NREL
Transforming ENERGY

Accounting for Uncommon Resources in Planning Models

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NARUC – Bulk Power System Learning Modules

April 11, 2024

Outline

1 Introduction to NREL's Planning Model: ReEDS

2 Key Considerations for Representing Hybrids

3 Key Considerations for Representing New Nuclear

4 Key Considerations for Representing CCS

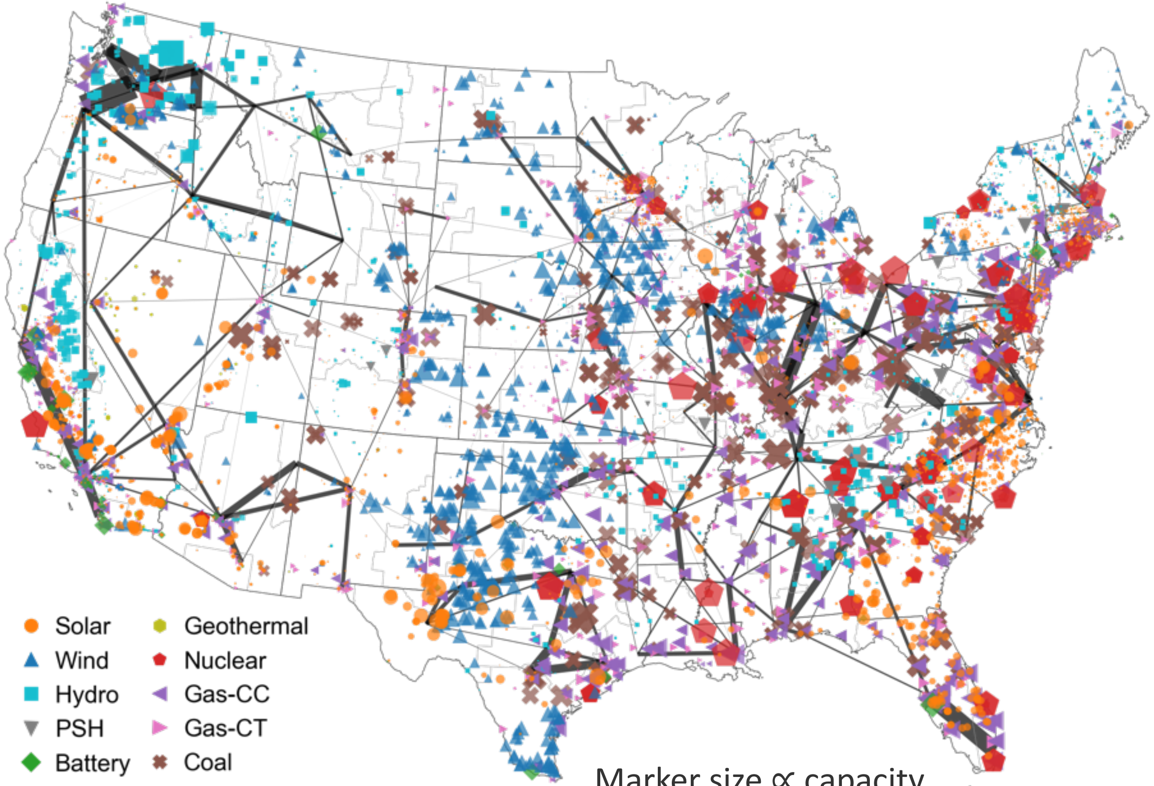
5 Key Considerations for Representing Hydrogen

6 Key Considerations for Representing Pumped Storage

7 Closing Thoughts

Regional Energy Deployment System (ReEDS) Model

2022 Generation and Transmission Capacity



Marker size ∝ capacity

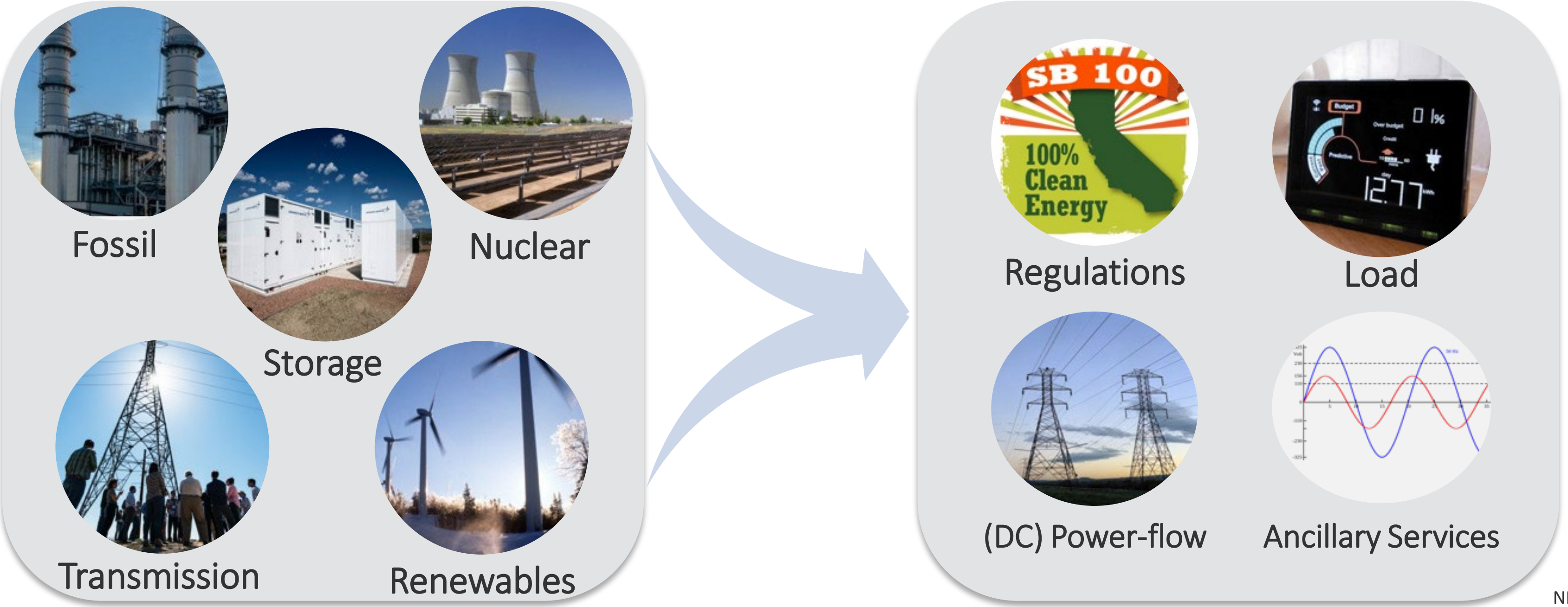
A Long-Term, “Hypothetical” Planning Model for the Continental United States

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

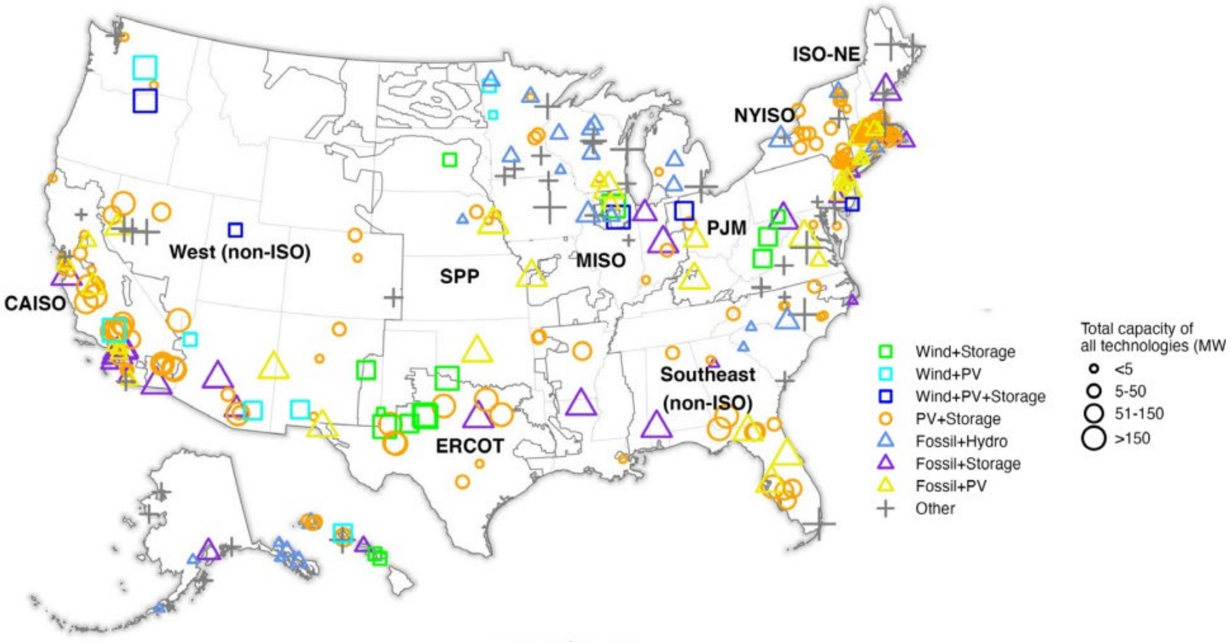
Interface transmission limits derived from transmission data from The North American Renewable Integration Study (NARIS) using a “maximum potential flow” optimization

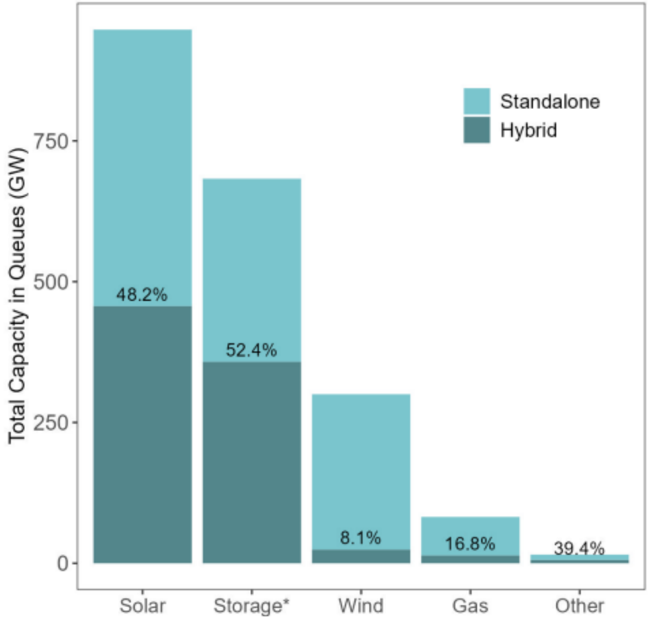
Technology and Policy Representations Supported by the U.S. Department of Energy

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.



Hybrids Overview



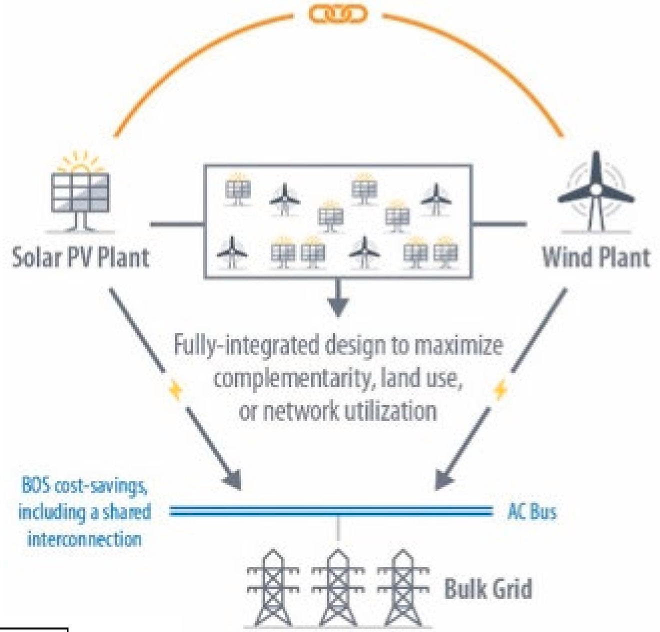


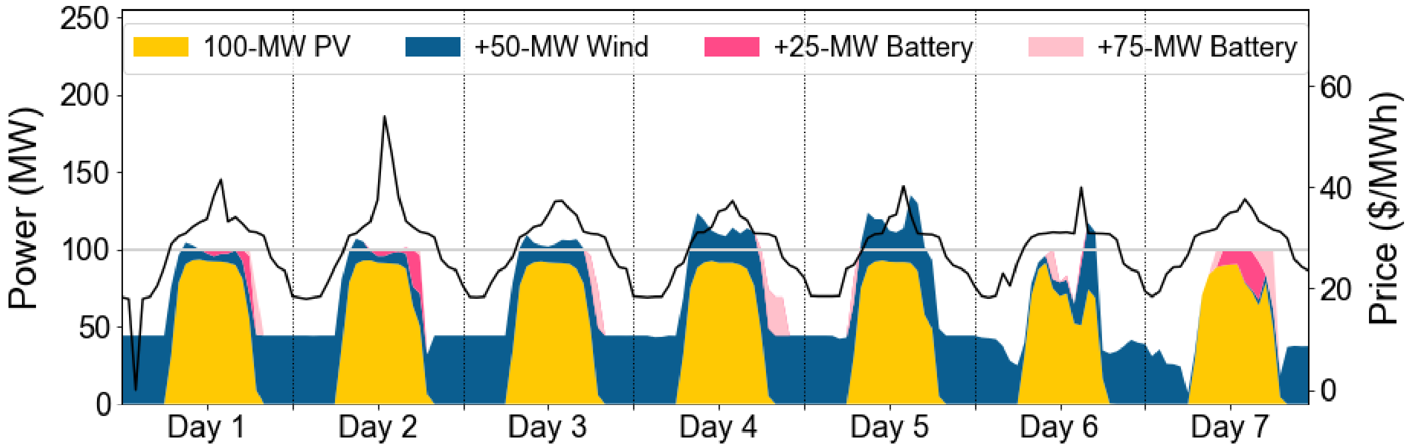
- Hybrid plants exist in **many configurations** and are broadly **distributed across the United States**
- **PV+storage** is the dominant hybrid system
- Hybrids represent **37% of generation capacity in interconnection queues**, with many projects proposed in the West and CAISO

https://eta-publications.lbl.gov/sites/default/files/hybrid_plant_tracking_2023_08.08.2023.pdf

Key Elements

- **Shared balance of system costs** including shared spurline costs and potentially faster permitting/siting
- **Increased capacity factor** for hybrids that combine complementary resources (i.e., those whose generation profiles are anticorrelated, or out of sync)
- **Reduced variability**, which helps to facilitate VRE integration, increases dispatchability/reliability services with reduced storage requirements, and maximizes transmission utilization





Murphy et al. (2021), https://doi.org/10.1016/j.rser.2021.110711

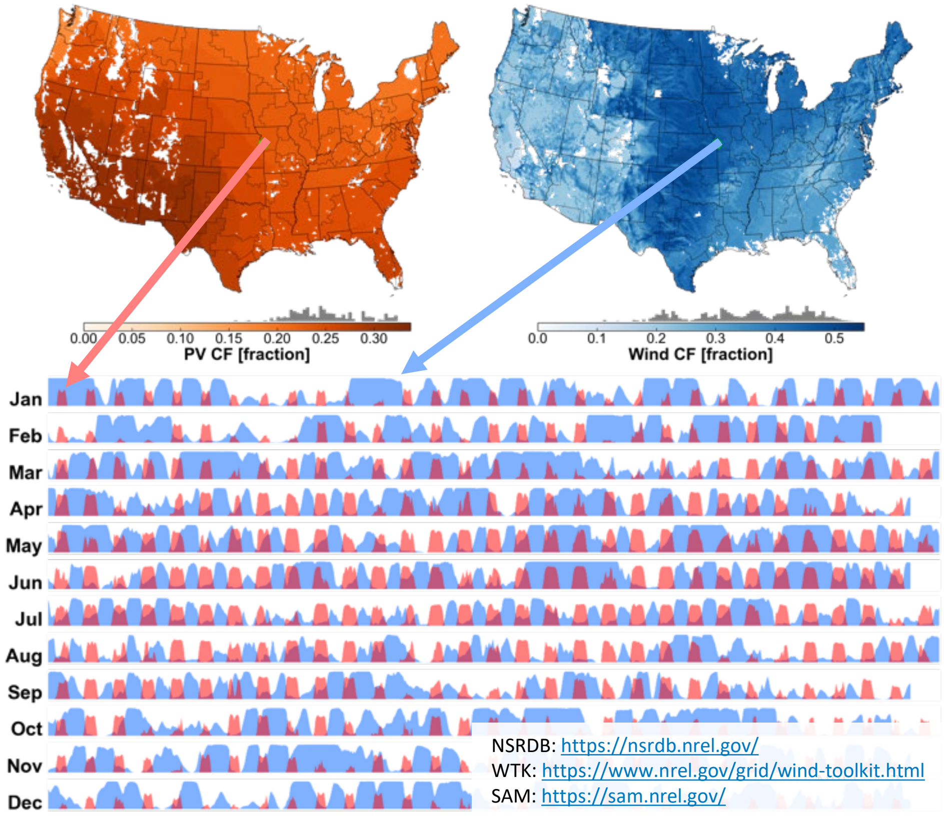
Schleifer et al. (2023), https://www.frontiersin.org/articles/10.3389/fenrg.2023.1036183/full

Key Feature: Hourly Data

https://github.com/NREL/reV

- Capturing enhanced energy production and potential for avoided curtailment in hybrid systems requires **hourly resource data**
- Smoothing output and maximizing transmission utilization requires designing hybrids with **complementary production profiles** and **appropriately sized components**
    - This is especially important for determining capacity credit/capacity value/**resource adequacy contributions**

Temporal availability

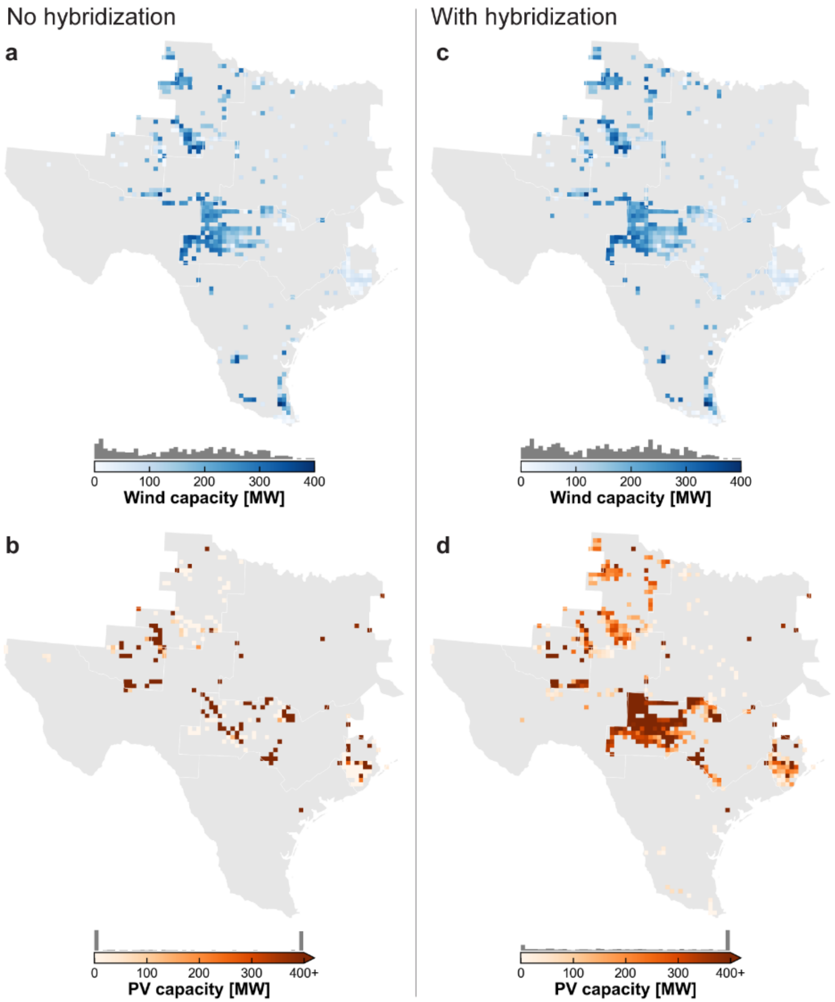


NSRDB: https://nsrdb.nrel.gov/
WTK: https://www.nrel.gov/grid/wind-toolkit.html
SAM: https://sam.nrel.gov/

Key Feature: Individual Sites

- **Site-specific representation** is required to understand siting potential, as well as interconnection costs and synergies
  - Designing a beneficial hybrid system can be thought of as an optimization of generation, storage, and transmission capacity
- Analysis insight: the **primary impact of allowing hybridization is spatial** – when hybridization is allowed, ReEDS simulations show that one technology tends to be relocated from standalone sites to sites where the coupled technology has previously or is currently being deployed

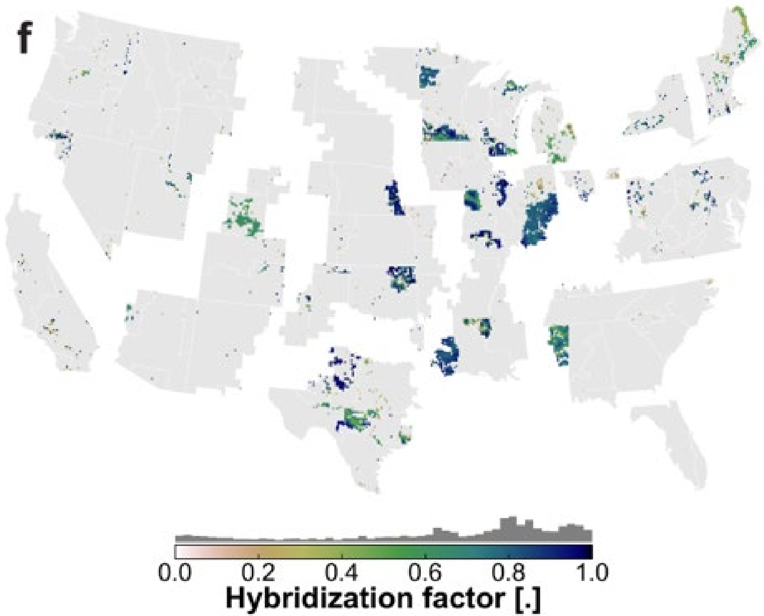
PV → Wind // Battery → PV



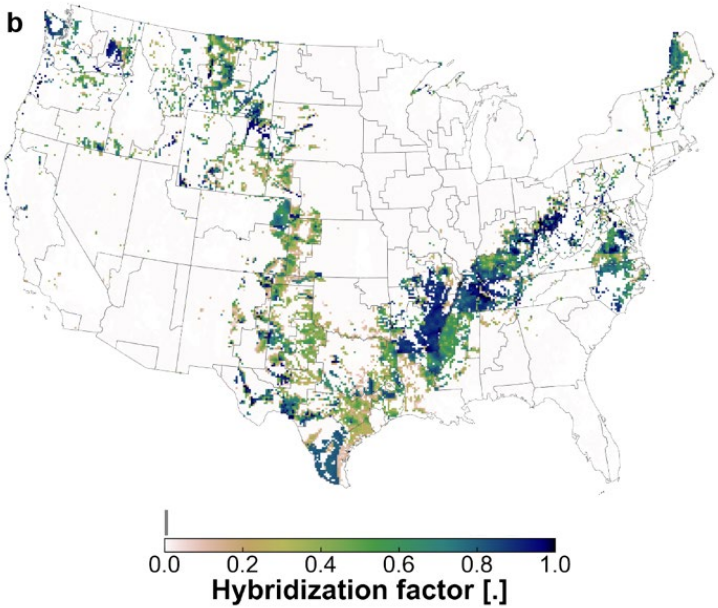
Key Feature: Net Value

- When designing a hybrid plant, you want to design a plant that can produce energy, and be available, during **high-value periods**
  - Levelized cost of energy **(LCOE) is not a reliable indicator** of beneficial hybrid location or design
  - Maximizing output does not necessarily offer the greatest value (to the owner or the grid)

Hybrid deployment based on **net value**



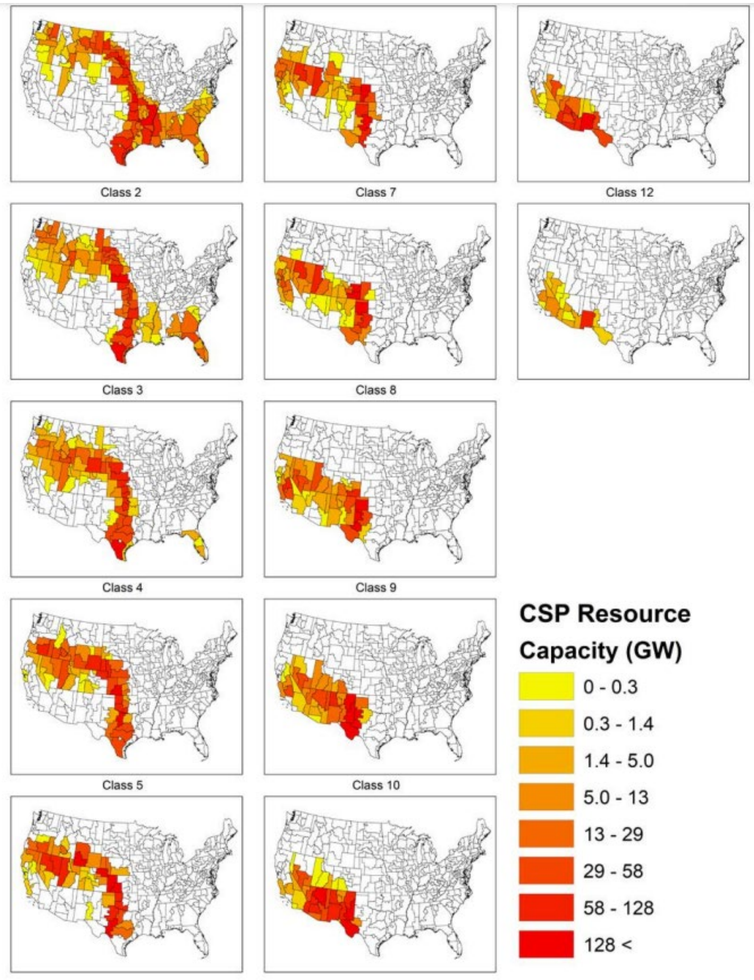
Hybrid deployment based on **LCOE**



Concentrating Solar Power

Concentrating Solar Power (CSP) is a lot like PV+Storage but…

- **Thermal storage** can be longer duration but must be converted back to electricity
- The resource potential is **more limited in spatial extent**, and it could be **further limited by cooling requirements**
- There are **currently no proposals** for new CSP plants in the United States
- The **technology is still evolving**; ReEDS exclusively considers a tower-based configuration with a molten-salt heat-transfer fluid, but this does not reflect the majority of existing CSP plants in the United States

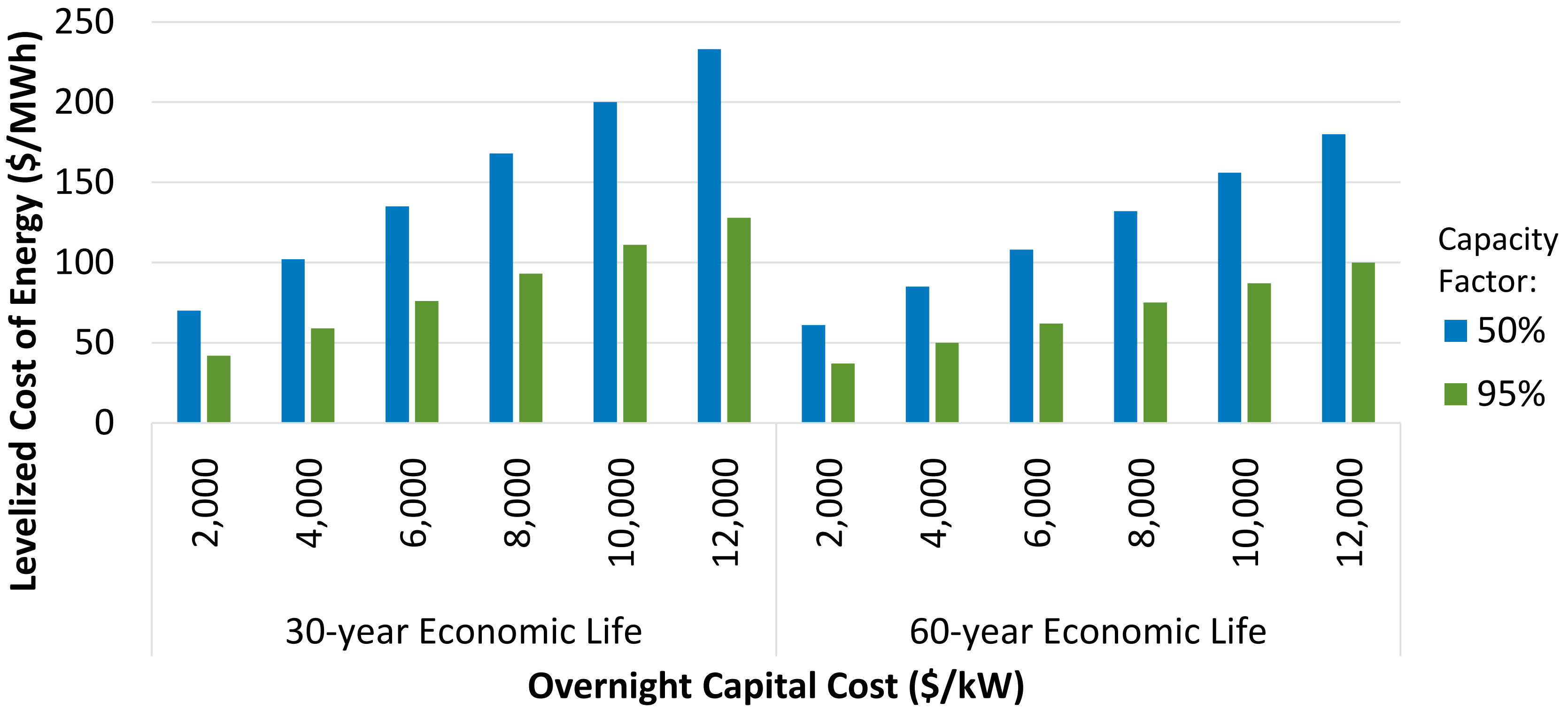


Murphy et al. (2019)

Important Factors for New Nuclear

- Cost of new nuclear is likely to be the most important driver of nuclear's role in a resource plan
- Relevant cost factors
  - Overnight capital costs (current estimates are $5,000-20,000/kW versus ~$1,000-1,500/kW for natural gas combined cycle)
  - Financing costs
  - Fixed operating costs
  - Energy community bonus tax credit

Utilization also Impacts Costs for New Nuclear



Source: Cole et al. (2023), The Potential Role for New Nuclear in the U.S. Power System: A View from Electricity System Modelers.

Timeline Considerations for New Nuclear

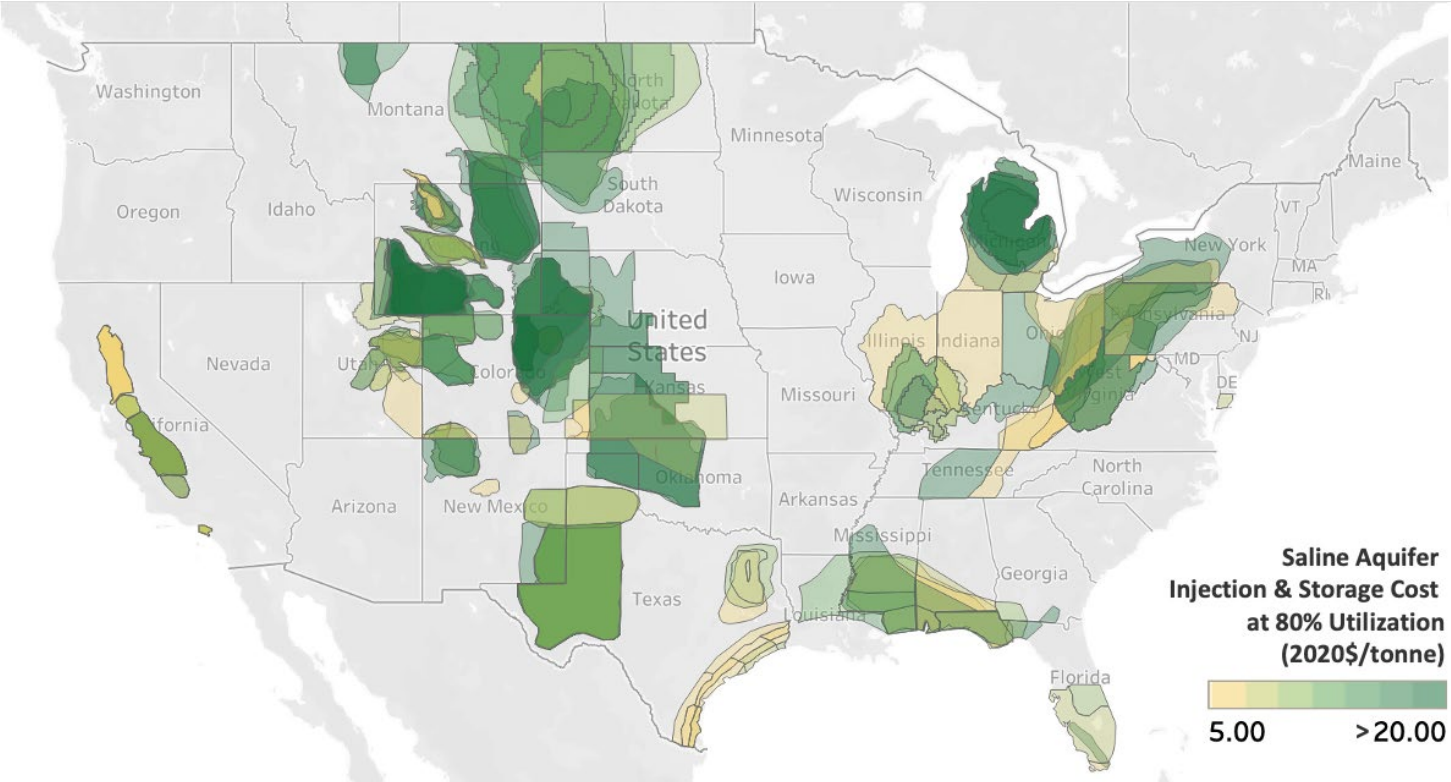
- Initial advanced reactor plants are currently scheduled to come online around 2030
- Several utilities are looking into adding nuclear in ~2035
- Unless the utility already has something it the works, it might be challenging to bring on any new nuclear capacity before 2035
  - Challenges to currently planned plants could push this back further; plants coming on ahead of schedule is unlikely

Key Elements for Carbon Capture and Storage (CCS)

- Policy drivers for clean energy or emissions reductions
  - Potential for negative emissions
  - Challenges of zero emissions
- Carbon capture has been demonstrated as a technically viable technology
  - Uncertainty is in cost and total emissions impact (via upstream and downstream leakage)
- Storage aspect is locationally dependent

CO_2 Storage Locations and Cost

Color indicates the levelized cost of injection and storage (but excludes transport costs)



Hydrogen Overview

- Hydrogen might be produced from electricity, thereby increasing electricity demand
- Hydrogen can also be consumed for electricity production via gas turbines or fuel cells
  - Fuel cost is likely to be very high ($20-30/MMBtu versus $3-6/MMBtu for natural gas)
  - Hydrogen subsidies can lower this; specifics of how to qualify are still in development

Key Elements for Hydrogen

- Hydrogen might be challenging to transport
  - Production and consumption are likely to be collocated
- Technologies for converting pure hydrogen streams into electricity are still nascent, but appear technically viable
- The high fuel cost of hydrogen means that any hydrogen-fueled power plants are likely to be low utilization plants
  - Hydrogen will need to be stored until it is needed

Pumped Storage Hydropower (PSH) Overview

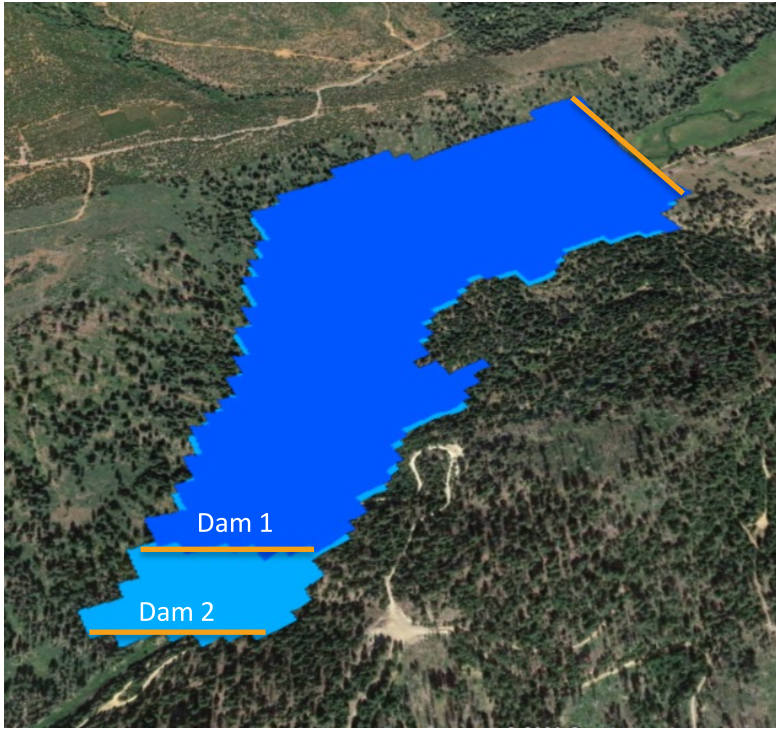
- In the United States, PSH comprises approximately 23 GW of the nation's 28 GW of installed storage capacity
- 50+ year lifespan vs 10-15 for batteries
- PSH systems are well suited for diurnal energy storage and have competitive round-trip efficiency (US PSH fleet average of 79%)

Global Energy Storage by Type

Storage technology	Installed capacity (GW)	% Share
2016 World total	168.6	100
Pumped-hydro	162.2	96.2
Electrochemical	1.6	0.95
Thermal	3.2	1.9
Mechanical	1.6	0.95

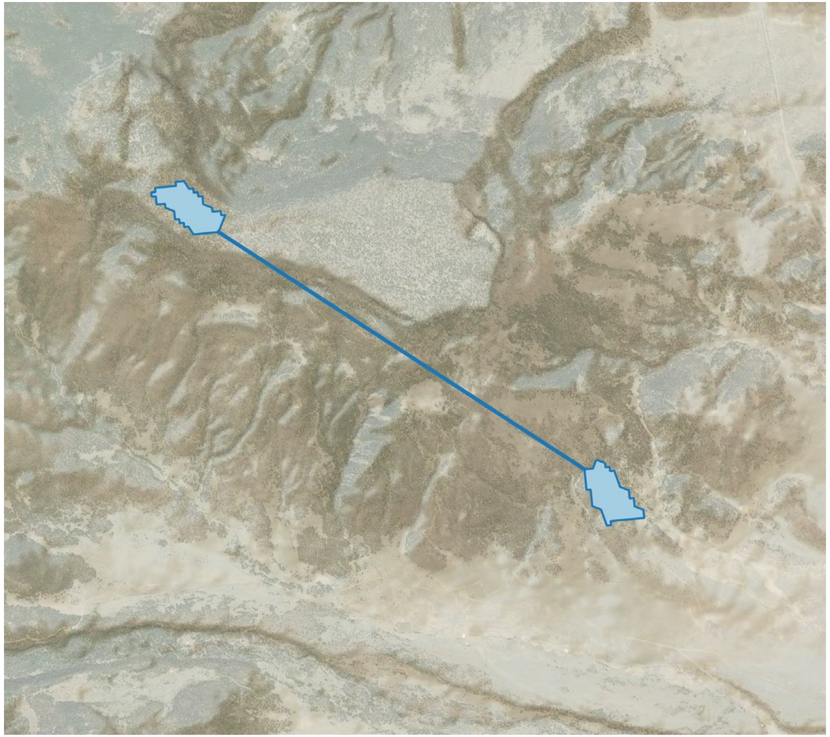
Potential Reservoirs are Modelled Using Input Digital Elevation Models (DEM)

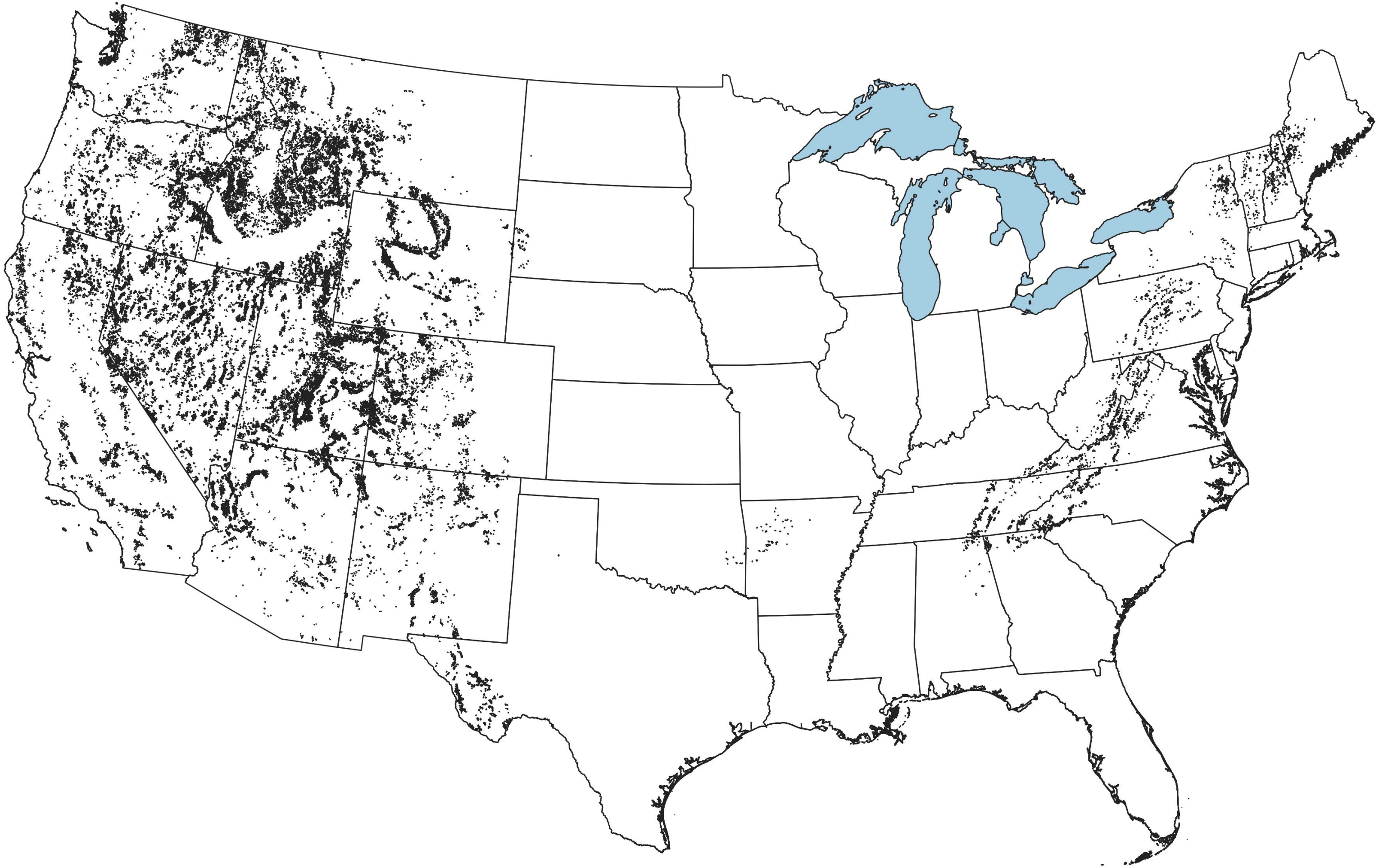
- Reservoirs are modelled as area of watershed impounded by a 40m dam.
- Algorithm can create multiple overlapping reservoirs along gulley.
- Geometries exported along with key attributed (reservoir and dam volume, elevation).



Reservoirs Paired with Other Reservoirs to form PSH Systems

- Remaining reservoirs joined via spatial distance join with other reservoirs in area to form systems.
- Systems must have min head height of 300m, max horizontal length of 3.5 km, and be have reservoirs of similar volumes.
- Simple cost model applied





Closing Thoughts

- Technology innovation and evolution means that “uncommon resources” are likely to become available in the coming decades
- These technologies can serve as additional tools for achieving planning goals
- The role of new technologies will depend on the specific needs and situations of a region or entity
- Experts are available to help support decision-making around these technologies

+ Many others who provide critical data, input, and guidance for the model

Thank you.

www.nrel.gov

https://www.nrel.gov/docs/fy23osti/85242.pdf

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