Evolving US Energy Sector: Intersections of Technology, Policy, and Economics

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Outline

- What is role of gas turbines, fuels and combustion in a net zero energy/transportation sector?

- Gas Turbine R&D:
  - What are key R&D drivers in this landscape?
  - What are R&D needs in this new landscape?

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What is Role of Fuels in Net Zero Society?

- Least Cost Generation Mix
- Geopolitics and global interactions
- Equity and Energy Justice
- Reliability and Resilience
- Jobs, Existing Infrastructure

Key Discussion Points

- Least Cost Generation Mix
- Geopolitics and global interactions
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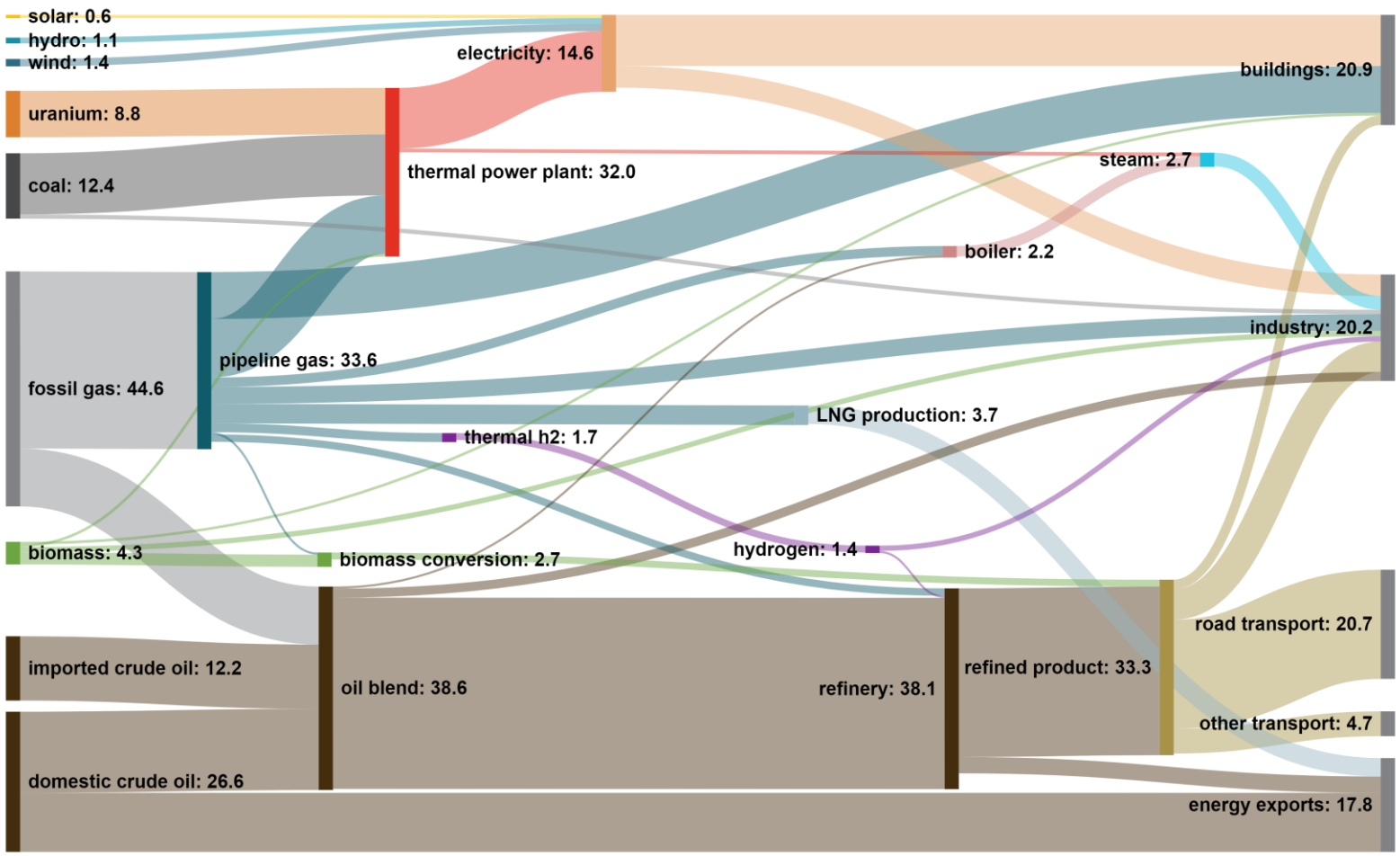
US Energy System



Haley, B., Jones, R.A., Williams, J.H., Kwok, G., Farbes, J., Hargreaves, J., Pickrell, K., Bentz, D., Waddell, A., Leslie, E., Annual Decarbonization Perspective: Carbon Neutral Pathways for the United States 2022. Evolved Energy Research, 2022.

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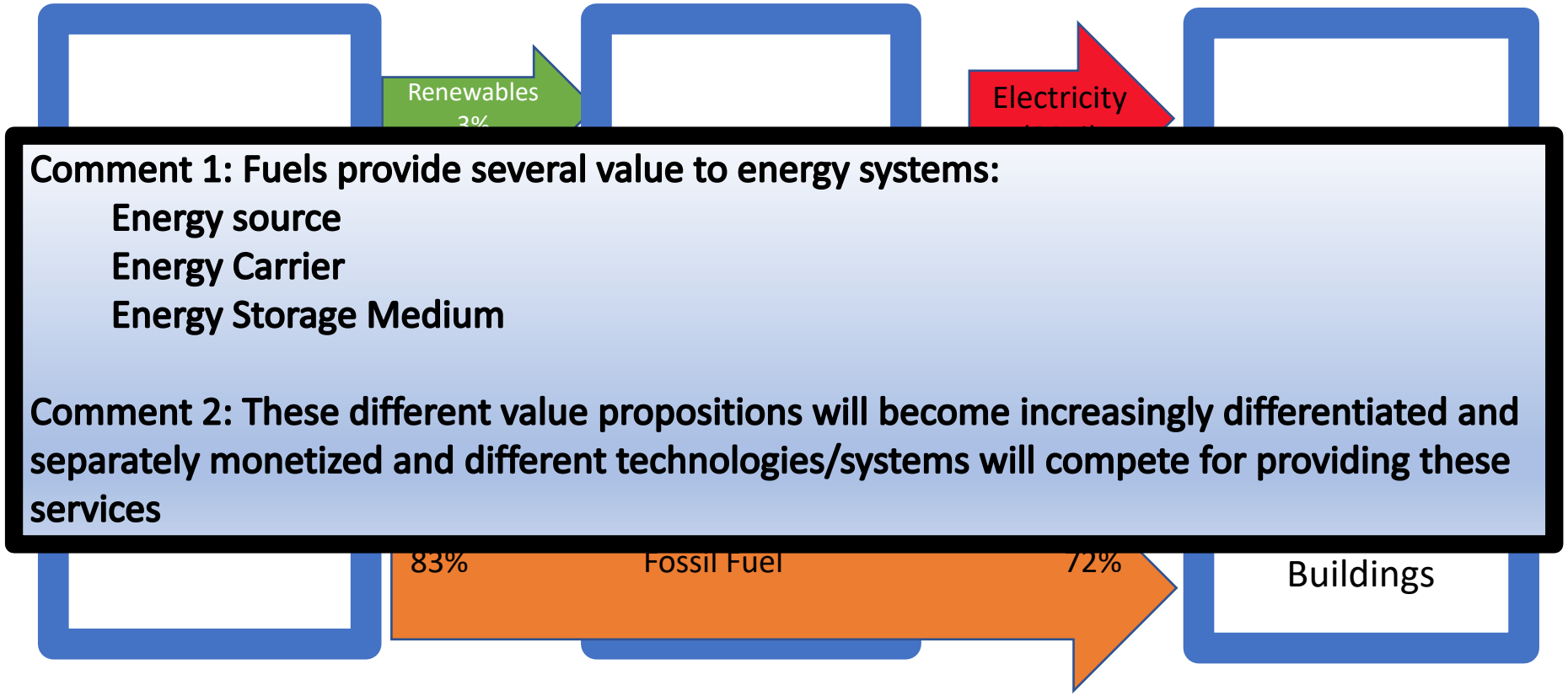
US Energy System

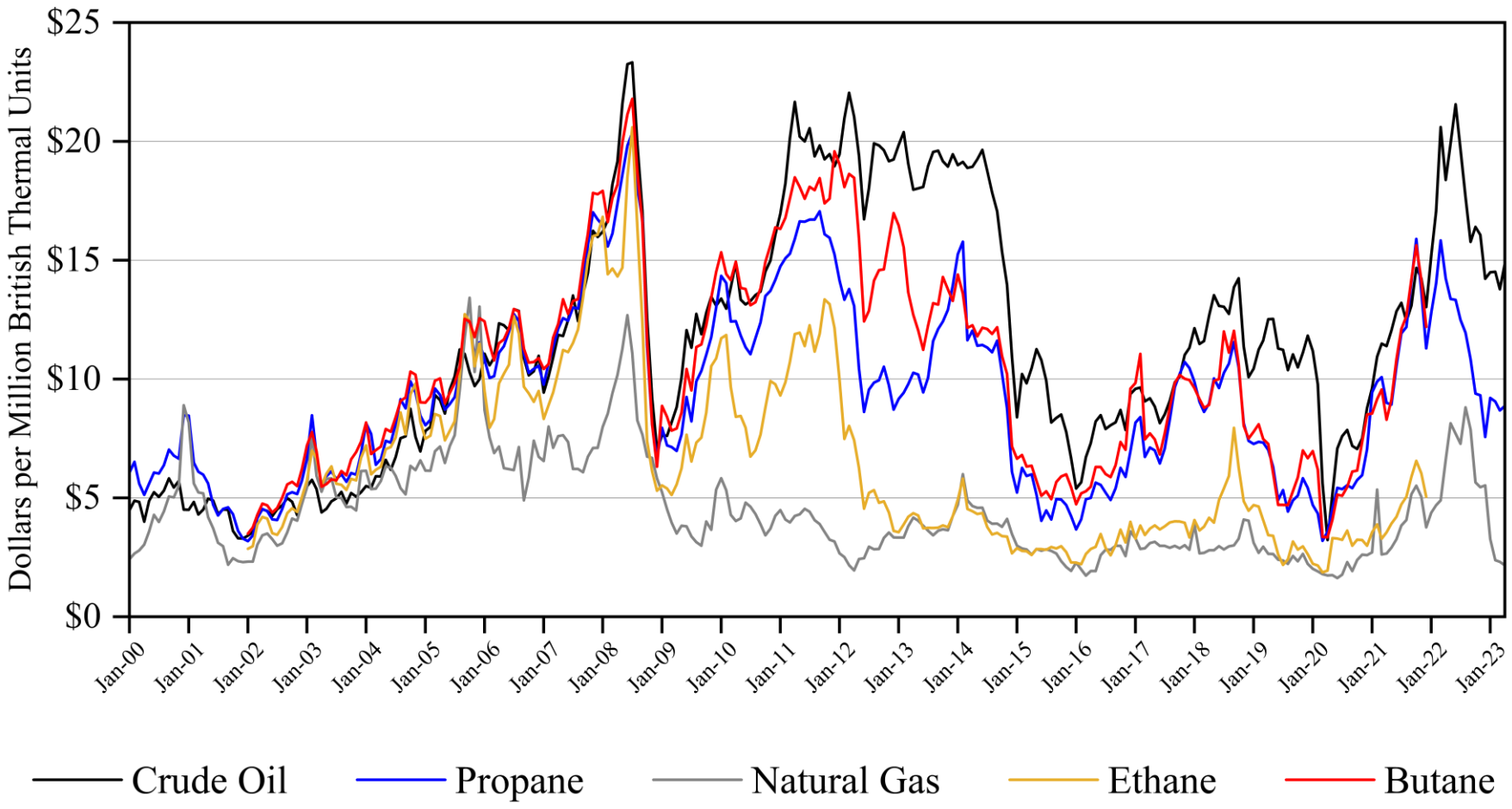


Comment 1: Fuels provide several value to energy systems:

- **Energy source**
- **Energy Carrier**
- **Energy Storage Medium**

Comment 2: These different value propositions will become increasingly differentiated and separately monetized and different technologies/systems will compete for providing these services

Whats the Value of a Fuel?



Source: eia.gov/energyexplained/hydrocarbon-gas-liquids/prices-for-hydrocarbon-gas-liquids.php
Date: February 19, 2021

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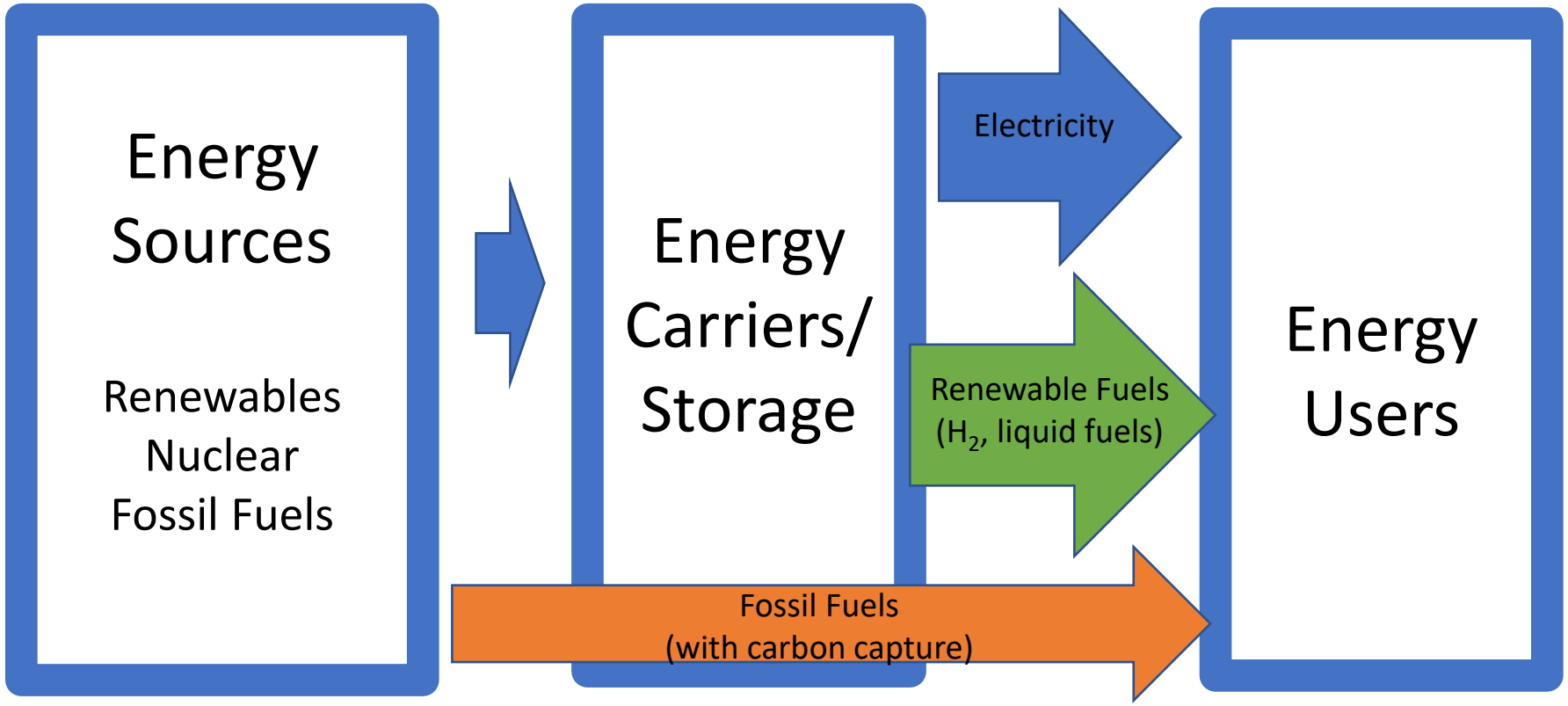
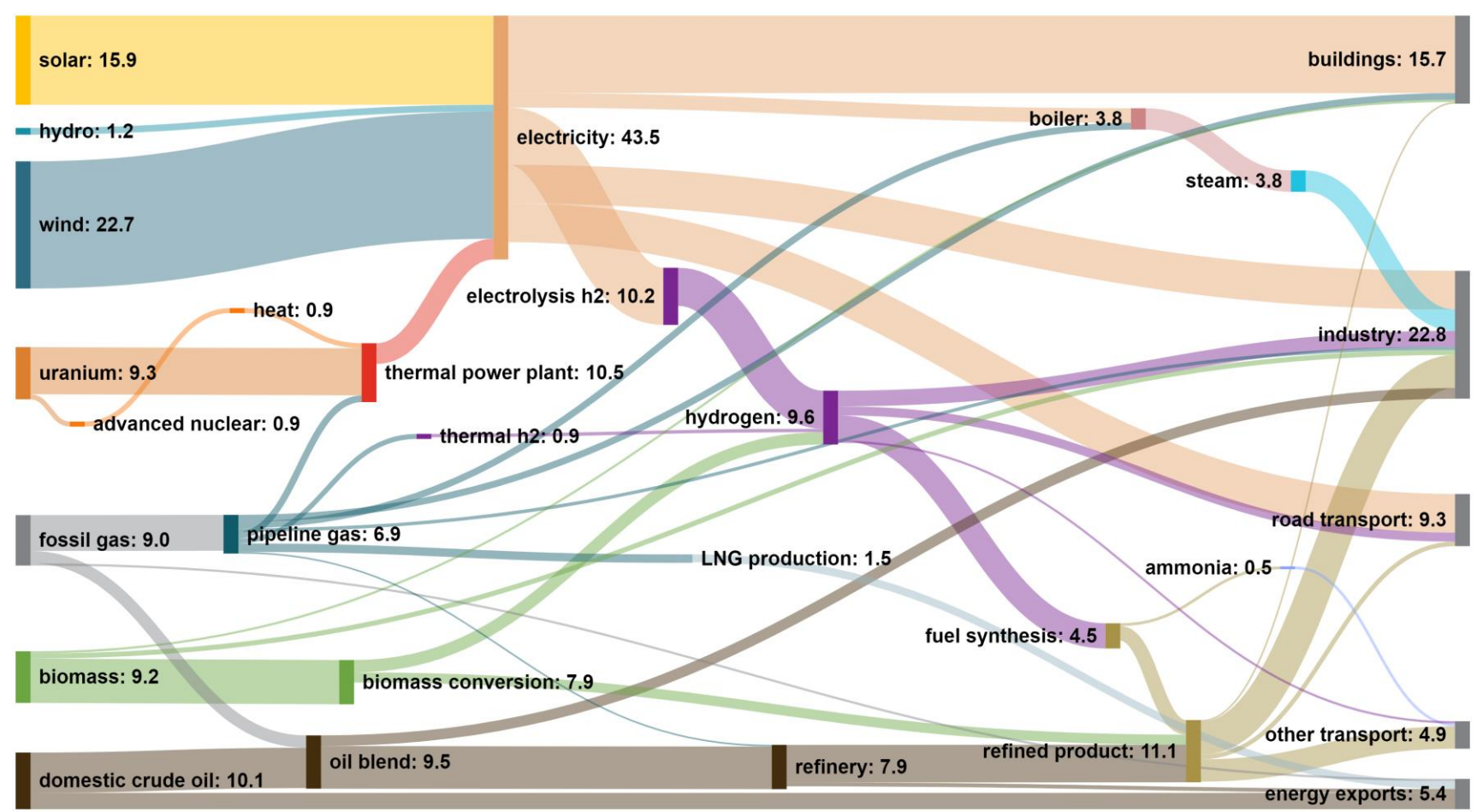
US Energy System – What will the net-zero CO_2 system look like?



2050 – Net Zero (Central Scenario)



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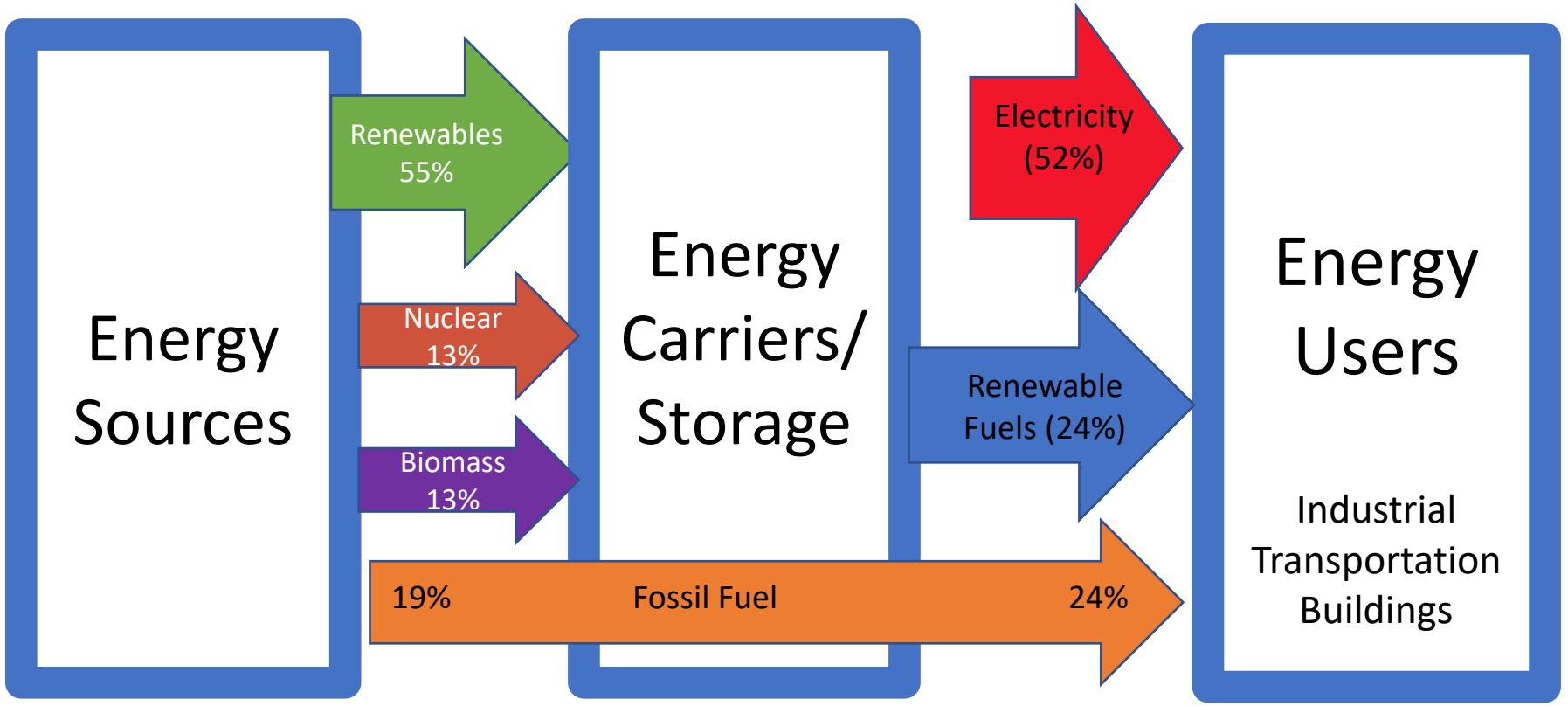

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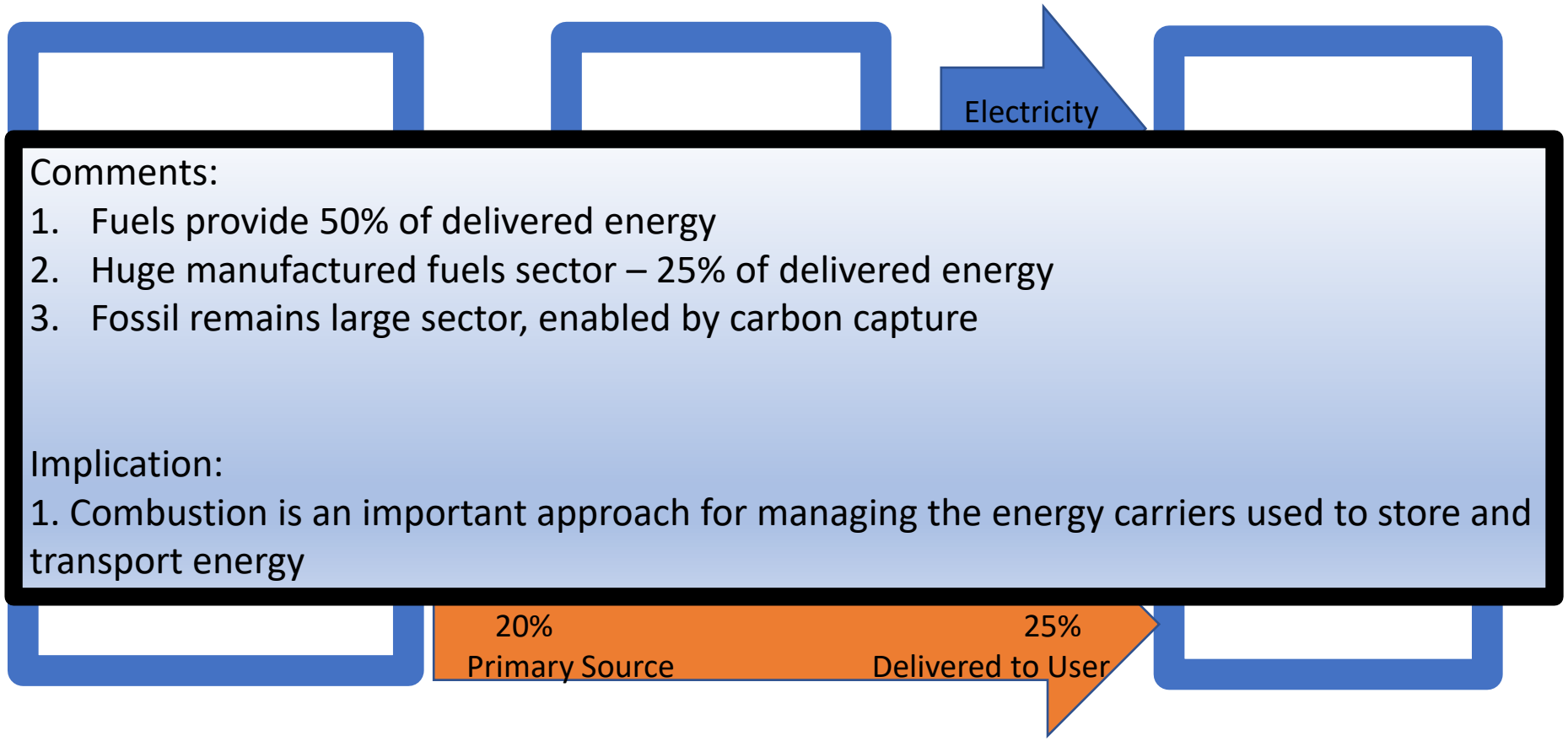

Key Discussion Points

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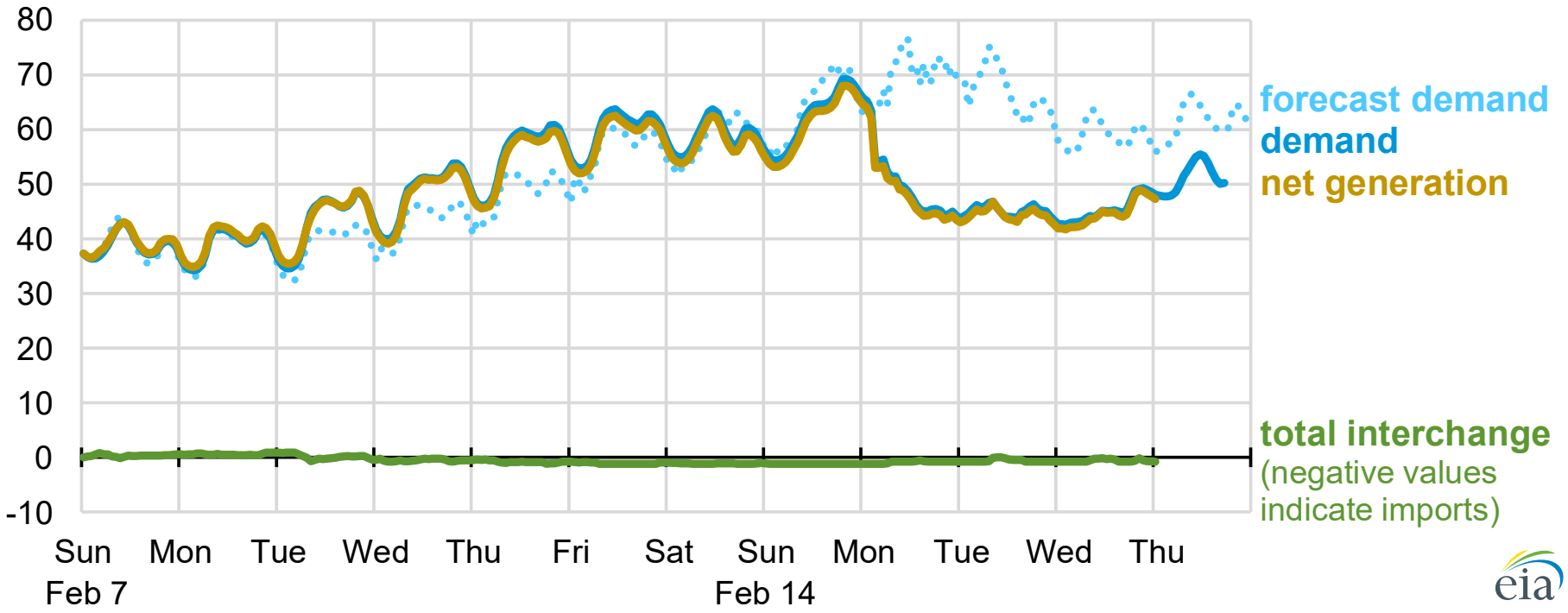
Revisiting Texas…

Hourly electricity demand, net generation, and total interchange (Feb 7–Feb 18, 2021)
Electric Reliability Council of Texas, Inc (ERCOT)
gigawatts



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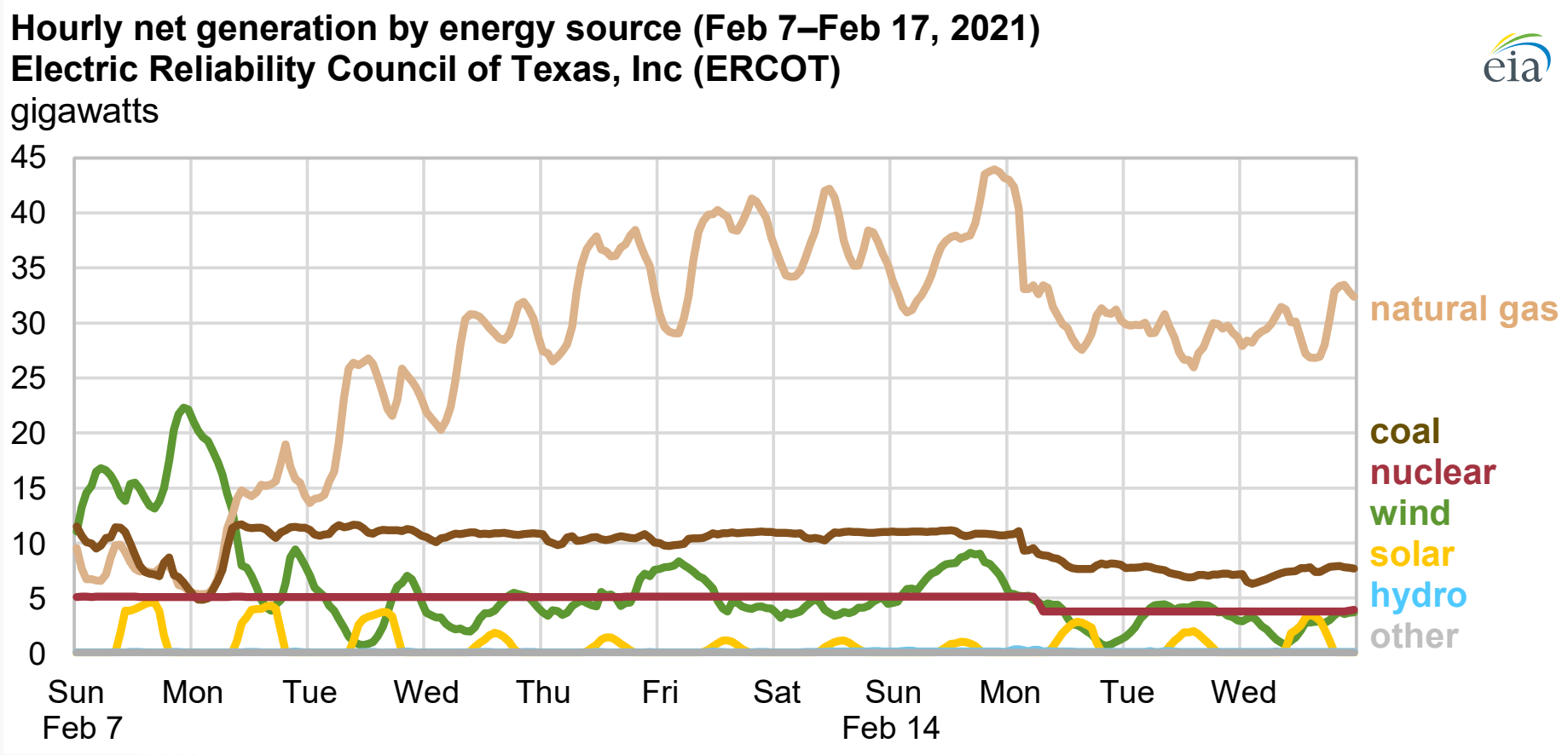
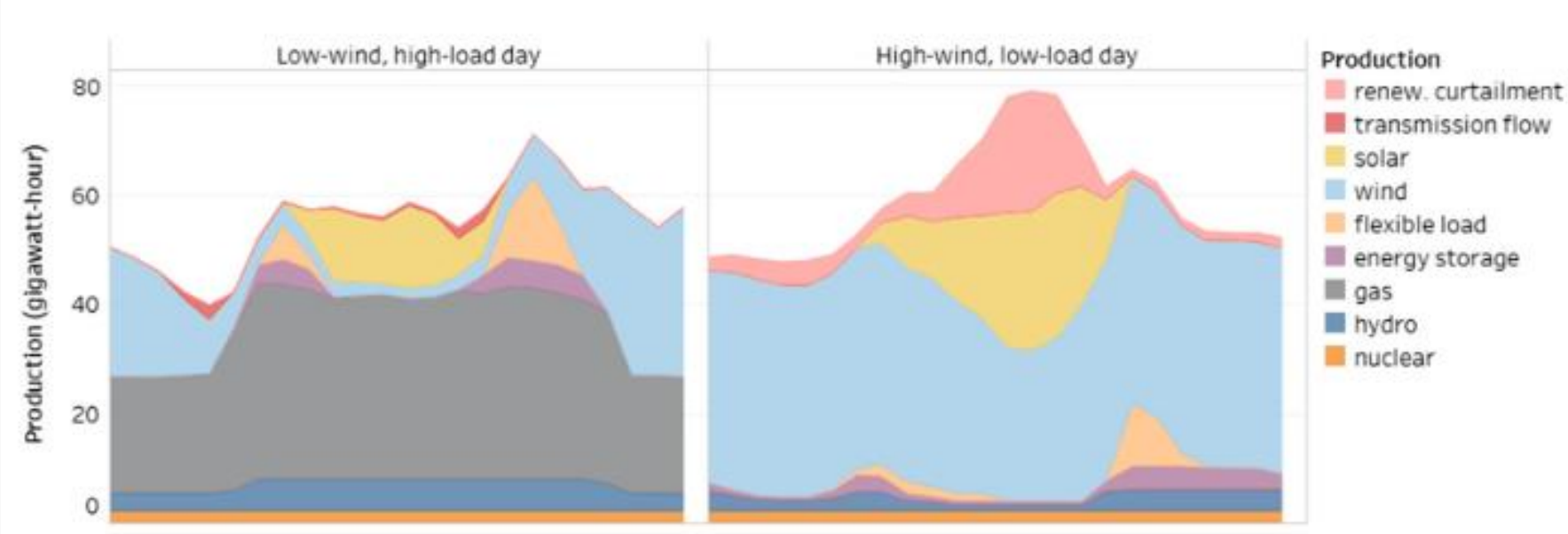
Revisiting Texas…



2050 Net Zero Scenario

- Dominant value add of gas turbines evolves from energy to capacity, reliability, and resilience



Williams, J. H., Jones, R., Haley, B., Kwok, G., Hargreaves, J., Farbes, J., et al. (2021). Carbon-neutral pathways for the United States. *AGU Advances*, 2, e2020AV000284. https://doi.org/10.1029/2020AV000284

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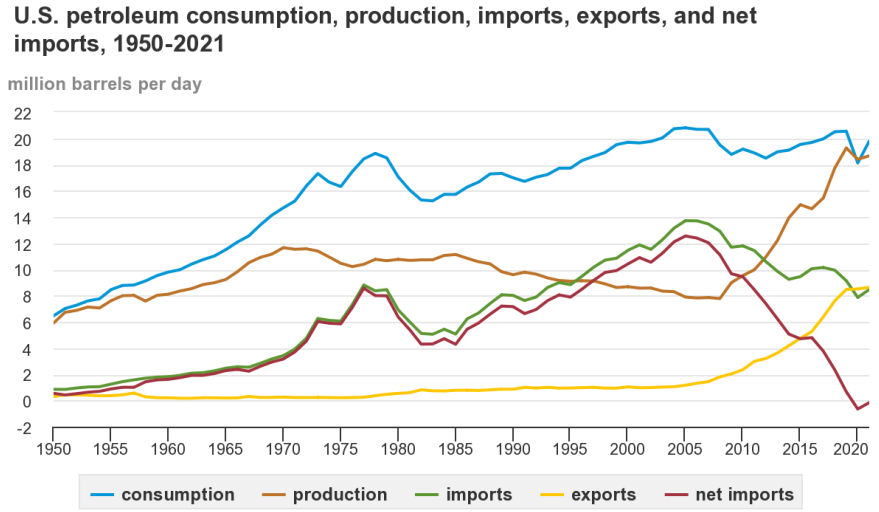
Global Interactions and Geopolitics

- US is energy independent in so far as electric power generation
  - Pricing decoupled from electricity prices globally
- Oil: US is net exporter, but also a major importer and prices fully coupled to global markets
- Energy security issue is coupled to
  - Transportation- oil imports
  - Strategic alliances – natural gas



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Pollutant

- Growing sc ustice (EJ) groups abo n PM and NO emissions
- Concern al spective from ammonia

Hydrogen Hype in the Air

(https://www.cleanegroup.org/hydrogen-hype-in-the-air/)

H2 Combustion and NOx – The New Air Pollution Threat. What happens when H2 is combusted?

Burning H2 does not produce carbon dioxide (CO2) emissions. That is good news for the climate.

However, hydrogen combustion produces other air emissions. And that scientific fact is the untold story in this aggressive industry plan, one that could turn green H2 into ghastly H2.

The bad news is that H2 combustion can produce dangerously high levels of nitrogen oxide (NOx). Two European studies have found that burning hydrogen-enriched natural gas in an industrial setting can lead to NOx emissions up to ***six times that of methane*** (the most common element in natural gas mixes).[17],[18] There are numerous other studies in the scientific literature about the difficulties of controlling NOx emissions from H2 combustion in various industrial applications.[19],[20]

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Environmental Justice – Carbon Capture

GEOENGINEERING 101

CLIMATE JUSTICE ALLIANCE
COMMUNITIES UNITED FOR A JUST TRANSITION

CARBON CAPTURE AND STOR

An Array of False Solutions

Carbon Capture and Storage

In Carbon Capture and Storage (CCS), carbon dioxide (CO2) is collected from industrial smokestacks, compressed into a liquid and transported by pipeline to a site where it can be pumped underground for storage in saline aquifers, oil or gas reservoirs, or beneath the ocean. This is a dangerous practice. There is no guarantee the CO2 will stay underground. Imagine, for example, an earthquake under a CCS storage site that causes a release of large ammounts of CO2 into the atmosphere.

CCS was developed over 40 years ago for use in enhanced oil recovery (EOR), a practice in which oil companies pump liquid CO2 into old, nearly depleted wells to access deep pools of

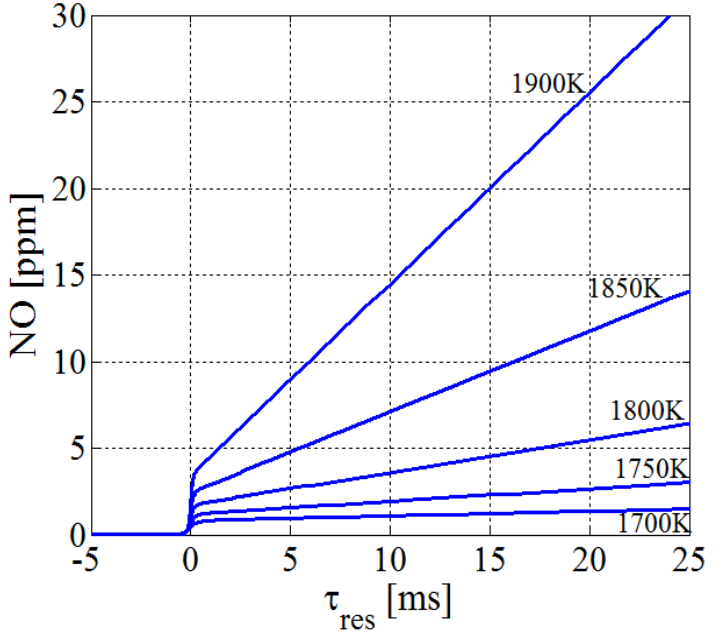
the environment and atmosphere when these products are incinerated or decompose. This is (at best) postponing the problem of CO2 emissions and perpetuating the problem of acute environmental injustice from these polluting operations. CCUS creates more emissions than it reduces[2] and contributes to the production of plastics and other polluting materials. Even if some of the emissions are temporarily captured, all the problems with CO2 storage remain.

Direct Air Capture: The New False Hope

Direct Air Capture (DAC) is a largely theoretical technique to remove CO2 (and potentially other greenhouse gases) directly from the atmosphere, using chemical and mechanical means. The current proposed technique would use large fans to move air through a filter, where it passes through a chemical adsorbent to produce a pure CO2 stream that could be stored. To have any significant effect on global CO2 concentrations,

Environmental Justice –Air Quality Impacts of Combustion

- Heating up air (N_2 +O_2) leads to NO production, even from 100% renewable fuels
- Particulate emissions from renewable hydrocarbons



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Outline

- What is role of combustion in rapidly evolving energy/transportation sectors?

- Combustion R&D:
  - What are key R&D drivers in this landscape?
  - What are R&D needs in this new landscape?

- Efficiency
- Operational Flexibility
- Pollutant Emissions
- Fuel Flexibility

Summary Comments

- **Fuels provide three distinct values to energy system: Source, Carrier, and Storage Medium**

- **These value propositions will become increasingly differentiated and separately monetized**
  - **Different technologies/systems will compete for providing these services**
  - **Fuel value moving toward carrier/storage, substantially reduced role as source**
  - **Gas turbine value in energy decreasing, dominant value in capacity/resilience/reliability**

- **Drivers that will control role of gas turbine relative to competing technologies:**
  - Efficiency
  - Operational Flexibility
  - Pollutant Emissions
  - Fuel Flexibility

Thank You

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