APPENDIX C
AB 197 MEASURE ANALYSIS

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Introduction

This appendix provides estimates for information associated with GHG emissions reduction measures and potential measures evaluated for four alternatives in the Draft 2022 Scoping Plan Update.[1] These estimates, which were developed as part of the process for meeting the requirements of AB 197 (E. Garcia, Chapter 250, Statutes of 2016), provide information on the relative impacts of the evaluated measures when compared to each other. To support the design of a suite of policies that result in GHG reductions, air quality co benefits, and cost-effective measures it is important to understand if a measure will increase or reduce criteria pollutants or toxic air contaminant emissions, or if increasing stringency at additional costs yields few additional GHG reductions. To this end, AB 197 requires the following for each potential emissions reduction measure evaluated in any Scoping Plan update:

- The range of projected GHG emissions reductions that result from the measure;
- The range of projected criteria pollutant emission reductions that result from the measure; and
- The cost-effectiveness, including avoided social costs, of the measure.

The following sections describe the evaluation of measures for the AB 32 GHG Inventory sectors and NWL. For the purposes of this Scoping Plan, the identified emissions reduction measures for the analysis required by AB 197 are actions grouped by sectors where several policies and programs are expected to overlap. This approach reflects the most granular feasible analysis given the modeling tools available[2], the overlap and interaction effects among policies and incentive programs, the longer planning horizon used for this Scoping Plan compared to previous efforts, and the scale of transition needed to achieve carbon neutrality. To implement this Scoping Plan, dozens of individual regulations, policies, and incentive programs are anticipated that work together to drive down emissions across all economic sectors and support actions. Every specific policy or incentive program that could contribute to the deployment of clean technology and energy called for in this plan may overlap in ways that make it infeasible to tease out those policies and programs' individual effects with any reasonable degree of certainty. For example, in the transportation sector, deploying ZEVs and reducing driving demand may be achieved through a combination of the implementation of new or existing regulations, fuels programs, incentive programs, and VMT reduction initiatives that can each contribute to reductions in emissions for the sector. It is not feasible to isolate each sub action from each other at this time in terms of the share of

[1] CARB. 2022. Draft 2022 Scoping Plan Update. *https://ww2.arb.ca.gov/sites/default/files/2022-05/2022-draft-sp.pdf*

[2] See Appendix H (AB 32 GHG Inventory Sector Modeling and Appendix I (NWL Technical Support Document)

contribution to total reductions. The estimated emission reductions, health endpoints, and costs by measure for the Scoping Plan Scenario are presented in Chapter 3, and the corresponding estimates for the Proposed Scenario from the Draft 2022 Scoping Plan and Alternatives 1, 2, and 4 are included in this appendix.

Each measure is evaluated by examining the change in fuel combustion, cost, and emissions associated with just that measure using the PATHWAYS model. The difference between the alternative scenario and the Reference Scenario is estimated for each measure. Starting from the alternative scenario, the modeling assumptions for an individual measure are reverted to the Reference Scenario values, resulting in GHG reductions, changes to fuel combustion, and costs (or savings). This approach does not reflect interactions between sectors in PATHWAYS that influence the results for each complete alternative, presented earlier. As such, the values associated with each measure should not be added to obtain an overall scenario estimate.

To arrive at the 2045 target for NWL, CARB modeled the ecological impact that climate smart land-based management strategies (suites of on-the-ground actions, or *treatments*, that are used across the landscape to manipulate an ecosystem) will have on ecosystem carbon; and whenever possible, additional co-benefits from those actions. Each alternative incorporates a set of land management actions at varying scales of implementation for each land type to achieve the GHG emission reductions. Each land type, and its associated management actions, was considered a measure for this analysis. For modeling individual landscapes and management actions, CARB used a suite of models. The complexity of these models varies by land type, depending on the existing science, data, and availability of existing models to use. Appendix I (NWL Technical Support Document) provides detailed modeling assumptions for each NWL type. The estimated emission reductions, health endpoints, and costs by measure under the Scoping Plan Scenario for each NWL type are presented in Chapter 3, and the corresponding estimates for the Proposed Scenario from the Draft 2022 Scoping Plan and NWL Alternatives 1, 2, and 4 are included in this appendix.

The estimated emission reductions, health endpoints, and costs by measure for the Proposed Scenario and Alternatives 1, 2, and 4 are included in this appendix. These alternatives are discussed in more detail below and in the Draft 2022 Scoping Plan Update.

Evaluation of Scoping Plan Alternatives (AB 32 GHG Inventory Sectors)

CARB staff solicited feedback from topical experts, affected stakeholders, and the EJ Advisory Committee at public meetings toward assembling input assumptions for four carbon neutrality scenarios for purposes of modeling using PATHWAYS to inform the plan’s update process. These revisions were informed by direction in statute, the Governor’s Executive Orders, public comments, and the recommendations of the EJ Advisory Committee. The three alternative scenarios were designed to explore the potential speed, magnitude, and impacts of transitioning California's energy demand away from fossil fuels. The modeling assumptions listed below identify the primary fossil fuel alternative that is commercially available and technically feasible for widespread use by 2045 for each sector. CARB assumes that any energy demand that remains after the alternative technology or fuel is applied—such as on-road internal combustion engines, industrial processes, and gas use in existing buildings that have not yet decarbonized—will continue to be met by fossil fuels, resulting in residual GHG emissions. The descriptions of alternatives below do not include the Proposed Scenario from the Draft 2022 Scoping Plan Update. That Proposed Scenario was further modified and presented as the Scoping Plan Scenario in this Scoping Plan.

Alternative 1: Carbon Neutral by 2035

Alternative 1 includes many of the same actions and clean technology and fuels as the other alternatives and Proposed Scenario, but limits the role of some fuels and technologies. It:

- Accelerates the 2030 target from 40 percent below 1990 levels.
- Aims to achieve carbon neutrality by 2035 by eliminating fossil fuel combustion.
- Nearly phases out all combustion, including fossil, biomass-derived, or hydrogen.
- Requires early retirement of vehicles, appliances, and industrial equipment to eliminate combustion, with aggressive deployment and adoption of non-combustion technologies.
- Directly regulates dairies to achieve the SB 1383 methane target.
- Has a high likelihood of leakage for hard to decarbonize sectors such as cement, aviation, etc., unless carbon capture and sequestration and biomass-derived liquid fuels are utilized.
- Requires CO_2 removal to compensate for non-combustion emissions (industrial process emissions) and short-lived climate pollutants; otherwise it does not achieve carbon neutrality.

Alternative 1 reflects many of the priorities shared by the EJ Advisory Committee. No new digesters or landfill dairy capture would be supported; instead, there would need to be an overall reduction in herd size over time and more composting. Oil and gas fugitive methane emissions would be nearly eliminated as combustion is phased out. Hard to electrify sectors such as stone, clay, glass, and cement may need to close unless some amount of CCS is allowed with some combustion technology to meet their energy needs. If demand for those goods persists, there is a high likelihood of leakage for those sectors. Alternatives to cement such as hempcrete may not be suitable for all applications, including heavy load-bearing works. To ensure no transportation fossil fuel combustion in 2035, the state may need to establish programs to buy back vehicles before end of life and help ensure low-income households have access to ZEVs and any required charging access. There would be no petroleum supply to support any internal combustion vehicles after 2035. Similar buy-back programs may need to be established for replacing gas appliances before their end of life because of no availability of gas. Oil and gas extraction and refining operations would be phased out by 2035 as demand for these fuels would also be forced to zero in 2035. In addition, all combustion-based generation resources for electricity would no longer be available. Firming capacity would need to be achieved through hydrogen fuel cells.

Summary of the Alternative 1 modeling:

- Most reduction in fossil fuel combustion in 2035 and 2045
- Most reduction in GHG emissions without the use of mechanical carbon dioxide removal (CDR) in 2035 and 2045
- Highest direct costs due to early retirement of nearly all vehicles and gas appliances by 2035 and large number of end-of-life replacements that begin 10 to 20 years later, around 2045
- Highest rate of slowing for economic growth in 2035 and 2045
- Highest Social Cost of Carbon (highest avoided damages) in 2035 and 2045
- Highest health benefit savings in 2045
- Highest rate of slowing for job growth in 2035, and tied with Alternative 2 in 2045
- High degree of uncertainty due to highest pace of clean energy and technology deployment and adoption

Alternative 2: Carbon Neutral by 2035

Alternative 2 takes an "all tools" approach and does not place any limits on feasible fuels and technologies. It does anticipate strong consumer preferences and adoption of clean fuels and technologies. The list below provides a summary of the key characteristics of this alternative. It:

- Accelerates the 2030 target beyond 40 percent below 1990 levels.
- Aims to achieve carbon neutrality by 2035 by relying on rapid scale-up of CO_2 removal.
- Does not phase out all combustion, including fossil, biomass-derived, or hydrogen combustion.
- Allows for retirement of combustion vehicles, appliances, and industrial equipment at end of life.
- Allows for the capture and use of biogas from dairies to achieve the SB 1383 methane target.
- Allows for the use of CCS for hard to electrify sectors.
- Requires CO_2 removal to compensate for non-combustion emissions (e.g., industrial process emissions) and short-lived climate pollutants.

This alternative reflects direction from some stakeholders and members of the Legislature to evaluate what it would take to achieve carbon neutrality by 2035 while deploying all tools available today. Unlike Alternative 1, this alternative does not exclude biomass-derived fuels or CCS. This alternative also allows for legacy combustion technology to reach a natural end of life with no need for early buyback programs, except in the case of medium- and heavy-duty vehicles. For electricity generation, all Renewable Portfolio Standard and SB 100 Zero Carbon sources are allowed. Oil and gas extraction and refining operations are phased down in line with the reduction in demand. To the extent demand persists past 2045, oil and gas extraction and refining would continue, but they are paired with CCS where applicable to avoid shutting down operations while still reducing GHG emissions.

Summary of Alternative 2 modeling:

- Second most reduction in fossil fuel combustion in 2035 and 2045
- Second most reduction in GHG emissions without the use of CDR in 2045
- Second highest direct costs due to significant investment in CDR in 2035
- Second highest rate of slowing for economic growth in 2045
- Second highest Social Cost of Carbon (second highest avoided damages) in 2035 and 2045
- Second highest health benefit savings in 2045, comparable to the Proposed Scenario
- Second highest rate of slowing for job growth in 2035, and tied with Alternative 1 in 2045
- High degree of uncertainty due to the highest pace of mechanical CDR deployment

Alternative 4: Carbon Neutral by 2045

Alternative 4 takes an "all tools" approach and does not place any limits on feasible fuels and technologies. It anticipates a less aggressive adoption of clean fuels and technologies by consumers and slower rates of clean fuels and technology deployment. The list below provides a summary of the key characteristics of this alternative. It:

- Achieves the 2030 target of 40 percent emissions reductions from 1990 levels.
- Aims to achieve carbon neutrality by 2045 by reducing direct emissions while transitioning away from fossil fuels.
- Does not phase out all combustion, including fossil, biomass-derived, or hydrogen combustion.
- Allows for retirement of combustion vehicles, appliances, and industrial equipment at end of life.
- Allows for the capture and use of biogas from dairies to achieve the SB 1383 methane target.
- Allows for the use of CCS for hard to electrify sectors.

- Requires a larger amount of CO_2 removal to compensate for non-combustion emissions (industrial process emissions) and short-lived climate pollutants than the Proposed Scenario does.

This alternative reflects modeling that was conducted for the AB 74 Studies on Vehicle Emissions and Fuel Demand and Supply. Like the Proposed Scenario, this alternative does not exclude biomass-derived fuels or CCS. This alternative also allows for legacy combustion technology to reach a natural end of life with no need for early buyback programs. For electricity generation, all Renewable Portfolio Standard and SB 100 Zero Carbon sources are allowed. Oil and gas extraction and refining operations are phased down in line with the reduction in demand. To the extent demand persists past 2045, oil and gas extraction and refining would continue, but paired with CCS where applicable to avoid leakage and manage GHG emissions. This scenario results in the largest share of fossil fuels remaining in the economy in 2045. Also, this scenario does not achieve the 2050 80 percent reduction in GHGs below 1990 levels as called for in Executive Order S-3-05.

Summary of Alternative 4 modeling:

- Least reduction in fossil fuel combustion in 2045
- Least reduction in GHG emissions without the use of CDR in 2045
- Third highest direct costs in 2034 and 2045, comparable to the Proposed Scenario
- Second highest rate of slowing for economic growth in 2045
- Least Social Cost of Carbon (least avoided damages) in 2035 and 2045
- Less health benefit savings in 2045, comparable to the Proposed Scenario
- Second least rate of slowing for job growth in 2035 and tied with the Proposed Scenario in 2035
- Lesser degree of uncertainty, due to longer time frame for clean energy and technology (including CDR) to be deployed

Evaluation of Scoping Plan Alternatives (NWL)

For the NWL sectors, staff significantly expanded the scale of the scientific analysis for NWL from previous Scoping Plan update efforts. CARB staff utilized modeling tools for this expanded analysis to assess both the carbon and other ecological, public health, and economic outcomes of management actions on forests, shrublands, grasslands, croplands, developed lands, wetlands, and sparsely vegetated lands. CARB staff aligned the scenarios with both the landscape types and actions identified in other efforts called for in the Governor's Executive Order (e.g., California's Climate Smart Strategy and Pathways to 30x30). As part of the 2022 Scoping Plan update, CARB staff modeled as many of the management actions identified in the Natural and Working Lands Climate Smart Strategy as were feasible. The management actions that were included in the model were selected because of the State of California's previous work to quantify these actions' impacts. It was not feasible to model every land management strategy for NWLs, and so it is possible that larger volumes of sequestration (e.g., in soils or in oceans) could result from additional non-modeled activities. California's Natural and Working Lands Climate Smart Strategy includes a more comprehensive listing of priority nature-based solutions and management actions. It is important to note that the absence of a particular management action or its climate benefit in the modeling is not an indication of its importance or potential contributions toward meeting the target or toward supporting the carbon neutrality target for California.

Forests: Management strategies modeled for forests: biological/chemical/herbaceous treatments (e.g., herbicide application), clearcut, various timber harvests (e.g., variable retention, seedtree/shelterwood, selection harvesting), mastication, other mechanical treatments (e.g., piling of dead material, understory thinning), prescribed burning, and thinning. Avoided land conversion to another land use is also included in the modeling. Wildfire is modeled and is responsive to management strategies and climate conditions.

Shrublands and chaparral: Management strategies modeled for shrublands and chaparral: biological/chemical/herbaceous treatments, prescribed burning, mechanical treatment (e.g., mastication, crushing, mowing, piling), and avoided conversion from shrubland to another land use. Wildfire is modeled and is responsive to management strategies and climate conditions.

Grasslands: Management strategies modeled for grasslands: biological, chemical, herbaceous treatments, prescribed burning, and avoided land conversion from grasslands to another land use. Wildfire is modeled and is responsive to management strategies and climate conditions.

Croplands: Management strategies modeled for row crops: cover cropping, no till, reduced till, compost amendment, transition to organic[5] farming, avoided conversion of annual crop agricultural land through easements, establishing riparian forest buffers, alley cropping, establishing windbreaks/shelterbelts, establishing tree and shrubs in croplands, and establishing hedgerows. For perennial crops, windbreaks/shelterbelts, hedgerows, conversion from annual crops to perennial crops, and avoided conversion to other land uses were modeled.

Developed lands: Management strategies modeled for developed lands: Increasing tree canopy cover through planting trees and improved management of existing trees, and removing vegetation surrounding structures in accordance with the CALFIRE Defensible Space PRC 4291.

Wetlands: Management strategies modeled for wetlands: Restoring wetlands through submerging cultivated land in the Sacramento-San Joaquin Delta and avoided land conversion in the Sacramento-San Joaquin Delta.

Sparsely vegetated lands: Management strategies modeled for sparsely vegetated lands: Avoided conversion of sparsely vegetated lands to another land use.

NWL Alternative 1: Land management activities that prioritize short term carbon stocks in our forests and through increased climate smart agricultural practices on croplands.

NWL Alternative 1 takes a "no management" approach for forests, shrublands/chaparral, and grasslands to maximize short term carbon stocks while maintaining current fire suppression levels. Climate smart agriculture practices are maximized to increase carbon on croplands. The list below provides a summary of the alternative's key characteristics:

- No change in fire suppression
- Goal is to increase climate smart agricultural practices to the maximum level feasible based on topography, water, and agronomic constraints.
- Significant amount (30 percent by 2045) of croplands change from conventional to organic farming
- Significant increase in statewide urban forest investment to maximize carbon storage in urban forests
- Compliance with CalFire defensible space requirements of PRC 4291 on all parcels up to ownership boundaries
- Maximum number of acres (120,000 acres) of Delta wetlands restoration
- Sparsely vegetated lands are prevented from conversion to another land use.

This alternative reflects stakeholder feedback to reduce management on forests. It maximizes the retention of aboveground carbon stocks on these land types in the short term and allows climate change and disturbance to determine the long-term carbon and wildfire emissions trends. In this alternative, other land types outside of forests, shrublands/chaparral, and grasslands receive extremely aggressive levels of management practices in order to increase carbon stocks immediately, and were established through discussions with other state agencies. For example, the climate smart agriculture practice acreages were determined based on feedback from the California Department of Food and Agriculture (CDFA) and their familiarity with the technical limits of these practices. The large increase in statewide urban forest investment (a 20x increase relative to historic levels) was chosen to illuminate the maximum potential for carbon sequestration in urban forests. The implementation rates in both agriculture and urban forestry are at the upper end of feasibility due to technical, financial, and policy-related constraints that govern management decisions.

NWL Alternative 1 results in the most significant air quality related health impacts from $PM_{2.5}$ wildfire emissions of any scenario. It also has the highest direct costs of any scenario by an order of magnitude because of the large increases in urban forestry expansion and maintenance costs. This scenario also has the largest reduction in personal income as funding is shifted to support urban forestry maintenance.

NWL Alternative 2: Current state commitments and plans will be the basis for the land management activities

NWL Alternative 2 bases the modeled acreage on current state commitments where they exist. The One Million Acre Strategy, 30x30 Strategy, and other existing regional commitments and plans were referenced for this scenario. The list below provides a summary of the key assumptions of this alternative:

- An increase from the Reference Scenario to 1 million acres treated across forest, shrubland/chaparral, and grasslands focused on fuel reduction treatments, consistent with the currently announced California/United States Forest Service Shared Stewardship Agreement[3]
- Second highest increases in climate smart agricultural practices
- Second highest increase in statewide urban forest investment
- Compliance with CalFire defensible space requirements of PRC 4291 on all parcels up to ownership boundaries
- Restoration of Delta wetlands in line with existing regional plans
- More reduction in land conversion of sparsely vegetated lands than Alternative 1

This alternative was developed to assess the impact of existing state commitments and plans on future carbon stocks and sequestration rates. For land types that do not currently have these commitments, CARB scaled acreages to complement the range of acreages among all the alternatives while maintaining an aggressive rate of implementation. All practices are increased over the Reference Scenario. This will help provide insight into the range of outcomes that can be expected for NWL and help set a realistically ambitious target.

NWL Alternative 2 results in higher wildfire $PM_{2.5}$ emissions than the Proposed Scenario, and therefore more air quality related health impacts than the Proposed Scenario. This scenario also has the second highest direct costs of any scenario. It also has the second largest reduction in personal income as funding is shifted to support urban forestry maintenance

[3] State of California and the USDA, Forest Service. August 12, 2020. Agreement for Shared Stewardship of California's Forest and Rangelands Between the State of California and the USDA, Forest Service Pacific Southwest Region. *https://www.gov.ca.gov/wp-content/uploads/2020/08/8.12.20-CA-Shared-Stewardship-MOU.pdf*

NWL Alternative 4: Land management activities that prioritize reducing forest, shrubland, and grassland wildfire fuels.

NWL Alternative 4 prioritizes actions on forests, shrubland/chaparral, and grasslands that reduce wildfire risks. The list below provides a summary of the key assumptions of this alternative:

- Significant increase in acres treated across forests, shrubland/chaparral, grasslands, focused on fuel reduction treatments
- Limited prescribed burning in chaparral
- Modest increase in climate smart agricultural practices
- Modest increase in statewide urban forest investment
- Compliance with CalFire defensible space requirements of PRC 4291 on all parcels up to the maximum defensible space distance regardless of ownership boundaries
- Restoration of Delta wetlands in line with existing regional plans
- Modest reduction in land conversion of sparsely vegetated lands

This alternative analyzes reducing wildfire risk as the top priority for the state, which results in an approximately 20x increase in forest management and fuels reduction treatments. The acreage of fuels reduction treatments on forests, shrublands/chaparral, and grasslands is based on the low end of the range of the historic estimated annual area burned during the Little Ice Age. This historic annual area burned range was assessed as part of CARB's analysis for the report *California's Historical Wildfire Activity before Modern Wildfire Suppression* developed pursuant to SB 901. This amount of treatment acreage attempts to replicate how much area was historically disturbed by fire, in order to explore how this level of treatment would affect carbon stocks and sequestration. Within wildland urban interface (WUI) areas, creation of defensible space was modeled to the maximum distance required under Public Resources Code (PRC) 4291, regardless of whether this resulted in the removal of vegetation beyond a parcel's ownership boundary. This maximizes the protection afforded to each parcel through defensible space.

In other land types, which are less susceptible to wildfires and their impacts, implementation rates are above Reference Scenario rates but were decreased compared to all other alternatives (except for Delta wetlands, which were set equal to Alternative 2). This was to highlight this alternative's primary focus on wildfire risk reduction.

NWL Alternative 4 has the least amount of wildfire emissions, and therefore has the most health benefits of any scenario. This alternative results in significant shifts in employment in the forestry and logging sector because of the very rapid and significant increase of forest management to 5 million acres annually, starting in 2025. This scenario also results in the second largest reduction in gross state product (GSP) but has the lowest reduction in personal income of any scenario, as employment shifts from state and local government and from construction jobs to forestry and logging.

AB 197 Measures Evaluated

This section lists the modeled assumptions incorporated by each emissions reduction measure[4] evaluated for the AB 32 GHG Inventory Sectors and for the Natural and Working Lands. Four alternative scenarios were developed for the AB 32 GHG Inventory Sector analysis, and four alternatives were developed for the NWL analysis.

AB 32 GHG Inventory Sector Measures

Four alternative scenarios that transition energy needs away from fossil fuels and achieve carbon neutrality no later than 2045 were developed. Each alternative incorporates the same seven key measures to achieve the GHG emission reductions. The pace and magnitude of transition away from fossil fuels differs among alternatives. Table C-1 summarizes the modeling assumptions associated with each measure for each of the four alternatives.

Because many of the measures and underlying assumptions interact with each other, isolating the GHG emission reductions, corresponding changes to fuel combustion, and associated cost of an individual measure is analytically challenging. Each measure is evaluated by performing a series of sensitivity model runs in the PATHWAYS model. The difference between the Draft 2022 Scoping Plan Proposed Scenario (or Alternative) and the Reference Scenario is estimated for each measure. Starting from the Proposed Scenario (or Alternative), the modeling assumptions for an individual measure are reverted to the Reference Scenario values, resulting in GHG reductions, changes to fuel combustion, and costs (or savings). This approach does not reflect interactions between sectors in PATHWAYS that influence the results for each complete alternative, presented earlier. As such, the values associated with each measure should not be added to obtain an overall scenario estimate.

[4] AB 197 calls for the evaluation of "emissions reduction measures." This Scoping Plan treats each action grouped by sector as an emissions reduction measure for the purposes of the information identified in Chapter three of the Scoping Plan and this Appendix.

Table C-1. Scenario modeling assumptions incorporated by each AB 197 measure by alternative (AB 32 GHG Inventory sectors)

AB 197 Measure	Alternative 1	Alternative 2	Proposed Scenario[5]	Alternative 4
Deploy ZEVs and reduce driving demand	VMT per capita reduced 25% below 2019 levels by 2030 and 30% below 2019 levels by 2035	VMT per capita reduced 15% below 2019 levels by 2030 and 20% below 2019 levels by 2035	VMT per capita reduced 12% below 2019 levels by 2030 and 22% below 2019 levels by 2045	VMT per capita reduced 10% below 2019 levels by 2030 and 15% below 2019 levels by 2045
Deploy ZEVs and reduce driving demand	Light Duty Vehicle (LDV) Fuel Economy Standards: Advanced Clean Cars I GHG standards for 2017 - 2025 model years, 2% annual fuel economy improvement for 2026-2035.			
Deploy ZEVs and reduce driving demand	100% of LDV sales are ZEV by 2030; no Plug-in Hybrid Electric Vehicle (PHEV) sales after 2030 Only ZEVs on road by 2035; no PHEVs on road by 2035	100% of LDV sales are ZEV by 2030; no PHEV sales after 2035	Executive Order N-79-20: 100% of LDV sales are ZEV by 2035	AB 74 ITS Report: 100% of LDV sales are ZEV by 2040
Deploy ZEVs and reduce driving demand	Truck Fuel Economy Standards: California Phase II GHG Standards.			
Deploy ZEVs and reduce driving demand	100% of MD/HDV sales are ZEV by 2030 Only ZEVs on road by 2035; no PHEVs on road by 2035	100% of MD/HDV sales are ZEV by 2035 Only ZEVs on road by 2045; no PHEVs on road by 2045	AB 74 ITS Report: 100% of MD/HDV sales are ZEV by 2040	100% of MD/HDV sales are ZEV by 2045

[5] This is the "Proposed Scenario" released in the Draft 2022 Scoping Plan. The estimated emission reductions, health endpoints, and costs by measure for the final Scoping Plan Scenario are presented in Chapter 3.

AB 197 Measure	Alternative 1	Alternative 2	Proposed Scenario[5]	Alternative 4
Deploy ZEVs and reduce driving demand	25% of aviation fuel demand is met by electricity (batteries) or hydrogen (fuel cells) in 2030 and 50% in 2035 Sustainable aviation fuel meets rest of aviation fuel demand that has not already transitioned to hydrogen or batteries	25% of aviation fuel demand is met by electricity (batteries) or hydrogen (fuel cells) in 2045 Sustainable aviation fuel meets most or rest of aviation fuel demand that has not already transitioned to hydrogen or batteries	10% of aviation fuel demand is met by electricity (batteries) or hydrogen (fuel cells) in 2045 Sustainable aviation fuel meets most or rest of aviation fuel demand that has not already transitioned to hydrogen or batteries	0% of aviation fuel demand is met by electricity (batteries) or hydrogen (fuel cells) in 2045 Sustainable aviation fuel meets most or rest of aviation fuel demand in 2045
Deploy ZEVs and reduce driving demand	100% of Ocean Going Vessels (OGVs) utilize shore power by 2030 10% of OGVs utilize hydrogen fuel cell electric technology by 2035 Rest of OGVs fuel demand not met in 2035 because non-combustion alternative not available	100% of OGVs utilize shore power by 2030 10% of OGVs utilize hydrogen fuel cell electric technology by 2035	2020 OGV At-Berth regulation fully implemented with most OGVs utilizing shore power by 2027 25% of OGVs utilize hydrogen fuel cell electric technology by 2045	2020 OGV At-Berth regulation fully implemented, with most OGVs utilizing shore power by 2027 0% of OGVs are zero-emission by 2045
Deploy ZEVs and reduce driving demand	100% of cargo handling equipment (CHE) is zero-emission by 2030 100% of drayage trucks are zero emission by 2030	100% of cargo handling equipment (CHE) is zero-emission by 2030 100% of drayage trucks are zero emission by 2030	Executive Order N-79-20: 100% of cargo handling equipment (CHE) is zero-emission by 2037 100% of drayage trucks are zero emission by 2035	100% of cargo handling equipment (CHE) is zero-emission by 2045 100% of drayage trucks are zero emission by 2035

AB 197 Measure	Alternative 1	Alternative 2	Proposed Scenario[5]	Alternative 4
Deploy ZEVs and reduce driving demand	100% of passenger and other locomotive sales are ZEV by 2030 50% of line haul locomotive sales are ZEV by 2030 and 100% by 2035 Line haul and passenger rail rely primarily on hydrogen fuel cell technology, and others primarily utilize electricity	100% of passenger and other locomotive sales are ZEV by 2030 50% of line haul locomotive sales are ZEV by 2030 and 100% by 2035 Line haul and passenger rail rely primarily on hydrogen fuel cell technology, and others primarily utilize electricity	100% of passenger and other locomotive sales are ZEV by 2030 100% of line haul locomotive sales are ZEV by 2035 Line haul and passenger rail rely primarily on hydrogen fuel cell technology, and others primarily utilize electricity	100% of passenger and other locomotive sales are ZEV by 2040 100% of line haul locomotive sales are ZEV by 2045 Line haul and passenger rail rely primarily on hydrogen fuel cell technology, and others primarily utilize electricity
Coordinate supply of liquid fossil fuels with declining CA fuel demand	Phase out oil and gas extraction operations by 2035	Reduce oil and gas extraction operations in line with petroleum demand by 2035	Phase out oil and gas extraction operations by 2045	Reduce oil and gas extraction operations in line with petroleum demand
Coordinate supply of liquid fossil fuels with declining CA fuel demand	Phase out petroleum refining production by 2035 in line with petroleum demand	CCS on majority of petroleum refining operations by 2030 Production reduced in line with petroleum demand	CCS on majority of petroleum refining operations by 2030 Production reduced in line with petroleum demand	CCS on majority of petroleum refining operations by 2030 Production reduced in line with petroleum demand

AB 197 Measure	Alternative 1	Alternative 2	Proposed Scenario[5]	Alternative 4
Generate clean electricity	Electric sector GHG target of 23 MMTCO$_2$e in 2030 and 0 MMTCO$_2$e in 2035 Total load coverage Excludes combustion-based generation resources regardless of fuel; hydrogen fuel cells provide firm capacity	Electric sector GHG target of 30 MMTCO$_2$e in 2030 and 30 MMTCO$_2$e in 2035[6] Retail sales load coverage Includes Renewables Portfolio Standard (RPS)-eligible and zero-carbon generation resources (see Appendix H (AB 32 GHG Inventory Sector Modeling))	Electric sector GHG target of 38 MMTCO$_2$e in 2030 and 31 MMTCO$_2$e[7] in 2045 Retail sales load coverage Same generation resources as Alternative 2	Electric sector GHG target of 38 MMTCO$_2$e in 2030 and 30 MMTCO$_2$e[8] in 2045 Retail sales load coverage Same generation resources as Alternative 2
Decarbonize buildings	Building Energy Efficiency: Align with 2019 IEPR Mid-High (electric) / Mid-Mid (gas)			
Decarbonize buildings (New Residential and Commercial Buildings)	All electric appliances beginning 2026	All electric appliances beginning 2026	All electric appliances beginning 2026 (residential) and 2029 (commercial)	All electric appliances beginning 2029

[6] The GHG target is determined from the Scoping Plan modeling results to meet the loads associated with the scenario and corresponds to meeting the 2021 SB 100 Joint Agency Report's 100% of retail sales with eligible renewable and zero-carbon resources definition.

[7] Ibid.

[8] Ibid.

AB 197 Measure	Alternative 1	Alternative 2	Proposed Scenario[5]	Alternative 4
Decarbonize buildings (Existing Residential Buildings)	80% of appliance sales are electric by 2025 and 100% of appliance sales are electric by 2030 All buildings retrofitted to electric appliances by 2035	80% of appliance sales are electric by 2030 and 100% of appliance sales are electric by 2035 Appliances are replaced at end of life	80% of appliance sales are electric by 2030 and 100% of appliance sales are electric by 2035 Appliances are replaced at end of life	75% of appliance sales are electric by 2030 and 100% of appliance sales are electric by 2035 Appliances are replaced at end of life
Decarbonize buildings (Existing Commercial Buildings)	80% of appliances sales are electric by 2025 and 100% of appliance sales are electric by 2030 All buildings retrofitted to electric appliances by 2035	80% of appliance sales are electric by 2030 and 100% of appliance sales are electric by 2045 Appliances are replaced at end of life	80% of appliance sales are electric by 2030 and 100% of appliance sales are electric by 2045 Appliances are replaced at end of life	75% of appliance sales are electric by 2030 and 100% of appliance sales are electric by 2045 Appliances are replaced at end of life
Decarbonize industrial energy supply	Energy Efficiency: Energy demand reduced 6% relative to 2019 IEPR Mid-Mid			
Decarbonize industrial energy supply (Food Products)	50% energy demand directly and/or indirectly electrified by 2030; 100% by 2035	50% energy demand electrified directly and/or indirectly by 2030; 100% by 2035	7.5% energy demand electrified directly and/or indirectly by 2030; ~~100~~75% by 2045	7.5% energy demand electrified directly and/or indirectly by 2030; ~~10~~30% by 2045
Decarbonize industrial energy supply (Construction Equipment)	50% energy demand electrified by 2030 and 100% by 2035	50% energy demand electrified by 2030 and 100% by 2035	25% energy demand electrified by 2030 and 75% by 2045	0% energy demand electrified by 2030 and 50% by 2045

AB 197 Measure	Alternative 1	Alternative 2	Proposed Scenario[5]	Alternative 4
Decarbonize industrial energy supply (Chemicals and Allied Products; Pulp and Paper)	Electrify 50% of boilers by 2030 Electrify 100% of boilers and process heat by 2035 Electrify 100% of other energy demand by 2030	Electrify 50% of boilers by 2030 and 100% of boilers by 2035 Hydrogen for 50% of process heat by 2035 and 100% by 2045 Electrify 100% of other energy demand by 2035	Electrify 0% of boilers by 2030 and 100% of boilers by 2045 Hydrogen for 25% of process heat by 2035 and 100% by 2045 Electrify 100% of other energy demand by 2045	Electrify 0% of boilers by 2030 and 10% of boilers by 2045 Hydrogen for 0% of process heat by 2035 and 10% by 2045 Electrify 0% of other energy demand by 2045
Decarbonize industrial energy supply (Stone, Clay, Glass & Cement)	CCS on all facilities by 2035 Some process emissions reduced through alternative materials	Carbon Capture and Sequestration (CCS) on 40% of operations by 2035 and on all facilities by 2045 Some process emissions reduced through alternative materials	CCS on 40% of operations 2035 and on all facilities by 2045 Some process emissions reduced through alternative materials	CCS on 40% of operations by 2035 and on all facilities by 2045 Some process emissions reduced through alternative materials
Decarbonize industrial energy supply (Other Industrial Manufacturing)	50% energy demand electrified by 2030 and 100% by 2035	50% energy demand electrified by 2035	0% energy demand electrified by 2030 and 50% by 2045	0% energy demand electrified by 2030 and 10% by 2045
Decarbonize industrial energy supply (Combined Heat and Power)	50% waste heat demand electrified by 2030 and 100% by 2035	Facilities retire by 2040	Facilities retire by 2040	Facilities retire by 2040
Decarbonize industrial energy supply (Agriculture Energy Use)	50% energy demand electrified by 2030 and 100% by 2035	50% energy demand electrified by 2035	25% energy demand electrified by 2030 and 75% by 2045	0% energy demand electrified by 2030 and 50% by 2045

AB 197 Measure	Alternative 1	Alternative 2	Proposed Scenario[5]	Alternative 4
Deploy ZEVs and reduce driving demand	No biofuels consumption by 2035, except for aviation demand	Biomass supply used to produce conventional and advanced biofuels as well as hydrogen	Biomass supply used to produce conventional and advanced biofuels as well as hydrogen	Biomass supply used to produce conventional and advanced biofuels as well as hydrogen
Decarbonize buildings **Decarbonize industrial energy supply** **Coordinate supply of liquid fossil fuels with declining CA fuel demand**	RNG directed to Cement facilities by 2035	In 2030s RNG blended in pipeline Renewable Hydrogen blended in natural gas pipeline at 7% energy (~20% by volume), ramping up between 2030 and 2040[9] In 2030s, dedicated hydrogen pipelines constructed to serve certain industrial clusters	In 2030s RNG blended in pipeline Renewable Hydrogen blended in natural gas pipeline at 7% energy (~20% by volume), ramping up between 2030 and 2040 In 2030s, dedicated hydrogen pipelines constructed to serve certain industrial clusters	In 2030s RNG blended in pipeline Renewable Hydrogen blended in natural gas pipeline at 7% energy (~20% by volume), ramping up between 2030 and 2040 In 2040s, dedicated hydrogen pipelines constructed to serve certain industrial clusters

[9] The renewable hydrogen blending assumptions are for modeling purposes. Both SB 1440 implementation and hydrogen injection considerations are being handled in CPUC proceeding R.13-02-008 (Order Instituting Rulemaking to Adopt Biomethane Standards and Requirements, Pipeline Open Access Rules, and Related Enforcement Provisions). On November 10, 2022, CPUC released a Proposed Decision, which adopts an interim definition for renewable hydrogen and directs the development of pilot projects to further evaluate standards for the safe injection of renewable hydrogen into California's common carrier pipeline system. Proceeding R.13-02-008: *https://apps.cpuc.ca.gov/apex/f?p=401:56:0::NO:RP,57,RIR:P5_PROCEEDING_SELECT:R1302008*

AB 197 Measure	Alternative 1	Alternative 2	Proposed Scenario[5]	Alternative 4
Reduce non-combustion emissions (Methane)	No additional landfill or dairy digester methane capture Maximize deployment of alternative manure management strategies Aggressive adoption of enteric strategies by 2030 Rate of dairy herd size reduction increases compared to historic levels Divert 75% of organic waste from landfills by 2025 Oil and gas methane emissions are nearly eliminated when combustion phased out	Rapidly increase landfill and dairy digester methane capture Some alternative manure management deployed for smaller dairies Aggressive adoption of enteric strategies by 2030 Rate of dairy herd size reduction increases compared to historic levels Divert 75% of organic waste from landfills by 2025 Oil and gas fugitive methane emissions reduced 50% by 2030 and further reductions as infrastructure components retire in line with reduced natural gas demand	Increase landfill and dairy digester methane capture Some alternative manure management deployed for smaller dairies Moderate adoption of enteric strategies by 2030 Divert 75% of organic waste from landfills by 2025 Oil and gas fugitive methane emissions reduced 50% by 2030 and further reductions as infrastructure components retire in line with reduced natural gas demand	Increase landfill and dairy digester methane capture Limited alternative manure management deployed Moderate adoption of enteric strategies by 2030 Divert 75% of organic waste from landfills by 2025 Oil and gas fugitive methane emissions reduced 45% by 2030 and further reductions as infrastructure components retire in line with reduced natural gas demand
Reduce non-combustion emissions (Hydrofluorocarbons [HFC])	Low GWP refrigerants introduced as building electrification increases mitigating HFC emissions	Low GWP refrigerants introduced as building electrification increases mitigating HFC emissions	Low GWP refrigerants introduced as building electrification increases mitigating HFC emissions	Low GWP refrigerants introduced as building electrification increases mitigating HFC emissions

AB 197 Measure	Alternative 1	Alternative 2	Proposed Scenario[5]	Alternative 4
Compensate for remaining emissions	Carbon Dioxide Removal (CDR) scaled to compensate for remaining, limited GHG emissions in 2035	CDR scaled to compensate for remaining GHG emissions in 2035	CDR demonstration projects deployed by 2030 CDR scaled to compensate for remaining GHG emissions in 2045	CDR demonstration projects deployed by 2030 CDR scaled to compensate for remaining GHG emissions in 2045

NWL Measures

To arrive at the 2045 target for NWL, CARB modelled the ecological impact that climate smart land-based management strategies (suites of on-the-ground actions, or treatments, that are used across the landscape to manipulate an ecosystem) will have on ecosystem carbon under various climate change alternatives and whenever possible, additional co-benefits from those actions. Four alternatives that explore how NWLs can contribute to carbon neutrality in 2045 and beyond were developed. Each alternative incorporates a set of land management actions at varying scales of implementation for each land type, to achieve the GHG emission reductions. Each land type, and its associated incorporated modeled management actions, is considered a measure for this analysis. For modeling individual landscapes and management actions, CARB used a suite of models. The complexity of these models varies by land type depending on the existing science, data, and availability of existing models to use. The alternatives are presented in Table C-2. Appendix I (NWL Technical Support Document) provides detailed modeling assumptions for each NWL type/measure.

Table C-2. Scenario modeling assumptions for each AB 197 measure by alternative (NWL)

Land Type	Activity	Reference	Alternative 1	Alternative 2	Proposed Scenario (Alt 3)[10]	Alternative 4
Forest Shrublands / Chaparral (a) Grassland (b)	Biological, Chemical, and Herbaceous Treatments	891 acres annually	0	13,664 acres annually	39253 acres annually	119002 acres annually
	Clearcut	25,308 acres annually	0	21,362 acres annually	24,652 acres annually	19,802 acres annually
	Harvesting	61,345 acres annually	0	117,107 acres annually	283,724 acres annually	606,892 acres annually
	Thinning	70,592 acres annually	0	191,901 acres annually	535,155 acres annually	1,229,399 acres annually
	Mastication	14,167 acres annually	0	90,286 acres annually	197,041 acres annually	379,493 acres annually
	Other Mechanical	38,577 acres annually	0	264,975 acres annually	756,240 acres annually	1,736,904 acres annually

[10] This is the "Proposed Scenario" released in the Draft 2022 Scoping Plan. The estimated emission reductions, health endpoints, and costs by measure for the final Scoping Plan Scenario are presented in Chapter 3.

Land Type	Activity	Reference	Alternative 1	Alternative 2	Proposed Scenario (Alt 3)[10]	Alternative 4
	Prescribed Burning	37,235 acres annually	0	300,794 acres annually	507,457 acres annually	1,093,877 acres annually
Croplands	Cover cropping (legumes)	0	12,822 acres annually	9,617 acres annually	6,411 acres annually	3,206 acres annually
	Cover cropping (non-legumes)	0	12,822 acres annually	9,617 acres annually	6,411 acres annually	3,206 acres annually
	No Till	0	7,177 acres annually	5,383 acres annually	3,589 acres annually	1,794 acres annually
	Reduced Till	0	18,440 acres annually	13,830 acres annually	9,220 acres annually	4,610 acres annually
	Compost Amendment	0	53,522 acres annually	40,142 acres annually	26,761 acres annually	13,381 acres annually
	Transition to organic farming	0	129,516 acres annually	97,137 acres annually	64,758 acres annually	32,379 acres annually
	Conservation of Annual Cropland	0	11,120 acres annually	8,340 acres annually	5,560 acres annually	2,780 acres annually
	Establishing Riparian Forest Buffers	0	75 acres annually	56 acres annually	38 acres annually	19 acres annually
	Alley Cropping	0	22 acres annually	17 acres annually	11 acres annually	6 acres annually

Land Type	Activity	Reference	Alternative 1	Alternative 2	Proposed Scenario (Alt 3)[10]	Alternative 4
	Establishing Windbreaks/Shelterbelts	0	23 acres annually	17 acres annually	12 acres annually	6 acres annually
	Establishing Tree and Shrubs in Croplands	0	16 acres annually	12 acres annually	8 acres annually	4 acres annually
	Establishing Hedgerows	0	87 acres annually	65 acres annually	44 acres annually	22 acres annually
	Establishing Hedgerows in Perennial Croplands	0	191 acres annually	143 acres annually	96 acres annually	48 acres annually
	Establishing Windbreak/Shelterbelts in Perennial Croplands	0	72 acres annually	54 acres annually	36 acres annually	18 acres annually
Developed Lands	Urban Forest Investment	~$1.5 billion total estimated	2,000% above current investment levels (~$30 billion total estimated)	200% over current investment levels (~$3 billion total estimated)	20% over current investment levels (~$1.8 billion total estimated)	2% over current investment levels (~$1.53 billion total estimated)
	Defensible Space in Wildland Urban Interface Communities	No defensible space	Complete defensible space up to property boundaries	Complete defensible space up to property boundaries	Complete defensible space up to property boundaries	Complete defensible space regardless of property boundaries
Wetlands	Wetland Restoration	0	120,000 acres in total	18,000 acres in total	60,000 acres in total	18,000 acres in total

Land Type	Activity	Reference	Alternative 1	Alternative 2	Proposed Scenario (Alt 3)[10]	Alternative 4
Sparsely Vegetated Lands/Other Lands	Avoided Conversion	2,607 acres converted annually	0 acres converted annually	652 acres converted annually	1,303 acres converted annually	1,955 acres converted annually

Estimated Emissions Reductions and Health Endpoints

Different methodologies were used to estimate GHG emission reductions, criteria pollutant emission reductions and associated health endpoints for the AB 32 GHG Inventory Sectors and for NWL. These methodologies were described in Chapter 3 and are summarized here.

Emissions Reductions and Health Analysis for AB 32 GHG Inventory Sector Measures

As described in Chapter 3, CARB estimated criteria pollutant emissions impacts by using changes in fuel combustion in units of exajoules (EJ) from PATHWAYS and emission factors in units of tons per EJ to estimate the change in emissions in tons per year. Emission factors from a variety of sources for each sector were utilized, including but not limited to *CARB's mobile source emissions models*,[11] *U.S. EPA's AP 42 Emissions Factors*[12] as well as *District Rules*[13]. These emission factors are applied to fuel burn change by fuel type, sector, equipment type and process, where applicable. Statewide annual average emissions were estimated for three criteria pollutants: NOx, $PM_{2.5}$, and ROG.

Table C-3, Table C-4, Table C-5, and Table C-6 provide the estimated GHG and criteria pollutant emission reductions for the measures in the Proposed Scenario, Alternatives 1, 2, and 4 in years 2035 and 2045. Based on the estimates below, these measures are expected to provide air quality benefits. The estimates provided here are appropriate for comparing across alternatives considered for the development of the Draft 2022 Scoping Plan Update

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[11] CARB. MSEI - Modeling Tools. *https://ww2.arb.ca.gov/our-work/programs/mobile-source-emissions-inventory/msei-modeling-tools*.

[12] U.S EPA. AP-42: Compilation of Air Emissions Factors. *https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emissions-factors*.

[13] South Coast AQMD. South Coast AQMD Rule Book. *https://www.aqmd.gov/home/rules-compliance/rules/scaqmd-rule-book*.

but are not precise estimates even though the values have several significant digits in their presentation

Table C-3: Estimated GHG and criteria pollutant emission reductions relative to the Reference Scenario for the Proposed Scenario in 2035/2045

Measure	GHG Reductions ($MMTCO_2$)	NOx Reductions (Short Tons/Year)	$PM_{2.5}$ Reductions (Short Tons/ Year)	ROG Reductions (Short Tons/Year)
Deploy ZEVs and reduce driving demand	-42 / -78	-49,458 / -119,882	-1,873 / -6,535	-16,576 / -29,246
Coordinate supply of liquid fossil fuels with declining California fuel demand	-26 / -32	-1,502 / -2,852	-617 / -1,504	-653 / -1,338
Generate clean electricity	N/A[a] / -6	-116 / -534	-95 / -440	-30 / -140
Decarbonize industrial energy supply	-7 / -16	-15,981 / -30,588	-848 / -2,234	-3,102 / -5,840
Decarbonize buildings	-14 / -29	-7,424 / -94,200	-686 / -6,903	-1,007 / -8,100
Reduce non-combustion emissions[b]	-0.40 / -0.52 ($MMTCH_4$)	N/A	N/A	N/A
Compensate for remaining emissions	-17 / -80	N/A	N/A	N/A

[a] SB100 does not lead to further GHG emissions reductions than the Reference Scenario until after 2035.

[b] Methane emissions reductions are reported for this measure.

Table C-4. Estimated GHG and criteria pollutant emission reductions relative to the Reference Scenario for Alternative 1 in 2035/2045

Measure	GHG Reductions (MMTCO2)	NOx Reductions (Short Tons/Year)	PM2.5 Reductions (Short Tons/Year)	ROG Reductions (Short Tons/Year)
Deploy ZEVs and reduce driving demand	-102 / -94	-161,242 / -161,171	-7,682 / -8,603	-44,694 / -37,419
Coordinate supply of liquid fossil fuels with declining CA fuel demand	-37 / -34	-4,063 / -3,640	-2,526 / -2,304	-1,932 / -1,756
Generate clean electricity	-15 / -15	-1,583 / -1,512	-1,304 / -1,245	-415 / -396
Decarbonize industrial energy supply	-25 / -25	-48,635 / -50,450	-3,967 / -4,201	-9,718 / -10,116
Decarbonize buildings	-50 / -46	-85,355 / -97,242	-6,572 / -7,337	-7,460 / -8,394
Reduce non-combustion emissions[a]	-0.52 / -0.70 ($MMTCH_4$)	N/A	N/A	N/A
Compensate for remaining emissions	-30 / -22	N/A	N/A	N/A

[a] Methane emissions reductions are reported for this measure.

Table C-5. Estimated GHG and criteria pollutant emission reductions relative to the Reference Scenario for Alternative 2 in 2035/2045

Measure	GHG Reductions (MMTCO2)	NOx Reductions (Short Tons/Year)	PM2.5 Reductions (Short Tons/Year)	ROG Reductions (Short Tons/Year)
Deploy ZEVs and reduce driving demand	-61 / -83	-82,877 / -144,959	-3,997 / -8,005	-23,955 / -33,683
Coordinate supply of liquid fossil fuels with declining CA fuel demand	-29 / -32	-2,329 / -2,786	-1,198 / -1,531	-1,011 / -1,394
Generate clean electricity	-8 / -8	-849 / -884	-699 / -728	-222 / -232
Decarbonize industrial energy supply	-13 / -17	-31,282 / -33,044	-2,562 / -2,640	-6,353 / -6,713
Decarbonize buildings	-23 / -24	-73,361 / -94,112	-5,358 / -6,829	-6,398 / -8,077
Reduce non-combustion emissions[a]	-0.54 / -0.71 ($MMTCH_4$)	N/A	N/A	N/A
Compensate for remaining emissions	-123 / -60	N/A	N/A	N/A

[a] Methane emissions reductions are reported for this measure.

Table C-6. Estimated GHG and criteria pollutant emission reductions relative to the Reference Scenario for Alternative 4 in 2035/2045

Measure	GHG Reductions (MMTCO2)	NOx Reductions (Short Tons/Year)	PM2.5 Reductions (Short Tons/Year)	ROG Reductions (Short Tons/Year)
Deploy ZEVs and reduce driving demand	-32 / -67	-38,514 / -99,350	-1,490 / -5,313	-12,603 / -25,088
Coordinate supply of liquid fossil fuels with declining CA fuel demand	-24 / -29	-1,285 / -2,344	-489 / -1,246	-515 / -1,090
Generate clean electricity	N/A[a] / -8	-73 / -408	-60 / -336	-19 / -107
Decarbonize industrial energy supply	-6 / -12	-8,289 / -16,970	-370 / -841	-1,694 / -3,293
Decarbonize buildings	-13 / -28	-7,054 / -93,952	-644 / -6,894	-970 / -8,084
Reduce non-combustion emissions[b]	-0.37 / -0.43 ($MMTCH_4$)	N/A	N/A	N/A
Compensate for remaining emissions	-23 / -99	N/A	N/A	N/A

[a] SB100 does not lead to further GHG emissions reductions than the Reference Scenario until after 2035

[b] Methane emissions reductions are reported for this measure.

CARB used the same approach to estimate health endpoints for the alternatives as that described in Chapter 3. In the absence of having direct modeling results for criteria pollutant estimates from PATHWAYS, CARB used the criteria pollutant emissions in Table C-3, Table C-4, Table C-5, and Table C-6 to understand potential health impacts. Similarly, to the air quality estimates, this information should be used to understand the relative health benefits of the various measures and should not be taken as absolute estimates of health outcomes. CARB used the incidence-per-ton (IPT) methodology to quantify the health benefits of emission reductions.

For the analysis underlying the information presented in this Appendix, CARB calculated the health benefits associated with the five key measures that are represented by changes to fuel combustion. The health benefits associated with emission reductions for each alternative were estimated for each air basin and then aggregated for the entire state of California. CARB assumed that the statewide emission reductions distribution among the air basins is proportional to the baseline emissions in that air basin.

Calculated health endpoints include premature mortality, cardiovascular emergency department (ED) visits, acute myocardial infarction, respiratory ED visits, lung cancer incidence, asthma onset, asthma symptoms, work loss days, hospitalizations due to cardiopulmonary illnesses, hospitalizations due to respiratory illnesses, hospital admissions for Alzheimer's disease, and hospital admissions for Parkinson's disease.[14, 15, 16] Table C-7, Table C-8, Table C-9, and Table C-10 compare the health benefits of emission reductions associated with each measure for the Proposed Scenario, Alternatives 1, 2, and 4 in the year specified (2035 or 2045).

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[14] CARB. CARB’s Methodology. *https://ww2.arb.ca.gov/resources/documents/carbs-methodology-estimating-health-effects-air-pollution*.

[15] CARB. 2022. Updated Health Endpoints in CARB’s Health Benefits Methodology. *Evaluating New Health Endpoints for Use in CARB’s Health Analyses*.

[16] Cardio-pulmonary mortality, hospitalizations due to cardiopulmonary illnesses and hospital admissions due to respiratory illnesses endpoints utilize studies documented in CARB’s methodology document. For future assessments, CARB will use more recent studies to estimate cardiovascular hospital admissions and respiratory hospital admissions, as documented in CARB's updated health endpoints memo.

Table C-7: Estimated avoided incidence of mortality, cardiovascular and respiratory disease onset, work loss days and hospital admissions relative to the Reference Scenario for the Proposed Scenario

Measure	Mortality	Cardiovascular ED Visits	Acute Myocardial Infarction	Respiratory ED Visits	Lung Cancer Incidence	Asthma Onset	Asthma Symptoms	Work Loss Days	Hospital Admissions, Cardiovascular	Hospital Admissions, Respiratory	Hospital Admissions, Alzheimer's Disease	Hospital Admissions, Parkinson's disease
Deploy ZEVs and reduce driving demand in 2035	600	160	65	380	45	1,400	122,460	87,870	95	110	235	40
Deploy ZEVs and reduce driving demand in 2045	1,800	470	195	1,100	130	3,945	338,845	252,630	290	345	735	125
Coordinate supply of liquid fossil fuels with declining CA fuel demand in 2035	75	20	10	50	5	185	15,655	11,230	10	15	30	5
Coordinate supply of liquid fossil fuels with declining CA fuel demand in 2045	195	50	20	120	15	440	36,825	27,435	30	35	85	15

Generate clean electricity in 2035	10	5	-	5	-	25	2,225	1,595	-	-	5	-
Generate clean electricity in 2045	55	15	5	35	5	125	10,265	7,650	10	10	25	5
Decarbonize industrial energy supply in 2035	220	60	25	140	15	515	44,740	32,100	35	40	85	15
Decarbonize industrial energy supply in 2045	525	135	55	320	40	1,150	98,550	73,465	85	100	215	35
Decarbonize buildings in 2035	135	35	15	85	10	310	27,010	19,380	20	25	55	10
Decarbonize buildings in 2045	1,610	420	175	985	120	3,555	303,960	226,595	260	310	665	115
Note: All values are rounded to the nearest 0 or 5.												

Table C-8. Estimated avoided incidence of mortality, cardiovascular and respiratory disease onset, work loss days and hospital admissions relative to the Reference Scenario for Alternative 1

Measure	Mortality	Cardiovascular ED Visits	Acute Myocardial Infarction	Respiratory ED Visits	Lung Cancer Incidence	Asthma Onset	Asthma Symptoms	Work Loss Days	Hospital Admissions, Cardiovascular	Hospital Admissions, Respiratory	Hospital Admissions, Alzheimer's Disease	Hospital Admissions, Parkinson's disease
Deploy ZEVs and reduce driving demand in 2035	2,125	570	235	1,340	155	4,955	432,810	310,550	325	390	830	140
Deploy ZEVs and reduce driving demand in 2045	2,395	625	260	1,470	175	5,260	451,665	336,745	385	460	980	170
Coordinate supply of liquid fossil fuels with declining CA fuel demand in 2035	295	80	35	185	20	715	60,625	43,485	45	55	125	20
Coordinate supply of liquid fossil fuels with declining CA fuel demand in 2045	290	75	30	180	20	660	55,195	41,125	45	55	130	20
Generate clean electricity in 2035	150	40	15	95	10	360	30,440	21,835	25	25	65	10

Measure	Mortality	Cardiovascular ED Visits	Acute Myocardial Infarction	Respiratory ED Visits	Lung Cancer Incidence	Asthma Onset	Asthma Symptoms	Work Loss Days	Hospital Admissions, Cardiovascular	Hospital Admissions, Respiratory	Hospital Admissions, Alzheimer's Disease	Hospital Admissions, Parkinson's disease
Generate clean electricity in 2045	155	40	15	95	10	350	29,075	21,660	25	30	70	10
Decarbonize industrial energy supply in 2035	815	220	90	515	60	1,910	165,715	118,895	125	150	325	55
Decarbonize industrial energy supply in 2045	920	240	100	565	70	2,030	173,555	129,375	150	175	385	65
Decarbonize buildings in 2035	1,385	370	155	875	100	3,255	282,520	202,700	215	255	550	95
Decarbonize buildings in 2045	1,690	440	185	1,035	125	3,720	318,285	237,275	270	325	700	120
Note: All values are rounded to the nearest 0 or 5												

Table C-9. Estimated avoided incidence of mortality, cardiovascular and respiratory disease onset, work loss days and hospital admissions relative to the Reference Scenario for Alternative 2

Measure	Mortality	Cardiovascular ED Visits	Acute Myocardial Infarction	Respiratory ED Visits	Lung Cancer Incidence	Asthma Onset	Asthma Symptoms	Work Loss Days	Hospital Admissions, Cardiovascular	Hospital Admissions, Respiratory	Hospital Admissions, Alzheimer's Disease	Hospital Admissions, Parkinson's disease
Deploy ZEVs and reduce driving demand in 2035	1,100	295	120	695	80	2,560	223,495	160,360	170	200	430	75
Deploy ZEVs and reduce driving demand in 2045	2,185	570	240	1,340	160	4,800	411,940	307,125	350	420	895	155
Coordinate supply of liquid fossil fuels with declining CA fuel demand in 2035	145	40	15	90	10	345	29,425	21,105	20	25	60	10
Coordinate supply of liquid fossil fuels with declining CA fuel demand in 2045	195	50	20	120	15	445	37,280	27,775	30	40	85	15
Generate clean electricity in 2035	80	20	10	50	5	190	16,315	11,705	10	15	35	5

Measure	Mortality	Cardiovascular ED Visits	Acute Myocardial Infarction	Respiratory ED Visits	Lung Cancer Incidence	Asthma Onset	Asthma Symptoms	Work Loss Days	Hospital Admissions, Cardiovascular	Hospital Admissions, Respiratory	Hospital Admissions, Alzheimer's Disease	Hospital Admissions, Parkinson's disease
Generate clean electricity in 2045	90	25	10	55	5	205	17,005	12,670	15	15	40	5
Decarbonize industrial energy supply in 2035	525	140	60	330	40	1,230	106,815	76,635	80	95	210	35
Decarbonize industrial energy supply in 2045	590	155	65	360	45	1,300	111,290	82,965	95	115	245	40
Decarbonize buildings in 2035	1,160	310	130	730	85	2,725	236,635	169,780	180	215	460	80
Decarbonize buildings in 2045	1,605	420	175	980	120	3,535	302,255	225,325	255	305	665	115
Note: All values are rounded to the nearest 0 or 5												

Table C-10. Estimated avoided incidence of mortality, cardiovascular and respiratory disease onset, work loss days and hospital admissions relative to the Reference Scenario for Alternative 4

Measure	Mortality	Cardiovascular ED Visits	Acute Myocardial Infarction	Respiratory ED Visits	Lung Cancer Incidence	Asthma Onset	Asthma Symptoms	Work Loss Days	Hospital Admissions, Cardiovascular	Hospital Admissions, Respiratory	Hospital Admissions, Alzheimer's Disease	Hospital Admissions, Parkinson's disease
Deploy ZEVs and reduce driving demand in 2035	470	125	50	300	35	1,095	96,025	68,900	75	85	185	30
Deploy ZEVs and reduce driving demand in 2045	1,480	385	160	905	110	3,245	278,620	207,730	240	285	605	105
Coordinate supply of liquid fossil fuels with declining CA fuel demand in 2035	60	15	5	40	5	145	12,565	9,015	10	10	25	5
Coordinate supply of liquid fossil fuels with declining CA fuel demand in 2045	160	40	20	100	10	365	30,480	22,710	25	30	70	10
Generate clean electricity in 2035	5	-	-	5	-	15	1,400	1,005	-	-	5	-

Measure	Mortality	Cardiovascular ED Visits	Acute Myocardial Infarction	Respiratory ED Visits	Lung Cancer Incidence	Asthma Onset	Asthma Symptoms	Work Loss Days	Hospital Admissions, Cardiovascular	Hospital Admissions, Respiratory	Hospital Admissions, Alzheimer's Disease	Hospital Admissions, Parkinson's disease
Generate clean electricity in 2045	40	10	5	25	5	95	7,840	5,840	5	10	20	5
Decarbonize industrial energy supply in 2035	105	30	10	65	10	250	21,720	15,585	15	20	40	5
Decarbonize industrial energy supply in 2045	245	65	25	150	20	535	46,180	34,430	40	45	100	15
Decarbonize buildings in 2035	125	35	15	80	10	295	25,505	18,300	20	25	50	10
Decarbonize buildings in 2045	1,610	420	175	985	120	3,545	303,360	226,150	260	310	665	115
Note: All values are rounded to the nearest 0 or 5												

Emissions Reductions and Health Analysis for NWL Measures

As described in Chapter 3, the NWL ecosystem carbon stock changes projected through mid-century by the suite of models were used to estimate net emissions or emissions reductions relative to the Reference Scenario. These changes in carbon stocks were impacted by projected climate change, the implementation of management actions under the various scenarios, land conversion, and for forests, shrublands, and grasslands, wildfire. PM2.5 wildfire emissions were evaluated for forests, shrublands, and grasslands only. Additional modeling details are included in Appendix I (NWL Technical Support Document). Each NWL type was evaluated under all alternatives and the results for the Proposed Scenario and Alternatives 1, 2, and 4 are provided in Table C-11, Table C-12, Table C-13, and Table C-14.

Table C-11: Estimated average annual GHG and criteria pollutant emission reductions relative to the Reference Scenario for the Proposed Scenario from 2025–2045

Measure	GHG Reductions ($MMTCO_2e$/year)	$PM_{2.5}$ Reductions (MT/Year)
Forests/Shrublands/Grasslands	-0.12	-17,500
Annual Croplands	-0.23	N/A
Perennial Croplands	-0.01	N/A
Urban Forest	-0.52	N/A
Wildland Urban Interface (WUI)	0.75	N/A
Wetlands	-0.43	N/A
Sparsely Vegetated Lands	<-0.01	N/A

Table C-12. Estimated average annual GHG and criteria pollutant emission reductions relative to the Reference Scenario for Alternative 1 from 2025–2045

Measure	GHG Reductions (MMTCO2e/year)	PM2.5 Reductions (MT/Year)
Forests/Shrublands/Grasslands	2.28	2,800
Annual Croplands	-0.46	N/A
Perennial Croplands	-0.02	N/A
Urban Forest	-6.19	N/A
Wildland Urban Interface	0.75	N/A
Wetlands	-0.70	N/A
Sparsely Vegetated Lands	0.00	N/A

Table C-13. Estimated average annual GHG and criteria pollutant emission reductions relative to the Reference Scenario for Alternative 2 from 2025–2045

Measure	GHG Reductions (MMTCO2e/year)	PM2.5 Reductions (MT/Year)
Forests/Shrublands/Grasslands	3.10	-4,500
Annual Croplands	-0.34	N/A
Perennial Croplands	-0.01	N/A
Urban Forest	-1.29	N/A
Wildland Urban Interface	0.75	N/A
Wetlands	-0.05	N/A
Sparsely Vegetated Lands	0.00	N/A

Table C-14. Estimated average annual GHG and criteria pollutant emission reductions relative to the Reference Scenario for Alternative 4 from 2025–2045

Measure	GHG Reductions (MMTCO2e/year)	PM2.5 Reductions (MT/Year)
Forests/Shrublands/Grasslands	3.90	-39,200
Annual Croplands	-0.11	N/A
Perennial Croplands	0.00	N/A
Urban Forest	-0.25	N/A
Wildland Urban Interface	0.95	N/A
Wetlands	-0.05	N/A
Sparsely Vegetated Lands	0.00	N/A

As described in Chapter 3, the NWL health benefit estimate analysis was focused on increases or decreases to particulate matter pollution (PM2.5) resulting from wildfire emissions on forests, shrublands, and grasslands. CARB used the PM2.5 emissions in Table C-11, Table C-12, Table C-13, and Table C-14 to understand potential health impacts for each alternative. This information should be used to understand the relative health endpoints of the various measures and should not be taken as absolute estimates of health outcomes of the Scoping Plan statewide, or within a specific community. Nor should the number of significant digits imply precision. The IPT methodology was used to calculate health endpoints, similar to the AB 32 GHG Inventory Sector analysis. CARB calculated the annual health endpoints associated with the wildfire emissions changes resulting from the implementation of management strategies on forests, shrublands, and grasslands under each alternative. The annual health endpoints associated with emission reductions for the alternatives were estimated for the entire state of California. Calculated health endpoints include emissions caused mortality, hospital admittance and emergency room visits from asthma, hospital admittance from chronic obstructive pulmonary disease, and emergency room visits from respiratory and cardiovascular outcomes. Table C-15 provides the average annual health endpoints of wildfire emission reductions associated with Alternatives 1, 2, 4, and the Proposed Scenario over the period 2025-2045. Additional health benefit analysis details are included in Appendix I (NWL Technical Support Document).

Table C-15. Estimated average annual avoided incidence of hospital admissions, emergency room visits, and mortality relative to the Reference Scenario for NWL Alternative 1, NWL Alternative 2, NWL Alternative 4, and the Proposed Scenario resulting from forest, shrubland, and grassland wildfire emissions

Health Endpoint from Forest, Shrubland, and Grassland Wildfire Emissions	NWL Alternative 1 Average Annual Avoided Incidence [a]	NWL Alternative 2 Average Annual Avoided Incidence	NWL Alternative 4 Average Annual Avoided Incidence	Proposed Scenario Average Annual Avoided Incidence
Hospital admissions from asthma	-3	6	49	22
Hospital admissions from chronic obstructive pulmonary disease without asthma	-3	5	44	20
Hospital admissions from all respiratory outcomes	-10	16	141	63
Emergency room visits from asthma	-25	40	348	155
Emergency room visits from all respiratory outcomes	-67	109	942	419
Emergency room visits from all cardiovascular outcomes	-25	41	351	157
All cause mortality	-63	102	886	395

[a] Negative values indicate an increase incidence of hospital admissions, emergency room visits, and mortality relative to the Reference Scenario.

Estimated Social Cost

This section describes the assumptions and calculations employed to estimate the social cost of greenhouse gases (SC-GHG) – specifically the social cost of carbon (SC-CO_2) and social cost of methane (SC-CH_4), for the Proposed Scenario and the measures within the Proposed Scenario, as well as the alternative scenarios (Alternatives 1, 2, and 4). Only SC-CO_2 is included for the NWL social cost estimates.

Background and Recent Social Cost Activity at the Federal Level

In 2008, federal agencies began incorporating SC-CO_2 estimates into the analysis of their regulatory actions. In 2009, under the Obama Administration, an interagency working group (IWG) was established to ensure agencies were using the best available science and to promote consistency in the values used. The IWG published SC-CO_2 estimates in 2010 developed from three highly-cited integrated assessment models (IAM) that estimate global climate damages using representations of climate processes and the global economy combined into a single modeling framework. These estimates were updated in 2013 based on new versions of each IAM, with a subsequent July 2015 revision.[17] In August 2016, the IWG published estimates of the SC-CH_4 and social cost of nitrous oxide (SC-N_2O) using methodologies consistent with the methodology underlying the SC-CO_2 estimates.[18] In January 2017, the National Academies of Sciences, Engineering, and Medicine (National Academies) issued recommendations for an updating process to ensure the estimates continue to reflect the best available science. However, in March 2017, the Trump Administration issued Executive Order 13783, disbanding the IWG and instructing federal agencies to follow the Office of Management and Budget's Circular A-4 when monetizing the value of changes in GHG emissions resulting from regulations, which resulted in substantially reduced social cost figures.

On January 20, 2021, President Biden issued Executive Order 13990, which re-established the IWG and directed it to ensure that SC-GHG estimates used by the U.S. government reflect the best available science and the recommendations of the National Academies (2017), and work towards approaches that take account of climate risk, environmental justice,

[17] *"Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866" (archives.gov)*

[18] *Addendum to Technical Support Document on Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866: Application of the Methodology to Estimate the Social Cost of Methane and the Social Cost of Nitrous Oxide (archives.gov)*

and intergenerational equity.[19] The IWG was tasked with first reviewing the SC-GHG estimates currently used by the U.S. government and publishing interim estimates. While the IWG works to assess how best to incorporate the latest, peer reviewed science to develop an updated set of SC-GHG estimates, it set interim estimates to be the most recent estimates developed by the IWG prior to the group being disbanded in 2017. The IWG concluded that these interim estimates represent the most appropriate estimate of the SC-GHG until the revised estimates are developed. The interim estimates are reported in a February 2021 IWG Technical Support Document (TSD) in 2020 dollars at 2.5, 3, and 5 percent discount rates.[20] The 2020 dollar values in the 2021 IWG TSD are otherwise identical to those presented in the prior version of the TSD and its Addendum, adjusted using a national implicit GDP deflator.

The interim SC-GHG values are currently the subject of legal proceedings. In February 2022, a Louisiana federal judge granted a motion that blocked the Biden Administration from using the interim values. However, in March 2022, a U.S. Circuit Court of Appeals stayed the lower court's injunction, reinstating the SC-GHG metric used to measure the climate impacts of rulemakings.[21] This means federal policy makers can continue to use the IWG's SC-GHG estimates, while the underlying legal proceedings continue.[22]

Social Cost Values

Based on the IWG's SC-GHG estimates, CARB staff used the SC-CO_2 and SC-CH_4 values in Table C-16 and Table C-17 to estimate social costs in the Draft 2022 Scoping Plan Update. These values are consistent with the 2021 IWG TSD's interim numbers but utilize a different inflation adjustment methodology.

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[19] Protecting Public Health and the Environment and Restoring Science to Tackle the Climate Crisis, Executive Order 13990 (Jan. 20, 2021), 86 Fed. Reg. 7037 (Jan. 25, 2021). *https://www.energy.gov/sites/default/files/2021/02/f83/eo-13990-protecting-public-health-environment-restoring.pdf*. IWG, Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates Under Executive Order 13990 (February 2021), *https://www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf.* See also, The White House. 2021. A Return to Science: Evidence-Based Estimates of the Benefits of Reducing Climate Pollution. *https://www.whitehouse.gov/cea/written-materials/2021/02/26/a-return-to-science-evidence-based-estimates-of-the-benefits-of-reducing-climate-pollution/*.

[20] U.S. Government. Interagency Working Group on Social Cost of Greenhouse Gases. February 2021. Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide – Interim Estimates under Executive Order 13990. *https://www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf*

[21] *Louisiana v. Biden* (W.D. La. 2022) 585 F.Supp.3d 840, stayed pending review (5th Cir. Mar. 16, 2022) 2022 WL 866282.

[22] A separate federal appeals court upheld the Biden administration's use of the IWG SC-GHG estimates in October 2022. *Missouri v. Biden* (8th Cir. 2022) ____ F.4th ____.

Social cost values are year-specific; the integrated assessment models estimate the environmental damages from a given year in the future and discount the value of the damages back to the present. For example, the SC-CO_2 for the year 2045 represents the value of climate change damages from a release of CO_2 in 2045 discounted back to today. The SC-GHG increases over time as systems become stressed from the aggregate impacts of climate change and future emissions cause incrementally larger damages. The SC-GHG is highly sensitive to the discount rate. Higher discount rates decrease the value today of future environmental damages; as such, the value today of environmental damages in 2045 is higher under the 2.5 percent discount rate compared to the 3 or 5 percent discount rate, reflecting the trade-off of consumption today and future damages.

Table C-16. Social Cost of CO_2, 2020-2050 (in 2021$ per metric ton CO_2)[a]

Year	5% Discount Rate	3% Discount Rate	2.5% Discount Rate
2020	$16	$57	$85
2025	$19	$63	$93
2030	$22	$68	$100
2035	$25	$75	$107
2040	$29	$82	$115
2045	$31	$88	$122
2050	$36	$94	$130

[a] CARB staff has been using the IWG July 2015 revision TSD 2007-dollar values and updating them for inflation using California's Consumer Price Index for All Urban Consumers (CPI-U).

Table C-17. Social Cost of CH_4, 2020-2050 (in 2021$ per metric ton CH_4)[a]

Year	5% Discount Rate	3% Discount Rate	2.5% Discount Rate
2020	$739	$1,641	$2,188
2025	$889	$1,915	$2,462
2030	$1,039	$2,188	$2,735
2035	$1,231	$2,462	$3,146
2040	$1,368	$2,735	$3,556
2045	$1,641	$3,146	$3,830
2050	$1,778	$3,419	$4,240

[a] CARB staff has been using the IWG August 2016 TSD 2007-dollar values and updating them for inflation using California's Consumer Price Index for All Urban Consumers (CPI-U).

Social Costs for AB 32 GHG Inventory Sector Measures

The estimated social cost of each scenario or measure is calculated by multiplying the IWG SC-CO_2 and SC-CH_4 values in Table C-16 and Table C-17 by the CO_2 and CH_4 emissions reductions in Table C-3, Table C-4, Table C-5, and Table C-6. For example, to calculate the social cost for the AB 32 GHG Inventory Sector Alternative 1 measure in 2035: deploy ZEVs and reduce driving demand:

102 $MMTCO_2e$ x 10^6 $MTCO_2e/MMTCO_2e$ x \$25/$MTCO_2$ = \$2,505,305,215 (\$2.5 billion)

The estimated social costs for the Proposed Scenario and Alternatives 1, 2, and 4 – by measure and by scenario – are summarized in Table C-18, Table C-19, Table C-20, and Table C-21 at the 5 percent and 2.5 percent discount rates, which represent bookend values.

Table C-18: Estimated social cost (avoided economic damages) of measures considered in the Proposed Scenario

Measure	Social Cost of Carbon in 2035, 5%–2.5% discount rate billion USD (2021 dollars)	Social Cost of Carbon in 2045, 5%–2.5% discount rate billion USD (2021 dollars)
Deploy ZEVs and reduce driving demand	1.03–4.50	2.46–9.53
Coordinate supply of liquid fossil fuels with declining California fuel demand	0.64–2.78	0.99–3.84
Generate clean electricity	N/A[a]	0.20–0.79
Decarbonize industrial energy supply	0.18–0.78	0.49–1.89
Decarbonize buildings	0.35–1.50	0.91–3.52
Reduce non-combustion emissions	0.49–1.26 (SC-CH_4)	0.85–1.98 (SC-CH_4)
Compensate for remaining emissions	0.41–1.76	2.50–9.68
Proposed Scenario SC-CO_2 Proposed Scenario SC-CH_4 Proposed Scenario (Total)[c]	2.2–9.7 0.49–1.3 2.7–11.0	4.9-19.1[b] 0.85–2.0 5.8-21.1

[a] SB100 does not lead to further GHG emissions reductions than the Reference Scenario until after 2035.

[b] CARB staff discovered a post-processing spreadsheet error that affected the total Reference Scenario CO_2 emissions in 2045. The corrected values from the Draft 2022 Scoping Plan Update are shown here.

[c] CARB staff could not precisely separate some CO_2 and CH_4 from other GHGs from PATHWAYS outputs, but the contribution is believed to be small for purposes of calculating the social cost of carbon. The approach used to estimate GHG emissions reductions for individual measures in PATHWAYS does not reflect cross-sector interactions. Therefore, the GHG values for each measure do not sum to the overall scenario total. The total GHG emissions reduction used in this calculation is 91 $MMTCO_2e$ in 2035 and 157 $MMTCO_2e$ in 2045.

Table C-19. Estimated social cost (avoided economic damages) of measures considered in Alternative 1

Measure	Social Cost of Carbon in 2035, 5% - 2.5% discount rate billion USD (2021 dollars)	Social Cost of Carbon in 2045, 5% - 2.5% discount rate billion USD (2021 dollars)
Deploy ZEVs and reduce driving demand	2.5-10.9	3.0-11.5
Coordinate supply of liquid fossil fuels with declining CA fuel demand	0.9-3.9	1.1-4.1
Generate clean electricity	0.4-1.6	0.5-1.8
Decarbonize industrial energy supply	0.6-2.6	0.8-3.1
Decarbonize buildings	1.2-5.4	1.4-5.6
Reduce non-combustion emissions	0.6-1.6 (SC-CH_4)	1.1-2.7 (SC-CH_4)
Compensate for remaining emissions	0.7-3.2	0.7-2.6
Alternative 1 SC-CO_2 Alternative 1 SC-CH_4 Alternative 1 (Total)[b]	5.3-23.2 0.6-1.6 5.9-24.8	6.4-24.8[a] 1.1-2.7 7.5-27.5

Note: All values are rounded to the nearest 0 or 5.

[a] CARB staff discovered a post-processing spreadsheet error that affected the total Reference Scenario CO_2 emissions in 2045. The corrected values from the Draft 2022 Scoping Plan Update are shown here.

[b] CARB staff could not precisely separate some CO_2 and CH_4 from other GHGs from PATHWAYS outputs, but the contribution is believed to be small for purposes of calculating the social cost of carbon. The approach used to estimate GHG emissions reductions for individual measures in PATHWAYS does not reflect cross-sector interactions. Therefore, the GHG values for each measure do not sum to the overall scenario total. The total GHG emissions reduction used in this calculation is 217 $MMTCO_2e$ in 2035 and 204 $MMTCO_2e$ in 2045.

Table C-20. Estimated social cost (avoided economic damages) of measures considered in Alternative 2

Measure	Social Cost of Carbon in 2035, 5% - 2.5% discount rate billion USD (2021 dollars)	Social Cost of Carbon in 2045, 5% - 2.5% discount rate billion USD (2021 dollars)
Deploy ZEVs and reduce driving demand	1.5-6.6	2.6-10.1
Coordinate supply of liquid fossil fuels with declining CA fuel demand	0.7-3.1	1.0-3.9
Generate clean electricity	0.2-0.9	0.3-1.0
Decarbonize industrial energy supply	0.3-1.4	0.5-2.1
Decarbonize buildings	0.6-2.4	1.0-3.8
Reduce non-combustion emissions	0.7-1.7 (SC-CH_4)	1.2-2.7 (SC-CH_4)
Compensate for remaining emissions	3.0-13.1	1.9-7.3
Alternative 2 SC-CO_2 Alternative 2 SC-CH_4 Alternative 2 (Total)[b]	3.2-13.7 0.7-1.7 3.9-15.4	5.2-20.3[a] 1.2-2.7 6.4-23.0

Note: All values are rounded to the nearest 0 or 5.

[a] CARB staff discovered a post-processing spreadsheet error that affected the total Reference Scenario CO_2 emissions in 2045. The corrected values from the Draft 2022 Scoping Plan Update are shown here.

[b] CARB staff could not precisely separate some CO_2 and CH_4 from other GHGs from PATHWAYS outputs, but the contribution is believed to be small for purposes of calculating the social cost of carbon. The approach used to estimate GHG emissions reductions for individual measures in PATHWAYS does not reflect cross-sector interactions. Therefore, the GHG values for each measure do not sum to the overall scenario total. The total GHG emissions reduction used in this calculation is 129 $MMTCO_2e$ in 2035 and 166 $MMTCO_2e$ in 2045.

Table C-21. Estimated social cost (avoided economic damages) of measures considered in Alternative 4

Measure	Social Cost of Carbon in 2035, 5% - 2.5% discount rate billion USD (2021 dollars)	Social Cost of Carbon in 2045, 5% - 2.5% discount rate billion USD (2021 dollars)
Deploy ZEVs and reduce driving demand	0.8-3.5	2.1-8.2
Coordinate supply of liquid fossil fuels with declining CA fuel demand	0.6-2.6	0.9-3.5
Generate clean electricity	N/A[a]	0.2-1.0
Decarbonize industrial energy supply	0.2-0.7	0.4-1.5
Decarbonize buildings	0.3-1.4	0.9-3.4
Reduce non-combustion emissions	0.5-1.2 (SC-CH_4)	0.7-1.7 (SC-CH_4)
Compensate for remaining emissions	0.6-2.5	3.1-12.1
Alternative 4 SC-CO_2 Alternative 4 SC-CH_4 Alternative 4 (Total)[c]	1.9-8.2 0.5-1.2 2.4-9.4	4.4-16.9[b] 0.7-1.7 5.1-18.6

Note: All values are rounded to the nearest 0 or 5.

[a] SB100 does not lead to further GHG emissions reductions than the Reference Scenario until after 2035

[b] CARB staff discovered a post-processing spreadsheet error that affected the total Reference Scenario CO_2 emissions in 2045. The corrected values from the Draft 2022 Scoping Plan Update are shown here.

[c] CARB staff could not precisely separate some CO_2 and CH_4 from other GHGs from PATHWAYS outputs, but the contribution is believed to be small for purposes of calculating the social cost of carbon. The approach used to estimate GHG emissions reductions for individual measures in PATHWAYS does not reflect cross-sector interactions. Therefore, the GHG values for each measure do not sum to the overall scenario total. The total GHG emissions reduction used in this calculation is 77 $MMTCO_2e$ in 2035 and 139 $MMTCO_2e$ in 2045.

Social Costs for NWL Measures

The estimated social cost of each NWL scenario or measure is calculated using the same approach as for the AB 32 GHG Inventory Sectors. The IWG SC-CO_2 and SC-CH_4 values in Table C-13 are multiplied by the CO_2 emissions reductions in Table C-11, Table C-12, Table C-13, and Table C-14.

The estimated social costs for the Proposed Scenario and Alternatives 1, 2, and 4 – by measure and by scenario – are summarized in Table C-22, Table C-23, Table C-24, and Table C-25 at the 5 percent and 2.5 percent discount rates, which represent bookend values.

Table C-22: Estimated social cost (avoided economic damages) of measures considered in the Proposed Scenario

Measure	Social Cost of Carbon in 2035, 5%–2.5% discount rate Billion USD (2021 dollars)	Social Cost of Carbon in 2045, 5%–2.5% discount rate Billion USD (2021 dollars)
Forests/Shrublands/Grasslands	0.003–0.012	0.004–0.014
Annual Croplands	0.006–0.025	0.007–0.028
Perennial Croplands	<0.001–0.001	0.000–0.001
Urban Forest	0.012–0.055	0.016–0.063
Wildland Urban Interface (WUI)	(0.018) – (0.080)	(0.023) – (0.091)
Wetlands	0.011–0.046	0.014–0.053
Sparsely Vegetated Lands	<0.001	<0.001

Table C-23. Estimated social cost (avoided economic damages) of measures considered in NWL Alternative 1

Measure	Social Cost of Carbon in 2035, 5% - 2.5% discount rate Billion USD (2021 dollars)	Social Cost of Carbon in 2045, 5% - 2.5% discount rate Billion USD (2021 dollars)
Forests/Shrublands/Grasslands	(0.056) – (0.243)	(0.072) – (0.278)
Annual Croplands	0.011 - 0.049	0.014 - 0.056
Perennial Croplands	0 - 0.002	0.001 - 0.002
Urban Forest	0.017 - 0.661	0.195 - 0.754
Wildland Urban Interface	(0.018) – (0.080)	(0.023) – (0.091)
Wetlands	0.017 - 0.075	0.022 - 0.086
Sparsely Vegetated Lands	<0.001	<0.001

Table C-24. Estimated social cost (avoided economic damages) of measures considered in NWL Alternative 2

Measure	Social Cost of Carbon in 2035, 5% - 2.5% discount rate Billion USD (2021 dollars)	Social Cost of Carbon in 2045, 5% - 2.5% discount rate Billion USD (2021 dollars)
Forests/Shrublands/Grasslands	(0.076) – (0.331)	(0.098) – (0.378)
Annual Croplands	0.008 - 0.037	0.011 - 0.042
Perennial Croplands	0 - 0.002	0 - 0.002
Urban Forest	0.032 - 0.138	0.041 - 0.157
Wildland Urban Interface	(0.018) – (0.080)	(0.023) – (0.091)
Wetlands	0.001 - 0.005	0.001 - 0.006
Sparsely Vegetated Lands	<0.001	<0.001

Table C-25. Estimated social cost (avoided economic damages) of measures considered in NWL Alternative 4

Measure	Social Cost of Carbon in 2035, 5% - 2.5% discount rate Billion USD (2021 dollars)	Social Cost of Carbon in 2045, 5% - 2.5% discount rate Billion USD (2021 dollars)
Forests/Shrublands/Grasslands	(0.096) – (0.416)	(0.123) – (0.475)
Annual Croplands	0.003 - 0.012	0.004 - 0.014
Perennial Croplands	0 - 0	0 - 0
Urban Forest	0.006 - 0.027	0.008 - 0.031
Wildland Urban Interface	(0.023) – (0.101)	(0.030) – (0.115)
Wetlands	0.001 - 0.005	0.001 - 0.006
Sparsely Vegetated Lands	<0.001	<0.001

Estimated Cost per Metric Ton of Evaluated Measures

Cost per Metric Ton for AB 32 GHG Inventory Sector Measures

As described in Chapter 3, the cost per metric ton for the AB 32 GHG Inventory Sectors is computed for each measure independently relative to the Reference Scenario using the sensitivity model runs in PATHWAYS. The difference in the annualized cost between the Proposed Scenario and the Reference Scenario is computed for each measure in 2035 and in 2045. The incremental cost is divided by the incremental GHG emission impact to calculate the cost per metric ton in each year. To capture the fuel and GHG impacts of investments made from 2022 through 2035 or from 2022 through 2045, CARB computed an average annual cost per metric ton. The incremental cost in each year is averaged over the period. This value is divided by the corresponding annual, incremental GHG impact averaged over the same period. The cost per metric ton of a measure reflects the stock costs and any fuel or efficiency savings associated with a measure. Costs are reported as positive values and savings are reported as negative values. Table C-26, Table C-27, Table C-28, and Table C-29 show estimated cost per metric ton for measures considered in the Proposed Scenario and Alternatives 1, 2, and 4.

Table C-26: Estimated cost per metric ton of reduced CO2e relative to the Reference Scenario for measures considered in the Proposed Scenario

Measure	Annual Cost, 2035 ($/ton)	Average Annual Cost, 2022–2035 ($/ton)	Annual Cost, 2045 ($/ton)	Average Annual Cost, 2022–2045 ($/ton)
Deploy ZEVs and reduce driving demand	-157	-85	-121	-128
Coordinate supply of liquid fossil fuels with declining CA fuel demand	36	91	-38	38
Generate clean electricity[a]	N/A	N/A	450	497
Decarbonize industrial energy supply	290	240	429	356
Decarbonize buildings	595	754	463	598
Reduce non-combustion emissions	93	95	109	100
Compensate for remaining emissions	745	945	236	745

[a] SB100 does not lead to further reductions than the Reference Scenario until after 2035. NOTE: The denominator of this calculation (2045) does not include GHG reductions occurring outside of California resulting from SB 100. If these reductions were included, this number would be lower.

Table C-27. Estimated cost per metric ton of reduced CO_2e relative to the Reference Scenario for measures considered in Alternative 1

Measure	Annual Cost, 2035 ($/ton)	Average Annual Cost, 2022 – 2035 ($/ton)	Annual Cost, 2045 ($/ton)	Average Annual Cost, 2022 – 2045 ($/ton)
Deploy ZEVs and reduce driving demand	517	270	124	274
Coordinate supply of liquid fossil fuels with declining CA fuel demand	-67	-52	-68	-61
Generate clean electricity	975	323	839	607
Decarbonize industrial energy supply	519	601	518	550
Decarbonize buildings	764	714	554	665
Reduce non-combustion emissions	303	484	250	337
Compensate for remaining emissions	745	945	236	745

Table C-28. Estimated cost per metric ton of reduced CO_2e relative to the Reference Scenario for measures considered in Alternative 2

Measure	Annual Cost, 2035 ($/ton)	Average Annual Cost, 2022 – 2035 ($/ton)	Annual Cost, 2045 ($/ton)	Average Annual Cost, 2022 – 2045 ($/ton)
Deploy ZEVs and reduce driving demand	-60	-23	-34	-43
Coordinate supply of liquid fossil fuels with declining CA fuel demand	3	65	-50	15
Generate clean electricity	209	96	438	213
Decarbonize industrial energy supply	436	405	499	452
Decarbonize buildings	366	413	442	416
Reduce non-combustion emissions	290	265	226	263
Compensate for remaining emissions	745	945	236	745
[a] NOTE: denominator of this calculation (2045) does not include GHG reductions occurring outside of CA resulting from SB 100. If these reductions were included, this number would be lower.				

Table C-29. Estimated cost per metric ton of reduced CO_2e relative to the Reference Scenario for measures considered in Alternative 4

Measure	Annual Cost, 2035 ($/ton)	Average Annual Cost, 2022 – 2035 ($/ton)	Annual Cost, 2045 ($/ton)	Average Annual Cost, 2022 – 2045 ($/ton)
Deploy ZEVs and reduce driving demand	-172	-66	-123	-129
Coordinate supply of liquid fossil fuels with declining CA fuel demand	58	102	-18	54
Generate clean electricity[a]	N/A	N/A	450	497
Decarbonize industrial energy supply	198	155	288	233
Decarbonize buildings	593	757	448	585
Reduce non-combustion emissions	75	89	64	79
Compensate for remaining emissions	745	945	236	745

[a] SB100 does not lead to further reductions than BAU until after 2035; NOTE: denominator of this calculation (2045) does not include GHG reductions occurring outside of CA resulting from SB 100. If these reductions were included, this number would be lower.

Cost per Metric Ton for NWL Measures

As described in Chapter 3, the cost per metric ton for NWL measures is computed for each alternative relative to the Reference Scenario using the projected carbon stock/sequestration data from the NWL modeling and the direct cost estimates for each management action. Direct costs represent the cost of implementing a certain management action. The projected emissions reductions take into account the loss of carbon that results from the management action, e.g., fuels reduction treatments in forests, as well as climate change effects on growth. The direct cost for each NWL measure in Chapter 3, Table 3-1 was divided by the average annual emission reductions presented in Chapter 3, Table 3-6 to produce the cost per metric ton. The increasing effect of climate change on diminished future growth reduces the ability of the land to sequester or store carbon, driving up the cost per ton.

Table C-30 includes the average cost per metric ton estimates for the average annual CO_2e reductions from 2025 through 2045 for Alternatives 1, 2, 4 and the Proposed Scenario.

Table C-30. Estimated average cost per metric ton of reduced CO_2e relative to the Reference Scenario for measures considered in NWL Alternative 1, NWL Alternative 2, NWL Alternative 4, and the Proposed Scenario

Measure	NWL Alternative 1 Average Cost per Reduced Ton CO2e ($/Ton)	NWL Alternative 2 Average Cost per Reduced Ton CO2e ($/Ton)	NWL Alternative 4 Average Cost per Reduced Ton CO2e ($/Ton)	Proposed Scenario Average Cost per Reduced Ton CO2e ($/Ton)
Forests/Shrublands/Grasslands	N/A	N/A	N/A	15,500
Annual Croplands	1,209	1,209	1,209	1,209
Perennial Croplands	410	410	4,733	412
Urban Forest	12,963	3,267	336	1,637
Wildland Urban Interface	N/A	N/A	N/A	N/A
Wetlands	76	180	180	64
Sparsely Vegetated Lands	450,446	450,389	450,619	450,619