Industrial Decarboniztion in the Annual Decarbonization Perspective

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Agenda

- Model Approach
- Scenario Results
- Key Findings

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Model Approach

Model Approach – Industry

- We leverage the U.S. Energy Information's Annual Energy Outlook's projections for energy by end-use and industry
- We perform further disaggregation of some of this industrial energy use and also downscale their regional projections to our modeled zones
- This underlying energy data projection is altered with scenario-based measures (to change the carrier/amount of energy demand by industry over time)
- We then optimize the energy to supply these energy carriers over time in our RIO optimization
- The next slide shows the types of decarbonization approaches shown by industrial subsector/end-use

Industrial Decarbonization Approach

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Industry$_{1..x}$

Process Heat	Process Heat - Steam	Transport	Buildings	Feedstocks	Machine Drives
• Heat Pumps • Other Electrification Technologies • Hydrogen	• Dual-Fuel boilers (electric + fuel) • Thermal Energy Storage • Heat Pumps • Hydrogen Boilers	• Electrification • Hydrogen	• Energy Efficiency • Electrification	• Biofuels • Synthetic Fuels	• Energy Efficiency • Electrification

Specific Industrial Process
• Cement: CCS; Coal to Biomass substitution • Iron and Steel: CCS; hydrogen-DRI/EAF

- We break down energy use by industry and end-use to tailor decarbonization approaches depending on the nature of energy use in these industry/end-use combinations
- Many decisions are scenario-based (blue) while others are optimized (orange) in our RIO model

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Scenario Results

Scenarios

Scenario	Description
Central	This is the least-cost pathway for achieving net-zero greenhouse gas emissions by 2050 in the U.S. It is economy-wide and includes energy and industrial CO_2, non-CO_2 GHGs, and the land CO_2 sink. It is built using a high electrification demand-side case, and on the supply-side has the fewest constraints on technologies and resources available for decarbonization.
Drop-In	This net-zero scenario prioritizes maintaining the use of existing infrastructure to the greatest extent possible consistent with carbon neutrality, implemented by placing cost penalties on new infrastructure build, delaying the uptake of electrification technologies by twenty years, and avoiding the uptake of other zero-carbon fuel-using technologies (hydrogen and ammonia). It is designed to explore the effects of trying to minimize dislocation on the existing energy industry in the U.S.
High Hydrogen	This net-zero scenario emphasizes the direct use of hydrogen in some applications in which the potential for electrification is uncertain, specifically in industry and heavier vehicles. It is designed to explore the effects of a hydrogen economy that extends all the way to energy end-users.
Low Demand	This net-zero scenario reduces the demand for energy services from that used in the other net-zero scenarios. It is designed to explore how high levels of conservation and energy efficiency, achieved through behavior, planning, policy, and other means, could reduce requirements for low-carbon infrastructure and land.
Low Land	This net-zero scenario limits the use of land-intensive mitigation solutions, including bioenergy crops, wind and solar power generating plants, and transmission lines. It is designed to explore the effect of societal barriers to the siting of low-carbon energy infrastructure for environmental and other reasons.
Slow Consumer Uptake	This net-zero scenario delays by twenty years the uptake of fuel-switching technologies including electric vehicles, heat pumps, fuel-cell vehicles, etc. It is designed to explore the effects of slow consumer adoption on energy system decarbonization, including the impacts on electricity and alternative fuel demand.
100% Renewables	This net-zero scenario allows only wind, solar, biomass, and other forms of renewable energy by 2050. It is designed to explore the effects of eliminating fossil fuels and nuclear power altogether on energy infrastructure, electric power, and the production of alternative fuels and feedstocks.

Final Energy Demand – Industrial Subsector

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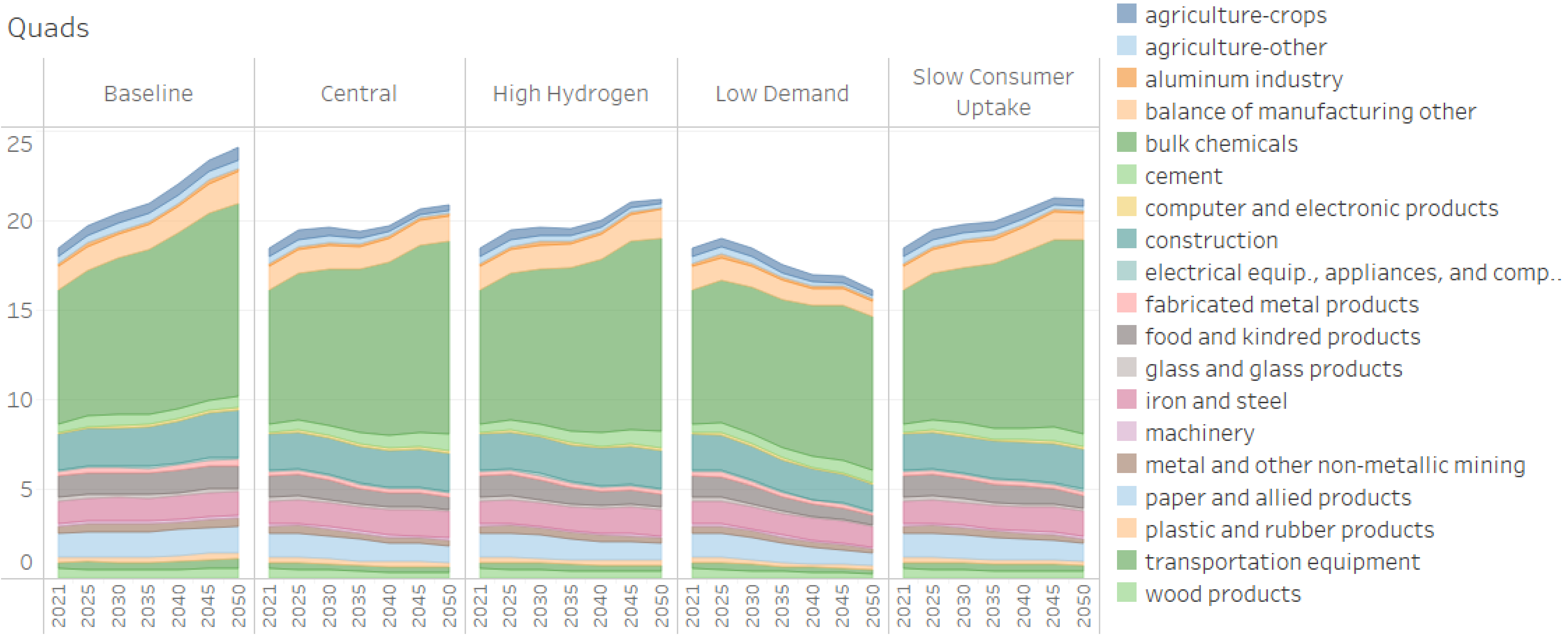
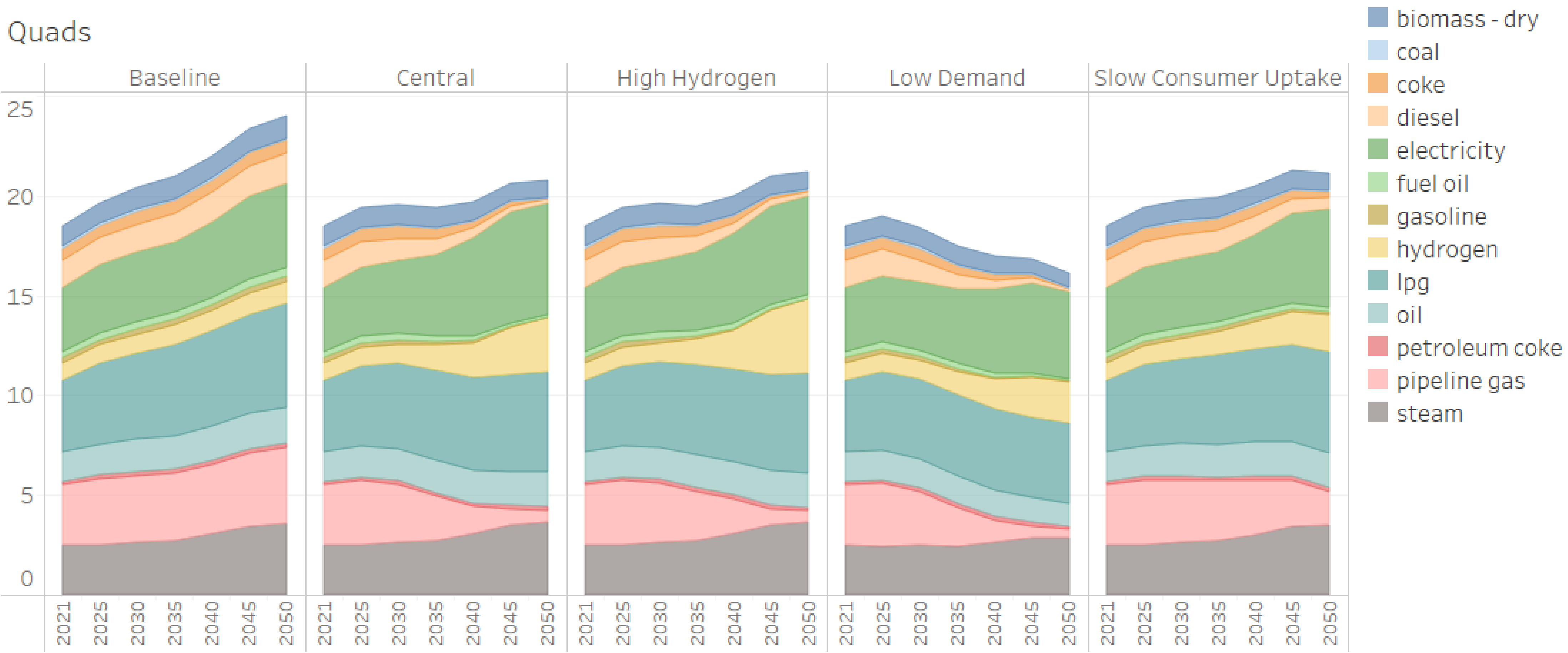


Final Energy Demand – Energy Carrier



Final Energy Demand

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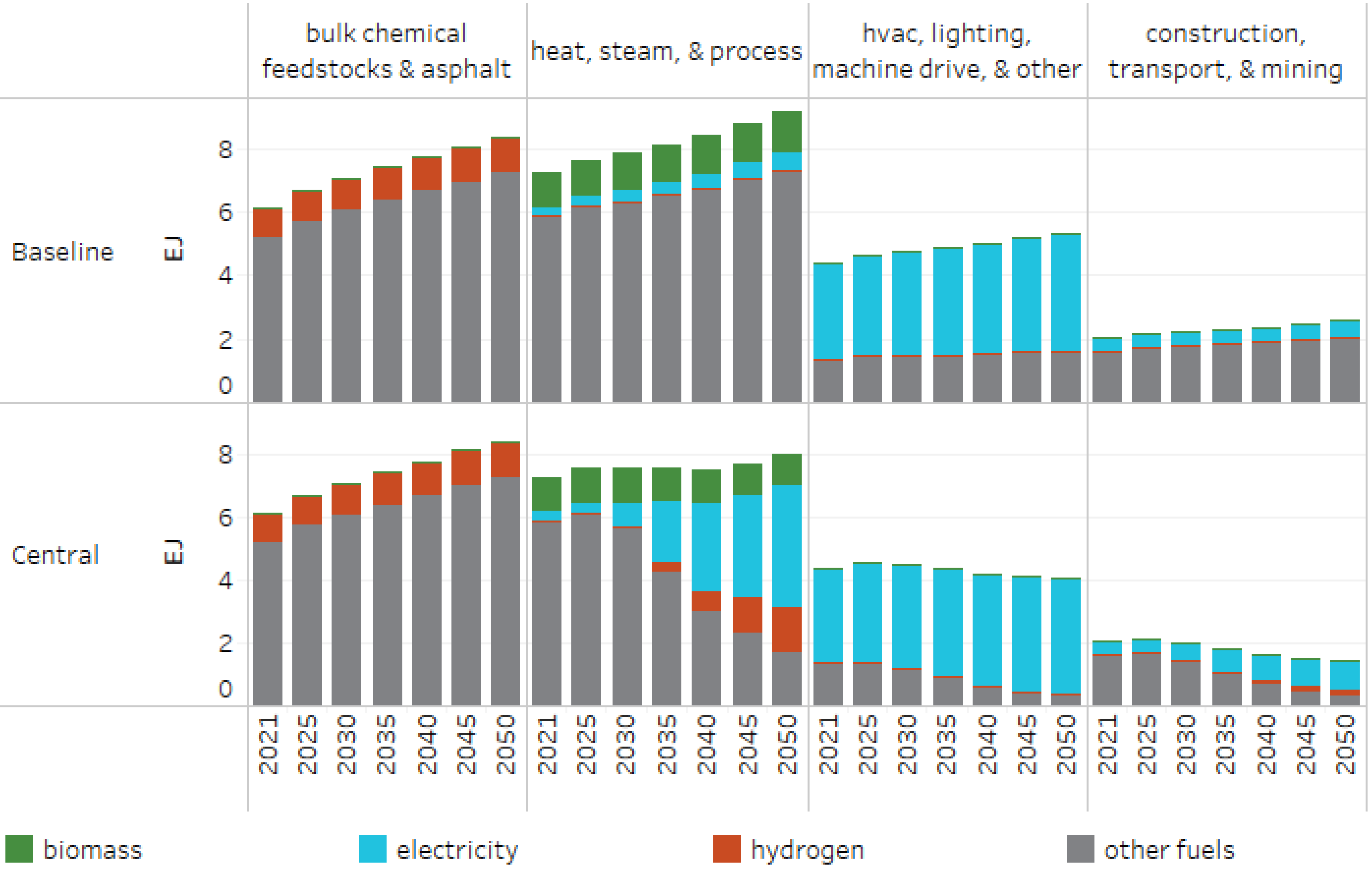
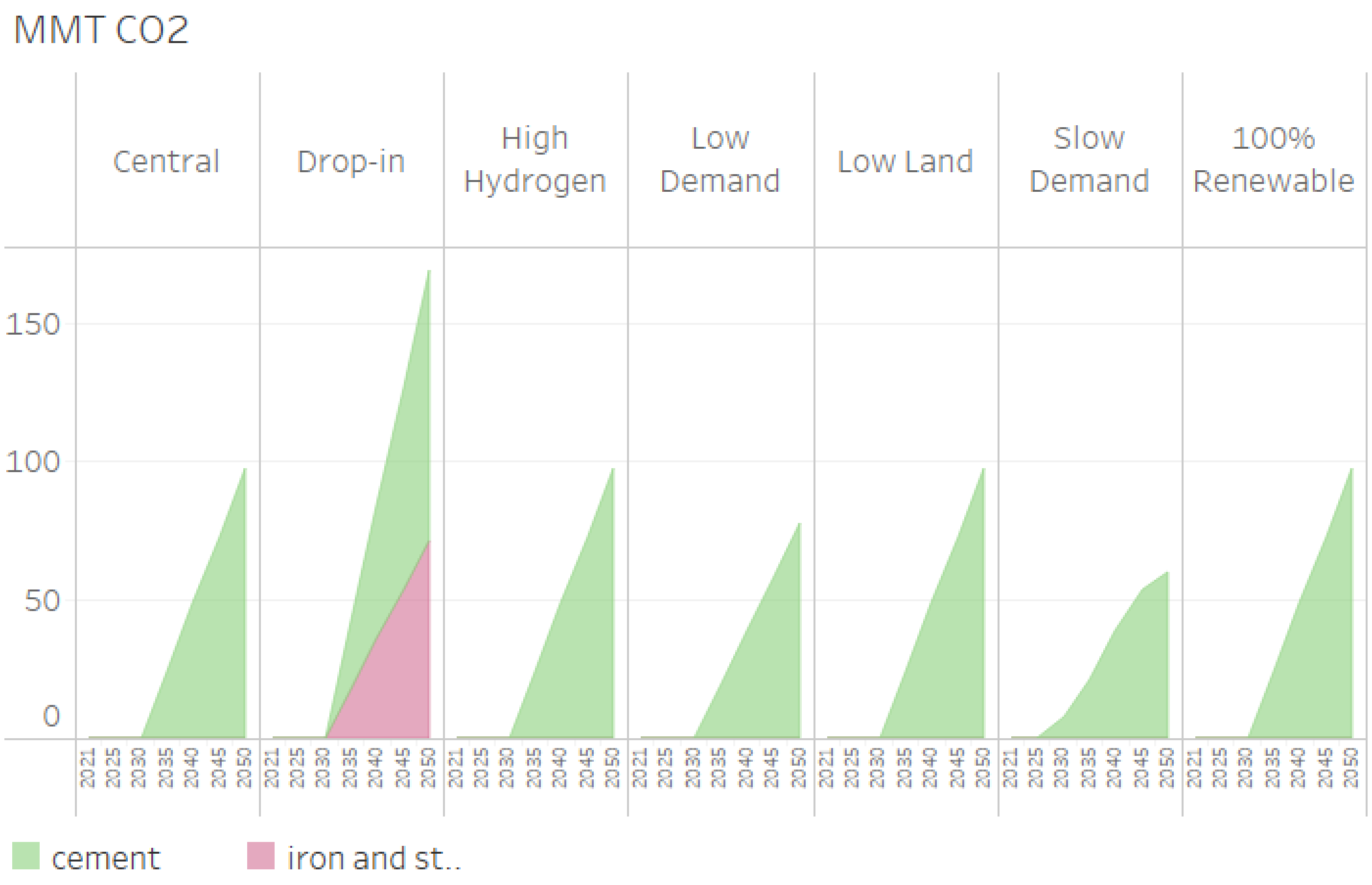
- Comparison to the **Baseline** scenario shows a decline in overall energy demand in the **Central** scenario (through EE and electrification) as well as the deployment of hydrogen in heat and transport



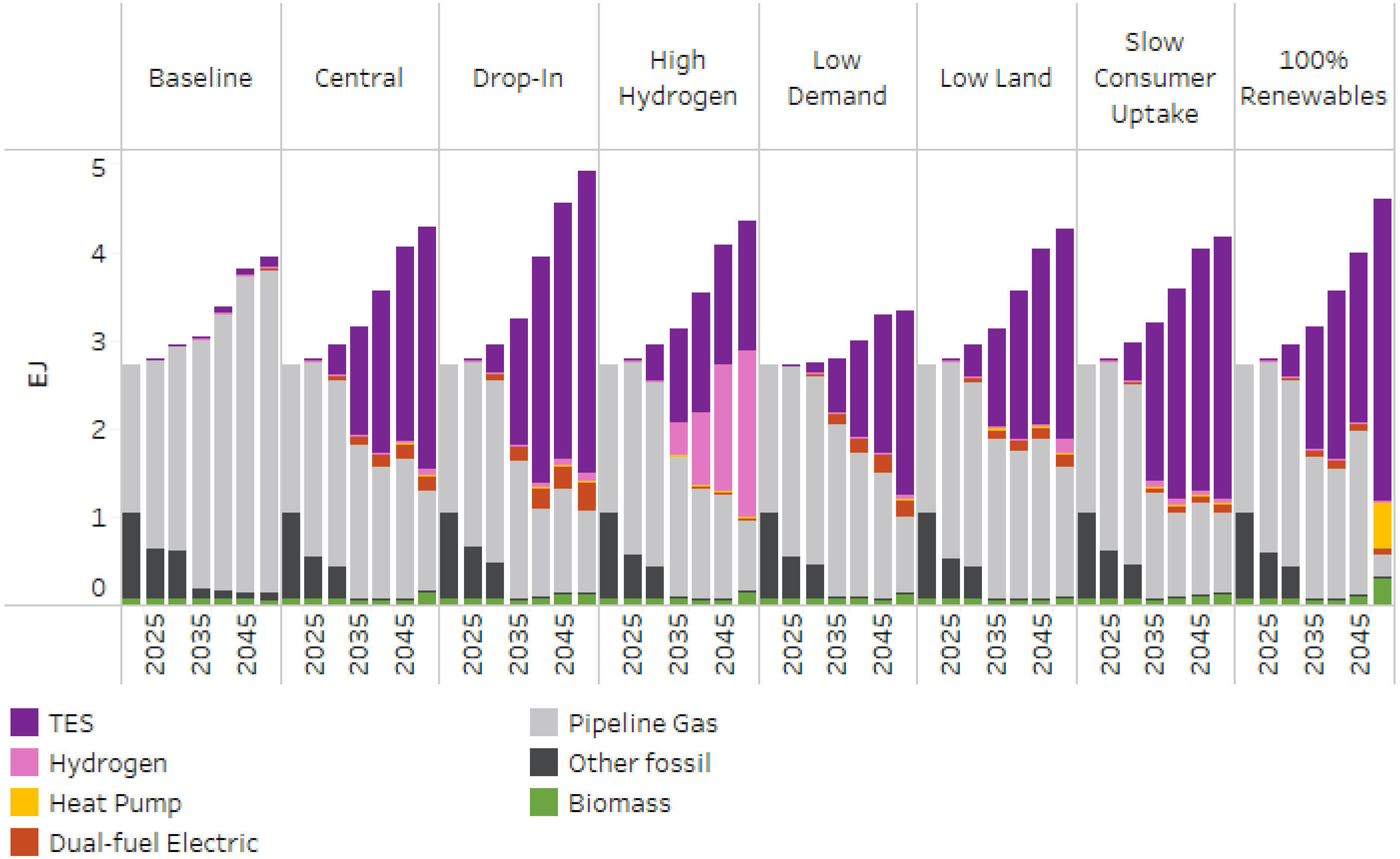
Industrial CCS

- Industrial CCS applied to cement in all cases
  - slower deployment in **Slow Demand**
  - fewer emissions captured in **Low Demand** due to lower industrial activity
- **Drop-in** scenario deploys CCS on existing iron and steel facilities

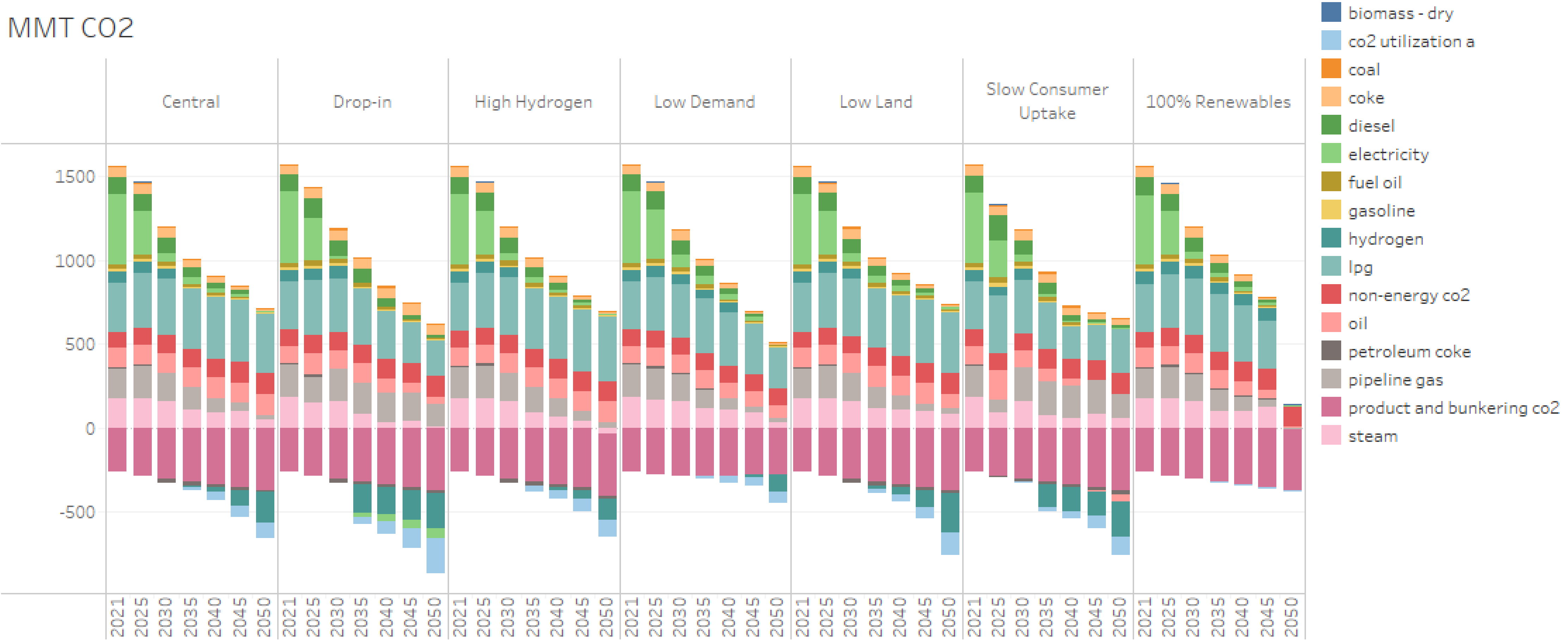


Industrial Steam Production

- Most of industrial steam production becomes electrified either through integrated TES, heat pumps, or dual-fuel gas/electric boilers
- Heat pumps have high capital costs that hinder deployment (opportunity for improved technological representation)



Industrial Emissions



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Key Findings

Key Findings

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- Significant emissions reductions from electrification of buildings, transport, and process heat
- One of the more interesting areas of technology competition is in the provision of steam. We end up seeing a diverse solution set of electrified technologies (dual-fuel boilers, heat pumps, TES). The competition and proliferation of these technologies is likely to be driven at least in part by rate design.
- We use CCS processes in industries where direct electrification is not currently possible (though this is an area where we can improve our representation of decarbonization in the future)
- The chemical industry is a large source of emissions in the U.S., and even more significantly, the biggest demander of fossil fuels in the long-term energy economy. We rely heavily on alternative fuel substitution but there may be more direct processes of decarbonization (i.e. electrochemical synthesis)

THANK YOU

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