CARB Draft Scoping Plan: AB32 Source Emissions Initial Modeling Results

Costs

April 20, 2022

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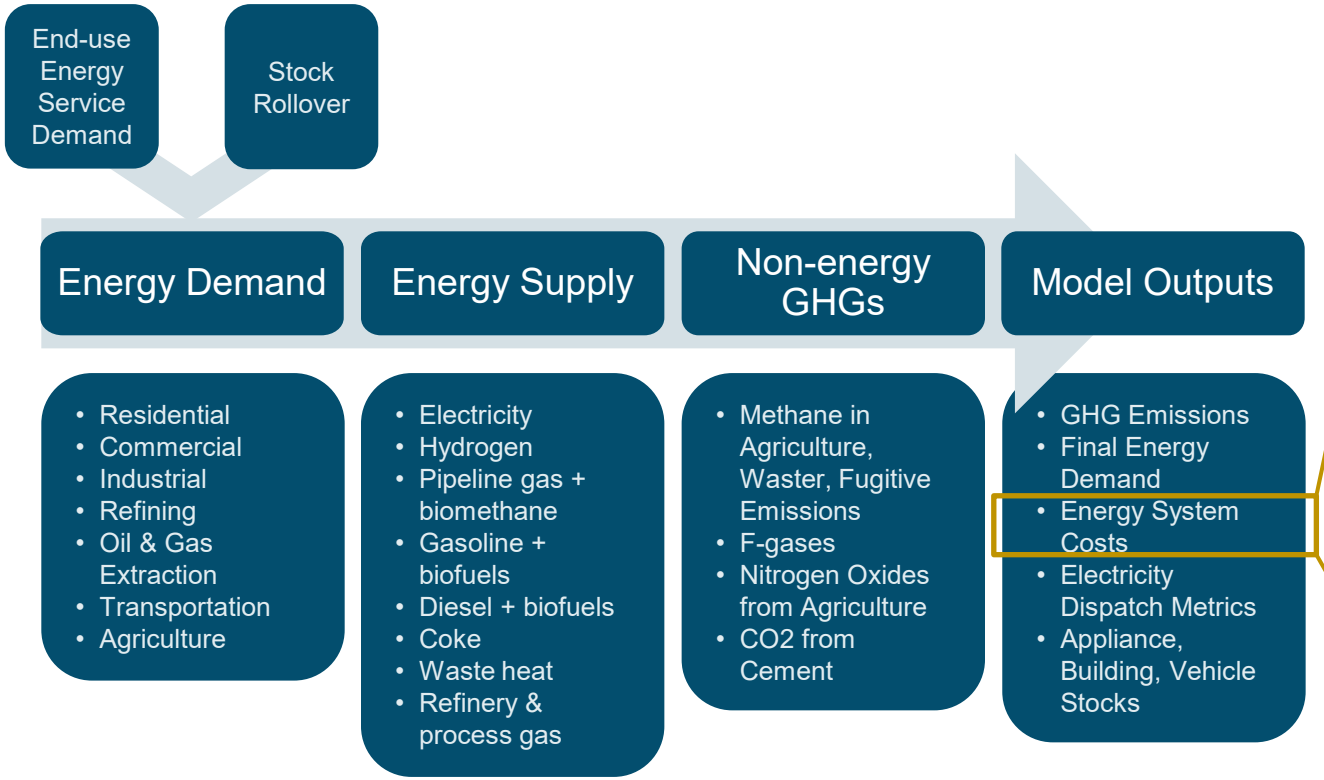
PATHWAYS Cost Modeling

Energy+Environmental Economics PATHWAYS model

California economy-wide energy and greenhouse gas scenarios. User-defined, bottom-up approach which captures interactions between sectors



+ Annualized incremental cost of energy infrastructure (stocks) compared to BAU

- Transportation: light-, medium- & heavy-duty vehicles, vehicle chargers, panel upgrades, planes, trains, etc.
- Buildings: lighting, water heaters, space heaters, cooking, clothes drying, refrigeration, panel upgrades, etc.
- Electricity generation: revenue requirement of all electric assets including distribution and transmission upgrade needs

+ Annual incremental fuel savings and costs (efficiency and demand changes) compared to BAU

- Electricity, hydrogen, gasoline, diesel, renewable diesel, natural gas, biofuel, biomethane, sustainable aviation fuel, non-energy methane & HFCs, etc.

+ Excluded:

- Macroeconomic impacts (GDP, jobs, price responsiveness)
- Health benefits of reduced criteria pollutants

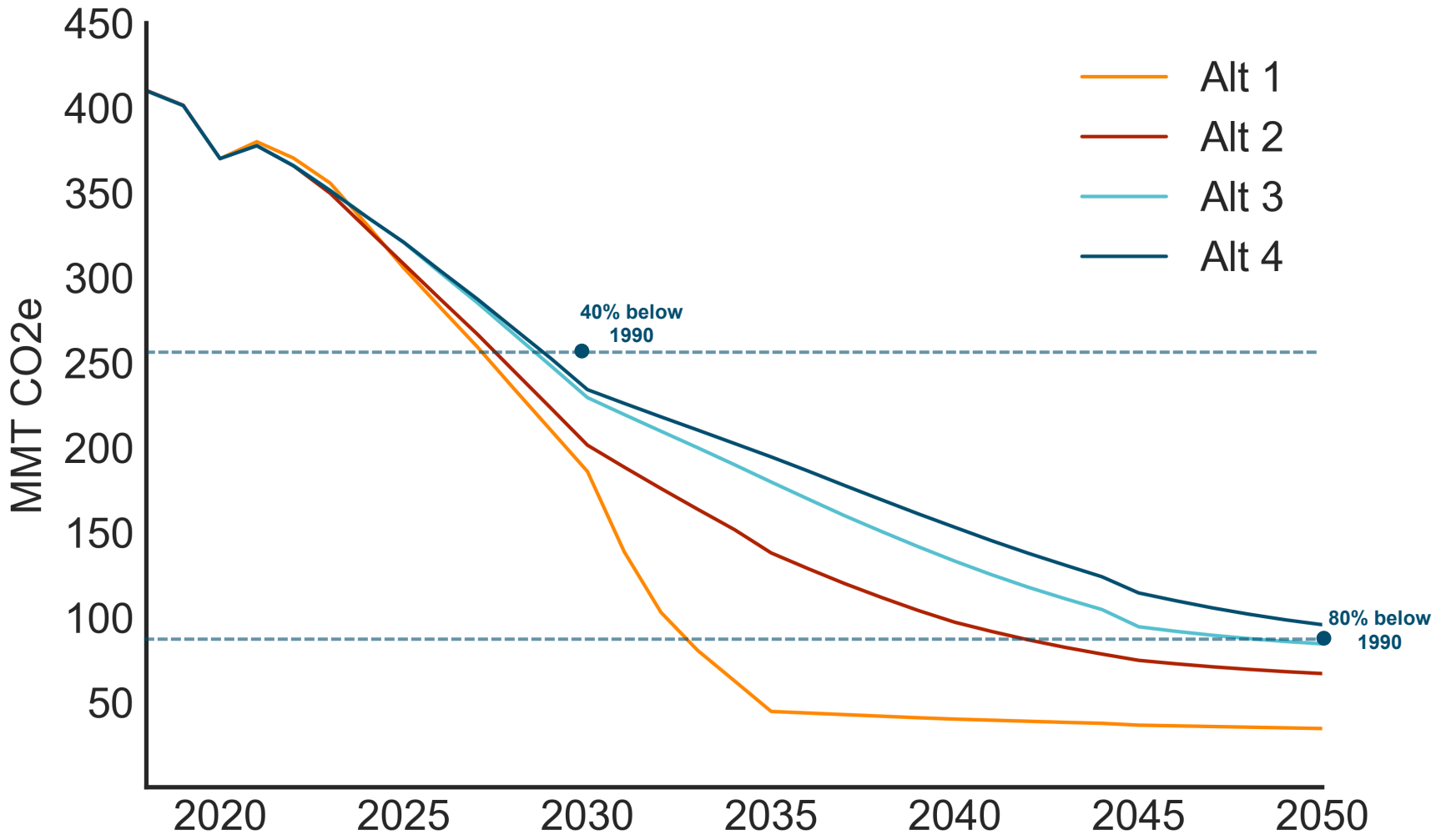
Key Cost Data Sources

Transportation	***LDV*** *– 2020 Mobile Source Strategy, CARB, 2021* **MHDV –** *CA Institute of Transportation Studies, 2021*	**Cost for Vehicle Miles Traveled (VMT) Reduction Measures not Included**	**Off-road –** • H2 rail and ships: *U.S. DOE Hydrogen and Fuel Cells Program* • Electric rail: *Nature Energy Publications* • H2 aviation*: Hydrogen-Powered Aviation; prepared by McKinsey and co.*	**EV Charging –** • *California Electric Vehicle Infrastructure Project (CALeVIP)* • *CEC AB 2127 Electric Vehicle Charging Infrastructure Assessment 2021* • *CARB Advanced Clean Trucks 2019*
Buildings	**Residential Space & Water Heating** *– Residential Building Electrification in California, E3, 2019*		**Commercial Space & Water Heating –** *EIA AEO 2021*	**Other end uses –** *EIA AEO 2021*
Industry	**Energy efficiency –** *CARB internal analysis consistent with 2017 Scoping Plan*	**Petroleum refining, Oil & Gas Extraction and Transmission –** • *CARB internal analysis* • *Blending Hydrogen into Natural Gas Pipeline Networks; NREL 2010*		**Carbon Capture & Sequestration (CCS) –** *Global CCS Institute, 2017* **Industrial Electrification Capital Costs are not Included**
Fuels	**Fossil fuels –** *EIA AEO 2021*	**H2 –** *The Challenge of Retail Gas in California's Low Carbon Future; E3 & UC Irvine for CEC, 2020*	**Renewable Liquid Fuels -** *Transport and Environment Publications, 2020*	**Biomethane -** *Institute of Transportation Studies, UC Davis, 2016*
Methane	**Organic Waste –** *Short-Lived Climate Pollutant Reduction Strategy, CARB, March 2017*		**Dairy and Livestock –** *Feasibility of Renewable Natural Gas as a Large-Scale, Low Carbon Substitute, A. M. Jaffe, Institute of Transportation Studies, UC Davis, 2016*	
Hydrofluorocarbons (HFCs)	**Transportation –** *CARB Transport Refrigeration Unit Regulation, 2021*	*Various Publications & Regulations: ICF International 2016; CEC AB 3232 docket log, SMUD Residential Electrification Project Costs, 2020; CARB 2020 HFC Regulation Initial Statement of Reasons, 2020; ACEEE Summer Study on Energy Efficiency in Buildings; CEC 2021 IEPR Building Decarbonization*		
Carbon Dioxide Removal (CDR)	*Various Publications: LLNL, January 2020; Science and Technology, 2021; Joule; Energy Futures Initiative and Stanford University, October 2020*			

Scenario Descriptions

- **Scoping Plan Scenarios:**
  - **Alternative 1 "Alt 1":** Carbon neutral by 2035. Nearly complete phaseout of combustion, limited reliance on engineered carbon removal, restricted applications for biomass derived fuels, and ambitious innovation in technology and aggressive consumer adoption trends (e.g. electric aviation adoption and 100% electrification by 2035).
  - **Alternative 2 "Alt 2":** Carbon neutral by 2035. Use of full suite of technology options, including heavy reliance on engineered carbon removal.
  - **Alternative 3 "Alt 3":** Carbon neutral by 2045. Use of broad portfolio of existing and emerging fossil fuel alternatives and alignment with statutes and Executive Orders
  - **Alternative 4 "Alt 4":** Carbon neutral by 2045. Use existing and emerging technologies, slower rate of clean technology and fuel deployment and consumer adoption. Reflects a higher reliance on engineered carbon removal.
- **Reference Business-as-Usual (BAU) "BAU Reference":** Aligns with current trends and includes the estimated impact of all current regulations. Reflects our best estimate of what will happen with no further policy intervention

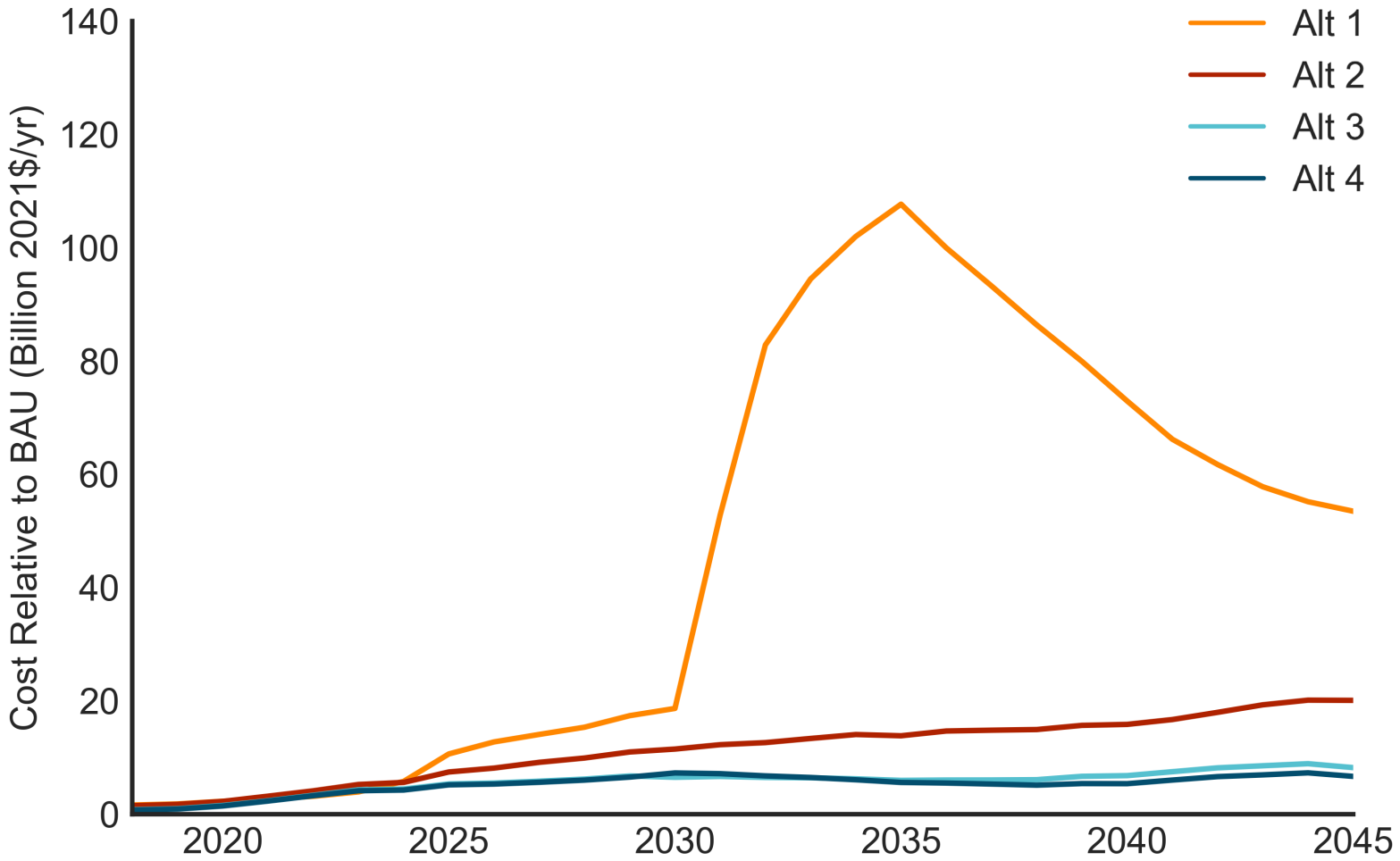
Direct Emissions



- Each Alternative meets the 2030, 40% below 1990 target
- All Scoping Plan Alternatives, except Alternative 4, meet the 2050 80% below 1990 target
- All Alternatives will need to rely on carbon dioxide removal (CDR) to achieve carbon neutrality by 2035, for Alt 1 and 2, and 2045, for Alt 3 and 4

Emissions shown after CCS, before CDR

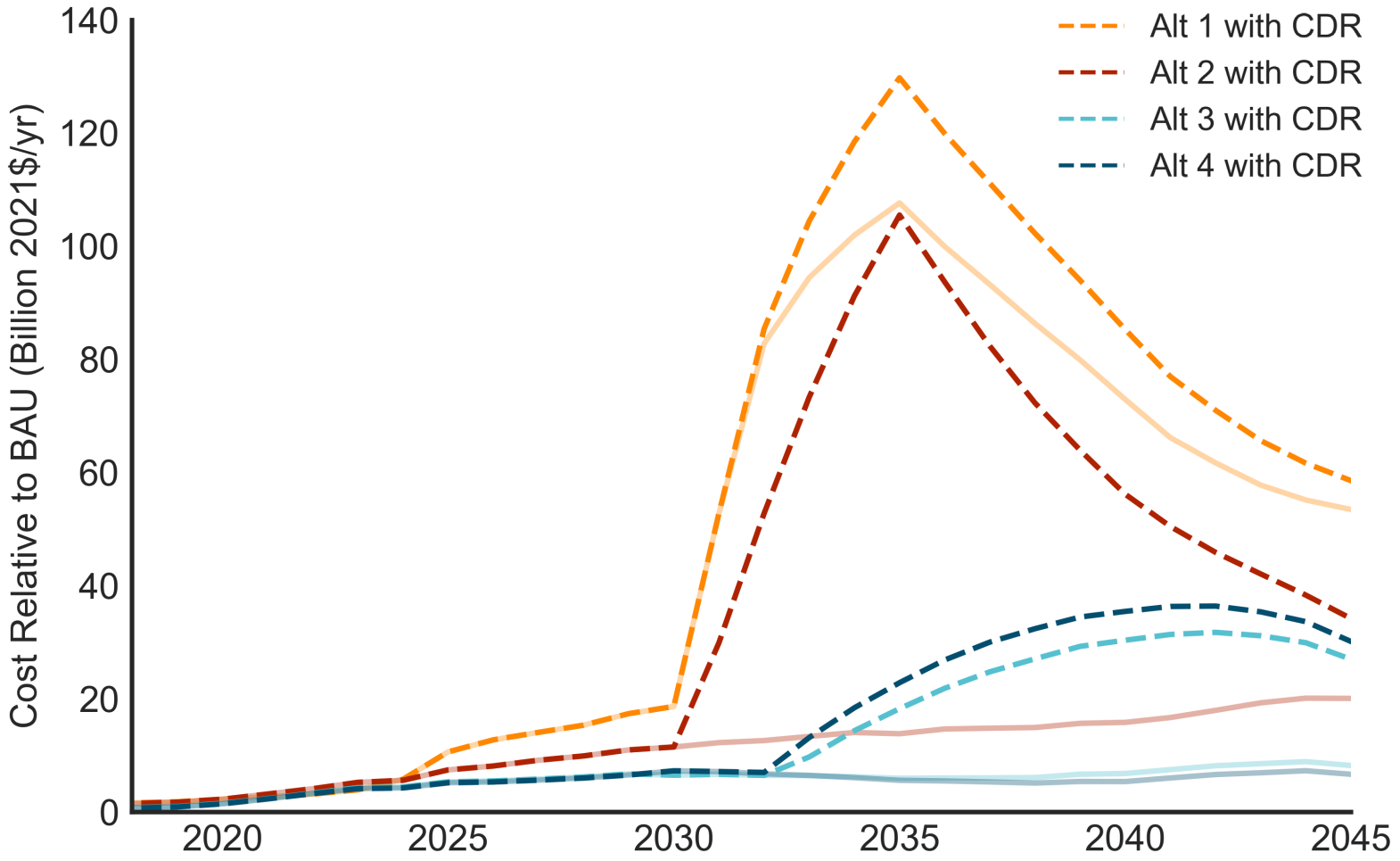
Total Costs Relative to Business-as-Usual (BAU)*



- Pre-CDR costs of Alternatives reflect the rate and scale of adoption of clean technologies
- Alternative 1 has aggressive measures in 2035 including retiring and replacing all ICE vehicles with ZEVs and all gas appliances with electric appliances
- Alts 3 & 4 have similar cost trajectories pre-CDR

*Costs shown before CDR

Total Costs Relative to Business-as-Usual (BAU)



- Pre-CDR costs of Alternatives reflect the rate and scale of adoption of clean technologies
- Alternative 1 has aggressive measures in 2035 including retiring and replacing all ICE vehicles with ZEVs and all gas appliances with electric appliances
- Alts 3 & 4 have similar cost trajectories pre-CDR
- **Alternative 1 and 2 have the same 2035 Carbon Neutral target, but Alternative 2 relies heavily on CDR**
- **CDR needs increase as Alternatives 3 and 4 approach 2045, but CDR costs drop overtime so total cost increase is mitigated**
- **Cumulative costs of Alternatives 1 and 2 in 2045 is ~2-4 times the cost of Alternatives 3 and 4**

Sectoral Costs Relative to Business-as-Usual (BAU)

+ Transportation

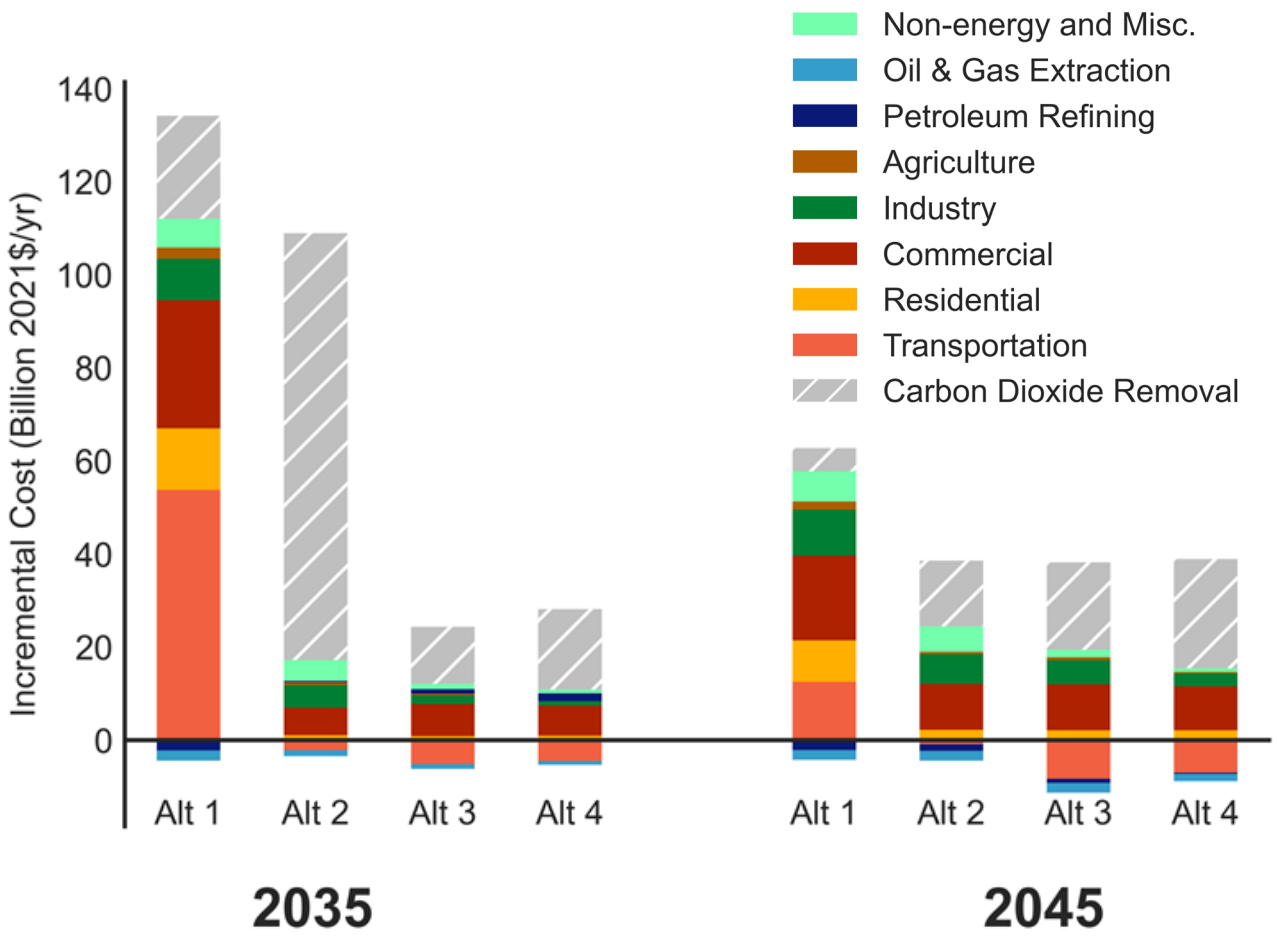
- Alternative 1 incurs increased costs for early retirement of ICE vehicles by 2035 and stock purchases of ZEVs in 2035 and 2045
- Alternatives 2 - 4 see cost savings reflective of fuel savings net of costs from ZEV stocks and electricity and hydrogen use
- Alternative 2 has additional costs in 2045 due to MHDV ICE retirements and replacement with ZEVs

+ Commercial & Residential

- Commercial electrification stock and energy costs comprise a large cost in all scenarios
- Residential and commercial appliance early retirement and replacement in Alternative 1 lead to increased costs

+ Industry

- Each Alternative reflects fuel cost savings due to electrification and increased costs for electricity
- Incremental industrial stock costs were not included and would significantly increase costs to achieve ambitious decarbonization measures



Thank You

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