Challenges and opportunities in the path towards decarbonized power systems: U.S. Perspective

Bethany Frew

Challenges and Solutions for Power Systems with Large Shares of Renewables: Global trends and implication for Japan

May 10, 2023

NREL at-a-Glance

2,926

Workforce, including

219 postdoctoral researchers

60 graduate students

81 undergraduate students

World-class

facilities, renowned technology experts

More than 900

Partnerships

with industry, academia, and government

Campus

operates as a living laboratory

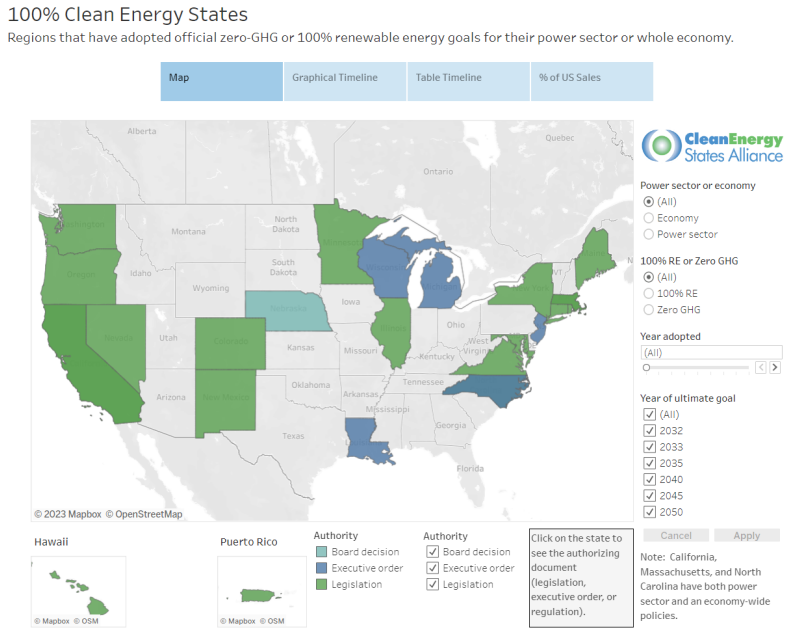
Why are we talking about decarbonized power systems?

Largely driven by policy:

1) Decarbonization targets

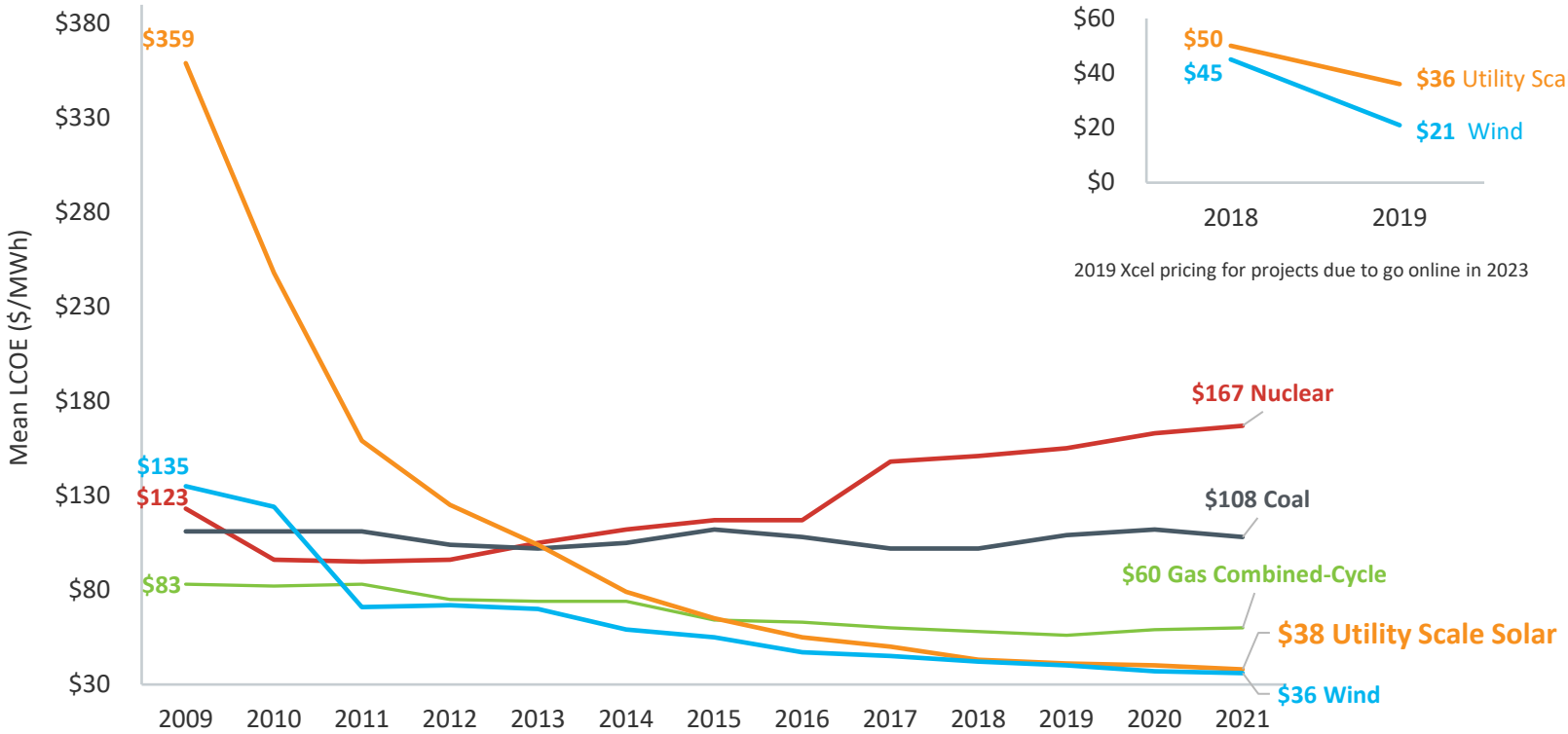
2) Recent federal legislation

- *Inflation Reduction Act of 2022 (**IRA**)*
- *Infrastructure Investment and Jobs Act of 2021 (also known as the "Bipartisan Infrastructure Law" or **BIL**)*
- *Biden Administration target of 100% by 2035*



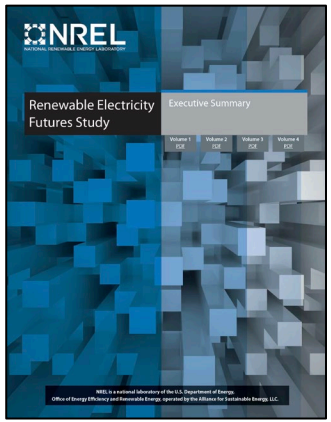
https://www.cesa.org/projects/100-clean-energy-collaborative/guide/map-and-timelines-of-100-clean-energy-states/

But declining costs for renewables are also a factor



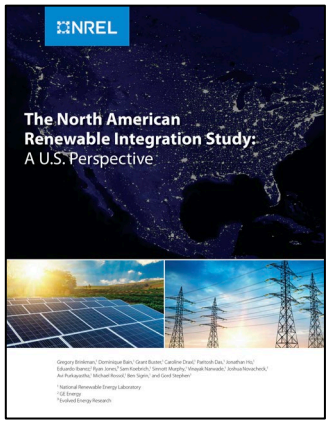
Source: *Lazard's 2019 Levelized Cost of Energy Analysis*

This talk: Highly decarbonized U.S. power systems



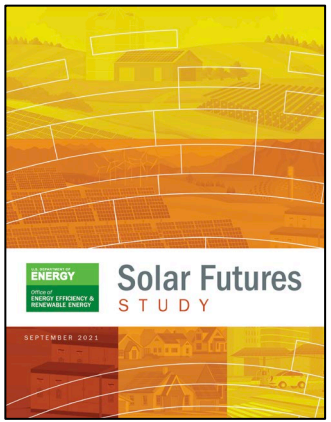
Renewable Electricity Futures Study (2012)

80% renewable by 2050



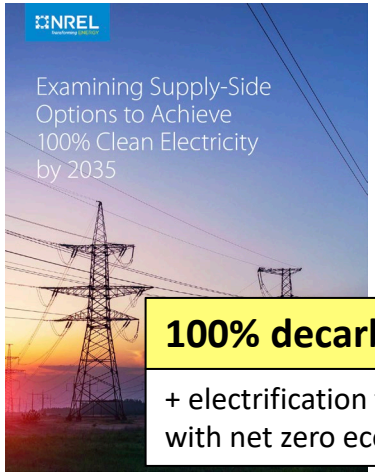
North American Renewable Integration Study (2021)

80% decarbonized by 2050



Solar Futures Study (2021)

100% decarbonized by 2050



100% decarbonized by 2035

+ electrification trajectory consistent with net zero economy-wide by 2050

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

Up to 90% decarbonized by 2033

Impacts of IRA and BIL policy

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

Decarbonized = wind, solar, hydroelectric, geothermal, biomass, nuclear, combustion with CCS

Challenges and Opportunities

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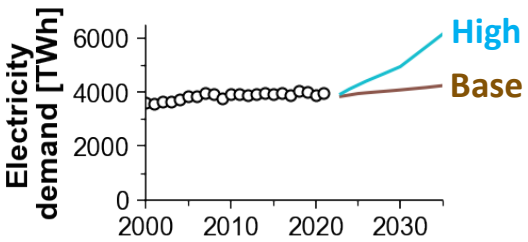
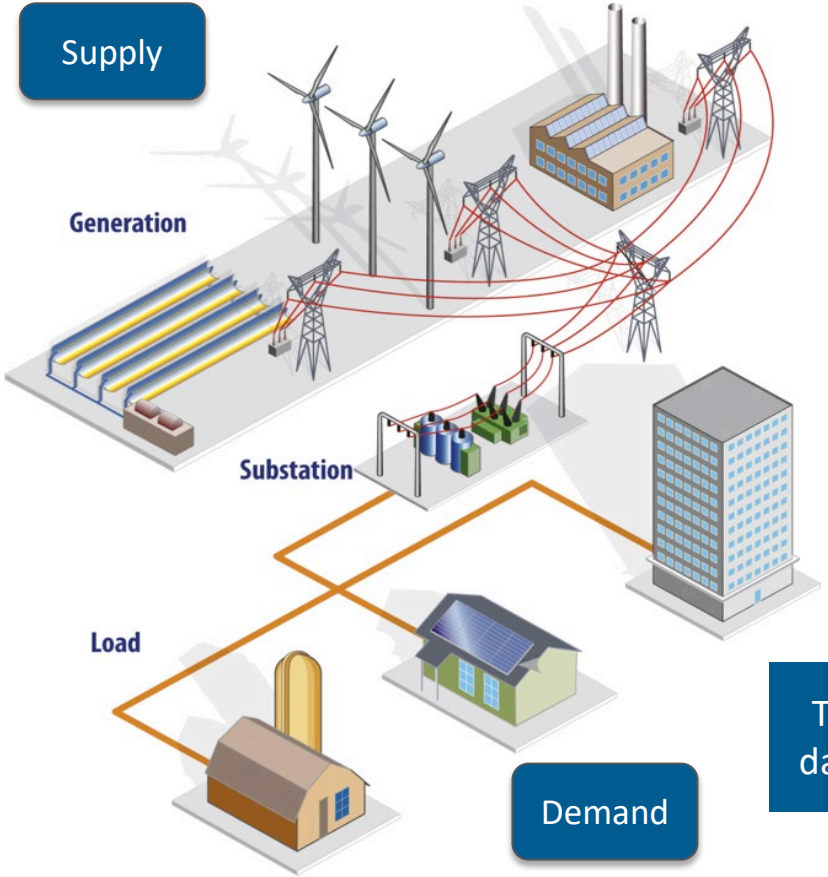
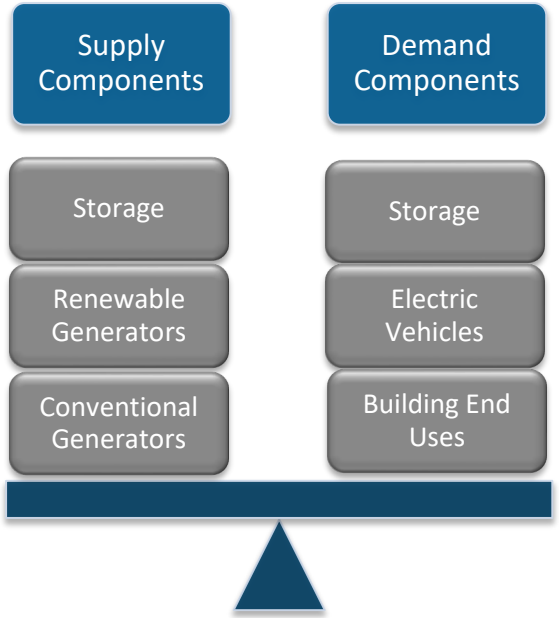
Challenge: Must meet new and changing demand from electrified loads



Opportunity: Accelerate electrification, leverage the flexibility of new loads, and increase efficiency

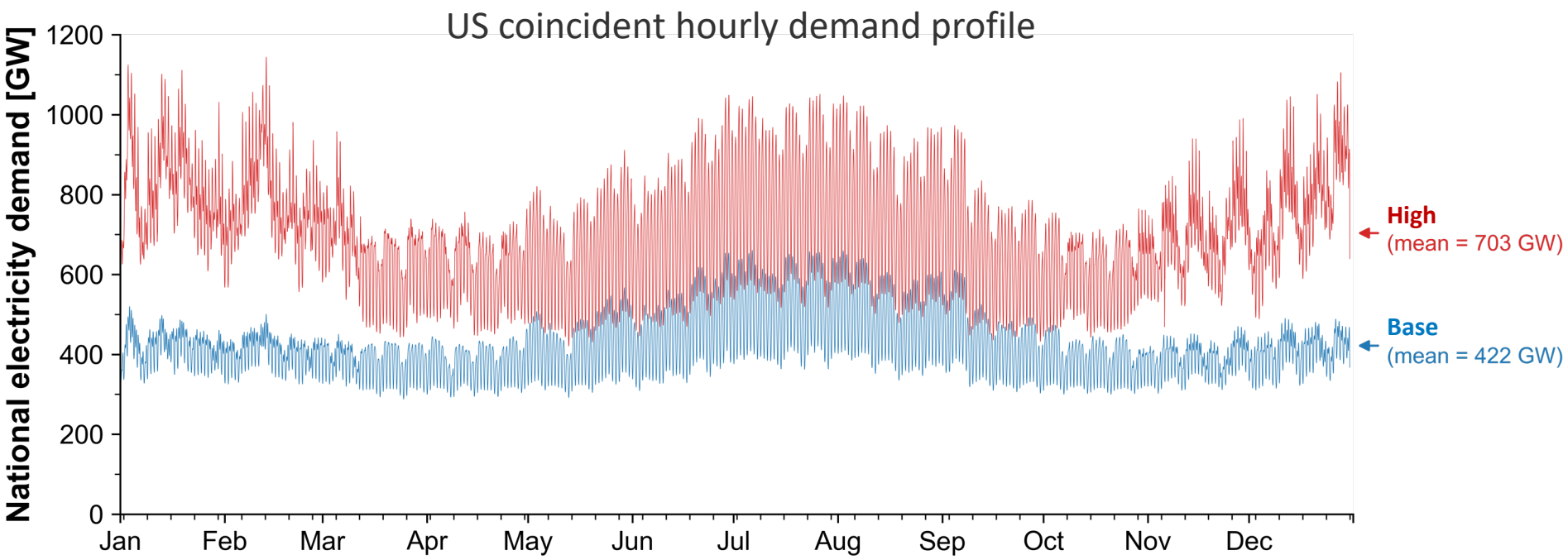
Overarching challenge: Supply and demand need to be balanced at all times



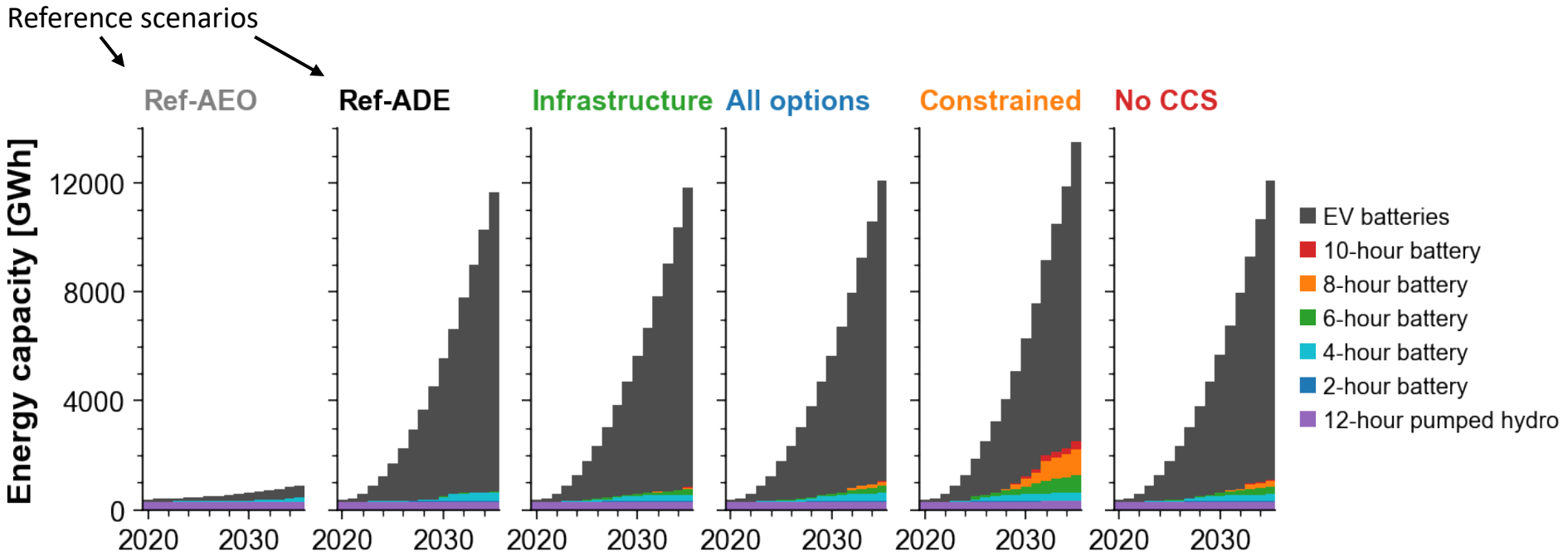


The electric grid operates at timescales from sub-seconds to days using assets that can take years to build and last decades

Future power systems must decarbonize while also meeting new and changing demand from electrified loads

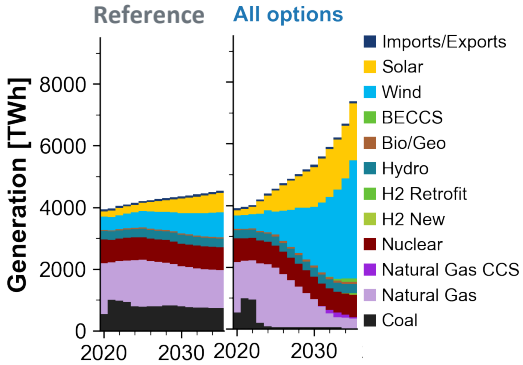


But these electrified load can provide needed flexibility to maintain balance



Challenges and Opportunities

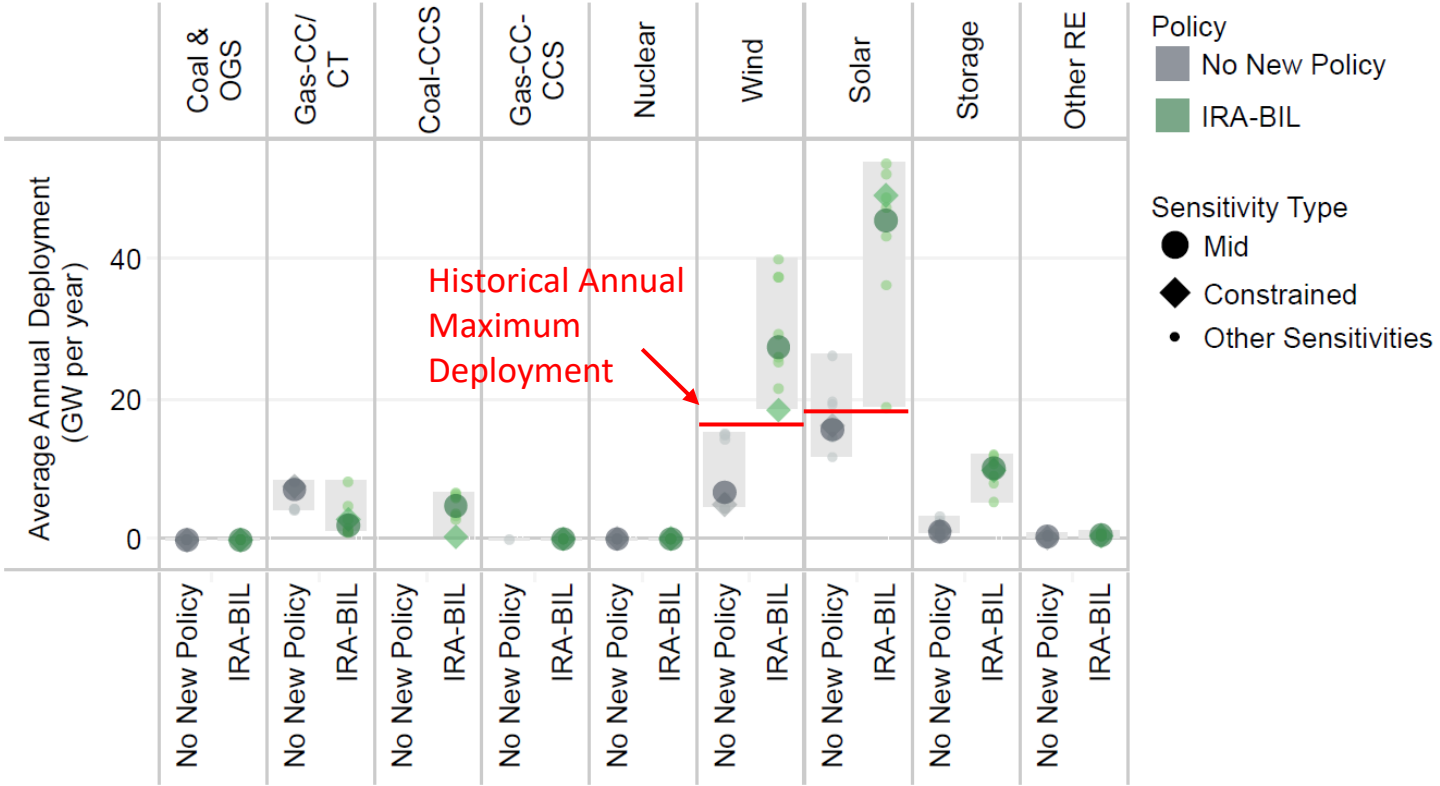
Challenge: Will need massive development of clean energy resources, particularly wind and solar



Opportunity: Expand clean technology manufacturing and supply chains

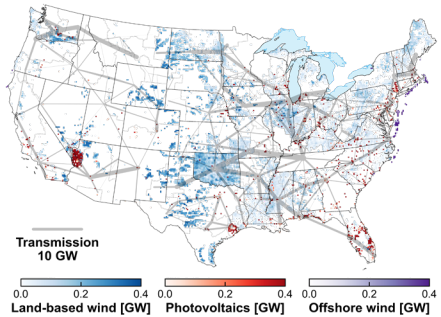
Decarbonizing the grid will require unprecedented development of clean energy resources—particularly wind and solar

With IRA and BIL: Wind, solar, and storage deployment rates could more than double relative to historical annual maximum levels



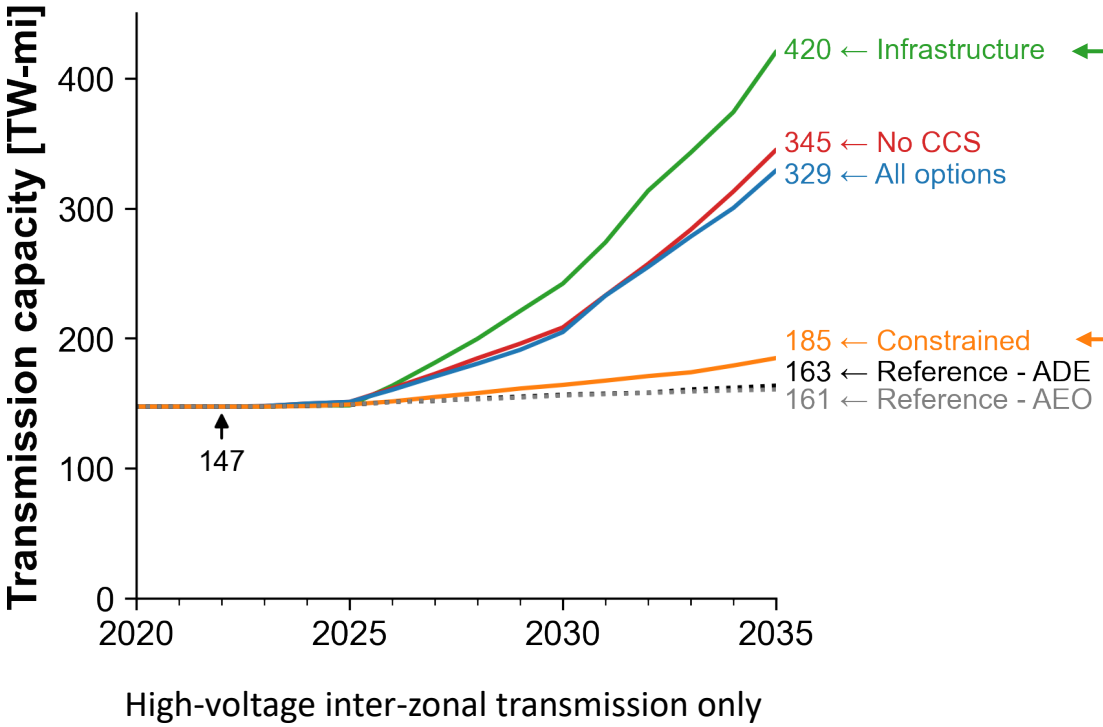
Challenges and Opportunities

Challenge: Large amounts of transmission and storage are needed to support buildout and operations of high quality wind and solar



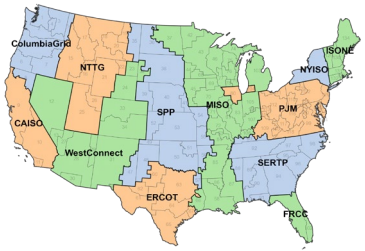
Opportunity: Install new energy infrastructure rapidly throughout the country

Transmission expansion (mainly for wind) and energy storage (mainly for solar) are important enablers for a low-carbon grid



Multi-terminal HVDC macrogrid

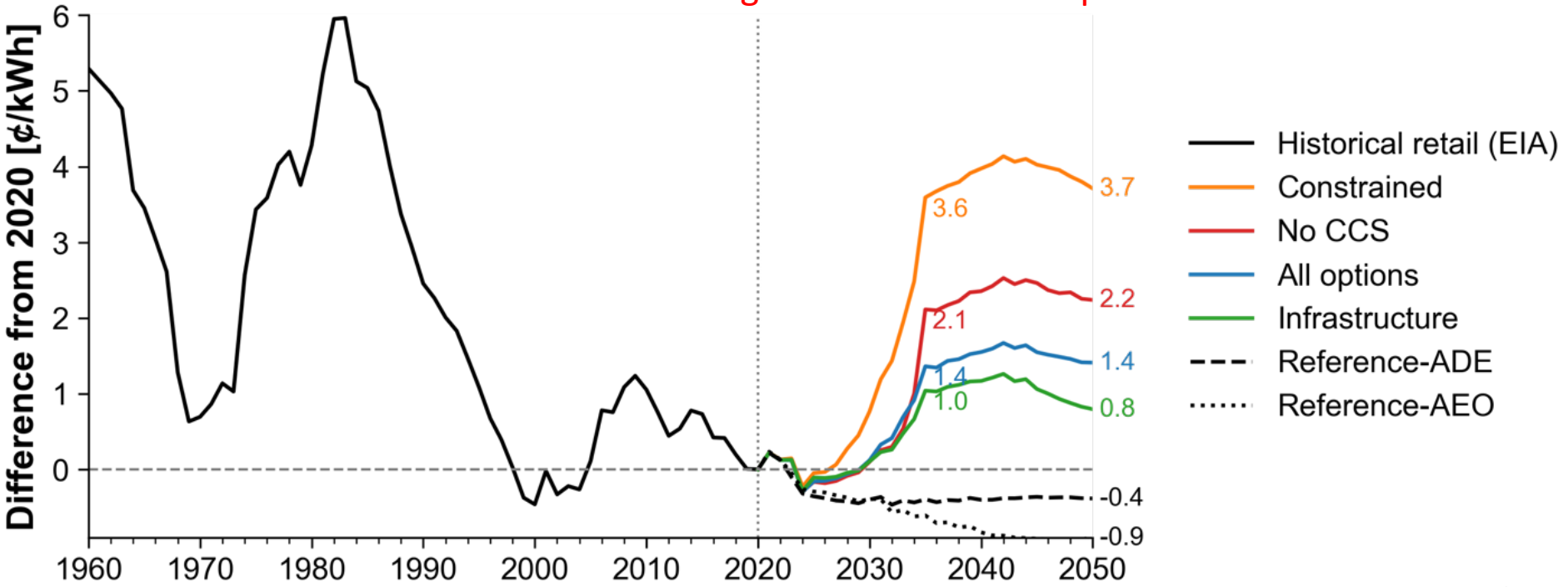
5× transmission cost, No interregional (defined by FERC Order 1000 regions)



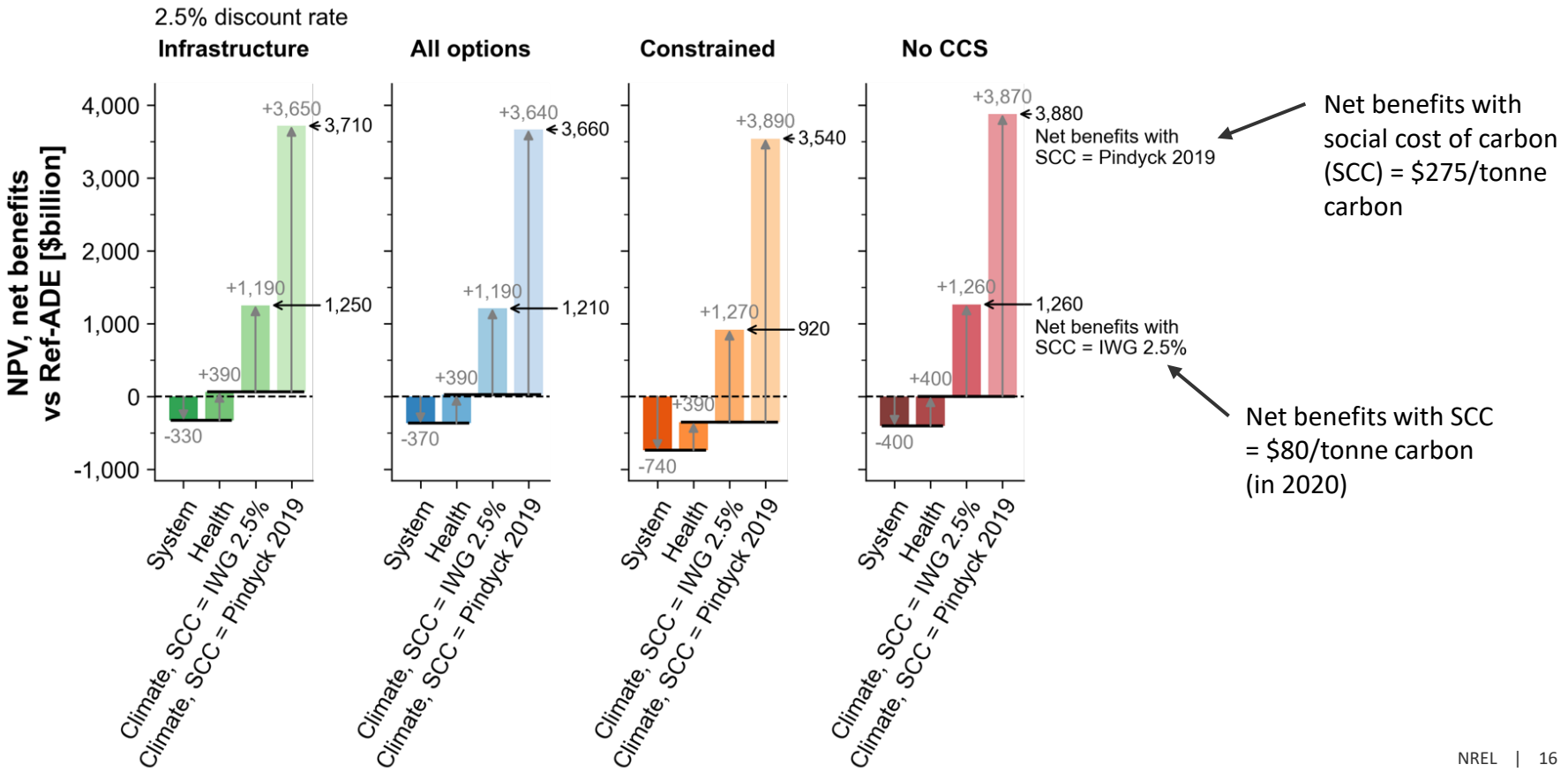
These large transmission buildouts enable access to high-quality, low-cost resources, and only contribute ≤10% to overall system cost

Of key importance, these massive resource and transmission buildouts do not significantly impact consumer costs

Direct electricity system costs increase in the 100% scenarios, but these increases are well within the range of historical retail price fluctuations



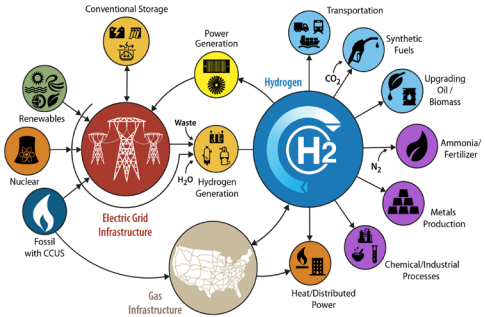
In fact, benefits from improving air quality and avoided climate damages exceed the incremental costs of the 100% clean electricity



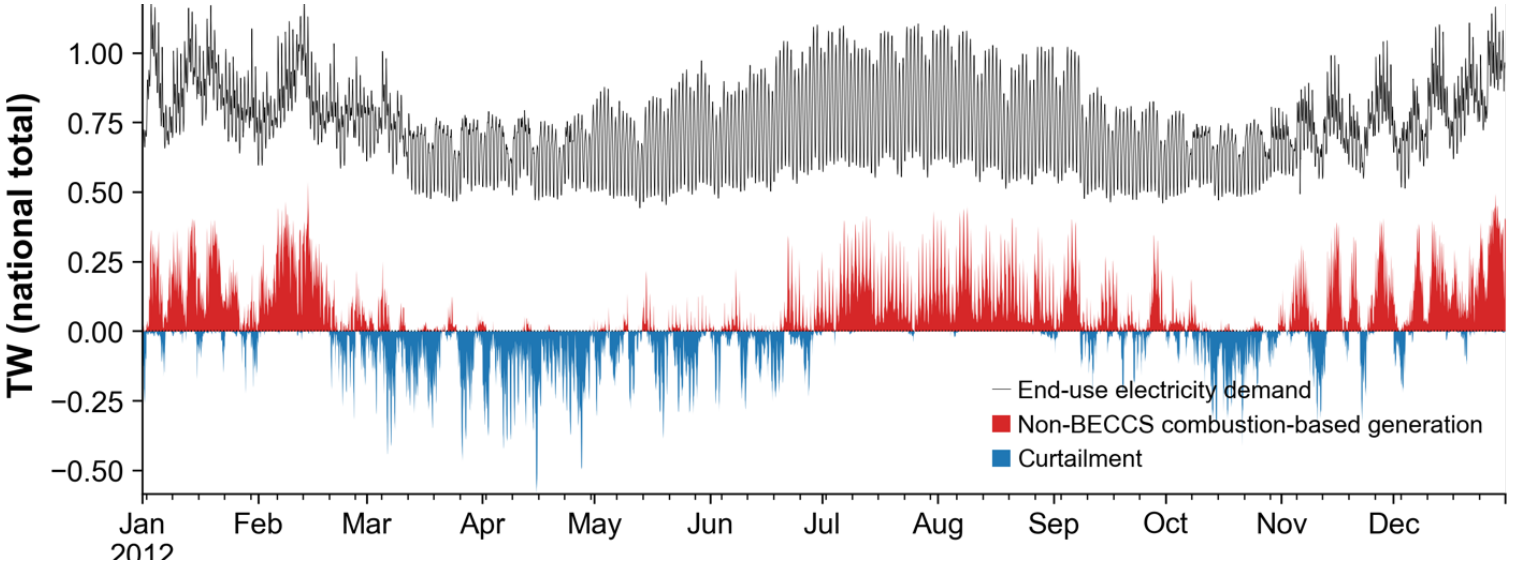
Challenges and Opportunities

Challenge: We have not determined the optimal pathway to overcome seasonal imbalances

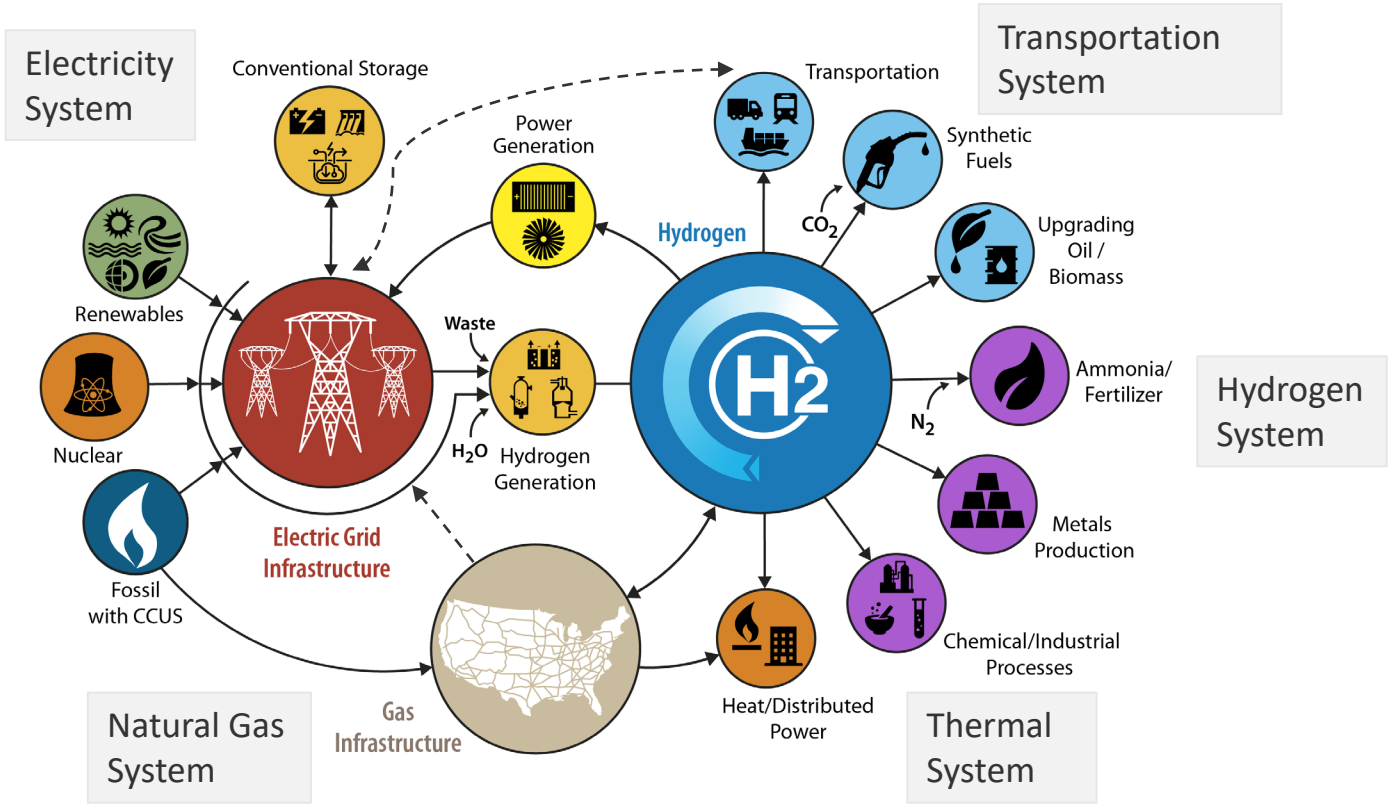
Opportunity: Accelerate research, development, demonstration, and deployment to bring emerging technologies to market



Getting all the way to 100% requires overcoming the seasonal imbalance challenge, but we don't yet know the optimal technology pathway to accomplish this



Energy systems integration can help meet seasonal imbalance challenge



H2@Scale: image modified from https://www.energy.gov/eere/fuelcells/h2scale

Summary: Challenges and Opportunities

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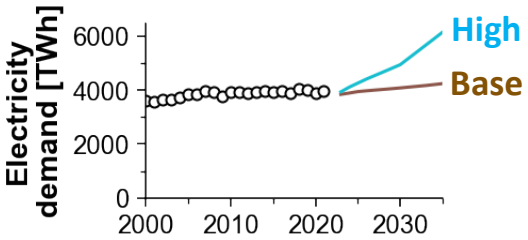

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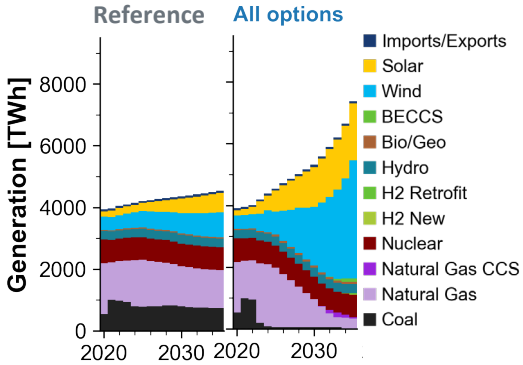

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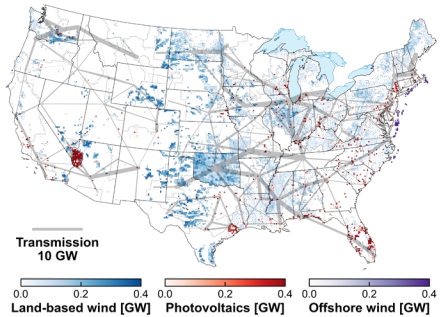

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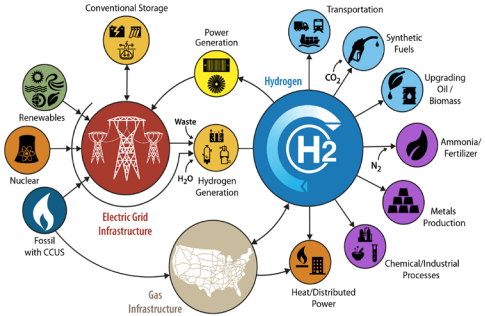

Thank you to my NREL colleagues:

- Paul Denholm
- Patrick Brown
- Wesley Cole
- Trieu Mai
- Brian Sergi
- Daniel Steinberg
- Maxwell Brown

Thank you!

www.nrel.gov

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