OnLocation's U.S. Energy Horizons to 2050

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Disclaimers

This material was produced by OnLocation, Inc. who provides unbiased predictive energy analysis using quantitative analytical methods and an integrated modeling approach of the U.S. energy system. All data provided and opinions expressed in this analysis are based on OnLocation's research and experience. This material follows from available public information that we consider current and reliable; however, we do not represent it as fully accurate or complete.

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The OL-NEMS model used in this analysis is a modified version of the U.S. Energy Information Administration's National Energy Modeling System (EIA NEMS) developed by OnLocation for use in this analysis. The OL-NEMS model is based on the EIA Annual Energy Outlook (AEO) 2023 and includes the same market and technology assumptions unless otherwise noted. For more information, visit https://www.eia.gov/outlooks/aeo/.

Presenters

- **Francisco de la Chesnaye**, Vice President, Economic and Climate Strategy
- **Sharon Showalter**, Associate Director, Report Lead
- **Frances Wood**, Senior Director

Corporate Overview

KeyLogic

Mid-tier firm offers deep domain expertise in our country's most critical undertakings within the energy, federal civilian, and defense sectors

Innovative Integration	**Large-scale data management**, advanced analytics, enterprise transformation, science & technology advisory services, R&D management, and systems engineering
Thought Leaders in Emerging Technologies	**Technology readiness scale:** Experience in modeling and assessing range of energy-relevant at low-technology-readiness levels
Critical Materials Expertise	**Material and resource analysis**, including LCA, across the supply chain in support of energy production, generation, and storage technologies

OnLocation

Specialized firm with decades of experience in developing and applying innovative energy system and economic models to address key energy, climate, and environmental regulations and policies

Assess Role of New Energy Technologies	**Evaluate system and economic impacts** of new energy and climate mitigation technologies (unconventional natural gas, direct air capture, hydrogen, carbon capture & storage)
Explore Alternative Energy Futures	**Design "what-if" scenarios** and alternative energy futures for use in uncertainty analyses, including alternative energy prices and macroeconomic forecasts
Inform Energy & Environmental Policy	**Perform economic impact assessments** of proposed energy and environmental regulations and policies (Inflation Reduction Act, EPA proposed Standards for Light- and Medium-Duty Vehicles)

Points of Contact

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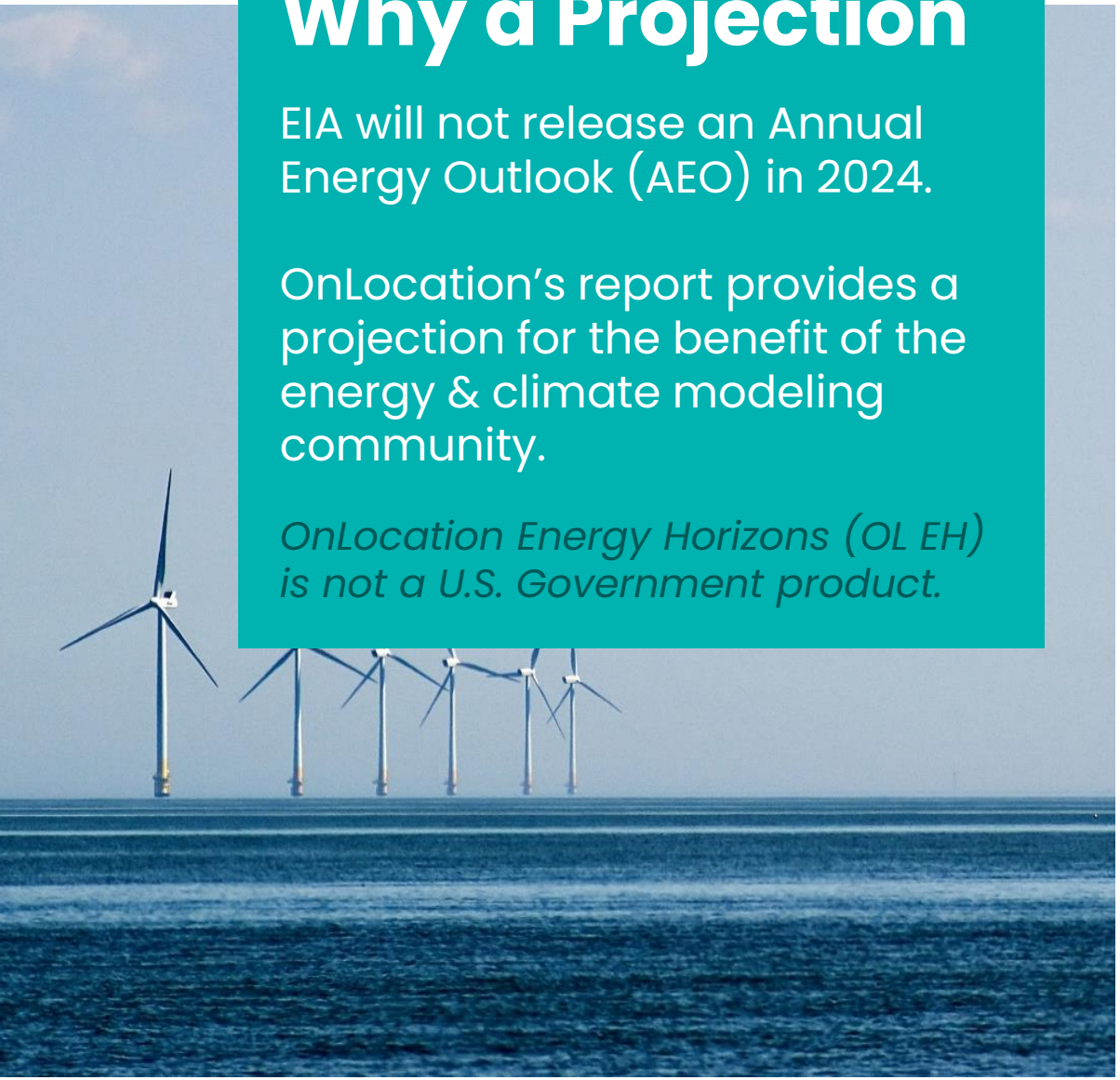


Why a Projection

EIA will not release an Annual Energy Outlook (AEO) in 2024.

OnLocation's report provides a projection for the benefit of the energy & climate modeling community.

OnLocation Energy Horizons (OL EH) is not a U.S. Government product.

Goals of OL Energy Horizons

Provide updated reference case projections using the OL-NEMS model

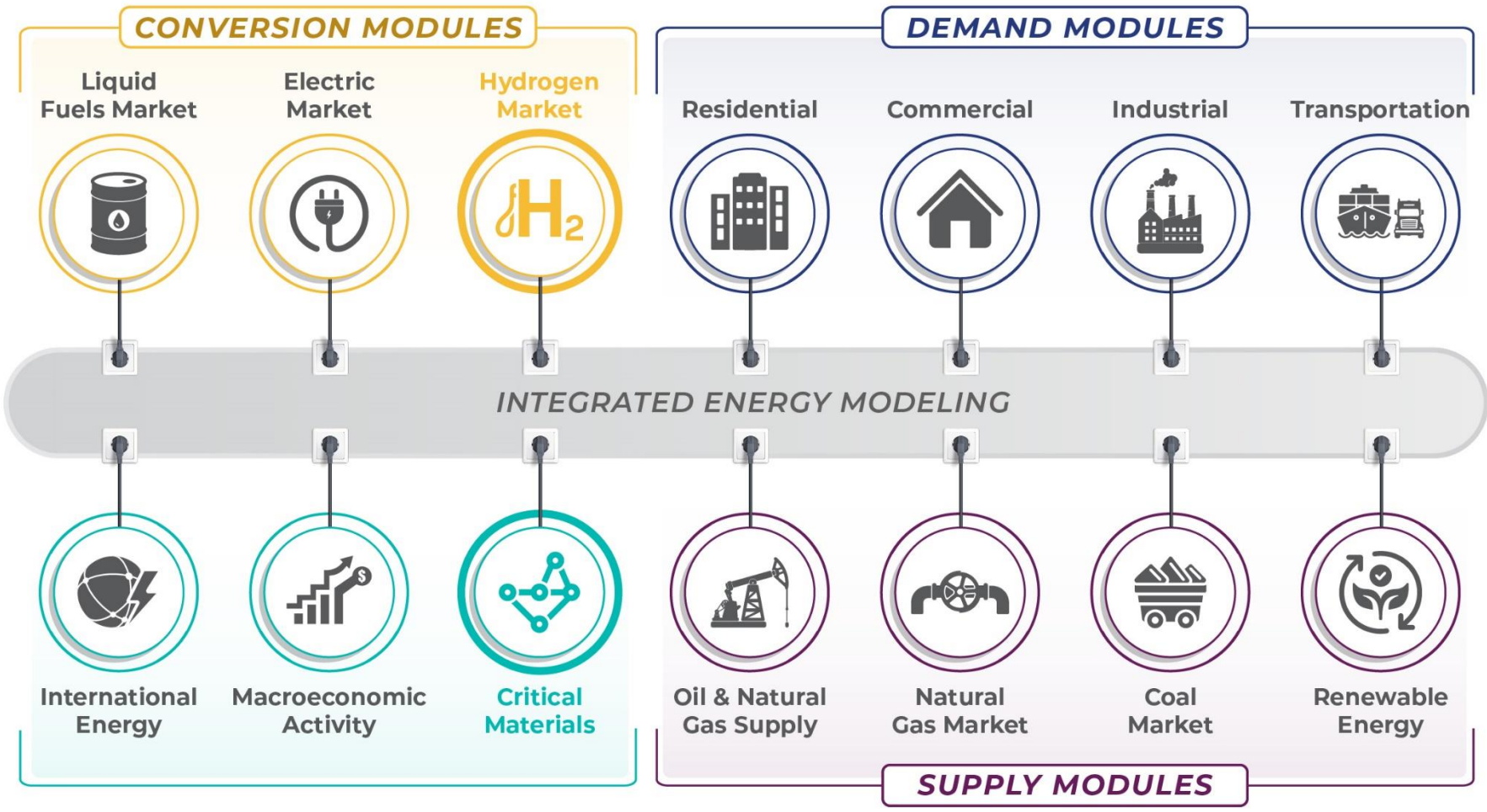
Update model representation of laws and regulations since EIA's AEO2023 release

Demonstrate new model capabilities and enhancements using an Advanced Technologies case

Explore CO_2 mitigation strategies for the U.S. energy system

Evaluate driving forces and challenges to achieve deep decarbonization

OL-NEMS: OnLocation's Customized Version of the National Energy Modeling System (NEMS)



Official version of NEMS developed by the Energy Information Administration (EIA), U.S. DOE

Development & Application of Energy System Models

- Analyzing Energy and Climate Policy Impacts
- Assessing New Energy Technologies
- Informing Cost-effective Approaches and Policies

Customization & Analyses

- Inflation Reduction Act
- Renewables and EV Expansion
- H_2 Economy
- Critical Materials Analysis
- Energy demand of AI

Highlights of OL EH Results

Clean Technologies and Enabling Policies reduce CO_2 emissions over time in the U.S. energy system

Additional R&D leading to new and lower cost clean technologies assumed in the Advanced case

All Energy Sectors Contribute:

- **Power:** Renewables, CO_2 Capture
- **Transportation:** Electric Vehicles, Biofuels
- **Industry:** Electrification, Hydrogen, CO_2 Capture
- **Buildings:** Electrification, Energy Efficiency

Decarbonizing the Electric Grid facilitates emission reductions in other sectors

CO_2 Removal Technologies also play a role

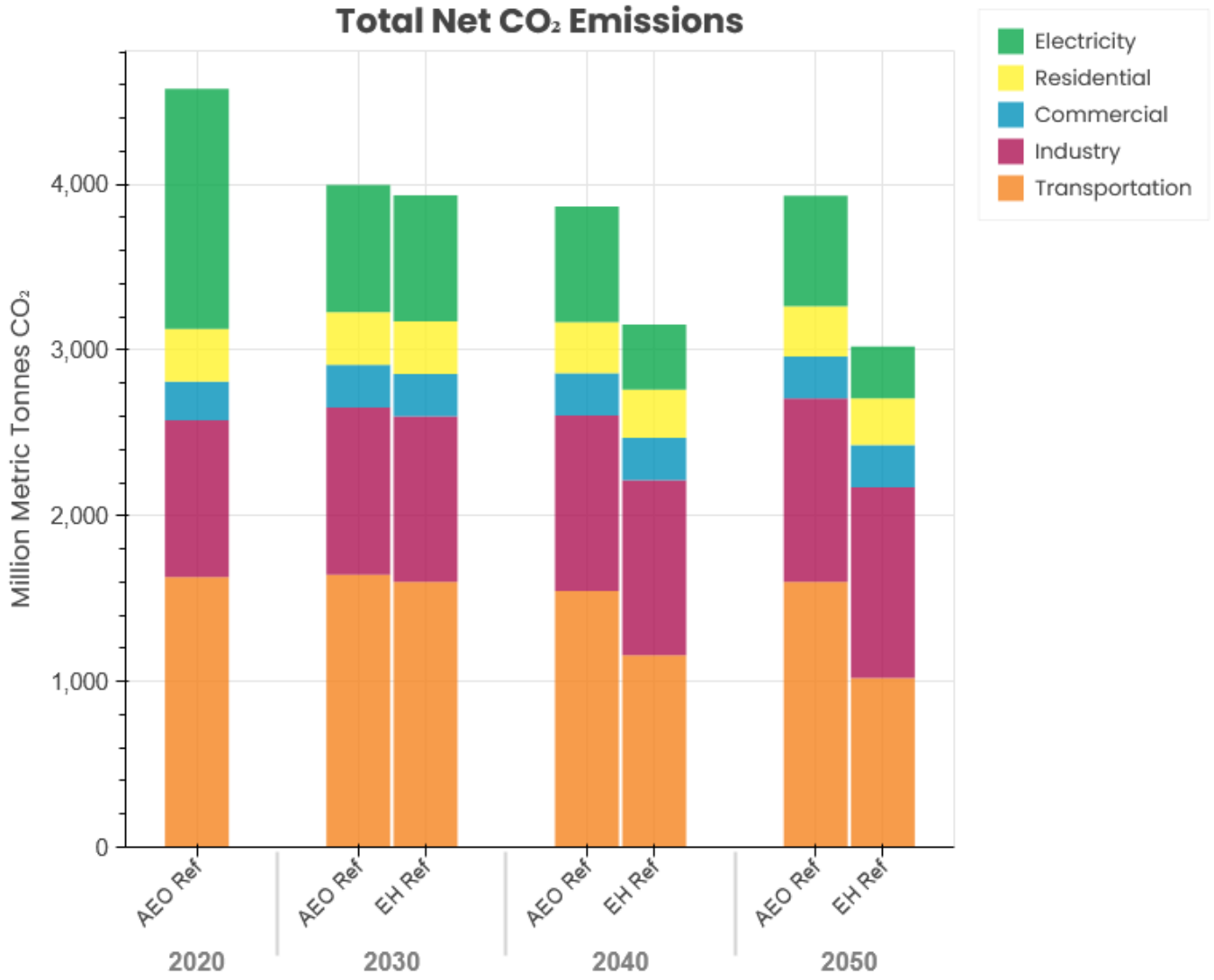
Summary Comparison: OL EH Reference and EIA AEO 2023 Reference

CO_2 Emissions by Energy Sector

Key differences in EH Reference case compared to the AEO 2023 Reference:

- Updated policies and regulations including new EPA greenhouse gas standards for power plants and vehicles.
- More complete representation of the Inflation Reduction Act (IRA) and Bipartisan Infrastructure Law (BIL).
- Lower cost assumptions for renewables, carbon capture, and electric vehicles.
- Greater data center electricity demand growth in the commercial sector.

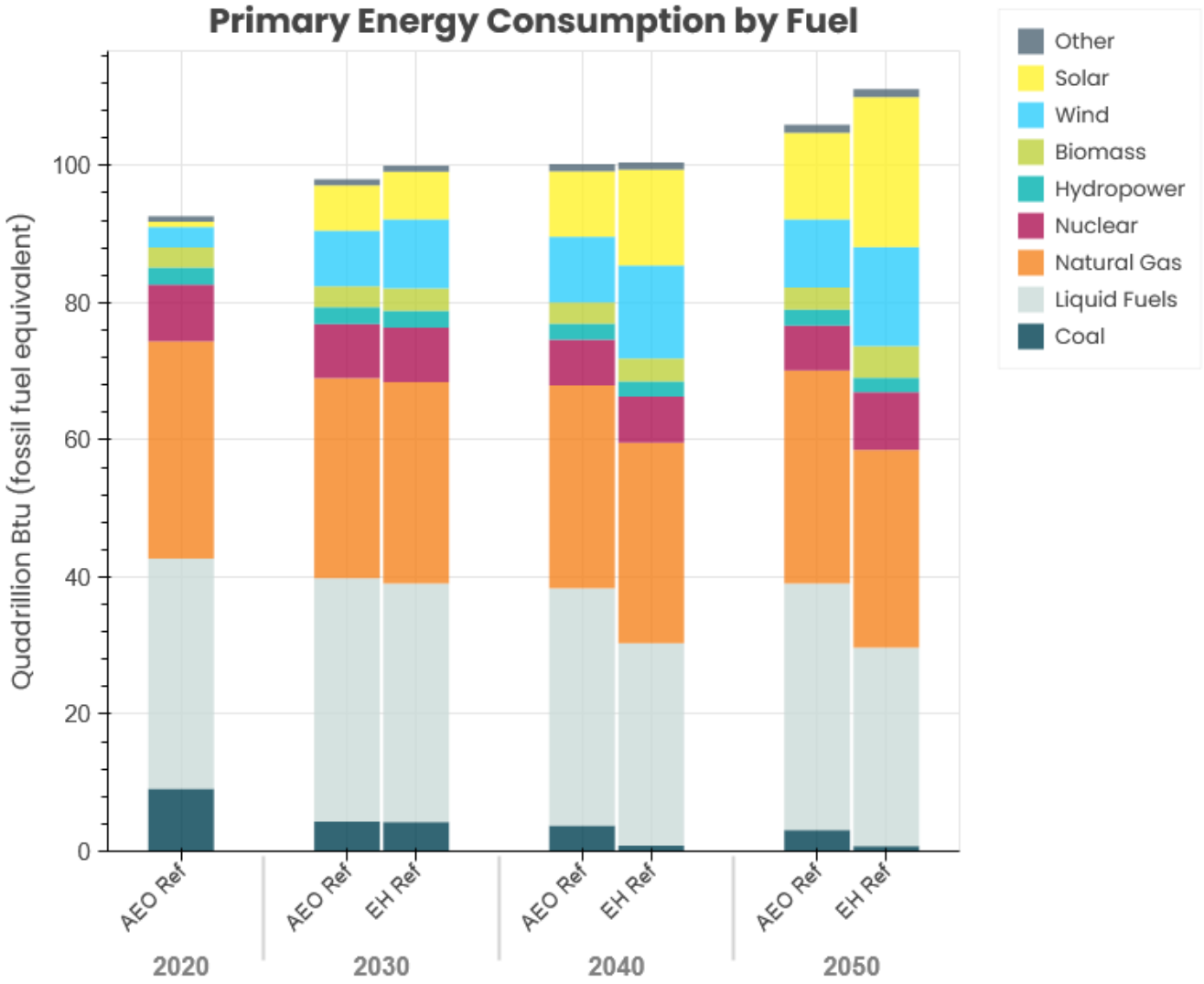
The EH Reference case achieves greater CO_2 reductions in most energy sectors



Source: OnLocation OL24-NEMS

U.S. Primary Energy Consumption

- Updated policies and regulations and lower technology costs result in a more rapid phase-out of conventional fossil fuels in favor of renewables and electric vehicles, in the EH Ref compared to AEO.
- Total consumption is higher in the EH case primarily due to higher growth in electricity sales.



Source: OnLocation OL24-NEMS

OL EH Reference and Advanced Technologies Scenarios

OL EH Advanced Technologies Scenario

Scenario highlights model enhancements focused on CO_2 mitigation technologies:

- **CO_2 capture options** in industry
- **Hydrogen markets**
- **Direct Air Capture (DAC)** technologies
- **Bioenergy with CO_2 capture** in power and liquid fuels
- **Sustainable Aviation Fuel**

Assumed CO_2 price incentivizes deployment of direct air capture and clean hydrogen

Transition to advanced technologies with lower costs than OL EH Reference case

Greater consumer acceptance of new technologies, electrification, and energy efficiency

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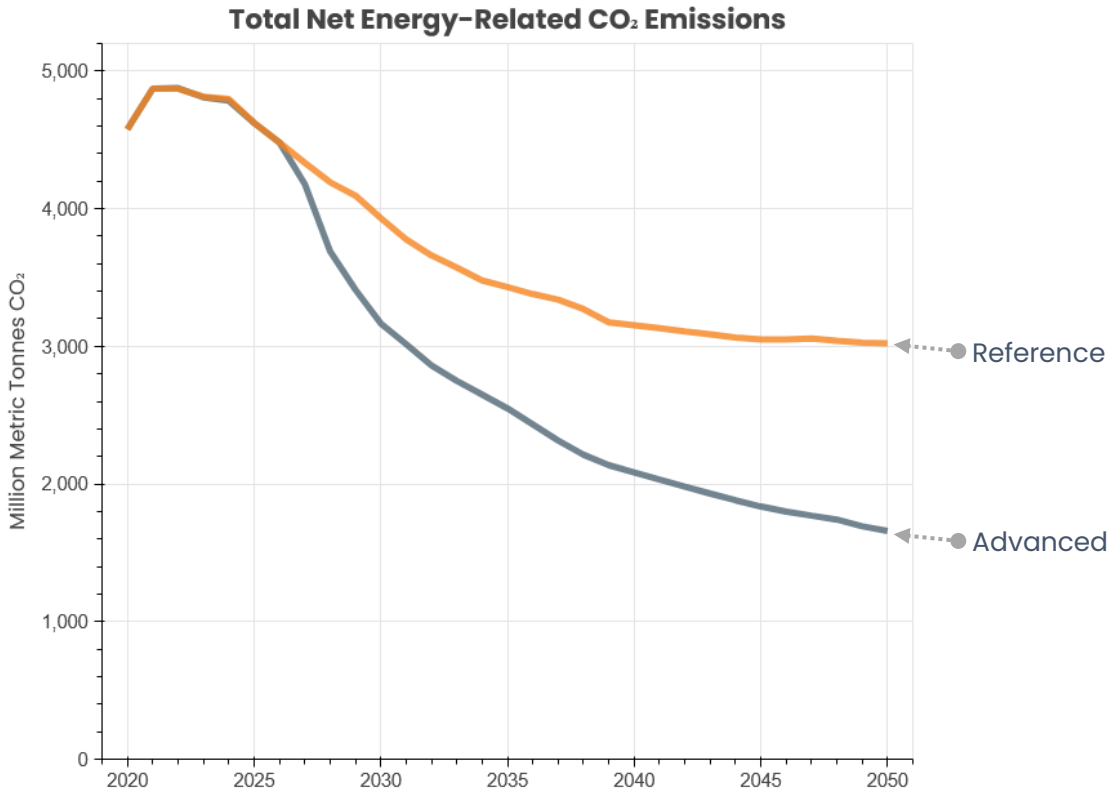
CO_2 Emissions: Economy-wide by Sector



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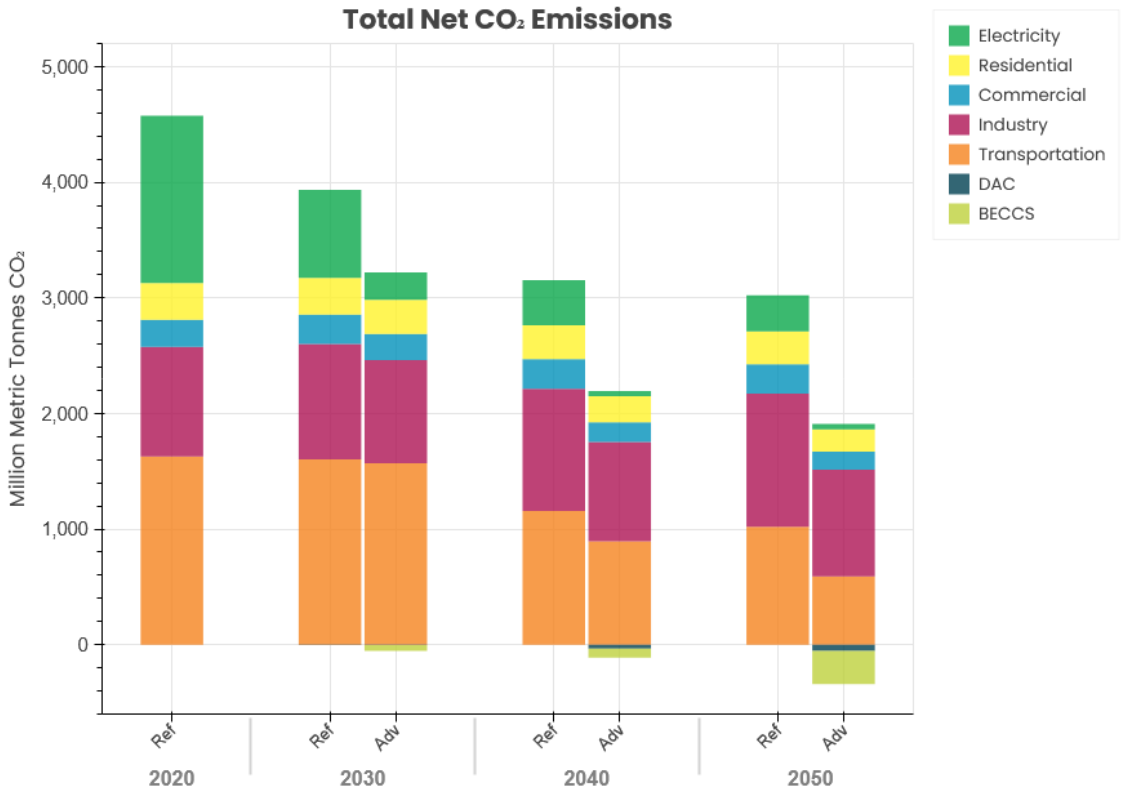
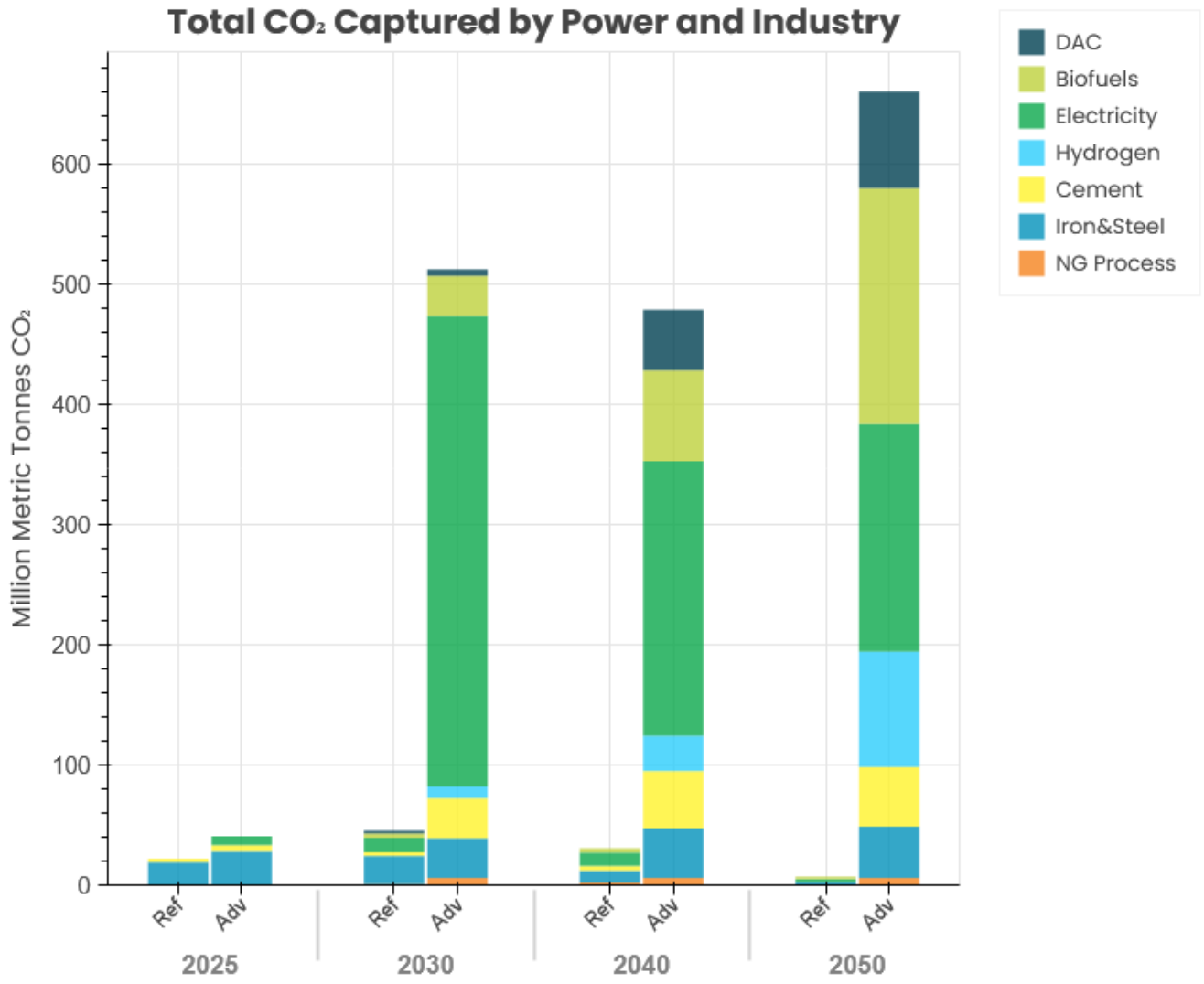


Source: OnLocation OL24-NEMS

- In Advanced Tech case, net CO_2 emissions are significantly lower than Reference case. Power sector achieves net zero CO_2, and some emissions are offset by net negative emissions from DAC and BECCS.
- Industry and transportation account for most of remaining emissions in 2050 in both cases.

Total CO_2 Captured in Power and Industry

- Carbon capture and storage (CCS) adoption is significantly higher in Advanced Tech case in power and several industrial processes compared to Reference case.
- In the Reference case, CO_2 capture declines by 2040 as Inflation Reduction Act 45Q sequestration credits end.
- In contrast, total CO_2 capture, especially Direct Air Capture and BECCS in industry, hydrogen, and biofuels, continues to grow in the Advanced case supported by the assumed CO_2 price.

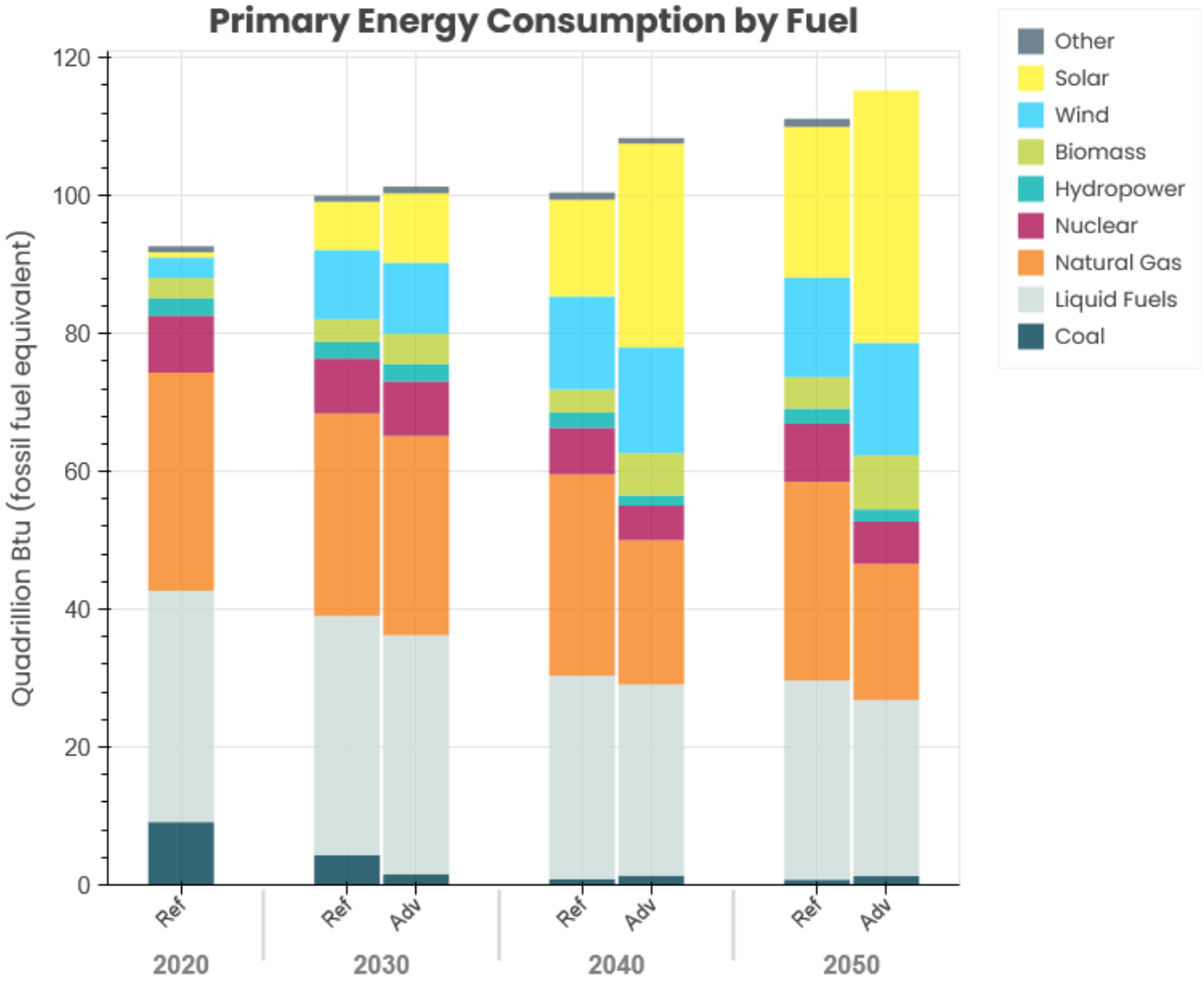


Source: OnLocation OL24-NEMS

U.S. Primary Energy Consumption

- Advanced technology costs and higher fossil fuel costs due to CO2 prices result in even greater shifts from fossil fuels to renewables and electrification in all energy sectors.

- Biomass consumption increases in later years due to greater use of biofuels in transportation and bioenergy with CO2 capture (BECCS) in industry, power, and hydrogen production.

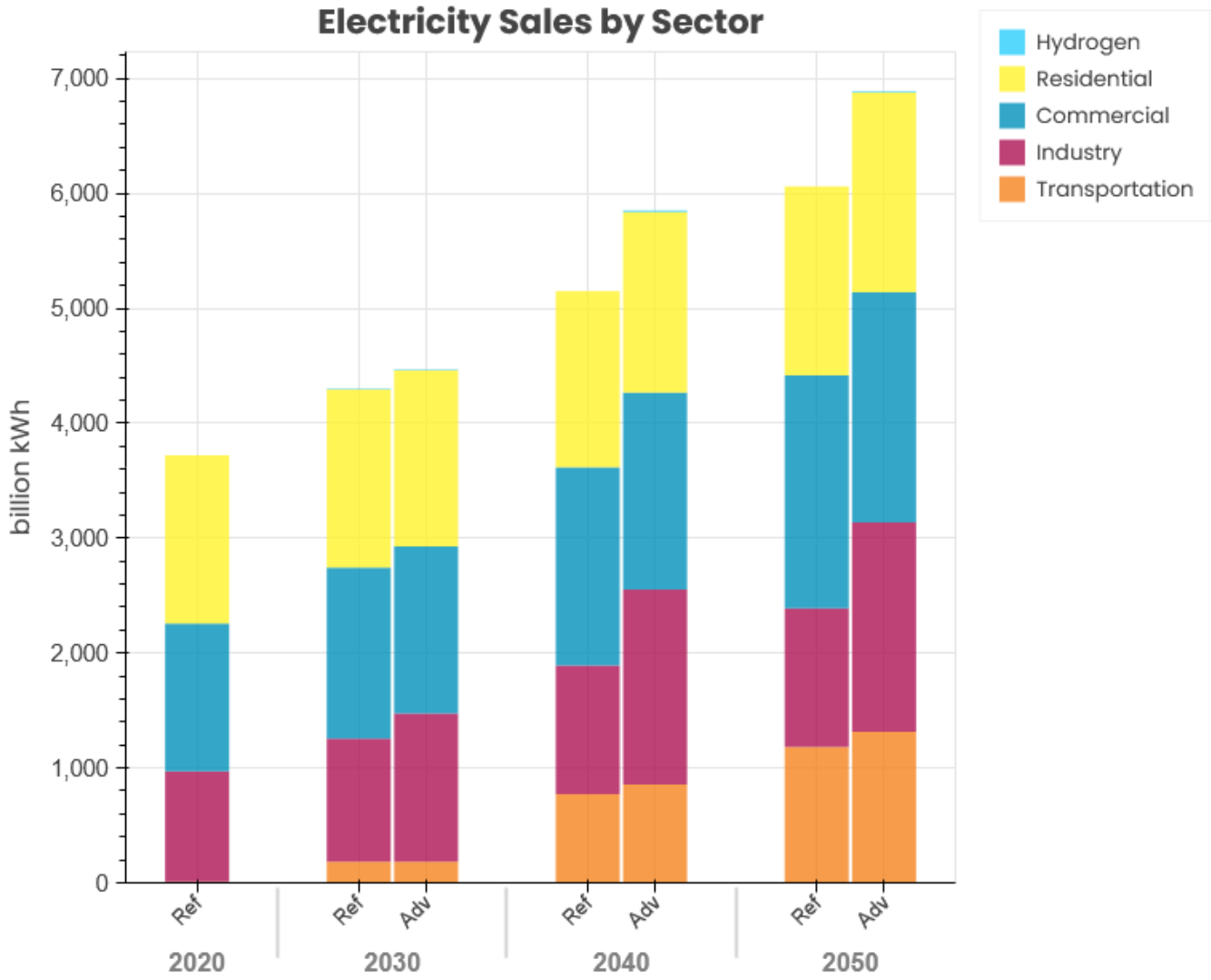


Source: OnLocation OL24-NEMS

Electricity Consumption

- Increasing electrification occurs in all energy sectors in the Advanced Tech case due to greater consumer acceptance of electric technologies, increasing electrification in industry, and new regulations that promote electric vehicles.

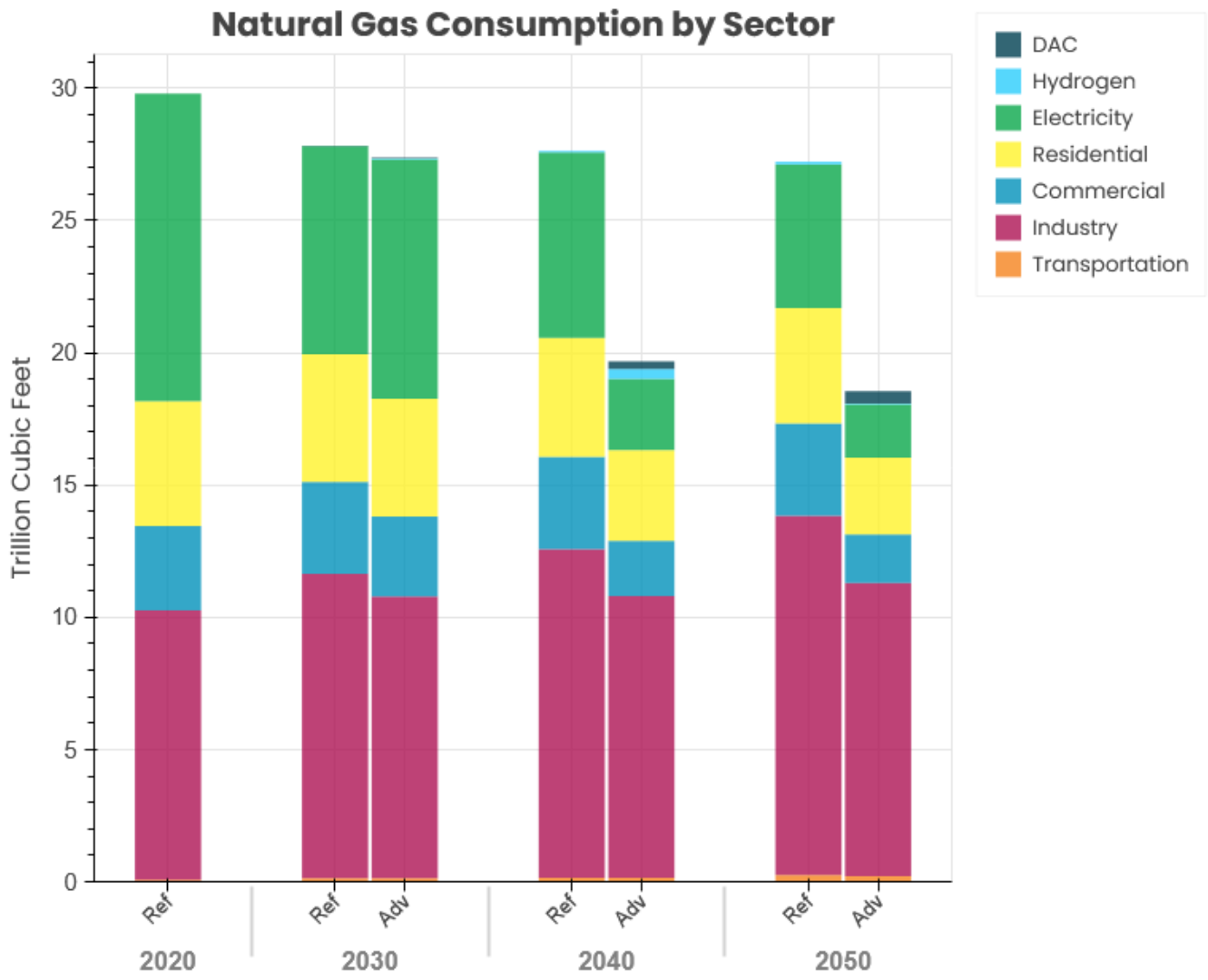
- In both cases, continued growth of data centers results in higher commercial electricity sales over time.



Source: OnLocation OL24-NEMS

Natural Gas Consumption

- By contrast, natural gas consumption declines significantly in all sectors due to electrification, energy efficiency, and greater adoption of renewables.
- Some of the remaining natural gas consumed includes CO_2 capture in power sector, hydrogen production, and direct air capture (DAC).

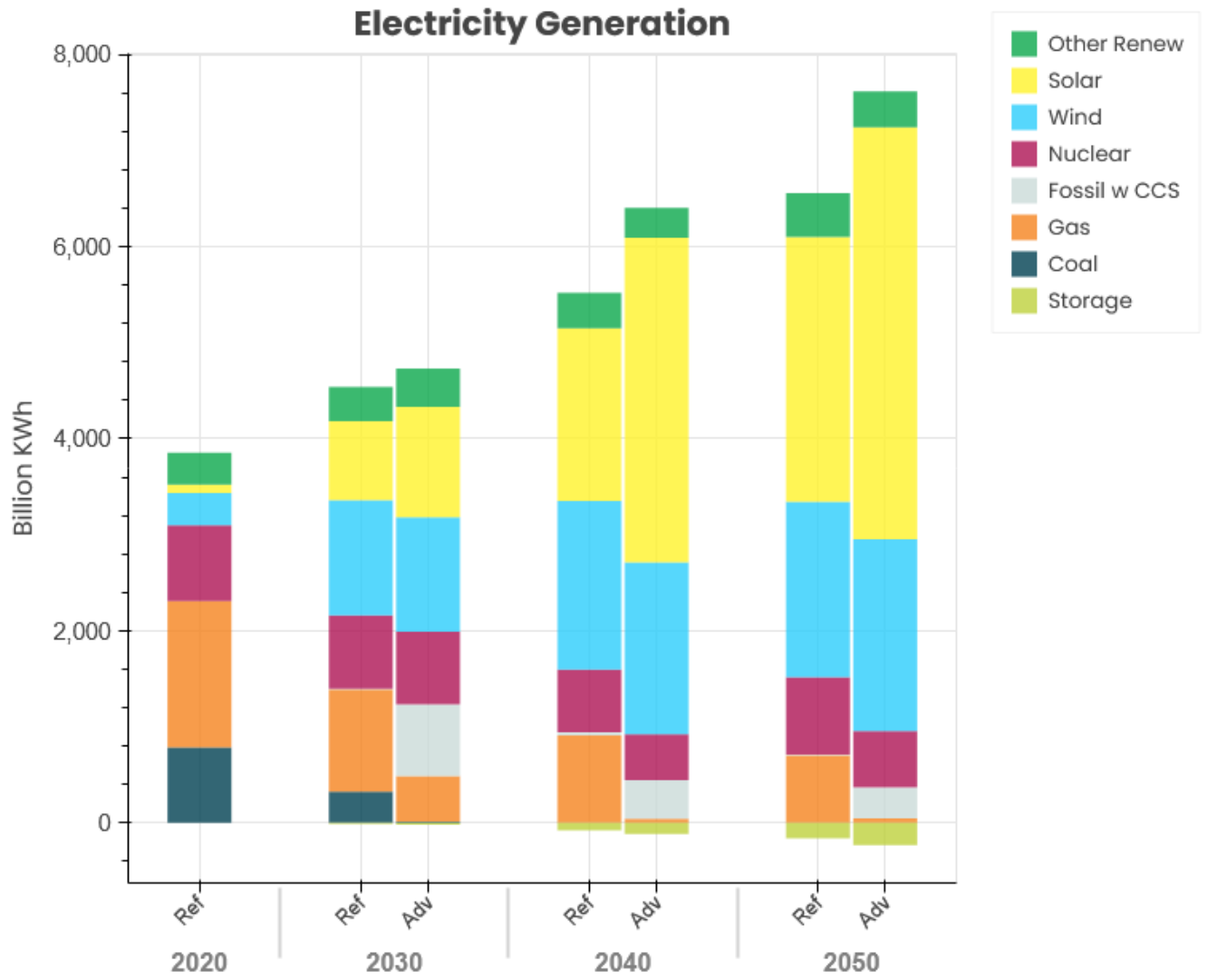


Source: OnLocation OL24-NEMS

OL EH Scenario Results: Power Sector

Electricity Generation

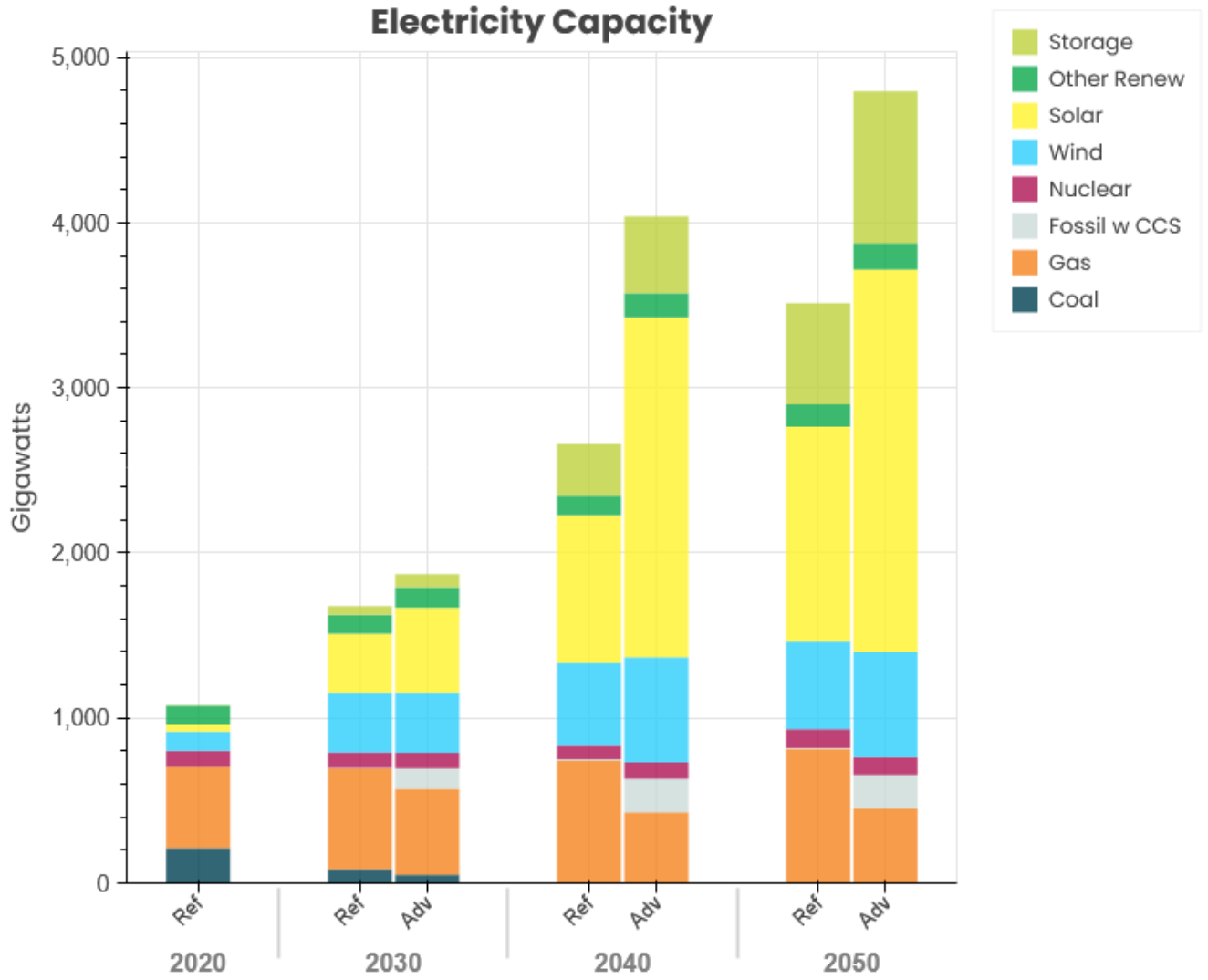
- Power sector achieves net zero CO_2 emissions by 2040 in Advanced Tech case due to an increasing share of generation from renewables and CO_2 capture technologies that displace conventional fossil generation.
- Electricity generation is higher in Advanced Tech case due to greater electrification in the demand sectors.
- Coal generation without carbon capture retires after 2039 due to EPA greenhouse gas standards.



Source: OnLocation OL24-NEMS

Electricity Capacity

- Greater investment in clean technologies displaces most conventional fossil capacity by 2050 in both cases.
- This additional investment is driven by low renewable costs and IRA tax credits in both cases, and by greater electricity demand and the assumed CO_2 price in the Advanced case.
- Remaining natural gas capacity without capture is primarily used to maintain grid reliability.



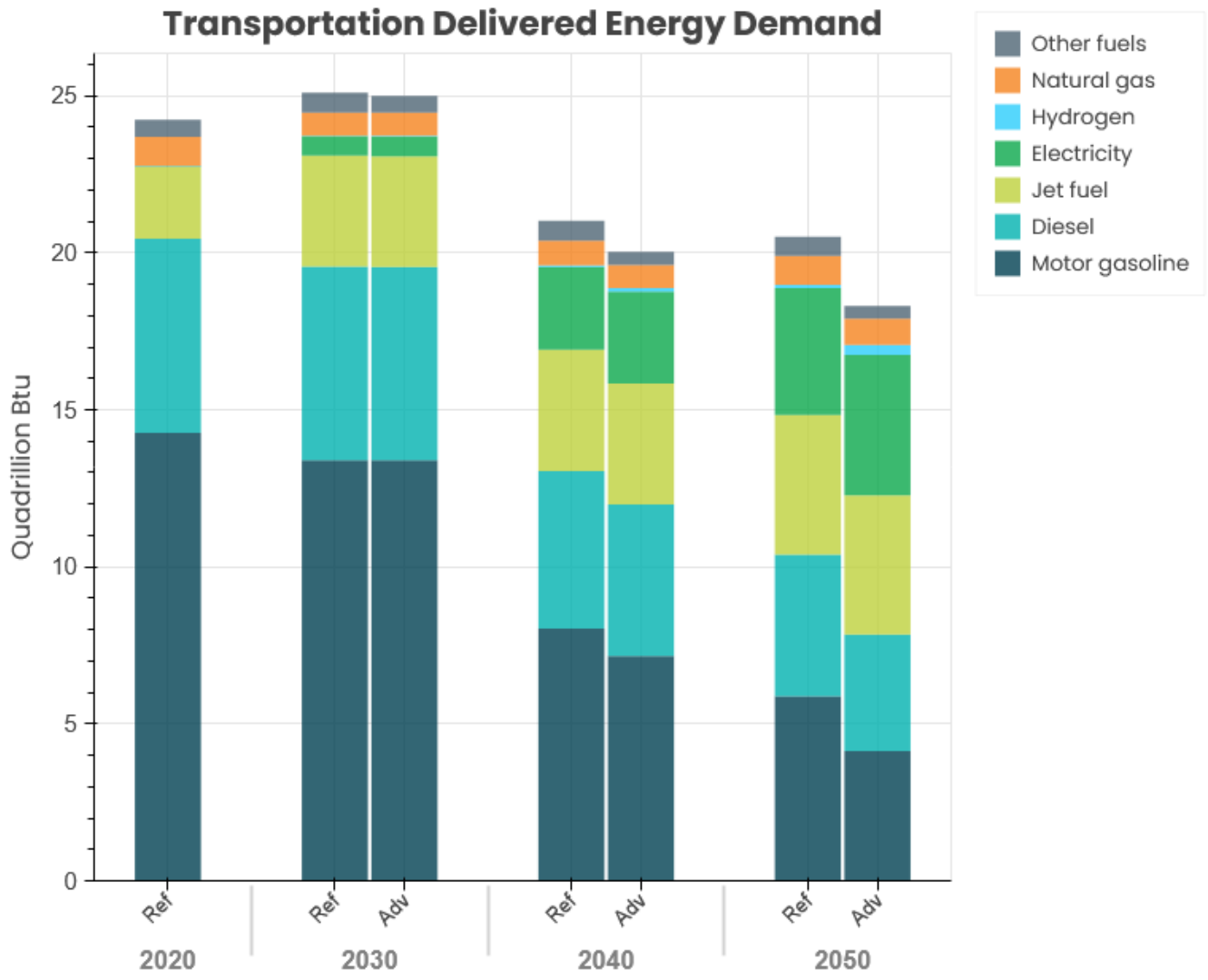
Source: OnLocation OL24-NEMS

OL EH Scenario Results: Transport Sector

Transportation Energy Demand

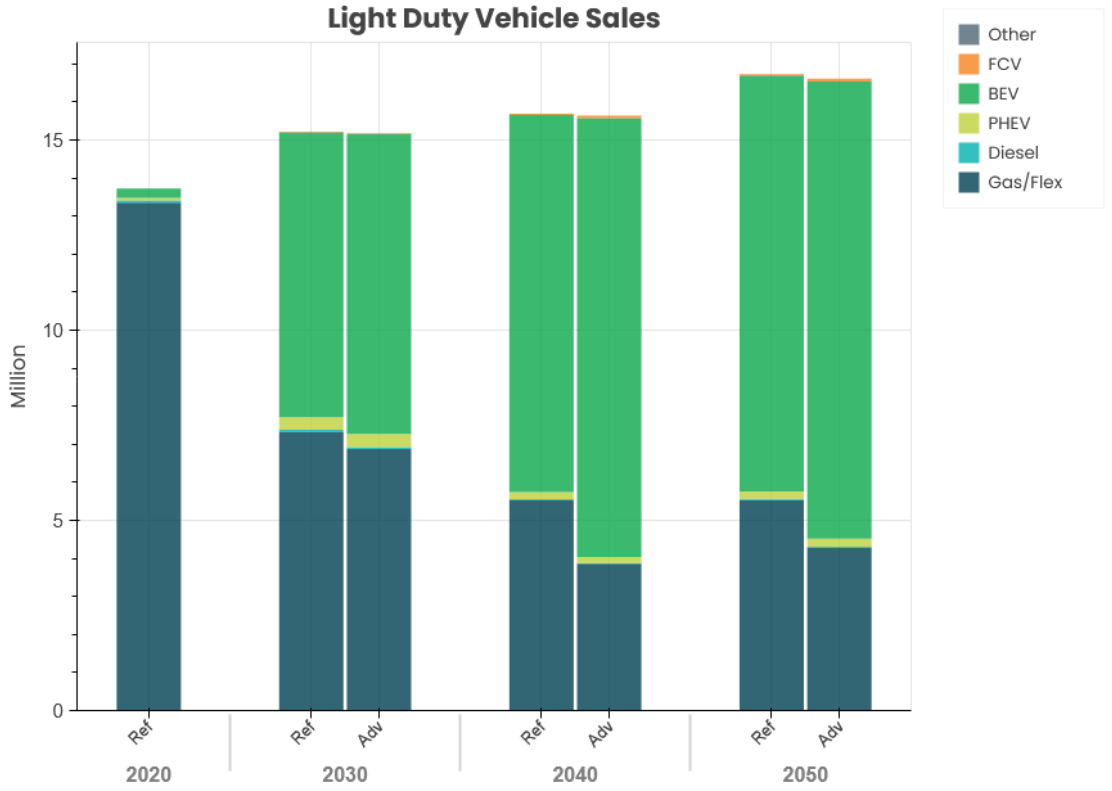
- Transportation energy demands decline over time in both cases due to vehicle electrification and increased fuel economies driven by:
  - Technology improvements
  - Tax credits
  - Federal and state regulatory policies

- Greater demand reductions occur in Advanced Tech case relative to Reference case in response to CO_2 prices as well as lower-cost electric vehicles.



Source: OnLocation OL24-NEMS

Vehicle Sales



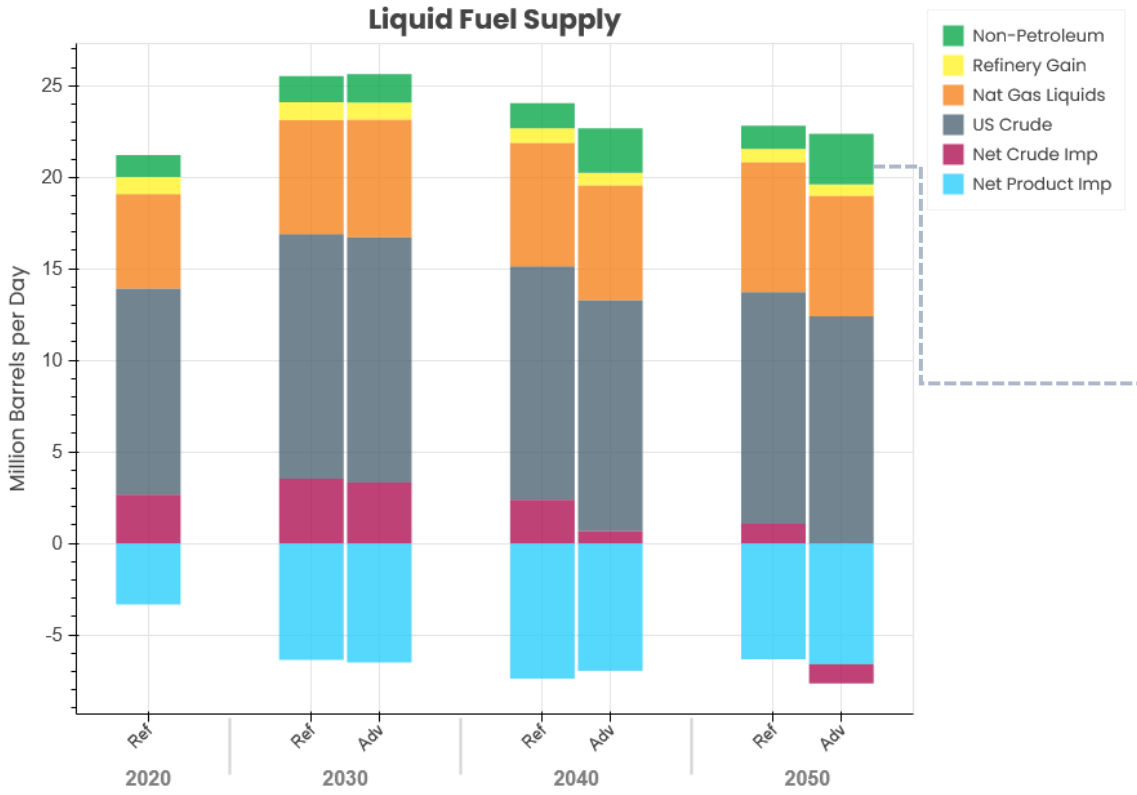
Source: OnLocation OL24-NEMS

Source: OnLocation OL24-NEMS

- Sales of electric vehicles increase significantly as tailpipe GHG standards and state mandates become more stringent through 2035; EV cost declines and tax credits also support sales in this period.
- In the Advanced Tech case, EV shares increase further in the longer term, as well as fuel cells in heavy trucks.

Note: the scales are different between the two charts.

Liquid Fuels including Biofuels



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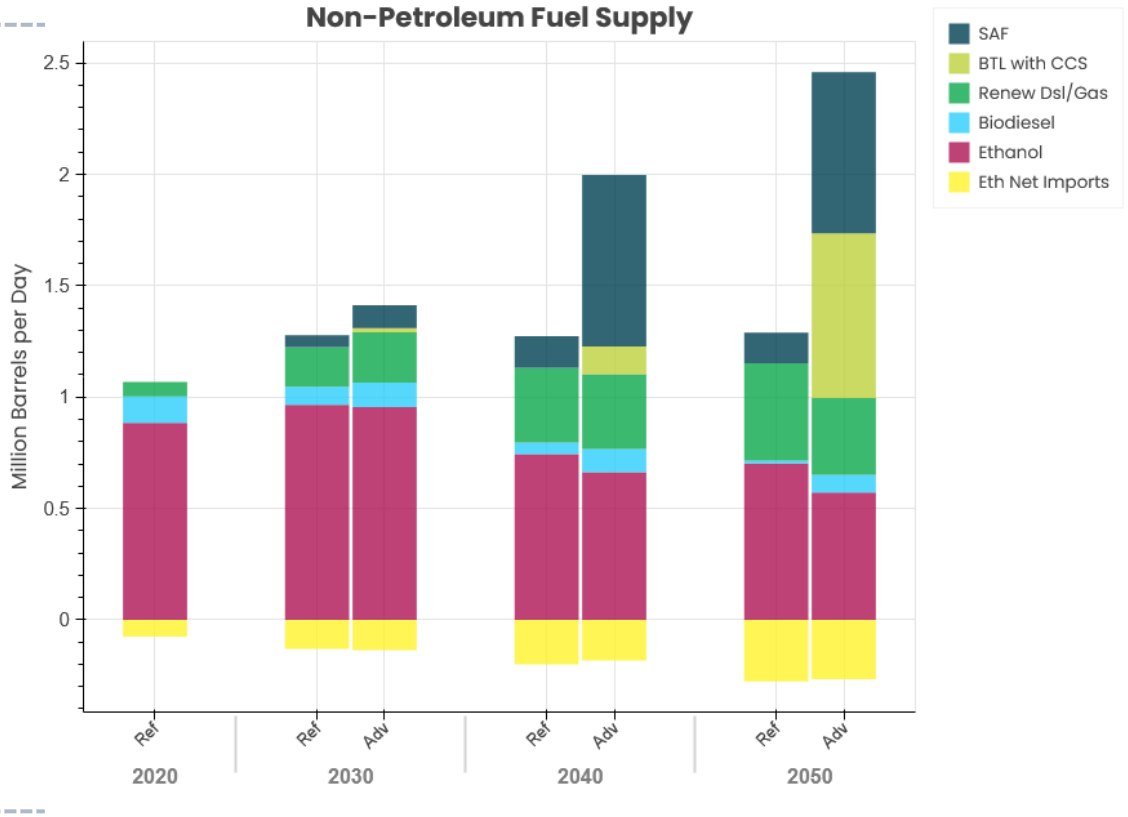


Source: OnLocation OL24-NEMS

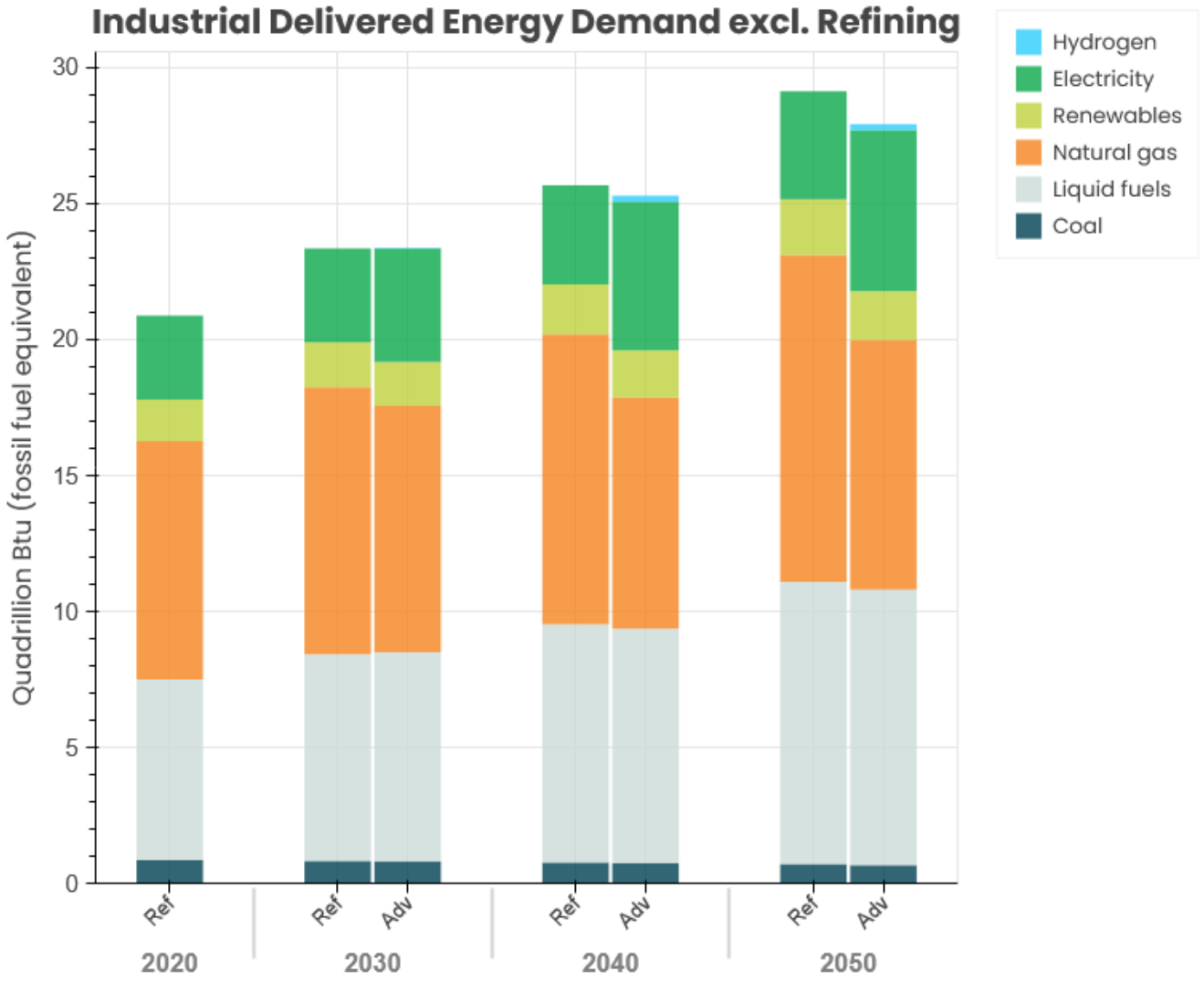
- Liquid fuel supply and demand shrink over time due to increased vehicle electrification.
- In the Advanced Tech case, non-petroleum sources expand.
- Sustainable Aviation Fuel (SAF) and Biomass-to-liquids with carbon capture (BTL w/ CCS) are key technologies decarbonizing liquids fuels in Advanced Tech case, along with more traditional ethanol CCS.

Note: the scales are different between the two charts.

OL EH Scenario Results: Industrial Sector

Industry Energy Use Excluding Refining

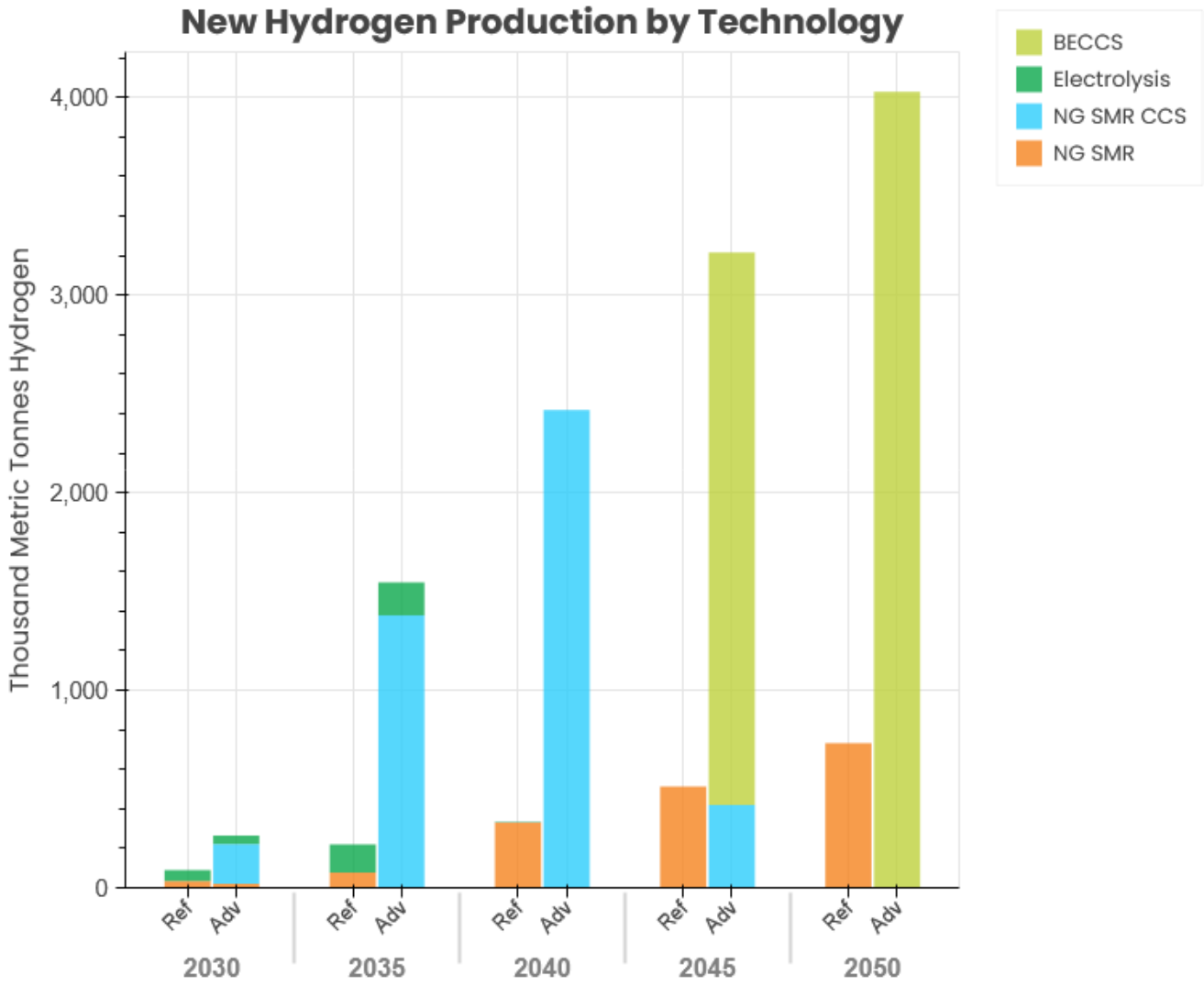
- In Advanced Tech case, higher rates of electrification lead to lower fossil fuel, especially natural gas, and higher electricity consumption.
  - Particularly in bulk chemicals, food, metal durables and non-manufacturing industries.
- Additional energy consumption for carbon capture is relatively minor.



Source: OnLocation OL24-NEMS

Hydrogen Production

- New hydrogen demand In the Reference case is met by conventional NG SMR and some electrolysis when the IRA 45V credits are available.
- In Advanced Tech case, demand is met mostly by NG SMR with CCS in early years and by BECCS in later years when available and after 45Q credits expire.

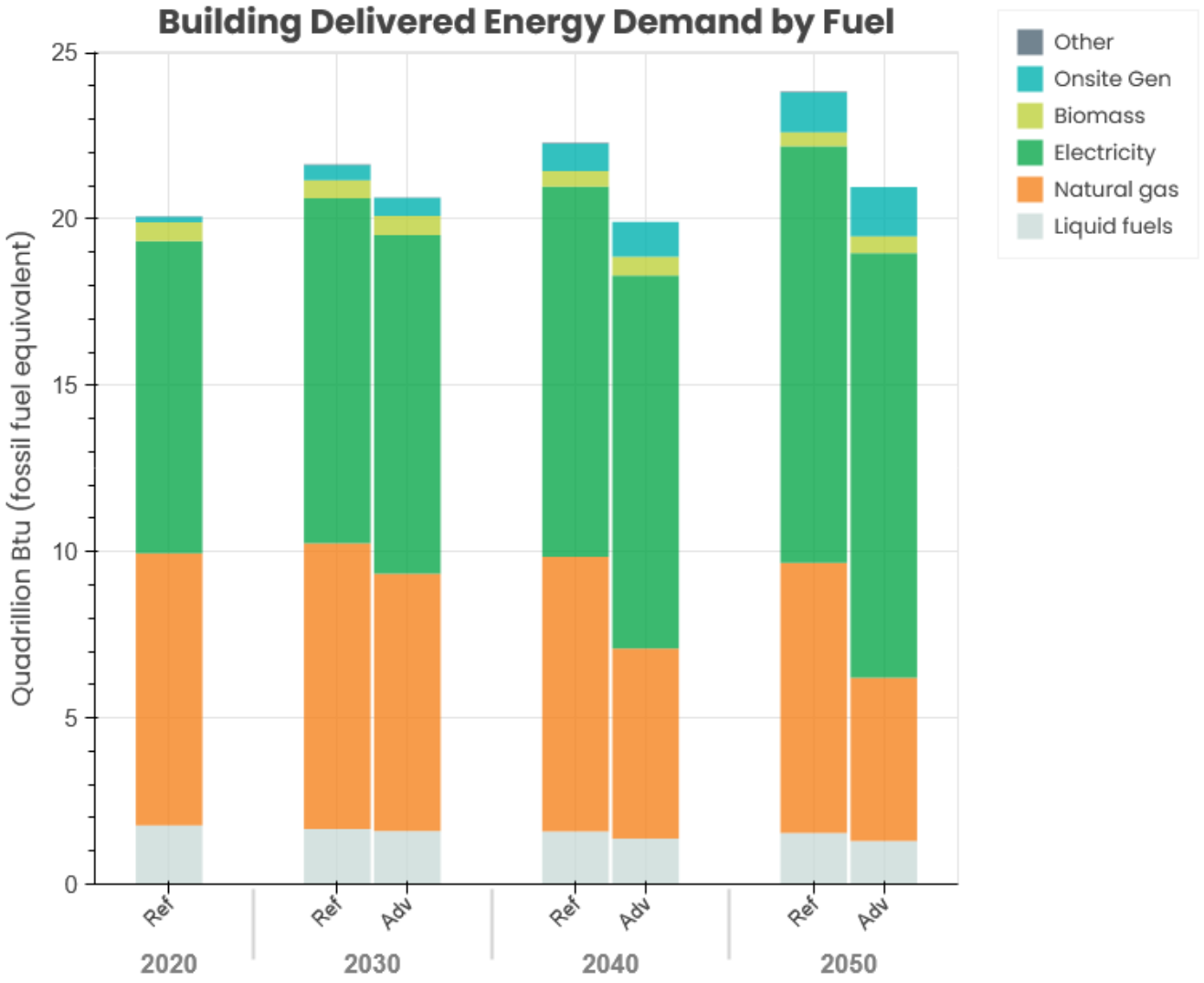


Source: OnLocation OL24-NEMS

OL EH Scenario Results: Buildings Sector

Buildings Sector Energy Consumption

- While energy consumption rises in the Reference case, a combination of electrification and energy efficiency lowers fossil fuel consumption and total energy consumption over time in the Advanced Tech case.
- Growth in commercial electricity demand in both cases partially due to the rapid growth in data centers.
- Both cases also include recently enacted appliance standards.



Source: OnLocation OL24-NEMS

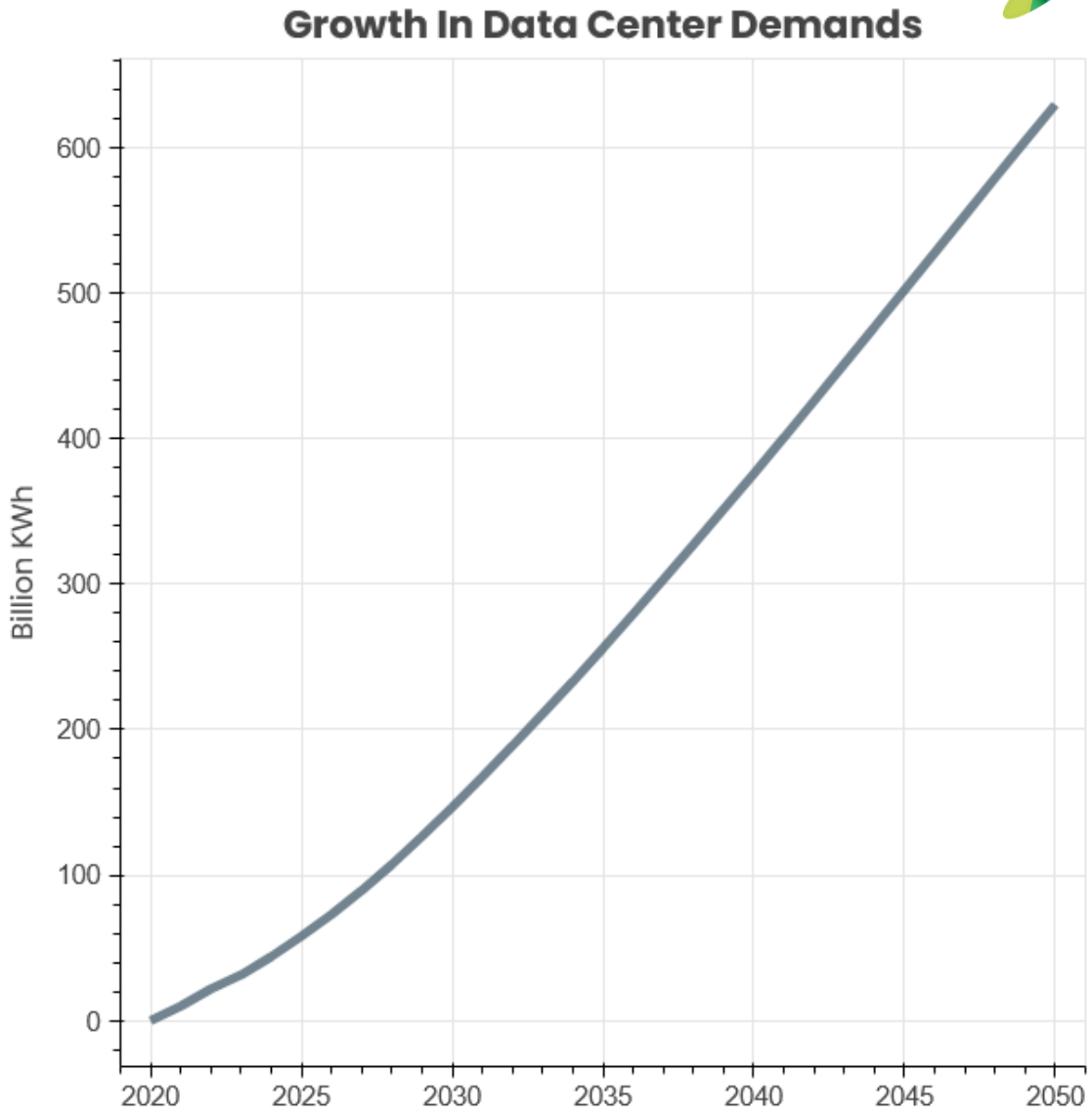
Buildings Sector Electrification

- In the Reference case, the shares of residential heating technologies are relatively constant with a modest shift towards more electric heat pumps.
- In the Advanced Technology case, the adoption of electric heat pumps steadily increases over time, replacing fossil fuel consuming equipment, primarily natural gas furnaces.

Source: OnLocation OL24-NEMS

Data Centers

- Electricity demands of data centers have been growing rapidly in recent years.
- Pace of continued growth is highly uncertain.
- Energy Horizons Reference case includes growth of roughly 630 TWh over next 30 years with centers becoming almost a third of commercial electricity demand by 2050.
- Follow-on report focused on Data Center Energy Demand (AI & cryptocurrency) to be released in September 2024.



Source: OnLocation OL24-NEMS

Recap of OL EH Results

Clean Technologies and Enabling Policies reduce CO_2 emissions over time in the U.S. energy system

Additional R&D leading to new and lower cost clean technologies assumed in the Advanced case

All Energy Sectors Contribute:

- **Power:** Renewables, CO_2 Capture
- **Transportation:** Electric Vehicles, Biofuels
- **Industry:** Electrification, Hydrogen, CO_2 Capture
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Decarbonizing the Electric Grid facilitates emission reductions in other sectors

CO_2 Removal Technologies also play a role

Caveats

Scope

1. **Energy Sector Coverage**: While comprehensive, certain emerging sectors (like energy storage technologies beyond batteries or advanced nuclear technologies) might not be fully represented.
2. **Time Horizon**: The projections extend to 2050, and longer-term implications beyond this period are not considered.
3. **Technological Developments**: Assumptions about future technological advancements and their adoption rates are speculative and subject to significant uncertainty.
4. **Modeling Challenges**: As with all models, OL-NEMS is an economic abstraction of the energy industry and may not fully reflect the complexities associated with significant energy transitions including electric grid reliability and infrastructure buildout.

Framework

1. **Model Enhancements and Updates:** The model includes several enhancements over the AEO 2023 baseline, such as improved CCS, DAC, and hydrogen market representations. These enhancements are based on current knowledge and might need revision as new data becomes available.
2. **Policy Assumptions:** Assumes continuation and full implementation of current laws and regulations. Any changes in policy direction could significantly alter projected outcomes.
3. **Economic Assumptions:** Macroeconomic growth rates, crude oil prices, and other economic parameters are based on current projections and could vary with economic fluctuations. Macroeconomic Implications in the Advanced Technologies Scenario were not considered.
4. **Consumer Behavior**: Assumptions about consumer acceptance of new technologies, such as electric vehicles, are based on analyst judgement and may not materialize as expected.

Advanced Scenario Assumptions

1. **CO_2 Price Trajectory**: The economy-wide CO_2 price trajectory, reaching $330 per metric tonne CO2 by 2038, was used to demonstrate deployment of climate mitigation technologies. It is not a proxy or advocation for any new energy or climate policies.
2. **Technology Costs**: The assumed reductions in technology costs, especially for renewables, EVs, and CCS, are based on optimistic R&D outcomes and learning rates which might not be realized.
3. **Energy Efficiency Improvements**: The assumptions about energy efficiency improvements across various sectors are optimistic and depend on sustained policy support and technological breakthroughs.
4. **Electrification and Fuel Switching**: The rate of electrification and fuel switching in buildings and industry sectors depends on overcoming significant infrastructural, technical, and market barriers.
5. **Hydrogen Adoption**: The demand for hydrogen in transportation and industry assumes rapid development of hydrogen infrastructure and favorable economic conditions for hydrogen production and distribution.

OnLocation Report & Analysis Team

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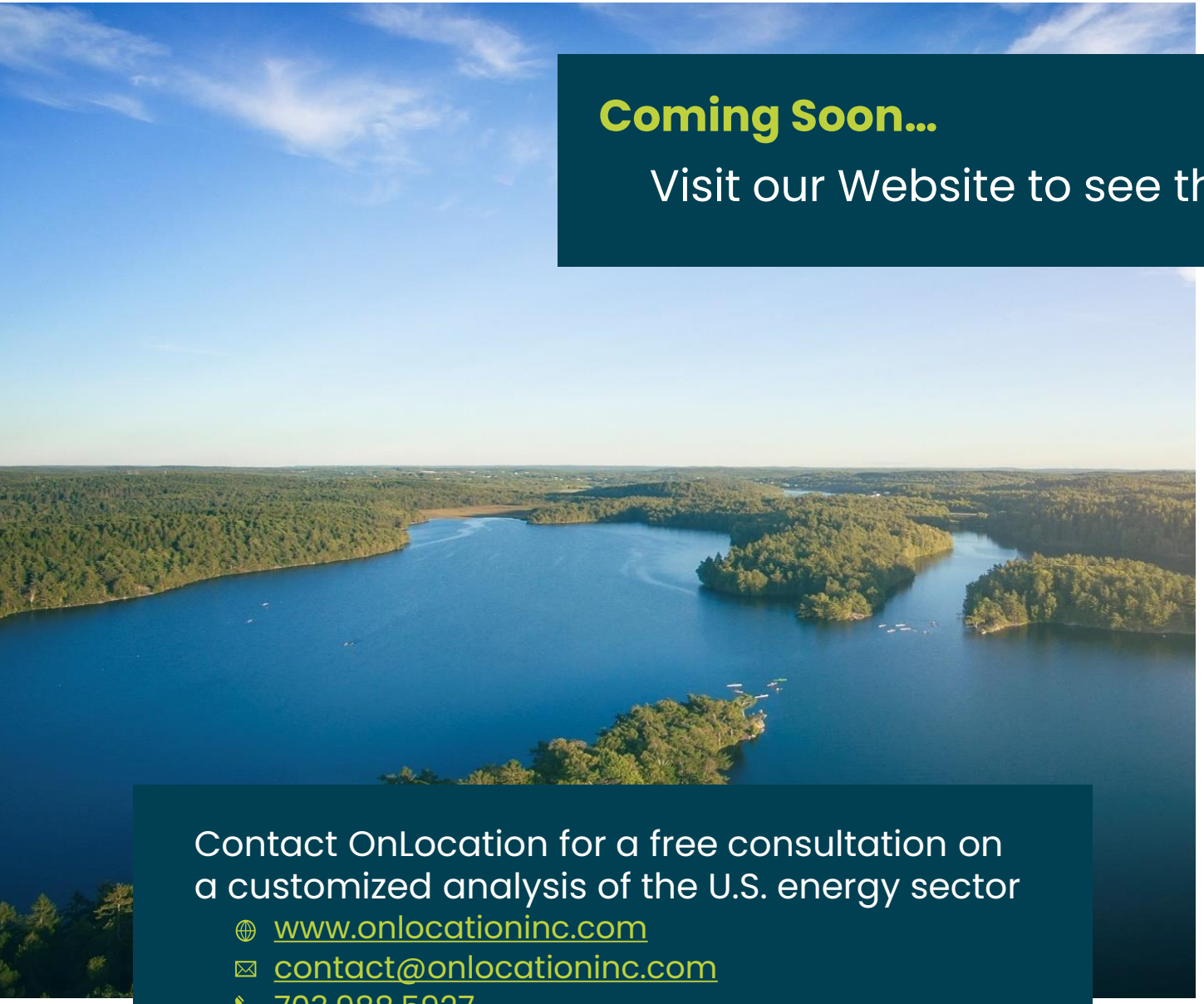
- Jessica Winter, Head Of Creative Production & Virtual Services
- Sarah Doyle, Technical Director
- Eric Bugash and Adam Sese, Technical Team

TeamPeople www.teampeople.tv



Coming Soon...

Visit our Website to see the **Webinar Recording & Full Report**

Follow-On Energy Horizons Reports, 2024

Data Center (AI & Crypto) Energy Demands September 2024

Employment Impacts of the U.S. Energy Transition November 2024

Critical Materials Demands of the U.S. Energy Sector (*Update to Sept 2023 Report*) November 2024

Contact OnLocation for a free consultation on a customized analysis of the U.S. energy sector

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