Appendix D
PATHWAYS

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Scoping Plan Scenario & Alternatives Modeling Description

This document summarizes the input assumptions and data sources for the Reference Scenario, Scoping Plan Scenario, No Cap-and-Trade Scenario (Alternative 1), Carbon Tax Scenario (Alternative 2), All Cap-and-Trade Scenario (Alternative 3), and the Cap-and-Tax Scenario (Alternative 4) developed as part of the Scoping Plan. The Carbon Tax Scenario (Alternative 2) has the same set of policies as the Scoping Plan Scenario and only differs in the structure of the carbon pricing mechanism, so both scenarios are discussed together.

These are scenarios developed by the California Air Resources Board (ARB) and implemented by Energy and Environmental Economics, Inc. (E3) in the California PATHWAYS model.[1] **NOTE: The scenarios and modeling assumptions have been updated from the January 2017 draft based on stakeholder comments, the requirements under Assembly Bill 398 (E. Garcia, 2017) and other technical refinements.**

The modeling assumptions and results in this document are not intended to establish specific strategies or adopted targets for GHG emissions reductions. Rather, the Scoping Plan shows the types of action the State must take in order to reach its GHG reduction goals. It's important to note that the modeling assumptions used in this document may differ from other models used by State agencies. Modeling exercises undertaken to support future regulatory proceedings based on updated or more detailed information may result in different designs of measures, programs, program implementation, and performance results than those used in the modeling for this Scoping Plan.[2]

[1] For background about the PATHWAYS model, see the January 15th, 2016 ARB Scoping Plan Update Economic Analysis Workshop presentation on PATHWAYS available here: https://www.arb.ca.gov/cc/scopingplan/meetings/1142016/e3pathways.pdf as well as supporting materials posted here: https://www.arb.ca.gov/cc/scopingplan/meetings/meetings.htm

[2] State agencies responsible for implementing actions, including the CEC and CPUC, will be vetting their respective goal-setting processes separately from ARB Scoping Plan activities with their own focused public discussions.

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Scenario Overview

Six scenarios are described in the Scoping Plan, as described below:

1) **Reference Scenario,** which represents current policies prior to the passage and implementation of California Senate Bill 350 (SB 350, De Leon, 2015). The known commitments as described in the Scoping Plan are additional to assumptions in the Reference scenario.

2) **Scoping Plan Scenario**, which represents current policies and known commitments, including the impacts of SB 350, the Cleaner Technology and Fuels Scenario of the Mobile Source Strategy, as well as a more stringent Low Carbon Fuel Standard through 2030. The PATHWAYS scenario does not model the impacts of cap-and-trade, but this policy is assumed to deliver GHG emissions reductions through a declining cap to help meet the 2030 GHG target. The impact of the cap-and-trade program is modeled outside of PATHWAYS in the economic analysis of the Scoping Plan as discussed in Appendix E.

3) **Alternative 1: No Cap-and-Trade** includes all of the policies and programs that exist in the Scoping Plan Scenario, as well as additional measures to meet the 2030 target without reliance on cap-and-trade or a carbon tax. The types of actions in this scenario may be described as enhancements to existing statutes or other requirements. These descriptions are not to advocate for changes to existing statute, but rather to describe increased action of the type already called for by the existing statute. For example, an increased RPS in this scenario is used to illustrate the possibility of deploying more renewable power than called for by SB 350.[3,4]

4) **Alternative 2: Carbon Tax** is identical to the Scoping Plan Scenario in the PATHWAYS model but is assumed to use a carbon tax rather than cap-and-trade to deliver the remaining reductions to achieve the 2030 target. The impact of the carbon tax is modeled outside of PATHWAYS in the economic analysis of the 2030 Target Scoping Plan as discussed in Appendix E.

5) **Alternative 3: All Cap-and-Trade** includes the impacts of SB 350, but not the additional carbon intensity reductions in fuels from a more stringent Low Carbon Fuel Standard that are assumed in the Scoping Plan Scenario. These emission reductions are instead intended to be achieved via the cap-and-trade program.

[3] The total amount of renewable electricity generation in the Alternative 1 scenario is unchanged from the January 2017 Draft Scoping Plan. However, the calculation of the implied RPS associated with this level of renewable generation has been revised from 60 to 70 percent to attempt to better reflect specific details of the state policy. This scenario continues to exclude behind-the-meter CHP and state water project pumping loads from RPS compliance requirements.

[4] Business-as-usual emissions (i.e., Reference Scenario) for these alternatives are unchanged from the January modeling version. Specifically, business-as-usual emissions have not been updated to reflect changes to out-of-state coal contract assumptions.

The impact of the cap-and-trade program is modeled outside of PATHWAYS in the economic analysis of the Scoping Plan as discussed in Appendix E.

6) **Alternative 4: Cap-and-Tax** includes all of the policies and programs that exist in the Scoping Plan Scenario, as well as additional measures to meet the 2030 target without reliance on cap-and-trade. Instead, it is assumed that the additional reductions are achieved via a firm cap on each regulated entity, and that emissions trading is not allowed. In PATHWAYS, this is implemented by starting with the Alternative 1 scenario, and then adding or removing measures so that each emissions sector (as categorized in the ARB emissions inventory) achieves the same proportional reductions from the Scoping Plan 2020 levels. The cap-and-tax sectoral emission reduction targets are specified as a 37 percent reduction from each sector's 2020 Scoping Plan emission levels. Since the 2020 Scoping Plan emissions level is slightly below 1990 levels, the combined impact of these sectoral targets equates to a statewide reduction of 40 percent below 1990 levels. We note that this scenario as modeled in PATHWAYS underestimates the true cost of this scenario, as PATHWAYS is incapable of modeling a facility-specific cap. The macroeconomic impacts associated with the assumed levels of reduced economic output in industrial sectors that could result from a facility-level emissions caps is modeled in REMI as discussed in Appendix E.[5]

The key assumptions for each of the scenarios are summarized in the table below, and described in more detail in the following sections. The specific modeling assumptions are illustrative of the types of actions that could be undertaken to achieve a policy and do not denote the specific actions that will be undertaken. Note that none of the scenarios currently include assumptions about sources and sinks of greenhouse gas emissions from natural and working lands; research is ongoing in this area and as such, is not part of the PATHWAYS modeling at this time.

Since the January 2017 draft Scoping Plan release, the following scenarios were updated and re-run in the PATHWAYS model to reflect the changes required under AB 398 (E. Garcia, 2017), to make other small model fixes, and to update the RPS compliance assumptions discussed in the Electricity Supply section of this document:

- Reference Scenario
- Scoping Plan Scenario
- Carbon Tax Scenario
- All Cap-and-Trade Scenario

The No Cap-and-Trade Scenario (Alternative 1) and the Cap-and-Tax Scenario (Alternative 4) have not been updated or re-run in the PATHWAYS model. Additionally, neither emission mitigation measures nor the business-as-usual emissions (i.e., Reference Scenario) have been updated for these two scenarios. It was determined

[5] Ibid.

that it was not necessary to change these scenarios because they are assumed to be driven by direct GHG reduction requirements rather than by existing RPS law or by the cap-and-trade program. As a result, the requirements of AB 398 are assumed to not pertain to these scenarios. Likewise, assumptions for coal generation and the total amount of renewable generation is unchanged in these scenarios compared to the January 2017 modeling information. However, the calculation of the implied RPS associated with the renewable generation in each case has been updated to reflect more precise assumptions, as discussed in the Electricity section of this document.

Table A. Summary of Assumptions by Scenario

	Reference	Scoping Plan (SP) & Carbon Tax (Alt. 2)	No Cap-and-Trade (Alt. 1)	All Cap-and-Trade (Alt. 3)	Cap-and-Tax (Alt. 4)
Energy Efficiency	2015 IEPR Mid-AAEE in buildings, industry and agriculture	2x 2015 IEPR Mid-AAEE in buildings, industry and agriculture	2.5x 2015 IEPR mid-AAEE in buildings, industry and agriculture	2x 2015 IEPR Mid-AAEE in buildings, industry and agriculture	Same as Alt. 1 plus additional gas efficiency in buildings
Electrification of buildings	No new electrification		Heat pumps for new water heaters and HVAC; residential electric stoves, Early retirement of some HVAC; Replacement with heat pumps	No new electrification	Same as Alt. 1 plus earlier adoption of heap pumps in space heating and water heating
Electricity Supply	Current Procurement Trajectory, 41 percent by 2030; 18 GW behind the meter PV in 2030	50 percent RPS by 2030; 18 GW behind the meter PV in 2030	70 percent RPS by 2030; 28 GW behind the meter PV in 2030	50 percent RPS by 2030; 18 GW behind the meter PV in 2030	62 percent RPS by 2030; 18 GW behind the meter PV in 2030

	Reference	Scoping Plan (SP) & Carbon Tax (Alt. 2)	No Cap-and-Trade (Alt. 1)	All Cap-and-Trade (Alt. 3)	Cap-and-Tax (Alt. 4)
Transportation	Vision model Current Control Program scenario 3.0 million ZEVs by 2030	Vision model Clean Fuels & Technology Scenario, and expanded heavy duty ZEV scenario, Sustainable Freight Strategy 4.2 million ZEVs by 2030	Vision model Clean Fuels & Technology Scenario plus 500-600K additional ZEVs in South Coast; Early retirement of 1M pre-2015 ICE LDVs by 2030; Add'l reductions in VMT and off-road transportation energy demand 4.7 million ZEVs by 2030	Vision model Clean Fuels & Technology Scenario, and expanded heavy duty ZEV scenario, Sustainable Freight Strategy 4.2 million ZEVs by 2030	Same as Alt. 1 except: no early retirement of LDVs and fewer reductions in VMT & off-road transportation energy demand 4.7 million ZEVs by 2030
Biofuels	Additional biofuel needed to meet a 10 percent reduction in carbon intensity by 2030 after accounting for other transportation measures	Additional biofuel needed to meet an 18 percent reduction in carbon intensity by 2030 after accounting for other transportation measures	Additional biofuel needed to meet a 25 percent reduction in carbon intensity by 2030 after accounting for other transportation measures	Additional biofuel needed to meet a 10 percent reduction in carbon intensity by 2030 after accounting for other transportation measures	Same biofuel quantity as in Alt. 1

	Reference	Scoping Plan (SP) & Carbon Tax (Alt. 2)	No Cap-and-Trade (Alt. 1)	All Cap-and-Trade (Alt. 3)	Cap-and-Tax (Alt. 4)
Res., Com. & Industrial Pipeline Gas	No renewable gas		5 percent increased utilization of renewable gas by 2030	No renewable gas	Same as Alt. 1
Refining	No new measures		30 percent reduction in energy demand (including electricity) by 2030	No new measures	37 percent reduction in direct fuel combustion emissions by 2030, relative to 2020 SP[6]
Industrial & Oil and Gas Extraction	No new measures		25 percent reduction in energy demand (including electricity) by 2030 (including the 2.5 x IEPR mid-AAEE)	No new measures	37 percent reduction in direct fuel combustion emissions by 2030, relative to 2020 SP[3]

[6] The cap-and-tax sectoral emission reduction targets are specified as 37 percent reduction from each sector's 2020 Scoping Plan emission levels by 2030, which equates to a statewide total emissions target of 40 percent below 1990 levels by 2030.

	Reference	Scoping Plan (SP) & Carbon Tax (Alt. 2)	No Cap-and-Trade (Alt. 1)	All Cap-and-Trade (Alt. 3)	Cap-and-Tax (Alt. 4)
Non-Energy GHGs	Current practice in Short-Lived Climate Pollutant Strategy	Mitigation scenario in Short-Lived Climate Pollutant (SLCP) Strategy			Mitigation scenario in SLCP Strategy plus additional reductions in some sub-sectors to achieve reductions in each sector of 37 percent by 2030 relative to 2020 SP[3]
Carbon Pricing	Not modeled	Not modeled in PATHWAYS but assumes cap-and-trade in Proposed Scoping Plan or Carbon Tax in Alternative 2 Scenario	None assumed or modeled	Not modeled in PATHWAYS but assumes cap-and-trade	Not modeled in PATHWAYS but assumes carbon tax along with facility-level carbon caps

Electricity and Natural Gas Energy Efficiency and Building Electrification

Energy efficiency in buildings and industry is implemented in the PATHWAYS model in one of three ways:

1) As new HVAC, building shell or end use technology used in the residential and commercial sectors (e.g., a greater share of high efficiency appliances is assumed to be purchased). New equipment is typically assumed to replace existing equipment "on burn-out", e.g., at the end of the useful lifetime of existing equipment. However, early replacement or early retirement can also be modeled, whereby existing equipment is assumed to be replaced with a more

efficient alternative before the end of its useful life (as demonstrated in the No Cap-and-Trade Scenario (Alternative 1)).
2) As a reduction in energy services demand, due to conservation or behavior change, and
3) For the sectors that are not modeled using specific technology stocks (industrial and agriculture), energy efficiency is modeled as a reduction in total energy demand.

Since the model is based on a bottom-up forecast of technology stock changes in the residential and commercial sectors, the model does not use a single load forecast or energy efficiency savings forecast as a model input. The data sources for baseline technology shares, performance characteristics and costs are described in the "key data sources" section of this report. It is important to note that the modeling assumptions used in this plan may not reflect specific future energy efficiency programs or activities.

Reference Scenario

The Reference Scenario electricity and natural gas demand are benchmarked to the California Energy Demand 2016 – 2026 Adopted Forecast "mid-case" including Additional Achievable Energy Efficiency (AAEE). The benchmarking is accomplished by changing the composition of new sales of technologies and equipment in the California PATHWAYS model as described above.

Scoping Plan Scenario and Carbon Tax Scenario (Alternative 2)

In the Proposed Scoping Plan Scenario and in the Carbon Tax scenario, the SB 350 goal of doubling Additional Achievable Energy Efficiency (AAEE) by 2030 is met. Relative to the California Energy Demand 2016 – 2026 Adopted Forecast, electric energy efficiency is 2 times higher than the 2015 IEPR AAEE.

These scenarios do not include fuel-switching of natural gas or diesel end uses to electric end-uses. Efficiency measures are included in residential and commercial buildings, industry, agriculture, and street lighting. Examples of energy efficiency measures include:

- Residential
  - Between 2016 and 2025, the share of new residential electric water heaters that are high efficiency increases from 5 percent in 2025 in the Reference Scenario to 100 percent in 2025 in the Scoping Plan Scenario.
  - Between 2016 and 2050, the share of new residential central air conditioners that are high efficiency increases from 5 percent in 2025 in the Reference Scenario to 100 percent in 2050 in the Scoping Plan Scenario.
  - The share of new residential gas clothes driers that are high efficiency increases from 30 percent in 2035 in the Reference Scenario to 100 percent by 2025 in the Scoping Plan Scenario.

  - Between 2016 and 2030, the share of residential refrigerators that are high efficiency increases from 60 percent in 2025 in the Reference Scenario to 100 percent by 2035 in the Scoping Plan Scenario.
  - Several types of lighting are modeled in the residential sector: lamps, torchiers, linear fluorescents and reflectors. In the residential sector, by 2032, 68 percent of new sales of lighting are high efficiency LEDs.
  - 10 percent improvement in the electric efficiency of "other" equipment such as televisions and cable set top boxes by 2050 relative to the Reference Scenario. 70 percent of plug-load equipment is affected by these efficiency improvements.
- Commercial
  - Between 2020 and 2035, the share of new commercial natural gas water heaters that are high efficiency increases from 20 percent in 2020 in the Reference Scenario to 100 percent. In addition, 75 percent of commercial electric water heater sales are high efficiency heat pump water heaters by 2035 in this scenario.
  - Between 2020 and 2035, the share of electric space heating in the commercial sector that is high efficiency heat pumps increases from 0 to 90 percent.
  - Between 2016 and 2025, the share of new commercial electric cooking ranges that are high efficiency increases from 5 to 100 percent.
  - In the commercial sector, lighting types include: lamps, linear fluorescents, outdoor and high intensity discharge. Commercial lighting efficiency improvements include an increase in the sale of LED lamps from 15 percent by 2025 in the Reference Scenario to 100 percent by 2040 in the Scoping Plan Scenario.
  - Between 2016 and 2025, the share of new commercial refrigerators that are high efficiency increases from 15 percent in the Reference Scenario to 100 percent in the Scoping Plan Scenario.
  - Between 2016 and 2025, the share of new commercial ventilation that are high efficiency increases from 33 percent in the Reference Scenario to 100 percent in the Scoping Plan Scenario.
  - There are additional efficiency improvements in commercial "other" end-uses including plug-loads such as computers and other electronics. Total efficiency is assumed to increase by 35 percent, increasing linearly between 2020 and 2050.
- Street Lighting and Agriculture
  - There is a 75 percent efficiency improvement in street lighting by 2050.
  - 68 percent improvement in agricultural lighting between 2020 and 2050 due to LED adoption.

In addition to appliance technology substitution, there are also service demand reductions/behavior change measures, such as:

- 10 percent reduction in water heating demand by 2020 in the residential sector and by 2024 in commercial sector due to urban water efficiency measures.

- 3 percent reduction in residential heating load due to behavior change by 2024 (i.e., change in thermostat set point).
- 3 percent reduction in residential cooling load from improved windows and 1.4 percent reduction from behavioral change by 2024 (i.e., change in thermostat set point).
- 2 percent reduction in residential lighting service demand by 2024 due to behavior change (i.e., turning off lights when not in use).
- 6 percent reduction in industrial energy consumption by 2030 at an assumed cost of $16.84/GJ of energy reduced (approximately $35/ton of CO_2 avoided in 2030).

No Cap-and-Trade Scenario (Alternative 1)

The Alternative 1 Scenario inherits all the above measures. In addition, it includes additional electrical efficiency in industry, agriculture, residential and commercial lighting, and residential air conditioning, freezing and refrigeration. The Alternative 1 scenario also includes building electrification in end uses that currently use natural gas with the introduction of high efficiency electric heat pumps in water heating, space heating, and air conditioning. Moreover, approximately 1.2 million residential space heaters and 358 thousand residential air conditioners are retired before the end of their useful lifetimes by 2030 and replaced with higher efficiency heat pumps. In the commercial sector, early retirement of space heating affects 12 percent of total space heating energy demand by 2030, and 3 percent of commercial air conditioning by 2030, replaced with high efficiency heat pumps. Furthermore, there is incremental energy efficiency in commercial space heating. Early retirement measures include:

- Between 2025 and 2030, 6 percent per year of natural gas, distillate, and LPG residential space heaters and air conditioners from 2013 or older are retired early and replaced with electric heat pumps. This measure results in approximately 1.2 million early retirements of residential space heaters (radiators and furnaces) by 2030 and 358 thousand early retirements of residential air conditioners by 2030.
- Between 2025 and 2035, 6 percent per year of commercial space heaters and air conditioners from 2013 or older are retired early and replaced with electric heat pumps. This early retirement measure affects 12 percent of total commercial space heating energy demand by 2035, and 3 percent of total commercial air conditioning energy demand by 2035.

Electrification and efficiency measures in this scenario include:

- Between 2020 and 2035, the proportion of new residential water heater sales that are electric heat pumps increases from 0 to 75 percent.
- Between 2020 and 2035, the proportion of new residential space heater (radiators and furnaces) sales that are electric heat pumps increases from 0 to 75 percent.

- Between 2020 and 2035, the proportion of new residential central air conditioner sales that are high efficiency electric heat pumps increases from 0 to 100 percent.
- Between 2020 and 2035, the proportion of new commercial water heater sales that are electric heat pumps increases from 0 to 75 percent.
- Between 2020 and 2035, the proportion of new commercial space heater sales that are electric heat pumps increases from 0 to 75 percent.
- Between 2020 and 2035, the proportion of retiring commercial reference central air conditioner sales being replaced with high efficiency electric heat pumps increases from 0 to 100 percent.
- Between 2020 and 2030, 50 percent of new residential gas and liquid petroleum gas (LPG) cook stove sales switch to electric stoves.

<u>All Cap-and-Trade Scenario (Alternative 3)</u>

Energy efficiency assumptions in the All Cap-and-Trade Scenario are identical to those in the Scoping Plan Scenario. The SB 350 goal of doubling Additional Achievable Energy Efficiency (AAEE) by 2030 is met. Relative to the California Energy Demand 2016 – 2026 Adopted Forecast, electric energy efficiency is 2 times higher than the 2015 IEPR AAEE.

This scenario does not include fuel-switching of natural gas or diesel end uses to electric end-uses. Efficiency measures are included in residential and commercial buildings, industry, agriculture, and street lighting.

<u>Cap-and-Tax Scenario (Alternative 4)</u>

The Cap-and-Tax Scenario inherits all of the building energy efficiency and building electrification assumptions as the No Cap-and-Trade Scenario (Alternative 1) plus additional measures to ensure that natural gas combustion in buildings achieves a 37 percent reduction in GHG emissions relative to 2020 Scoping Plan levels.[7] These additional measures include:

- Increase in natural gas efficiency in buildings: between 2017 and 2022, new sales of conventional natural gas residential gas water heaters and space heaters and commercial water heaters are replaced with high efficiency gas heaters for space heating and water heating.
- Additional building electrification: Between 2020 and 2030, new sales of residential natural gas water heaters are replaced with electric heat pump water heaters, so that 100 percent of new sales are electric by 2030. In addition, the maximum sales rate for electric heat pumps for new residential and commercial space heaters are achieved in 2025 rather than 2030.

[7] The cap-and-tax sectoral emission reduction targets are specified as a 37 percent reduction from each sector's 2020 Scoping Plan emission levels. Since the 2020 Scoping Plan emissions level is slightly below 1990 levels, the combined impact of these sectoral targets equates to a statewide reduction of 40 percent below 1990 levels.

Electricity Supply

In the electricity sector, two of the major scenario inputs include the percentage of renewable generation that must serve retail sales (modeled as an RPS), and the megawatts of behind-the-meter solar PV online in each year. Behind-the-meter solar PV and the RPS measures interact with each other, in that the rooftop solar reduces retail sales but is not assumed to count towards the RPS. There are many other electricity sector input assumptions as well, which also have an impact on costs and emissions, as discussed in this section, although many of these input assumptions are constant across the scenarios. The model calculates hourly electricity supply relative to hourly electricity demand, considering the impact of electrification, demand response, flexible loads and flexible electric vehicle charging, energy storage and flexibility in hydropower production and imported power. As a post-processing step in the model, total renewable curtailment is calculated and additional renewable capacity is added to the model, to ensure that the specified RPS target is met in each scenario, after taking curtailment into account.

Since the January 2017 draft Scoping Plan release, model changes have been made to: 1) reflect the latest load serving entity (LSE) plans regarding end dates for out-of-state coal generation contracts, and 2) to better represent the requirements of the state RPS. Updated modeling assumptions for coal generation include less imports of specified coal generation between 2016 and 2030, with an end date for all out-of-state coal contracts by 2025. Updates to the RPS modeling include the exclusion of state water project pumping loads from RPS compliance, as well as a model fix to deduct behind-the-meter combined and power (CHP) from retail sales. In addition, the scenarios have been modified to include 12.3 TWh of out-of-state Portfolio Content Category 3 (PCC3) Renewable Electricity Credits (RECs) in 2030, which count toward meeting the RPS, as well as 8.4 TWh of in-state banked RECs in 2030.[8]

Reference Scenario

The Reference Scenario is characterized by the following:

- The Renewable Portfolio Standard follows the current trajectory of renewable procurement including existing contracted resources, reaching 41 percent of retail sales in 2020. This stays constant through 2030 and declines thereafter to 34 percent by 2050.
- Renewable portfolios are based on the CPUC RPS Calculator version 6.2 through 2030 (http://www.cpuc.ca.gov/RPS_Calculator/). Renewables are assumed to be built largely in-state, and for new renewable procurement beyond existing resources, to require energy-only deliverability rather than full capacity delivery service for the purposes of transmission development and pricing.

[8] The quantify of banked RECs that will be used for RPS compliance in 2030 is uncertain. This estimate is based on the assumption applied in the CPUC's proposed Reference System Plan for a 50 percent RPS scenario as part of the Integrated Resource Plan Proceeding (R.16-02-007).

- Behind-the-meter solar photovoltaic (BTM PV) is assumed to reach 18.2 GW statewide by 2030, based on an extrapolation of the California Energy Demand 2016 – 2026 Adopted Forecast mid-case.
- Diablo Canyon is retired by 2025 and all out-of-state coal generation contracts end by 2025.
- Frequency response requirements, not including frequency response provided by existing hydroelectricity, are assumed to be 376 MW throughout the analysis period. This requirement can be met with energy storage or thermal generation.
- Rate design changes are assumed to result in the participation of flexible loads on the grid to help balance renewable generation. By 2018, 10 percent of residential and commercial electric water heating, space heating, air conditioning, and refrigeration are assumed to be capable of operating flexibility, providing between 2 to 3 hours of shifted load. In addition, by 2018, one half of electric light duty vehicles are assumed to have access to "smart charging", such that over the course of 12 hours, vehicle charging needs can be shifted to help integrate renewables on the grid.
- By 2030, one half of light-duty electric vehicles are assumed to have access to workplace charging, enabling greater use of day-time charging of electric vehicles.
- The Reference scenario includes an increase of approximately 5,500 cumulative MW of conventional, load shedding demand response by 2031, over and above the approximately 2,000 MW of existing demand response available in 2015. This quantity of demand response is not optimized for the scenario but reflects prior state goals to increase the availability of demand response.
- The Reference Scenario reflects existing pumped hydro storage capacity, as well as the CPUC energy storage mandate of 1.325 GW by 2020. The energy storage mandate is implemented in the model as a mixture of 2-hour, 5-hour and 8-hour batteries.
- Net exports of electricity from California to neighboring jurisdictions are capped at 1,500 MW in each hour throughout the analysis period.
- Existing combined heat and power (CHP) is assumed to remain constant throughout the analysis period in the Reference Scenario. There is no new CHP development in this scenario.

<u>Scoping Plan Scenario and Carbon Tax Scenario (Alternative 2)</u>

These scenarios inherit all the above measures in the Reference Scenario. In addition, these scenarios include:

- The Renewable Portfolio Standard is 50 percent of retail sales by 2030, increasing to 80 percent by 2050. RPS compliance includes the use of banked RECs through 2030, reaching 3 percent of retail sales in that year in the Scoping Plan Scenario (8.4 TWh). There are no banked RECs applied to RPS compliance after 2030.
- In the Scoping Plan Scenario, a limited quantity of existing CHP in the commercial, industrial, oil and gas, TCU and refining sectors is assumed to retire

and not be replaced starting in 2031. There is no new CHP development in this scenario.

No Cap-and-Trade Scenario (Alternative 1)

The Alternative 1 Scenario inherits all the above measures in the Scoping Plan Scenario with following exceptions:

- BTM PV is assumed to reach 28.4 GW statewide by 2030 based on extrapolation of the California Energy Demand 2016-2030 Adopted Forecast high rooftop PV scenario.
- The Renewable Portfolio Standard is 70 percent of retail sales by 2030, increasing to 80 percent by 2050.
- Flexible loads increase from 10 percent of specified subsectors by 2018 to 20 percent of specified subsectors by 2030. The additional flexible loads come from residential and commercial electric space heating, water heating, A/C and refrigeration.

All Cap-and-Trade Scenario (Alternative 3)

The Cap-and-Trade scenario inherits all of the same electricity sector assumptions as the Scoping Plan scenario.

Cap-and-Tax Scenario (Alternative 4)

The Cap-and-Tax scenario inherits all of the same electricity sector assumptions as the Scoping Plan scenario, with the exception of the renewable generation, which is increased to 62 percent of retail sales by 2030.

Transportation

Reference Scenario

On-road transportation vehicle stocks, vehicle miles traveled, and fuel efficiency in the Reference Scenario are calibrated to match the Current Control Programs scenario presented in the 2016 California Mobile Source Strategy report.[9] This Current Control Programs scenario was developed using the California Air Resources Board's Vision 2.1 scenario-planning model[10], which provided PATHWAYS with data inputs for vehicle stock, vehicle miles traveled (VMT), and vehicle efficiency assumptions. The Vision model in turn draws from EMFAC2014, with VMT updated to reflect adopted Regional Transportation Plans (RTPs) and Sustainable Communities Strategies (SCSs) from

[9] https://www.arb.ca.gov/planning/sip/2016sip/2016mobsrc.htm
[10] https://www.arb.ca.gov/planning/vision/vision.htm

Metropolitan Planning Organizations (MPOs).[11] The Reference Scenario is designed to reflect the transportation policy environment prior to the passage of SB 350. Among other policies, the Reference Scenario incorporates:[12]

- VMT from 2015 FSTIP (Federal Statewide Transportation Improvement Program) for 17 MPOs and SCAG's draft 2016 RTP/SCS.
- The California ZEV Action Plan to get 1.5 million zero-emissions vehicles (ZEVs) on the road by 2025, including plug-in hybrid electric vehicles (PHEVs), battery electric vehicles (BEVs), and hydrogen fuel cell electric vehicles (FCEVs), expressed through fleet composition trajectories.[13]
- The Low-Carbon Fuel Standard (discussed in the section on transportation biofuels).

Calibration to the Vision Current Control Programs scenario values is accomplished in PATHWAYS through a series of inputs that determine which vehicles replace retiring vehicles that have reached the end of their lifetimes. Between 2015 and 2030, these inputs increase the total number of ZEVs from 0.1 million in 2015 to about 3 million in 2030. Tables 1, 2 and 3 show the composition of the Reference Scenario light-duty (LDV), medium-duty (MDV), and heavy-duty vehicle (HDV) fleets in 2015, 2025, and 2030.

Table 1. Reference Scenario light-duty vehicle fleet composition
(components may not sum to total due to rounding)

Vehicle Type (millions)	2015	2025	2030
Gasoline	25.3	25.9	26.8
BEV	0.02	0.45	0.78
Hydrogen	0.01	0.20	0.44
PHEV	0.07	1.03	1.75
Total	25.4	27.6	29.7

[11] https://www.arb.ca.gov/planning/vision/docs/vision2.1_model_documentation_20170202.pdf
[12] For an expanded list of regulations included in the Vision Baseline/Current Control Programs scenario, see page 159 of the Mobile Source Strategy report.
[13] https://www.gov.ca.gov/docs/2016_ZEV_Action_Plan.pdf

Table 2. Reference Scenario medium-duty vehicle fleet composition
(components may not sum to total due to rounding)

Vehicle Type (thousands)	2015	2025	2030
Gasoline	632	363	358
Diesel	716	827	845
Total	1,347	1,190	1,203

Table 3. Reference Scenario heavy-duty vehicle fleet composition
(components may not sum to total due to rounding)

Vehicle Type (thousands)	2015	2025	2030
Diesel	246	310	344
CNG	9	15	17
Total	255	326	361

Table 4. Reference Scenario bus fleet composition
(components may not sum to total due to rounding)

Vehicle Type (thousands)	2015	2025	2030
Gasoline	25	32	36
Diesel	31	30	31
CNG	5	5	5
Total	61	67	72

The PATHWAYS model also includes assumptions for off-road transportation, but specific technology stocks and vintages are not modeled for off-road vehicles. The off-road transportation categories modeled include: aviation, passenger rail, freight rail, ocean-going vessels and harbor craft. Energy demand in these sectors is calibrated to reflect the ARB emissions inventory and projected forward based on historical trends. There are no emission reductions measures in the Reference Scenario for off-road transportation.

Scoping Plan Scenario and Carbon Tax Scenario (Alternative 2)

In these scenarios, VMT, vehicle fuel efficiency, and on-road light duty vehicle fleet composition are calibrated to the Vision Cleaner Technologies and Fuels scenario, which is described in the 2016 Mobile Source Strategy. Medium and heavy-duty vehicle fleet compositions are based on the expanded heavy duty ZEV beyond Cleaner Technologies and Fuels scenario as described in the 2016 Mobile Source Strategy. This scenario reflects the impacts of SB 350 among other policies.

For on-road vehicles, this scenario includes reductions in light-duty VMT, increases in gasoline and diesel vehicle efficiency, and additional adoption of ZEV technologies. In addition, there are emission reductions assumed from off-road subsectors such as aviation, rail and ocean-going vessels, which reflect the guidance in the California Sustainable Freight Action Plan.

Alternative vehicle measures include:

- In the light-duty vehicle fleet:
    - PHEVs increase to 8.2 percent of the fleet in 2030 from 5.9 percent in the Reference Scenario, an increase of 686,000 PHEVs
    - BEVs increase to 3.7 percent of the fleet in 2030 from 2.6 percent in the Reference Scenario, an increase of 309,000 BEVs
    - FCEVs increase to 2.2 percent of the fleet in 2030 from 1.5 percent in the Reference Scenario, and increase of 203,000 FCEVs

- In the medium-duty fleet, FCEV, CNG, and BEV vehicles are introduced and displace a portion of the gasoline and diesel vehicles that make up the Reference MDV fleet:
    - FCEVs make up 0.3 percent of the fleet in 2030, about 3,700 vehicles
    - CNG trucks make up 6.2 percent of the fleet in 2030, about 75,000 vehicles
    - BEVs make up 2.7 percent of the fleet in 2030, about 33,000 vehicles

- In the heavy-duty fleet, electric and hydrogen trucks are introduced and displace a portion of the diesel and CNG vehicles that make up the Reference HDV fleet:
    - BEVs make up 0.5 percent of the fleet in 2030, about 1,900 vehicles
    - FCEVs make up 0.1 percent of the fleet in 2030, about 200 vehicles

- In the bus fleet, electric buses are introduced and CNG is partially phased out:
    - BEVs make up 4.4 percent of the fleet by 2030, about 3,100 vehicles
    - CNG trucks decrease to 5.3 percent of the fleet in 2030 from 7.3 percent in the Reference Scenario, a decrease of about 1,500 trucks

Table 5. Scoping Plan Scenario light-duty vehicle fleet composition (components may not sum to total due to rounding)

Vehicle Type (millions)	2015	2025	2030
Gasoline	25.3	25.9	25.6
BEV	0.02	0.45	1.09
Hydrogen	0.01	0.20	0.64
PHEV	0.07	1.03	2.44
Total	25.4	27.6	29.7

Table 6. Scoping Plan Scenario medium-duty vehicle fleet composition (components may not sum to total due to rounding)

Vehicle Type (thousands)	2015	2025	2030
Gasoline	632	364	348
Diesel	715	787	742
BEV	0	9	33
CNG	0	30	75
Hydrogen	0	1	4
Total	1,347	1,190	1,203

Table 7. Scoping Plan Scenario heavy-duty vehicle fleet composition (components may not sum to total due to rounding)

Vehicle Type (thousands)	2015	2025	2030
Diesel	246	308	337
BEV	0	1	2
CNG	9	17	22
Hydrogen	0	0.1	0.2
Total	255	326	361

Table 8. Scoping Plan Scenario bus fleet composition
(components may not sum to total due to rounding)

Vehicle Type (thousands)	2015	2025	2030
Gasoline	24	31	32
Diesel	31	30	33
BEV	0	2	3
CNG	6	4	4
Total	61	67	72

On-road service demand reduction measures from the Vision Cleaner Technologies and Fuels scenario include a 5 percent reduction in light-duty VMT in 2030 compared to the Reference Scenario, with VMT reductions first starting in 2020.

Efficiency and cleaner fuels measures in the PATHWAYS model for off-road subsectors include:

- A 70 percent reduction in jet fuel demand for aviation from BAU based on the FAA CLEEN program, beginning at 0 percent in 2020 and saturating in 2050.
- 4 percent of passenger and freight rail diesel use is converted to electric, starting in 2020 and saturating in 2050.
- 45 percent efficiency improvement in passenger rail and freight rail diesel demand affecting 95 percent of rail energy use, starting in 2020 for passenger rail and in 2020 for freight rail and saturating in 2050.
- 80 percent of in-port fuel use from ocean-going vessels is electrified by 2050, beginning in 2020.
- 40 percent efficiency improvement of in-transit diesel use for ocean-going vessels by 2050, beginning in 2020.
- We assume a conversion of harbor craft energy demand from diesel to electricity, starting in 2020:
    - 6 percent of harbor craft energy demand is fully electric by 2050
    - 71 percent of harbor craft energy demand is diesel hybrid by 2050

No Cap-and-Trade Scenario (Alternative 1)

This scenario adds 550,000 additional light-duty ZEVs to the vehicle fleet by 2030 and introduces early retirement for a portion of pre-2015 vintage gasoline light-duty vehicles.

The additional ZEVs in the Alternative 1 Scenario are phased in between 2024 and 2030. They are distributed between the LDV classes (light-duty autos and light-duty trucks) and the three ZEV technologies (PHEV, BEV, and FCEV) in proportion to their distribution in the Vision Cleaner Technologies and Fuel Scenario. The additional

550,000 ZEVS increase the total light-duty ZEV population to 4.7 million in 2030, an increase of 13 percent over the Scoping Plan Scenario. See Table 9 for the composition of the light-duty fleet in the Alternative 1 Scenario. No changes were made to the MDV, HDV, and bus fleets in this scenario.

The early retirement of light-duty gasoline vehicles is implemented between 2025 and 2030. Approximately 1 million of the 4.5 million pre-2015 vintage gasoline vehicles that are still in service in 2030 in the Scoping Plan Scenario are retired early and replaced with newer, more fuel-efficient gasoline models. Vehicles retired early are not replaced with ZEVs.

Table 9. Alternative 1 Scenario light-duty vehicle fleet composition (components may not sum to total due to rounding)

Vehicle Type (millions)	2015	2025	2030
Gasoline	25.3	25.8	25.0
BEV	0.02	0.46	1.23
Hydrogen	0.01	0.21	0.72
PHEV	0.07	1.12	2.77
Total	25.4	27.6	29.7

In addition, this scenario includes additional transportation energy service demand reduction measures and rail electrification, beyond those included in the Vision Cleaner Technologies and Fuels scenario, including:

- 5 percent reduction in heavy duty vehicle miles traveled (VMT) by 2030.
- 5 percent reduction in light duty VMT by 2030.
- 5 percent reduction in energy demand in ocean going vessels and rail by 2030.
- 6 percent reduction in aviation energy demand by 2030.
- Additional 16 percent rail electrification (passenger and freight) by 2050.

<u>All Cap-and-Trade Scenario (Alternative 3)</u>

The transportation assumptions (excluding biofuels) in the All Cap-and-Trade scenario are identical to those in the Scoping Plan.

<u>Cap-and-Tax Scenario (Alternative 4)</u>

The transportation assumptions in the Cap-and-Tax scenario are identical to those in the No Cap-and-Trade Scenario (Alternative 1) with the following exceptions:

- No early replacement measures for light-duty automobiles and trucks (LDVs).

- No demand reduction measure for aviation (rather than 6 percent in Alt. 1).
- For LDVs, the incremental VMT reduction from the Scoping Plan is 1 percent by 2030 (rather than 5 percent in the Alternative 1 scenario).
- No ocean-going vessel demand reduction measure (rather than 5 percent in Alt. 1).
- Additional rail electrification of 10 percent by 2050 (rather than 16 percent in Alt. 1).

Transportation Biofuels and the Low Carbon Fuel Standard

Transportation biofuel assumptions, including the impacts of a post-2020 Low Carbon Fuel Standard (LCFS), were developed by ARB staff using the Biofuel Supply Module. The Biofuel Supply Module (BFSM) uses the PATHWAYS transportation energy demand by scenario as an input. The BFSM then calculates the type and quantity of transportation biofuels that would be cost-effective for consumers relative to fossil fuel prices for gasoline, diesel, and compressed natural gas, given a set of assumptions about biofuel subsidies, LCFS prices, carbon prices and the cost of delivered biofuels. For more information about the biofuel assumptions used in the scenarios, see ARB's Technical Documentation of the Biofuel Supply Module.[14]

The BFSM provides the PATHWAYS model with estimates of annual transportation biofuel supply by type and estimated biomass usage by feedstock, based on each scenario's input assumptions. The quantities of biofuels from the BFSM are then input into the PATHWAYS model.

The PATHWAYS model and BFSM use the same underlying assumptions about biomass resource potential, conversion efficiencies, transport costs and process costs. The BFSM also reflects the impact of LCFS credit prices and California cap-and-trade carbon prices on final, delivered biofuel prices. These market prices are not included in the biofuel prices modeled in PATHWAYS because the LCFS and cap-and-trade programs reflect in-state transfers of costs. As a result, the biofuel costs in PATHWAYS and the BFSM will be different.

Another important distinction between the BFSM and the PATHWAYS model is how the carbon intensity of biofuels are calculated. The PATHWAYS model uses the ARB's emission inventory accounting standard for biofuels, whereby combustion of biofuels are treated as zero-emission fuels and emissions associated with producing fuels and feedstocks outside of California are not considered. In contrast, the BFSM applies the LCFS lifecycle emissions accounting framework, which takes into account all GHG emissions (or savings) associated with the production, transportation, and use of a given fuel, whether they occur in-state or out-of-state. For example, avoided greenhouse gas emissions from methane that would have otherwise been released from manure, had the biogas not been captured for use as a fuel, are credited to

[14] Biofuel Supply Module Technical Documentation available as part of the materials from the September 14, 2016 CARB Public Workshop on the Transportation Sector to Inform Development of the 2030 Target Scoping Plan Update, available here: https://www.arb.ca.gov/cc/scopingplan/meetings/meetings.htm

transportation fuels under the LCFS lifecycle emissions accounting framework. Under the ARB emissions inventory accounting, these avoided methane emissions are reflected in the "non-energy, non-CO_2" sector in PATHWAYS rather than as part of biofuels carbon accounting in the transportation fuels sector.

This difference in GHG accounting between the PATHWAYS model and the BFSM is not a problem from an analytical perspective, since the differences reflect how greenhouse gas emissions are allocated between fuels and sectors. However, it is important to keep in mind this distinction in GHG accounting when comparing results across models. For example, while the BFSM may calculate a scenario that has a 20 percent reduction in the carbon intensity of fuels using the LCFS lifecycle emissions accounting framework, the PATHWAYS model, using the ARB emission inventory framework, will typically show fewer carbon reductions coming from biofuels for the same total quantity of biofuels.

Reference Scenario

The LCFS allowance price assumptions reflect a 10 percent carbon intensity reduction from 2020 through 2030 in the Reference Scenario. In addition, this scenario assumes:

- An LCFS credit price of $10/ton in 2030.
- By 2030, in addition to conventional ethanol and biodiesel, there are 552 million gallons of advanced biofuels in the transportation sector, including cellulosic ethanol, renewable gasoline and renewable diesel (reported on a gallon of gasoline equivalent (GGE) basis, using the lower heating value for gasoline).
- In addition, 100 percent of compressed natural gas (CNG) for transportation is biogas (2.1 percent of total pipeline gas).

Scoping Plan Scenario and Carbon Tax Scenario (Alternative 2)

The LCFS allowance price assumptions reflect an 18 percent carbon intensity reduction from 2020 through 2030 in the Scoping Plan and Carbon Tax scenarios. In addition, these scenarios assume:

- An LCFS credit price of $80/ton in 2030.
- By 2030, in addition to conventional ethanol and biodiesel, there are 1,165 million gallons of advanced biofuels in the transportation sector, including cellulosic ethanol, renewable gasoline and renewable diesel (reported on a GGE basis, using the lower heating value for gasoline).
- In addition, 100 percent of CNG is biogas (3.1 percent of total pipeline gas).

No Cap-and-Trade Scenario (Alternative 1)

The LCFS credit price assumptions reflect a 25 percent carbon intensity reduction from 2020 through 2030 in the Alternative 1 Scenario. In addition, this scenario assumes:

- An LCFS credit price of $180/ton in 2030 as well as a renewable diesel credit of $0.34/GGE.
- By 2030, in addition to conventional ethanol and biodiesel, there are 2,067 million gallons of advanced biofuels in the transportation sector, including cellulosic ethanol, renewable gasoline and renewable diesel (reported on a GGE basis, using the lower heating value for gasoline).
- In addition, 100 percent of CNG is biogas (3.7 percent of total pipeline gas).

All Cap-and-Trade Scenario (Alternative 3)

The biofuels assumptions in the All Cap-and-Trade Scenario reflect a 10 percent reduction in the carbon intensity of fuels between 2020 and 2030.

Cap-and-Tax Scenario (Alternative 4)

The cap-and-tax scenario includes the same quantities of biofuels as the Alternative 1 Scenario.

Renewable Gas for Residential, Commercial, Industrial and Agricultural Customers

Reference Scenario,

In the Reference Scenario there is no biogas or renewable gas used by residential, commercial, industrial, or agricultural customers.

Scoping Plan Scenario and Carbon Tax Scenario (Alternative 2)

In the Scoping Plan and Carbon Tax Scenarios there is no biogas or renewable gas used by residential, commercial, industrial, or agricultural customers.

No Cap-and-Trade Scenario (Alternative 1)

In the Alternative 1 Scenario, 5 percent of the energy in the gas pipeline is assumed to be renewable gas by 2030. This renewable gas serves residential, commercial, industrial, and agricultural customers. Renewable gas is introduced into these sectors beginning in 2023. The penetration increases linearly for four years and reaches 1 percent of pipeline gas in 2026. Each year from 2026 through 2030, an additional 1 percent of pipeline gas is converted to renewable gas, resulting in renewable gas composing 5 percent of total pipeline gas in 2030.

The utilization of renewable gas by 2030 is modeled in PATHWAYS as hydrogen blended into the gas pipeline to represent a conservative estimate of the cost for renewable gas; although in practice, renewable gas could be biomethane, renewable hydrogen, or a mixture of the two fuels.

All Cap-and-Trade Scenario (Alternative 3)

In the All Cap-and-Trade scenario there is no biogas or renewable gas used by residential, commercial, industrial, or agricultural customers.

Cap-and-Tax Scenario (Alternative 4)

In the Cap-and-Tax scenario, the renewable gas assumptions are identical to those in the No Cap-and-Trade Scenario (Alternative 1): 5 percent of the energy in the gas pipeline is assumed to be renewable gas by 2030.

Hydrogen Production

Reference Scenario

In the Reference Scenario, hydrogen is used as fuel for light duty fuel cell vehicles. The hydrogen is assumed to be produced using a combination of steam reformation and grid electrolysis. Throughout the analysis period, 33 percent of incremental hydrogen demand is assumed to be produced with grid electrolysis, while the remaining 67 percent of hydrogen demand is produced via natural gas steam reformation. The grid electrolysis is assumed to be operated flexibly, with a 25 percent load factor, such that the hydrogen production helps to integrate solar generation onto the electric grid.

Scoping Plan Scenario and Carbon Tax Scenario (Alternative 2)

In the Scoping Plan Scenario and the Carbon Tax Scenario, hydrogen is used as fuel for light duty fuel cell vehicles. The hydrogen is assumed to be produced using a combination of steam reformation and grid electrolysis. Between 2015 and 2020, this mix is assumed to be 33 percent electrolysis/67 percent natural gas steam reformation. The share of new hydrogen production that is produced with electrolysis increases between 2020 and 2030 such that by 2030, 100 percent of incremental hydrogen demand is met with grid electrolysis. The grid electrolysis is assumed to be operated flexibly, with a 25 percent load factor, such that the hydrogen production helps to integrate solar generation onto the electric grid.

No Cap-and-Trade Scenario (Alternative 1)

In the Alternative 1 Scenario, hydrogen is used as fuel for light duty fuel cell vehicles and to meet the 5 percent utilization of renewable gas for residential, commercial and industrial customers. The same assumptions about the production and operation of hydrogen facilities are applied in this scenario as in the Scoping Plan Scenario.

<u>All Cap-and-Trade Scenario (Alternative 3)</u>

The hydrogen production assumptions are identical to those in the Scoping Plan Scenario.

<u>Cap-and-Tax Scenario (Alternative 4)</u>

The hydrogen production assumptions are identical to those in the Alternative 1 Scenario.

Refining

<u>Reference Scenario</u>

No changes in Refining sector energy demand are assumed in the Reference Scenario.

<u>Scoping Plan Scenario and Carbon Tax Scenario (Alternative 2)</u>

No changes in Refining sector energy demand are assumed in these scenarios.

<u>No Cap-and-Trade Scenario (Alternative 1)</u>

Refining sector emissions (including emissions associated with direct-fuel combustion and electricity use) are reduced by 8 $MMTCO_2$ relative to business-as-usual by 2030 (30 percent of present-day emissions). Energy reductions, assumed to come from energy efficiency, are used as the proxy to achieve the intended emission reductions. These measures are assumed to start in 2020 and increase linearly to 30 percent by 2030. These energy efficiency measures have costs which are assumed to be approximately $35/ton of CO_2 avoided for the first 10 percent reduction, $135/ton for the second 10 percent reduction, and $300/ton for the final 10 percent reduction.

<u>All Cap-and-Trade Scenario (Alternative 3)</u>

No changes in Refining sector energy demand are assumed in the All Cap-and-Trade Scenario.

<u>Cap-and-Tax Scenario (Alternative 4)</u>

In the Cap-and-Tax scenario, energy demand in the Refining sector is assumed to be reduced beyond the level assumed in the Alternative 1 Scenario. These reductions are intended to achieve a sector-wide reduction in direct, on-site combustion emissions of

37 percent below 2020 Scoping Plan emissions levels in 2030.[15] These reductions are assumed to occur as a result of reduced refining output (rather than energy efficiency) and are assumed to occur at zero cost in PATHWAYS (and, indeed, they reduce total energy system costs by reducing fuel demands). The macroeconomic costs of the reduced refining output are modeled externally in REMI and discussed in Appendix E. The 2030 reduction in direct fuel-combustion greenhouse gases (excluding electricity consumption) result in an additional 11 MMT CO2 reduction relative to the proposed 2020 Scoping Plan levels.

Industry and Oil and Gas

Reference Scenario

No changes in Industry and Oil and Gas sector energy demand are assumed in the Reference Scenario.

Scoping Plan Scenario and Carbon Tax Scenario (Alternative 2)

There are no incremental measures in these scenarios beyond the 6 percent industrial energy efficiency measures described in the energy efficiency section above.

No Cap-and-Trade Scenario (Alternative 1)

Relative to the above measures, Industrial and Oil and Gas energy demands are reduced another 19 percent between 2020 and 2030. The 19 percent (in addition to the 6 percent for the industrial efficiency described above) represents the potential preliminary estimate of reductions across the sector as estimated by ARB using efficiency benchmark data. These reductions are based on energy efficiency at assumed costs of approximately $135/ton of CO_2 avoided for the first 10 percent reduction and $300/ton for the remaining 9 percent reduction.

All Cap-and-Trade Scenario (Alternative 3)

No changes in Industry and Oil and Gas sector energy demand are assumed in the All Cap-and-Trade Scenario.

Cap-and-Tax Scenario (Alternative 4)

In the Cap-and-Tax scenario, energy demand in the Industrial (other manufacturing), and Oil and Gas Extraction sectors is assumed to be reduced beyond the level

[15] The cap-and-tax sectoral emission reduction targets are specified as a 37 percent reduction from each sector's 2020 Scoping Plan emission levels. Since the 2020 Scoping Plan emissions level is slightly below 1990 levels, the combined impact of these sectoral targets equates to a statewide reduction of 40 percent below 1990 levels.

assumed in the Alternative 1 Scenario. These reductions are intended to achieve a sector-wide reduction in direct, on-site combustion emissions of 37 percent below 2020 Scoping Plan emissions levels in 2030.[16] These reductions are assumed to occur as a result of reduced industrial output and reduced oil and gas extraction (rather than through energy efficiency) and are assumed to occur at zero cost in PATHWAYS (and, indeed, they reduce total energy system costs by reducing fuel demands). The macroeconomic costs of the reduced industrial and oil and gas extraction output are modeled externally in REMI and discussed in Appendix E. The 2030 reduction in direct fuel-combustion greenhouse gases (excluding electricity consumption) result in an:

- Additional 12 MMT reduction for industry, relative to the proposed 2020 Scoping Plan levels, and
- Additional 7 MMT reduction for oil and gas extraction, relative to the proposed 2020 Scoping Plan levels.

Agriculture

The scope of the agriculture sector as described in this section pertains to agricultural fossil fuel CO_2 emissions. Land-use and land change emissions and sinks are not included in this definition. Likewise, other greenhouse gas emissions that are not associated with fossil fuel combustion, such as methane and nitrogen oxides are not included in this definition, but rather appear in the “non-energy, non-CO_2 GHG” category.

<u>Reference Scenario</u>

There are electric and natural gas efficiency improvements assumed in the Reference Scenario, consistent with the 2015 IEPR AAEE building efficiency assumptions described in the section above. These measures result in a 7 to 15 percent efficiency improvement in lighting, motors, refrigeration, water heating and cooling, and other miscellaneous electric and natural gas end-uses by 2024 relative to current practice (Baseline).

<u>Scoping Plan Scenario and Carbon Tax Scenario (Alternative 2)</u>

There is additional energy efficiency in lighting in these scenarios, which is described in the energy efficiency section of this report. There are no additional agricultural measures in these scenarios.

[16] The cap-and-tax sectoral emission reduction targets are specified as a 37 percent reduction from each sector’s 2020 Scoping Plan emission levels. Since the 2020 Scoping Plan emissions level is slightly below 1990 levels, the combined impact of these sectoral targets equates to a statewide reduction of 40 percent below 1990 levels.

No Cap-and-Trade Scenario (Alternative 1)

Agriculture (fossil fuel combustion) measures are the same as in the Scoping Plan Scenario.

All Cap-and-Trade Scenario (Alternative 3)

Agriculture (fossil fuel combustion) measures are the same as in the Scoping Plan Scenario.

Cap-and-Tax Scenario (Alternative 4)

Agriculture (fossil fuel combustion) measures are the same as in the Scoping Plan Scenario.

Non-Energy, Non-CO_2 GHGs

The "non-energy, non-CO_2" greenhouse gas sector in PATHWAYS encompasses all GHGs in the ARB California emissions inventory that are not associated with the direct combustion of fossil fuels. This category includes methane emissions, methane leakage and fugitive emissions, F-gases and nitrogen oxides as well as non-fossil fuel based CO_2 emissions associated with the production of cement. The categories of emissions modeled in this sector include:

- Cement (non-combustion CO_2)
- Waste
- Petroleum refining fugitive emissions
- Oil extraction fugitive emissions
- Electricity generation fugitive emissions and process emissions
- Pipeline fugitive emissions
- Enteric fermentation in agriculture
- Soil emissions in agriculture associated with fertilization
- Manure
- Other agricultural emissions
- F-gases in all sectors, primarily associated with refrigerants, insulation and cooling

Reference Scenario

Emissions in this sector are benchmarked to the ARB 2015 Edition Emission Inventory (covering emission years 2000 – 2013). The growth trajectories for emissions by category are based on the "current practice" scenario described in the ARB Short-Lived Climate Pollutant Strategy.

Scoping Plan Scenario and Carbon Tax Scenario (Alternative 2)

Non-energy GHG emissions are reduced from business-as-usual per SB 1383, as reflected in the ARB Short-Lived Climate Pollutant (SLCP) Strategy for most categories, and based on prior research in the categories of cement and soil emissions, which are not included in the SLCP Strategy. With the exception of methane reductions from landfill gas and manure, all measures are assumed to begin in 2017 and to increase linearly through 2030. Manure and landfill gas reduction measures start in 2020 and increase linearly through 2030. The percent reductions in GHGs are relative to the baseline emissions in 2030.

Emission reduction measures that are based on prior research done for E3 of mitigation potential, and are not reflected in the SLCP, include:

- 9 percent reduction in cement non-energy emissions due to the use of fly ash and other substitutes.
- 22 percent reduction in soil emissions due to optimized application of fertilizers. Research suggests optimized fertilizer application can lead to significant reductions in emissions of N_2O both directly and indirectly, without affecting crop yields.[17]

Measures that are designed to reflect the emission reduction targets in SB 1383, and described in the SLCP Strategy, include:

- 14 percent reduction in waste emissions due to organic diversion of waste
- 45 percent reduction in petroleum refining and oil and gas fugitive emissions
- 40 percent reduction in electricity generation fugitive and process emissions
- 45 percent reduction in pipeline fugitive emissions
- 65 percent reduction in manure methane emissions
- 16 percent reduction in enteric fermentation emissions
- 63 percent reduction in F-gases (high global-warming potential pollutants)

The estimated emissions reductions as modeled in PATHWAYS represent one potential way to achieve the reductions outlined in SB 1383. Emission reduction categories in PATHWAYS do not correspond specifically to the sector targets outlined in SB 1383 and the SLCP Strategy.

No Cap-and-Trade Scenario (Alternative 1)

The non-energy, non-CO_2 GHG emissions follow the same trajectory as the Scoping Plan Scenario.

[17] C.S. Snyder, T.W. Bruulsema, T.L. Jensen and P.E. Fixen (2009) Review of greenhouse gas emissions from crop production systems and fertilizer management effects. Agriculture, Ecosystems and Environment 133: 247-266. And George Silva (2011) Slow release nitrogen fertilizers. Available online http://msue.anr.msu.edu/news/slow_release_nitrogen_fertilizers [Accessed November 6, 2014]

All Cap-and-Trade Scenario (Alternative 3)

The non-energy, non-CO_2 GHG emissions follow the same trajectory as the Scoping Plan Scenario.

Cap-and-Tax Scenario (Alternative 4)

The non-energy, non-CO_2 GHG emissions follow the same trajectory as the Scoping Plan Scenario with additional reductions applied to meet the GHG caps assumed under the Cap-and-Tax Alternative. These include:

- Additional 17 percent reduction in manure methane from 2014 levels between 2021 and 2030 at $75/ton CO_2e.
- Additional 20 percent reduction in waste emissions from 2014 levels between 2021 and 2030 at $125/ton CO_2e.
- Additional 28 percent reduction in cement non-energy emissions from 2014 levels between 2021 and 2030 at zero cost, which is assumed to correspond with reduced output from cement manufacturing.

Key Data Sources for Scenarios

Residential

Description	Reference
Calibration of sectoral electricity demand input data (GWh)	California Energy Demand 2016-2026 Adopted Forecast, California Energy Commission, January 2016, CEC-200-2016-001 (15-IEPR-03)
Calibration of sectoral pipeline gas demand input data (Mtherms)	2009 residential gas usage demand from CEC Energy Consumption database and KEMA, 2009. California RASS.
Reference technology shares (percent of stock)	Kema, 2009. California RASS. Percent of high efficiency clothes washers based on 2013 Navigant Potential Study. Lighting based on 2010 DOE Lighting Market Characterization Report Tables
Technology inputs including useful life, energy type, and cost assumptions	Data used in support of AEO 2013 from the National Energy Modeling System: Input filenames “rsmlgt.txt” For lighting: Energy Savings Potential of Solid-State Lighting in General Illumination Applications (DOE, 2012)

Description	Reference
Subsector energy or service demand consumption estimate used to calibrate total service demand (kWh/household)	KEMA, 2009. California RASS Energy Star Program Requirements and Criteria for Dishwashers
Per-unit technology costs	Cost projections are taken from data used in support of AEO 2013 from the National Energy Modeling System: Input filenames “rsmlgt.txt” and Input filenames “rsmeqp.txt”. Lighting from the Energy Savings Potential of Solid-State Lighting in General Illumination Applications for LED lamps and luminaires.
Technology efficiencies	Data used in support of AEO 2013 from the National Energy Modeling System: Input filename “rsmshl.txt” and Input filename “rsmeqp.txt”. Adjusted from UEC values taken from "rsuec.txt" and stock efficiencies from "rsstkeff.txt". DOE, 2012. Energy Savings Potential of Solid-State Lighting in General Illumination Applications.

Commercial

Description	Reference
Calibration of sectoral electricity demand input data (GWh)	California Energy Demand 2016-2026 Adopted Forecast, California Energy Commission, January 2016, CEC-200-2016-001 (15-IEPR-03)
Calibration of sectoral pipeline gas demand input data (Mtherms)	California Energy Demand IEPR 2014 - Mid Demand Case
Energy use by technology per square foot	CEUS, 2006. SCE values used for LADWP and "Other" electric service territories. Adjusted for square footage with no cooling. And for lighting: DOE Lighting Market Characterization Report, 2010.
Reference technology shares (percent of stock)	Service demand share from National Energy Modeling System: Input filename “ktek.txt” adjusted for service saturation from 2006 CEUS, and for lighting: DOE Lighting Market Characterization Report, 2010.

Description	Reference
Technology inputs including useful life, energy type, and cost assumptions	Data used in support of AEO 2013 from the National Energy Modeling System: Input filenames “ktek.txt”.
Subsector energy or service demand consumption estimate used to calibrate total service demand (kWh/sq ft)	CEUS, 2006 and data used in support of AEO 2013 from the National Energy Modeling System: Input filenames “ktek.txt”.
Per-unit technology costs	Data used in support of AEO 2013 from the National Energy Modeling System: Input filenames “ktek.txt”.
Technology efficiencies	Data used in support of AEO 2013 from the National Energy Modeling System: Input filenames “ktek.txt”.

Transportation

Description	Reference
VMT/Fuel use	• CARB EMFAC 2014 (LDV, MDV, HDV, and Buses) • ARB Vision 2.1 Passenger Vehicle Module • ARB Vision 2.1 Heavy Duty Vehicle Module • ARB 2012 Vision off-road (passenger rail, freight rail, harbor craft, oceangoing vessels, aviation) • Historical levels of transportation diesel consumption are calibrated to the 2016 California GHG emission inventory • Historical levels of transportation natural gas consumption are calibrated to data from the Low-Carbon Fuel Standard regulation
Fuel efficiency	• CARB EMFAC 2014 (MDV, HDV, Buses, LDV motorcycles) • "Transitions to Alternative Vehicles and Fuels", National Academies Press, 2013, Mid case (LDV auto and truck) • ARB 2012 Vision off-road (passenger rail, freight rail, harbor craft, oceangoing vessels, aviation)

Description	Reference
New Technology costs	• California Environmental Protection Agency Air Resources Board Staff Report: Initial Statement of Reasons Advanced Clean Cars 2012 Proposed Amendments to the California Zero Emission Vehicle Program Regulations https://www.arb.ca.gov/regact/2012/zev2012/zevisor.pdf and supplementary guidance from the Air Resources Board staff. • Assessment of Fuel Economy Technologies for Medium- and Heavy-Duty Vehicles, National Academies Press (2010) https://www.nap.edu/catalog/12845/technologies-and-approaches-to-reducing-the-fuel-consumption-of-medium-and-heavy-duty-vehicles • 2012 MODEL YEAR ALTERNATIVE FUEL VEHICLE (AFV) GUIDE, https://www.gsa.gov/ • Department of Transportation Fuel Cell Bus Life Cycle Model: Base Case and Future Scenario Analysis • "Zero Emissions Trucks." Delft, 2013 • "Advancing Technology for America's Transportation Future." National Petroleum Council, 2012. • Electric bus costs data are from ARB, based on the 2013 CalSTART report.
Emissions	• EPA emission factors • CARB refining fuel combustion emissions • APTA 2010 Fact Book, Appendix B

Industrial

Description	Reference
Sectoral electricity demand input data	CEC data used in support of http://uc-ciee.org/downloads/CALEB.Can.pdf
Sectoral pipeline gas demand input data	CEC data used in support of http://uc-ciee.org/downloads/CALEB.Can.pdf
Sectoral "other" energy input data	CARB emissions inventory historical data
End-use energy decomposition by subsector	CPUC Navigant Potential Study, 2013.
Industrial energy efficiency costs	Based on costs estimates provided by ARB staff at \$35/ton, \$135/ton and \$300/ton.

Refining

Description	Reference
Sectoral electricity demand input data	California Energy Demand 2016-2026 Adopted Forecast, California Energy Commission, January 2016, CEC-200-2016-001 (15-IEPR-03)
Sectoral pipeline gas demand input data	CEC data used in support of http://uc-ciee.org/downloads/CALEB.Can.pdf. Allocated to gas utility service territories as a function of refinery electricity demand (broken out by electric service territory). Assumed that LADWP and SCE refining demand met by SCG.
Sectoral "other" energy input data. Input	CARB GHG Emissions Inventory. Allocated to gas utility service territories as a function of refinery electricity demand (broken out by electric service territory). Assumed that LADWP and SCE refining demand met by SCG.
End-use energy decomposition by subsector	CPUC Navigant Potential Study, 2013.
GHG abatement cost estimates	Based on costs estimates provided by ARB staff at $35/ton, $135/ton and $300/ton.

Oil and Gas

Description	Reference
Sectoral electricity demand input data	California Energy Demand 2016-2026 Adopted Forecast, California Energy Commission, January 2016, CEC-200-2016-001 (15-IEPR-03)
Sectoral pipeline gas demand input data	CEC data used in support of http://uc-ciee.org/downloads/CALEB.Can.pdf
GHG abatement cost estimates	Based on costs estimates provided by ARB staff at $35/ton, $135/ton and $300/ton.

Transportation Communications and Utilities (TCU)

Description	Reference
Sectoral electricity demand input data	California Energy Demand 2016-2026 Adopted Forecast, California Energy Commission, January 2016, CEC-200-2016-001 (15-IEPR-03)
Sectoral pipeline gas demand input data	California Energy Demand 2016-2026 Adopted Forecast, California Energy Commission, January 2016, CEC-200-2016-001 (15-IEPR-03)

Agricultural

Description	Reference
Sectoral electricity demand input data	California Energy Demand 2016-2026 Adopted Forecast, California Energy Commission, January 2016, CEC-200-2016-001 (15-IEPR-03)
Sectoral pipeline gas demand input data	California Energy Demand 2016-2026 Adopted Forecast, California Energy Commission, January 2016, CEC-200-2016-001 (15-IEPR-03)
Sectoral "other" energy input data.	Diesel: EIA Adjusted Sales of Distillate Fuel Oil by End Use Gasoline: CARB GHG Emissions Inventory
End-use energy decomposition by subsector	CPUC Navigant Potential Study, 2013.
Energy efficiency cost assumptions	Efficiency costs are estimated at $0.37/kWh (2012$) based on estimated cost of switching to LED lighting.

Water-Related Energy Demand

Description	Reference
Forecast of state water demand	State of California, Natural Resources Agency, Department of Water Resources. "The Strategic Plan." California Water Plan: Update 2013 1 (2013): 26 Feb. 2015. http://www.water.ca.gov/waterplan/
Embedded energy in water	GEI Consultants, and Navigant Consulting. Embedded Energy in Water Studies Study 2: Water Agency and Function Component Study and Embedded Energy- Water Load Profiles. California Public Utilities Commission Energy Division, 5 Aug. 2011. Web. 26 Feb. 2015. ftp://ftp.cpuc.ca.gov/gopher-data/energy%20efficiency/Water%20Studies%202/Study%202%20-%20FINAL.pdf.
Embedded energy in water used for agriculture	Wolff, Gary, Sanjay Gaur, and Maggie Winslow. User Manual for the Pacific Institute Water to Air Models. Rep. no. 1. Pacific Institute for Studies in Development, Environment, and Security, Oct. 2004. Web. 26 Feb. 2015. http://pacinst.org/wp-content/uploads/2013/02/water_to_air_manual3.pdf

Electricity

Category	Data source
Hourly end-use electric load shapes	Residential & commercial: Primarily DEER2008 and DEER 2011, BEopt for residential space heating, cooking and other, CEUS for commercial space heating, lighting and cooking. Agriculture & Industrial: PG&E 2010 load shape data
Hourly renewable generation shapes	Solar PV: simulated using System Advisor Model (SAM), PV Watts Concentrated solar power: simulated using System Advisor Model (SAM) Wind: Western Wind Dataset by 3TIER for the first Western Wind and Solar Integration Study performed by NREL https://www.nrel.gov/grid/wwsis.html
Hydroelectric characteristics	Monthly hydro energy production data from historical EIA data reported for generating units, https://www.eia.gov/electricity/data/eia923/ Daily minimum and maximum hydro generation limits based on CAISO daily renewable watch hydro generation data http://www.caiso.com/market/Pages/ReportsBulletins/DailyRenewablesWatch.aspx
Import/export limits	Consistent with assumptions used in base case of CA electric utility/E3 study "Investigating a Higher RPS Study" (2013).
Existing generation & heat rates	TEPPC 2022 Common Case, and "Capital cost review of power generation technologies, recommendations for WECC's 10- and 20-year studies" https://www.wecc.biz/_layouts/15/WopiFrame.aspx?sourcedoc=/Reliability/2014_TEPPC_Generation_CapCost_Report_E3.pdf&action=default&DefaultItemOpen=1
Renewable generation & transmission capital costs	CPUC RPS Calculator version 6.2
Thermal generation capital costs	"Capital cost review of power generation technologies, recommendations for WECC's 10- and 20-year studies" (E3, March 2014) https://www.wecc.biz/_layouts/15/WopiFrame.aspx?sourcedoc=/Reliability/2014_TEPPC_Generation_CapCost_Report_E3.pdf&action=default&DefaultItemOpen=1

Category	Data source
Energy storage capital costs	"Cost and performance data for power generation technologies," (Black and Veatch, prepared for NREL, February 2012) http://bv.com/docs/reports-studies/nrel-cost-report.pdf
Power plant financing assumptions	"Capital cost review of power generation technologies, recommendations for WECC's 10- and 20-year studies" (E3, March 2014) https://www.wecc.biz/_layouts/15/WopiFrame.aspx?sourcedoc=/Reliability/2014_TEPPC_Generation_CapCost_Report_E3.pdf&action=default&DefaultItemOpen=1
Current electric revenue requirement	Revenue requirement by component, historical FERC Form 1 data, https://www.ferc.gov/docs-filing/forms.asp

Fossil Fuels

Fossil fuel price forecasts are taken from the EIA's Annual Energy Outlook 2015 reference case scenario. State and federal taxes are excluded.

Hydrogen Fuel

Costs and performance assumptions for hydrogen production are based on the Department of Energy H2A Analysis. 2014. https://www.hydrogen.energy.gov/h2a_analysis.html (accessed 2014).

Biomass and Biofuels

California Air Resources Board Biofuel Supply Module Technical Documentation for Version 0.83 Beta, available on the ARB website.

Non-energy, Non-CO_2 Greenhouse Gases

All non-energy, Non-CO_2 greenhouse gas equivalent values are based on the 100-year global warming potential (for CH_4, the 100-yr potential is 0.347 times the 20-yr potential based on the IPCC).

Variable	Description
Categories of non-energy, non-CO_2 greenhouse gases	Subsector GHG emissions data from CARB's emission inventory by IPCC category: • Agriculture: (IPCC Level I Agriculture) • Cement: Clinker production • Waste: (IPCC Level I Waste) • Petroleum Refining: (IPCC Level I Energy/IPCC Level II Fugitive/Sector: Petroleum Refining) • Industrial: (IPCC Level I Industrial) minus Cement • Oil & gas Extraction: (IPCC Level I Energy/IPCC Level II Fugitive/Sector: Oil Extraction) • Electricity Fugitive Emissions: (IPCC Level I Energy/IPCC Level II Fugitive/Sector: Anything related to electricity generation including CHP) • Pipeline Fugitive Emissions: (IPCC Level I Energy/IPCC Level II Fugitive/Sector: Pipelines Natural Gas)
Cement (clinker production)	\$10/MTCO_2e with a 9 percent reduction by 2030 from the Reference from fly ash and other substitutes. In the “cap-and-tax” scenario, additional 28 percent reductions from baseline by 2030 at zero cost (assumed to correspond with reduced cement production) based on input from ARB staff.
Waste	\$0/MTCO_2e with a 14 percent reduction by 2030 from the Reference from organic waste diversion. Based on estimates from the Short-Lived Climate Pollutant Strategy and direct correspondence with California Air Resources Board staff. This estimate excludes the cost of biogas production and any revenue from electricity sales and LCFS credits. LCFS credits are not modeled in PATHWAYS as these assumed to be transfers within the state. In the “cap-and-tax” scenario, additional 20 percent reductions from baseline by 2030 are assumed to be achieved at \$125/ton CO2e based on input from ARB staff.
Petroleum Refining fugitive and non-energy emissions	\$33/MTCO_2e with a 45 percent reduction by 2030 from the Reference. Based on estimates from the Short-Lived Climate Pollutant Strategy.
Oil Extraction Fugitive Emissions	\$33/MTCO_2ewith a 45 percent reduction by 2030 from the Reference. Based on estimates from the Short-Lived Climate Pollutant Strategy.

Variable	Description
Electricity Generation Fugitive & Process	$50/MTCO$_2$e with a 40 percent reduction by 2030 from the Reference. Costs represent placeholder values as better cost data are needed.
Pipeline Fugitive	$33/MTCO$_2$e with a 45 percent reduction by 2030 from the Reference. Based on estimates from the Short-Lived Climate Pollutant Strategy.
Agriculture: Enteric fermentation	$100/MTCO$_2$e with a 16 percent reduction by 2030 from the Reference. Costs represent placeholder values as better cost data are needed.
Agriculture: Soil	$100/MTCO$_2$e with a 22 percent reduction by 2030 from the Reference based on estimates from C.S. Snyder, T.W. Bruulsema, T.L. Jensen and P.E. Fixen (2009) Review of greenhouse gas emissions from crop production systems and fertilizer management effects. Agriculture, Ecosystems and Environment 133: 247-266. And George Silva (2011) Slow release nitrogen fertilizers. Available online http://msue.anr.msu.edu/news/slow_release_nitrogen_fertilizers [Accessed November 6, 2014]
Agriculture: Manure	$0/MTCO$_2$e. Based on estimates from the Short-Lived Climate Pollutant Strategy and correspondence with California Air Resources Board staff. This estimate assumes that manure collection costs are borne by biogas production and captured within the biofuels module in PATHWAYS. LCFS credits are not modeled in PATHWAYS as these are assumed to be transfers within the state. In the “cap-and-tax” scenario, additional 17 percent reductions from Reference by 2030 are achieved at $75/ton CO2e based on input from ARB staff.
F-gases	$48/MTCO$_2$e with a 63 percent reduction by 2030 from the Reference due to coolant switching and leak mitigation. Based on correspondence with California Air Resources Board staff. This estimate excludes the costs and savings associated with energy efficiency appliance purchases as these are captured in the equipment stocks costs in the residential, commercial and transportation sectors.
Land use/ land change	Not currently modeled.