Energy+Environmental Economics

Deep Decarbonization in a High Renewables Future

Updated results from the California PATHWAYS model

CEC EPIC-14-069 Study Results

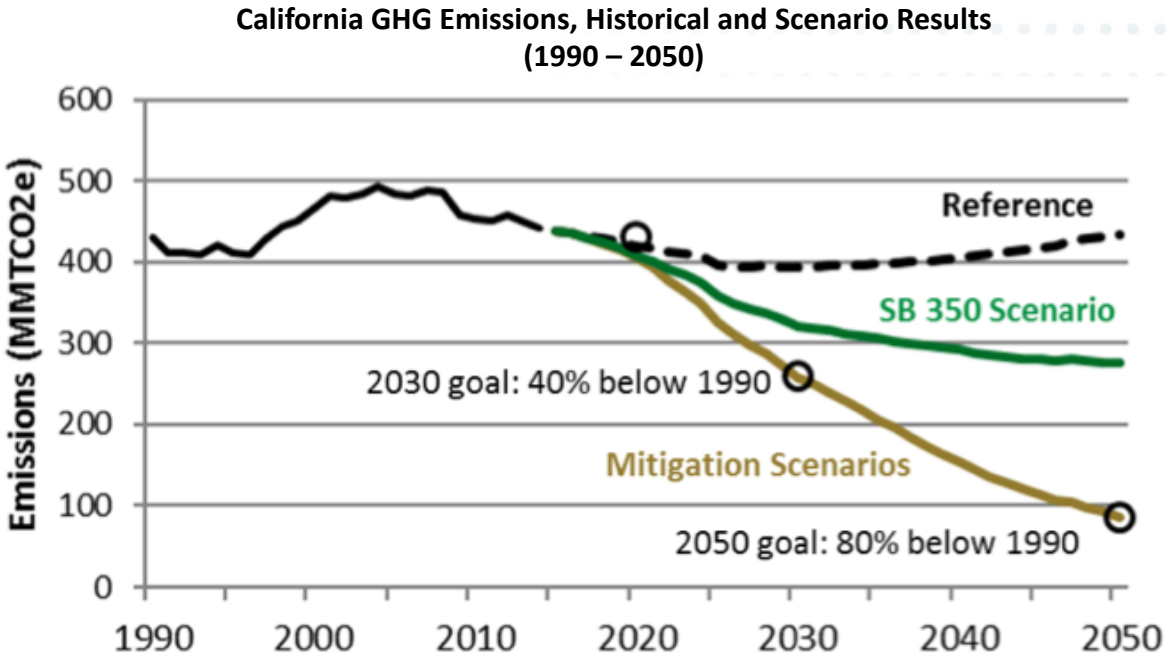
UC Davis California Climate Policy Modeling (CCPM-3) Workshop

May 14th, 2018

Amber Mahone, Dr. Zachary Subin,
Jenya Khan-Lang, Douglas Allen, Vivian Li, Gerrit De Moor,
Dr. Nancy Ryan, Snuller Price

Project Background

- **CEC EPIC funded research evaluated 10 "Mitigation Scenarios"**
  - All scenarios meet CA's 2030 & 2050 GHG goals
  - 40% GHG reduction by 2030 and 80% reduction by 2050, below 1990 level
- **Based on updated CA PATHWAYS model, builds off prior work**
  - California's 2017 Climate Change Scoping Plan
  - 2014/15: Inter-agency "Energy Principals' CA PATHWAYS analysis
  - Williams et al, *Science* (2012)

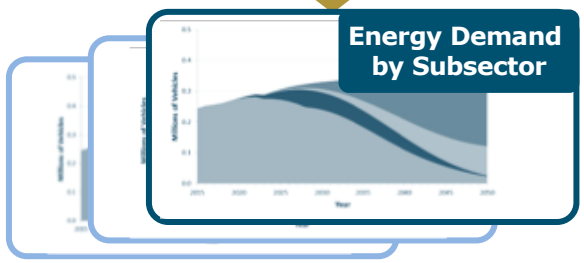


Modeling combines economy-wide GHG scenarios with electricity capacity expansion

PATHWAYS model:
California economy-wide energy scenarios

Technology Energy Demand

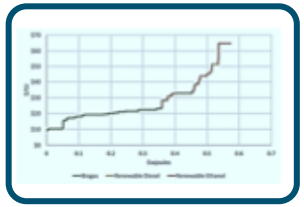
Stock Rollover

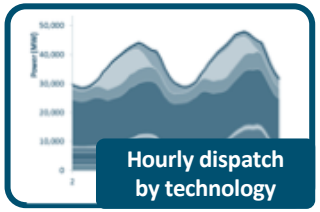


Fossil and Other Fuels

Biofuel Supply Curves

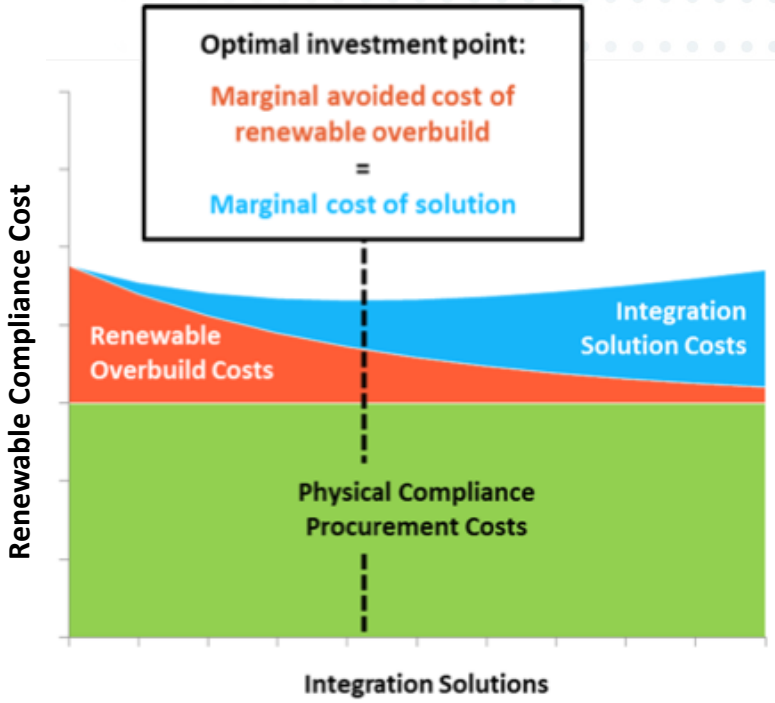
Hourly Electricity Supply



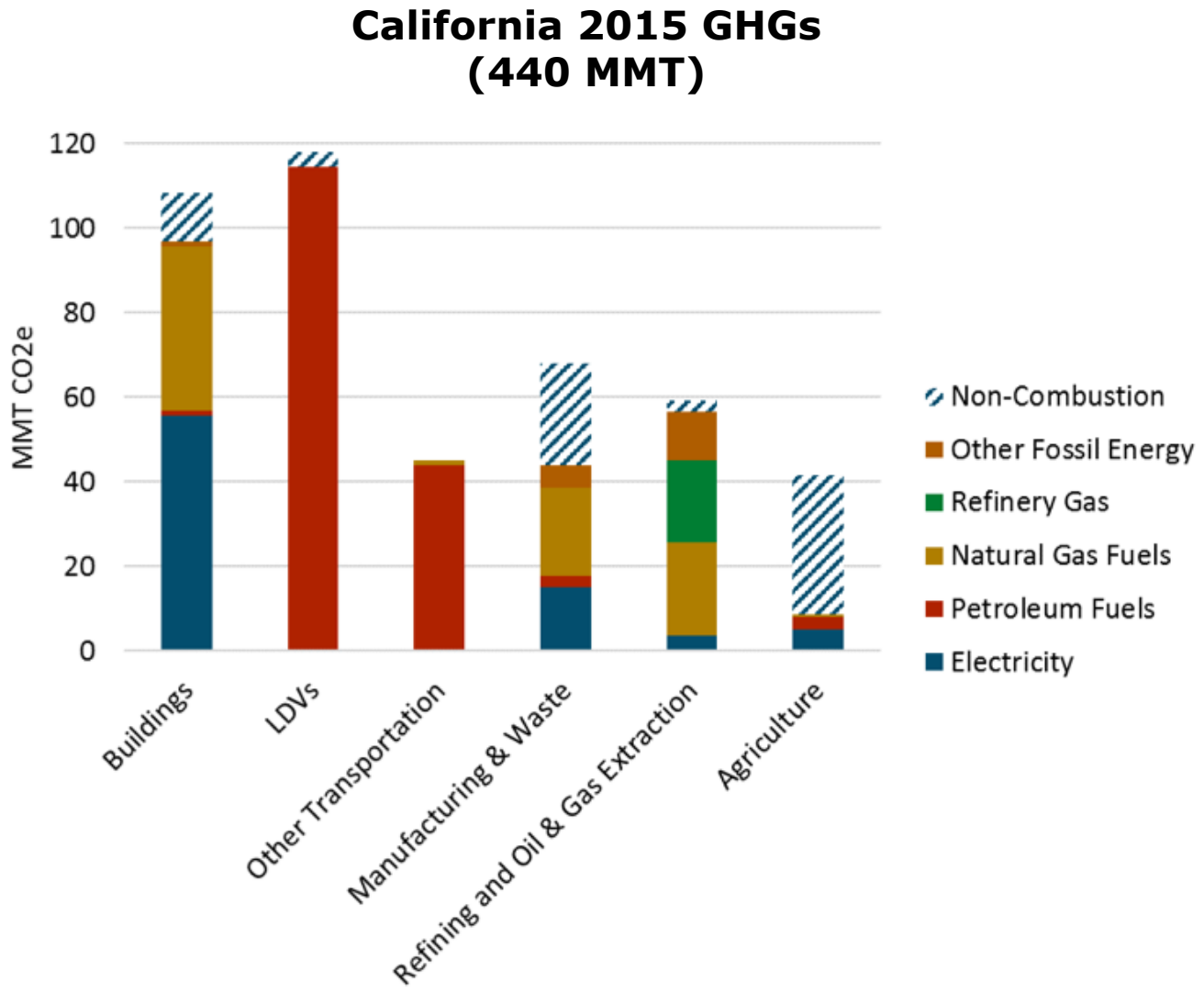


RESOLVE model: capacity expansion model
co-optimizes investment and operational decisions

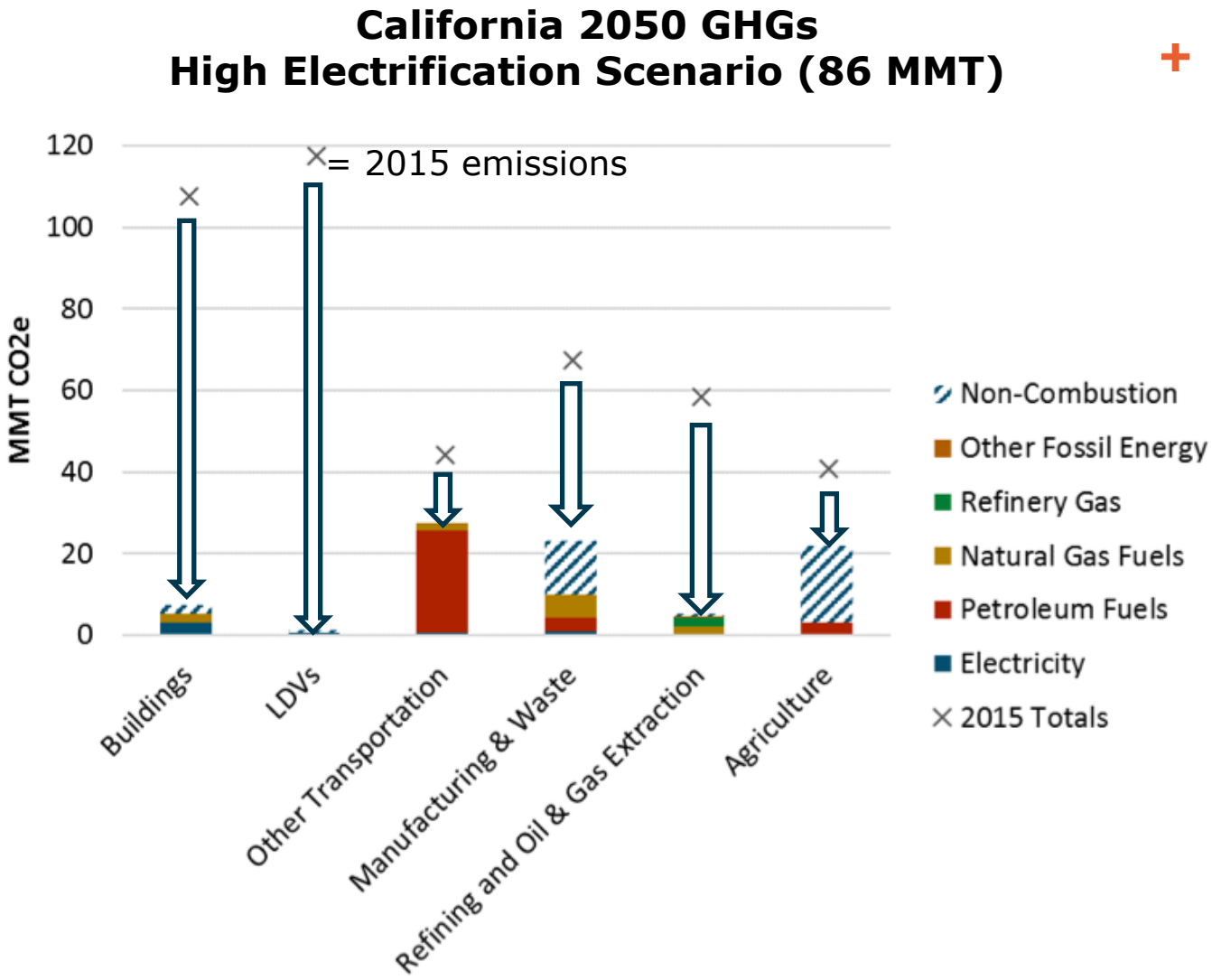
PATHWAYS provides RESOLVE with electric loads and electricity GHG limit consistent with economy-wide mitigation strategy



Light duty vehicles (LDVs) represent ~30% of California's GHG emissions today



By 2050, GHGs are in difficult to reduce sectors, largely non-combustion GHGs



+ ***Remaining 2050 emissions are mostly from trucking, aviation, cement, and waste, dairy & agricultural methane***

Four "Pillars" of Decarbonization

Energy efficiency & conservation

- Industrial efficiency
- Building efficiency & conservation
- Vehicle efficiency & smart growth

Electrification

- Industrial electrification
- Building electrification
- Vehicle and freight electrification

Low-Carbon Fuels

- Nuclear, Carbon Capture & Storage*
- Biofuels
- Renewables and hydroelectric

Sequester carbon & reduce non-combustion GHGs

- Soil & forest carbon, CO2 removal, black carbon*
- F-gases, N_2O, CO_2 from cement
- Methane (manure, dairy, gas leaks, etc.)

* Nuclear, Carbon Capture and Storage, CO2 removal technologies, and emissions from Land Use, Land-Use Change and Forestry (LULCF) and black carbon are not included in analysis.

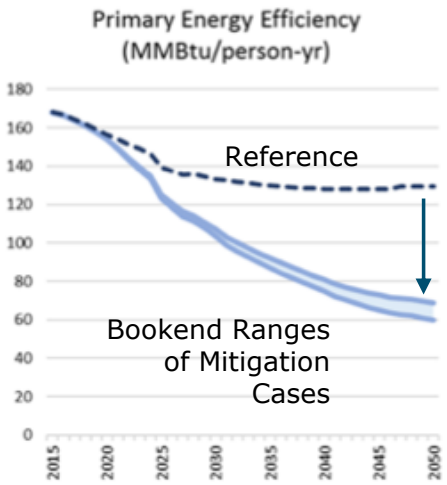
Four Pillars of GHG Reduction are Needed Across All Scenarios Evaluated

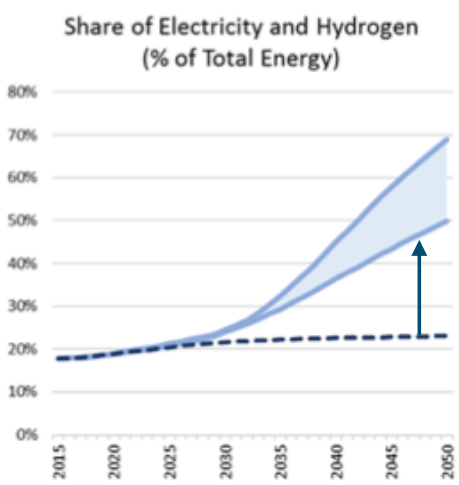
Energy efficiency & conservation

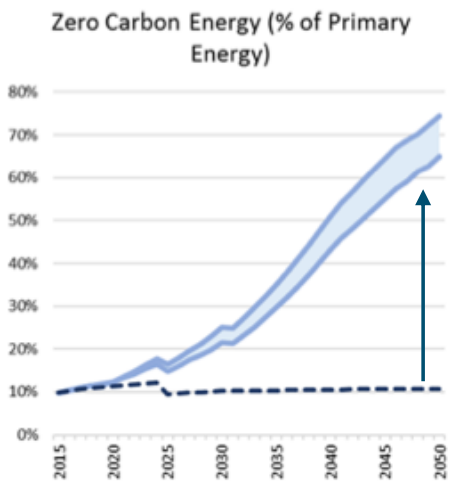
Electrification

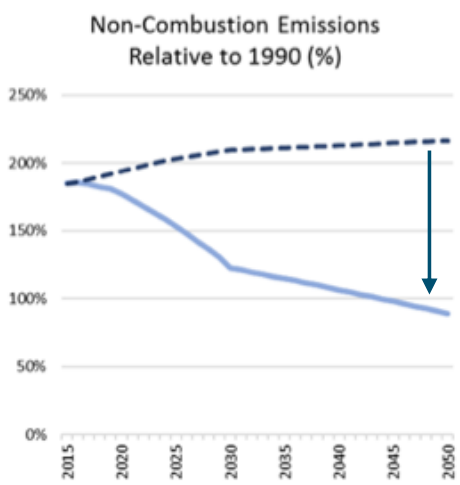
Low-Carbon Fuels

Reduce non-combustion emissions



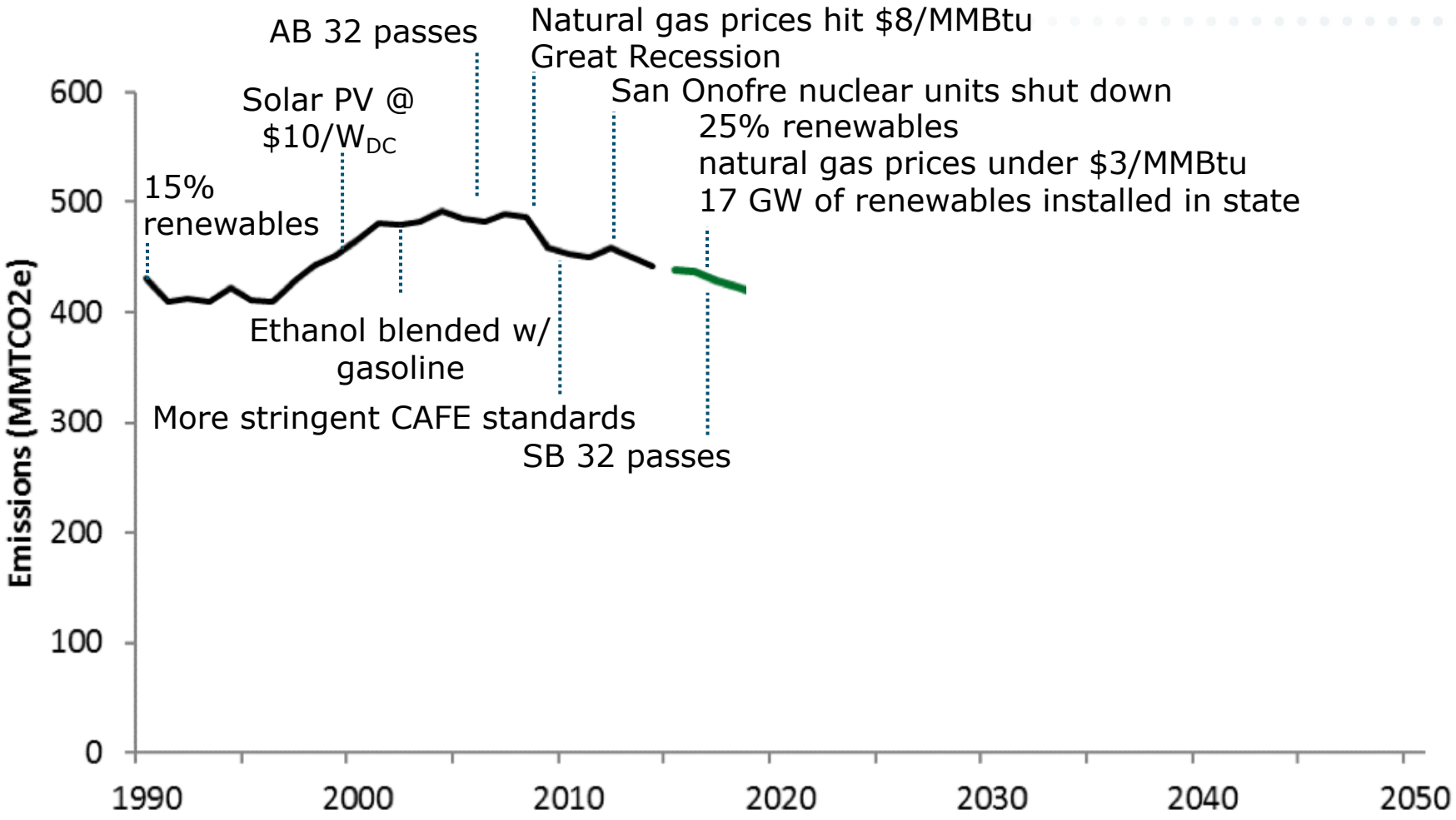




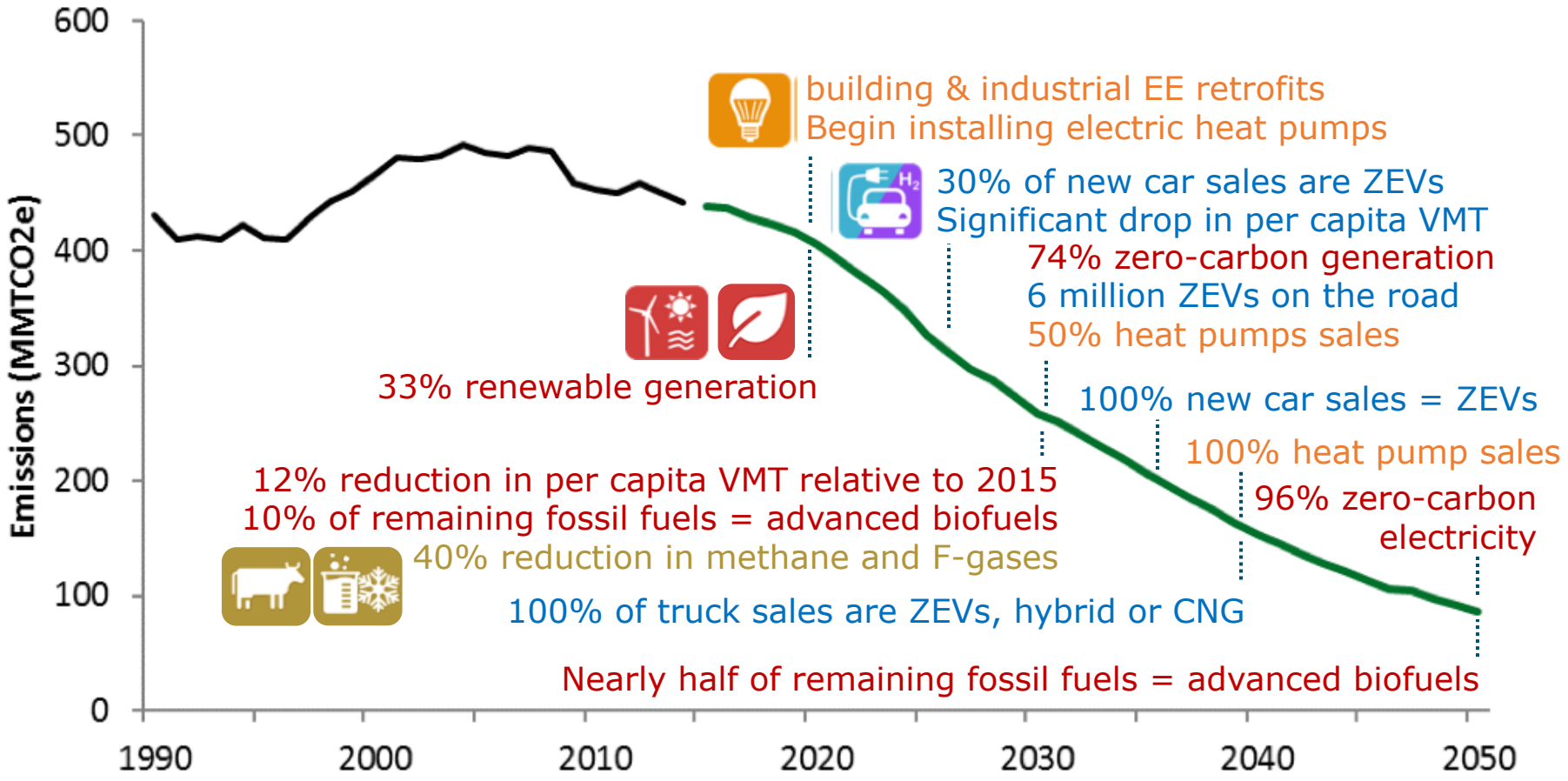


+ Significant progress is needed across all four pillars, with fastest ramp-up between today and 2030

Timeline of Statewide GHG Emissions

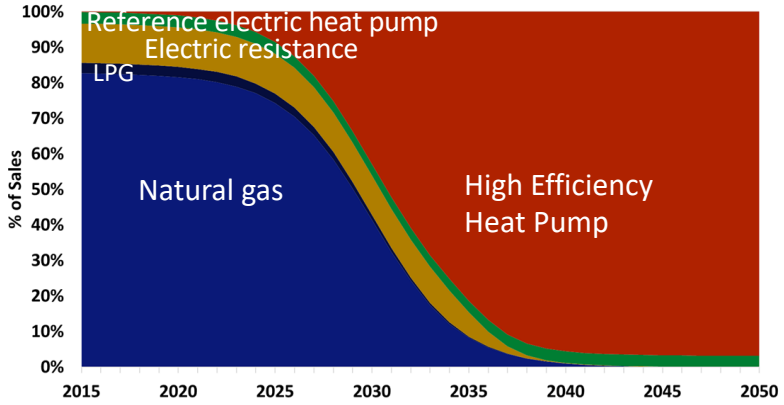


Timeline of GHG Reduction Measures in High Electrification Scenario

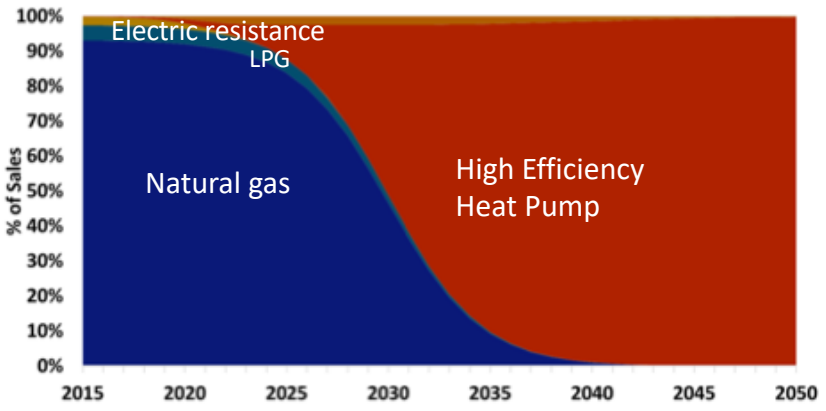


In the High Electrification Scenario, building equipment and vehicle sales shift to low emissions alternatives

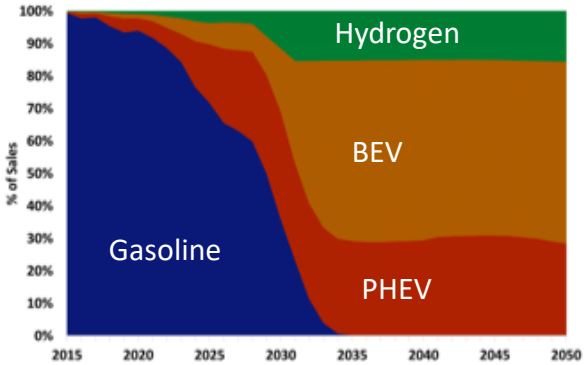
Space Heating (Residential, similar for Commercial)
% of new sales in High Electrification Scenario



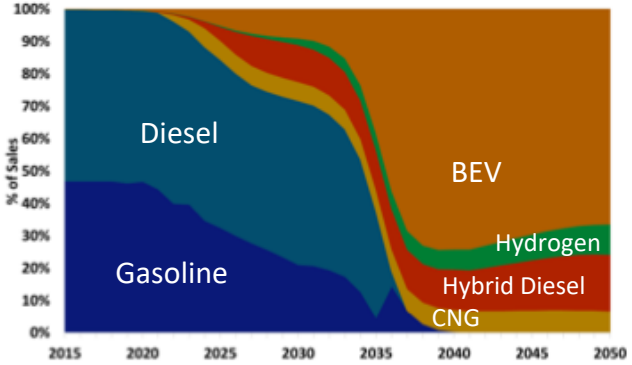
Water Heating (Residential, similar for Commercial)
% of new sales in High Electrification Scenario



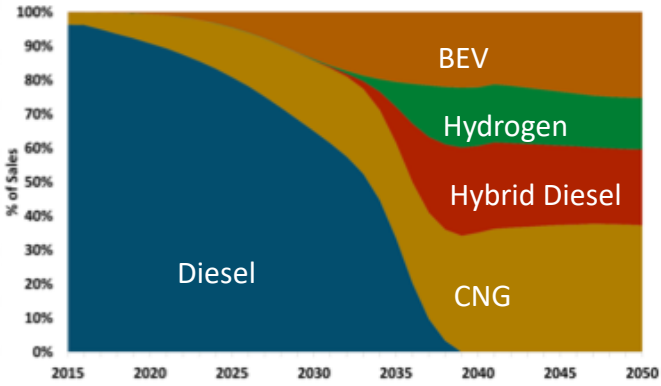
Light Duty Vehicles
% of new sales in High Electrification Scenario



Medium Duty Vehicles
% of new sales in High Electrification Scenario

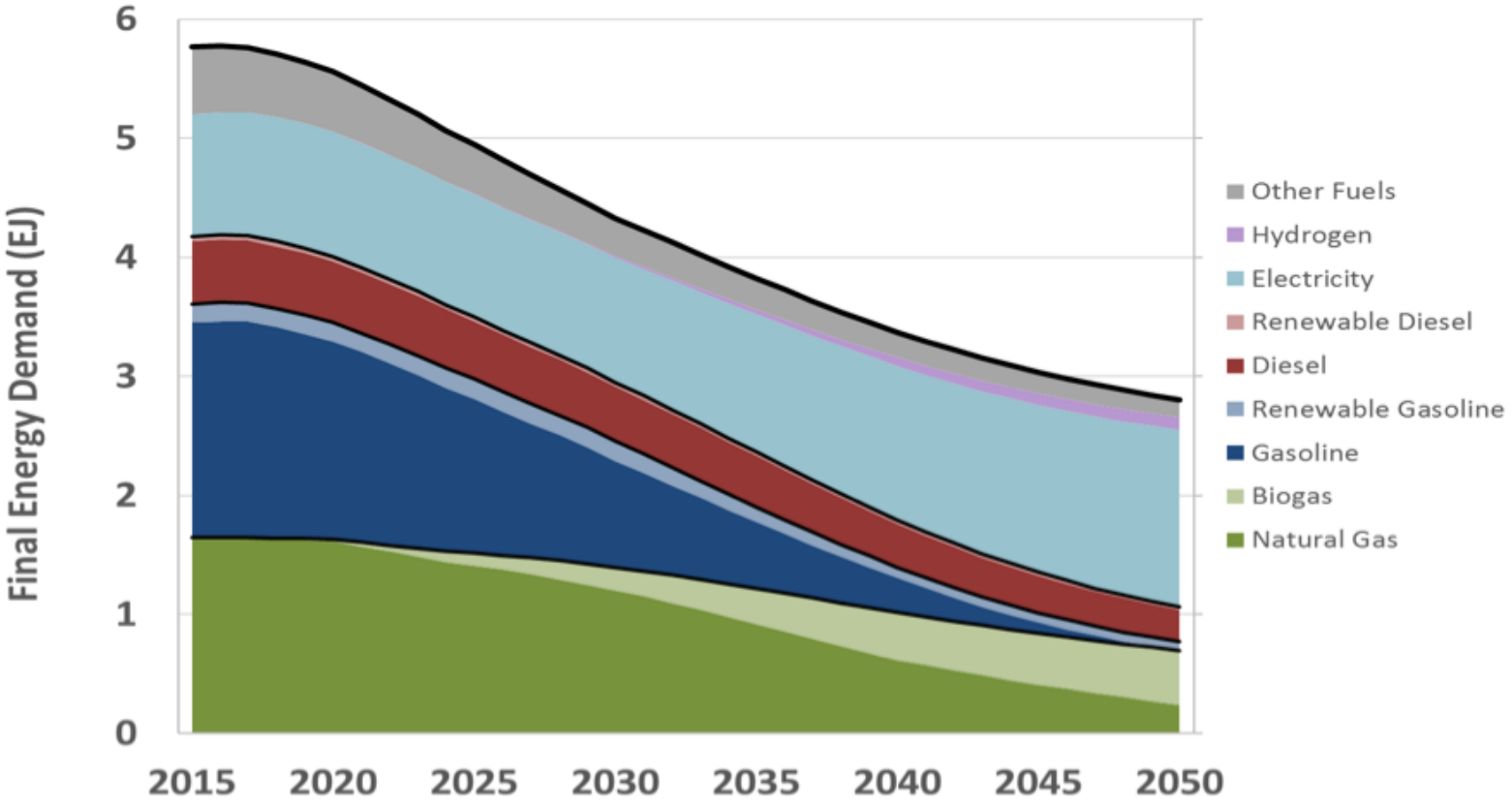


Heavy Duty Vehicles
% of new sales in High Electrification Scenario



Energy Demand is Increasingly Met with Low-Carbon Electricity, Limited Biofuels Used for Hard to Electrify End-Uses

- Electricity increases due to electrification of transportation and buildings, all other fossil fuels decrease
- Biomethane is used in this scenario to decarbonize industry, could be directed to renewable diesel to decarbonize trucking and off-road instead



High Priority GHG Mitigation Strategies & Key Challenges

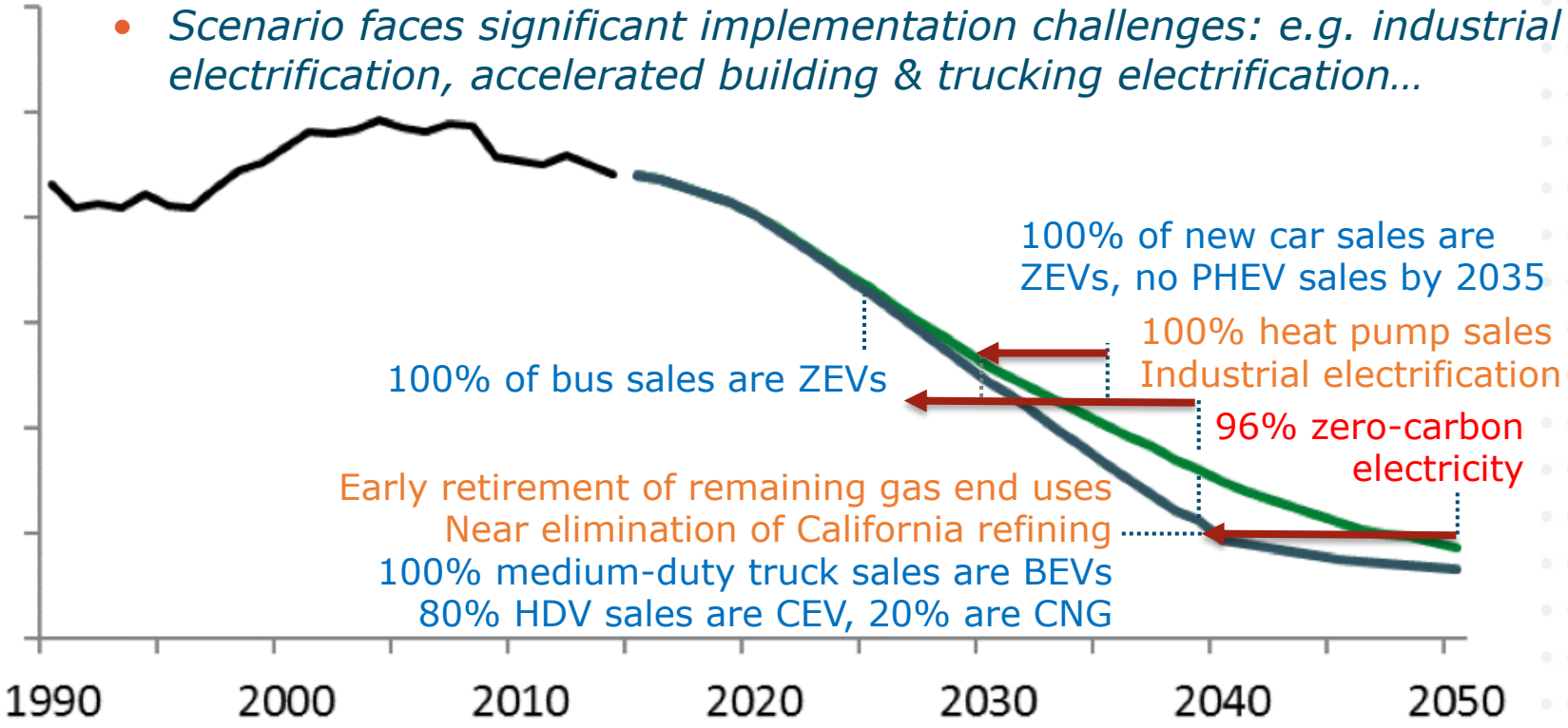
Scale Up & Deploy	Key Challenges
Energy efficiency in buildings & industry	**Consumer decisions** and market failures
Renewable electricity	Implementation of integration solutions
Smart growth	**Consumer decisions** and legacy development
Market Transformation	**Key Challenges**
Zero-emission light-duty vehicles	**Consumer decisions** and cost
Advanced efficiency/ building electrification	**Consumer decisions**, equity of cost impacts, cost and retrofits of existing buildings
F-gas replacement	Standards needed to require alternatives
Methane capture	Small and diffuse point sources
Reach technologies	**Key Challenges**
Advanced sustainable biofuels	Cost and sustainability challenges
Zero-emissions heavy-duty trucks	Cost
Industrial electrification	Cost & technical implementation challenges
Electrolysis hydrogen production	Cost

Key Conclusions

- **Meeting California's 2030 and 2050 climate goals will likely require higher carbon prices *and* new policies**
- ***Consumer decisions* are the lynchpin to 2030 GHG target**
  - Investing in energy efficiency improvements in existing buildings, installing electric heat pumps for HVAC and water heating
  - Purchasing and driving zero-emission vehicles
- ***Carbon pricing, incentives, and business and policy innovations* could all drive the needed *market transformation to* reduce costs, improve performance and increase choices for these key consumer-facing strategies**
- ***At least one "reach technology"* that has not been commercially proven is needed to help meet the longer-term 2050 GHG goal, and to mitigate risk of other solutions falling short**

Thought experiment: Acceleration of electrification and renewables?

- **78% reduction in GHGs by 2040 (85% by 2050) if electrification were accelerated by 5-15 years & 96% zero-carbon electricity accelerated by 10 years**
  - *We haven't evaluated feasibility or cost-benefit of this scenario*
  - *Scenario faces significant implementation challenges: e.g. industrial electrification, accelerated building & trucking electrification…*




Energy+Environmental Economics
Thank You!

Ten Mitigation Scenarios Test Different GHG Reduction Strategies & Risks

Mitigation Scenarios	Scenario description
High Electrification	Electrification of buildings and transportation, high energy efficiency, renewables, limited biomethane
No Hydrogen	No fuel cell vehicles or hydrogen fuel, includes industrial electrification
Reference Smart Growth	Less reductions in vehicle miles traveled, additional GHG mitigation measures in other sectors
Reduced Methane Mitigation	Higher fugitive methane leakage, additional GHG mitigation measures in other sectors
Reference Industry EE	Less industrial efficiency, additional GHG mitigation measures in other sectors
In-State Biomass	Less biofuels with no out-of-state biomass used, additional GHG mitigation measures in other sectors
Reference Building EE	Less building efficiency, additional GHG mitigation measures in other sectors
No Building Electrification with Power-to-Gas	No heat pumps or building electrification, additional GHG mitigation measures in other sectors
High Biofuels	Higher biofuels, including purpose grown crops, fewer GHG mitigation measures in other sectors
High Hydrogen	More fuel cell trucks, fewer all-electric vehicles