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Introduction





Contractor Team Overview

 VERDANT



EVOLVED
ENERGY
RESEARCH





Overview of Contractor Team Presentation

- High-level overview of the tools and methodologies used in the Demand Scenarios Project
- Annual and hourly energy and greenhouse gas emissions results and trends through 2050 by scenario, fuel type, and sector
- Conclusions and key takeaways



Acronyms and Initialisms

BUGL – Burbank/Glendale Water and Power
CAISO – California Independent System Operator
CARB – California Air Resources Board
CC – Carbon Capture
CEC – California Energy Commission
CH₄ – Methane
CO₂ – Carbon Dioxide
CO_{2e} – Carbon Dioxide Equivalent
EAD – Energy Assessments Division
EER – Evolved Energy Research
EP – Energy Pathways
EPS – Enhanced Policy Scenario
GWP – Global Warming Potential
IEPR – Integrated Energy Policy Report
IID – Imperial Irrigation District
IPCC – Intergovernmental Panel on Climate Change
LADWP – Los Angeles Department of Water and Power
LD – Light-Duty (vehicles)
LCFS – Low-Carbon Fuel Standard

LPG – Liquefied Petroleum Gas
H₂ – Hydrogen
MKRP – Mojave Kern River Pipeline
MMT – Million Metric Tons
MPG – Miles per Gallon
MPGe – Miles per Gallon Equivalent
NCNC – Northern California Non-CAISO Planning Area
N₂O – Nitrous Oxide
OGV – Ocean-Going Vessel
OOS – Out of State (aviation)
PGE – Pacific Gas and Electric
POU – Publicly-Owned Utility
SCE – Southern California Edison
SDGE – San Diego Gas and Electric
SLCPs – Short-Lived Climate Pollutants
TBtu – Trillion British Thermal Units
TE – Transportation Electrification
VMT – Vehicle Miles Traveled



Methodology





About Energy Pathways (EP)

- An advanced accounting framework that is used to develop economy-wide energy demand scenarios
- User-defined measures that change the composition of energy demand on a sub-sector level over time
- Used for a small subset of energy demand in these scenarios
 - Mostly fuels other than electricity and natural gas
 - About 10% of total statewide energy demand
 - Other demand developed by the CEC
- Additional electricity and natural gas script to integrate annual and hourly energy demand data provided by CEC Staff with EP results



Energy Pathways Detail

- For fuel/sector combinations developed using EP, model structure adapts to available data
- EP can use equipment stock rollover, projected service demand, or projected energy demand at the subsector level
- For the limited set of fuel/sector combinations that EP was used for in this analysis, projections were developed based on energy demand only from CEC provided drivers

Data-dependent analysis structures

Energy demand

- Track energy demand based on projections adjusted to the appropriate geographic scale and magnitude
- Can modify projections with revised driver inputs
- Examples: cement, agriculture

Stock with service or energy demand

- Track the stock rollover of technology stocks and new sales ensure the fleet can meet the required service demand or energy demand
- Examples: light duty trucks, res. water heating

Service with energy demand or efficiency

- Track service demand, either tracking projected energy demand or determining energy demand based on service efficiency
- Examples: aviation, iron & steel CO₂ capture



Multiple Scenarios from EP Customization

- Modified existing California geographic representation of each CEC planning area
- Incorporated CEC economic drivers of energy demand, including for industrial subsectors
- Calibrated model to previous demand scenario analysis
- Limited EP results to fuels and sectors not already addressed by CEC projections (see appendix for matrix of fuels/sectors using EP)
- Developed fuel switching and efficiency measures for ocean-going vessels and allocated minor transportation types (not previously disaggregated) to planning areas



Hourly Electricity Demand

- Verdant developed hourly profiles for POU planning areas where there were gaps in available CEC data
- EER developed a script to compile the numerous disparate hourly projections into a single projection
 - Hourly projections built from CEC and Verdant hourly projection files
 - Adjusts for planning area-specific losses
 - A number of TE subsectors are assumed to have flat hourly load profiles, and the script transforms the annual demand to flat hourly demand, including:
 - New aviation demand
 - Rail
 - Off-road transportation
 - Other new transportation electrification without a defined load shape



Limitations of Demand-Side Only Modeling

Because this is a demand-side only modeling effort, and these scenarios do not include energy supply, there are limitations to the results

- Energy amounts, types, and locations used to produce fuels for “retail” consumption are excluded in most cases
 - Energy consumption to generate electricity is excluded
 - Energy consumption to refine crude oil into imported petroleum products is excluded
 - Energy consumption to produce electrofuels and biofuels is excluded
- Some supply-side decarbonization measures not included in the analysis
 - Point-source carbon capture
 - Decarbonized fuel substitution for fossil fuels



Decarbonized Fuel Blending

- Decarbonized fuel supply not included in this demand-side analysis
 - Assumptions required for future decarbonization of fuel blends
- Scenarios assume today's level of gasoline, jet fuel, diesel, and natural gas decarbonization
 - Existing blending levels are calculated from the 2023 LCFS dashboard
 - Blending is held constant as a percent of total fuel demand through 2050
 - Because some fuels decline, the amount of decarbonized fuel consumed declines for some fuels (e.g., diesel fuel)



Bottom-Up Emissions Tool

- Excel spreadsheet using CARB fuel inventory emissions profiles to display all Demand scenarios
- Multiple Types of Emission Results
 - Statewide annual emissions in CO₂e from all fuels by sector and fuel type
 - Global warming impacts of fugitive methane and hydrogen
 - Display features that show 20-year and 100-year GWP timelines to help address SLCPs
 - Capability to assess multiple carbon emission reduction strategies (Fuel Blending, Hydrogen, CC)



Emission Factors Inputs

- Using real data to provide a robust forecast of future emissions profiles
 - Used CARB 2000-2021 Emissions Inventory data for CO₂, CH₄ and N₂O emissions profile as a function of energy consumption
 - CAISO projection of future electric power grid “Allowable Emissions” through 2050 used in the avoided cost calculator
 - Statewide grid average line loss values provided by CEC and projected through 2050
 - Inclusion of IPCC 2019 values of GWP values to produce CO₂e for trace gases (CH₄, N₂O and H₂)



Results





Summary of Results Produced

- Annual energy demand by fuel type and sector for all CEC Planning Areas through 2050
- Annual emissions results by fuel type for various scenarios
- Hourly electricity results by Planning Area



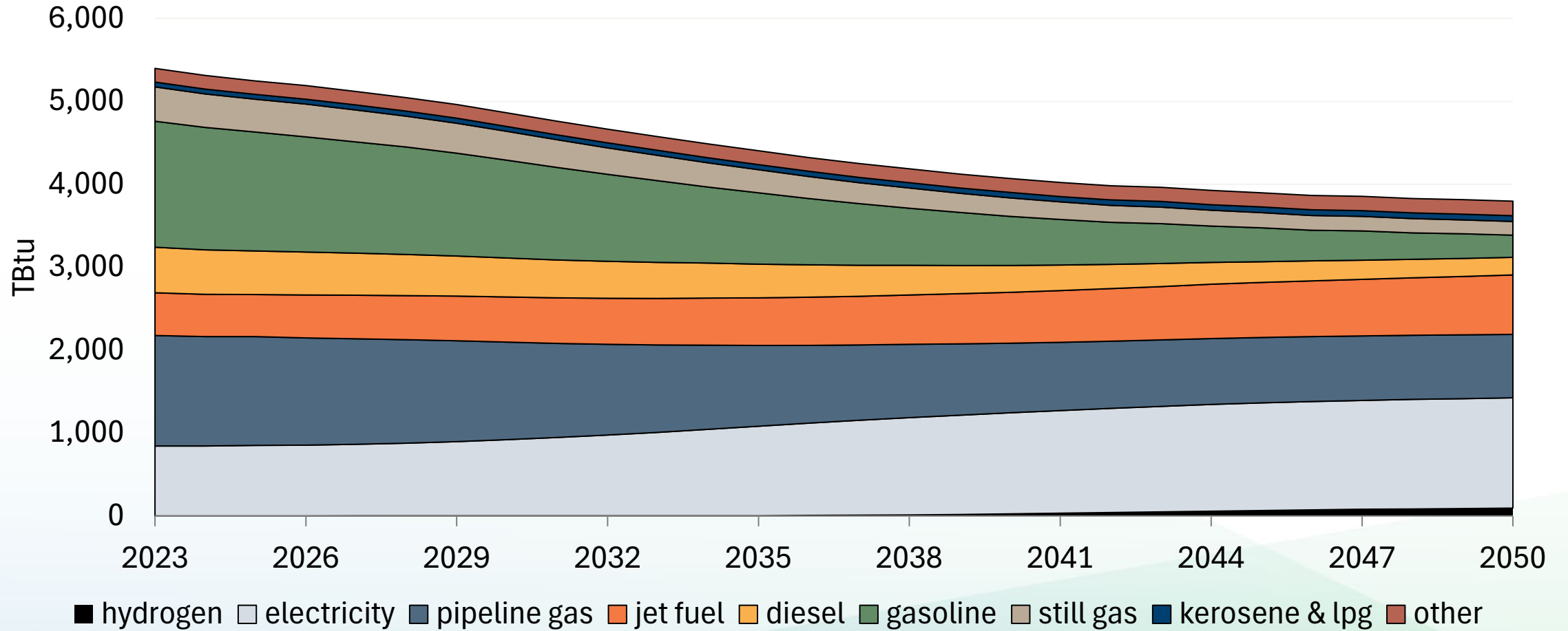
Annual Energy Results





Reference Scenario Statewide Energy Demand by Fuel

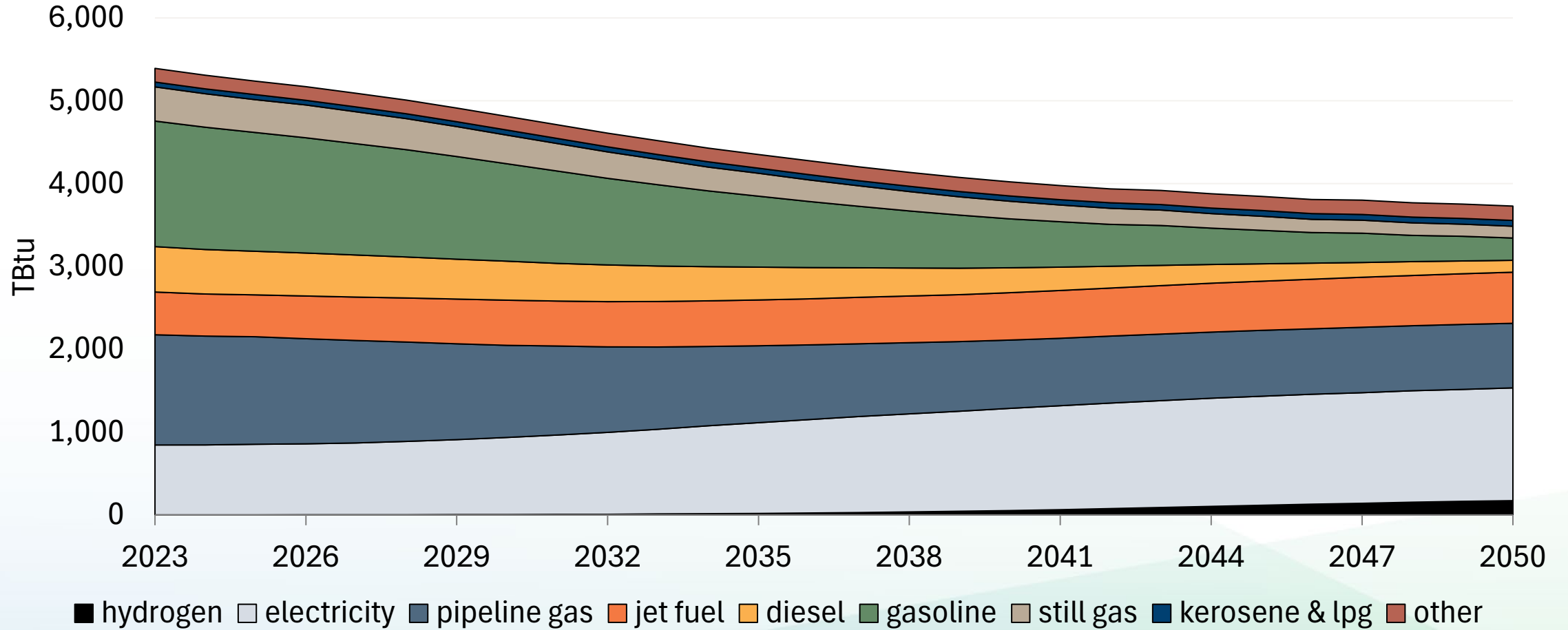
Reference Scenario Energy Demand by Fuel





Policy Scenario Statewide Energy Demand by Fuel

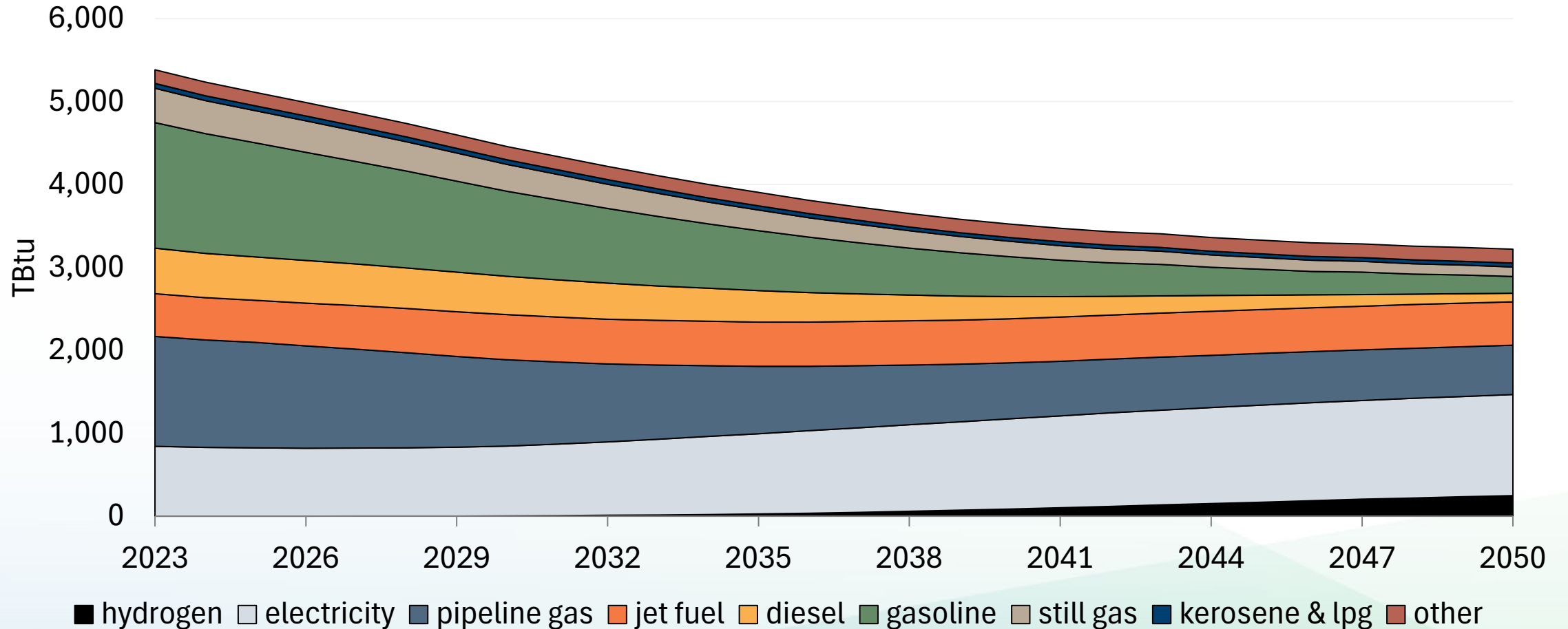
Policy Scenario Energy Demand by Fuel





Enhanced Policy Scenario Energy Demand by Fuel

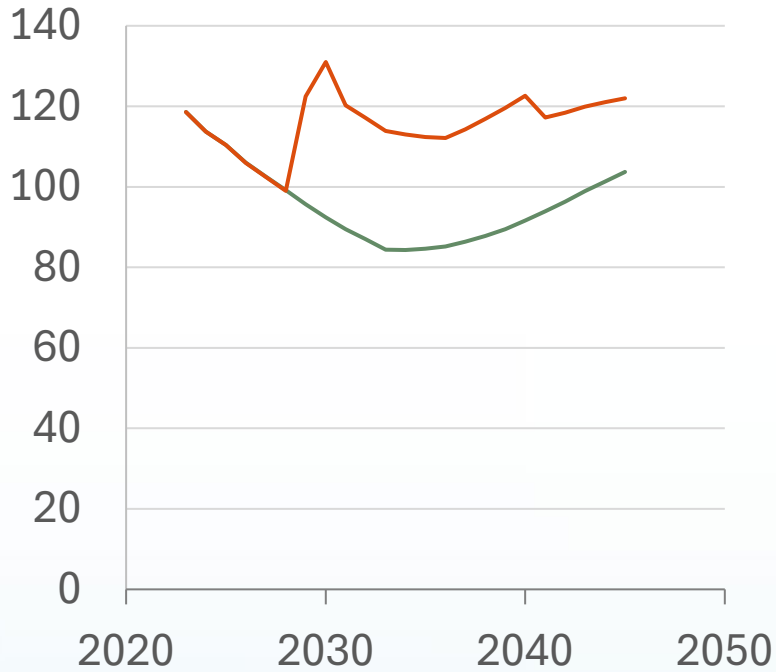
Enhanced Policy Scenario Energy Demand by Fuel





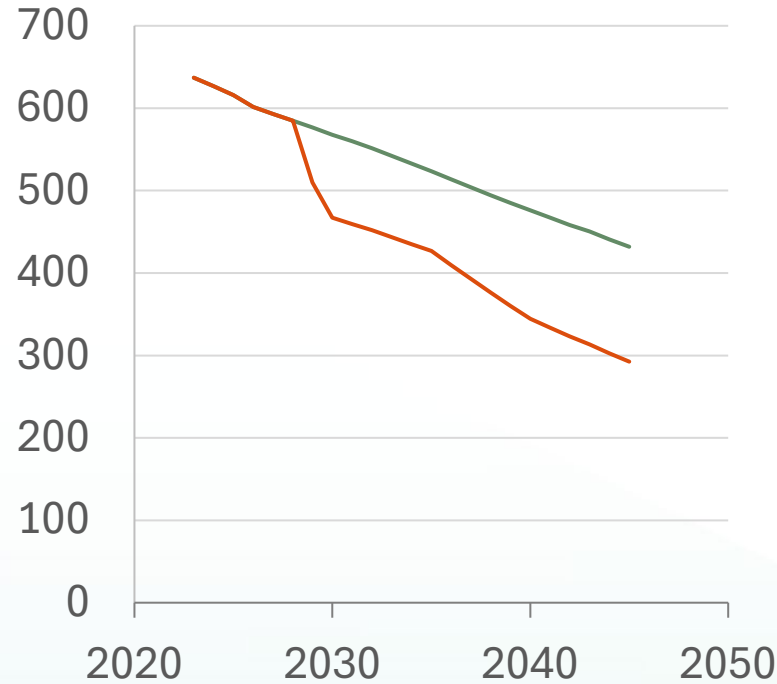
EPS Pipeline Hydrogen Sensitivity

Industrial Electricity Demand, TBtu



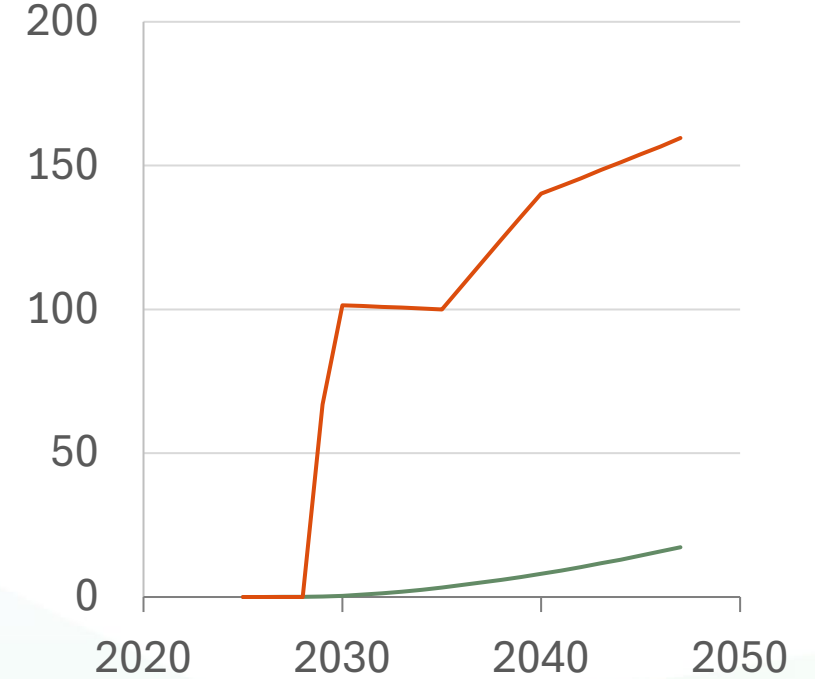
— Enhanced Policy scenario
— Enhanced Policy Hydrogen sensitivity

Industrial Pipeline Gas Demand, TBtu



— Enhanced Policy scenario
— Enhanced Policy Hydrogen sensitivity

Industrial Hydrogen Demand, TBtu

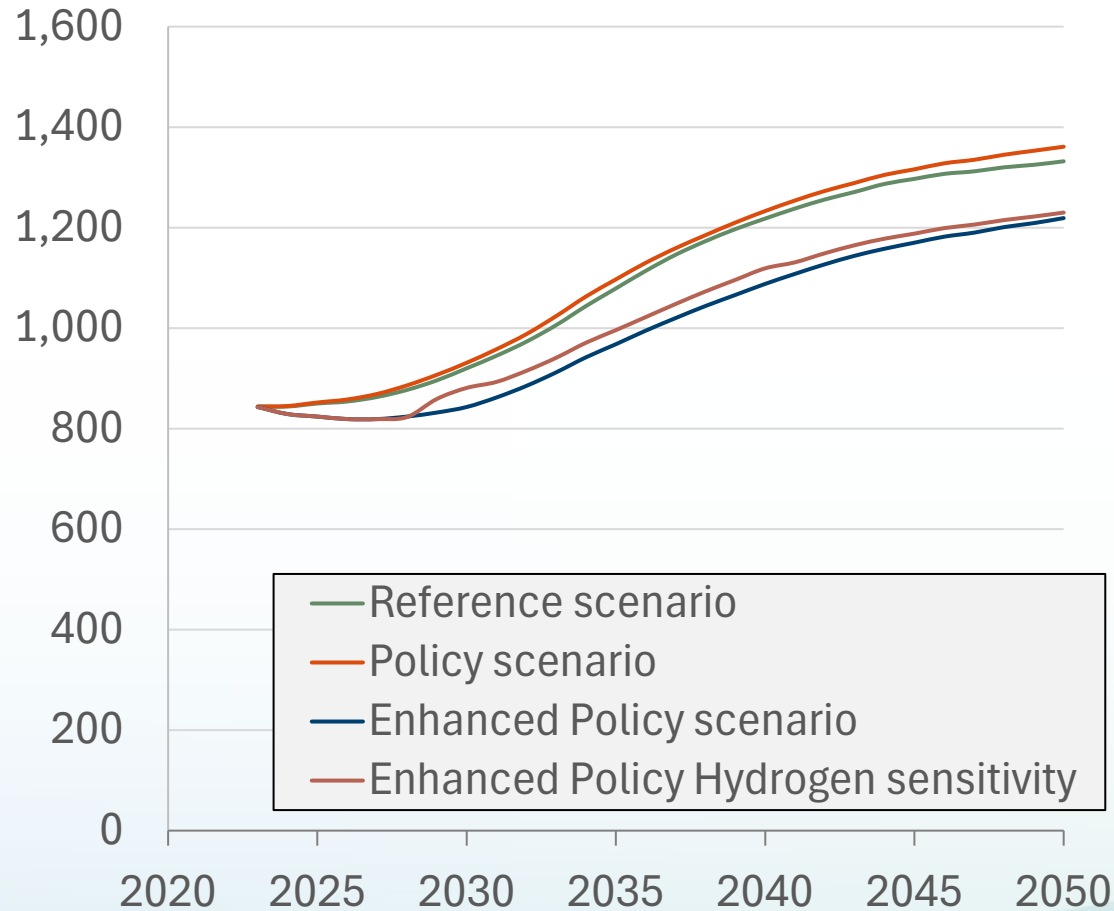


— Enhanced Policy scenario
— Enhanced Policy Hydrogen sensitivity

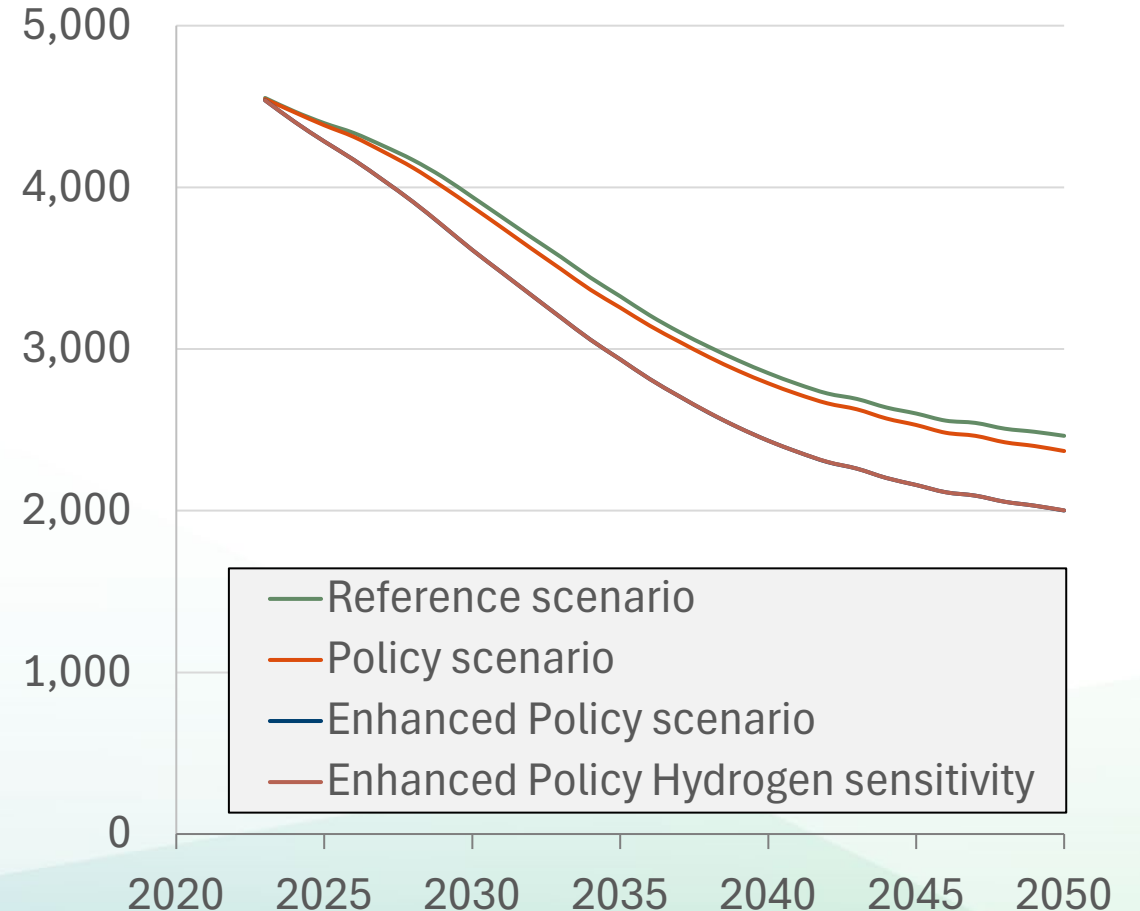


Annual Statewide Energy Demand

Statewide Electricity Demand, TBtu

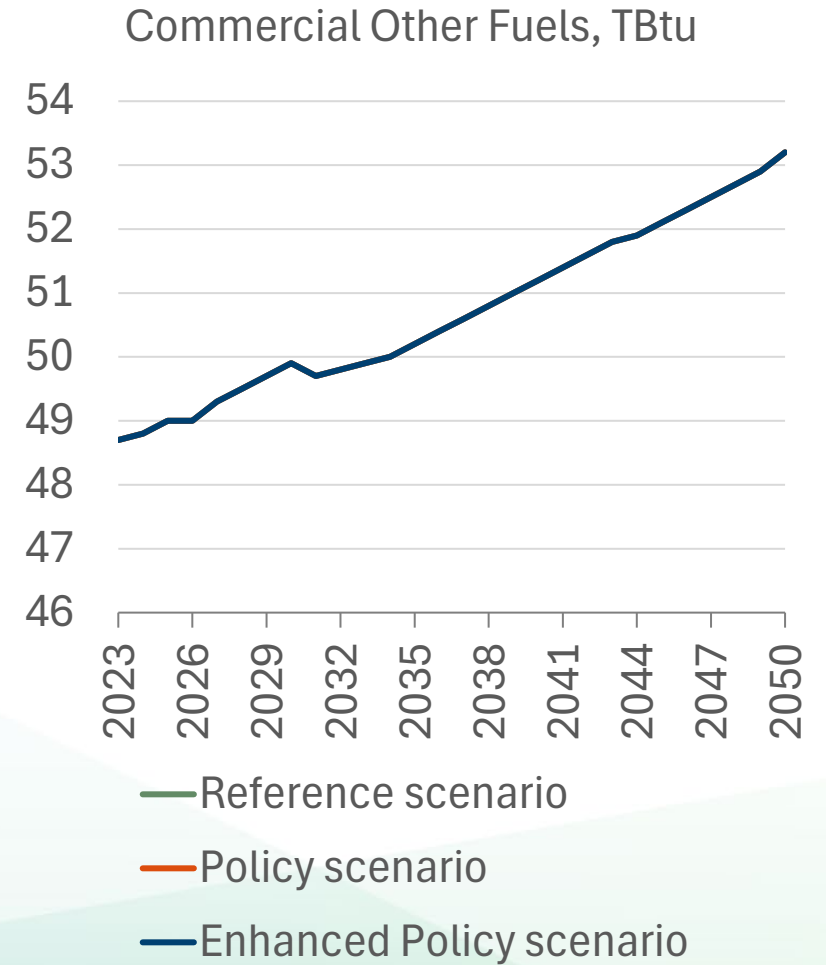
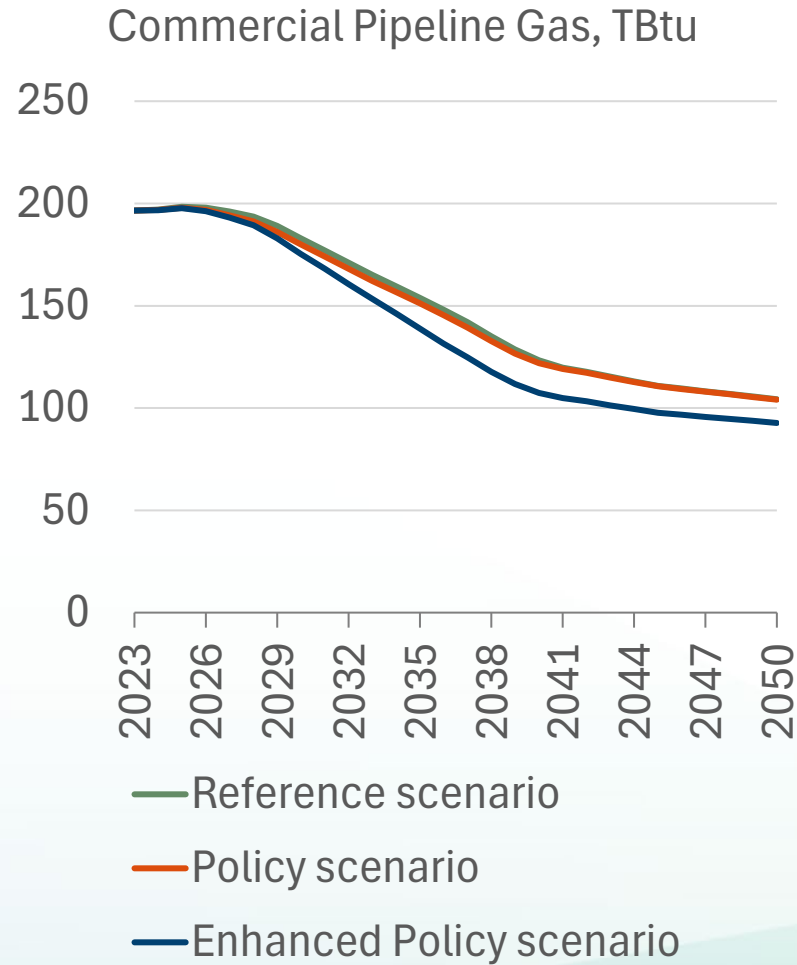
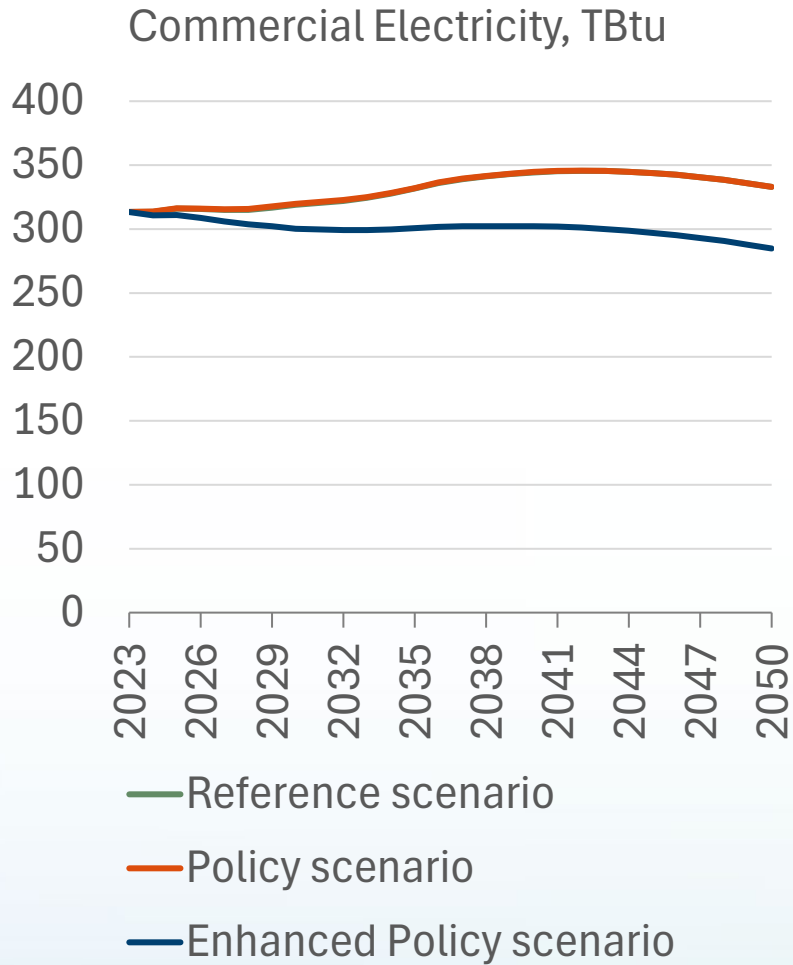


Statewide Non-Electric Fuel Demand, TBtu



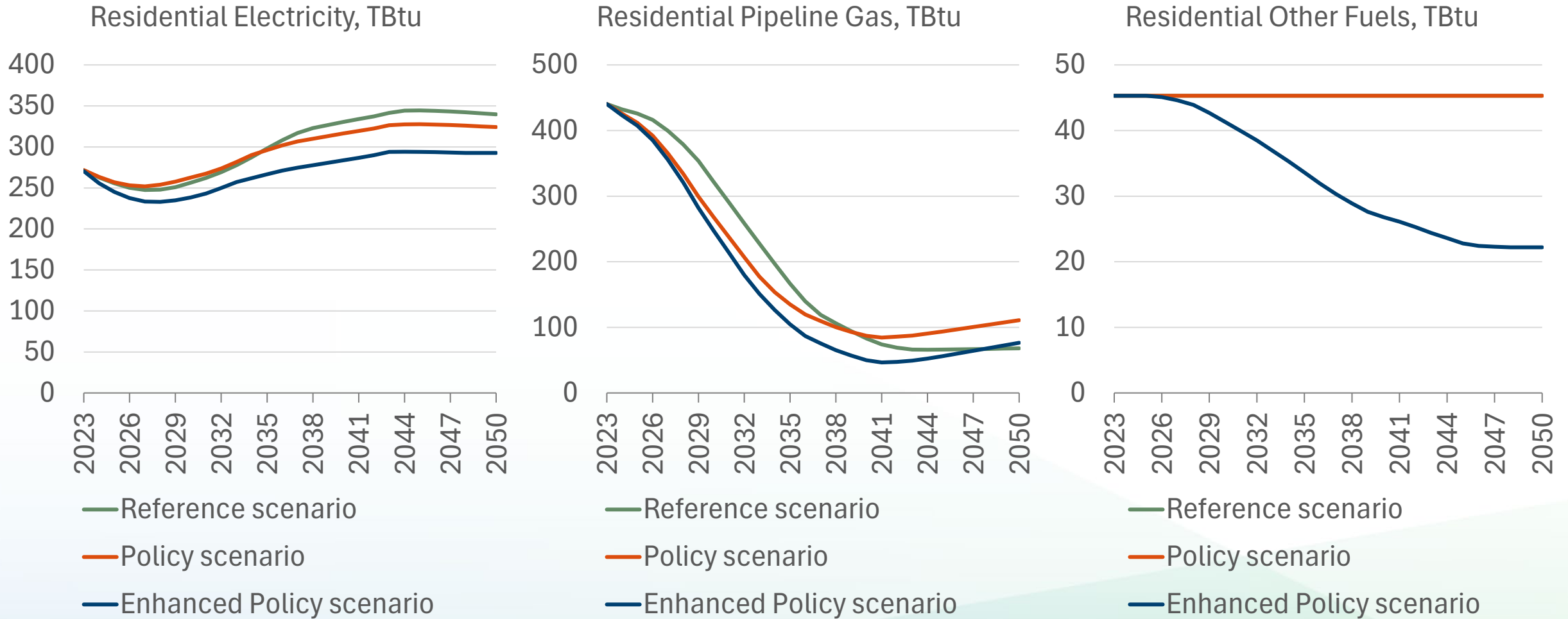


Commercial Building Energy Demand





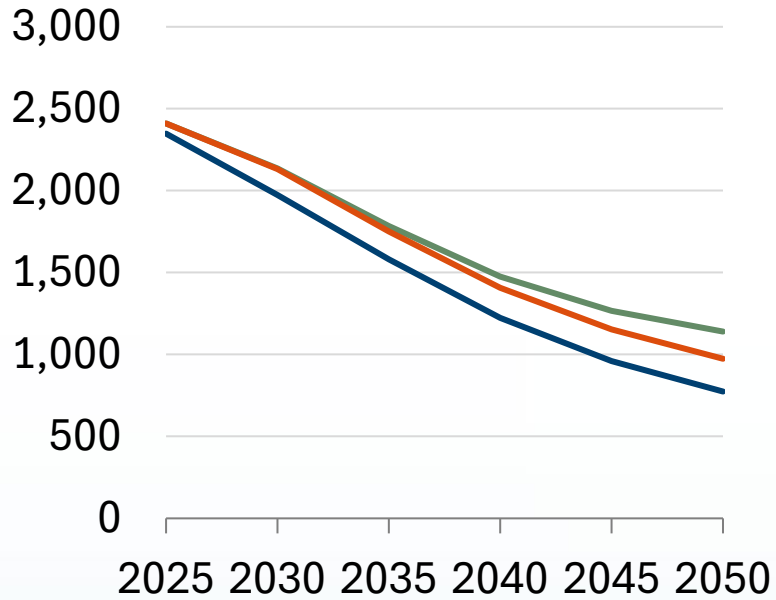
Residential Building Energy Demand





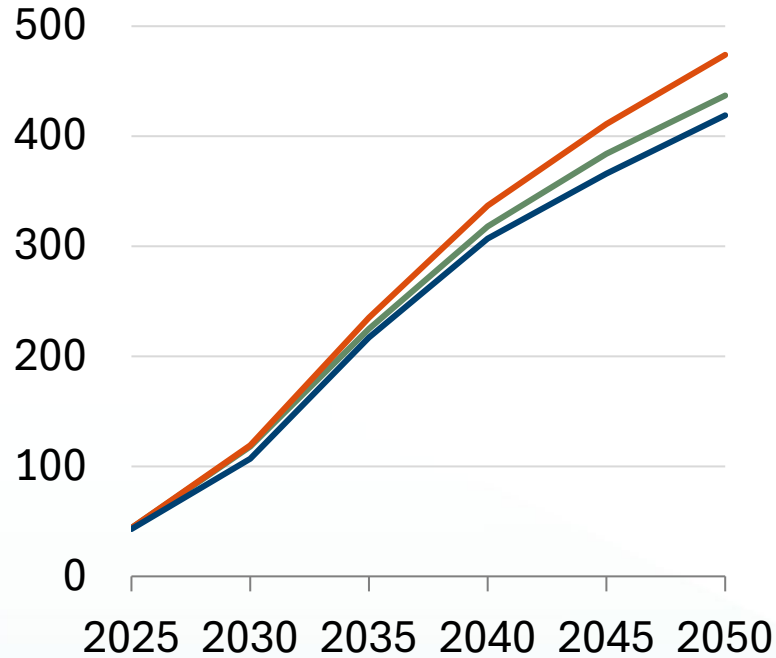
Transportation Energy Demand

Diesel, Gasoline and Jet Fuel, TBtu



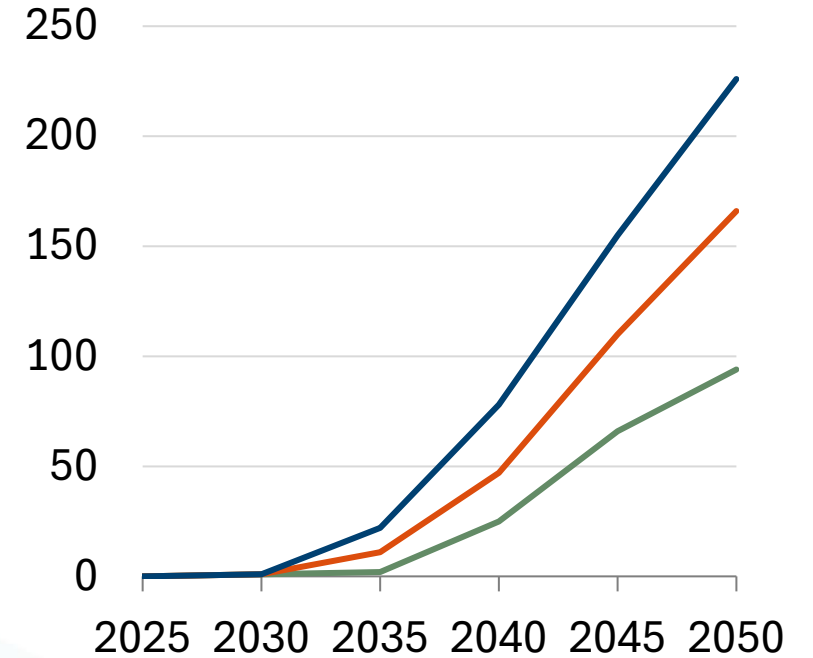
- Reference scenario
- Policy scenario
- Enhanced Policy scenario

Electricity, TBtu



- Reference scenario
- Policy scenario
- Enhanced Policy scenario

Hydrogen, TBtu

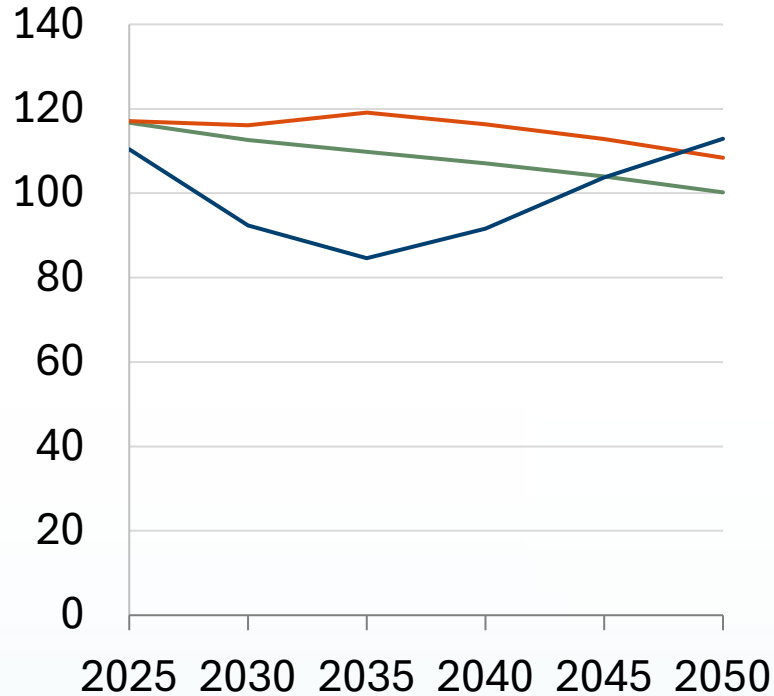


- Reference scenario
- Policy scenario
- Enhanced Policy scenario



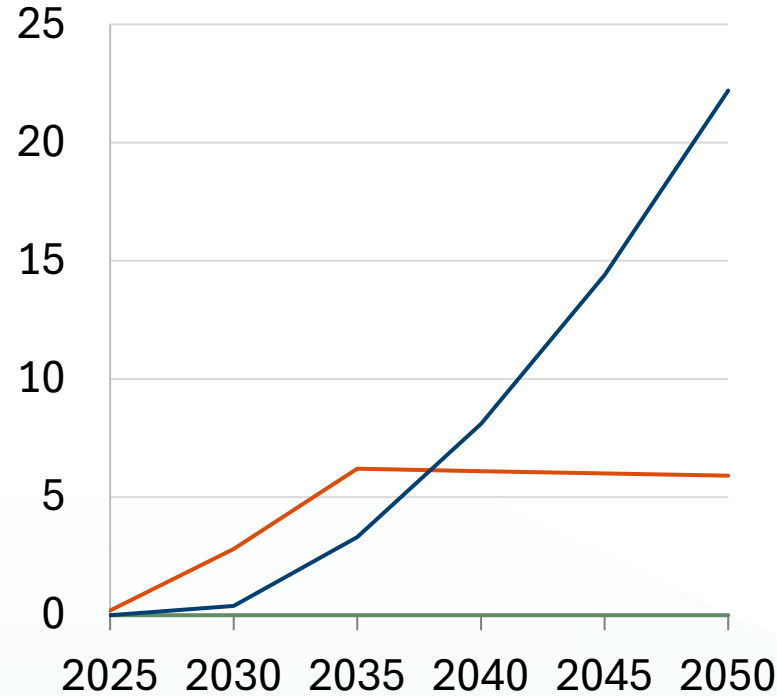
Industrial Energy Demand

Electricity, TBtu



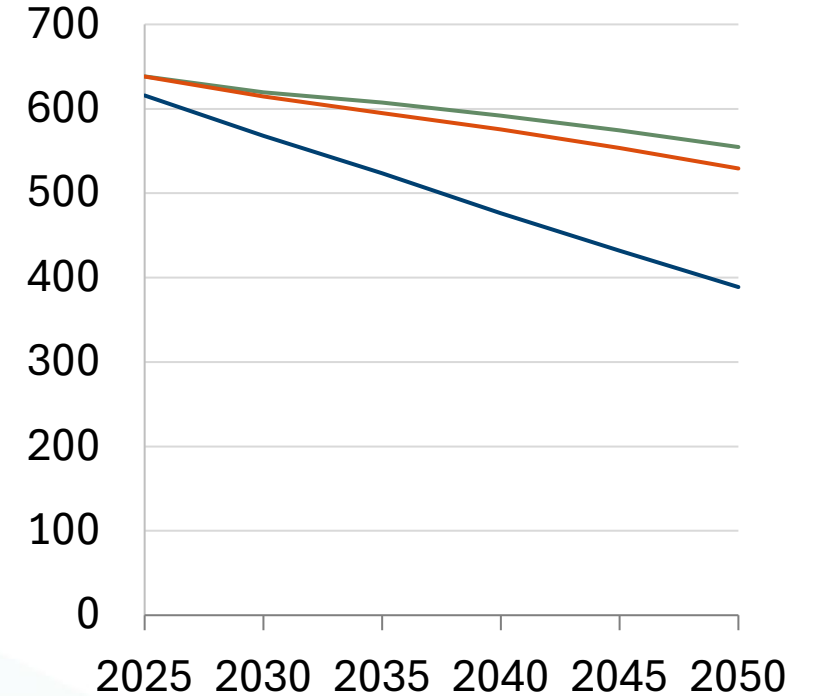
- Reference scenario
- Policy scenario
- Enhanced Policy scenario

Hydrogen, TBtu



- Reference scenario
- Policy scenario
- Enhanced Policy scenario

Pipeline Gas, TBtu



- Reference scenario
- Policy scenario
- Enhanced Policy scenario



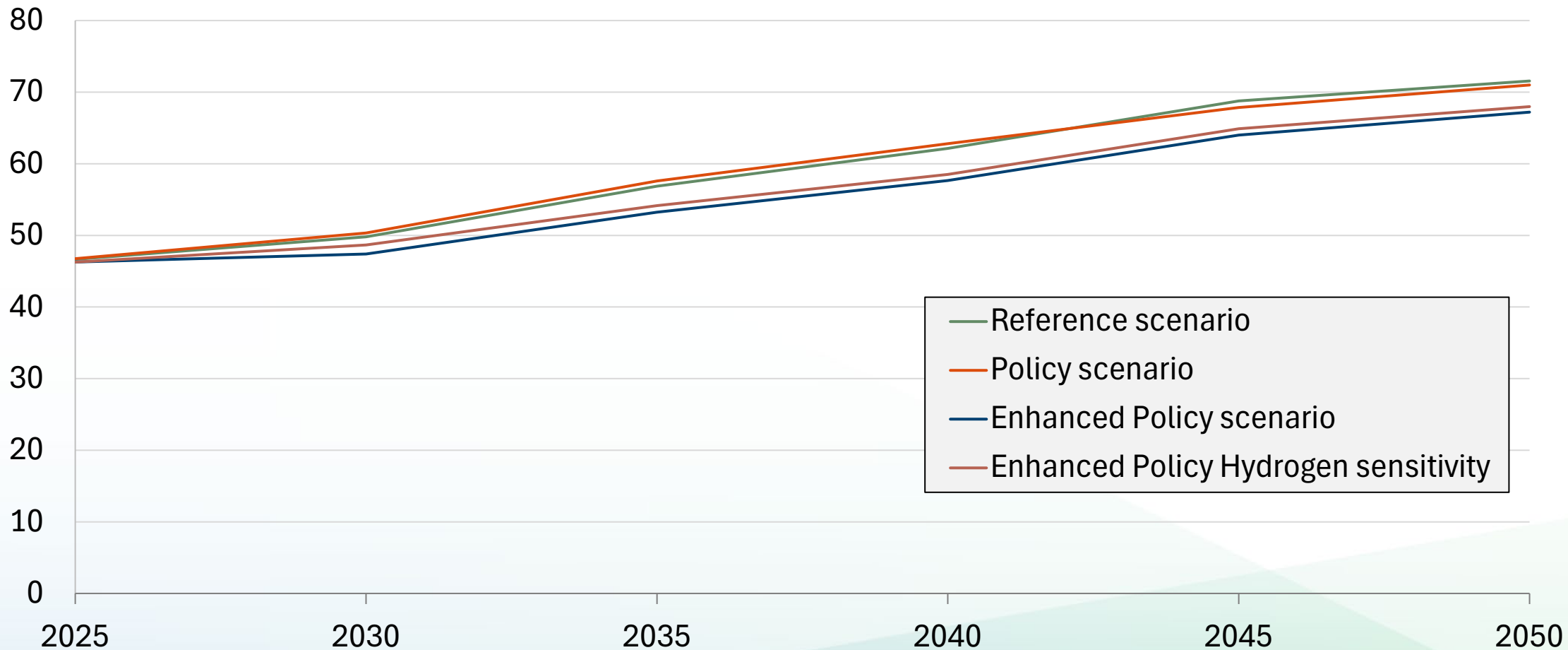
Hourly Electricity Results





Peak Electricity Demand (1 of 6)

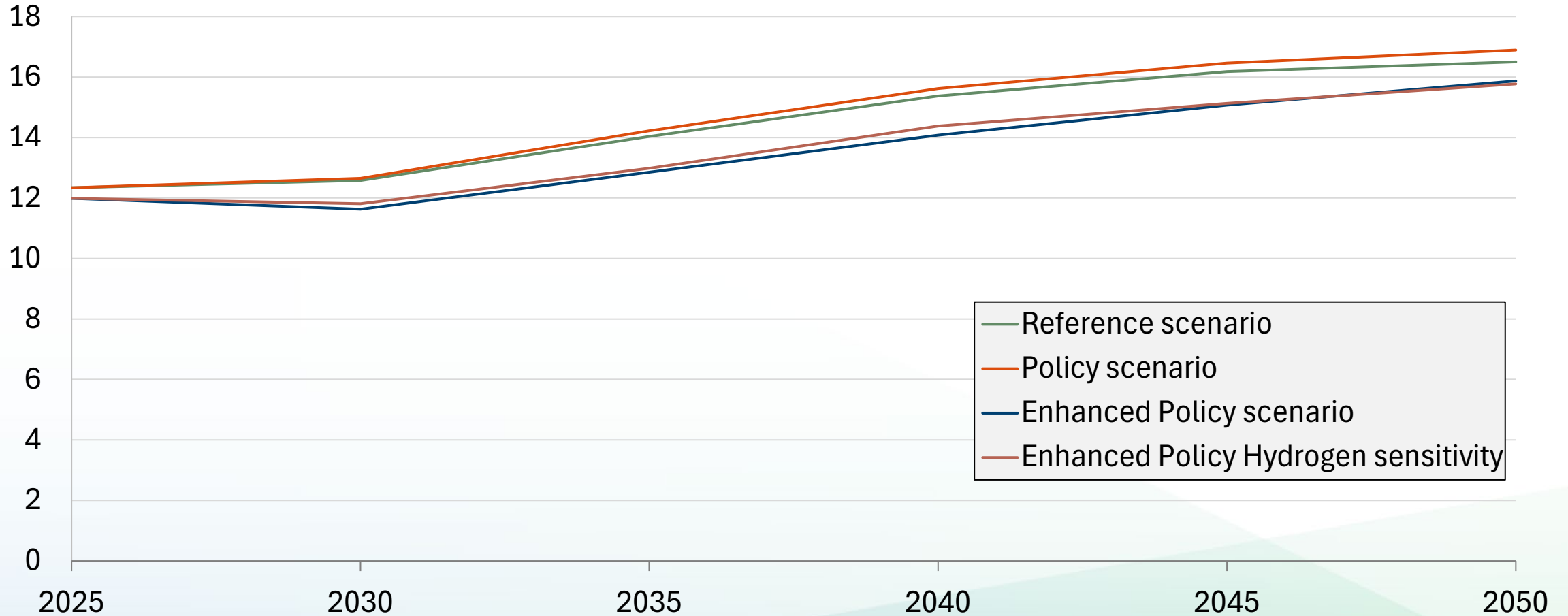
CAISO Annual Peak Load (GW)





Peak Electricity Demand (2 of 6)

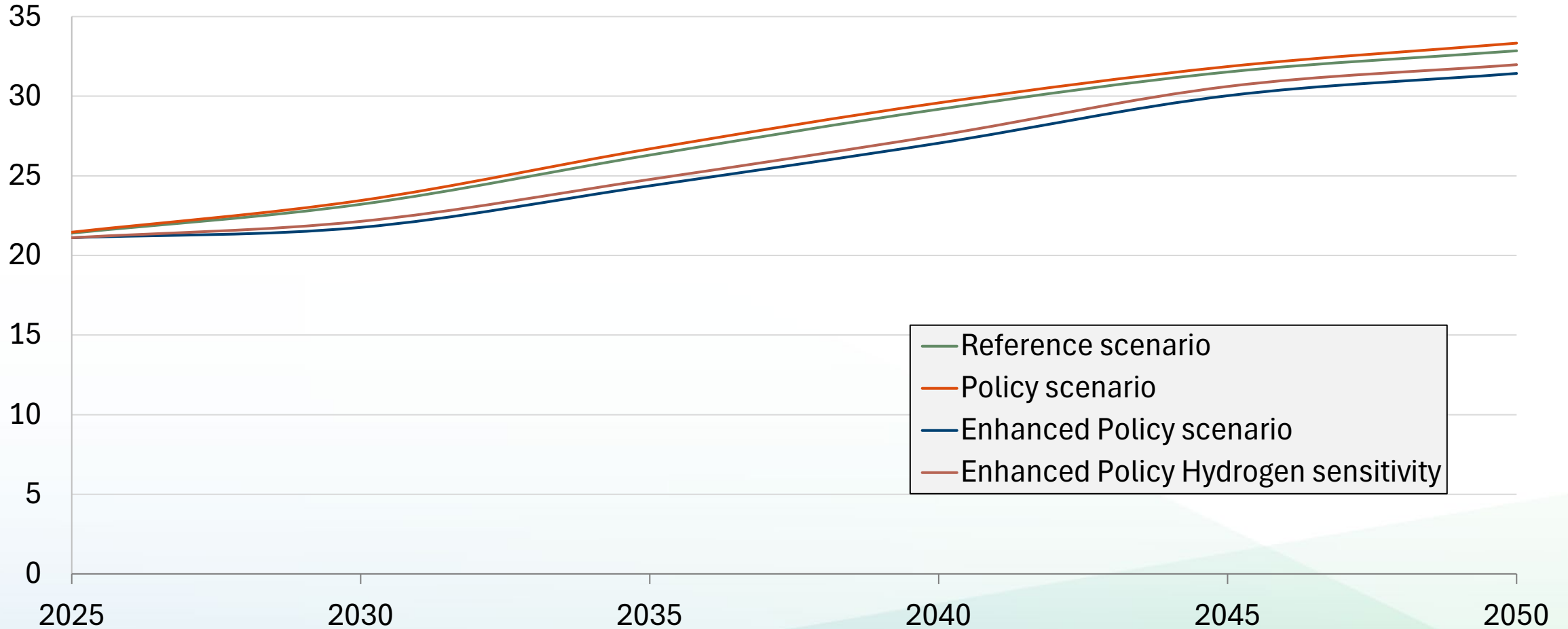
Non-CAISO Annual Peak Load (GW)





Peak Electricity Demand (3 of 6)

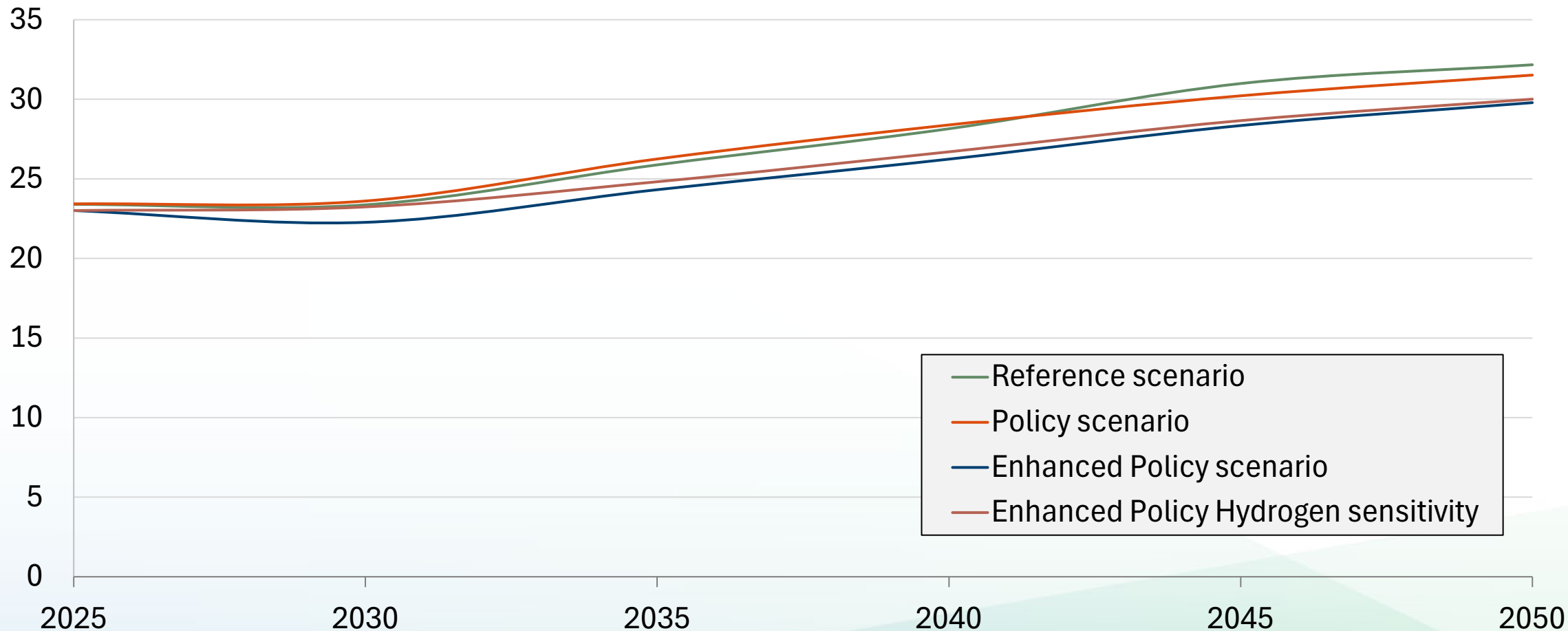
PG&E Annual Peak Load (GW)





Peak Electricity Demand (4 of 6)

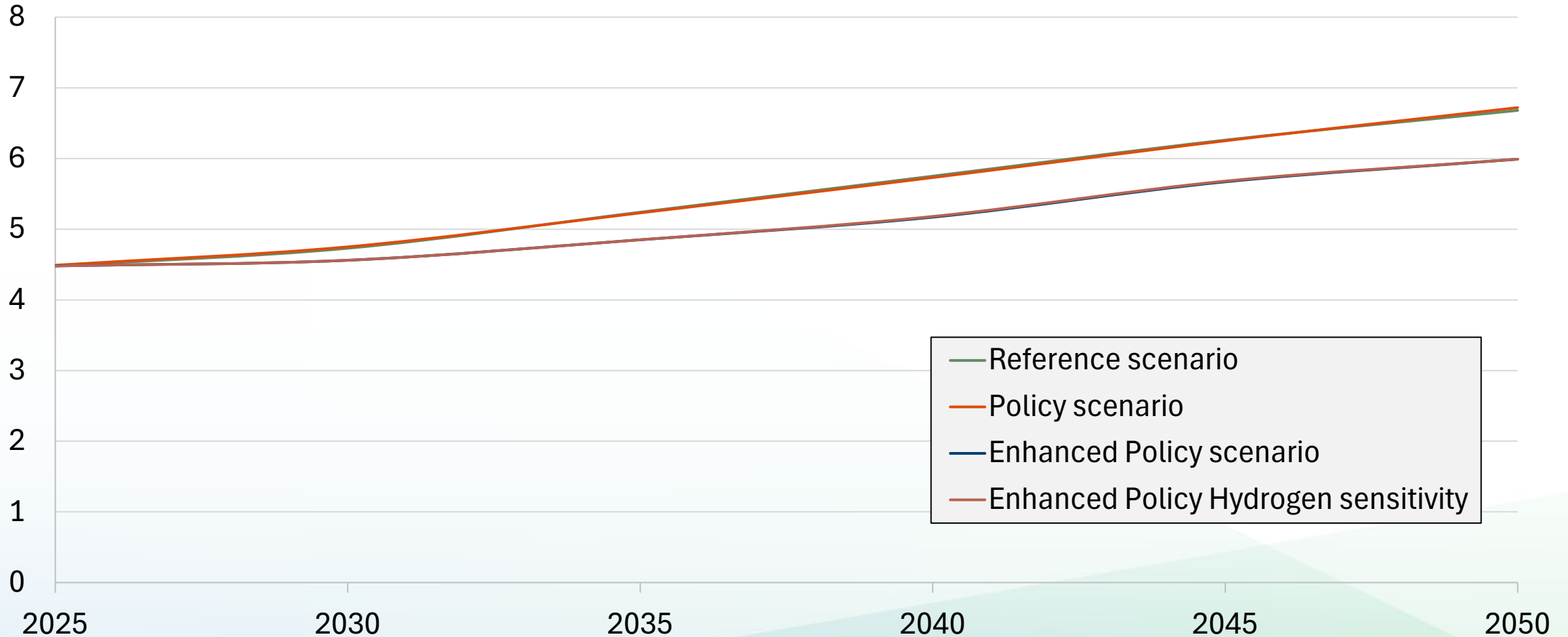
SCE Annual Peak Load (GW)





Peak Electricity Demand (5 of 6)

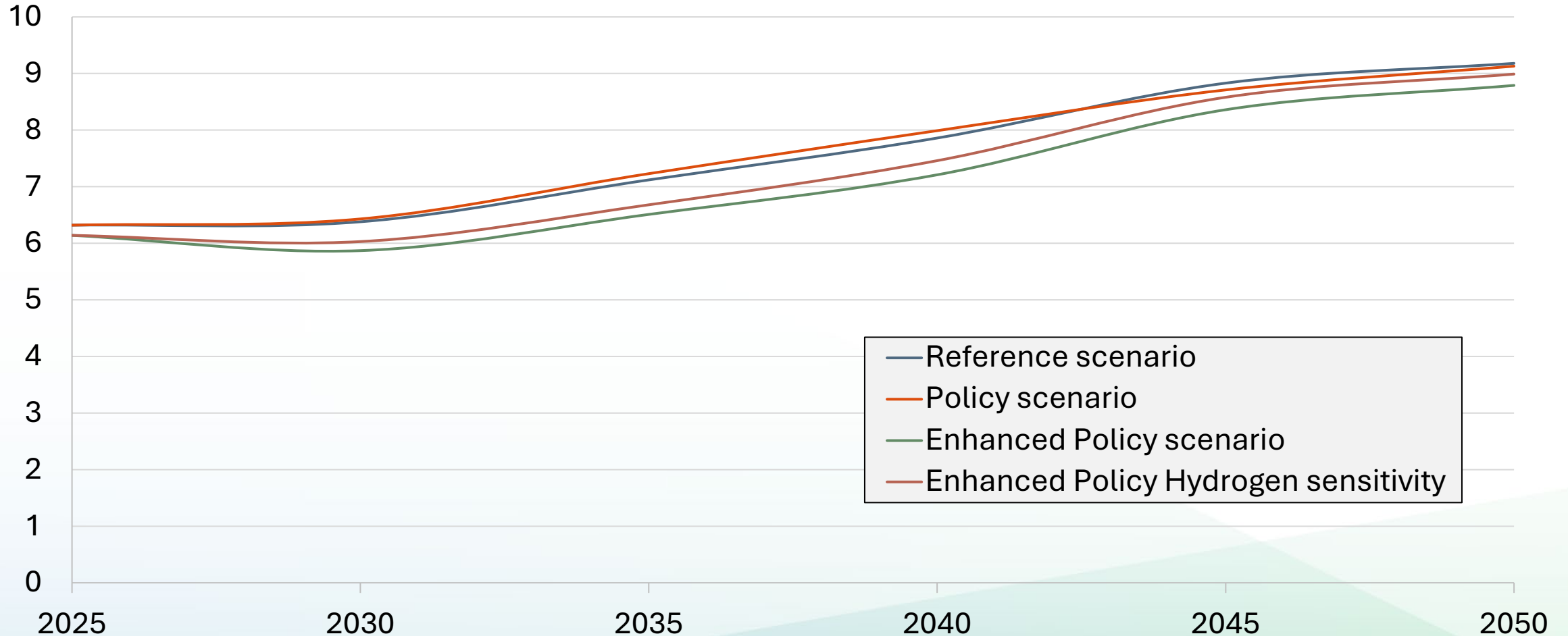
SDG&E Annual Peak Load (GW)





Peak Electricity Demand (6 of 6)

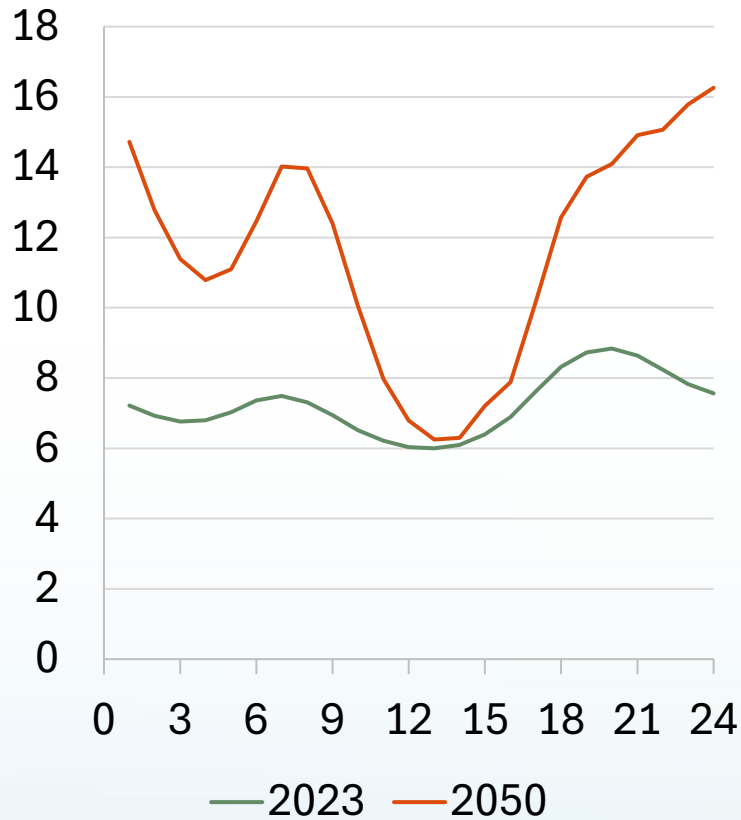
LADWP Annual Peak Load (GW)



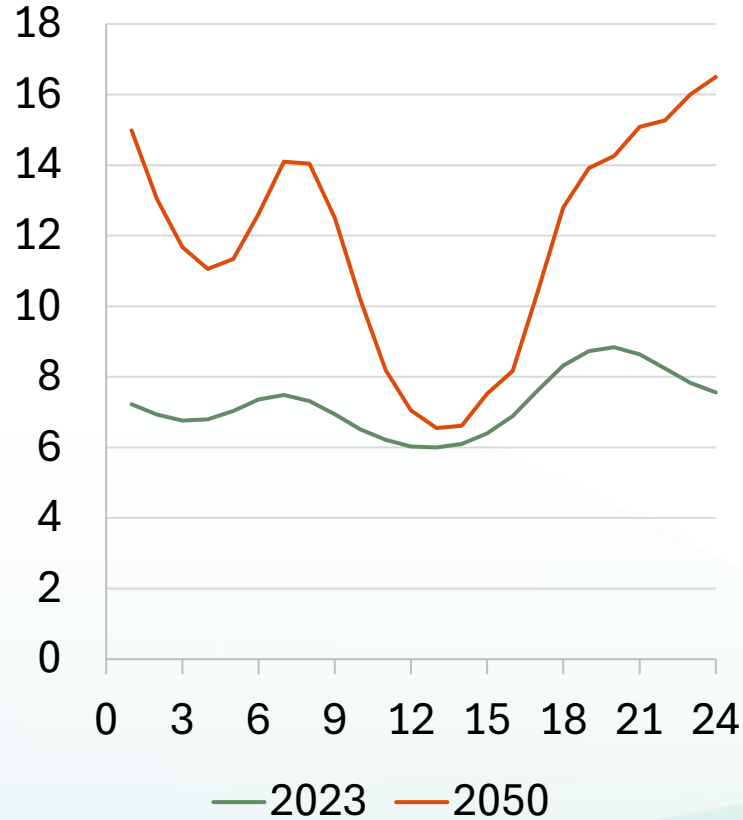


Changing Electricity Demand Profiles, CAISO

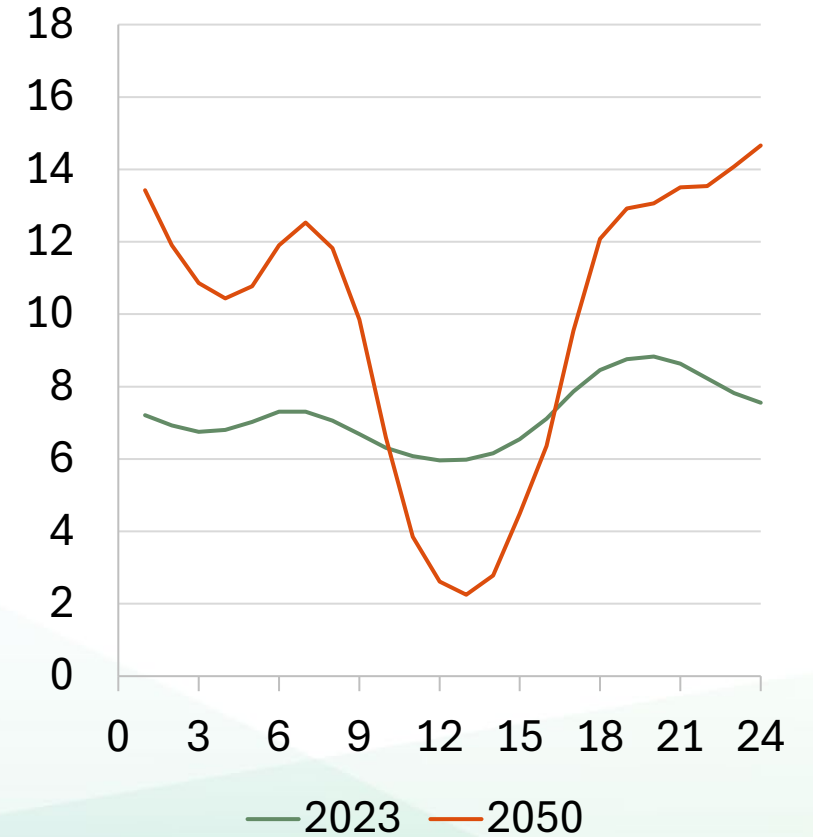
Reference Scenario
CAISO Hourly Load (GW)



Policy Scenario
CAISO Hourly Load (GW)



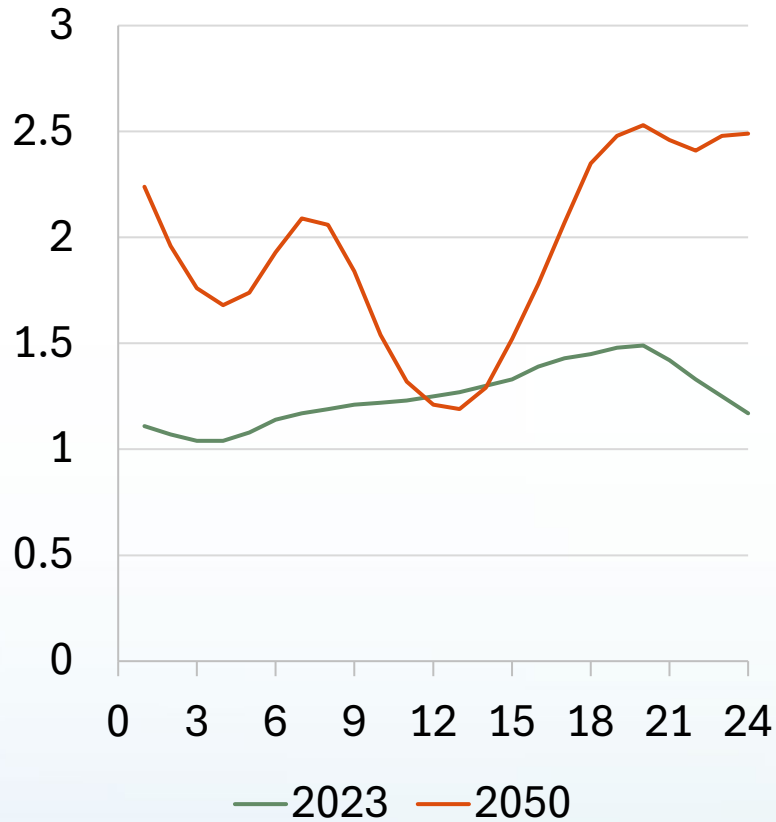
Enhanced Policy Scenario
CAISO Hourly Load (GW)



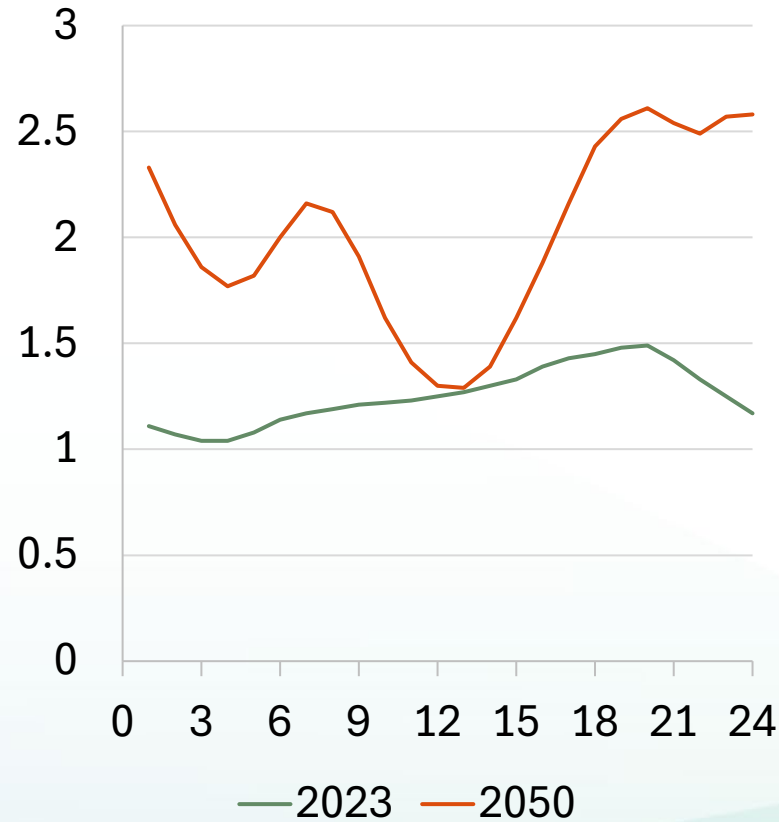


Changing Electricity Demand Profiles, non-CAISO

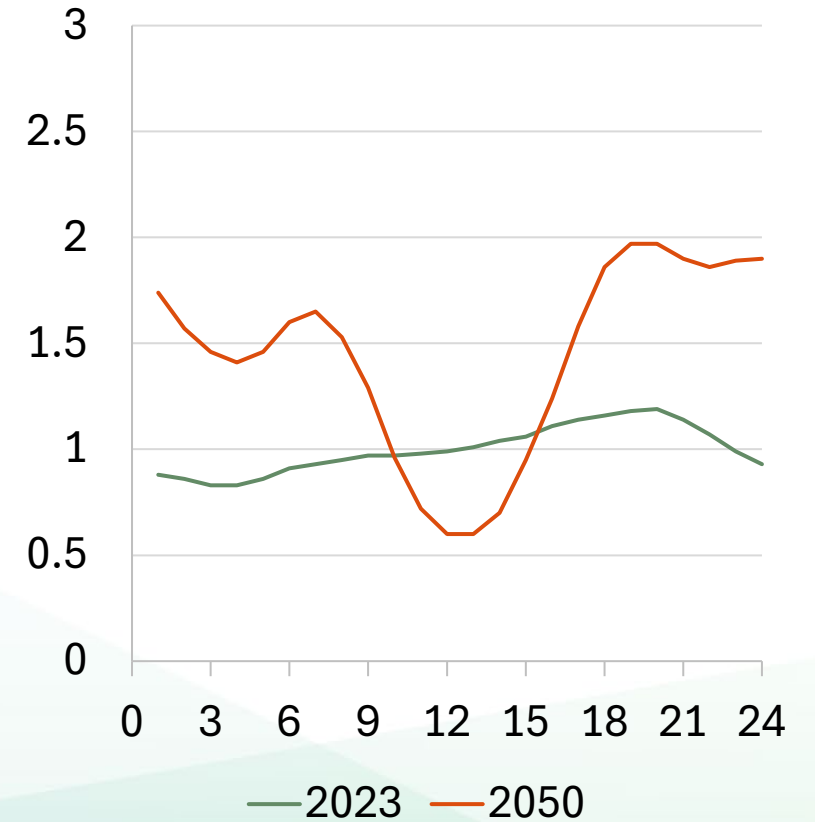
Reference Scenario
non-CAISO Hourly Load (GW)



Policy Scenario
non-CAISO Hourly Load (GW)



Enhanced Policy Scenario
non-CAISO Hourly Load (GW)





Seasonality of Electric Peak

Electric Planning Area	Reference Scenario	Policy Scenario	Enhanced Policy Scenario	Enhanced Policy H2 Sensitivity
BUGL	2043	2043	2043	2043
IID	n/a	n/a	n/a	n/a
LADWP	2042	2043	2040	2038
MKRP	n/a	n/a	n/a	n/a
NCNC	n/a	n/a	n/a	n/a
PGE	2045	n/a	2041	2040
SCE	2042	2043	2042	2042
SDGE	2044	n/a	2043	2043



Annual Emissions Results





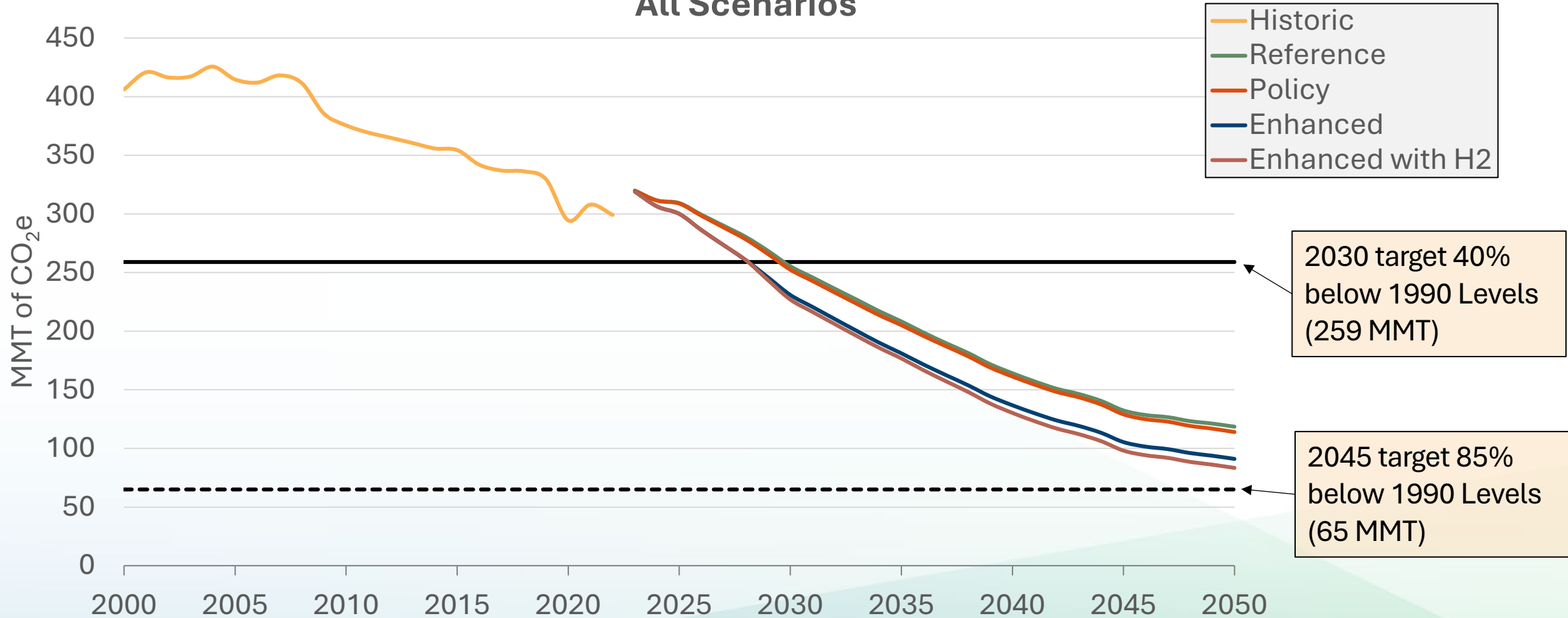
Additional Limitations and Conventions

- Energy consumption GHG emissions only
- Natural and working lands GHG emissions not accounted for
- With the exception of the historical emissions comparison chart, all aviation energy GHG emissions are accounted for
 - In-State + Out-of-State flights



Comparison to Statewide Historic Emissions

Total Emissions by Fuel Type (CO₂e) All Scenarios

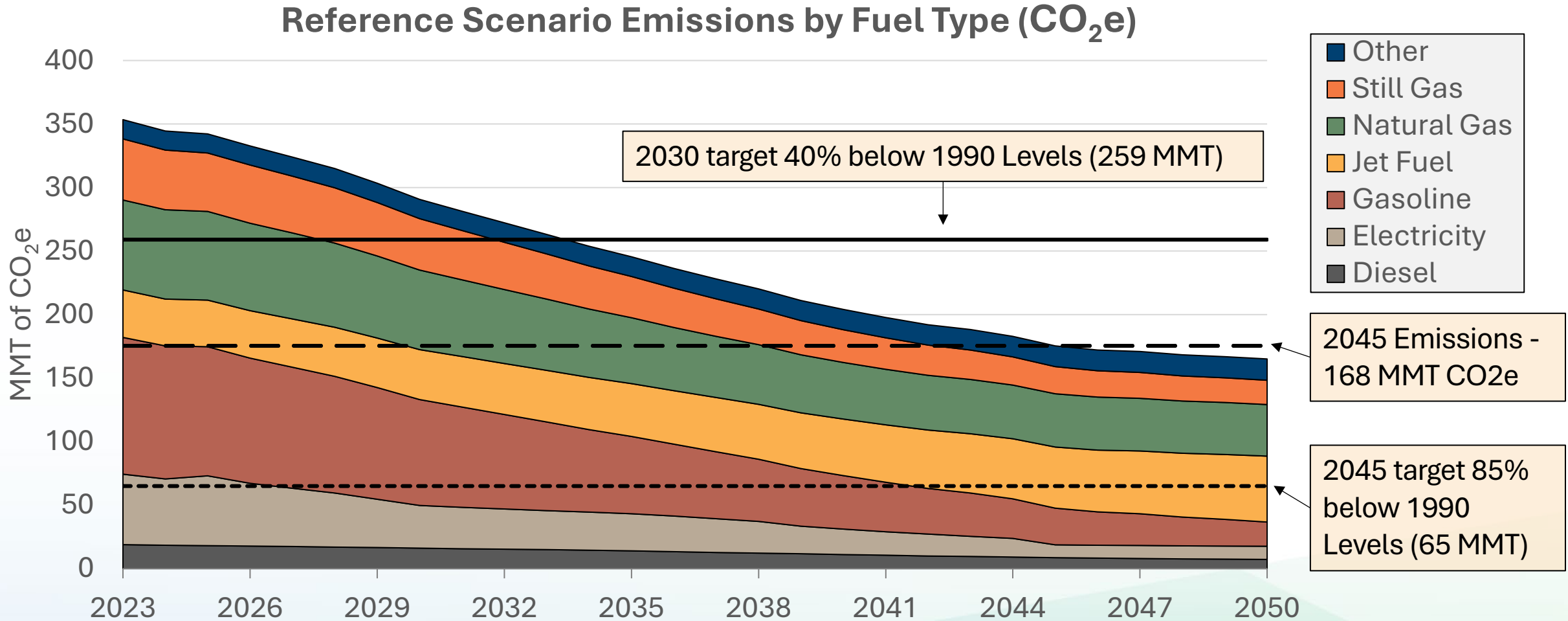


2030 target 40%
below 1990 Levels
(259 MMT)

2045 target 85%
below 1990 Levels
(65 MMT)



Reference Scenario Statewide Emissions By Fuel Type

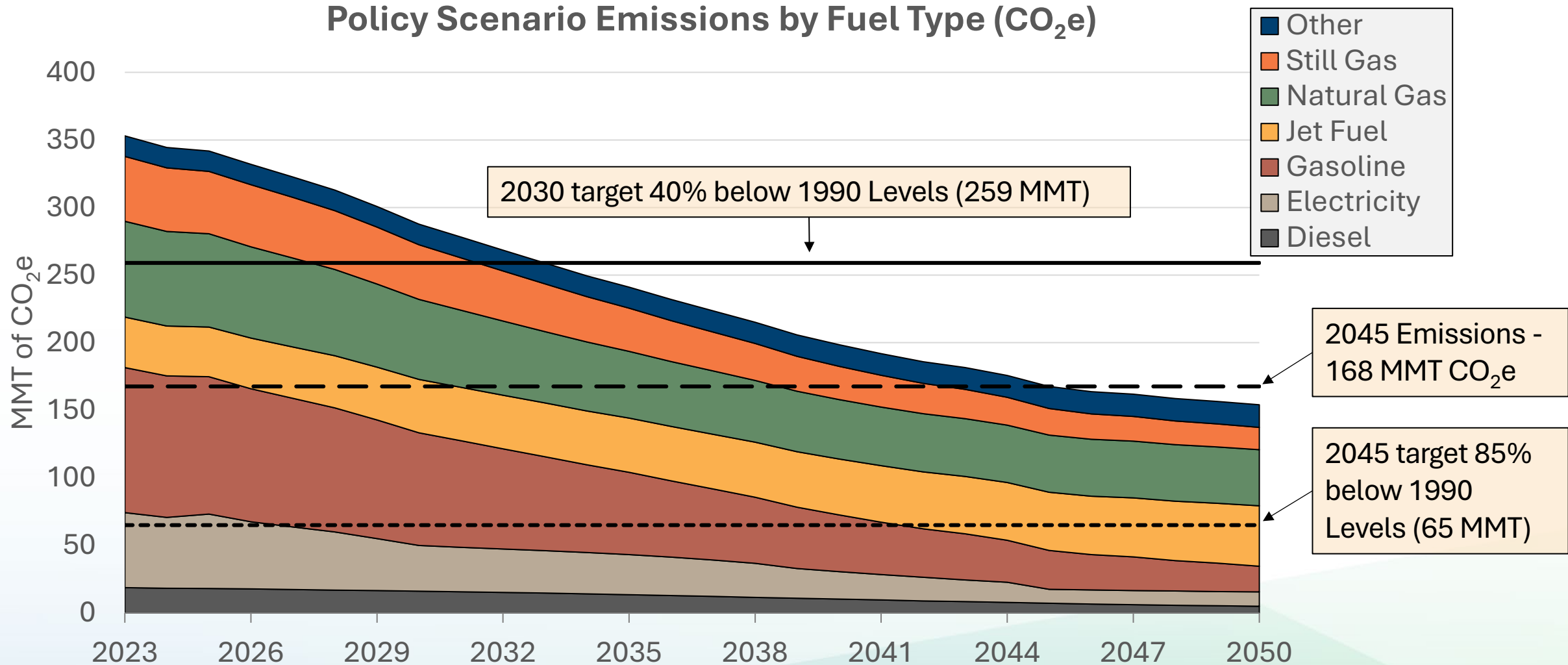


Source: Verdant, EER, CEC.

Other: Biomass/Wood, Coal, Coking Coal, Hydrogen, Kerosene Fuel, LPG, Residual Fuel Oil, Steam



Policy Scenario Statewide Emissions By Fuel Type



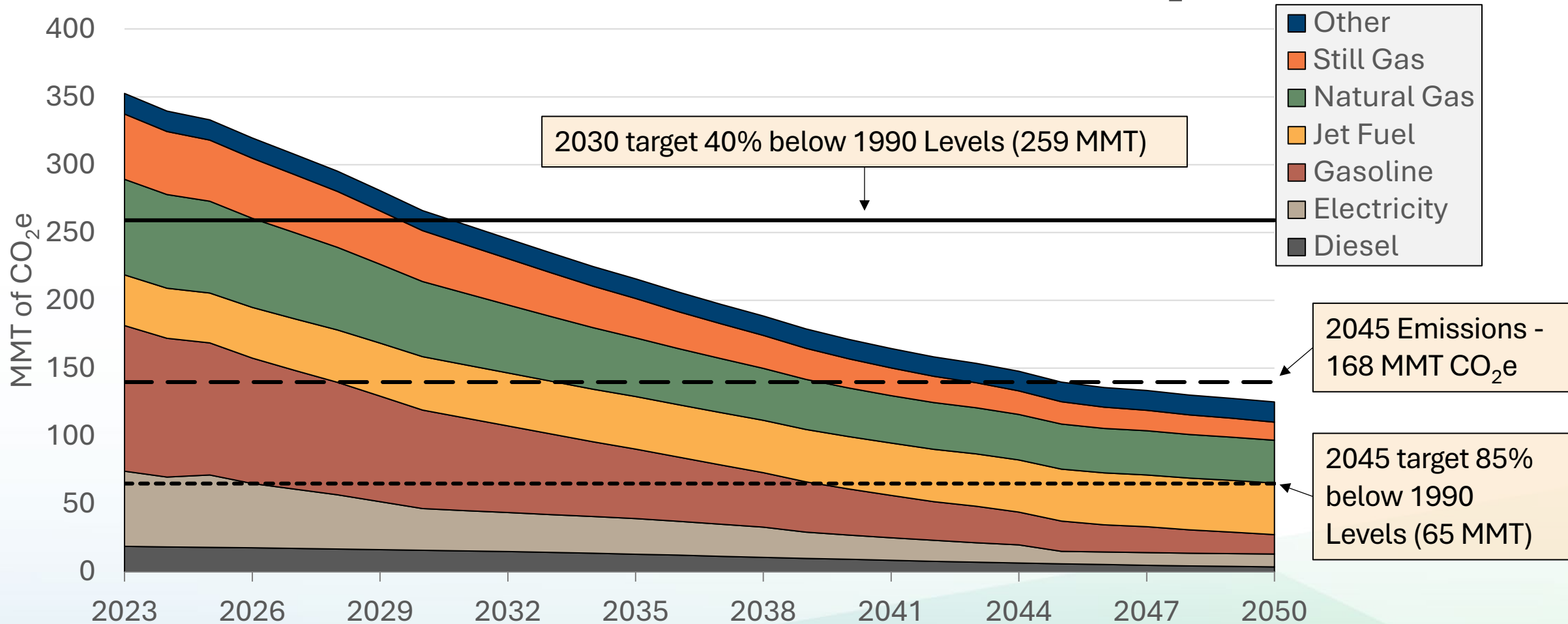
Source: Verdant, EER, CEC.

Other: Biomass/Wood, Coal, Coking Coal, Hydrogen, Kerosene Fuel, LPG, Residual Fuel Oil, Steam



Enhanced Policy Scenario Statewide Emissions By Fuel type

Enhanced Policy Scenario Emissions by Fuel Type (CO₂e)



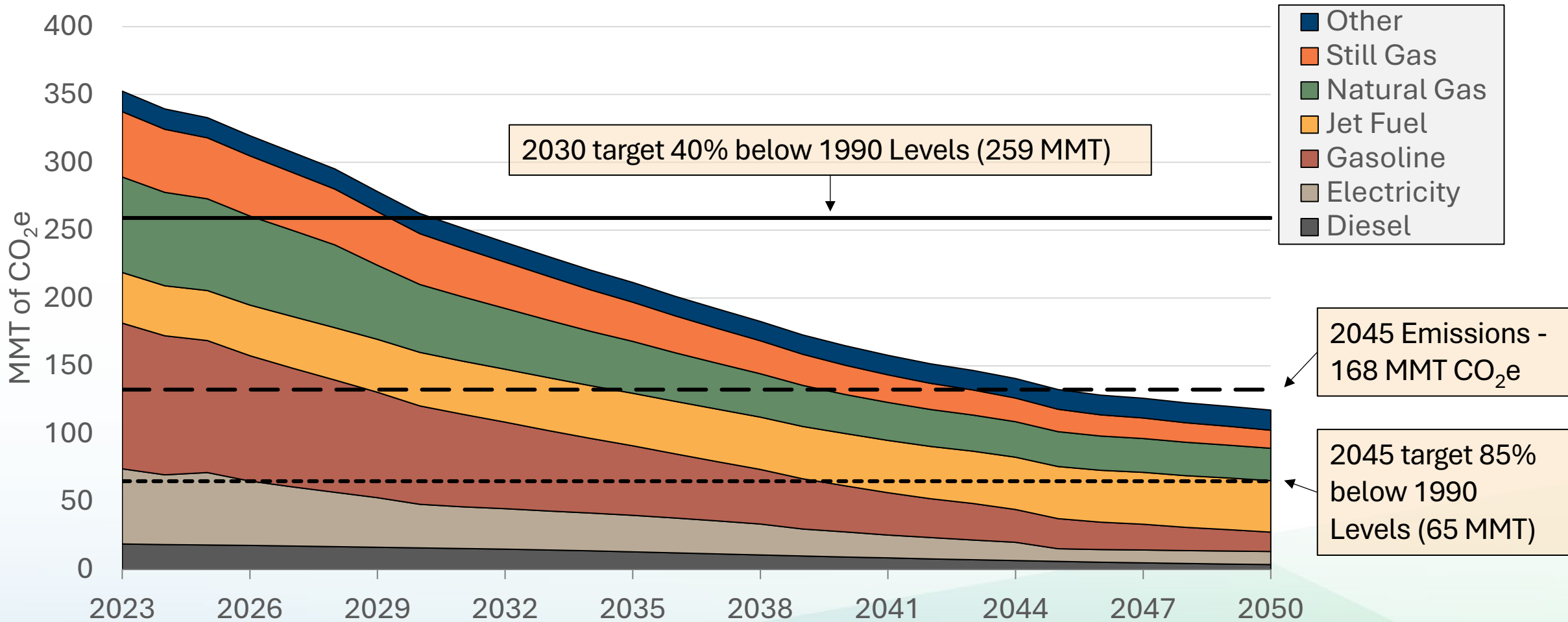
Source: Verdant, EER, CEC.

Other: Biomass/Wood, Coal, Coking Coal, Hydrogen, Kerosene Fuel, LPG, Residual Fuel Oil, Steam



Enhanced Policy Scenario H₂ Statewide Emissions By Fuel Type

Enhanced Policy with H₂ Scenario Emissions by Fuel Type (CO₂e)



Source: Verdant, EER, CEC.

Other: Biomass/Wood, Coal, Coking Coal, Hydrogen, Kerosene Fuel, LPG, Residual Fuel Oil, Steam



Conclusions





Changing Energy Landscape

- In all demand scenarios, fuel switching increases California's electricity load and decreases demand for non-electric fuels through 2050 in all planning areas
 - The extent of this transformation depends on assumptions about how energy policies translate to changes in energy demand
- In many planning areas, growth in new types of electric load causes a transition from a summer to a winter electric peak
 - The timing of that transition depends on scenario assumption but is as early as 2038 under some conditions
- Increased electricity demand paired with increased behind-the-meter solar generation changes the hourly shape of electricity demand in California



Reaching Emissions Targets

- None of the demand scenarios achieves California's 2050 emissions targets under existing fuel blending conditions
- The Enhanced Policy scenario reflects ambitious levels of demand side energy efficiency and fuel switching, and still falls short of the 2045 target by about 75 MMT
- Supply-side decarbonization measures will be required to close this gap
 - Decarbonized electricity supply
 - Decarbonized fuel blending
 - Point-source carbon capture
 - Direct air capture
- Understanding how these different supply-side measures can best contribute to meeting California's emissions targets requires energy supply modeling that integrates the fuel supply and electricity supply sectors