Pathways Project: Transitioning to Carbon Neutrality in the U.S.

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U.S. Deep Decarbonization Pathways Project

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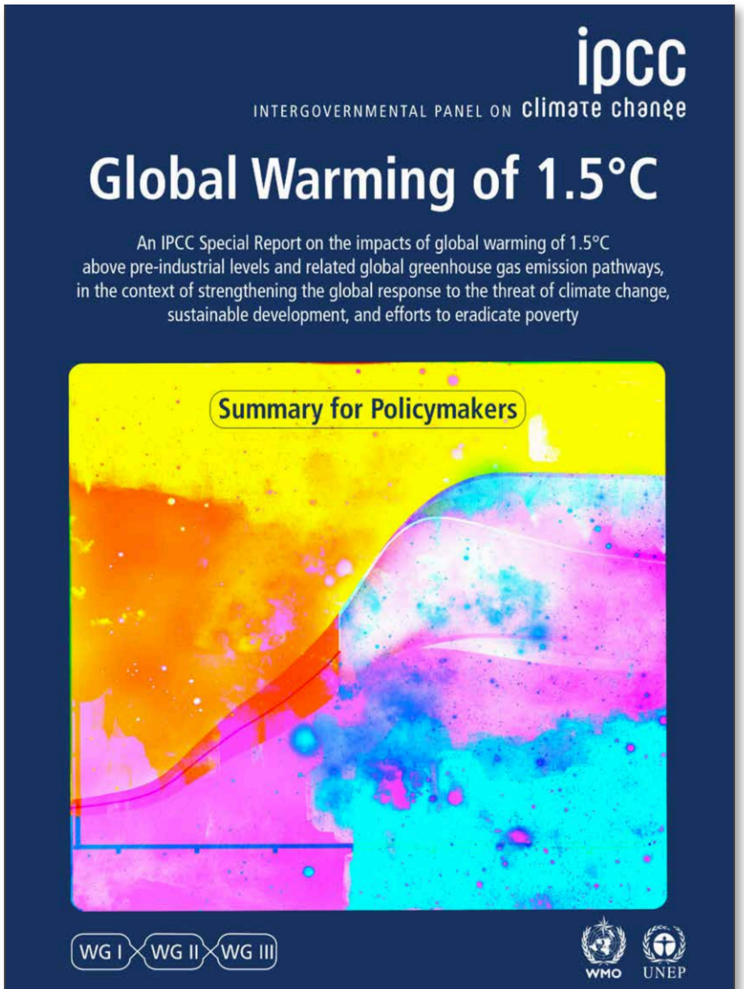
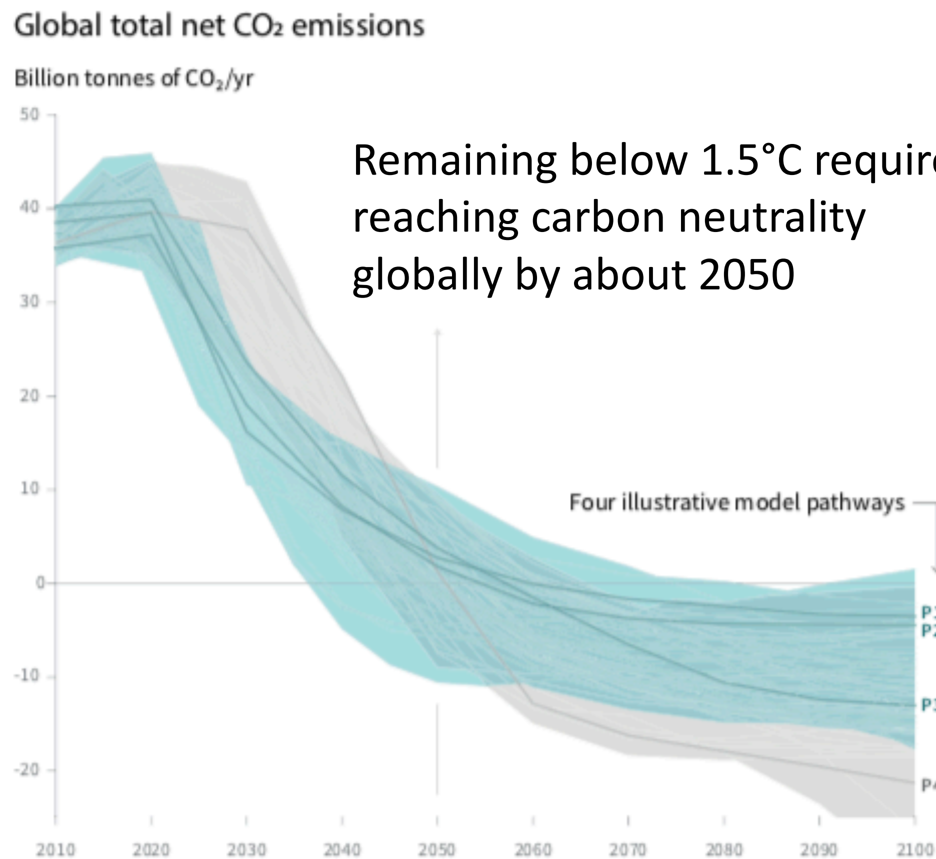
SDSN USA

Carbon neutrality by mid-century





Remaining below 1.5°C requires reaching carbon neutrality globally by about 2050

Questions

To achieve carbon neutrality in the U.S. by 2050:

- ➢ What changes in infrastructure are required?
- ➢ What is the cost of different pathways?
- ➢ What are the key challenges?
- ➢ What policies are needed?

Executive Department

State of California

EXECUTIVE ORDER B-55-18 TO ACHIEVE CARBON NEUTRALITY

Pathways Project

- White paper on pathways to carbon neutrality in the United States by mid-century
- Analysis and policy recommendations that add depth and realism to Green New Deal concept
- Chapters on infrastructure, federal policy, regional transitions, jobs, land use
- Aimed at federal and state policy audiences
- Internal SDSN draft in February, public release in March

Five Transitions

Pathways project examines five transitions entailed in reaching carbon neutrality:

- ➢ Infrastructure
- ➢ Economy
- ➢ Land use
- ➢ Jobs/communities
- ➢ Policy processes

Infrastructure Transition

- 4 pillars: (1) energy efficiency (2) electrification (3) electricity decarbonization (4) carbon capture
- Achieved by rapid, large-scale buildout of efficient, low carbon infrastructure to replace existing
- The least-cost carbon-neutral energy system is organized around renewable electricity
- Tradeoffs among technology choices, land use, jobs, social priorities more important than cost per se
- Physical actions required over next 10 years are well-understood and consistent across pathways

Economic Transition

- Carbon neutrality in energy and industry by 2050 is achievable at a net cost of 0.2 % of GDP
- Energy spending as % of GDP on low end of historical range, investment requirements not large for U.S.
- Changes in gross economic flows are large, ~$1T per year less on fossil fuels, more on infrastructure
- There are winners and losers among businesses, workers, and communities
- The most challenging part of the economic transition is political economy, not cost or finance

Jobs/Communities Transition

- Decarbonization will support jobs over multiple decades and across many sectors and regions.
- Phasing out fossil fuels will result in job losses in many industries, occupations, and regions
- Rural communities dependent on extraction will be most affected
- Planning, policies, and institutional support for a labor transition that explicitly accounts for social equity are required for rapid decarbonization

Land Use Transition

- ➢ Reaching carbon neutrality needs land in three ways: siting, biomass, and carbon sink
- ➢ Land requirements for wind, solar, and transmission siting are large → can be bottleneck if handled poorly
- ➢ Regional coordination enables low-cost, low-impact renewable energy development (vs. state-as-island)
- ➢ Regional energy solutions require early, proactive land use planning, esp. transmission
- ➢ Integrated land-energy-climate planning can identify development opportunities that avoid land use conflicts

Policy-Process Transition

- Carbon neutral pathways indicate need for policy processes that do not currently exist
- Planning and coordination across decades, sectors, geographies, and jurisdictional levels
- Short-term actions in a given arena informed by long-term system view, and vice-versa
- Stakeholder engagement increased, informed by realistic, rigorous, ongoing analysis

INFRASTRUCTURE AND ECONOMY TRANSITION

Research Focus

Energy and industrial (E&I) CO_2

- from fossil fuels used for energy and feedstocks
- more than 80% of current US GHG emissions
- not including land C sink, non-CO_2 GHGs

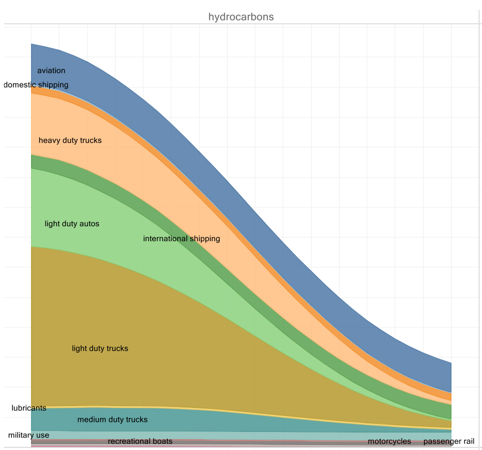
How would a carbon neutral system work?

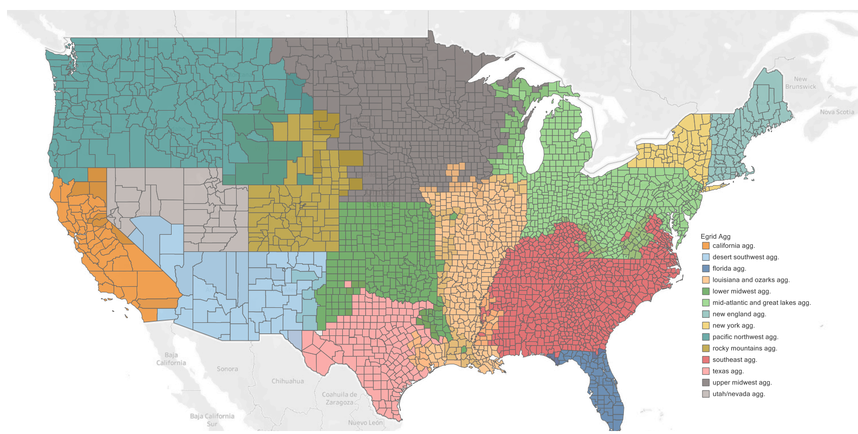
- reliability in high renewables electricity system
- production of low carbon fuels
- decarbonizing industry, freight transport, aviation
- integrating CCUS with energy system

Tools

Energy system model and scenario analysis tool

Optimal capacity expansion model for electricity and fuels





Scenarios

Reference case based on *Annual Energy Outlook*

- DOE's BAU projection of population, GDP, energy service demand used in all scenarios

Central case

- least-cost pathway to carbon neutrality

Cost sensitivities

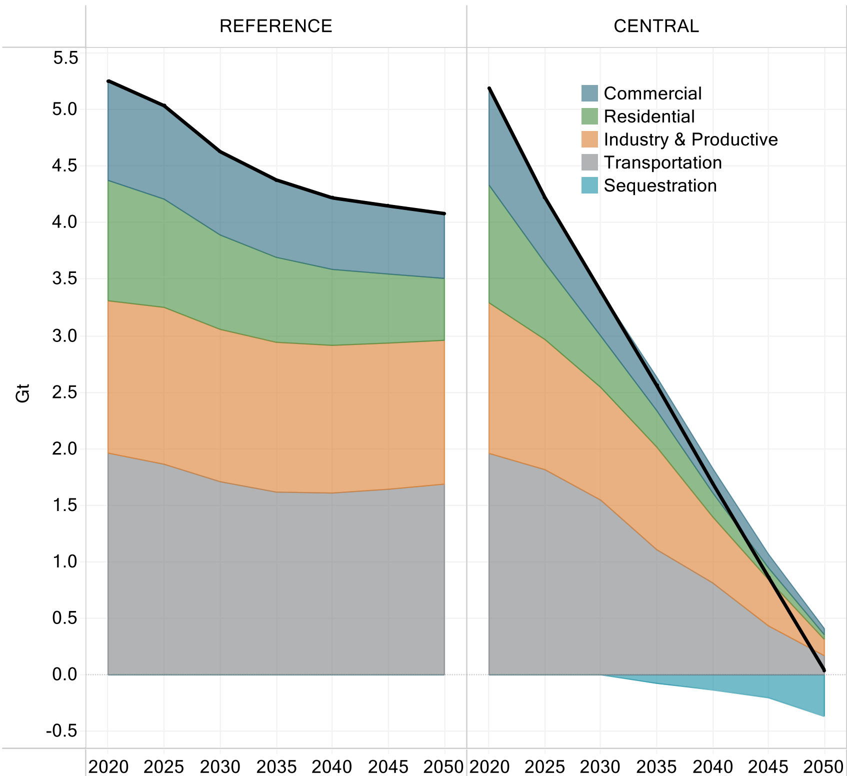
- high/low fossil fuel prices, technology costs

Constrained cases

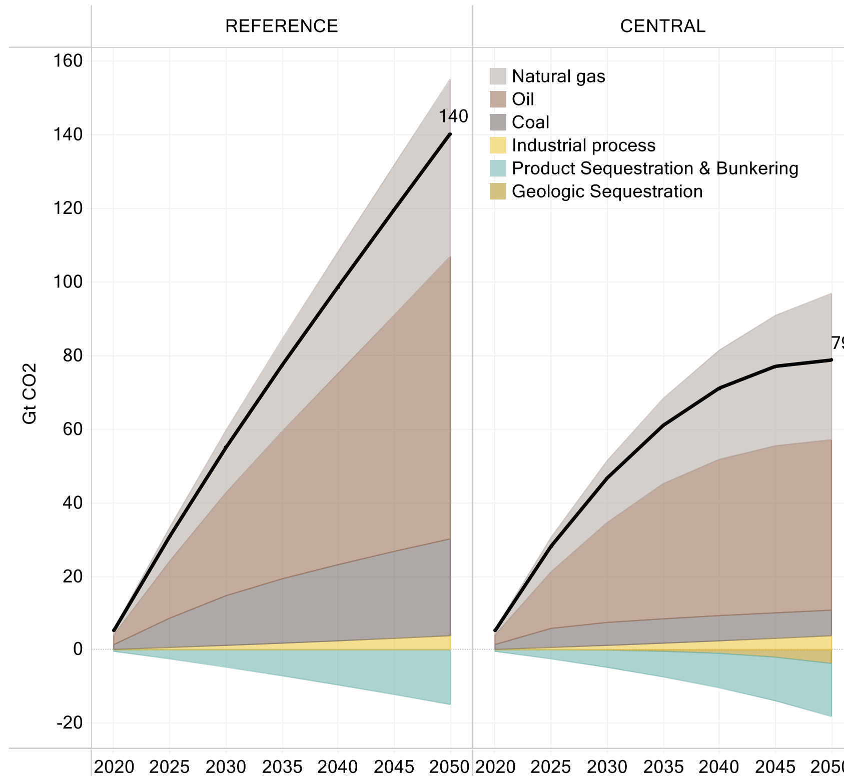
- limits on land, biomass, consumer adoption rates
- 100% renewable primary energy, high conservation
- net negative emissions (-500 Mt CO2 in 2050)

Emissions Trajectory

Annual CO_2



Cumulative CO_2 2020-2050



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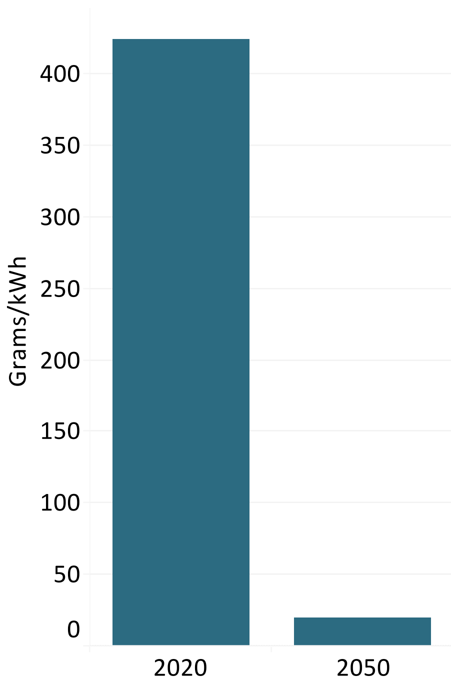
Four Pillars of Net Zero System

U.S. Benchmarks

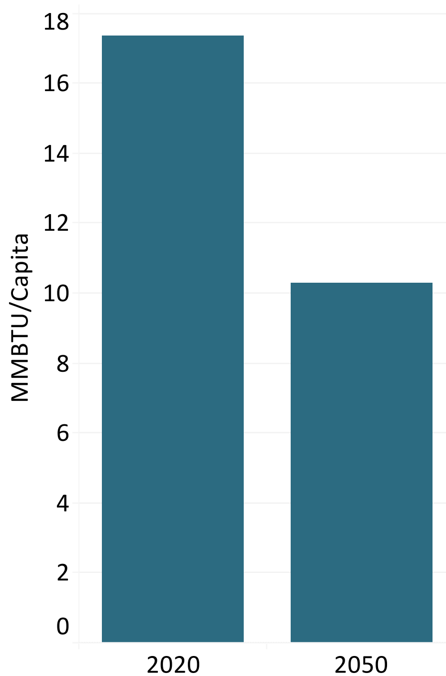
Electricity Decarbonization

95% reduction in emissions intensity

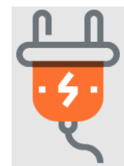


Energy Efficiency

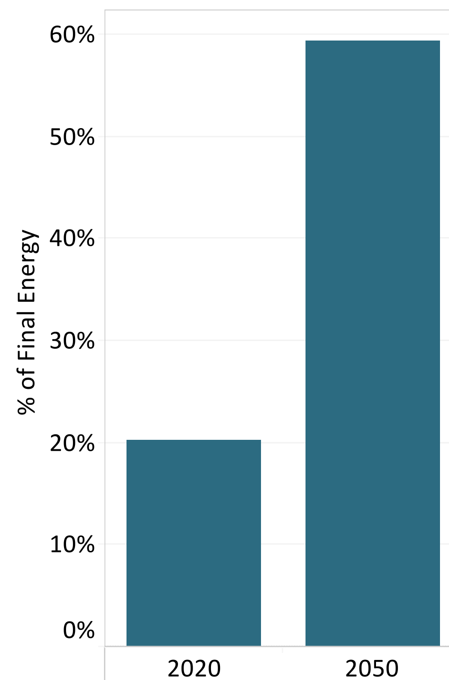
40% reduction in per-capita final energy demand



Electrification

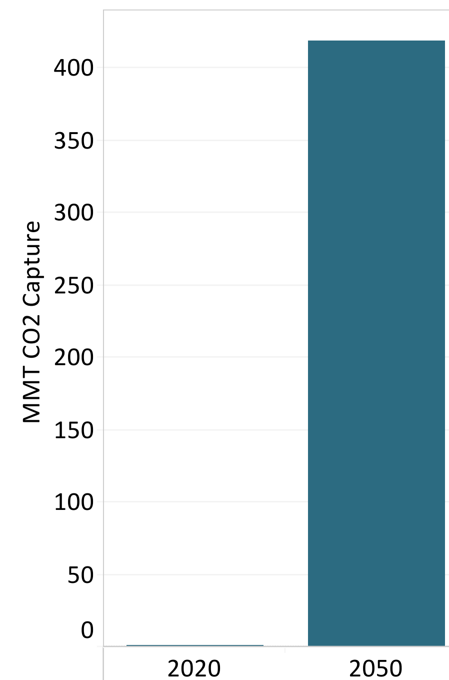


300% increase in share of energy from electricity



Carbon Capture

400 MMT+ carbon capture and use/storage



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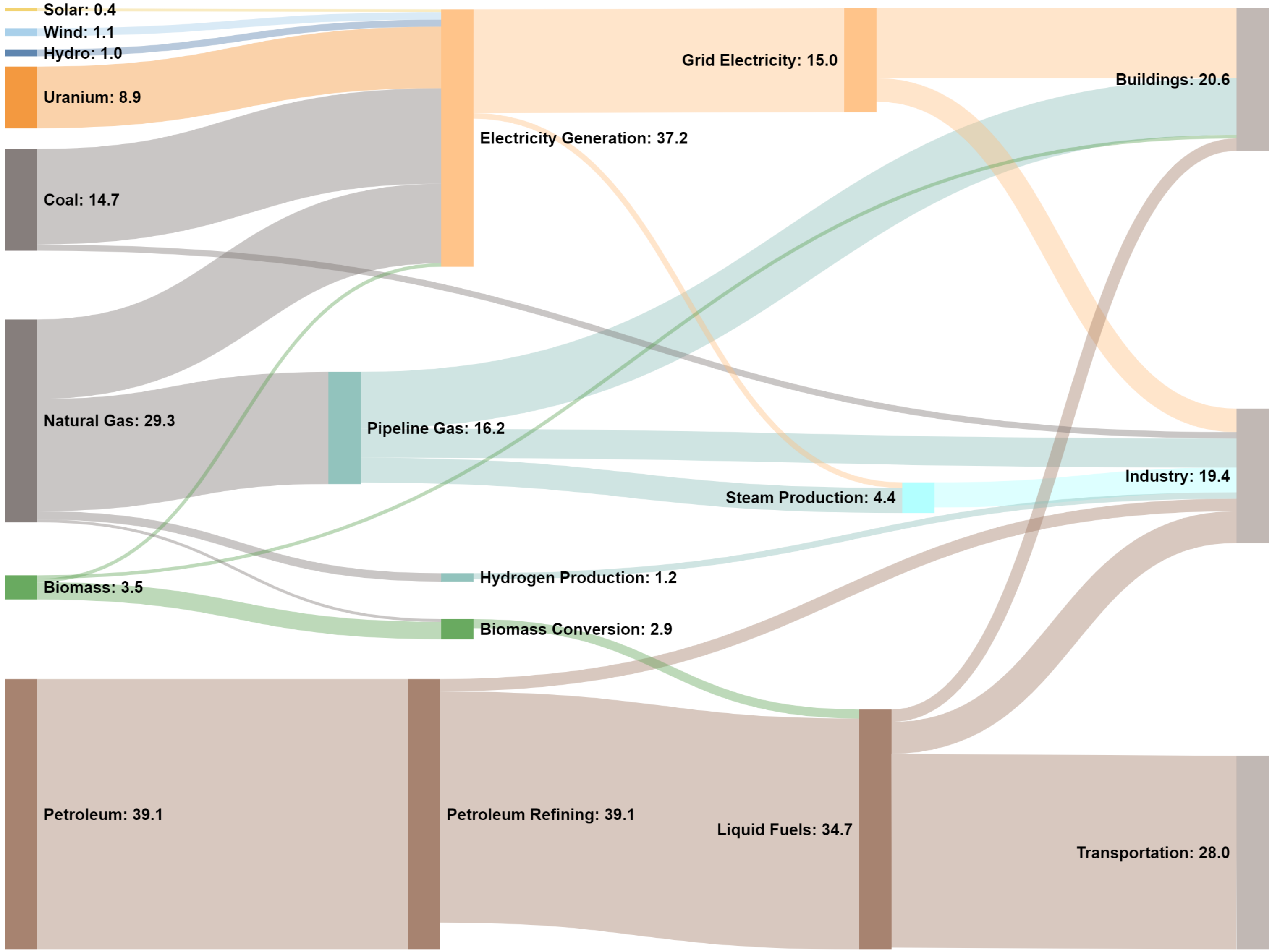
Current Energy System



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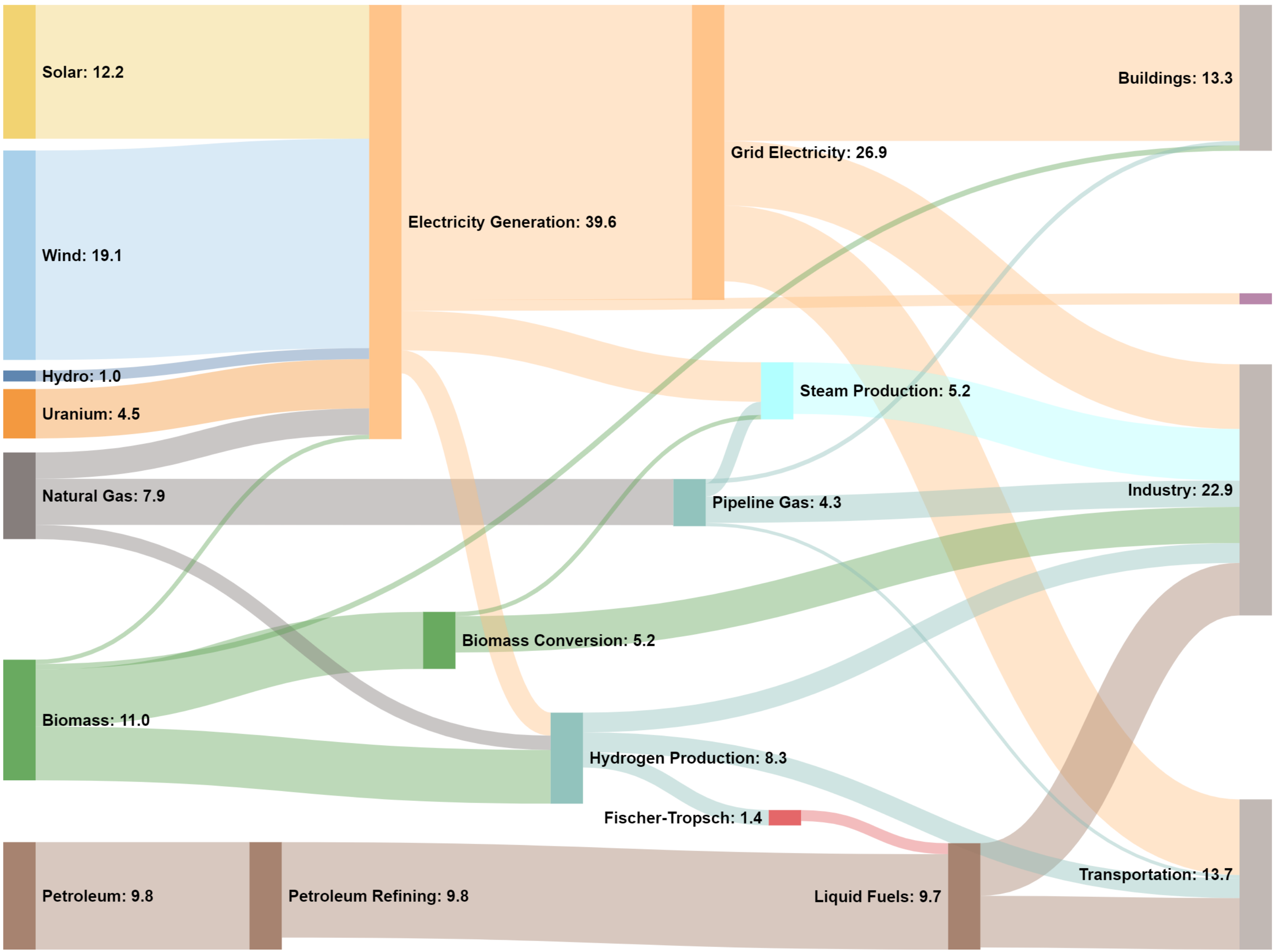
Central Case, Low Fossil Fuel Price (2050)



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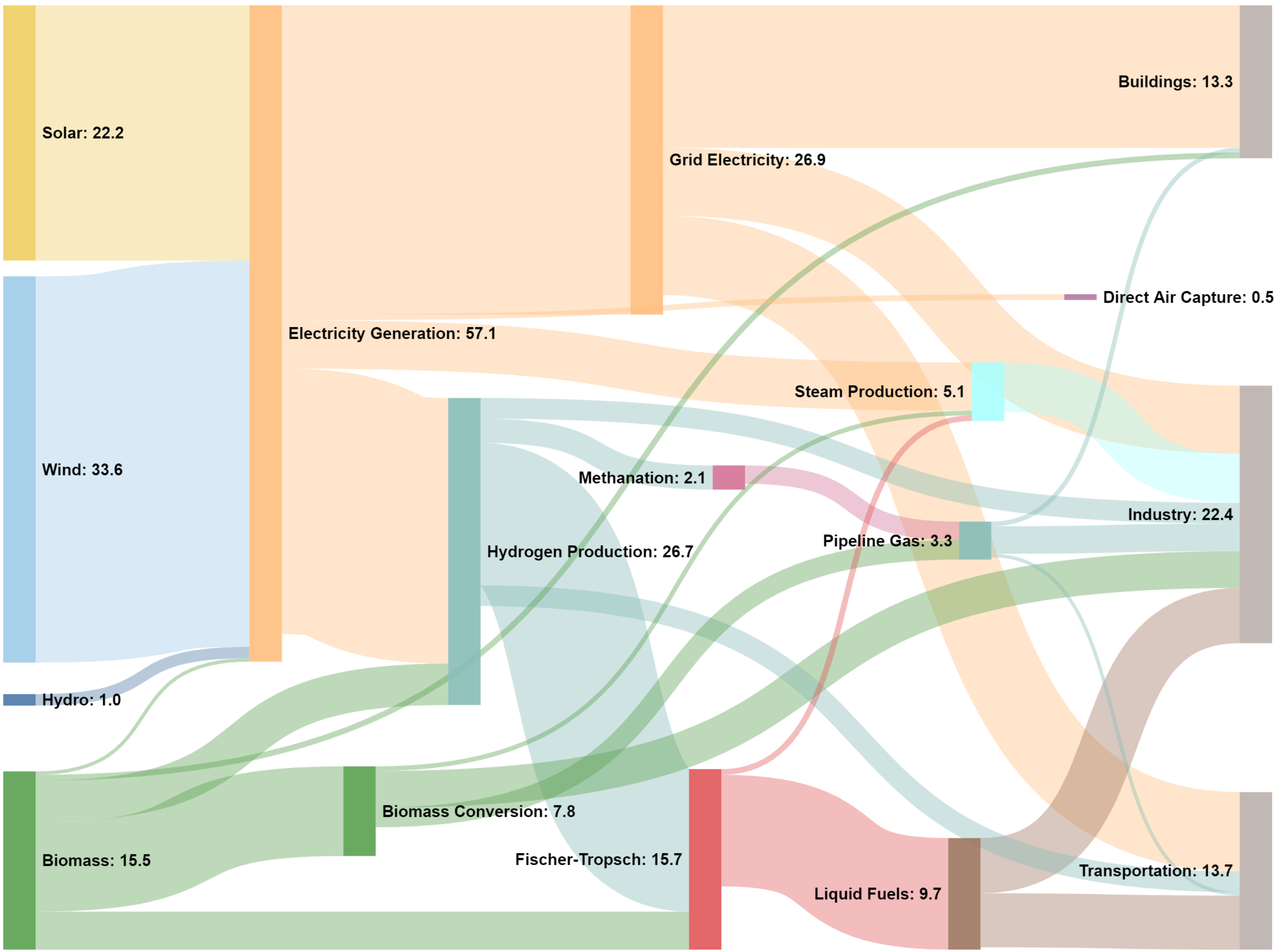
100% Renewable Primary Energy (2050)



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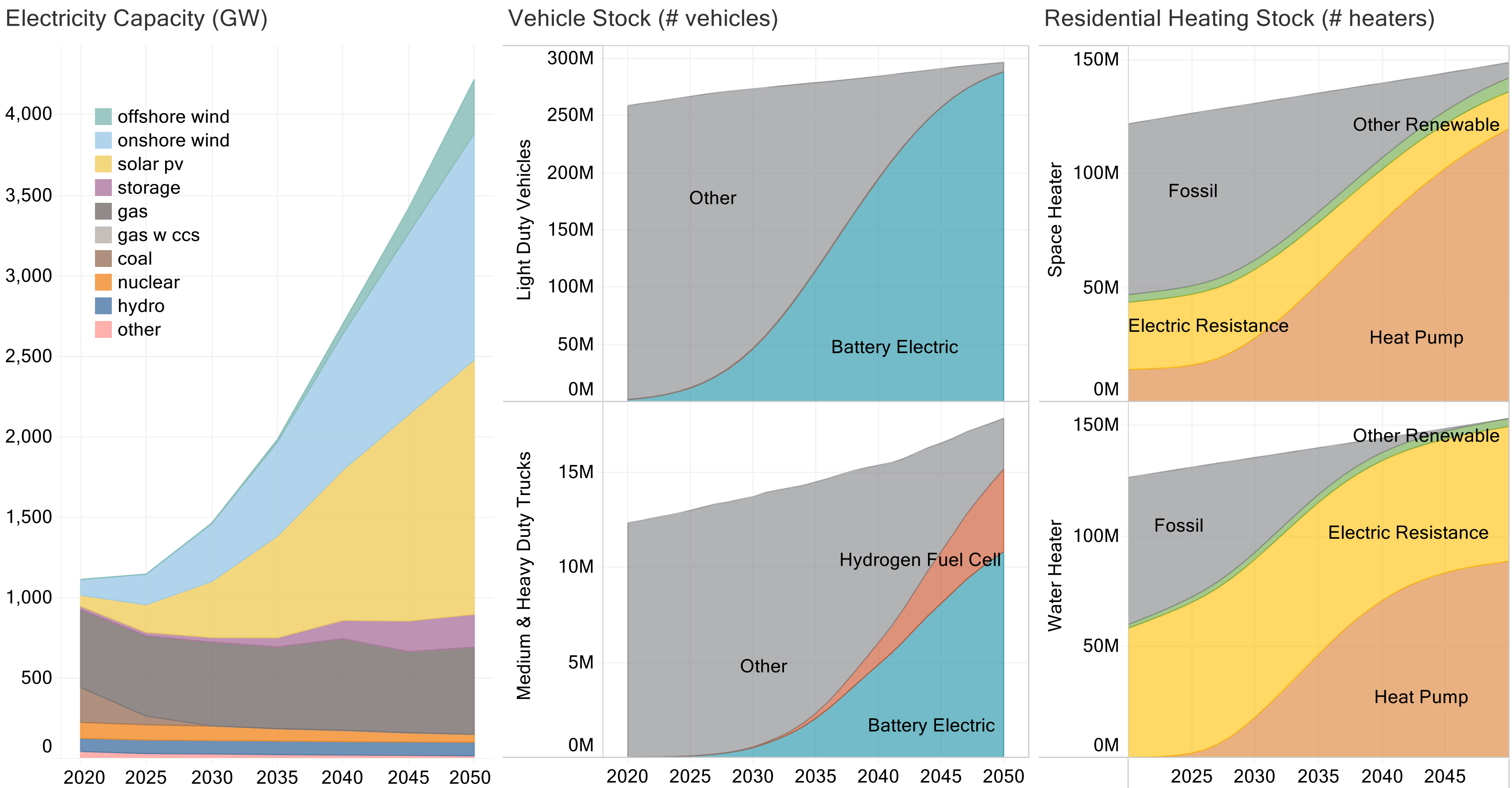
Infrastructure Transition



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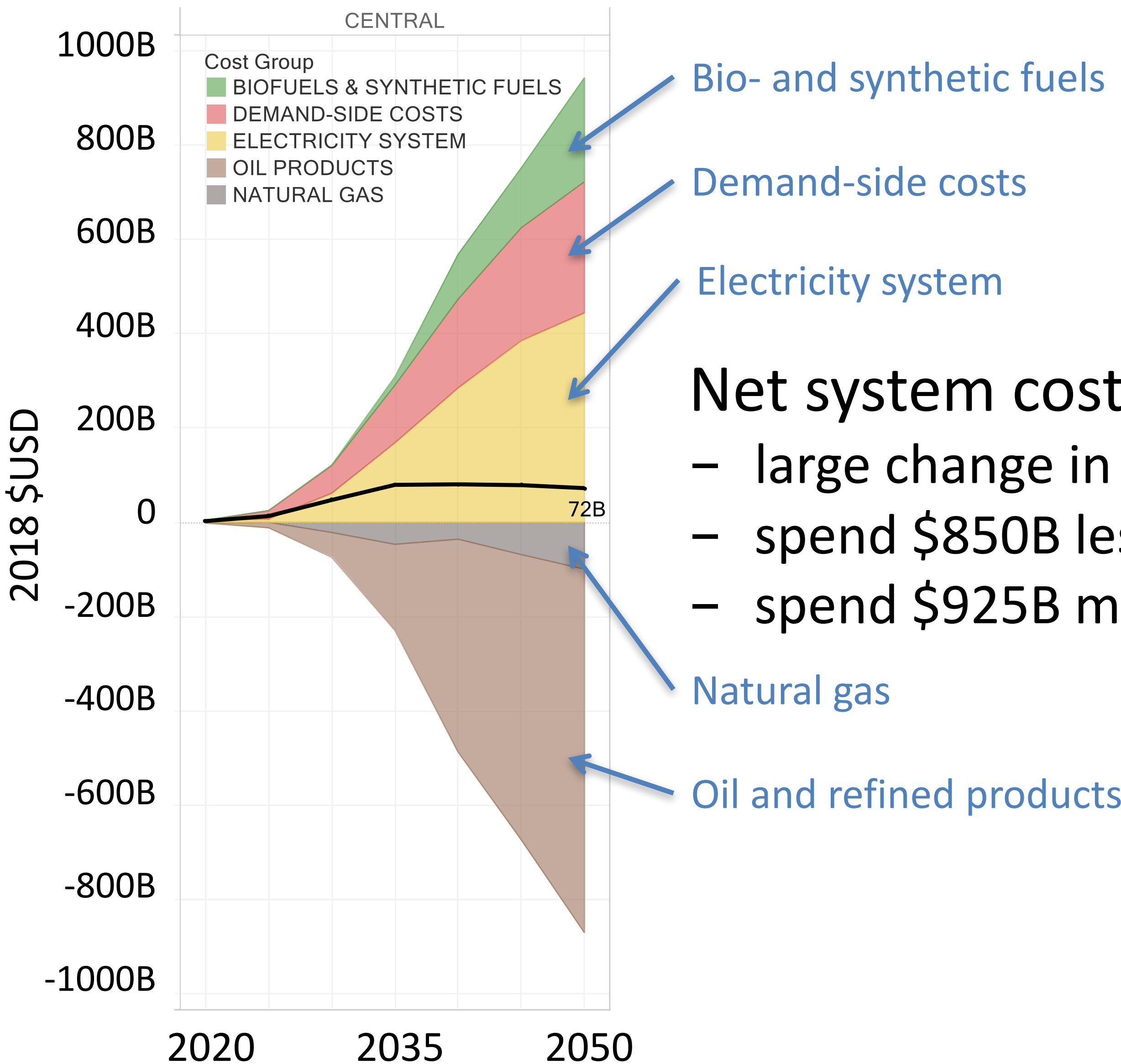
Net Cost (Central Case)



Net system cost = 0.2% of GDP

- large change in gross costs
- spend $850B less on fossil fuels
- spend $925B more on technology

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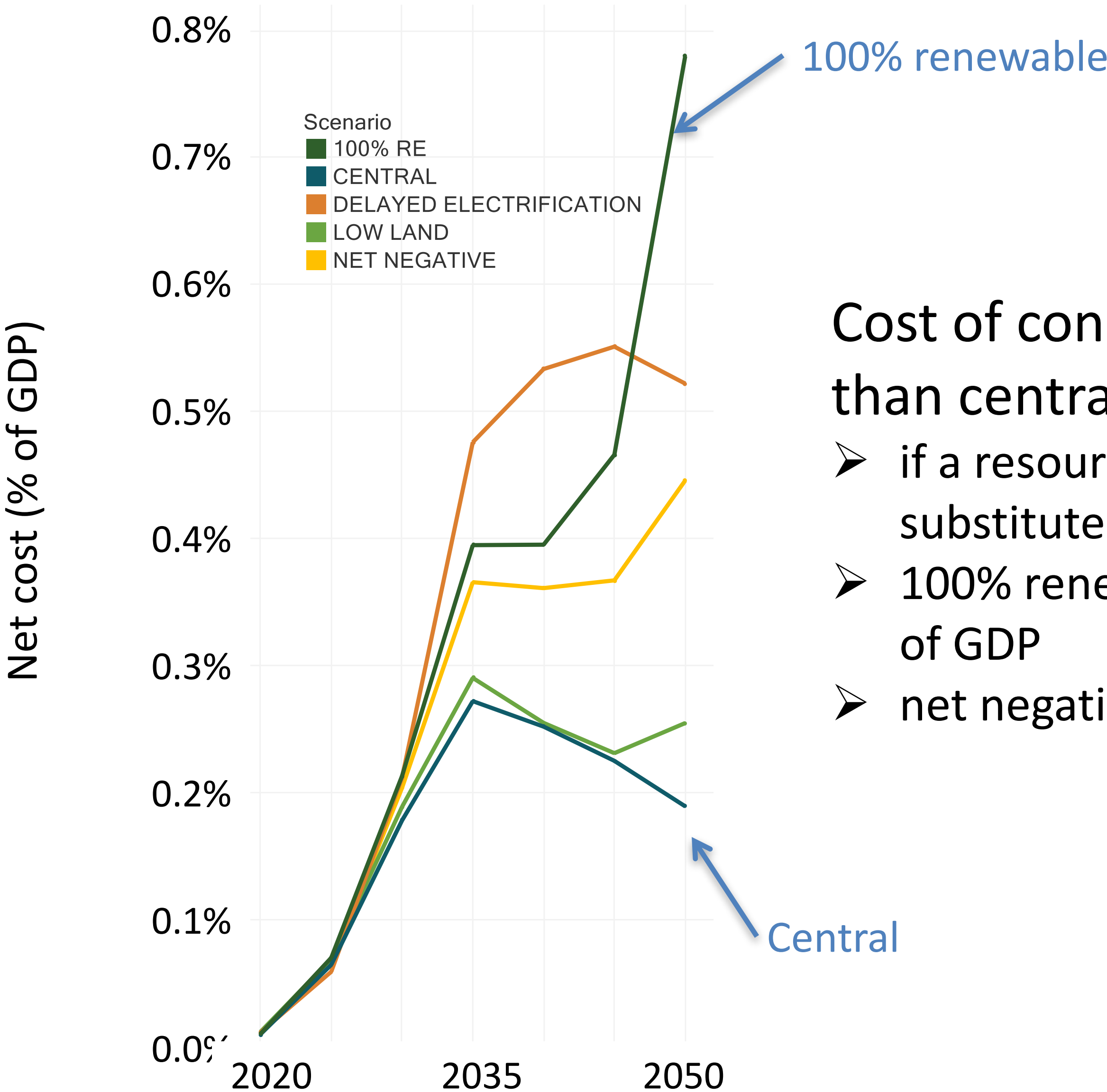
Net Cost Across Scenarios



Cost of constrained cases is higher than central case

- if a resource is limited, higher cost substitutes are required
- 100% renewable primary energy = ~0.8% of GDP
- net negative case <0.5% GDP

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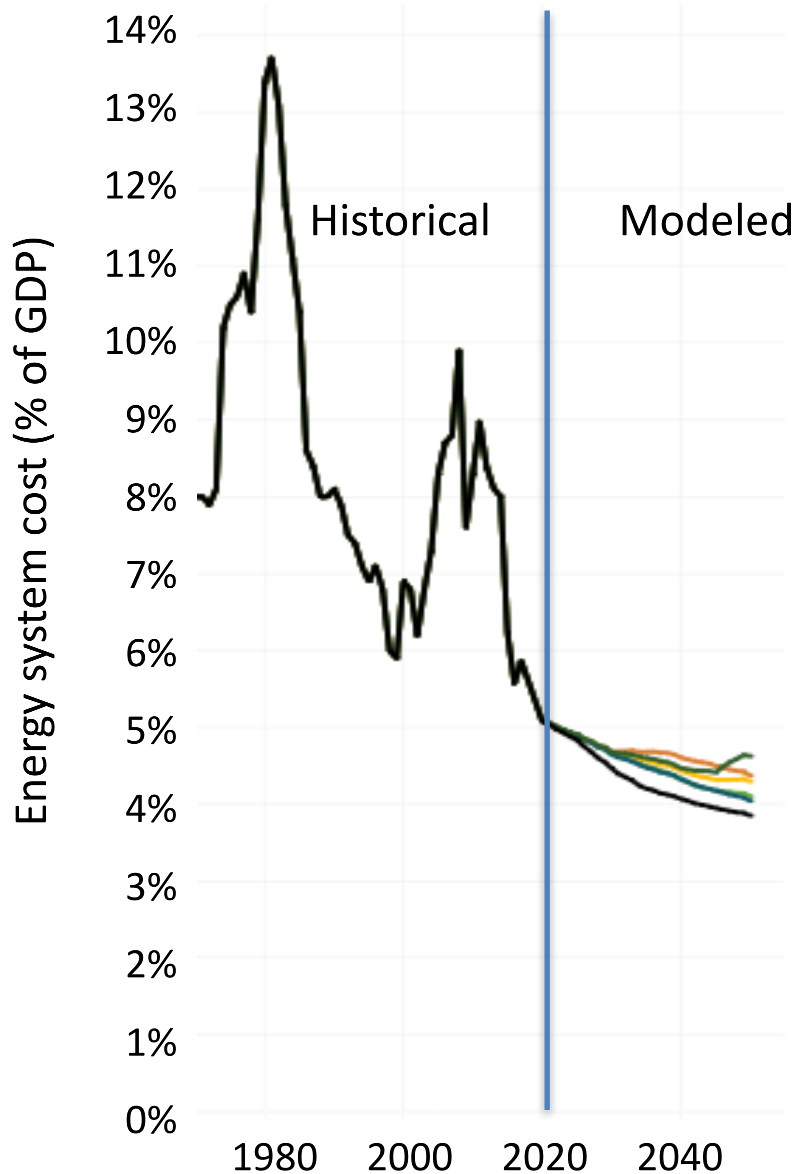
Historical Energy Spending as % GDP



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Pathway Choices and Societal Tradeoffs

- limited land and biomass → more natural gas and carbon sequestration, the only case where nuclear expansion is economic
- delayed electrification → greater use of electric fuels, biofuels, and land
- 100% primary RE → highest demand for electric fuels, biofuels, and land
- high conservation case → less infrastructure and land, requires major behavior change

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Required Actions in this Decade

Rapid ramp up to reach 2030 benchmarks

- Solar and wind capacity: 3.5x current
- Coal generation: <1% of total generation
- Electric light duty vehicles: >50% of sales
- Electric medium duty vehicles: >40% of sales
- Electric heavy duty vehicles: >30% of sales
- Heat pumps in buildings: >60% of sales
- Storage: >20 GW batteries
- No new oil and gas transport facilities
- Maintain existing nuclear fleet to extent feasible
- Maintain gas generating capacity at current level

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Thank you!

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Total CO_2e in 2050 Depends on Land Sink, Non-CO_2 GHG Mitigation

Scenario	E&I CO_2 (Mt)	High CO_2e (Mt)	Low CO_2e (Mt)
Central	0	500	0
Limited land	0	500	0
Delayed electrification	0	500	0
Low demand	0	500	0
100% RE	-350	150	-350
Net negative	-500	0	-500

Land sink range: -750 Mt (current) to -1125 Mt (50% improvement)

Non-CO_2 GHGs: 1250 Mt (current) to 1125 Mt (10% improvement)

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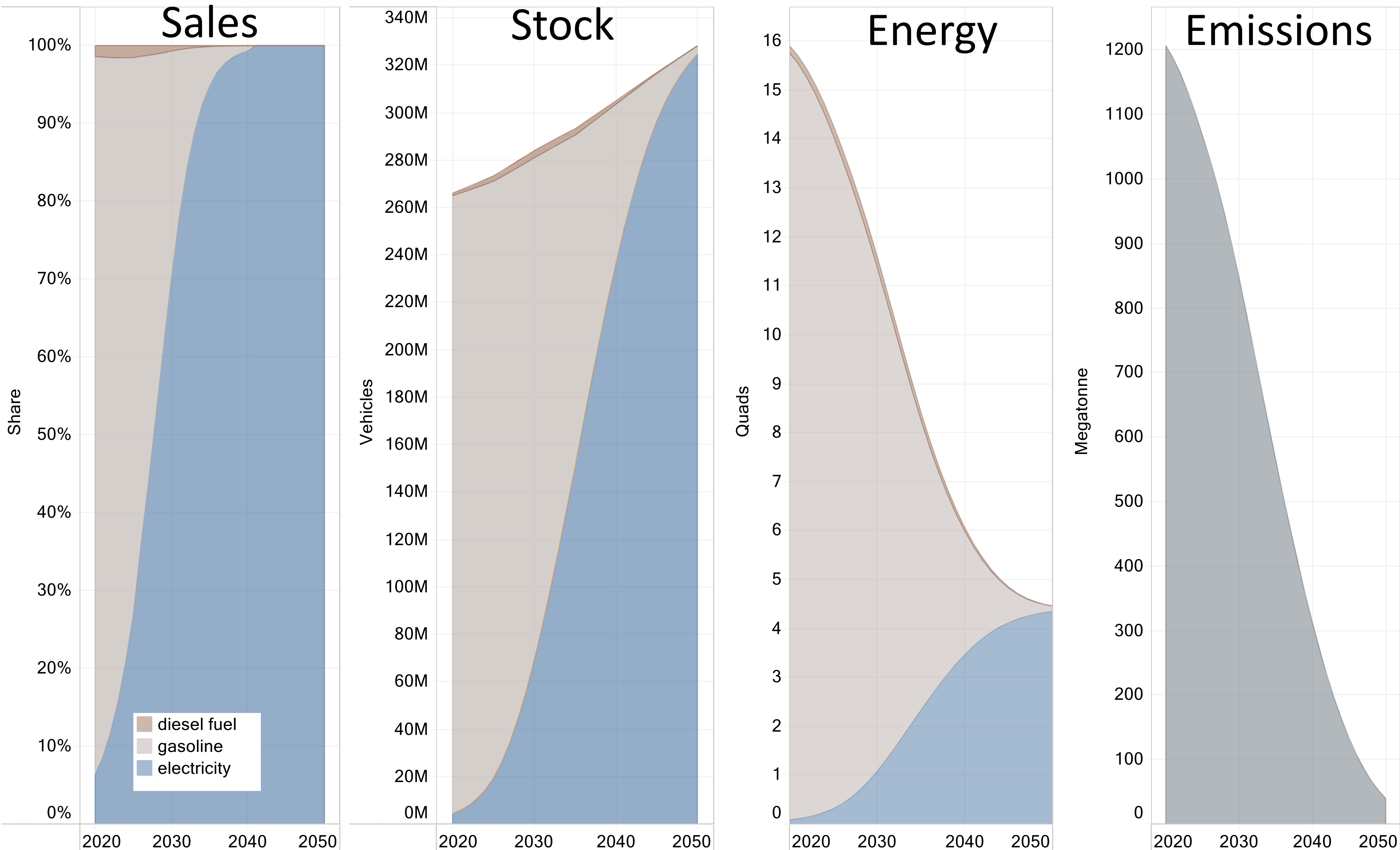
Infrastructure Transition and Emissions

Light duty vehicle example



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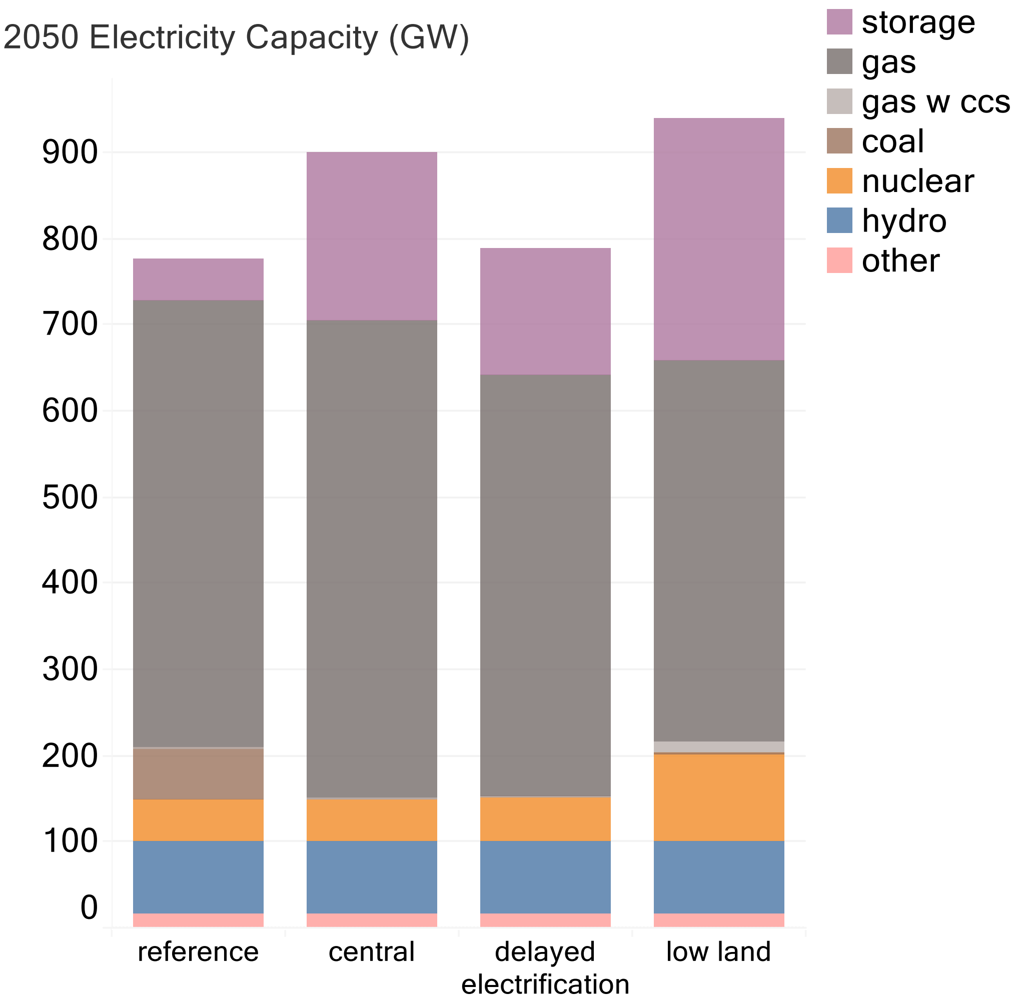
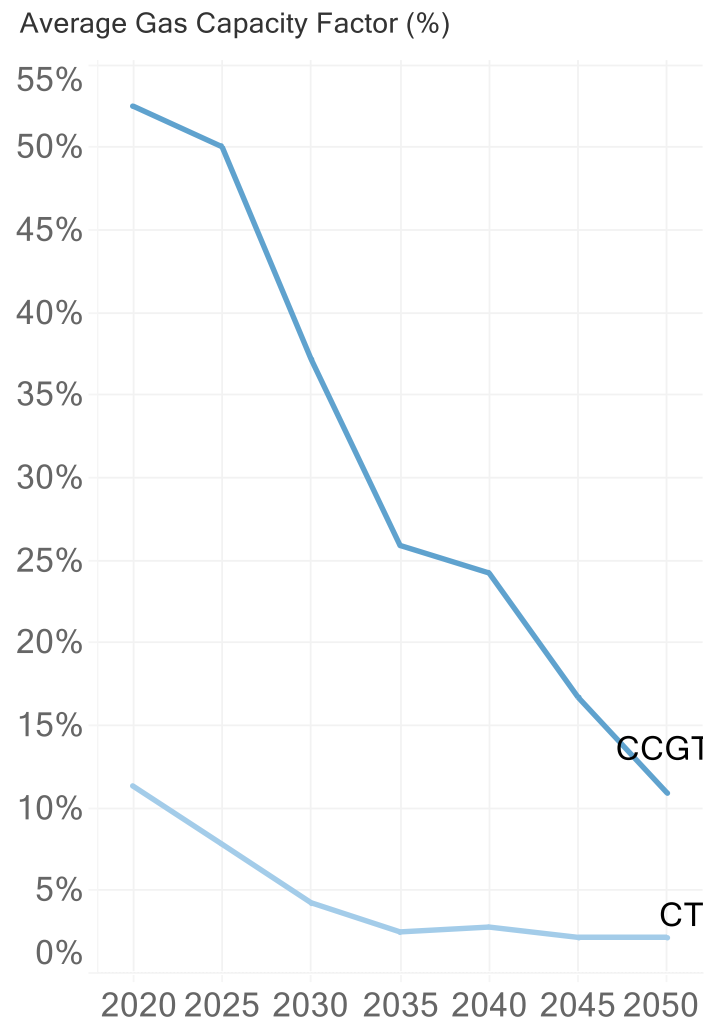
Electricity Balancing: Thermal Generation for Reliable Capacity





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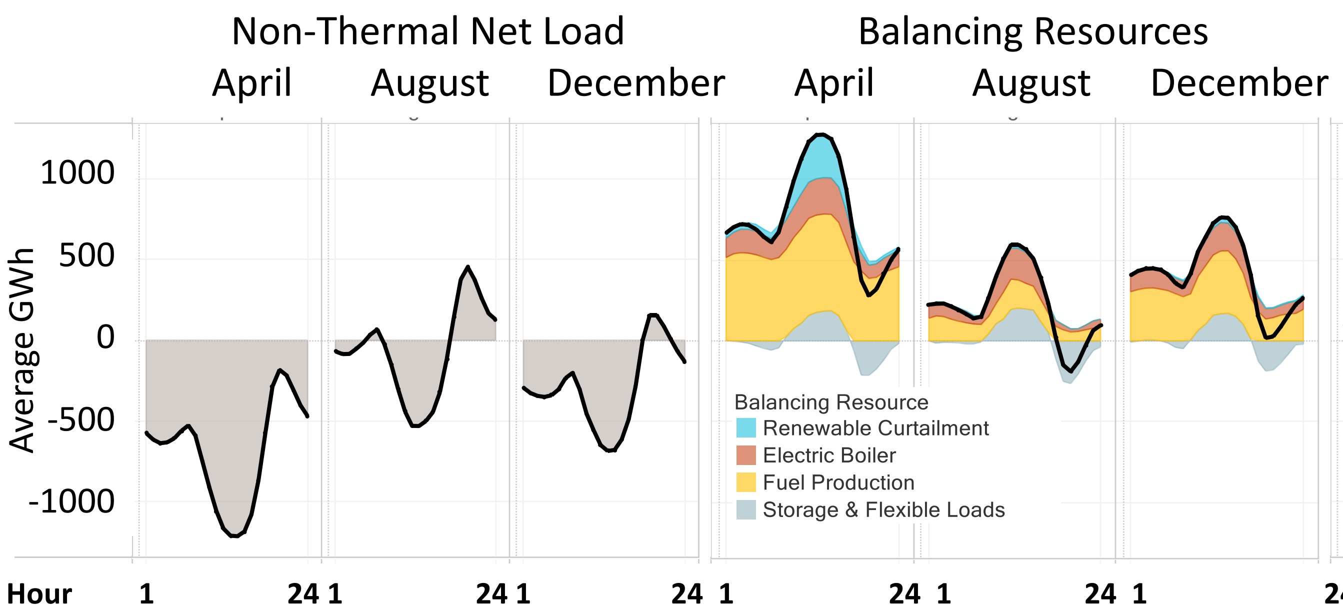
Electricity Balancing: Transmission, Energy Storage, Flexible Loads



Other balancing resources

- renewable curtailment
- 80% increase in inter-regional transmission capacity
- 200 GW of batteries for diurnal balancing
- large industrial flexible loads, e.g. electric fuel production, dual fuel boilers

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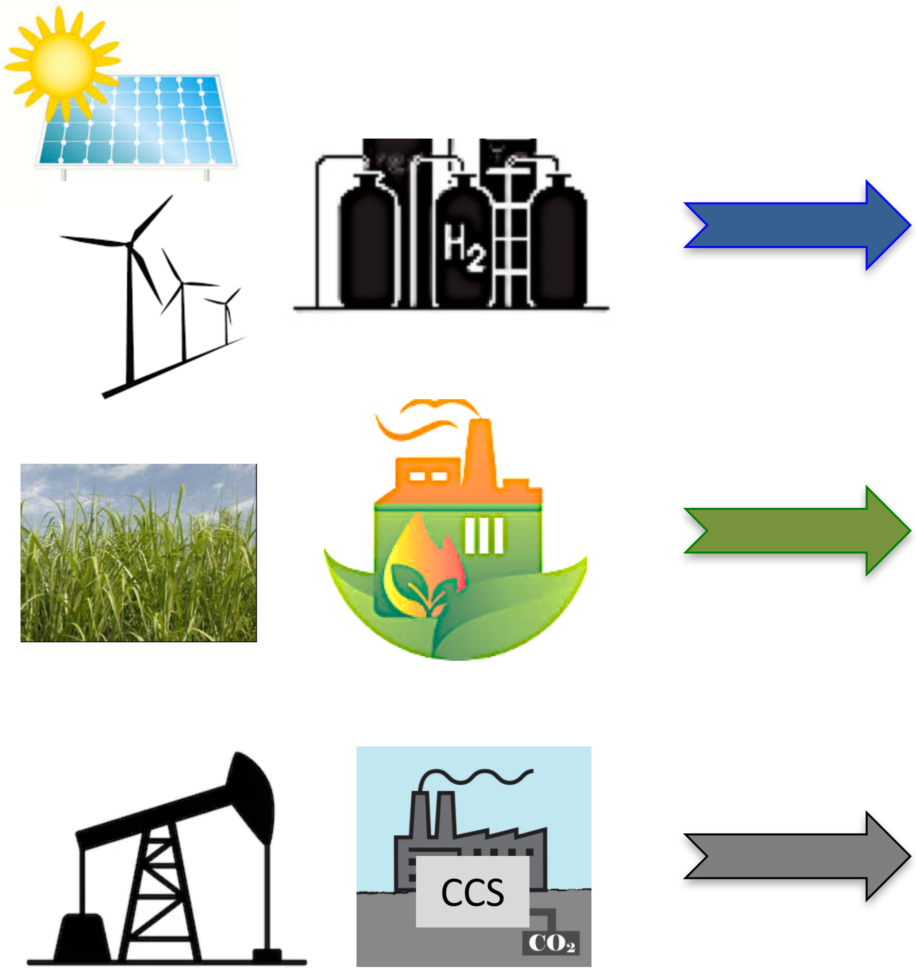
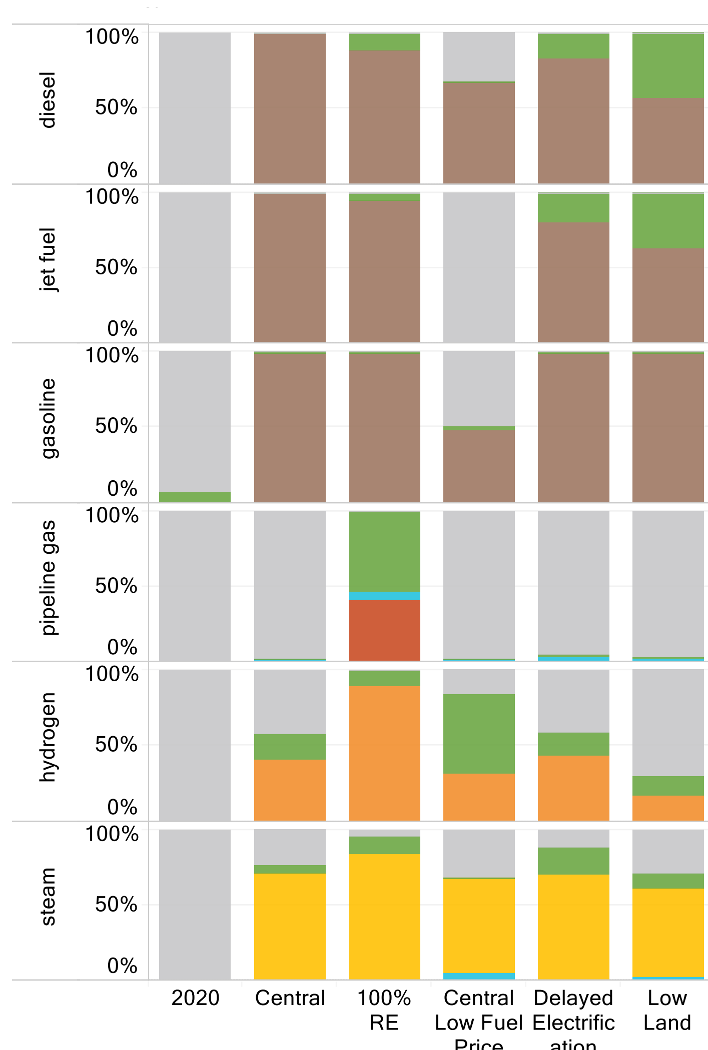
Fuels

About 60% of final energy can be electrified. The remaining 40% must be met with fuels.





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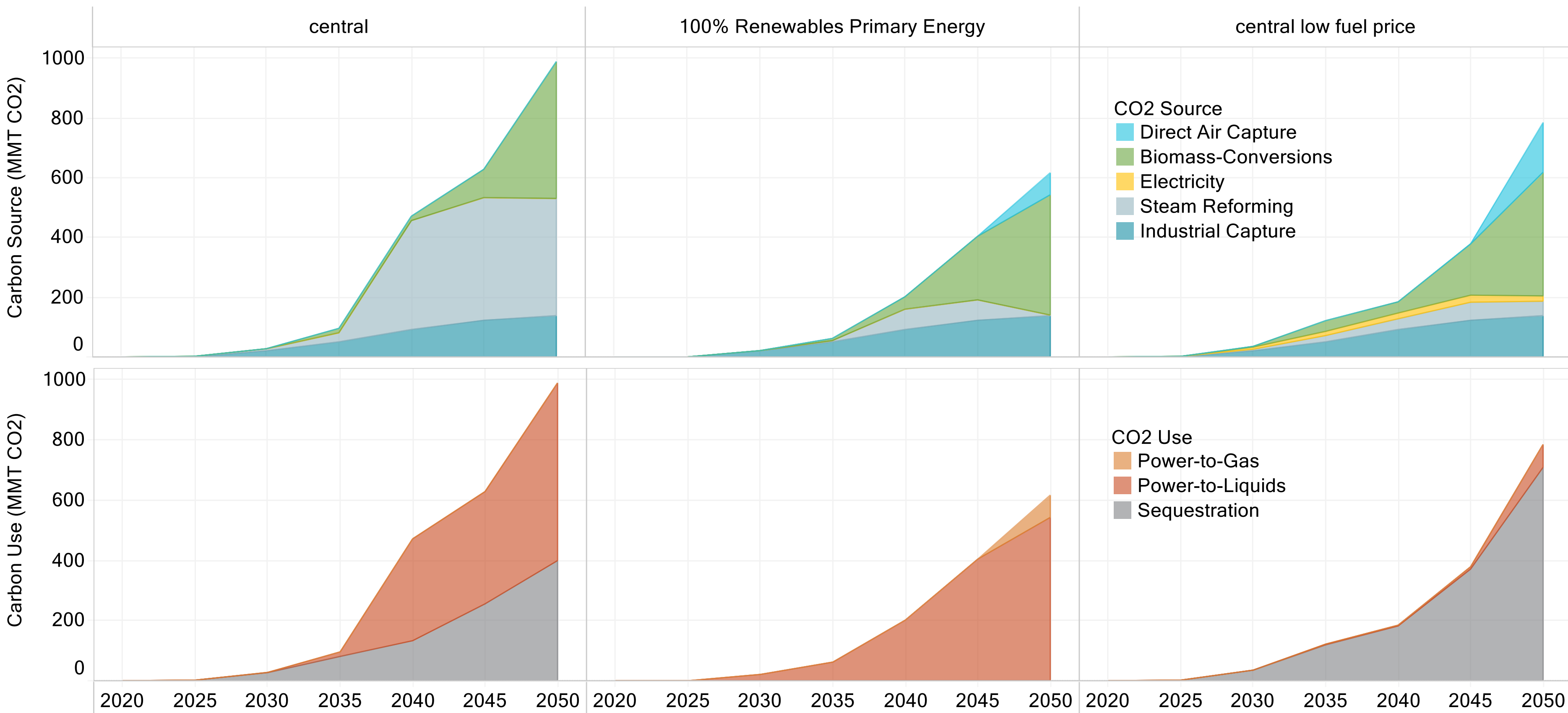
Carbon Capture Utilization & Storage (CCUS)



Carbon capture is a necessary complement (not alternative) to decarbonization

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Required Actions in this Decade, 2

- R&D, pilots, incentives for commercialization of technologies needed in bulk post-2030
  – freight transport, aviation, new industrial processes, hydrogen & synthetic fuels, advanced biofuels, CCUS
- Address scale-up challenges we already anticipate
  – wholesale electricity market design to support low capacity-factor thermal generation, flexible loads
  – incentives for customer adoption, especially EVs and heat pumps
  – land use planning to address competing priorities for siting, bioenergy, carbon sink, and existing uses

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