Integrating Cross-Sectoral Analysis into Planning:

How do the Answers Change Studying 100% Clean Electricity vs a Zero-Carbon Economy?

March 27, 2024

Prepared for:

Energy Systems Integration Group

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Evolved Energy Research

Evolved addresses key policy and strategy questions raised by transformation of our energy system

NGOs

NRDC, SDSN, GridLab, Sierra Club, CETI, OCT, UCS, EDF, CATF, BPC, Third Way, and others

State Energy Offices

Washington, California, Massachusetts, Maine and New Jersey

Utilities

DTE, PGE, Hydro Quebec, PG&E and others

Others

Princeton University, Breakthrough Energy, SPP, Rhodium Group, Inter-American Development Bank, DOE, NREL, RAP, and AGU Advances

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Cross-sectoral analysis

Models have improved to answer new questions

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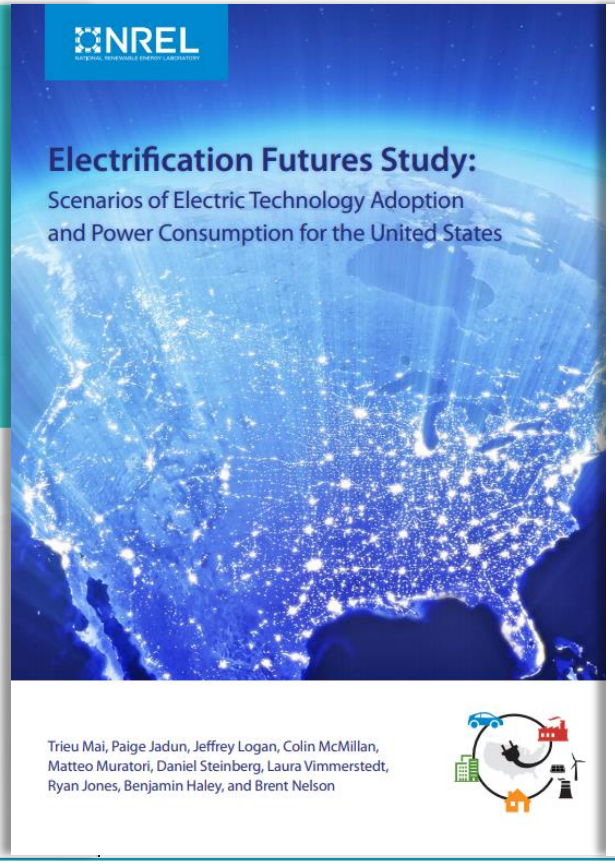
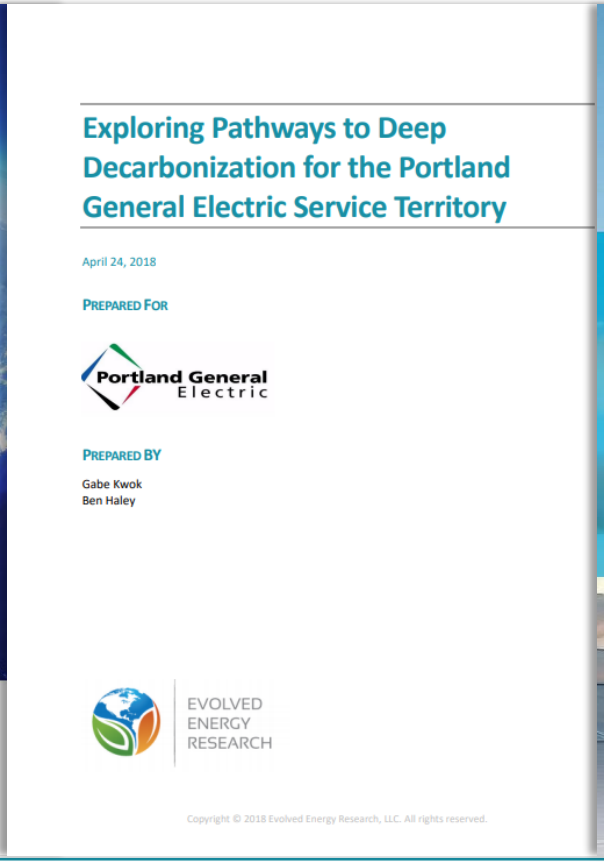
What are the infrastructure requirements for different clean energy pathways?

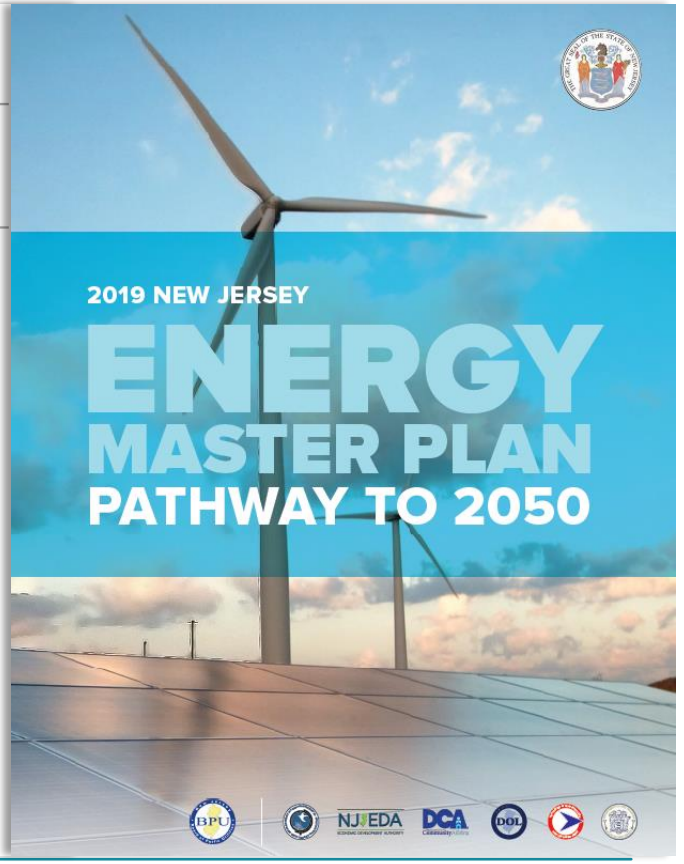
How will end-use electrification affect total electricity demand and load shapes?



How does economy-wide decarbonization impact electricity utility operations and planning?



What is the least-cost portfolio for the state to realize its 100% clean electricity and GHG objectives?



Defining sectoral coupling: Growth of non-traditional electric utility loads

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- The electric sector is central to achieving economy-wide emissions reductions
  - Lowest cost zero carbon energy
- Sector coupling includes:
  - Direct electrification of end-uses like transport and building heating
  - Novel electrification of industrial processes (E.g., steam, thermal storage)
  - The use of electricity to synthesize fuels (E.g., hydrogen, jet fuel)
- Good analysis methods recognize that these new loads can be quite different than traditional loads (locational and temporal flexibility)

Sectoral coupling example: Hydrogen

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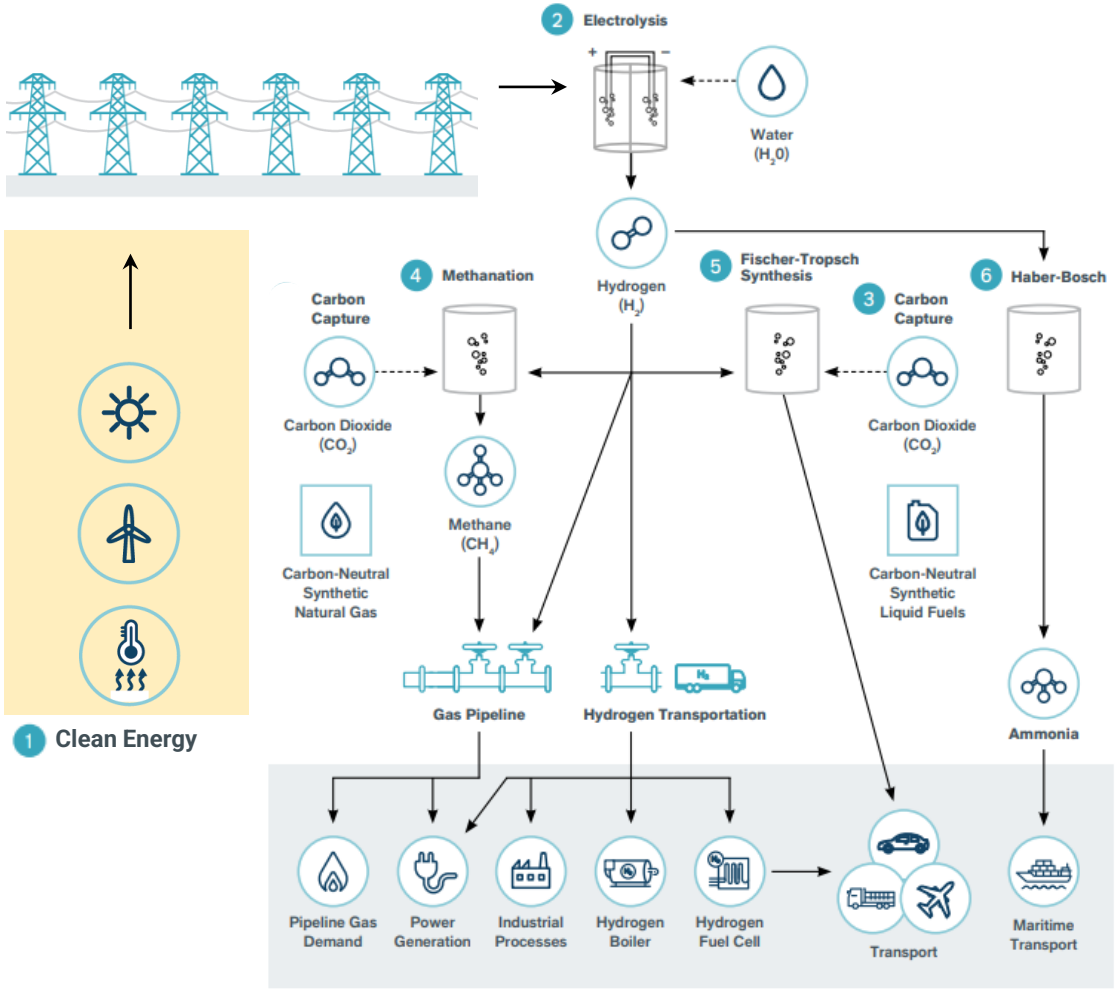

1. **Renewable Energy & Power Grid:** Clean electricity powered by sources such as solar, wind, and hydroelectricity supplies the power grid. Nuclear energy could also power high-temperature electrolysis.

2. **Electrolysis:** The process of using electricity, in this case carbon-free, to split water into hydrogen and oxygen.

3. **Carbon Capture:** Carbon dioxide is captured either through direct air capture powered by carbon-free electricity or from biorefineries, which convert biomass to biogas while capturing the carbon.

4. **Methanation:** Combines hydrogen with carbon dioxide to produce methane that can be injected into the gas pipeline as carbon-neutral synthetic gas.

5. **Fischer-Tropsch Synthesis:** Chemical reactions that change a mixture of carbon dioxide gas and hydrogen gas into liquid hydrocarbons, such as gasoline or kerosene, that can be used for transportation.

6. **Haber-Bosch:** The primary method of producing ammonia from nitrogen and hydrogen. Today, ammonia is mainly used to make fertilizer, cleaning products, and plastics, but is also seen as a promising clean fuel for maritime transport.

Source: CETI, NZNW, 2023

Requires economy-wide energy demand and supply modeling integrated across sectors

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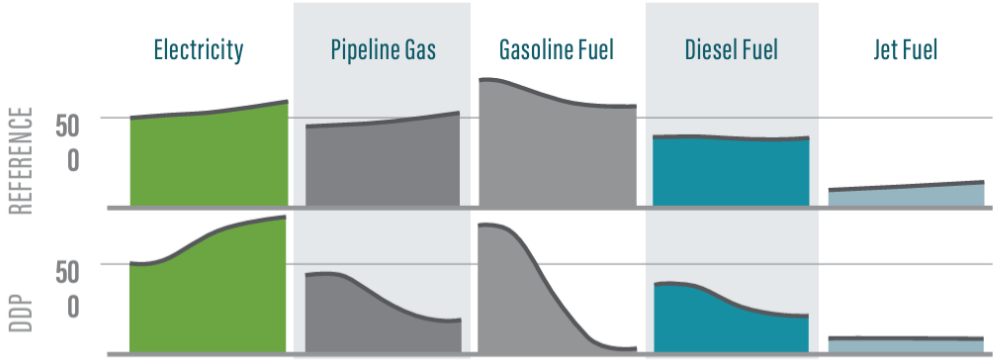
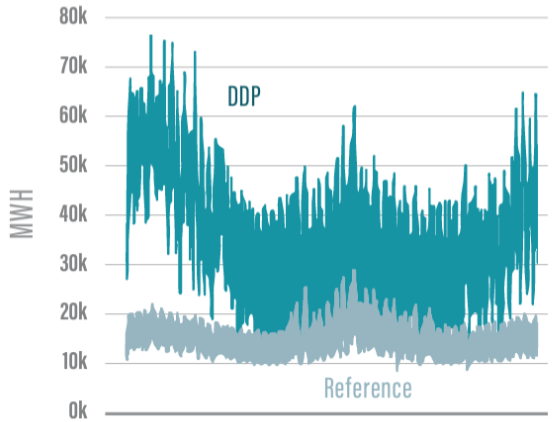
ENERGYPATHWAYS (EP)

Annual End-Use Energy Demand



Hourly Load Shape



REGIONAL INVESTMENT AND OPERATIONS (RIO)

INPUT	OUTPUT
End-use energy demand	**Electricity Sector** • Wind/solar build • Energy storage capacity/ duration • Capacity for reliability • Curtailment • Hourly operations • Transmission build
System emissions constraints	
RPS or CES constraints	
Technology and fuel cost projections	**Fuels Sector** • Fuel conversion and storage build • Fuels & electricity coupling (e.g. electrolysis) • Trading • Biomass allocation • Sequestration
New resource constraints	
Biomass and CO_2 Sequestration costs	Annual CO_2 emissions
Hourly load shape	Energy system cost

Economy-wide energy planning leads to increasing integration across sectors

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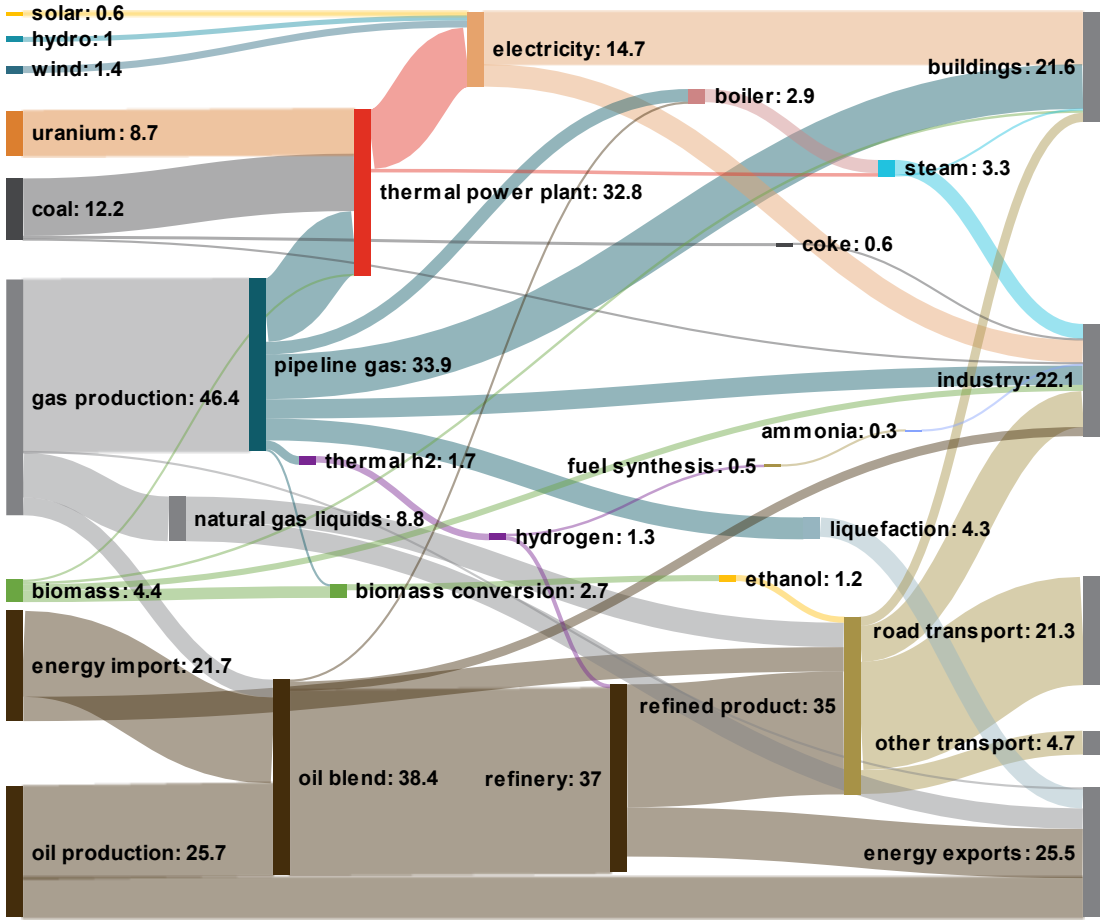
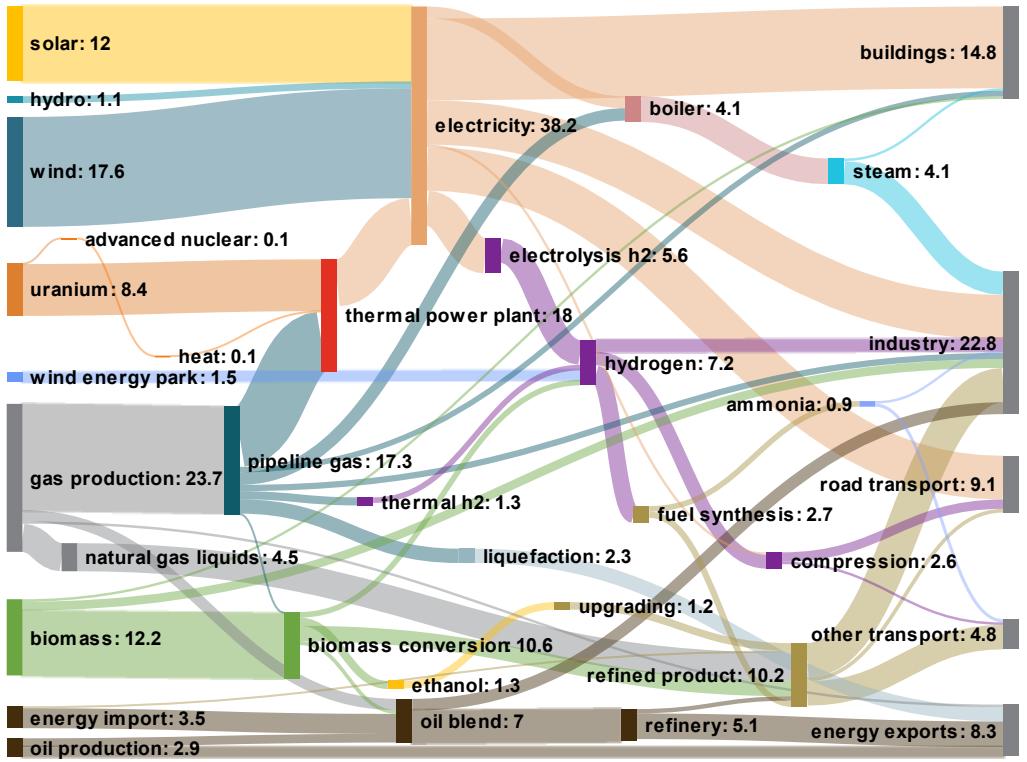
2021



2050 (Net Zero)



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Annual Decarbonization Perspective 2023

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Sector coupling under clean electricity and zero carbon economy policies

Three scenarios illustrating sector coupling

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Varying levels of sector coupling

	Clean Electricity	High Electrification	Zero Carbon Economy
Electricity CO_2 target	100% clean by 2050		
Electricity demand	Reference (0.7% AAGR)	High electrification (1.8% AAGR)	
Economy CO_2 target	N.A.		Net-zero Energy & Industrial CO2
Non-electric fuel demand	N.A.		60% reduction (high electrification)
Hydrogen use in thermal power plants	Disabled		Enabled
Energy service demand	2019 Annual Energy Outlook		
Additional assumptions	Continental U.S., 12 region optimal capacity expansion for fuels & electricity, 2020-2050 timeframe w 10-year model timestep, 2011 weather year, 7% WACC, AEO fuel prices		

Note: Scenarios run for demonstration purposes based on internal EER assumptions

Electricity load: Non-traditional load growth with tightening emissions targets

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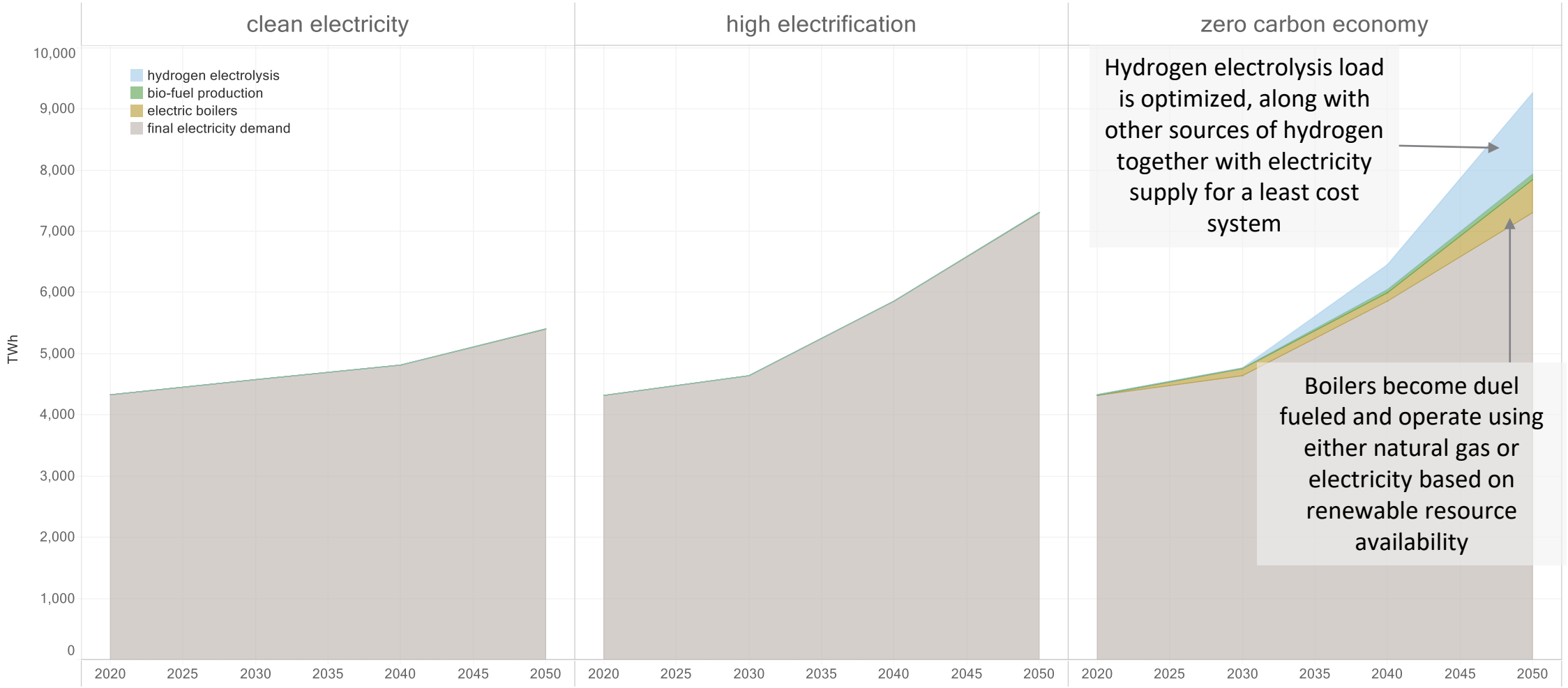
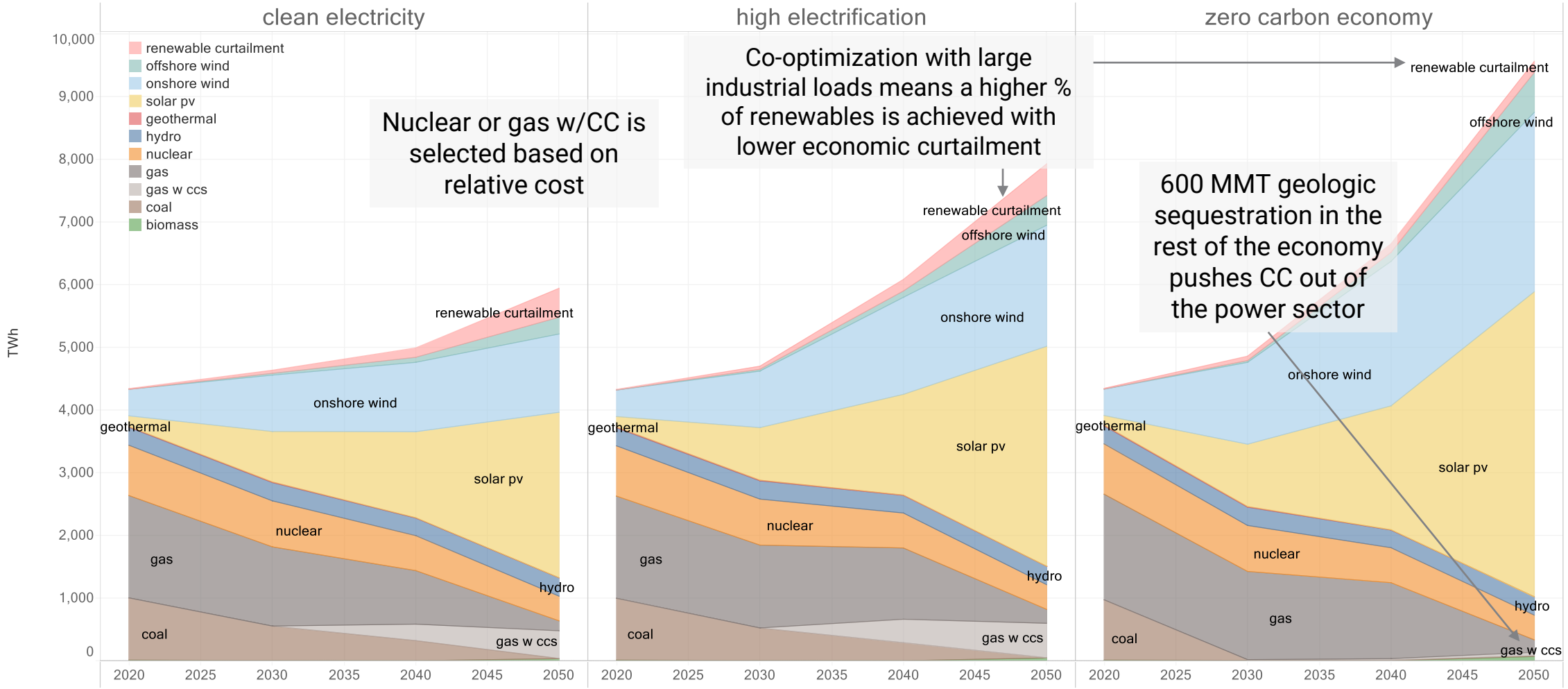


Electricity generation: New industrial loads increase flexibility as supply becomes less flexible



Average 2050 daily supply & demand

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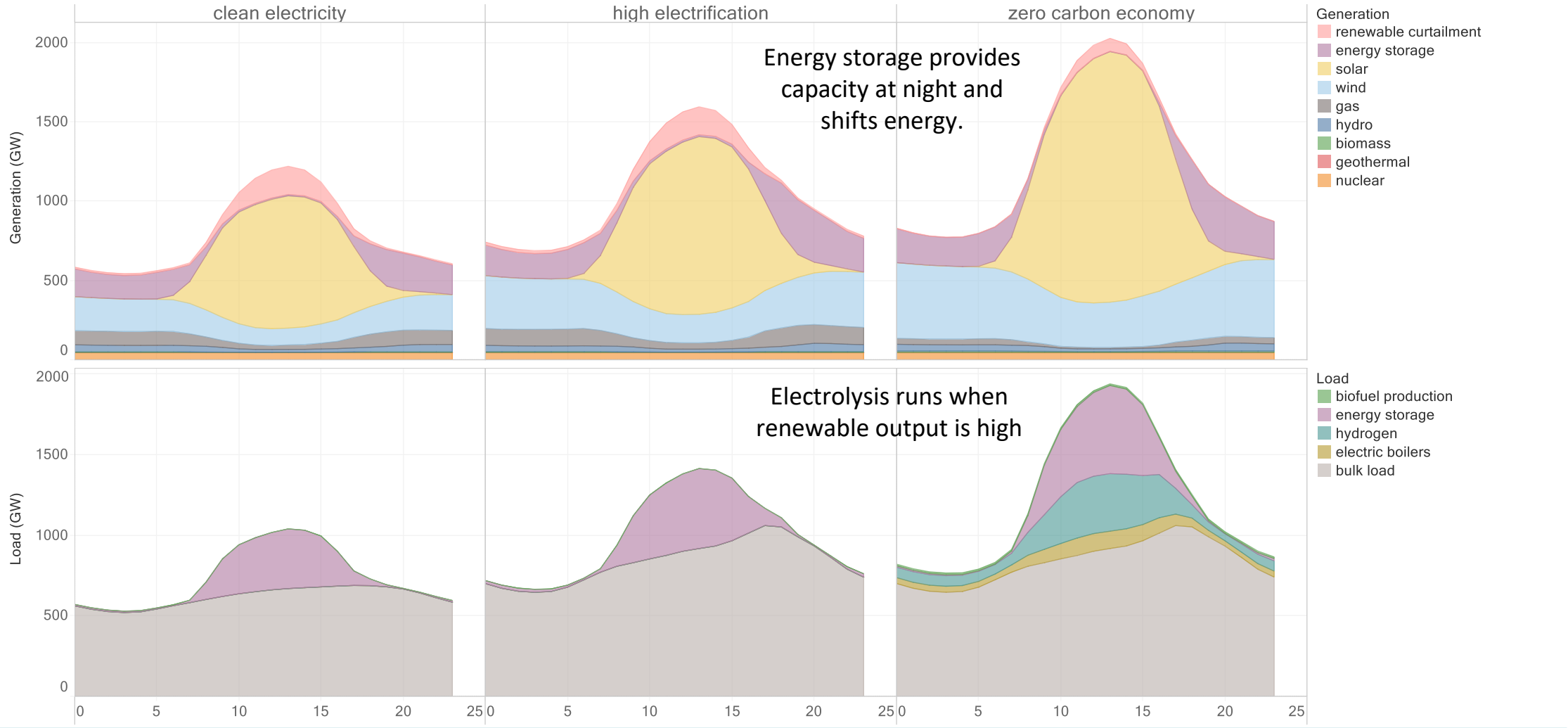
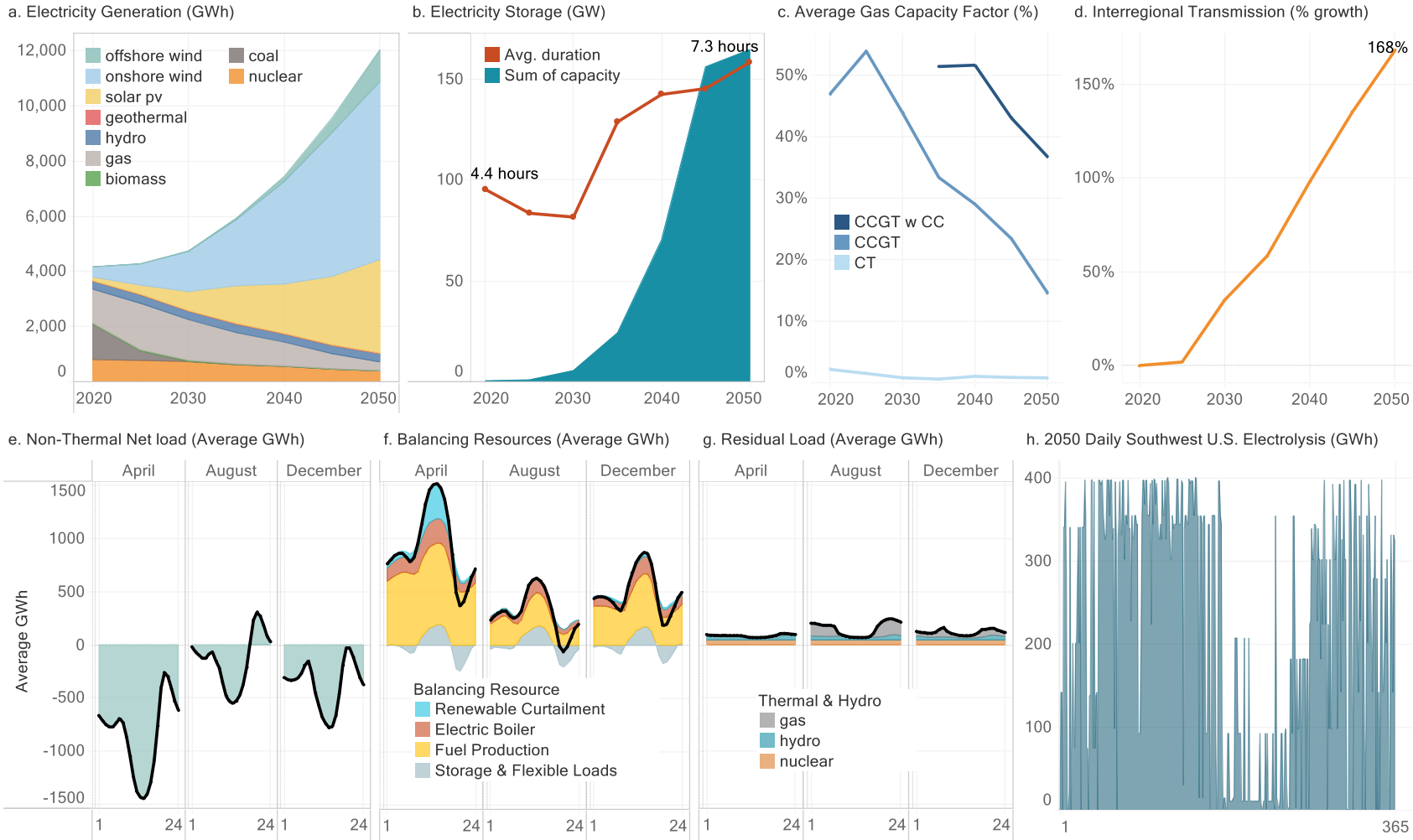


Electricity balancing strategies: Cross-sectoral solutions offer short and long-term balancing



https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2020AV000284

Sectoral coupling helps with multi-day balancing

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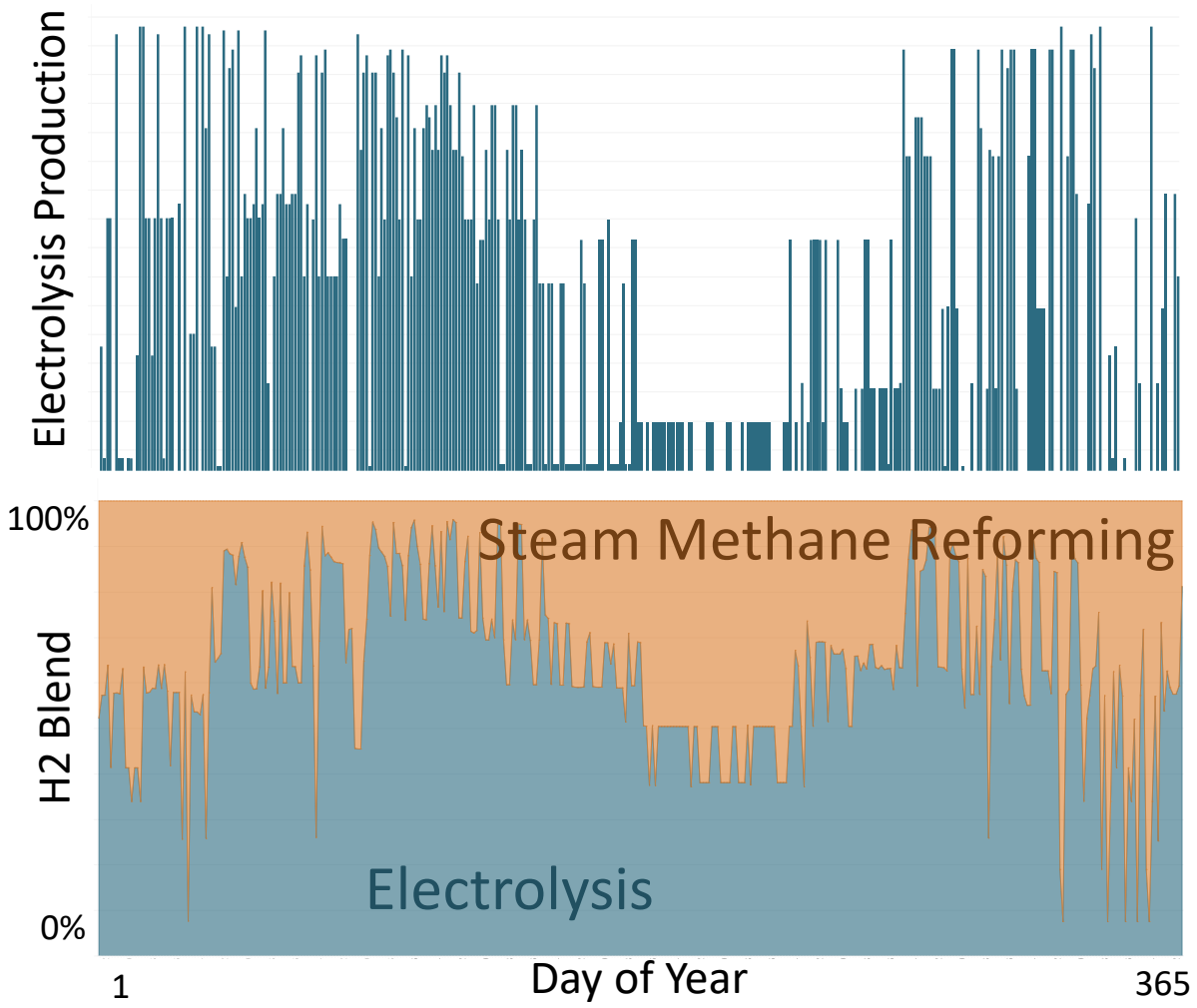
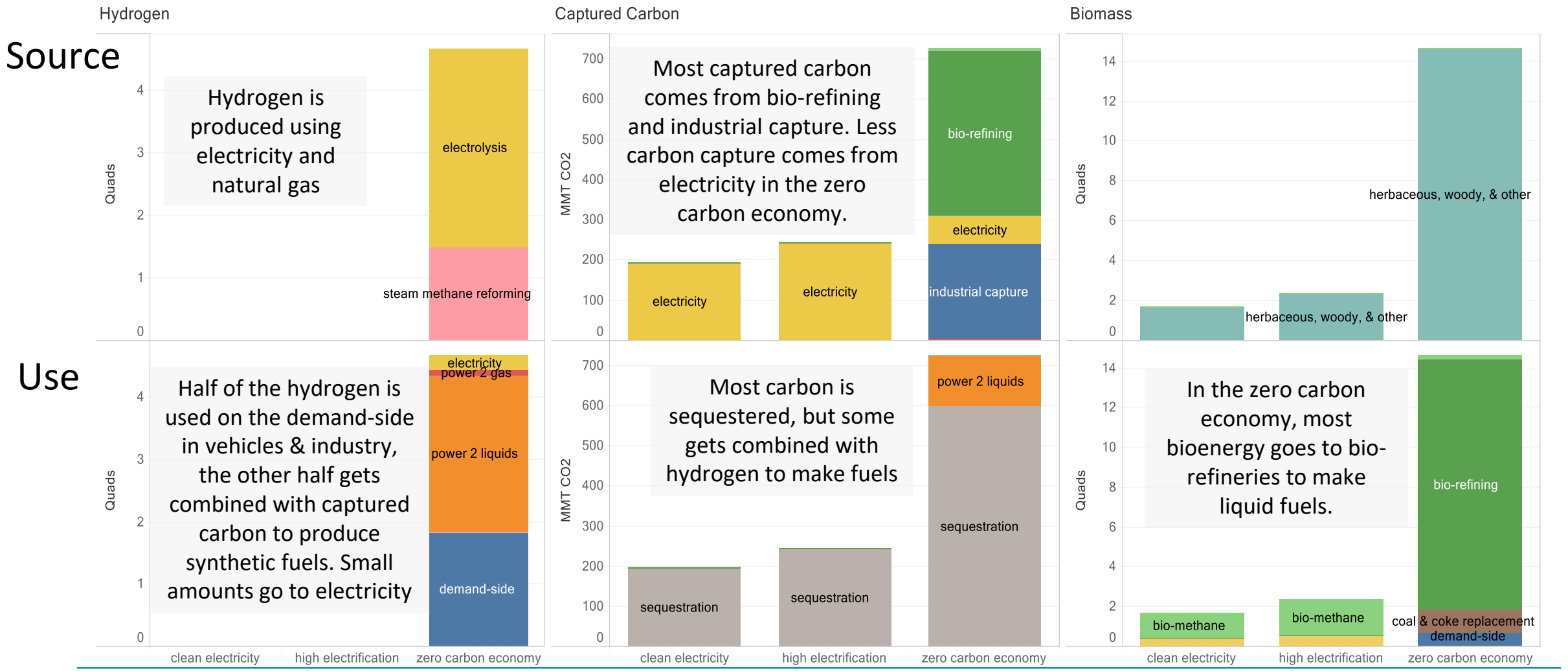
- Wind and solar are two of the lowest cost primary energy supplies that can potentially be deployed at large scale
- Coupling fuels with electricity unlocks large scale and low cost ‘storage’ for the electricity system
- Highest value e-fuel applications do not include electricity generation



Hydrogen, captured carbon, and biomass in 2050



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Sector Coupling: New challenges and opportunities

Sector Coupling: New challenges and opportunities

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- An economy-wide approach is needed to plan for electric load growth and operations when targeting a zero-carbon economy
  - What are the regional implications of fuel and electric sector coupling?
  - Future-proof investments and manage risk by understanding new opportunities and speed of change
- Make decisions in an economy-wide, temporal, and spatial context
  - Explore the tradeoffs between strategies that incorporate load growth, clean fuels, carbon management, electrification opportunities, and new industry
  - Chicken and egg: What comes first, what are the barriers to development, where should near-term efforts be focused?
  - Whack-a-mole: Doing less in one part of the economy requires more in another, understand cost and feasibility consequences of decision making

THANK YOU

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