity Futures Study (2012)

https://www.osti.gov/servlets/purl/1338443/

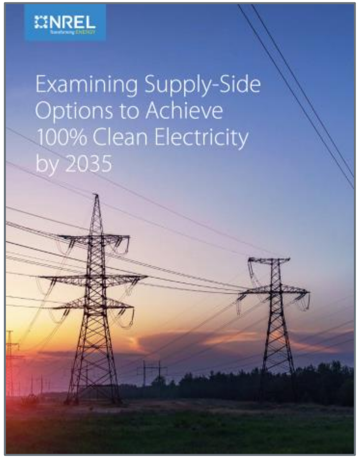
Zero-carbon by 2050



Solar Futures Study (2021)

https://www.energy.gov/sites/default/files/2021-09/Solar%20Futures%20Study.pdf

Zero-carbon by 2035

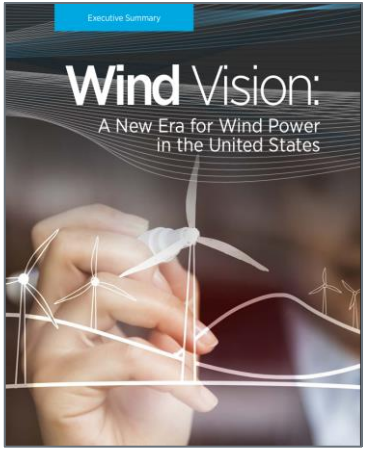


100% Clean Energy by 2035 Study (2022)

https://www.nrel.gov/docs/fy22osti/81644.pdf

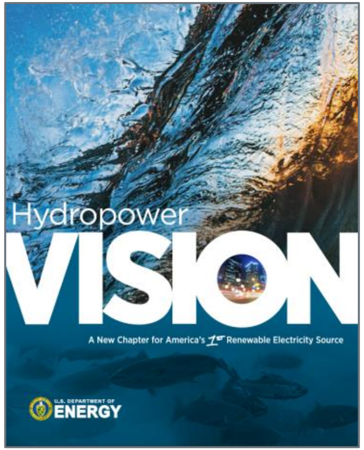
Exploring impacts of technology innovation

Wind Vision (2015)



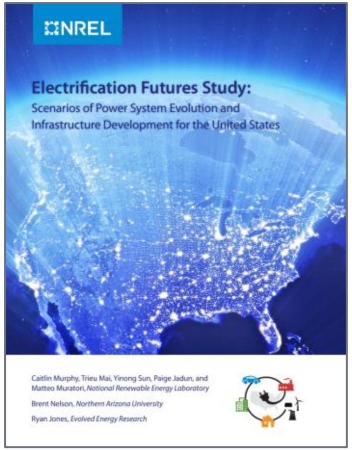
https://www.energy.gov/sites/prod/files/wv_executive_summary_overview_and_key_chapter_findings_final.pdf

Hydropower Vision (2016)



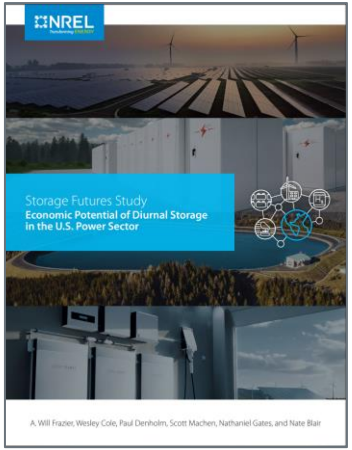
https://www.energy.gov/sites/default/files/2018/02/f49/Hydropower-Vision-021518.pdf

Electrification Futures (2021)



https://www.nrel.gov/docs/fy21osti/72330.pdf

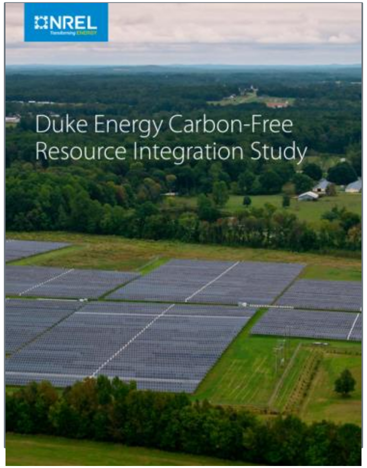
Storage Futures (2021)



https://www.nrel.gov/docs/fy21osti/77449.pdf

Informing utility and regional planning

Duke Energy (2022)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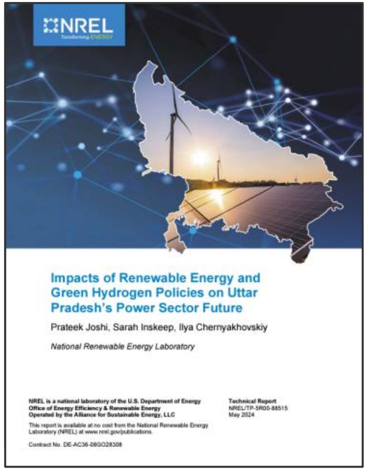
Duke Energy Carbon-Free Resource Integration Study

https://www.nrel.gov/grid/carbon-free-integration-study.html

India State Analysis (2024)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Impacts of Renewable Energy and Green Hydrogen Policies on Uttar Pradesh's Power Sector Future

Prateek Joshi, Sarah Inskeep, Ilya Chernyakhovskiy

National Renewable Energy Laboratory

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Office of Energy Efficiency & Renewable Energy
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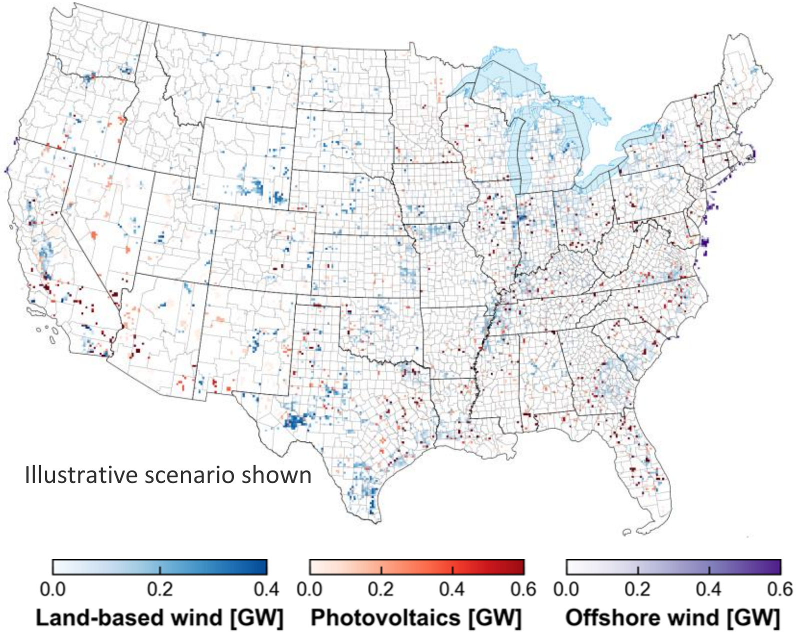
Contract No. DE-AC36-08GO28308

Technical Report
NREL/TP-5R00-88515
May 2024

https://www.nrel.gov/docs/fy24osti/88515.pdf

Newly enabled county-level resolution

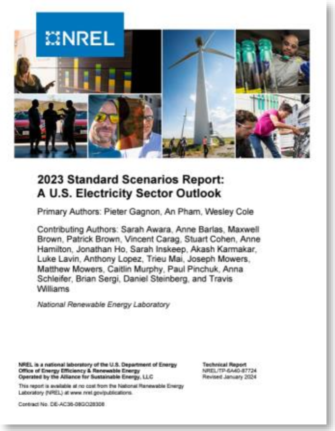


+ several other examples (ERCOT, ISO-NE, CAISO, BLM land)

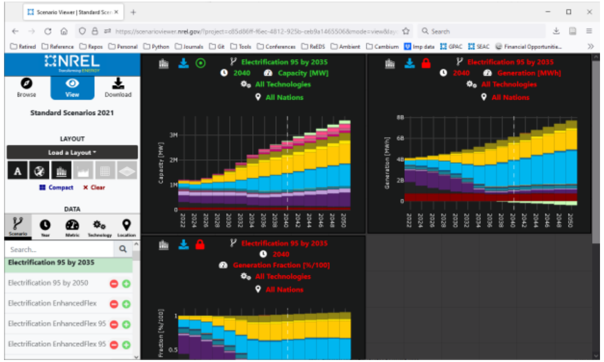
NREL’s Standard Scenarios

2023 marks the 9th edition of a report on a wide range of possible futures for the U.S. electric sector

Report

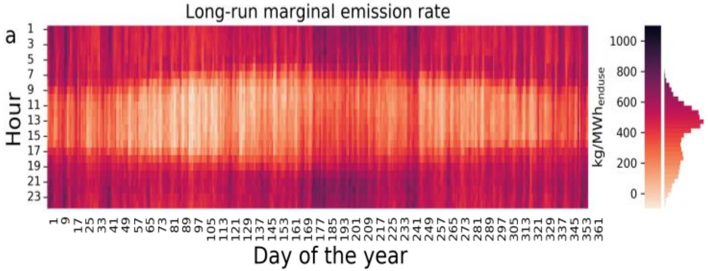


Scenario Viewer and Downloader



Cambium Database

(hourly metrics for a subset of scenarios)



https://www.nrel.gov/docs/fy24osti/87724.pdf

https://www.nrel.gov/analysis/standard-scenarios.html

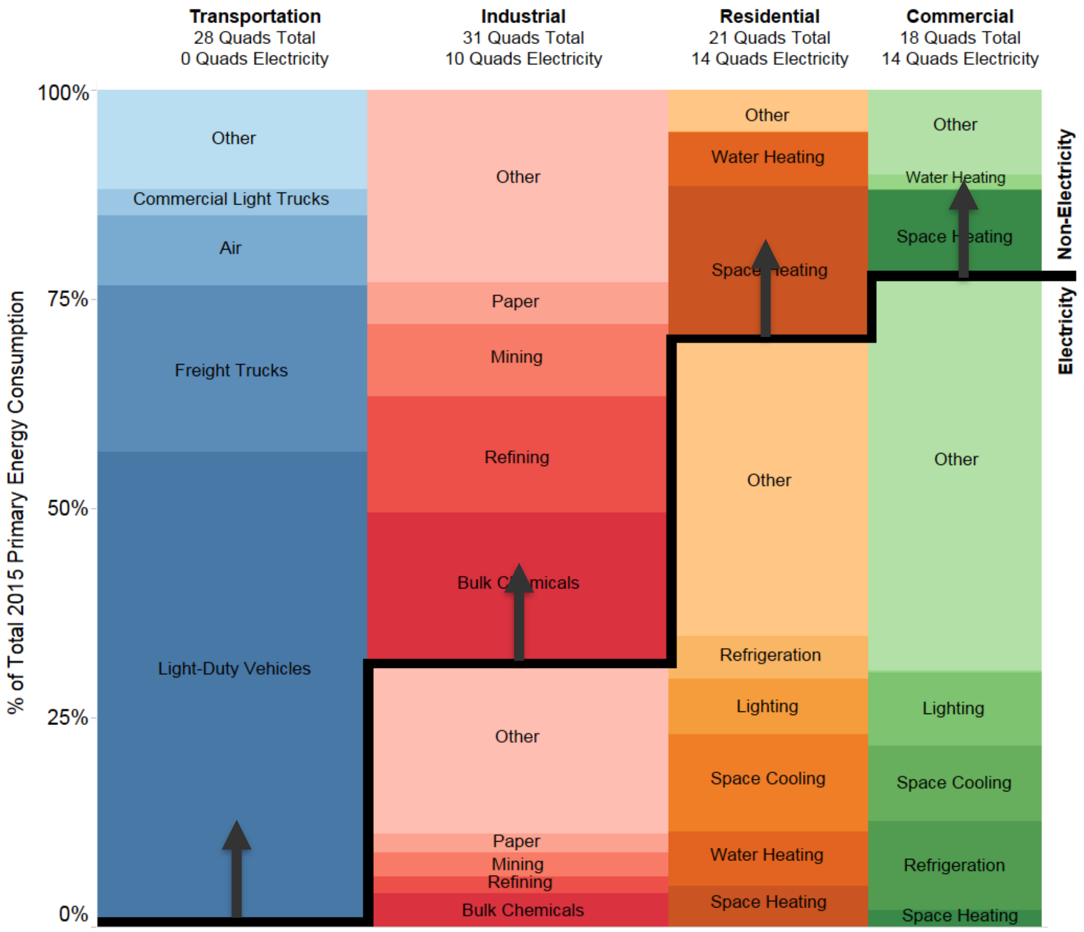
Electrification Futures Study

www.nrel.gov/efs

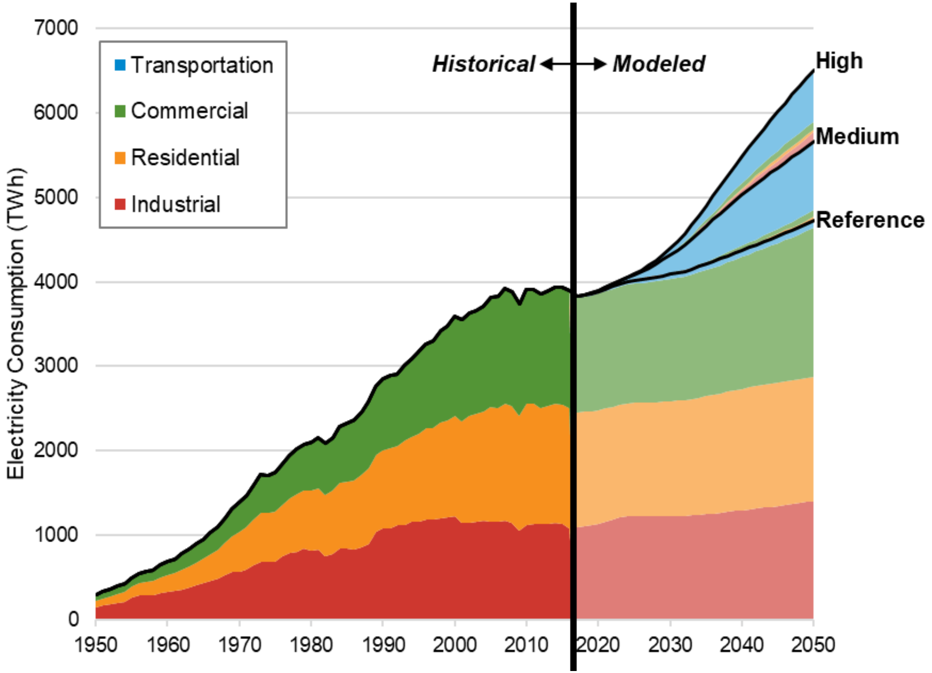
The Potential for Electrification

- **Electrification**: the shift from any non-electric source of energy to electricity at the point of final consumption
  - Direct electric technologies only
  - Not exploring new sources of demand

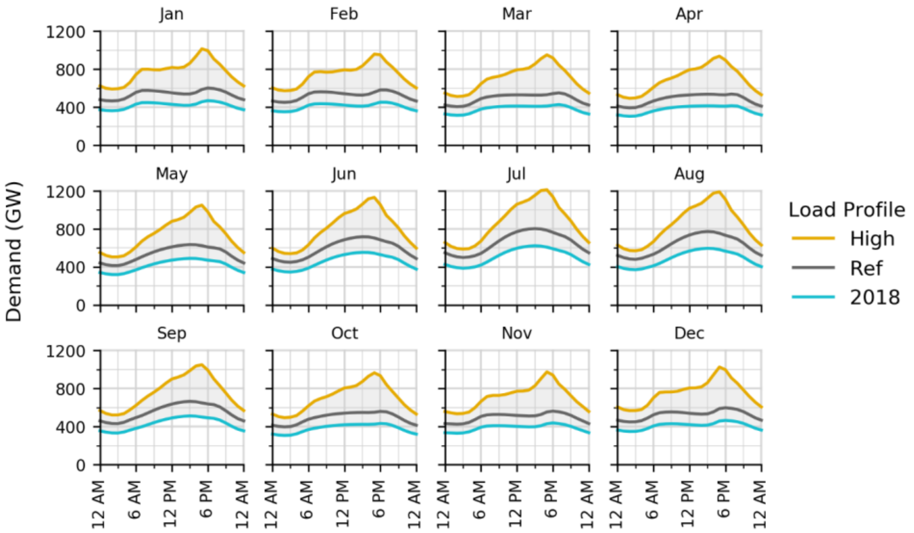
- **Contiguous U.S. energy system**, including transportation, residential and commercial buildings, industry
  - Sectors cover **74% of primary energy in 2015**
  - Did not consider electrification of air transport, petroleum refining and mining, CHP, outdoor cooking



Vehicle electrification dominates incremental growth in *annual* electricity demand



Greater electricity consumption

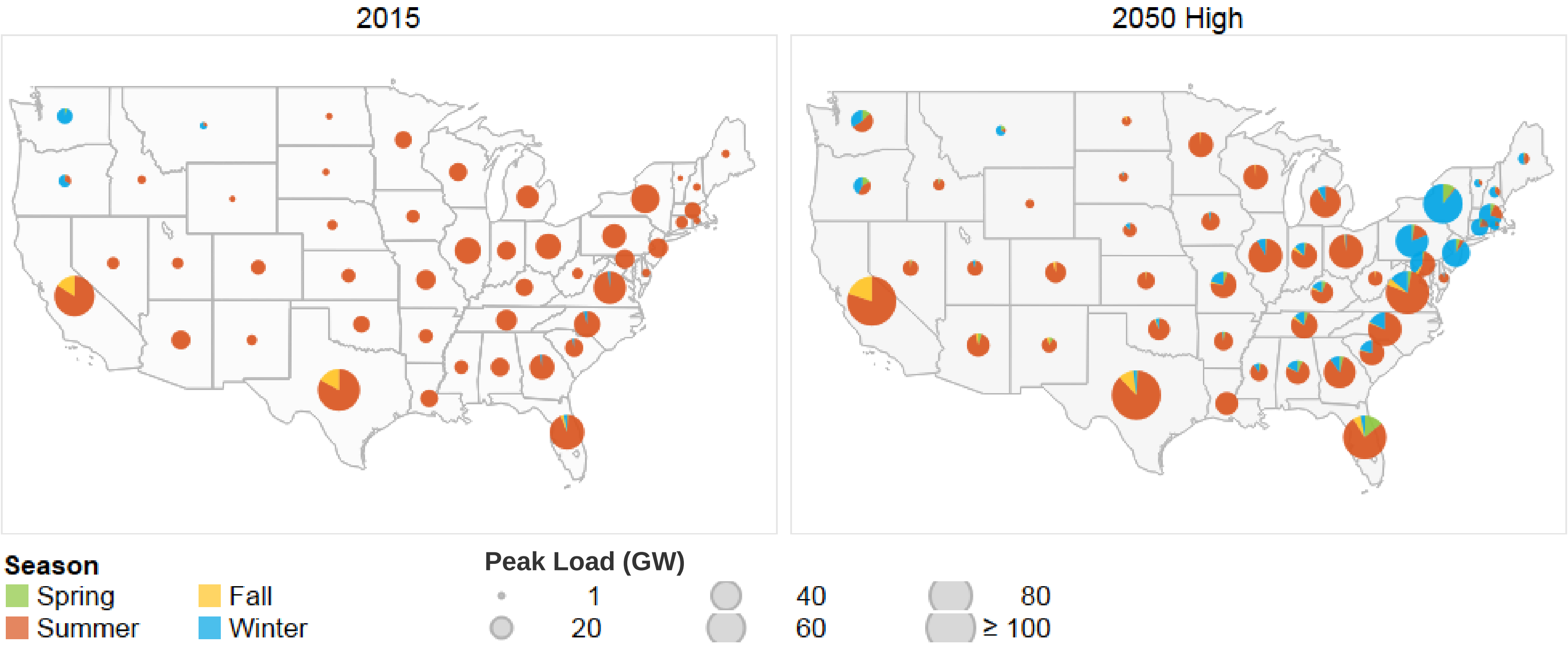


Possibly higher, sharper, and more frequent peaks in 2050

(in the absence of demand flexibility)

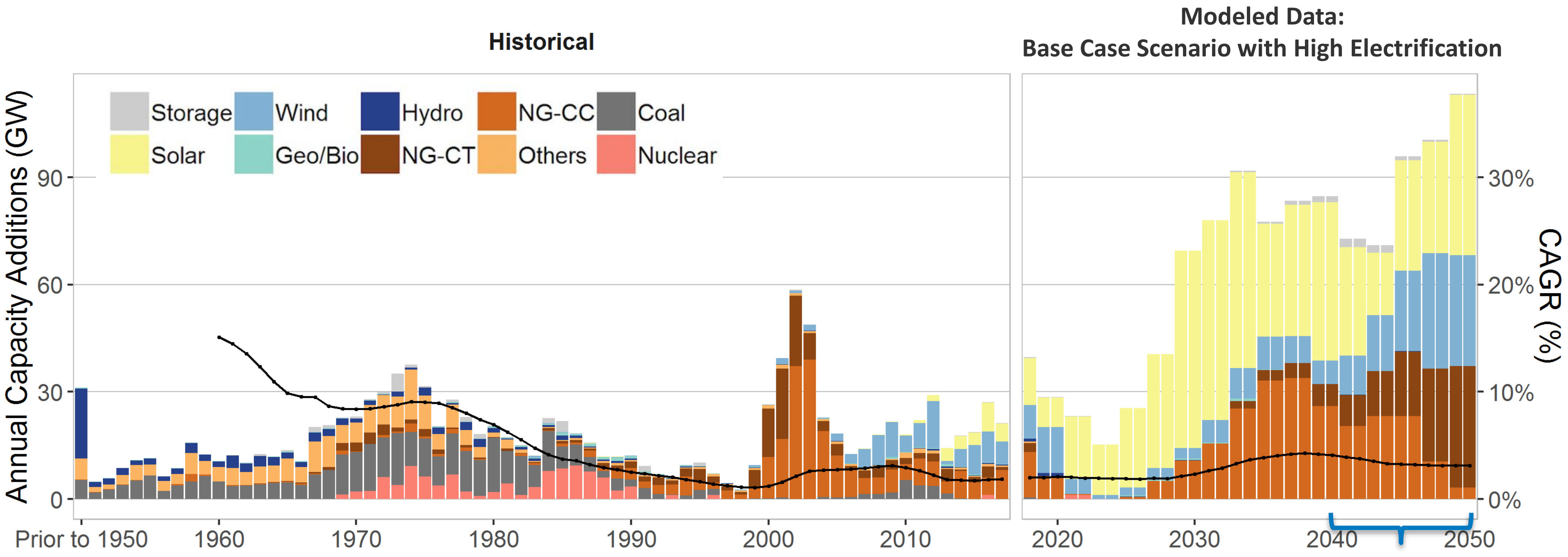
Source: Mai et al. 2018, Murphy et al. 2021, Sun et al. 2020, Zhou and Mai. 2021

Electric space heating has the most pronounced impact on the timing and magnitude of peak demand



Note: Summer = June-August, Fall = September-November, Winter = December-February, Spring = March-May

Capacity: Electrification drives total installed capacity in 2050 to be 58% greater than 2018 levels



Solar: ~30-45 GW/yr
Natural Gas: ~35 GW/yr
Wind: ~20 GW/yr
even higher rates in some scenarios

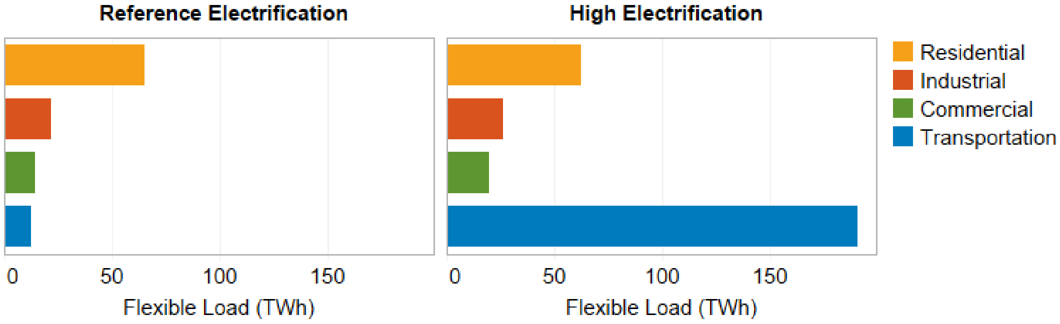
Murphy et al. (2021), https://www.nrel.gov/docs/fy21osti/72330.pdf

Modeling demand-side flexibility (DSF)

- 14 types of shiftable DSF across commercial, residential buildings, industrial, and transportation sectors are modeled for each modeled BA
- Parameterized by **timing, duration, participation, and capacity to increase and decrease**
- Amount and nature of flexibility depends on electrification, with greater potential for flexibility primarily from **optimized EV** charging but also managed **building and industrial** loads

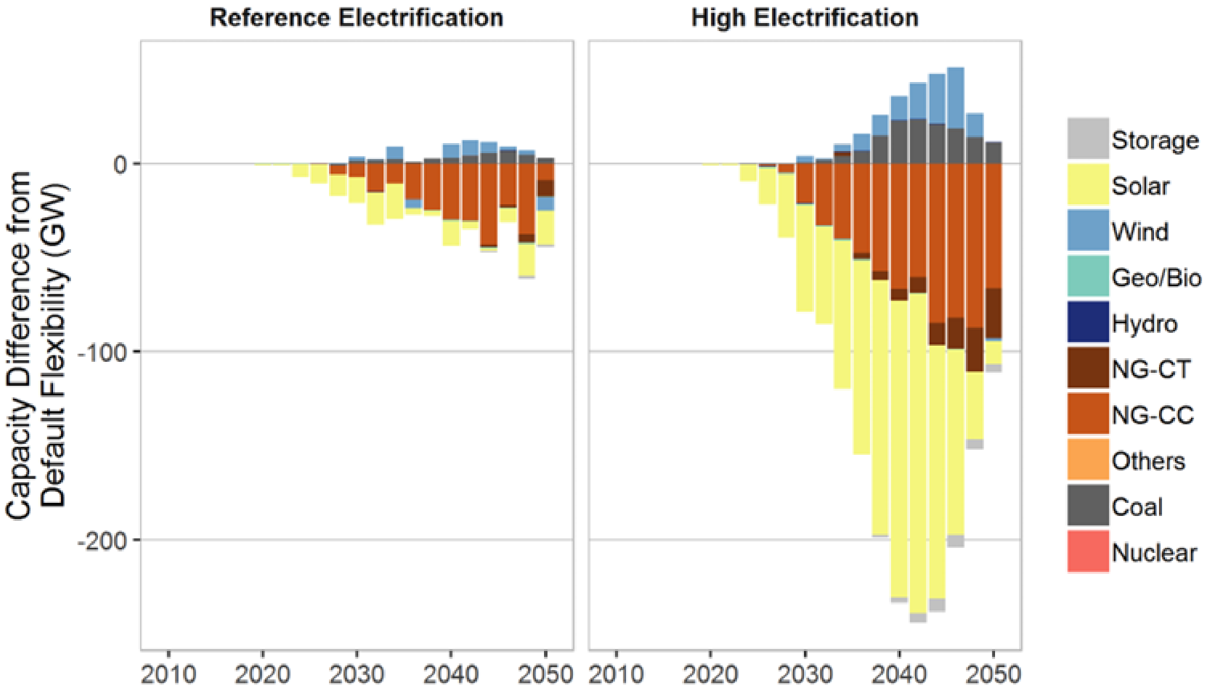
% of total 2050 load that is flexible:

0% Ref-NoFlex	0% High-NoFlex | High-HiRE-NoFlex
2% Ref-LoFlex	4% High-LoFlex | High-HiRE-LoFlex
7% Ref-HiFlex	17% High-HiFlex | High-HiRE-HiFlex



Murphy et al. (2021), https://www.nrel.gov/docs/fy21osti/72330.pdf

Value of demand flexibility includes reducing future capacity needs (along with operating expenditures)



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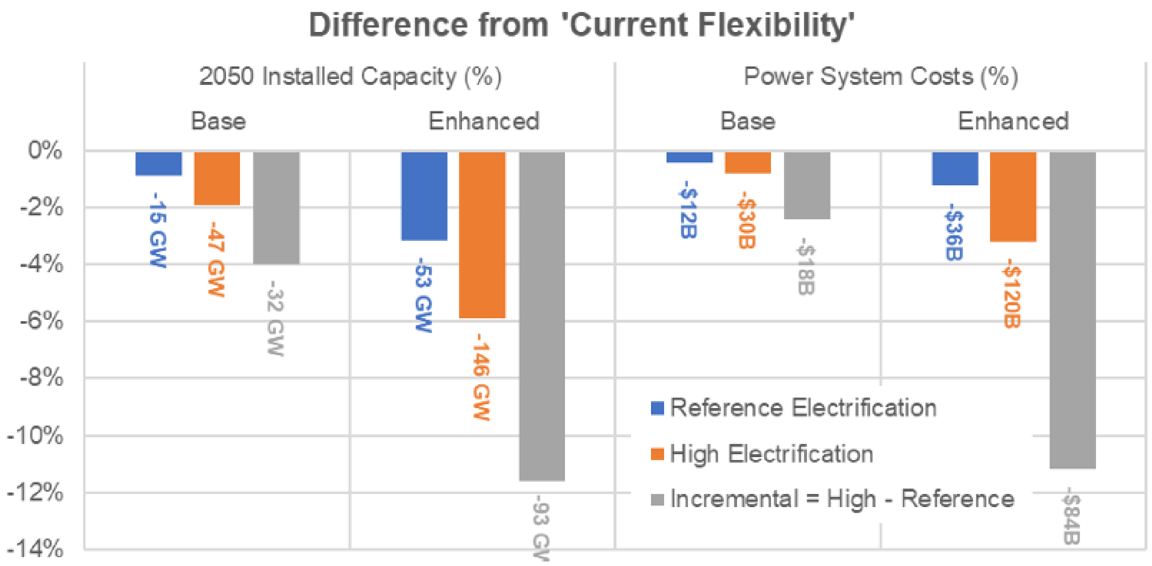
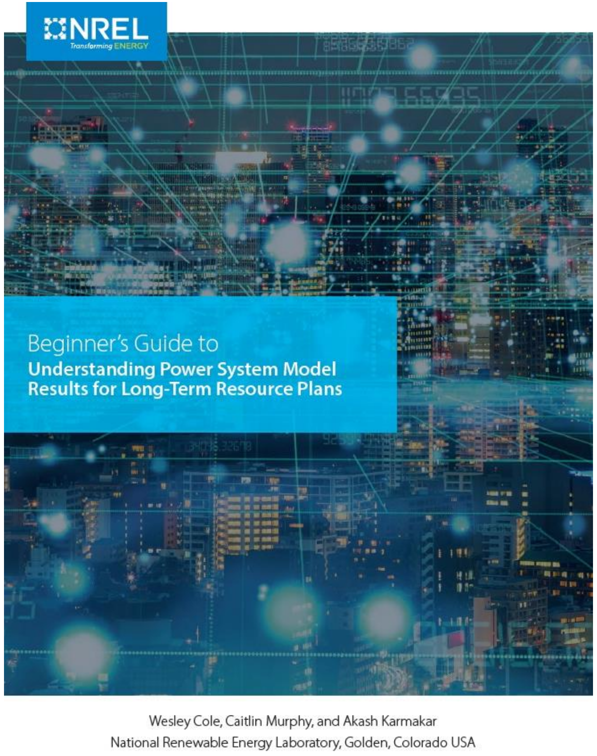
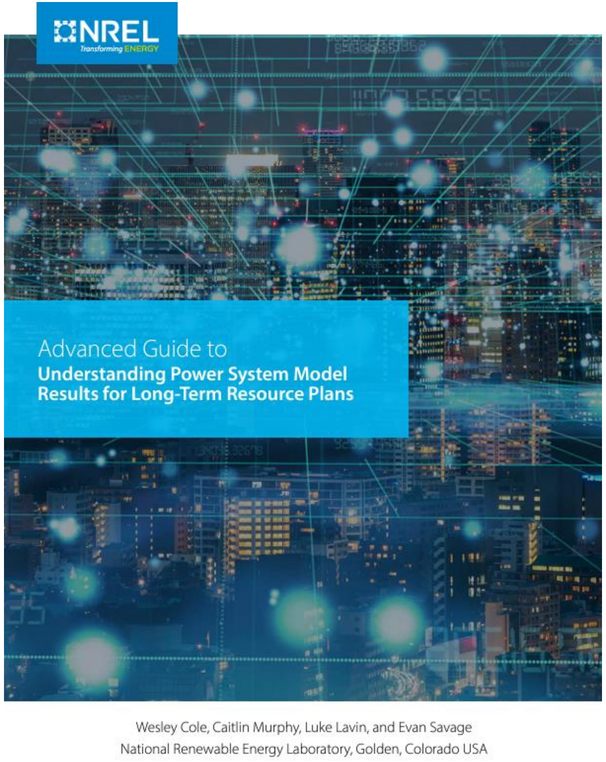


Levelized value of demand side flexibility estimated to be $11-19/MWh

New resources to help improve decision-making in the electricity planning process by strengthening dialogue between system planners and relevant stakeholders



https://www.nrel.gov/docs/fy24osti/87105.pdf



https://www.nrel.gov/docs/fy24osti/88337.pdf

Thank you.

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NATIONAL RENEWABLE ENERGY LABORATORY

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  - Cole et al. 2024. *Beginner's Guide to Understanding Power System Model Results for Long-Term Resource Plans*. www.nrel.gov/docs/fy24osti/87105.pdf
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  - Sun et al. 2020. *Electrification Futures Study: Methodological Approaches for Assessing Long-Term Power System Impacts of End-Use Electrification.*
  - Murphy et al. 2021. *Electrification Futures Study: Scenarios of Power System Evolution and Infrastructure Development for the United States.*
  - Zhou and Mai. 2021. *Electrification Futures Study: Methodological Approaches for Assessing Long-Term Power System Impacts of End-Use Electrification.*

- **Regional Energy Deployment System (ReEDS).** www.nrel.gov/analysis/reeds/
  - Standard Scenarios. www.nrel.gov/analysis/standard-scenarios.html
  - Scenario Viewer. https://scenarioviewer.nrel.gov

- **Other**
  - Renewable Energy Potential (reV). www.nrel.gov/gis/renewable-energy-potential.html
  - Denholm et al. 2019. *The Potential for Battery Energy Storage to Provide Peaking Capacity in the United States.* www.nrel.gov/docs/fy19osti/74184.pdf
  - Mai et al. Forthcoming. "Incorporating Stressful Grid Conditions for Reliable and Cost-Effective Electricity System Planning"