Energy+Environmental Economics

California Scenarios to 80% Reductions in GHGs by 2050

Insights from "Deep Decarbonization in a High Renewables Future" (CEC EPIC-14-069) and other recent E3 analysis

CARB Public Workshop on Carbon Neutrality: Scenarios for Deep Decarbonization

August 15, 2019

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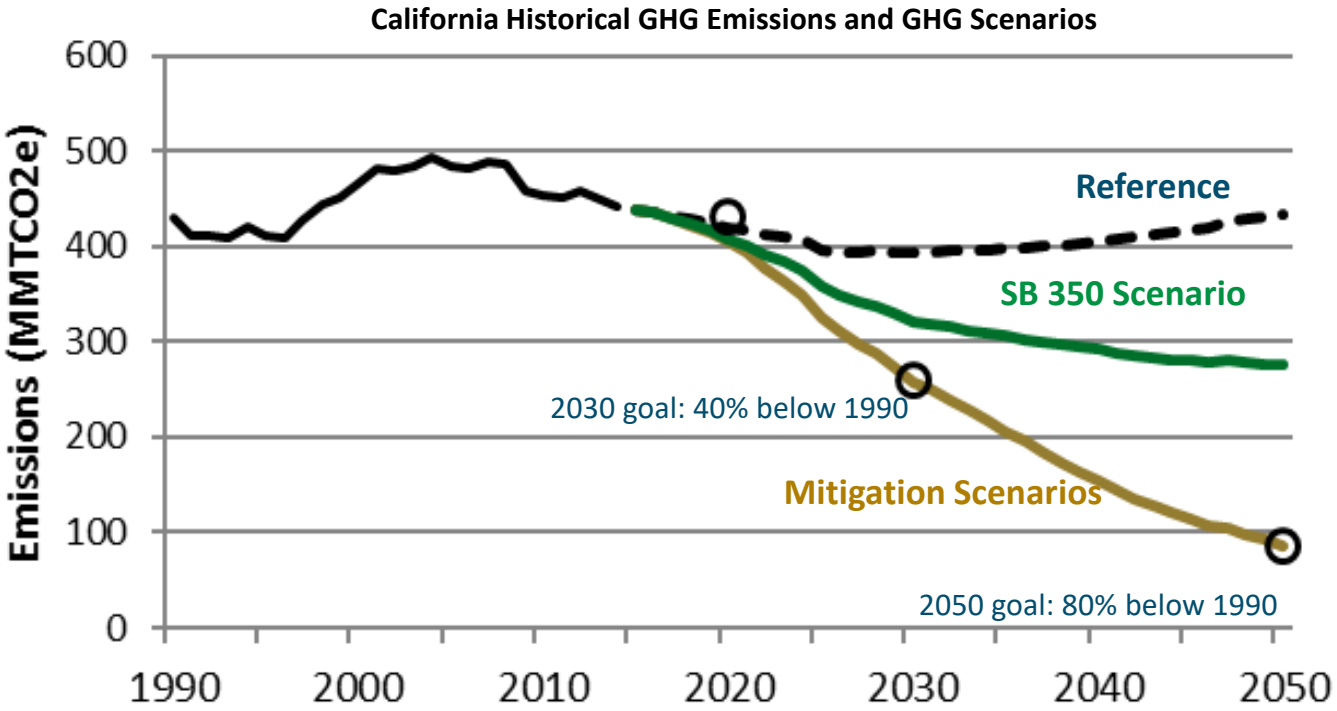
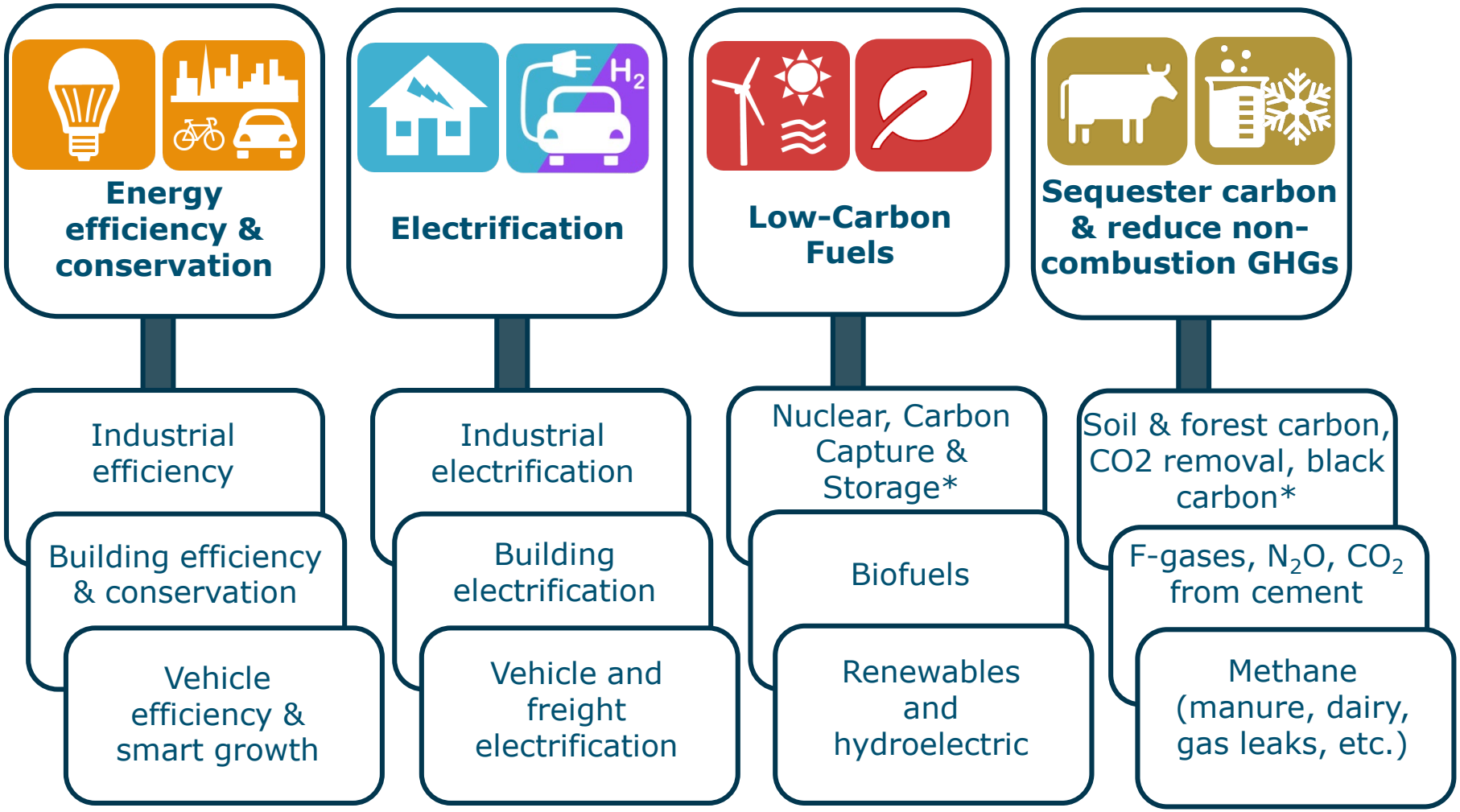
2018 CEC study evaluated 10 scenarios to 80% GHG reductions by 2050 ("80x50")

- **By 2020: return GHGs to 1990 levels** (AB 32, 2006)
- **By 2030: 40% below 1990 levels** (SB 32, 2015)
- **By 2050: 80% below 1990 levels** (EO B-30-15 and EO S-3-05)
- ***By 2045: Carbon neutrality*** *(EO B-55-18)* ***not evaluated in CEC analysis***



Source: Mahone et al, (2018) "*Deep Decarbonization in a High Renewables Future*", California Energy Commission CEC-500-2018-012

Four "Pillars" to an 80% GHG reduction
(Add negative emission technologies to hit carbon neutrality)



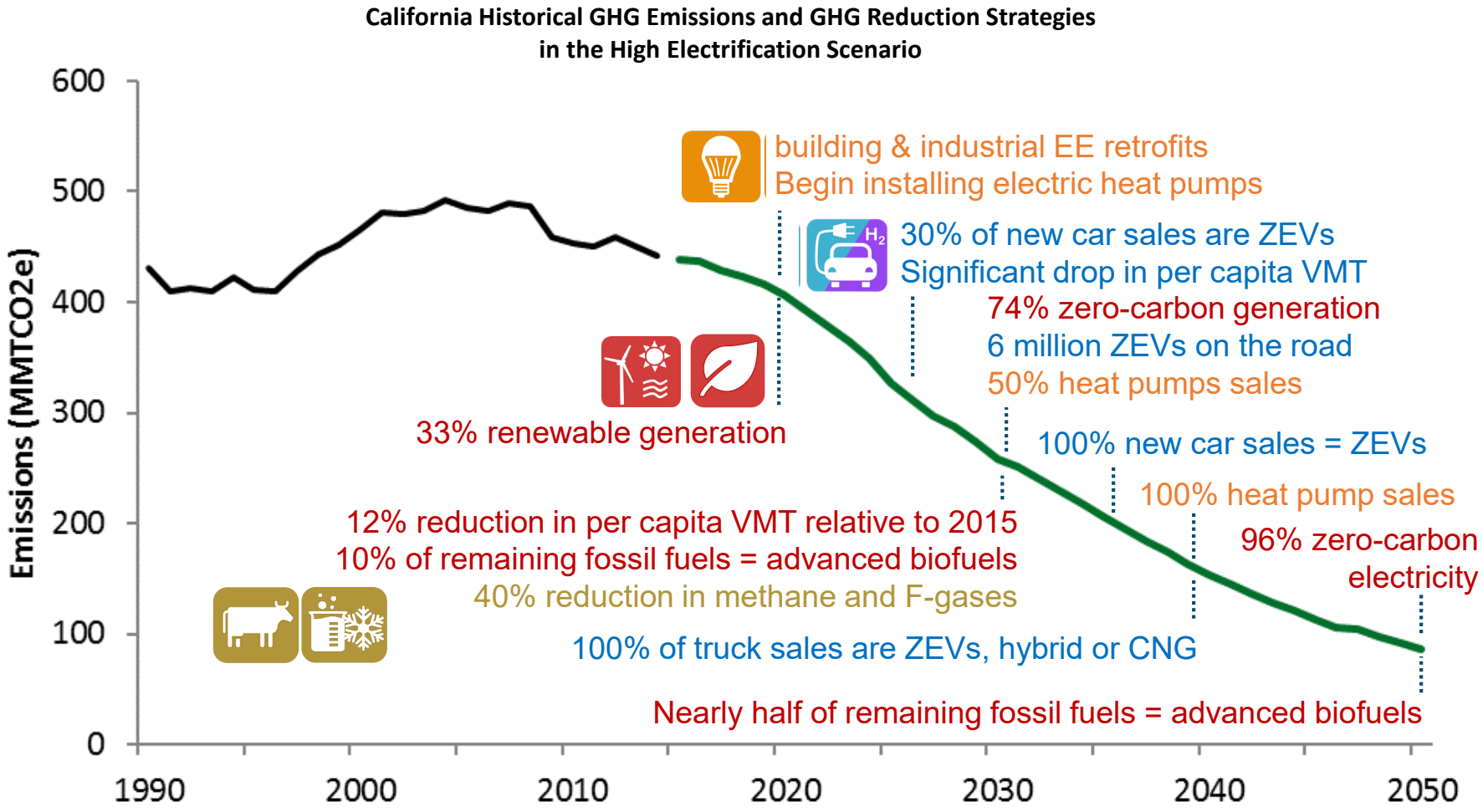
* Nuclear, Carbon Capture and Storage, CO2 removal technologies, and emissions from Land Use, Land-Use Change and Forestry (LULCF) and black carbon are not included in analysis.

Ten Mitigation Scenarios Test Different GHG Reduction Strategies & Risks

+ **The High Electrification Scenario is among the lower cost, lower-risk scenarios evaluated**

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

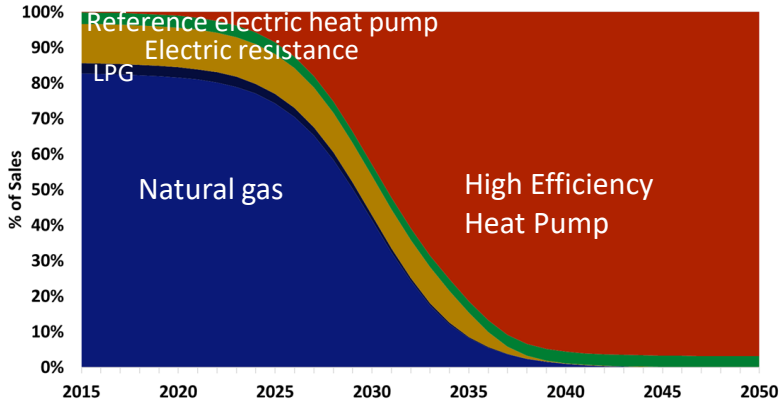
Example timeline of GHG reduction measures in High Electrification Scenario



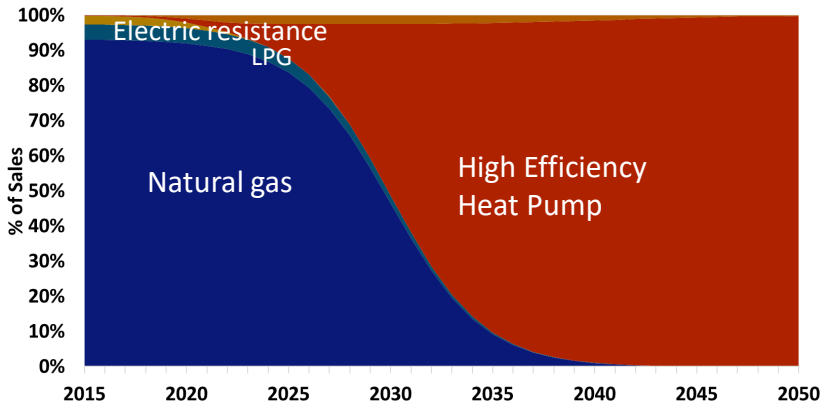
Source: Mahone et al, (2018) "*Deep Decarbonization in a High Renewables Future*", California Energy Commission CEC-500-2018-012

Buildings and vehicle sales shift to low emissions alternatives

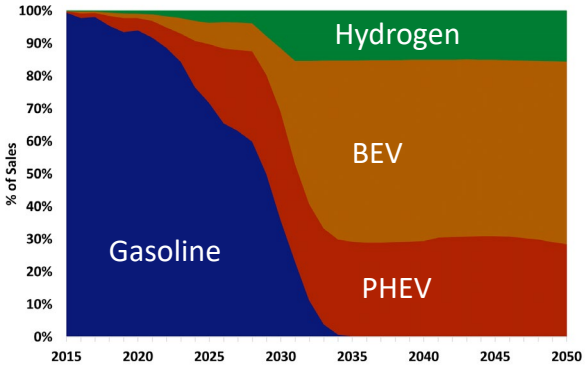
Space Heating (Residential, similar for Commercial)
% of new sales in High Electrification Scenario



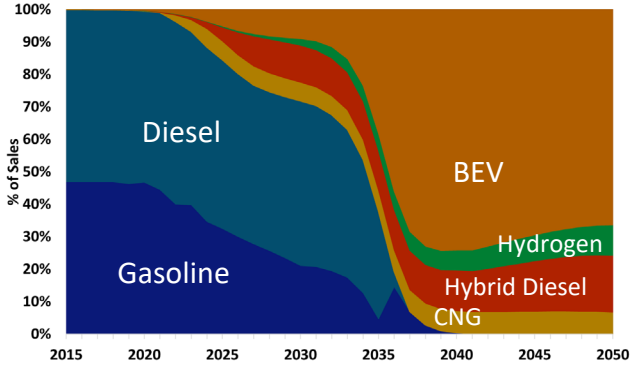
Water Heating (Residential, similar for Commercial)
% of new sales in High Electrification Scenario



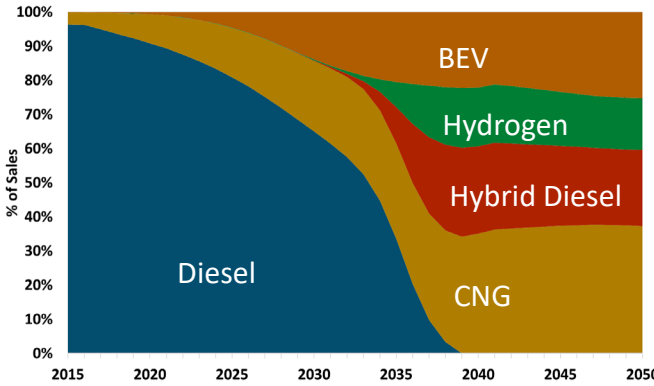
Light Duty Vehicles
% of new sales in High Electrification Scenario



Medium Duty Vehicles
% of new sales in High Electrification Scenario



Heavy Duty Vehicles
% of new sales in High Electrification Scenario

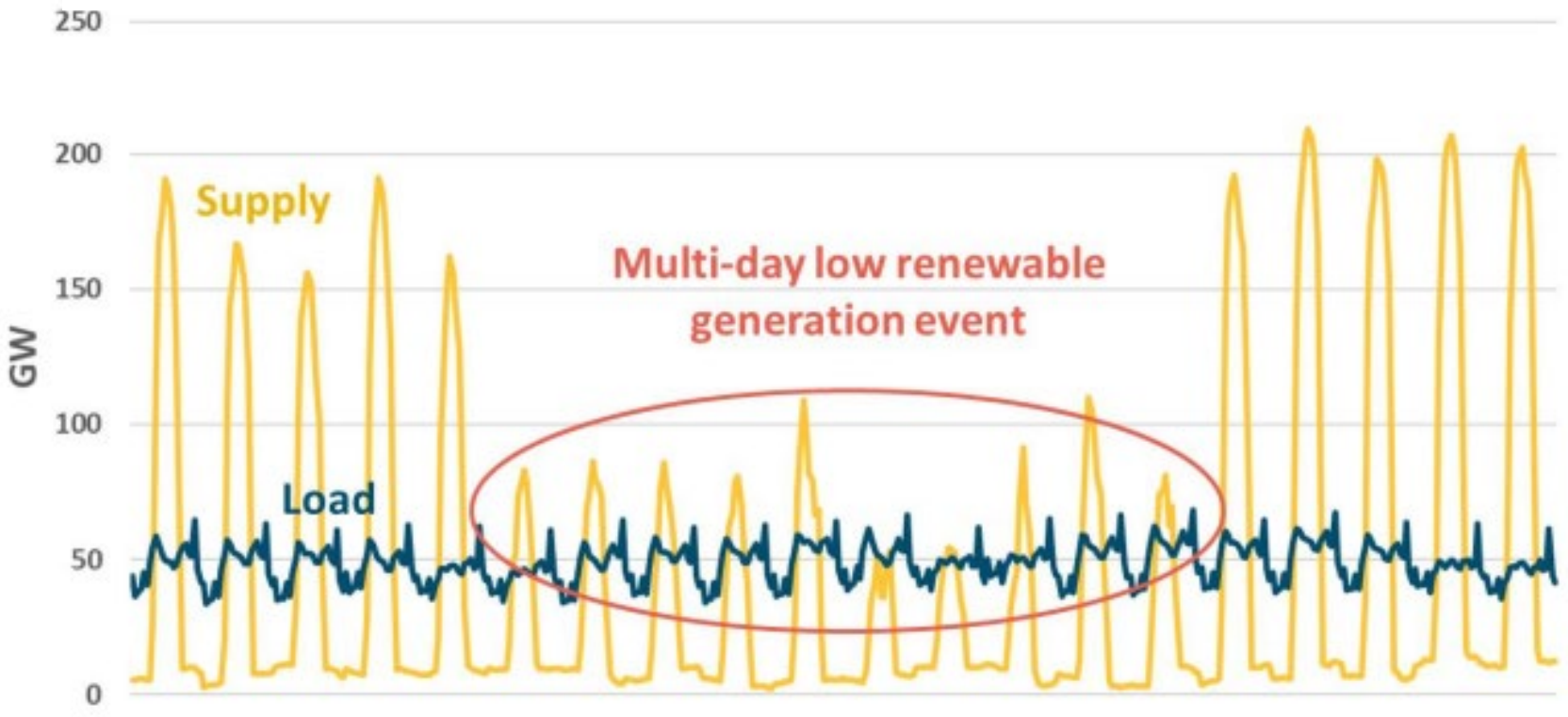


Source: Mahone et al, (2018) "*Deep Decarbonization in a High Renewables Future*", California Energy Commission CEC-500-2018-012

Maintaining electric reliability

- …in a high renewables, low-carbon future will require some form of very long-duration storage or firm dispatchable capacity (e.g. gas generation running on biomethane)

Electric Resource Supply and Loads During a Multi-Day Low Renewable Generation Event with Zero Dispatchable Gas Capacity (2050)



Source: E3, "Long-Run Resource Adequacy under Deep Decarbonization Pathways for California," June 2019

Achieving carbon neutrality by 2045 will likely require going beyond "80x50"

Energy efficiency & conservation

Faster and broader energy efficiency?

Electrification

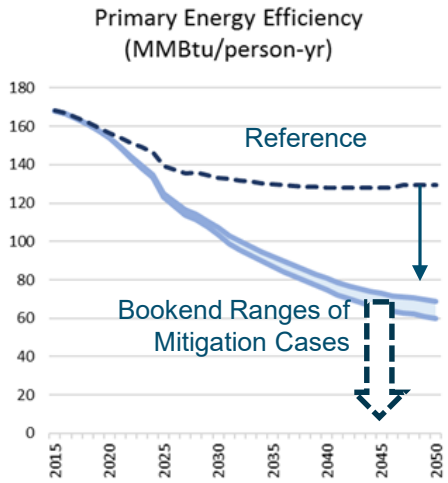
Faster and broader electrification?

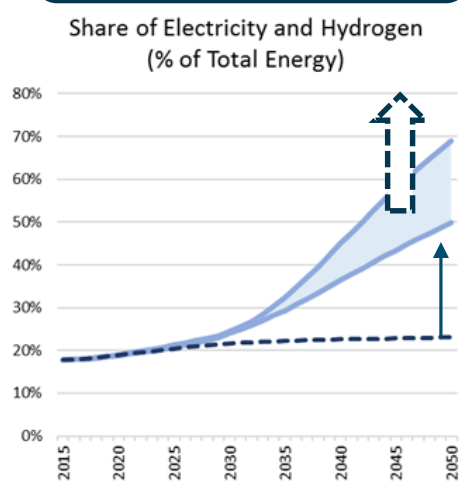
Low-Carbon Fuels

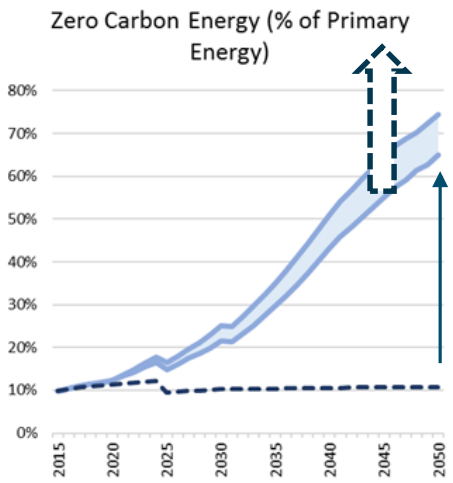
100% zero-carbon energy by 2045?

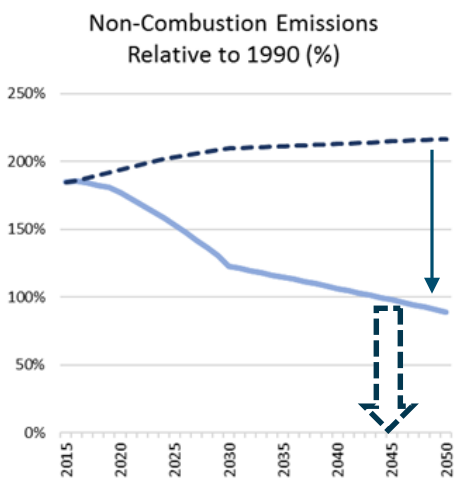
Reduce non-combustion emissions

100% reduction in non-energy GHGs by 2045?





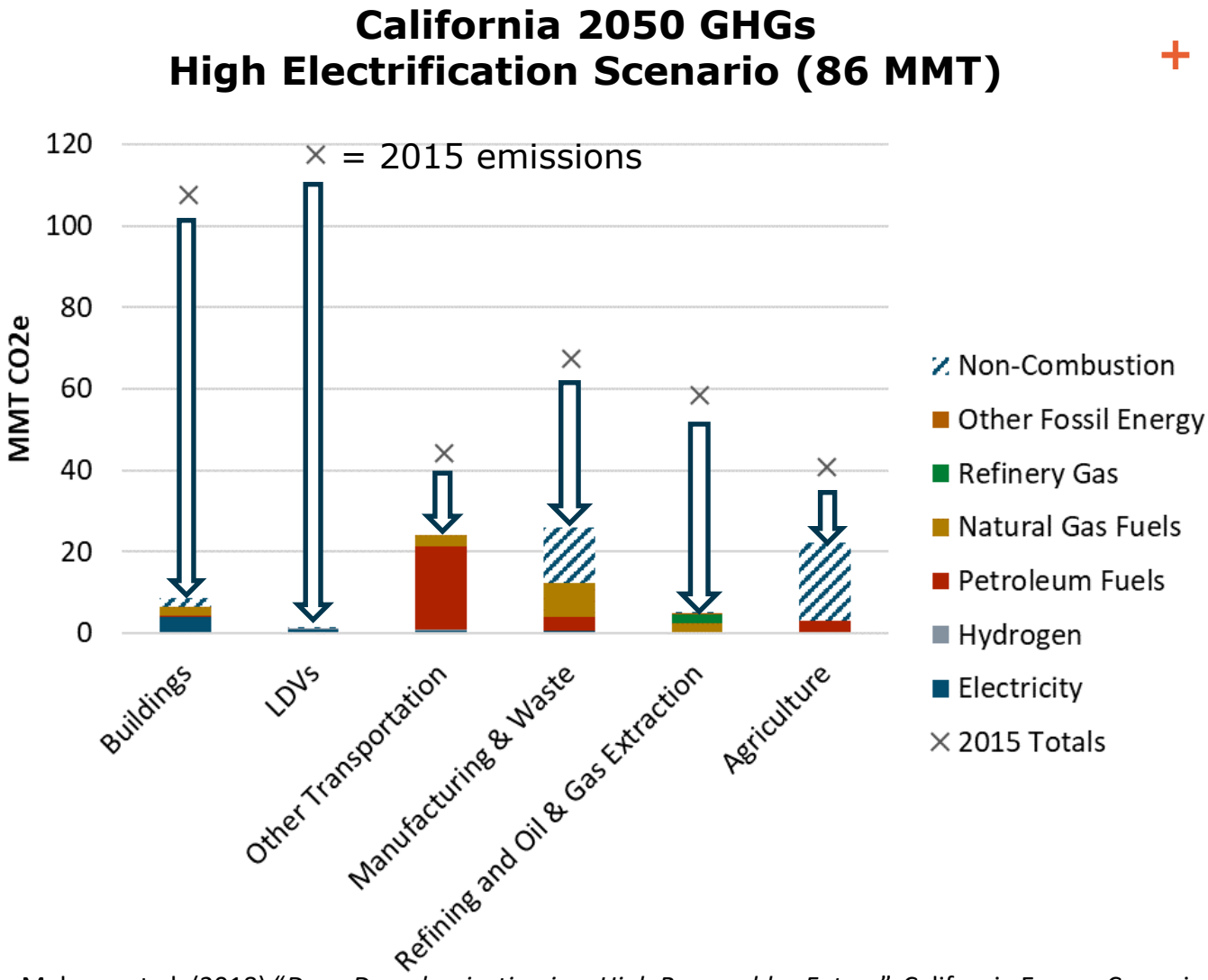




+ Significant progress is needed across all four pillars, with fastest ramp-up between today and 2030

Source: Mahone et al, (2018) "*Deep Decarbonization in a High Renewables Future*", California Energy Commission CEC-500-2018-012

Remaining GHGs in 2050 point to mitigation needed for carbon neutrality



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

Source: Mahone et al, (2018) "*Deep Decarbonization in a High Renewables Future*", California Energy Commission CEC-500-2018-012

High priority GHG mitigation strategies & key challenges to achieve '80x50'

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

Source: Mahone et al, (2018) "*Deep Decarbonization in a High Renewables Future*", California Energy Commission CEC-500-2018-012

Key Conclusions

+ ***Consumer decisions*** **are the lynchpin to meeting 2030 GHG target**
  - Investing in energy efficiency improvements in existing buildings
  - Purchasing and driving zero-emission vehicles
  - Installing electric heat pumps for HVAC and water heating
  - *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

+ ***85% - 95% zero-carbon electricity*** **is needed by 2050**
  - Renewable diversity and integration solutions are needed to reduce costs

+ ***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**
  - A "reach technology" should address difficult to electrify end-uses (e.g. heavy-duty trucking, industry)