CARB Draft Scoping Plan: AB32 Source Emissions Initial modeling Results

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Amber Mahone, Partner
Jessie Knapstein, Managing Consultant
Gabe Mantegna, Senior Consultant
Vivan Malkani, Consultant
Scoping Plan 2022

California economy-wide scenarios developed in collaboration with CARB

PATHWAYS model:
California economy-wide energy and greenhouse gas scenarios
(E3 lead & prime contractor for overall team)

Air Quality and Health Impacts

SMOKE + CMAQ air quality models + BenMAP model for health impacts

Economic Analysis

IMPLAN macroeconomic modeling
PATHWAYS is a transparent and in-depth approach to economy-wide emissions accounting.

- Bottom-up, user-defined, non-optimized scenarios test “what if” questions.
- Economy-wide model captures interactions between sectors & path-dependencies.
- Annual time steps for infrastructure-based accounting simulates realistic stock roll over.
- Hourly treatment of electric sector.
- Tracks capital investments and fuel costs over time.

Sample Outputs:

- GHG Emissions by Sector and Scenario
- Hourly dispatch by Technology
- Technology Energy Demand
- Stock Rollover
- Energy Demand by Subsector
- Hourly Electricity Supply
- Pipeline Supply and Other Fuels
- Annual Generation by Fuel Type
Executive Summary
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 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.
<table>
<thead>
<tr>
<th>Key Metrics</th>
<th>Alternative 1</th>
<th>Alternative 2</th>
<th>Alternative 3</th>
<th>Alternative 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Annual Build Rates</strong></td>
<td>Solar: 10GW</td>
<td>Solar: 5GW</td>
<td>Solar: 7GW</td>
<td>Solar: 6GW</td>
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<tr>
<td>Historic Max Builds:</td>
<td>Battery: 5GW</td>
<td>Battery: 3GW</td>
<td>Battery: 2GW</td>
<td>Battery: 2GW</td>
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<tr>
<td>Solar: 2.7GW</td>
<td>Battery: 0.3GW</td>
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<tr>
<td>Solar: 10GW</td>
<td>Battery: 5GW</td>
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<tr>
<td>Solar: 7GW</td>
<td>Battery: 2GW</td>
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</tr>
<tr>
<td><strong>Vehicle Early Retirements</strong></td>
<td>LDV: 16M 5-16 yr. old</td>
<td>LDV: 0</td>
<td></td>
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</tr>
<tr>
<td>US-wide Cash for Clunkers</td>
<td>MHDV: 1.4M 5-16 yr. old</td>
<td>MHDV: 0.6M 10-20 yr. old</td>
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<td>$3B and 690k vehicles</td>
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<td>LDV: 16M 5-16 yr. old</td>
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<tr>
<td><strong>Residential Early Retirements</strong></td>
<td>7M electric homes.</td>
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<td>Appliances 5-16 yr old</td>
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<tr>
<td><strong>Petroleum Refining Remaining</strong></td>
<td>2035: 0%</td>
<td>2035: 25%</td>
<td>2035: 33%</td>
<td>2035: 39%</td>
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<tr>
<td>2045: 0%</td>
<td>2045: 8%</td>
<td>2045: 13%</td>
<td>2045: 18%</td>
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<tr>
<td><strong>Total CCS Needs</strong></td>
<td>2035: &lt;1MMT</td>
<td>2035: 7MMT</td>
<td>2035: 10MMT</td>
<td>2035: 11MMT</td>
</tr>
<tr>
<td>Industrial &amp; Refining</td>
<td>2045: &lt;1MMT</td>
<td>2045: 2MMT</td>
<td>2045: 3MMT</td>
<td>2045: 5MMT</td>
</tr>
<tr>
<td><strong>Residual Emissions</strong></td>
<td>2035: 45MMT</td>
<td>2035: 138MMT</td>
<td>2035: 0MMT</td>
<td>2035: 0MMT</td>
</tr>
<tr>
<td>Current global DAC 0.01 MT/year</td>
<td>2045: 37MMT</td>
<td>2045: 75MMT</td>
<td>2045: 95MMT</td>
<td>2045: 114MMT</td>
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</tbody>
</table>
Emissions
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
Agriculture and other methane and fugitive emissions are a large source of remaining emissions in all alternatives explored. Persistent sources of emissions which remain in all alternatives include industrial emissions and high global warming potential (GWP) emissions. Electricity generation and transportation emissions remain in cases expect those with emphasis on non-combustion alternatives (e.g. Alternative 1).
Oil & Gas Extraction for Alts 2, 3, & 4 tracks demand for petroleum while Alt 1 was ramped down linearly. Full phase out of Oil & Gas Extraction in 2035 for Alt 1 and 2045 for Alt 3.

Petroleum Refining Emissions is shown with and without application of carbon capture & sequestration (CCS) with a 90% capture rate. All Alternatives track petroleum demand and Alts 2, 3, & 4 apply CCS on all major operations by 2030.
Non-Energy Emissions

Rapid increase in digesters:
- Some alt manure management;
- Aggressive enteric strategy 2030;
- Herd reductions;
- Divert 75% of waste;
- Oil & Gas 50% reduction 2030;
- Low GWP refrigerants

Increase in digesters:
- Some alt manure management;
- Moderate enteric strategy;
- Divert 75% of waste;
- Oil & Gas 50% reduction 2030;
- Low GWP refrigerants

No digester capture:
- Max alt manure management;
- Aggressive enteric strategy;
- Herd reductions;
- Divert 75% waste;
- Oil & Gas phased out;
- Low GWP refrigerants

Increase in digesters:
- Limited alt manure management;
- Moderate enteric strategy;
- Divert 75% of waste;
- Oil & Gas 45% reduction 2030;
- Low GWP refrigerants

Additional reductions in line with demand 2045

- Other
- Organic Waste
- Oil and Gas + Pipelines
- HFCs
- Agriculture: Enteric and Manure

Year

2020
Alt 1
Alt 2
Alt 3
Alt 4

2035

2045
Energy Demand
Building Energy Demand

Energy Efficiency: Aligned with Integrated Energy Policy Report (IEPR) Mid-High (electric) and Mid-Mid (gas)

Electrification:
- New construction 2026;
- 80% sales 2030;
- 100% res sales 2035

Electrification:
- New construction 2026 (res) & 2029 (comm);
- 80% sales by 2030;
- 100% res sales 2035

Electrification:
- New construction by 2029;
- 75% sales by 2030;
- 100% res sales 2035

Electrification:
- 100% comm sales 2045

Energy Efficiency: Aligned with Integrated Energy Policy Report (IEPR) Mid-High (electric) and Mid-Mid (gas)

Final Energy Demand (Exajoules)
Transportation Energy Demand

VMT reduced 15% by 2030;
VMT reduced 20% by 2035;
100% LDV ZEV sales by 2030;
100% MHDV ZEV sales by 2035;
PHEV sales phased out by 2035.

VMT reduced 25% by 2030;
VMT reduced 30% by 2035;
100% LDV ZEV sales by 2030;
100% MHDV ZEV sales by 2035;
PHEV sales phased out by 2035.

VMT reduced 12% by 2030;
EO 100% LDV ZEV sales by 2035.

VMT reduced 10% by 2030;
80% LDV ZEV sales by 2035;

VMT reduced 15% by 2045;
100% LDV ZEV sales by 2040;
100% MHDV ZEV sales by 2045.

VMT reduced 22% by 2045;
100% MHDV ZEV sales by 2040;
100% MHDV ZEV sales by 2045.

Only MHDV ZEVs by 2045.

Final Energy Demand (Exajoules)

- Liquid Petroleum Fuels
- Liquid Biofuels
- Hydrogen
- Biomethane
- Natural Gas
- Electricity

Energy-Environmental Economics
Industry and Agriculture Energy Demand

Energy Efficiency: Aligned with 2017 Scoping Plan with a 6% energy demand reduction for industry and agriculture

Electrification:
- Ag 50%
- Constr & Food: 100%
- Chem: Boilers 100%
- Chem Process Heat 50% H2;
  CCS on 40% cement and major operations for Petroleum Refining

100% Electrification (exc. cement);
CCS on 100% cement

~25% electrification of Ag,
Const & Food
Chem Process Heat 25% H2;
CCS on 40% cement and major operations for Petroleum Refining

CCS on 40% cement and major operations for Petroleum Refining

Electrification:
- Ag 70%
- Chem Process Heat 100% H2;
  CCS on 100% cement

Electrification: 30-60%
Chem Process Heat 10% H2;
CCS on 100% cement;

- Other
- Liquid Petroleum Fuels
- Liquid Biofuels
- Hydrogen
- Biogas
- Natural Gas
- Electricity

Final Energy Demand (Exajoules)

2020

2035

2045
Fuel and Stock Transitions
Energy Demand by Fuel

+ **Natural gas** phases down as electrification measures ramp up
+ **Hydrogen** is assumed to be biomass gasification with carbon capture and sequestration (CCS) and electrolysis and is heavily utilized in multiple sectors
  - Alt 1: 25% aviation 2035; 10% OGVs 2035; HFCV trucks 2030; line haul/passenger rail 2030
  - Alt 2: 7% pipeline blend 2040; 10% OGVs 2035; HFCV trucks 2035; line haul/passenger rail 2030
  - Alt 3: 7% pipeline blend 2040; 25% OGVs 2045; HFCV trucks 2040; line haul/passenger rail 2035
  - Alt 4: 7% pipeline blend 2040; HFCV trucks 2045; line haul/passenger rail 2045
+ **Gasoline** ramps down in line with ZEV targets
+ **Electricity** ramps up in line with building and transportation electrification targets
+ **Diesel** ramps down in line with MHDV targets and industrial electrification

**Biofuels categorized in natural gas, kerosene, and diesel**
Combustion Fuels Transition

- 25% Carbon Intensity Reduction 2035 Transportation; Targeted H2 use;
- 20% Carbon Intensity Reduction 2030 Transportation; H2 used in key sectors; Combustion phase outs;
- 20% Carbon Intensity Reduction 2030 Transportation; Biofuels used for Sustainable Aviation Fuel then BECCS H2; Increasing H2 pipeline blend up to 7%;
- Final Energy Demand (EJ)

Graph showing energy demand for different alternatives in 2020, 2035, and 2045.
Light Duty Vehicle Stocks

- Alternatives 1, 2, and 3 meet each of the Executive Orders
- Alt 1 has ~19M ICE vehicles remaining in 2030 and 0 by 2035
- Alt 2 has ~2M ICE vehicles remaining in 2045
- Alt 3 has ~5M ICE vehicles remaining in 2045
- Alt 4 has ~8M ICE vehicles remaining in 2045

LDV ZEV Stocks

- Alt 4
- Alt 3
- Alt 2
- Alt 1
- BAU Reference
Alt 1 requires large scale early retirement of internal combustion vehicles to achieve only ZEVS by 2035
Alt 2 requires some early retirement to achieve only ZEV MDV and HDV by 2045
Alt 3 and Alt 4 have a slower transition that requires no early retirement
Alt 1 requires large scale early retirement of gas end-use appliances to achieve gas retirement by 2035.

Alt 2, Alt 3, and Alt 4 have a slower transition that requires no early retirement.

### Residential

- **BAU**
  - 2030: 69% gas
  - 2035: 0% gas

- **Alt 1**
  - 2030: 69% gas
  - 2035: 0% gas

- **Alt 2**
  - 2030: 82% gas
  - 2045: 14% gas

- **Alt 3**
  - 2030: 85% gas
  - 2045: 21% gas

- **Alt 4**
  - 2030: 71% gas
  - 2035: 0% gas

### Commercial

- **BAU**
  - 2030: 69% gas
  - 2035: 0% gas

- **Alt 1**
  - 2030: 69% gas
  - 2035: 0% gas

- **Alt 2**
  - 2030: 82% gas
  - 2045: 14% gas

- **Alt 3**
  - 2030: 85% gas
  - 2045: 21% gas

- **Alt 4**
  - 2030: 71% gas
  - 2035: 0% gas
Electric Sector
Summary

- Reference case stays constant at currently-mandated 38 MMT target
- Alt 1 has a 0 MMT by 2035 target with no combustion
- Alts 2, 3 and 4 all feature an SB100 100% of retail sales clean energy target by 2045. All scenarios remain at around 30 MMT through 2050
Electric loads increase by 30-80% relative to today by 2035 and 60-90% by 2045.

Loads for direct air capture and hydrogen production are assumed to be provided by off-grid renewables, and are not included in this graphic.

Other transportation includes all non-LDVs and reflects electrification of things like passenger and freight rail, aviation, and ocean-going vessels (OGVs).
Alt 1 features a 100% no combustion target by 2035 and significantly higher electrification loads, causing resource builds to be much higher than the other scenarios.

This Alt 1 constraint leads to ~7GW of gas retirements in 2035 and ~6GW of new gas build for capacity (CF: 0%).

Alt 1 builds ~56GW of battery storage and ~26GW of hydrogen fuel cells as firm clean capacity.

Alt 2 also features a notably higher build in 2035 due to the higher loads.

Note the scale of these results: current CA installed nameplate capacity is 84GW.
In Alt 1, builds ~62 GW of battery storage and ~30 GW of hydrogen fuel cells as clean firm capacity.

Alt 1 builds ~124 GW of solar, compared to ~26 GW in the BAU.

Alts 2 through 4 are similar in 2045 due to SB100 goal, while in Alt 1 the model builds significantly more clean energy resources to meet the 0 MMT, no combustion target.

In Alt 3 scenario, model builds ~90 GW of solar and ~40 GW of batteries to meet SB100 retail sales target. All gas remains online and ~10 GW of new gas is built.

Note the scale of these results: current CA installed nameplate capacity is 84GW.
Thank You
Jessie.Knapstein@ethree.com