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

Amber Mahone
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

California Historical GHG Emissions and GHG Scenarios

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

- **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, N2O, CO2 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.
## Ten Mitigation Scenarios Test Different GHG Reduction Strategies & Risks

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

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

California Historical GHG Emissions and GHG Reduction Strategies in the High Electrification Scenario

- Building & industrial EE retrofits
  - Begin installing electric heat pumps
- 30% of new car sales are ZEVs
- Significant drop in per capita VMT
- 74% zero-carbon generation
- 6 million ZEVs on the road
- 50% heat pumps sales
- 100% new car sales = ZEVs
- 100% heat pump sales
- Nearly half of remaining fossil fuels = advanced biofuels
- 96% zero-carbon electricity
- 100% of truck sales are ZEVs, hybrid or CNG
- 12% reduction in per capita VMT relative to 2015
- 10% of remaining fossil fuels = advanced biofuels
- 40% reduction in methane and F-gases

Buildings and vehicle sales shift to low emissions alternatives

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

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)

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?**

**Reference**

Bookend Ranges of Mitigation Cases

Energy efficiency & conservation: Faster and broader energy efficiency?

Faster and broader electrification?: Share of Electricity and Hydrogen (% of Total Energy)

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

Remaining GHGs in 2050 point to mitigation needed for carbon neutrality

California 2050 GHGs
High Electrification Scenario (86 MMT)

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

## High priority GHG mitigation strategies & key challenges to achieve ‘80x50’

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<th>Key Challenges</th>
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<td>Consumer decisions and market failures</td>
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<th>Market Transformation</th>
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<td>Zero-emission light-duty vehicles</td>
<td>Consumer decisions and cost</td>
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<tr>
<td>Advanced efficiency/ building electrification</td>
<td>Consumer decisions, equity of cost impacts, cost and retrofits of existing buildings</td>
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<td>F-gas replacement</td>
<td>Standards needed to require alternatives</td>
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<td>Methane capture</td>
<td>Small and diffuse point sources</td>
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<th>Reach technologies</th>
<th>Key Challenges</th>
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<td>Advanced sustainable biofuels</td>
<td>Cost and sustainability challenges</td>
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<td>Zero-emissions heavy-duty trucks</td>
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<td>Industrial electrification</td>
<td>Cost &amp; technical implementation challenges</td>
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<td>Electrolysis hydrogen production</td>
<td>Cost</td>
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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)