Appendix E
Economic Analysis

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Introduction

This 2017 Scoping Plan proposes actions to achieve the goals of SB 32, a 40 percent reduction in greenhouse gas (GHG) emissions compared to 1990 levels. Under the 2017 Scoping Plan, the proposed emissions reduction is achieved by relying less on fossil fuels and more on low-carbon fuels, energy efficiency, and clean technology. All sectors of the California economy will play a role in reducing GHGs to achieve the SB 32 target. The analysis presented here demonstrates that the SB 32 target can be achieved with minimal impact on the growth of California's economy, and that the Scoping Plan is preferred to the alternatives examined.

This appendix is presented in two parts. The first part, Appendix E1 summarizes the economic analysis of the Scoping Plan and four alternatives: Alternative 1, No Cap-and-Trade; Alternative 2, Carbon Tax; Alternative 3, All Cap-and-Trade; Alternative 4, Cap-and-Tax. Each of these five policy scenarios is evaluated relative to the Reference (or no action) Scenario prior to passage of Assembly Bill 398 (AB 398), allowing for comparison across all scenarios.

Appendix E2 presents updated modeling that has occurred since the passage of AB 398. Subsequent to the January 2017 Proposed Scoping Plan, the Reference Scenario has been updated in PATHWAYS (as detailed in Appendix D) and the Scoping Plan is analyzed relative to this updated Reference Scenario. Presenting the economic analysis in two parts allows for the full comparison across scenarios and also details the updated economic impact for the Scoping Plan Scenario that conforms to the requirements of AB 398.

The economic analysis for the updated Scoping Plan Scenario also includes an uncertainty analysis of GHG emissions reduction and cost estimates, an analysis of the distribution of economic impacts across regions of the state, including disadvantaged communities, and an estimated valuation of avoided health impacts due to reductions in air pollution.

This economic analysis has benefited from public comments received over the past two years as well as input from the Environmental Justice Advisory Committee and the Economic Reviewers to the Scoping Plan. The Reviewers are a group of academic economists and researchers under contract with CARB to provide input on the tools and modeling assumptions used in this analysis. The Economic Reviewers are: Max Auffhammer, UC Berkeley; Jim Bushnell, UC Davis; Duncan Callaway, UC Berkeley; Meredith Fowlie, UC Berkeley; Christopher Knittel, Massachusetts Institute of Technology.

The appendix begins with Appendix E1 that outlines the economic analysis of the Scoping Plan and four alternatives; this is followed by Appendix E2, which includes updated modeling to reflect changes to the Reference Scenario and the Scoping Plan Scenario. The modeling updates reflect stakeholder input as well as the passage of Assembly Bill 398 (AB 398). Therefore, only the modeling related to the Scoping Plan

Scenario has been updated and is presented in Appendix E2. In Appendix E2, Section 1 includes a discussion on the updated modeling results and Section 2 includes results of an uncertainty analysis for the 2017 Scoping Plan.

Appendix E1

1. Modeling Framework

This analysis uses two models to examine how the Scoping Plan policies and measures to reduce GHG emissions may affect the California economy: the California PATHWAYS Model (PATHWAYS); and the Regional Economic Models, Inc. Model (REMI). As described below and in Appendix D, PATHWAYS includes the buildings and equipment in the California economy (residences, commercial buildings, power plants, vehicles, factories, furnaces, water heaters, etc.), and estimates the supply and use of all forms of energy. Policy impacts are evaluated by assessing how policies will change the future characteristics of buildings and equipment, and how the use of energy, GHG emissions, and costs will be affected. The REMI Model, described below, represents financial flows throughout the economy, focusing on how changes in expenditures and prices can affect economic growth, employment, and income. The PATHWAYS cost estimates are used as inputs in the REMI model.

Together, the two models provide a framework for assessing the impacts of reducing GHG emissions in California. PATHWAYS produces detailed bottom-up estimates of the costs and savings associated with each of the measures in the Scoping Plan and the alternatives. The REMI Model estimates the response of industries and consumers to resulting changes in costs and prices, and the cumulative impact of all costs and savings on the overall California economy.

Although the two models are highly detailed and customized to California conditions, the analysis has important limitations. This analysis focuses exclusively on the economic effects in California of taking action to reduce GHG emissions through changes in expenditures. The analysis does not include monetization of the environmental benefit of avoiding climate change as estimated through the Social Cost of Carbon and the Social Cost of Methane nor does it include the full public health benefits of avoiding climate change. These issues are discussed in Chapter 3. Also, the economic analysis does not include the monetized benefit of criteria and toxic pollutant emission reductions, which may be achieved while reducing GHG emissions. Similarly, the economic value of conserving natural and working lands is not examined.

Also notable is the uncertainty inherent in analyses of technological and economic developments as far into the future as 2030, and beyond. In particular, the cost of reducing future reliance on fossil fuels is strongly influenced by the future price of fossil fuels, which is not known with certainty. Similarly, progress will depend on the pace of innovation and commercialization that will improve equipment efficiency and reduces cost. New disruptive technologies and business models are possible, but by their nature are not known in advance. Also, consumer acceptance of new technologies will be instrumental in the overall costs of achieving the SB 32 target, particularly the zero-emission vehicles that play a significant role in all the scenarios examined.

The impact of uncertainty in the cost and emissions reductions is analyzed in Section 4. This analysis provides additional insight into the likelihood that the five policy scenarios are able to achieve the 2030 emissions limit given variation in Reference Scenario GHG emissions and the reductions achieved by policy measures. The analysis also includes the cumulative cost of the scenarios given variability in measure cost.

Finally, this analysis does not serve as the economic basis for adopting any specific policy or measure included in the Scoping Plan. Individual regulations implemented as a result of the Scoping Plan are required to go through the full public rulemaking process as outlined by the Administrative Procedure Act, including a full economic analysis of each proposed rule.

California PATHWAYS

California PATHWAYS was developed by Energy and Environmental Economics, Inc. (E3) to evaluate the feasibility and cost of GHG emission reduction scenarios in California. A brief description of PATHWAYS as it relates to the economic analysis is provided here, while additional detail can be found in Appendix D and the PATHWAYS technical documentation posted on the CARB website.

California PATHWAYS is a long-horizon energy model that can be used to assess the cost and greenhouse gas emissions impacts of a system's energy demand and supply choices. The model can identify the impacts of different individual energy choices on energy supply systems (electricity grid, gas, pipeline) and energy demand sectors (residential, commercial, industrial) as well as examine the combined impact of disparate strategies designed to achieve GHG targets.

The PATHWAYS model is an economy-wide "bottom-up" technology-rich model that includes representations of the buildings, industry, transportation, and electricity sectors, including hourly electricity supply and demand. PATHWAYS explicitly models stocks and replacement of buildings, vehicles and appliances over the 35-year timeframe from 2015 through 2050. Demand for energy is driven by external data on population, building square footage, and other energy demand forecasts. Energy and infrastructure costs are tracked, and GHG emissions are calculated based on energy demand and energy supply choices. The PATHWAYS model does not include macroeconomic analysis, price feedback effects or impacts, nor are the scenarios determined by optimization. Rather, the modeled scenarios are the result of input assumptions determined by the users of the model.

PATHWAYS calculates GHG emissions from California energy use and from non-energy activities (such as agriculture and the use of refrigerants). Costs are calculated as changes in capital costs and fuel costs that result from a policy or program, when evaluated against a business-as-usual or no-action scenario. In most cases, an emission reduction measure results in increases in capital expenditures, which may be offset to varying degrees by savings in energy consumption. PATHWAYS also incorporates relationships among energy supply and demand across sectors. For example, the electrification of transportation will increase the demand for electricity, which will interact with electric sector policies, such as the Renewables Portfolio Standard. The increased use of electricity for transportation also interacts with the Low Carbon Fuel Standard. PATHWAYS estimates the costs and savings for the combined set of measures included in the Scoping Plan and alternatives.

For this analysis, California PATHWAYS calculates annual costs for a policy scenario by comparing the scenario to the Reference Scenario, as described in Chapter 3 and Appendix D. The costs calculated for each policy scenario can be compared and reflect the different mixes of technology investments, fuel savings, and emission reductions associated with each. To facilitate the cost comparisons across scenarios, capital costs are levelized over the lifetime of the capital equipment. Fuel expenditures and savings are accounted for in the year in which they occur. All costs and savings are calculated in real 2012 dollars, but are adjusted by CARB to 2015 dollars for consistency with other modeling results.[1] Estimated results from PATHWAYS are detailed in Section 3.

PATHWAYS calculates costs using only the direct cost of technologies and fuels. Policy or administrative costs associated with promoting or requiring the adoption of technologies are not included, with the exception of utility energy efficiency administrative program costs, which are embedded in the electricity and natural gas retail rates. For example, PATHWAYS includes the incremental cost of battery electric vehicles (BEVs) relative to gasoline-powered vehicles. However, PATHWAYS does not include costs associated with incentivizing consumers to purchase BEVs or administrative costs associated with policy design and implementation.

The cost inputs used in PATHWAYS are informed by external sources (as outlined in Appendix D) as well as from the economic analyses of regulatory actions at CARB. Available cost information varies across sector and technology. Where the Scoping Plan relies on the extension of existing programs and regulations for GHG reductions, more detailed cost data is generally available than for newly proposed programs or policies. For instance, detailed incremental vehicle and fuel costs associated with the on- and off-road vehicle fleet and fuel efficiency assumptions are calibrated to the 2016 Mobile Source Strategy released in May 2016,[2] while anticipated costs and savings resulting from implementation of the Short-Lived Climate Pollutant Strategy are much less detailed and are represented as an average cost per ton of reductions based on input from CARB and external researchers. However, since there are currently very few regulations or polices in place for compliance with SB 1383, the costs are initial estimates that will be further developed as the SB 1383 requirements are fully implemented. In addition, there are policies and measures for which little cost information is known. For example, the costs associated with the proposed efficiency measures for refineries, oil and gas, and industrial sources are based on estimated

[1] PATHWAYS costs reported in 2012$ are inflated to 2015$ using the Bureau of Economic Analysis (BEA) Price Indexes for Gross Domestic Product Table 1.1.4 available at: https://www.bea.gov/national/pdf/SNTables.pdf.
[2] https://www.CARB.ca.gov/planning/sip/2016sip/2016mobsrc.pdf.

mitigation costs from a study of industrial energy efficiency costs by LBNL.[3] There are also measures for which no costs are available including anticipated reductions in vehicle miles traveled (VMT) due to smart growth as called for in SB 375. Measures under SB 375 are assumed to have zero cost.

California PATHWAYS is not an optimization model and is not designed to determine the most cost-effective way to achieve a policy objective. PATHWAYS does not consider micro- or macroeconomic effects in its calculations, and consequently, does not model price changes. Rather, the REMI Model is used to assess the impacts of costs and savings in capital and fuel expenditures on economic growth, employment and income in California. The estimated impact of carbon pricing, whether from the Cap-and-Trade Program or a carbon tax, is also examined using the REMI Model.

REMI

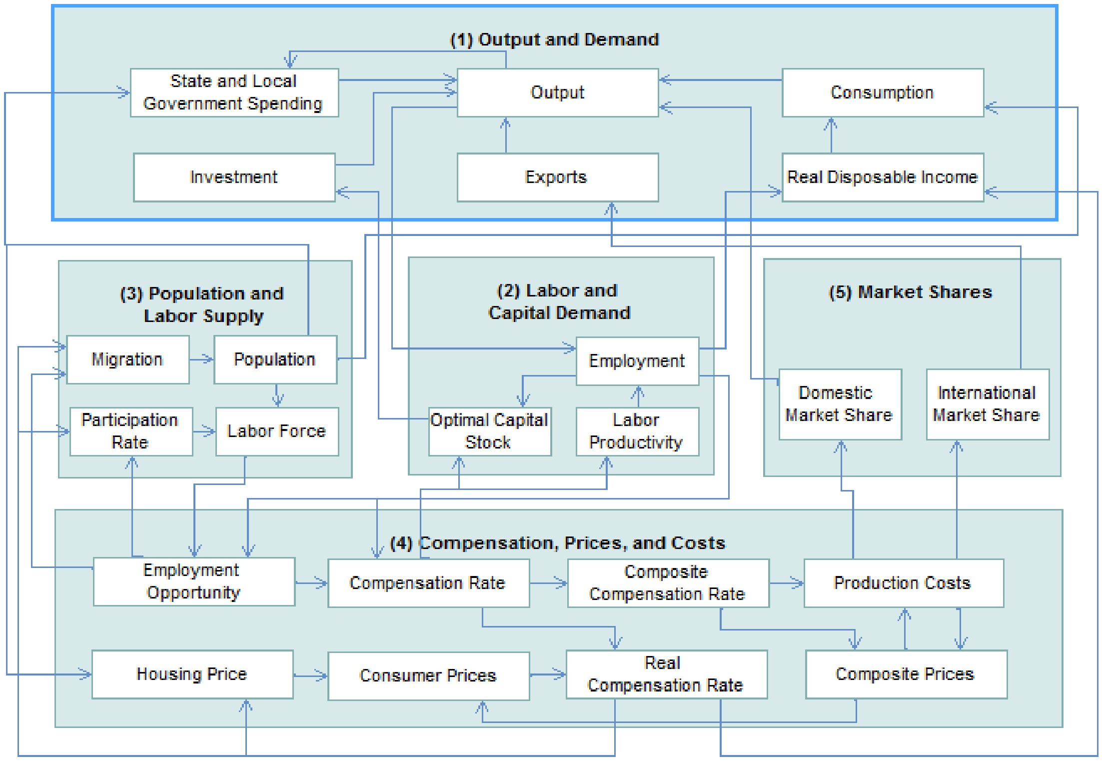
Regional Economic Models, Inc. (REMI), Policy Insight Plus (PI+) Version 1.7.2 is used to estimate the impact of policy scenarios on the California economy. CARB uses a single-region, 160-sector version of the PI+ model configured to the population, demographics, and employment of California. REMI is a structural economic forecasting and policy analysis model that relies on four methodologies in its framework. The methodologies include:[4]

- Input/output modeling: I/O modeling outlines the connection between different industries and households in the economy and is represented by multipliers that track the flow of goods and services between firms, sales to household, and wages paid to and spent by individuals. This data is sourced from the Bureau of Labor Statistics (BLS) and modified to reflect the California economy.[5]
- Econometrics: The REMI model includes statistical parameters representing the behavior of households and firms based on historical data. This includes how industries and consumers respond to changes in prices or wages.
- Computable General Equilibrium (CGE): Aspects of CGE modeling, including market concepts, market shares, and competiveness for businesses, are included in the REMI model. Inclusion of these concepts allows the REMI model to adjust the flow of goods and services over time in response to changing economic conditions. If demand for low-carbon technology is supplied by firms inside California that will impact the labor and capital markets in the state as compared to demand filled from firms outside of California.
- Economy geography: The REMI model represents the spatial dimension of the California economy and allows for clustering of industry and labor by geographic region.

[3] Cost inputs to the PATHWAYS model are detailed in Appendix D.
[4] http://www.remi.com/the-remi-model
[5] https://www.bls.gov/emp/ep_data_input_output_matrix.htm

Figure 1 presents the overall structure of the REMI model, which consists of five major blocks: (1) output and demand, (2) labor and capital demand, (3) population and labor supply, (4) compensation, prices, and costs, and (5) market shares.[6]

Figure 1: Structure of the REMI Model



Within Figure 1, the rectangles represent a variable with arrows representing the equations that link the pieces of the model together. Block 1 represents macroeconomic impacts and includes components of Gross Domestic Product (GDP) often used as a proxy for economic growth. Block 2 contains firm and industry related elements. Changes in demand for goods from block 1 require firms in block 2 to adjust through changes in labor and capital. Block 3 includes demographic modeling components including population and the labor force. Within block 4, households and businesses evaluate the markets for labor, housing, fuels, and energy prices and make decisions about consumption and location. Block 5 quantifies regional impacts and competitiveness and determines any exports from the region.

The REMI model provides year-by-year estimates of the total impacts of the Scoping Plan and alternatives relative to the Reference, or no action, Scenario. The Reference Scenario used in this economic analysis is the California Department of Finance Conforming Forecast dated June 2015. The Reference Scenario modeled in REMI includes a forecast of the California economy through 2030 based on current conditions

[6] A detailed explanation of each block in the REMI model is available at: http://www.remi.com/resources/technical.

that are adjusted for forecasted population and projected economic growth in the future. California PATHWAYS and REMI rely on assumptions related to changes in economic conditions over time including changes in population and fuel price assumptions. Whenever possible, inputs are harmonized between the two modes for consistency.

Linking Models

The impact of the five policy scenarios (Scoping Plan; Alternative 1, No Cap-and-Trade; Alternative 2, Carbon Tax; Alternative 3, All Cap-and-Trade; Alternative 4, Cap-and-Tax) on the California economy is estimated in REMI. The estimates of changes in capital, fuel, and carbon pricing expenditures (from PATHWAYS) and on households and businesses are input into REMI. The impact of carbon pricing on businesses and households is evaluated in REMI directly (and does not rely on output from PATHWAYS). The following section outlines the process for translating the output from PATHWAYS into the REMI model. Note that the level of detail varies between PATHWAYS and REMI, which does not change the overall costs calculated in PATHWAYS, but may impact how some costs are categorized by sector in REMI.

The PATHWAYS model output used in the REMI model consists of capital expenditures and spending on fuel categorized into household, commercial, industrial and transportation sectors. The industrial category is further divided into agriculture and waste, oil and gas extraction, refining, transportation communication and utilities (TCU) and other industrial. Table 1 categorizes the changes in capital expenditures and fuel purchases for each sector. For example, policies related to water heating, space heating, or lighting may result in changes in household expenditures, while policies related to the purchase of ventilation devices may shift expenditures in the commercial sector. Capital expenditures are levelized over the useful life of the device and fuel costs reflect spending on fuel in a particular year.

Table 1. Expenditure Data Output from PATHWAYS

Household	Commercial	Industrial	Transportation
Energy Efficiency End-use Expenditures			
Water Heating Space Heating Central Air Conditioning Room Air Conditioning Lighting Clothes Washing Clothes Drying Dishwashing Cooking Refrigeration Freezer Other	Cooking Lighting Refrigeration Space Heating Ventilation Water Heating Other	Conventional Boiler Use Lighting HVAC Machine Drive Process Heating Process Cooling & Refrigeration Other	Vehicle Capital (Households, Passenger and Freight)
Fuel Expenditures			
Electricity Natural Gas Oil Products	Electricity Natural Gas	Electricity Natural Gas Oil Products Liquid Biofuels	Oil Products Natural Gas Electricity Liquid Biofuels Hydrogen

The REMI model is used to assess the effect that these changes in spending have on the California economy. For example, a household spends money on an energy-consuming device and the efficiency of the device affects how much fuel the household (and thus the household sector) will consume. A policy that induces households to purchase more efficient devices (relative to what they would have purchased in the Reference Scenario without the policy) would increase spending on devices and decrease spending on energy. The REMI policy variables used to implement these spending changes (calculated from cost output from PATHWAYS) for the household sector are presented in Table 2.

Table 2. PATHWAYS Household Expenditure Changes Modeled in REMI

PATHWAYS Expenditure	REMI Policy Variable
	Consumer Price - Household appliances
	Consumer Price - Household maintenance
	Consumer Price - New motor vehicles*
	Consumer Spending - Electricity
	Consumer Spending - Natural gas
	Consumer Spending - Motor vehicle fuels, lubricants, and fluids*
	Consumer Spending - Fuel oil and other fuels

* All spending and fuel use changes from the PATHWAYS sector Light Duty Vehicles are assigned to the Consumer sector in REMI.

Measures also result in changes to expenditures on capital and fuel in the commercial, industrial and transportation sectors. The REMI model contains 156 commercial and industrial sectors while PATHWAYS has eight commercial and industrial sector designations, therefore the PATHWAYS aggregated expenditure data is distributed across REMI sectors based on their use for the capital or fuel. As sector definitions vary between the two models, the final modeling results are impacted by modeling decisions made in translating PATHWAYS sectors into REMI. The REMI policy variables used to implement spending changes for the commercial, industrial and transportation sectors are presented in Table 3.

Table 3. PATHWAYS Commercial, Industrial and Transportation Expenditure Changes Modeled in REMI

PATHWAYS Expenditure	REMI Policy Variable
End-use Capital Expenditure	Capital Cost
Fuel Expenditure - Electricity	Electricity (Industrial Sectors) Fuel Cost
Fuel Expenditure - Pipeline Gas	Natural Gas (Industrial Sectors) Fuel Cost
Fuel Expenditure - Oil Products	
Fuel Expenditure - Liquid Biofuels	

Change in capital costs and fuel expenditures from PATHWAYS are modeled in REMI as changes in the exogenous demand for final products that results from changes in capital and fuel production costs for the sectors. Table 4 presents the translations of capital and fuel expenditures from PATHWAYS (listed in the first column) to the REMI variable (listed in the second column). Modeling assumptions are made in assigning capital expenditures from PATHWAYS to corresponding variables in REMI. While this may impact the distribution of costs by sector, the modeling choice does not impact the reported state-level modeling results.

Table 4. PATHWAYS Commercial, Industrial and Transportation Demand Changes Modeled in REMI

Capital Expenditure	REMI Exogenous Demand Policy Variables
	Agriculture, construction, and mining machinery manufacturing
	Industrial machinery manufacturing
Oil and Gas Extraction	Agriculture, construction, and mining machinery manufacturing
Refining	Industrial machinery manufacturing
Other Industrial	Industrial machinery manufacturing
TCU	Engine, turbine, power transmission equipment manufacturing
	Aerospace product and parts manufacturing
	Motor vehicle manufacturing
	Railroad rolling stock manufacturing
	Motor vehicle manufacturing
	Railroad rolling stock manufacturing
	Ship and boat building
Commercial	Ventilation, heating, air-conditioning, and commercial refrigeration equipment manufacturing
Fuel Expenditures	**REMI Exogenous Demand Policy Variables**
Electricity	Electric power generation, transmission, and distribution
Pipeline Gas	Natural gas distribution
Oil Products	Petroleum and coal products manufacturing
Liquid Biofuels	Basic chemical manufacturing

2. Policy Scenarios

The economic impact of five policy scenarios is estimated using the California PATHWAYS and REMI models. Appendix G provides an overview of the Scoping Plan and alternative policy scenarios, while details related to the economic modeling of the scenarios in this analysis are presented below.

Scoping Plan

The Scoping Plan represents the preferred mix of strategies to achieve the SB 32 target and includes prescriptive measures as well as carbon pricing through the Cap-and-Trade Program. Among the analyzed scenarios, the Scoping Plan best balances the policy objectives outlined in Chapter 2 while ensuring that the SB 32 target is achieved at a low cost to the California economy.

The costs and savings of the prescriptive measures included in the Scoping Plan are calculated in PATHWAYS as changes in energy use and capital investment relative to the PATHWAYS Reference Scenario (detailed in Chapter 2). Depending on the ability of measures to deliver anticipated GHG reductions, the prescriptive measures in the Scoping Plan are anticipated to achieve approximately 62 percent of the reductions needed to meet the SB 32 target. The remaining GHG reductions are achieved through the Cap-and-Trade Program, the impact of which is calculated outside of PATHWAYS and input into the REMI model.

The Cap-and-Trade Program sets an economy-wide GHG emissions cap and gives firms the flexibility to choose the lowest-cost approach to reduce emissions. As with the prescriptive measures, the direct cost of any single specific GHG reduction activity under the Cap-and-Trade Program is subject to a large degree of uncertainty. However, as Cap-and-Trade allows covered entities to pursue the reduction options that emerge as the most efficient, overall abatement costs can be bounded by the allowance price. Covered entities will pursue reduction actions with costs less than or equal to the allowance price. An upper bound on the compliance costs under the Cap-and-Trade Program can therefore be estimated by multiplying the range of potential allowance prices by the anticipated GHG reductions needed (in conjunction with the reductions achieved through the prescriptive measures) to achieve the SB 32 target.

A large number of factors influence the allowance price including the ease of substitution by firms to low-carbon production methods, consumer price response, the pace of technological progress, and impacts of fuel prices. Other policy factors that also impact the allowance price include the use of auction proceeds from the sale of State-owned allowances to reduce GHG emissions and linkage with other jurisdictions.

This analysis includes a range of allowance prices bounded by the projected Cap-and-Trade auction floor price (C+T Floor Price) which represents the minimum sales price for allowances sold at auction and the Allowance Price Containment Reserve Price (C+T Reserve Price) which represents the price at which an additional pool of allowances can be accessed by regulated entities and is the highest anticipated price under the Program.[7] This modeling approach is consistent with the economic analysis for the 2016 Proposed Amendments to The California Cap On Greenhouse Gas Emissions And Market-Based Compliance Mechanisms[8] as well as the 2010 Cap-and-Trade Regulation in which CARB determined the GHG reductions required by the Program would likely be achieved at an allowance price ranging from $15 MTCO2e to $30 MTCO2e in 2020.[9]

The C+T Floor Price grows at a real rate of five percent per year and under proposed amendments to the Cap-and-Trade Regulation, the C+T Reserve Price is set at a fixed dollar amount above the C+T Floor from 2021 through 2030. The fixed dollar amount will be established in 2021 and will be the difference between the C+T Floor Price and the highest tier C+T Reserve Price in 2020.[10] The current estimate of the fixed dollar amount is $56.68. Table 5 outlines the projected allowance prices used in this analysis. All values are reported in 2015 dollars.

Table 5. Estimated Range of Cap-and-Trade Allowance Prices 2021 – 2030

(2015$)	2021	2025	2030
C+T Floor Price	$16.2	$19.7	$25.2
C+T Reserve Price	$72.9	$76.4	$81.9

The impact of the Cap-and-Trade Program is estimated by changing expenditures in REMI to reflect the purchase of Cap-and-Trade allowances by sectors covered by the Program, as well as the allocation of free allowances to covered sectors to prevent emission leakage and protect ratepayers, and the return of auction proceeds from the sale of State-owned allowances to the California economy.

Entities covered by the Cap-and-Trade Program comply by surrendering allowances and offset credits to cover their annual GHG emissions or compliance obligation. In this analysis, the future compliance obligation for each sector is estimated based on the reported and verified 2014 GHG emissions of each sector. For each sector, the share of total GHG emissions in each year is held at the proportion of the sector's 2014 GHG emissions relative to total capped emissions. Table 6 presents the estimated allowance value based on the estimated annual compliance obligation by sector from 2021 through 2030. Each sector in Table 6 is defined by a 2-digit North American Industrial Classification System (NAICS) code, which is used to classify business data. For the

[7] The C+T Floor Price and C+T Reserve Price projections reflect the Cap-and-Trade Regulation which went into effect October 1, 2017, https://www.arb.ca.gov/regact/2016/capandtrade16/capandtrade16.htm but do not reflect harmonization with AB 398, a process which began in October 2017, https://www.arb.ca.gov/cc/capandtrade/meetings/20171012/ct_presentation_11oct2017.pdf.
[8] https://www.arb.ca.gov/regact/2016/capandtrade16/isor.pdf Page 313.
[9] See https://www.arb.ca.gov/regact/2010/capandtrade10/capisor.pdf page Viii-8 for additional information.
[10] https://www.arb.ca.gov/regact/2016/capandtrade16/2nd15daynot.pdf.

REMI modeling, the sectors in Table 6 are disaggregated across forty-four 2- to 4-digit NAICS code sectors.

Table 6. Compliance Obligation Value by Sector at an Allowance Price Equal to the C+T Floor Price (Millions of 2015$)

NAICS	Sector	2021	2025	2030
11	Agriculture, Forestry, Fishing and Hunting	$2.3	$2.3	$2.2
21	Mining, Quarrying, and Oil and Gas Extraction	$281.2	$285.0	$272.5
22	Utilities	$1,489.6	$1,509.9	$1,443.8
31-33	Manufacturing	$1,241.2	$1,258.2	$1,203.1
42	Wholesale Trade	$1,770.9	$1,795.0	$1,716.5
44-45	Retail Trade	$39.2	$39.7	$38.0
48-49	Transportation and Warehousing	$331.5	$336.0	$321.3
52	Finance and Insurance	$25.0	$25.4	$24.2
54	Professional, Scientific, and Technical Services	$0.9	$0.9	$0.9
55	Management of Companies and Enterprises	$1.8	$1.8	$1.7
56	Administrative and Support and Waste Management and Remediation Services	$4.0	$4.0	$3.9
61	Educational Services	$12.8	$13.0	$12.4
62	Health Care and Social Assistance	$0.9	$0.9	$0.9
92	Public Administration	$2.1	$2.1	$2.0
	Total	**$5,203.4**	**$5,274.3**	**$5,043.6**

The cumulative allowance value (evaluated at the C+T Floor Price) is approximately $5 billion each year from 2021 through 2030. In this analysis, the total allowance value is returned to the California economy in a manner consistent with the current Cap-and-Trade Regulation and State law governing the Greenhouse Gas Reduction Fund (GGRF).

Under the current Cap-and-Trade Regulation, electric distribution utilities are provided free allowances on behalf of their ratepayers. These allowances must be consigned to auction by the State's largest investor owned utilities and the revenue must be used for ratepayer benefit, including the biannual California Climate Credit received by customers of those utilities.[11] Natural gas utilities are also provided free allowances, the value of which must benefit ratepayers. The allocation of allowances to utilities is intended to protect ratepayers from significant price increases due to compliance with the Cap-and-Trade Program. For this economic analysis, the value of allowances allocated to the electric and natural gas utilities is returned directly to consumers approximating a per capita dividend.

[11] More information on the California Climate Credit is available at: http://www.cpuc.ca.gov/climatecredit/

Industrial covered and opt-in covered entities receive free allocations to help them transition to the Cap-and-Trade Program and to minimize potential emissions leakage as mandated in AB 32. Free allocation can mitigate leakage by ensuring California industries remain competitive in a global market and that production and employment do not move out of State. Over time, the level of allocation provided for transition assistance declines, while the allocation of allowances for emissions leakage prevention persists until the leakage risk is removed, for example by adoption of comparable GHG emissions pricing in other jurisdictions. While actual allocation to industrial entities in the Program is based on production levels at each individual facility, allowance allocation in this analysis is set based on total sector emissions, which are a proxy for the total sector output multiplied by the product-based benchmark. While AB 398 included guidance for allowance allocation for the 2021-2030 period, that allocation will be part of a future Cap-and-Trade rulemaking. Therefore, in this analysis allocation is based on the second compliance period sector allocation in place in 2017.[12]

Under the current Cap-and-Trade Regulation, the value associated with the auction of State-owned allowances is directed to the GGRF and must be used to further reductions of GHG emissions. The Legislature appropriates GGRF monies to projects that included funding for high-speed rail, intercity rail, energy efficiency and weatherization, wetlands and forest health, and waste diversion.

As allowance value over time is not known with certainty, the total amount of GGRF funds available each year, as well as the distribution of monies, cannot be known with certainty. In order to capture some of the effects of these projects for illustrative purposes, $2 billion per year is directed to the REMI sectors indicated in Table 7. Decisions related to the redirection of allowance value through the GGRF have an effect on the sectors that receive the value.

Table 7: Distribution of GGRF Funds by Sector as Modeled in REMI (2015$)

Strategy	REMI Sector	Amount/Year
	Consumer & new motor vehicles	$250 Million
	Rail transportation	$1 Billion
	Truck transportation	$250 Million
	Consumer household maintenance	$400 Million
	Water, sewage, & other systems	$40 Million
	Forestry; fishing, hunting, trapping	$20 Million
	Waste management and remediation services	$40 Million
Total per Year		**$2 Billion**

[12] Second compliance period sector allocation is described in the current Cap-and-Trade Regulation available at: https://www.arb.ca.gov/cc/capandtrade/capandtrade/unofficial_ct_030116.pdf. Post-2020 allocation information available at: https://www.arb.ca.gov/regact/2016/capandtrade16/2nd15daynot.pdf.

In this analysis, any allowance value that remains after the allocation of allowances to industrial entities, electric and natural gas utilities, and distribution of $2 billion in funds to GGRF is returned to California consumers as a per-capita dividend. As there are many ways to apportion and disburse funds, the return of allowance value in this analysis through the GGRF and the per-capita dividend is illustrative and does not represent a policy proposal.

Alternative 1 – No Cap-and-Trade

Alternative 1 relies solely on prescriptive measures to achieve the SB 32 target and does not include any carbon pricing mechanism. The prescriptive measures in Alternative 1 are more stringent than those in the Scoping Plan, as they must achieve all the emission reductions to achieve the SB 32 target without carbon pricing. The measures included in Alternative 1 are outlined in Appendix G and the modeling inputs used to calculate the GHG emissions and costs of Alternative 1 are detailed in Appendix D. The direct costs of Alternative 1 are calculated in PATHWAYS and input into the REMI model to estimate the impact of Alternative 1 on the California economy.

Alternative 2 – Carbon Tax

Alternative 2 includes the same set of prescriptive measures as the Scoping Plan but relies on a carbon tax rather than the Cap-and-Trade Program to achieve the additional GHG reductions necessary to achieve the SB 32 target. Similar to emission reductions under the Cap-and-Trade Program, entities covered by the carbon tax will pursue reductions with costs less than or equal to the carbon tax, with the carbon tax representing an upper bound on the cost of compliance. As the direct cost of any single specific GHG reduction activity is unknown, there is a high degree of uncertainty in estimating the amount of GHG reductions that will occur for a given level of carbon tax. In addition, there is no mechanism within a carbon tax that can ensure the SB 32 target will be achieved (in a manner similar to the firm cap on emissions as in the Cap-and-Trade Program). As observed in British Columbia, a fixed carbon tax may not deliver anticipated reductions and may endanger meeting GHG targets.[13] Additional information on the carbon tax alternative is presented in Appendix G.

Alternative 2 can only meet the SB 32 target if the combination of the prescriptive measures and the carbon tax achieve the necessary GHG reductions. Consistent with the economic analysis for the Proposed Amendments to the Cap-and-Trade Regulation, this analysis assumes the carbon tax will deliver the necessary GHG reductions to achieve the SB 32 target.[14] In the absence of information relating a specific carbon price to anticipated GHG reductions, this assumption estimates the economic impact of the carbon price as if it were perfectly calibrated to achieve the SB 32 target. While it is highly unlikely that the modeled carbon tax will result in the exact abatement required to

[13] British Columbia, Environmental Reporting BC. 2016. Sustainability. Trends in Greenhouse Gas Emissions in B.C. (1990–2014). http://www.env.gov.bc.ca/soe/indicators/sustainability/ghg-emissions.html.

[14] For more information see: https://www.arb.ca.gov/regact/2016/capandtrade16/appc.pdf

achieve the target, this assumption allows for a comparison of the economic impact across scenarios. It is important to highlight that there is no guarantee that the carbon tax as modeled in Alternative 2 would result in sufficient GHG reductions to meet the SB 32 target.

The economic impact of the carbon tax is modeled outside of PATHWAYS as a fixed cost-per-ton of GHG emissions, priced at the Social Cost of Carbon (SC-CO_2). This analysis relies on the SC-CO_2 used by the IWG and U.S. federal agencies in regulatory impact assessments. As shown in Chapter 3, there is a range of SC-CO_2 estimates across different discount rates, which measures the value of money over time. Table 8 outlines the SC-CO_2 at a discount rate of 3 percent, in both 2007$ (as reported by the IWG) and inflated to 2015$. As modeled, the carbon tax increases over time from $48 in 2020 to $57 in 2030 (in 2015$).[15]

Table 8. Social Cost of Carbon 2020 - 2030[16]

	2020	2025	2030
Social Cost of Carbon (2007$)	$42	$46	$50
Social Cost of Carbon (2015$)	$48	$52	$57

The quantity of GHG reductions that will occur under a carbon tax is based on the level of the tax. The cost of complying with the carbon tax is estimated by multiplying the SC-CO_2 by the quantity of GHG reductions induced by the tax. As modeled in this analysis, any revenue from the carbon tax is fully returned to California consumers and is not used to fund the GGRF or similar programs. Alternative 2 does not include any modification to the tax for the benefit of utility ratepayers or any adjustments for industrial entities for the prevention of emissions and employment leakage.

Alternative 3 – All Cap-and-Trade

Alternative 3, the All Cap-and-Trade Scenario, is a variant of the Scoping Plan Scenario and relies more heavily on the Cap-and-Trade Program for GHG emission reductions. Alternative 3 includes the same prescriptive measures in the Scoping Plan Scenario, but does not include a 20 percent refinery sector measure and maintains the LCFS at a 10 percent reduction in carbon intensity in transportation fuels through 2030.

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[15] Information on the Social Cost of Carbon values is available at: available at: http://www.nap.edu/24651 The adjustment to 2015 dollars was performed using the Bureau of Economic Analysis (BEA) Price Indexes for Gross Domestic Product Table 1.1.4 available at: https://www.bea.gov/national/pdf/SNTables.pdf.

[16] See Chapter 3 for a discussion of the use of the Social Cost of Carbon and the Social Cost of Methane in the Scoping Plan. Additional information about the values is available at: https://obamawhitehouse.archives.gov/sites/default/files/omb/inforeg/scc_tsd_final_clean_8_26_16.pdf.

The costs and savings of the prescriptive measures included in Alternative 3 are calculated in PATHWAYS as changes in energy use and capital investment relative to the PATHWAYS Reference Scenario. Under Alternative 3, the prescriptive measures are anticipated to achieve approximately 60 percent of the reductions needed to achieve the SB 32 target. The remaining GHG reductions are achieved through the Cap-and-Trade Program, which is modeled using the same Program features, including allowance price range, allocation, and return of allowance value, as the Scoping Plan Scenario.

Alternative 4 – Cap-and-Tax

Alternative 4, the Cap-and-Tax Scenario, includes prescriptive measures based on Alternative 1 (as detailed in Appendix D) as well as facility-level GHG caps and a carbon tax. Under Alternative 4, each facility in California is required to keep its emissions below its individual declining cap - emissions trading and offsets are not permitted. The rate of decline in each facility's GHG cap is 4 percent per year, resulting in a 40 percent reduction across all sectors from 2021 to 2030. The Scoping Plan modeling tools do not include facility-level data. Consequently, the economic analysis is conducted at the sector level to approximate the cost and emissions impacts of the individual facility caps specified in Alternative 4.

The costs and savings of the prescriptive measures included in Alternative 4 are calculated in PATHWAYS as changes in energy use and capital investment relative to the PATHWAYS Reference Scenarios (detailed in Chapter 3 and Appendix D). The remaining GHG reductions are achieved through the reductions motivated by facility-level GHG caps. For all sectors, with the exception of the industrial sector, the cost of achieving a 40 percent reduction in Alternative 4 is calculated using PATHWAYS, as detailed in Appendix D.

Unlike the other sectors, sufficient technical opportunities have not been identified in the industrial sector to reduce GHG emissions by the 40 percent required from 2021 through 2030 in Alternative 4. Additionally, the cost of some emissions reduction options may be too high to be affordable for facilities that compete with producers outside of California. As a result, in the industrial sector, a portion of emissions reductions under Alternative 4 is likely to be achieved by a reduction in production.

PATHWAYS does not include methods for calculating the costs associated with facilities reducing production. By assuming that fuel consumption will decline proportionately with reductions in production, PATHWAYS models the impact of reducing production on GHG emissions in the industrial sector, including reductions in fuel expenditures. However, the full cost of reducing output is not calculated in PATHWAYS.

The direct cost of reducing output in the industrial sector under Alternative 4 is calculated in REMI as the change in 'value added' due to the reduction in production.[17]

[17] The Bureau of Economic Analysis defines value added for an industry as: Value added equals the difference between an industry's gross output (consisting of sales or receipts and other operating income,

The change in value added calculated in REMI is consistent with the direct compliance costs calculated in PATHWAYS. In particular, PATHWAYS calculates direct compliance costs assuming that facilities incur the costs without adjusting (e.g., raising) prices or changing output. Under these conditions, direct compliance costs calculated in PATHWAYS would translate exactly into changes in value added because the costs of production are changed while the value of the industry output remains unchanged. The change in valued added calculated in REMI due to reduced production can be thought of the same way. The only difference is that in the REMI analysis, the change in value added is caused by a change in industry production. Given this view, the change in value added from the REMI analysis can be added directly to the direct compliance costs calculated in PATHWAYS to calculate the total compliance costs for Alternative 4.

To calculate the change in value added in REMI, the reductions in production required in Alternative 4 are first calculated in PATHWAYS. Those estimated production reductions, reported as percent reductions each year, are input into REMI as exogenous changes in the industrial sector. The PATHWAYS production reduction estimates are grouped into three sections of the industrial sector: refining; oil and gas extraction; and other industry. The production reductions are then applied to the appropriate NAICS codes in REMI. The total change in value added for the California economy (relative to the reference case in REMI) is taken as the direct cost for reducing output to achieve the 2030 GHG target in Alternative 4.

commodity taxes, and inventory change) and the cost of its intermediate inputs (including energy, raw materials, semi-finished goods, and services that are purchased from all sources). See https://www.bea.gov/faq/index.cfm?faq_id=184.

3. Results

This section outlines the results of the economic analysis. All results are reported in 2015 dollars and represent costs and savings measured against the Reference Scenario in 2030.

PATHWAYS Results

California PATHWAYS estimates the costs and savings of the prescriptive measures in the scenarios. As modeled, the Scoping Plan and Alternative 2 contain the same prescriptive measures and vary only by carbon pricing mechanism. The PATHWAYS modeling of the two scenarios is therefore identical. Table 9 outlines the cost of the prescriptive measures in the Scoping Plan and Alternative 2 by sector in 2030 compared to the Reference Scenario, as calculated in PATHWAYS. The costs in Table 9 are disaggregated into capital costs and fuel costs, which includes gasoline, diesel, biofuels, natural gas, electricity and other fuels.[18] Table 9 assumes that all prescriptive measures deliver the anticipated GHG reductions, and does not include any uncertainty in GHG reductions or cost.[19]

The prescriptive measures result in incremental capital investments of $6.5 billion in 2030. But, the annual capital costs are nearly offset by annual fuel savings of $5.7 billion in 2030. The incremental net cost of prescriptive measures in the Scoping Plan is estimated at $800 million in 2030, which represents 0.02 percent of the California economy in 2030. Residential and commercial sectors are anticipated to see net savings in 2030 as the fuel savings vastly outweigh the annual capital investment. Several sectors, however, will see a net cost increase from implementation of the prescriptive measures. The industrial sector sees higher capital costs due to the purchase of more efficient equipment and an increase in fuel costs due to higher fuel costs, relative to the Reference Scenario. In the agriculture sector, capital expenditures due to investments in more efficient lighting and the mitigation of agricultural methane and nitrogen oxides increase costs relative to the Reference Scenario. Agricultural fuel costs also increase due to higher electricity and liquid biofuel costs under the Scoping Plan.

[18] Additional information on the fuels included in PATHWAYS is available at: https://www.arb.ca.gov/cc/scopingplan/meetings/meetings.htm.
[19] More information on the inputs to the California PATHWAYS model is available at: https://www.arb.ca.gov/cc/scopingplan/meetings/meetings.htm.

Table 9. Scoping Plan/Alternative 2: Change in PATHWAYS Sector Costs in 2030 Relative to the Reference Scenario (Billion 2015$)[20]

End Use Sector[21]	Capital Cost	Fuel Cost	Total Cost
Residential	$0.1	-$0.8	-$0.7
Commercial	$0.5	-$0.9	-$0.4
Transportation	$3.7	-$4.5	-$0.7
Industrial	$0.8	-$0.1	$0.8
Oil & Gas Extraction	$0.0	$0.1	$0.1
Petroleum Refining	$1.0	-$0.3	$0.7
Agriculture	$0.3	$0.4	$0.7
TCU[22]	$0.1	$0.3	$0.3
Total[23]	**$6.5**	**-$5.7**	**$0.8**

Table 9 outlines the costs associated with achieving approximately 70 percent of the GHG reductions required to achieve SB 32. The remaining reductions will be delivered either by the Cap-and-Trade Program (Scoping Plan) or a carbon tax (Alternative 2). The additional direct costs and savings associated with carbon pricing within these scenarios are presented in Table 13.

Table 10 presents the direct costs of Alternative 1. These costs represent the cost of achieving the SB 32 target assuming all measures in Alternative 1 deliver anticipated GHG reductions. Alternative 1 results in increased costs across all sectors. Under Alternative 1, efficiency measures specifically target the industrial, oil and gas extraction, and petroleum refining sectors, achieving a 25 percent reduction in GHGs for the oil & gas and industrial sectors and a 30 percent reduction in refinery GHGs. While these measures are anticipated to result in significant fuel cost savings, they also have significant capital costs. Under Alternative 1, the transportation sector sees significant capital costs due to additional ZEVs and early retirement of light-duty vehicles within the scenario. The residential sector also sees significant increases in fuel costs due to the increased stringency of the LCFS and transportation measures in Alternative 1.

[20] PATHWAYS costs are calculated in real 2012$. For this analysis, all costs are reported in 2015$. The PATHWAYS costs are inflated using Bureau of Economic Analysis (BEA) data available at: https://www.bea.gov/iTable/iTable.cfm?ReqID=9#reqid=9&step=1&isuri=1&903=4.

[21] Information on the end use sectors are available in the California PATHWAYS documentation available at: https://www.arb.ca.gov/cc/scopingplan/meetings/meetings.htm.

[22] Transportation, communications and utilities (TCU) energy supports public infrastructure including street lighting and waste treatment facilities.

[23] Values may not sum due to rounding.

Table 10. Alternative 1: Change in PATHWAYS Sector Costs in 2030 Relative to the Reference Scenario (Billion 2015$)[24]

End Use Sector	Capital Cost	Fuel Cost	Total Cost
Residential	$0.9	$2.7	$3.6
Commercial	$1.3	$1.0	$2.4
Transportation	$7.1	-$2.7	$4.4
Industrial	$4.3	-$0.4	$3.9
Oil & Gas Extraction	$1.4	-$0.5	$0.9
Petroleum Refining	$2.2	-$0.4	$1.8
Agriculture	$1.4	$0.6	$2.0
TCU	$0.1	$0.6	$0.6
Total[25]	**$18.7**	**$1.0**	**$19.7**

Prescriptive measures in Alternative 3 are anticipated to achieve 60 percent of the GHG reductions to meet the 2030 target. Table 11 includes the direct fuel and capital costs of the prescriptive measures in Alternative 3. The additional 40 percent of GHG reductions are achieved through a Cap-and-Trade Program, the cost of which is presented in Table 13.

Fewer emission reductions are achieved through prescriptive measures in Alternative 3 than any other scenario. As outlined in Table 11, this results in a net cost savings across sectors. The residential, commercial, and transportation sectors see savings due to significant reductions in fuel costs under the prescriptive measures in Alternative 3.

[24] PATHWAYS costs reported in 2012$ are inflated to 2015$ using the Bureau of Economic Analysis (BEA) Table 1.1.4 available at: https://bea.gov/national/pdf/dpga.pdf.
[25] Values may not sum due to rounding.

Table 11. Alternative 3: Change in PATHWAYS Sector Costs in 2030 Relative to the Reference Scenario (Billion 2015$)[26]

End Use Sector	Capital Cost	Fuel Cost	Total Cost
Residential	$0.1	-$0.8	-$0.7
Commercial	$0.5	-$0.9	-$0.4
Transportation	$3.7	-$6.0	-$2.3
Industrial	$0.8	-$0.3	$0.5
Oil & Gas Extraction	$0.0	$0.1	$0.1
Petroleum Refining	$0.0	$0.1	$0.1
Agriculture	$0.3	$0.2	$0.5
TCU	$0.1	$0.2	$0.3
Total[27]	**$5.6**	**-$7.4**	**-$1.8**

Table 12 presents the capital and fuel costs for Alternative 4 as calculated in PATHWAYS. These costs include the prescriptive measures as well as the cost of achieving reductions under the facility GHG caps. For the industrial sector, Table 12 includes the reduced fuel expenditure associated with reduced production, but does not include the reduction in value add that is modeled in REMI. The full direct cost of Alternative 4, including the reduction in value add is presented in Table 13.

[26] PATHWAYS costs reported in 2012$ are inflated to 2015$ using the Bureau of Economic Analysis (BEA) Table 1.1.4 available at: https://bea.gov/national/pdf/dpga.pdf.
[27] Values may not add due to rounding.

Table 12. Alternative 4: Change in PATHWAYS Sector Costs in 2030 Relative to the Reference Scenario (Billion 2015$)[28]

End Use Sector	Capital Cost	Fuel Cost	Total Cost
Residential	$2.1	-$0.9	$1.2
Commercial	$1.6	$0.0	$1.6
Transportation	$4.4	-$1.4	$3.0
Industrial	$4.3	-$1.7	$2.6
Oil & Gas Extraction	$1.4	-$0.8	$0.6
Petroleum Refining	$2.2	-$0.5	$1.7
Agriculture	$1.6	$0.6	$2.1
TCU	$0.4	$0.5	$0.9
Total[29]	**$17.9**	**-$4.3**	**$13.6**

The cost of carbon pricing, either through the Cap-and-Trade Program or a carbon tax is not calculated in PATHWAYS. Rather, the direct cost of GHG reductions achieved through the Cap-and-Trade Program or a carbon tax is estimated by multiplying the quantity of reductions needed to achieve the SB 32 target by the carbon price – either the range of allowance prices or the carbon tax. This analysis includes a range of allowance prices bounded by the C+T Floor Price and the C+T Reserve Price, presented in Table 5. The trajectory of the carbon tax is outlined in Table 8.

Table 13 shows the estimated direct cost (including prescriptive measures, carbon pricing, and reduced production) of the five scenarios. As presented in Table 13, the costs of the prescriptive measures are calculated in PATHWAYS, but the costs associated with reductions due to carbon pricing including the Cap-and-Trade Program or carbon tax are calculated outside of the model. The Scoping Plan and Alternative 3 include a range of costs due to carbon pricing, this range is the C+T Floor Price and the C+T Reserve Price.

For Alternative 4, the costs associated with reductions in production in the industrial sector are calculated using the value add variable in REMI as detailed in Section 2. The final column in Table 13 presents the estimated total direct cost of the scenarios, which range from a modest savings in 2030 under Alternative 3 to an annual cost of $63.6 billion under Alternative 4.

[28] PATHWAYS costs are calculated in real 2012$. For this analysis, all costs are reported in 2015$. The PATHWAYS costs are inflated using Bureau of Economic Analysis (BEA) data available at: https://www.bea.gov/iTable/iTable.cfm?ReqID=9#reqid=9&step=1&isuri=1&903=4.
[29] Values may not add due to rounding.

Table 13. Scenario Direct Cost Estimates in 2030 Relative to the Reference Scenario (Billion 2015$)[30]

Scenario	2030 Capital Costs	2030 Fuel Costs	2030 Cost of Reductions due to Carbon Pricing	2030 Cost of Reduced Production	2030 Total Direct Cost
Scoping Plan	$6.5	-$5.7	$1.1 to $3.7		$1.9 to $4.5
Alternative 1	$18.7	$1.0			$19.7
Alternative 2	$6.5	-$5.7	$2.6		$3.4
Alternative 3	$5.6	-$7.4	$1.6 to $5.3		-$0.2 to $3.5
Alternative 4	$17.9	-$4.3		$50	$63.6

Comparing the five scenarios in Table 13, scenarios with flexible carbon pricing have the lowest direct costs. Alternative 3 has the lowest direct costs given the large percentage of GHG reductions achieved through the Cap-and-Trade Program. Alternative 4 has the highest direct costs of $63.6 billion in 2030 as reduced production results in a $50 billion cost to the industrial sector.

[30] Numbers may not add due to rounding. While there is a carbon tax under Alternative 4, the cost of the GHG reductions is driven by the facility-level GHG caps, the cost of which are included in the capital, fuel, and reduced production columns. The carbon tax in Alternative 4 does not motivate reductions, but is collected on all GHG emissions and returned to Californians as a per-capita dividend in the macroeconomic modeling.

REMI Results

The macroeconomic impacts of the five scenarios are estimated using the REMI model. As detailed in Section 1, annual capital and fuel costs are estimated using PATHWAYS and input into the REMI model (along with a calculated cost of reductions under a carbon price and the cost of reduced production) to estimate the impact of the scenarios on the California economy. Key metrics that help identify the impact of the scenarios on the California economy include: California Gross Domestic Product (GDP), which is often used as a proxy for economic growth, employment, personal income, and changes in sector value add, which represents a sector's contribution to the California economy. As modeled in REMI, Table 14 outlines the macroeconomic impacts of implementing the Scoping Plan, based on the range of anticipated allowance prices.

Table 14. Scoping Plan: REMI Macroeconomic Indicators in 2030 Relative to the Reference Scenario

	Absolute Change	Percentage Change
California GDP (Billion 2015$)	-$13.21 to -$22.8	-0.4% to -0.7%
Employment (Jobs)	-68,700 to -106,300	-0.3% to -0.5%
Personal Income (Billion 2015$)	-$6.5 to -$3.9	-0.2% to -0.1%

In 2030, under the Scoping Plan, growth across the indicators is about one-half of one percent less than the Reference Scenario. The results in Table 14 include not only the estimated direct cost of the Cap-and-Trade Program, but also the return of allowance value from the auction of Cap-and-Trade allowances to California businesses and consumers, as detailed in Section 2.

It is important to put the results of Table 14 into context. First, reducing GHG emissions 40 percent below 1990 levels under the Scoping Plan (and using the Reference Scenario prior to passage of AB 398) will lead to avoided social damages from climate change on the order of $2 to $14 billion, as estimated using the SC-CO_2 and SC-CH_4, as well as additional potential savings from reductions in air pollution and petroleum dependence. These impacts are not included in this economic analysis. Second, in 2030, the California economy is projected to grow to $3.4 trillion, an average growth rate of 2.2 percent per year from 2020 to 2030.

Determining employment changes that result from implementing the scenarios presents a modeling challenge, due to a range of uncertainties and global trends that will influence the California economy, regardless of the implementation of the Scoping Plan. The global economy is seeing a shift toward automation and mechanization, which may lead to slowing of employment across some industries globally, irrespective of

California's energy and low carbon investments. In California, employment is projected to reach 23.5 million jobs in 2030.

Estimated personal income in California is relatively unchanged under the Scoping Plan relative to the Reference Scenario. Considering the uncertainty in the modeling, modest changes in the growth of personal income are not different from zero, which suggests that meeting the SB 32 target will not change the growth of personal income relative to the Reference Scenario.

Looking specifically at the contribution of sectors to the California GDP, Table 15 outlines the percentage change in value added by sector, i.e. a sector's contribution to California's economy, under the Scoping Plan. The sectors presented in Table 15 are defined in REMI by NAICS code at the 2-digit (or economic sector) level.[31] The range of results for each sector represents the estimated impact of the Scoping Plan including the cost of prescriptive measures and the impact of Cap-and-Trade allowance prices ranging from the C+T Price Floor to the C+T Reserve Price. Sector value add grows more slowly under the Scoping Plan across all sectors with the exception of "other services sector" which sees an increase in growth likely in response to changes in consumer spending resulting from the return on Cap-and-Trade auction proceeds. Sectors traditionally associated with high GHG emissions, for example, "mining" and "utilities" see the largest reduction in sector value add under the Scoping Plan.

[31] Additional information on the REMI model and included sectors can be found at the 'Data Sources and Estimation Procedures' link available at: http://www.remi.com/products/pi.

Table 15. Scoping Plan: Sector Value Add in 2030 by Category Relative to the Reference Scenario

Sector Value Add by Category	Percentage Change
Forestry, Fishing, and Related Activities	-1.0% to -1.1%
Mining	3.4% to -6.9%
Utilities	-1.6% to -5.0%
Construction	-0.7% to -1.3%
Manufacturing	-0.5% to -1.1%
Wholesale Trade	-0.6% to -1.2%
Retail Trade	-0.8% to -0.9%
Transportation and Warehousing	-1.0% to -1.7%
Information	-0.2% to -0.2%
Finance and Insurance	-0.2% to -0.1%
Real Estate and Rental and Leasing	-0.3% to -0.3%
Professional, Scientific, and Technical Services	-0.3% to -0.5%
Management of Companies and Enterprises	-0.3% to -0.5%
Administrative and Waste Management Services	-0.2% to -0.4%
Educational Services	-0.2% to –0.1%
Health Care and Social Assistance	-0.1% to -0.1%
Arts, Entertainment, and Recreation	-0.2% to -0.1%
Accommodation and Food Service	-0.3% to -0.4%
Other Services, Except Public Administration	0.0% to 0.2%

Table 16 presents some key macroeconomic impacts of Alternative 1 as modeled in REMI. Under Alternative 1, California GDP, employment, and personal income are expected to decrease slightly relative to the Reference Scenario in 2030. Across all indicators, Alternative 1 results in a reduction of approximately one percent relative to the Reference Scenario. As modeled, Alternative 1 will not change the annual rate of growth of GDP, employment, or personal income in California. Relative to the Scoping

Plan, Alternative 1 has higher costs to the California economy and may result in additional job losses through out the State.

Table 16. Alternative 1: REMI Macroeconomic Indicators in 2030 Relative to the Reference Scenario

	Absolute Change	Percentage Change
California GDP (Billion 2015$)	-$40	-1.2%
Employment (Jobs)	-271,600	-1.2%
Personal Income (Billion 2015$)	-$27.5	-0.9%

Table 17 outlines the impact of Alternative 1 on sector value add relative to the Reference Scenario. Sector value add grows more slowly under Alternative 1 across all sectors. Several sectors are estimated to see large declines in value add including the mining sector with a 2030 decline of 8.4 percent and the forestry and fishing sector which is estimated to see a decline of 5.4 percent under Alternative 1. As defined in REMI, this sector includes activities associated with forestry and agriculture. As modeled, the “utilities” sector sees an increase in value add due to increased energy efficiency and demand response in Alternative 1 of 7.6 percent. Relative to the Scoping Plan, sector value add is lower under Alternative 1 for many sectors, reflecting the increased economic cost of achieving the SB 32 target under Alternative 1. There is also additional uncertainty in achieving the SB 32 target under Alternative 1, given the inflexible prescriptive regulations. This uncertainty is detailed in Section 4 of Appendix E1.

Table 17. Alternative 1: Sector Value Add in 2030 by Category Relative to the Reference Scenario

Sector Value Add by Category	Percentage Change
Forestry, Fishing, and Related Activities	-5.4%
Mining	-8.4%
Utilities	7.6%
Construction	-3.3%
Manufacturing	-1.7%
Wholesale Trade	-1.3%
Retail Trade	-2.4%
Transportation and Warehousing	-1.6%
Information	-0.7%
Finance and Insurance	-1.0%
Real Estate and Rental and Leasing	-1.1%
Professional, Scientific, and Technical Services	-0.9%
Management of Companies and Enterprises	-0.9%
Administrative and Waste Management Services	-1.2%
Educational Services	-1.0%
Health Care and Social Assistance	-0.9%
Arts, Entertainment, and Recreation	-0.9%
Accommodation and Food Service	-1.1%
Other Services, Except Public Administration	-1.2%

The macroeconomic impact of Alternative 2 lies generally within the range of impacts estimated under the Scoping Plan, as the SC-CO_2 lies within the anticipated range of allowance prices from 2021 through 2030. Table 18 presents the impact on California GDP, employment, and personal income resulting from Alternative 2. The impact on personal income is slightly less than under the Scoping Plan given that all tax revenues are returned as a per capital dividend. The modeling shows declines on the order of one-half of one percent across California GDP and employment but a more modest decrease in personal income relative to the Reference Scenario. This impact may result from the return of tax revenue to consumers under the carbon tax. This result highlights the impact that different mechanisms for the return of tax revenue or allowance value can have on California consumers and the California economy.

Table 18. Alternative 2: Macroeconomic Indicators in 2030 Relative to the Reference Scenario

	Absolute Change	Percentage Change
California GDP (Billion 2015$)	-$21.3	-0.6%
Employment (Jobs)	-104,800	-0.5%
Personal Income (Billion 2015$)	-$2.9	-0.1%

The macroeconomic modeling of Alternative 2 does differ from the modeling of the Scoping Plan in the distribution of allowance value or tax revenue. Under the Scoping Plan, $2 billion each year is given to the sectors in Table 7, with any remaining funds distributed directly to consumers. Under Alternative 2, any revenue generated from the carbon tax is directly returned to consumers. Thus, transfers of payment within the economy under these different scenarios may influence the distribution of impacts across sectors but will not change the overall direct cost of the scenarios. Table 19 presents the change in sector value add of Alternative 2 relative to the Reference Scenario which shows declines in value add across all sectors with the exception of “heath care” and “other services”. These sectors show no change relative to the Reference Scenario, likely due to the return of tax revenue to consumers who reallocate expenditures in these sectors.

Table 19. Alternative 2: Sector Value Add in 2030 by Category Relative to the Reference Scenario

Sector Value Add by Category	Percentage Change
Forestry, Fishing, and Related Activities	-1.2%
Mining	-7.5%
Utilities	-3.7%
Construction	-1.5%
Manufacturing	-1.1%
Wholesale Trade	-0.9%
Retail Trade	-0.9%
Transportation and Warehousing	-1.5%
Information	-0.2%
Finance and Insurance	-0.1%
Real Estate and Rental and Leasing	-0.3%
Professional, Scientific, and Technical Services	-0.5%
Management of Companies and Enterprises	-0.5%
Administrative and Waste Management Services	-0.5%
Educational Services	-0.1%
Health Care and Social Assistance	0.0%
Arts, Entertainment, and Recreation	-0.1%
Accommodation and Food Service	-0.3%
Other Services, Except Public Administration	0.0%

The estimated macroeconomic impacts of Alternative 3 are presented in Table 20. Alternative 3 has a very slight estimated impact on the California economy, impacting GDP, employment, and personal income by no more than one-half of one percent relative to the Reference Scenario. Growth of employment and personal income are virtually unchanged under Alternative 3 relative to the Reference Scenario.

Table 20. Alternative 3: Macroeconomic Indicators in 2030 Relative to the Reference Scenario

	Absolute Change	Percentage Change
California GDP (Billion 2015$)	-$10.4 to -$20.2	- 0.3% to -0.6%
Employment (Jobs)	-54,400 to -91,900	- 0.2% to -0.4%
Personal Income (Billion 2015$)	-$4.9 to -$2.4	-0.2% to -0.1%

Table 21 presents the change in sector value add of Alternative 3 relative to the Reference Scenario which shows declines in value add across all sectors with the exception of "other services". This sector shows a slight increase relative to the Reference Scenario, likely due to the return of allowance value to consumers who reallocate expenditures in the service sector. Relative to the Scoping Plan, as a larger portion of GHG reductions are motivated by a carbon price in Alternative 3, there is more allowance value returned directly to consumers. Under the upper bounds of allowance prices, the mining and utility sectors still see significant reductions in value add under Alternative 3 as demand shifts within the California economy.

Table 21. Alternative 3: Sector Value Add in 2030 by Category Relative to the Reference Scenario

Sector Value Add by Category	Percentage Change
Forestry, Fishing, and Related Activities	-1.0 to -1.1%
Mining	-2.2% to -5.8%
Utilities	-1.3% to -4.7%
Construction	-0.5% to -1.1%
Manufacturing	-0.4% to -0.9%
Wholesale Trade	-0.5% to -1.1%
Retail Trade	-0.7% to -0.9%
Transportation and Warehousing	-0.9% to -1.7%
Information	-0.1% to -0.2%
Finance and Insurance	-0.1% to -0.1%
Real Estate and Rental and Leasing	-0.2% to -0.3%
Professional, Scientific, and Technical Services	-0.2% to -0.4%
Management of Companies and Enterprises	-0.2% to -0.5%
Administrative and Waste Management Services	-0.2% to -0.3%
Educational Services	-0.1% to 0.1%
Health Care and Social Assistance	-0.1% to -0.0%
Arts, Entertainment, and Recreation	-0.1% to -0.1%
Accommodation and Food Service	-0.2% to -0.3%
Other Services, Except Public Administration	0.1% to 0.2%

Alternative 4 has the largest estimated macroeconomic costs to the California economy. GDP, employment, and personal income decline between one and two percent relative to the Reference Scenario. Alternative 4 slows the growth of the California economy nearly two times any other scenario. Employment and personal income also slow significantly under Alternative 4, as outlined in Table 22. The results in Table 22 include the return tax revenue with a tax rate at the SC-CO_2 as a per-capita dividend to consumers. However, the estimated tax revenue does not offset the high economic impact of Alternative 4 to employment and the California economy.

Table 22. Alternative 4: Macroeconomic Indicators in 2030 Relative to the Reference Scenario

	Absolute Change	Percentage Change
California GDP (Billion 2015$)	-$90.0	- 2.6%
Employment (Jobs)	-502,700	- 2.1%
Personal Income (Billion 2015$)	-$45.4	-1.5%

Table 23 outlines the change in sector value add resulting from Alternative 4. There are significant decrease in many categories, most notable the mining sector with an estimated 29 percent reduction in value add in 2030. Consumer-focused sectors including "other services" and "heath care" also decline significantly as the per capita dividend in Alternative 4 is not sufficient to compensate Californians for the economic impacts under this alternative.

Table 23. Alternative 4: Sector Value Add in 2030 by Category Relative to the Reference Scenario

Sector Value Add by Category	Percentage Change
Forestry, Fishing, and Related Activities	-6.0%
Mining	-29.9%
Utilities	-5.2%
Construction	-5.6%
Manufacturing	-6.0%
Wholesale Trade	-2.6%
Retail Trade	-2.7%
Transportation and Warehousing	-3.2%
Information	-1.0%
Finance and Insurance	-1.3%
Real Estate and Rental and Leasing	-1.5%
Professional, Scientific, and Technical Services	-1.9%
Management of Companies and Enterprises	-2.9%
Administrative and Waste Management Services	-2.1%
Educational Services	-1.3%
Health Care and Social Assistance	-1.1%
Arts, Entertainment, and Recreation	-1.1%
Accommodation and Food Service	-1.5%
Other Services, Except Public Administration	-1.5%

Table 24 compares the percentage change in macroeconomic indicators for the five scenarios relative to the Reference Scenario. Across all scenarios, for the Scoping Plan, Alternative 2, and Alternative 3, the estimated economic impacts are negligible relative to the size of the California economy. However, Alternative 1 and Alternative 4 do represent modest slowing of the growth of the economy. Alternative 4 in particular has a dramatic impact on sectors of the California economy, particularly the industrial sector which can achieve the 2030 target under Alternative 4 only through reductions in production. This reduction leads to slowing in employment, personal, income, and the overall California economy.

Table 24. Comparison of Macroeconomic Indicator Growth in 2030 Relative to the Reference Scenario

	Scoping Plan	Alternative 1	Alternative 2	Alternative 3	Alternative 4
California GDP (Billion 2015$)	-0.4% to -0.7%	-1.2%	-0.6%	-0.3% to -0.6%	-2.6%
Employment (Thousand Jobs)	-0.3% to -0.5%	-1.2%	-0.5%	-0.2% to -0.4%	-2.1%
Personal Income (Billion 2015$)	-0.2% to -0.1%	-0.9%	-0.1%	-0.2% to -0.1%	-1.5%

The results in Table 24 assume that each scenario achieves the 2030 GHG target. Section 4 will explore the ability of each scenario to do so, given variability in Reference Scenario emissions and measure performance.

Household Impacts

Household Impacts Modeled in PATHWAYS

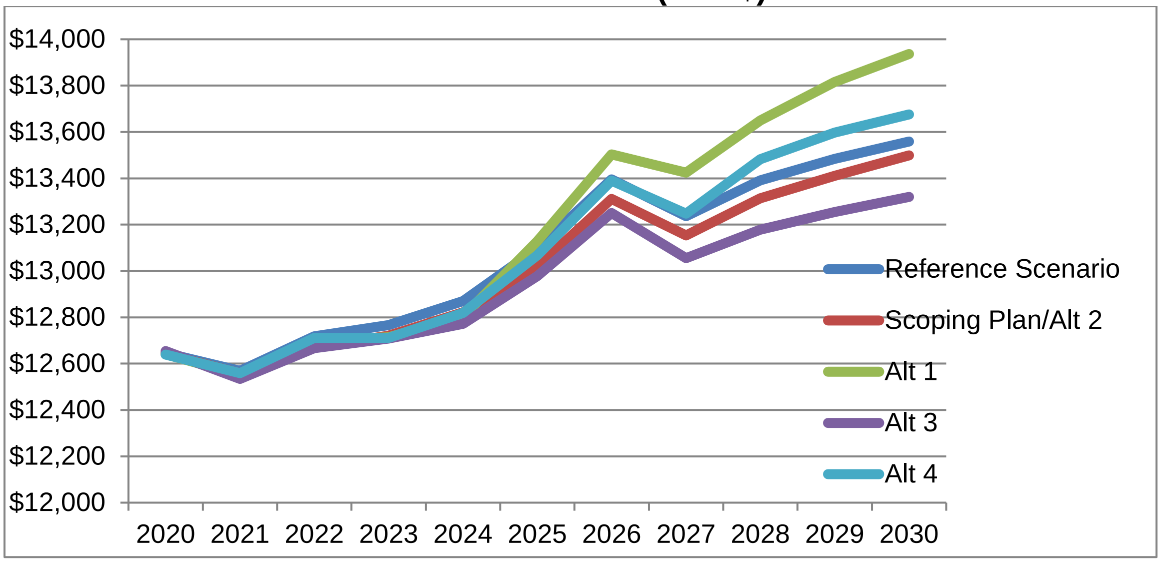
Implementation of the five policy scenarios will affect household spending, including expenditures on goods (such as appliances) and fuels. Household costs are modeled in PATWAYS for the prescriptive measures within each scenario.

The household costs of goods modeled in PATHWAYS include capital costs for energy-using appliances and products, like water heaters, as well as the capital cost of all light-duty vehicle purchases. Household fuel expenditures modeled in PATHWAYS include oil products, pipeline gas, and electricity. Fuel costs associated with light-duty vehicles are attributed to households in this analysis and include oil products, pipeline gas, electricity, and liquid biofuels. Attributing all costs associated with light-duty vehicles to households likely overstates the household expenditures on vehicles and fuel because a portion of these vehicles are used in commercial and industrial applications. These costs are attributed to households in this summary as a conservative, or likely upper bound, estimate.

Figure 2 presents the direct household expenditures as modeled in PATHWAYS on capital (or goods) and fuel for the Reference Scenario and five policy scenarios. Figure 2 does not include any household costs of carbon pricing nor any indirect costs passed along to households (e.g., due to increased prices of products or services). The annual household expenditures on capital and fuel range from approximately $12,500 to $14,000 per household across the scenarios. The magnitude of the expenditures is primarily the result of including light-duty vehicle purchases both in the Reference and five policy scenarios. Across all scenarios, approximately 80 percent of household capital expenses and 60 percent of household fuels expenses are associated with light-duty vehicles.

In Figure 2, Alternative 1 and Alternative 4 have household costs higher than the Reference Scenario in later years. There is a small discernable difference between the household costs of the Scoping Plan/Alternative 2 (which are modeled the same in PATHWAYS) and Alternative 3. While these scenarios have household expenditures below the Reference Scenario, it is important to note that the portion of these scenarios as modeled in PATHWAYS do not include carbon pricing measures. Therefore, the costs in Figure 2 do not represent the full costs to households of the scenarios.

Figure 2: Estimated Household Expenditures on Capital and Fuel as Modeled in PATHWAYS (2015$)[32]



Reduced expenditures on fuel in the Scoping Plan, Alternative 2, and Alternative 3 drive the household savings relative to the Reference Scenario. As presented in Figure 3, household capital expenditures are higher across all scenarios relative to the Reference Scenario. As Figure 4 shows, however, fuel expenditures are lower for all scenarios relative to the Reference Scenario. The divergences in capital and fuel expenditures from the Reference Scenario increase over time. Household impacts from carbon pricing are not included in Figures 2 through 4, but will be addressed in the next section of the Appendix.

[32] Figure 2 does not include any household impact resulting from carbon pricing in the Scoping Plan, Alternative 2, Alternative 3, and Alternative 4.

Figure 3: Estimated Household Capital Expenditures as Modeled in PATHWAYS (2015$)[33]

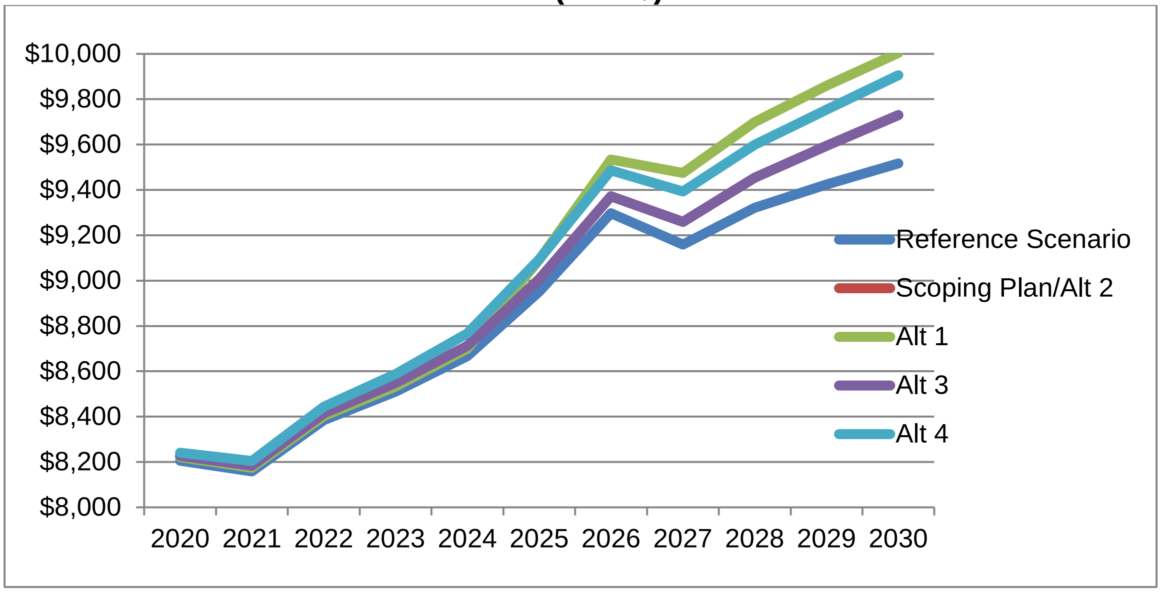
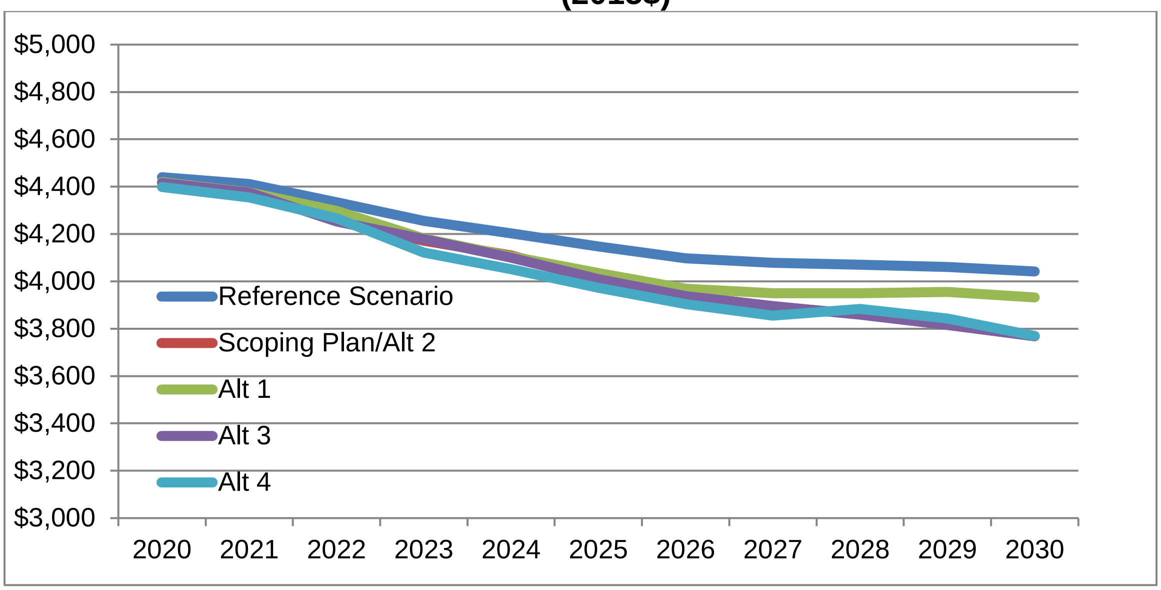


Figure 4: Estimated Household Fuel Expenditures as Modeled in PATHWAYS (2015$)[34]



Looking at the incremental cost of the five scenarios relative to the Reference Scenario, Table 24a shows significantly higher costs for Alternative 1 relative to the other scenarios. As modeled in PATHWAYS, only Alternative 1 and Alternative 4 achieve the 2030 target without additional carbon pricing measures. However, Alternative 1 results

[33] Figure 3 does not include any household impact resulting from carbon pricing in the Scoping Plan, Alternative 2, Alternative 3, and Alternative 4.
[34] Figure 4 does not include any household impact resulting from carbon pricing in the Scoping Plan, Alternative 2, Alternative 3, and Alternative 4.

in increased cost to households relative to the Reference Scenario each year 2025 through 2030. Alternative 4 is estimated to result in savings to households through 2026, when the costs to households increase relative to the Reference Scenario.

Per household impacts are based on projections from the California Department of Finance, which projects there will be about 13,864,699 households in 2020, 14,449,955 in 2025, and 15,021,712 households in California in 2030.[35] The estimated household impacts are based on a representative household with less than 3 people. As such, the actual impact across the range of California households will vary from the estimates included in Table 24a. As modeled, the household impacts are approximately equivalent across all scenarios in 2020. However, the impacts diverge in in later years as scenarios that include carbon pricing have a cost savings relative to the Reference Scenario.

Table 24a. Household Impacts: Annual Household Cost Relative to the Reference Scenario as Modeled in PATHWAYS (2015$)[36]

Scenario	2020 HH Fuel and Capital Costs	2025 HH Fuel and Capital Costs	2030 HH Fuel and Capital Costs
Scoping Plan	-$5	-$80	-$60
Alternative 1	-$5	$30	$380
Alternative 2	-$5	-$80	-$60
Alternative 3	-$5	-$80	-$60
Alternative 4	-$5	$30	$120

Household Impacts Modeled in REMI

The impact to households is not limited to changes in capital and fuel purchases. Households will be indirectly impacted by changes in the relative prices of goods, shifts in employment opportunities, as well as the distribution of allowance value and carbon tax revenue. One metric that captures these effects and is commonly used to estimate economic impacts on individuals and households is personal income. As defined in the REMI model, personal income includes wages and salaries, supplements to wages and salaries, less any contribution towards social security.[37]

Table 25 summarizes the impact of the Scoping Plan and alternatives on personal income. The values in Table 25 include the direct costs of capital and fuel included in

[35] Household data obtained from California Department of Finance P-4: State and County Projected Households, Household Population, and Persons per Household from 3/10/2015. Additional information available at: http://www.dof.ca.gov/Forecasting/Demographics/Projections/.
[36] All values are rounded. Table 24-A does not include any household impact resulting from carbon pricing in the Scoping Plan, Alternative 2, Alternative 3, and Alternative 4.
[37] Additional information is available at: http://www.remi.com/products/pi in the Data Sources and Estimation Procedures documentation.

Table 24a which are input into the REMI model. Table 25 also includes the costs of emission reductions achieved by carbon pricing (through Cap-and-Trade or a carbon tax), return of Cap-and-Trade allowance auction revenue through the GGRF and a per-capita dividend (under the Scoping Plan and Alternative 3) and the return of carbon tax revenue (under Alternative 2 and Alternative 4). In this analysis, the return of value from carbon pricing is critical to mitigate some of the impact to California households from increases in costs due to climate policy. The range of results for the Scoping Plan and Alternative 3 represent the impact of the range of allowance prices from the C+T Floor Price to the C+T Reserve Price anticipated under the 2017 Cap-and-Trade Regulation.

Table 25. Household Impacts: Personal Income Relative to the Reference Scenario as Modeled in REMI (Billion 2015$)[38]

Scenario	2020 Personal Income	2025 Personal Income	2030 Personal Income
Scoping Plan	$1.8 to $16.8 0.1% to 0.7%	-$1.8 to $5.4 -0.1% to 0.2%	-$6.5 to -$3.9 -0.2% to -0.1%
Alternative 1	-$1.3 -0.1%	-$10.2 -0.4%	-$27.5 -0.9%
Alternative 2	$15.1 0.7%	$5.5 0.2%	-$2.9 -0.1%
Alternative 3	$1.8 to $16.8 0.1% to 0.7%	-$1.7 to $5.5 -0.1% to 0.2%	-$4.9 to -2.4 -0.2% to -0.1%
Alternative 4	$15.0 0.6%	-$9.8 -0.4%	-$45.4 -1.5%

As modeled in REMI, personal income varies greatly across scenarios over time. The impact to households increases over time as measures across the policy scenarios are implemented. The Scoping Plan, Alternative 2, Alternative 3, and Alternative 4 show an increase in the growth of personal income relative to the Reference Scenario in early years of implementation.

Table 25a shows the estimated household impact across the five policy scenarios. The change in personal income relative to the Reference case is split across the over 15 million California households projected in 2030.[39] The impact to households includes

[38] The range of results for the Scoping Plan and Alternative 3 represents the estimated impact of the Cap and-Trade Program calculated at the C+T Floor Price (the lower bounds) and the C+T Reserve Price (the upper bounds).

[39] Values are rounded and based on 15,021,712 California households as projected by California Department of Finance.

the return of value related to carbon pricing and ranges from a modest $160 in 2030 under Alternative 3 to a high cost of over $3,000 per household under Alternative 4.

Table 25a. Reduction in Annual Household Personal Income Relative to the Reference Scenario in 2030 (2015$)[40]

Scenario	Estimated Household Cost in 2030
Scoping Plan	$430 to $260
Alternative 1	$1,830
Alternative 2	$195
Alternative 3	$325 to $160
Alternative 4	$3,025

To evaluate whether vulnerable populations and low-income households are disproportionately affected by California's climate policy, CARB is taking steps to better quantify localized economic impacts and ensure that low-income households see tangible benefits from the Scoping Plan as directed by AB 617. Researchers at the University of California, Los Angeles (UCLA) are also currently working on a retrospective analysis that will estimate the impacts across California communities of the implementation of AB 32, which will help identify areas of focus as 2030 measures are developed. Additionally, research teams from UCLA and the University of California, Berkeley are also working to analyze the co-benefits of GGRF funds on California communities, including impacts to employment in DACs. The Cap-and-Trade Program will also continue to provide benefits to disadvantaged communities through the disbursement of GGRF funds.

Economic Valuation of Health Impacts

Improved health outcomes are an important benefit of implementing measures within the five policy scenarios. In this economic analysis, the health benefits associated with reductions in diesel particulate matter (DPM) and nitrogen oxides (NOx) are monetized and included in the REMI macroeconomic modeling to determine the impact on the California economy. The health benefits are estimated by quantifying the harmful future health effects that will be avoided by reducing human exposure to DPM and NOx, as detailed in Appendix G, and monetized by estimating a health effect's economic value to society. Consistent with Appendix G, the economic valuation is based on an assumed one-to-one relationship between changes in GHGs, criteria pollutants, and toxic air contaminants, and it is unclear whether that is always the case.

[40] The range of results for the Scoping Plan and Alternative 3 represents the estimated impact of the anticipated Cap and-Trade Program calculated at the C+T Floor Price (the lower bounds) and the C+T Reserve Price (the upper bounds). The C+T Floor Price and C+T Reserve Price projections reflect the Cap-and-Trade Regulation which went into effect October 1, 2017, https://www.arb.ca.gov/regact/2016/capandtrade16/capandtrade16.htm but do not reflect harmonization with AB 398, a process which began in October 2017.

In this analysis, reductions in premature mortality, respiratory and cardiovascular hospitalizations, and ER visits due to asthma are monetized to identify the economic impact of changes in future health associated with the five policy scenarios. The approach to monetizing mortality risk benefits is based on the value of statistical life (VSL) method approved by U.S. EPA's Science Advisory Board's Environmental Economics Advisory Committee. The approach uses estimates of individual's willingness to pay for a reduction in mortality risk. The VSL is an aggregated measure of the value of small changes in mortality risk experienced by a large number of people.

The U.S. EPA guidelines for VSL recommend a central value of $7.4 million in $2006 at 2006 income levels, which is derived from multiple labor market and contingent valuation studies.[41] Following U.S. EPA's procedure for regulatory benefit calculation, the VLS is adjusted to 2015$ and to account for real income growth through 2015. After applying these adjustments, the VSL is $8.6 million (2015$). The VSL is not adjusted for anticipated real income growth through 2030 nor is the VSL discounted to account for health benefits that occur in the future.

The benefits of avoided morbidity health effects, including cardiovascular and acute respiratory hospitalizations and emergency room visits for asthma, are monetized used cost-of-illness estimates. The cost of hospitalizations are based on published estimated of California illness costs, including: hospital charges, post-hospitalization medical care, out-of-pocket expenses, and lost earnings.[42] Direct medical cost estimates during hospitalizations are obtained from the California Office of Statewide Health Planning and Development data for 1998-99 hospital admissions for patients 65 years of age of older.

In the absence of California-specific estimates of the cost of emergency room visits for asthma, the analysis relies on U.S. EPA's national estimates.[43] Table 26 outlines the VSL and value of morbidity health effects while Table 27 presents the estimated reduction in mortality and morbidity in 2030 from the five scenarios.

[41] The value is based on five contingent-valuation and 21 labor-market studies. The underlying studies, the distribution parameters, and other useful information are available in Appendix B of the EPA's Guidelines for Preparing Economic Analyses http://yosemite.epa.gov/ee/epa/eerm.nsf/vwAN/EE-0568-22.pdf/$file/EE-0568-22.pdf.

[42] Chestnut, L. G., Thayer, M. A., Lazo, J. K. And Van Den Eeden, S. K.. 2006. "The Economic Value Of Preventing Respiratory And Cardiovascular Hospitalizations." Contemporary Economic Policy, 24: 127–143. doi: 10.1093/cep/byj007 Available at: http://onlinelibrary.wiley.com/doi/10.1093/cep/byj007/full.

[43] The values are based on two cost-of-illness studies: Smith, D.H., D.C. Malone, K.A. Lawson, L.J. Okamoto, C. Battista, and W.B. Saunders. 1997. "A National Estimate of the Economic Costs of Asthma." American Journal of Respiratory and Critical Care Medicine 156(3 Pt 1):787-793.
Stanford, R., T. McLaughlin and L. J. Okamoto. 1999. "The cost of asthma in the emergency department and hospital." American Journal of Respiratory and Critical Care Medicine 160 (1): 211-5.

Table 26. Estimated Monetization of Value of Statistical Life and Morbidity Health Effects (2015$)

	(2015$)
Value of Statistical Life	$8.6 million
Acute Respiratory Hospitalizations	$45,000
Cardiovascular Hospitalizations	$52,000
ER Visits for Asthma	$740

The ranges in Table 27 are based on the potential range of emission reductions in the Scoping Plan in 2030 and do not reflect uncertainty within the health benefit modeling, which is discussed in Appendix G.

Table 27. Estimated Reduction in Premature Mortality and Morbidity in 2030 Relative to Reference Scenario*

Number of Avoided Incidences	Scoping Plan	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Premature Mortality	260 to 310	300 to 370	260 to 310	235 to 270	430 to 520
All Hospitaliza-tions	38 to 46	45 to 55	38 to 46	35 to 40	65 to 77
ER Visits	110 to 128	126 to 155	110 to 128	99 to 116	187 to 218

* See Appendix G for additional details on the health modeling for the Scoping Plan and Alternatives.

Table 28 presents the estimated economic valuation of the avoided health impacts for each scenario in 2030. The total health impact ranges from $1 billion to $4.5 billion. Alternative 4 has the highest economic valuation of avoided health impacts ranging from a total of $3.7 to $4.5 billion in 2030. The large avoided health impacts of estimated under Alternative 4 are likely the result of reduced air pollution from lowered economic activity that occurs from reduction of industrial production in California. As modeled, Alternative 4 includes reduced industrial production in order to achieve the SB 32 target, reducing employment in California and shifting emissions out of State.

The values in Table 28 do not include avoided health impacts from carbon pricing nor do they include the health impact of woodstoves or active transportation. These issues are discussed in greater detail in Appendix G.

Table 28. Estimated Economic Valuation of Avoided Health Impacts in 2030 Relative to Reference Scenario

Million 2015$	Scoping Plan	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Premature Mortality	$2,200-$2,700	$2,600-$3,200	$2,200-$2,700	$2,000-$2,300	$3,700-$4,500
All Hospitali-zations	$1.8 to $2.2	$2.2 to $2.7	$1.8 to $2.2	$1.7 to $1.9	$3.2 to $3.7
ER Visits	$0.08 to $0.09	$0.09 to $0.1	$0.08 to $0.09	$0.07 to $0.09	$0.1 to $0.2
Total	$2,200-$2,700	$2,600-$3,200	$2,200-$2,700	$2,000-$2,300	$3,700-$4,500

The estimated valuation of avoided hospitalizations, emergency room visits, and premature mortality were used as inputs into the REMI model to determine the impact of these health impacts on the California economy. The health impacts are modeled in REMI using the policy variables described the Table 29.

Table 29. REMI Policy Variables: Health Impacts

Health Impact	REMI Policy Variable
Avoided Premature Mortality	Non-Pecuniary (Amenity) Aspects
Acute Respiratory Hospitalizations	Consumer Spending Hospitals
Cardiovascular Hospitalizations	Consumer Spending Hospitals
ER Visits for Asthma	Consumer Spending Hospitals

The Consumer Spending policy variable functions as an exogenous change in industry demand, here for hospitals. Decreases in spending on hospitalizations and emergency room visits are reallocated in consumers' budgets using the Consumption Reallocation policy variable. Therefore, consumers shift away from spending on hospitalizations and can increase spending in other categories.

The Non-Pecuniary (Amenity) Aspects policy variable changes the non-market "quality of life" component within the migration equation by the amount entered (the premature mortality value for each scenario in Table 28). An amenity value increase, such as a reduction in premature mortality, makes California more attractive, so a greater number of economic migrants enter each year.

Including the monetized health impacts in the REMI modeling has no discernable impact on the overall modeled results. The incremental impacts of incorporating the health impacts into the REMI model are presented in Table 30 for the five scenarios. The impact of including the monetized health impacts is indiscernible relative to the impact of the scenarios relative to the Reference Scenario. The monetized health impacts do not represent any percentage change in macroeconomic indicators across the Scoping Plan or alternatives. It is important to note that the modeling does not include an assessment of the full public health impact of the Scoping Plan nor does it include the impact to changes in income and employment on health, which can greatly impact economies but are outside the scope of this analysis.

Table 30. Absolute Change in Macroeconomic Indicators of Health Impacts in 2030 Relative to the Reference Scenario

	Scoping Plan	Alternative 1	Alternative 2	Alternative 3	Alternative 4
California GDP (Billion 2015$)	$0.001 to $0.001	$0.001 to $0.001	$0.001 to $0.001	$0.0 to $0.001	$0.001 to $0.001
Employment (Thousand Jobs)	0.004 to 0.005	0.005 to 0.006	0.004 to 0.005	0.004 to 0.005	0.008 to 0.009
Personal Income (Billion 2015$)	$0.0 to $0.0	$0.0 to $0.0	$0.0 to $0.0	$0.0 to $0.0	$0.0 to $0.0

Distributional Impacts

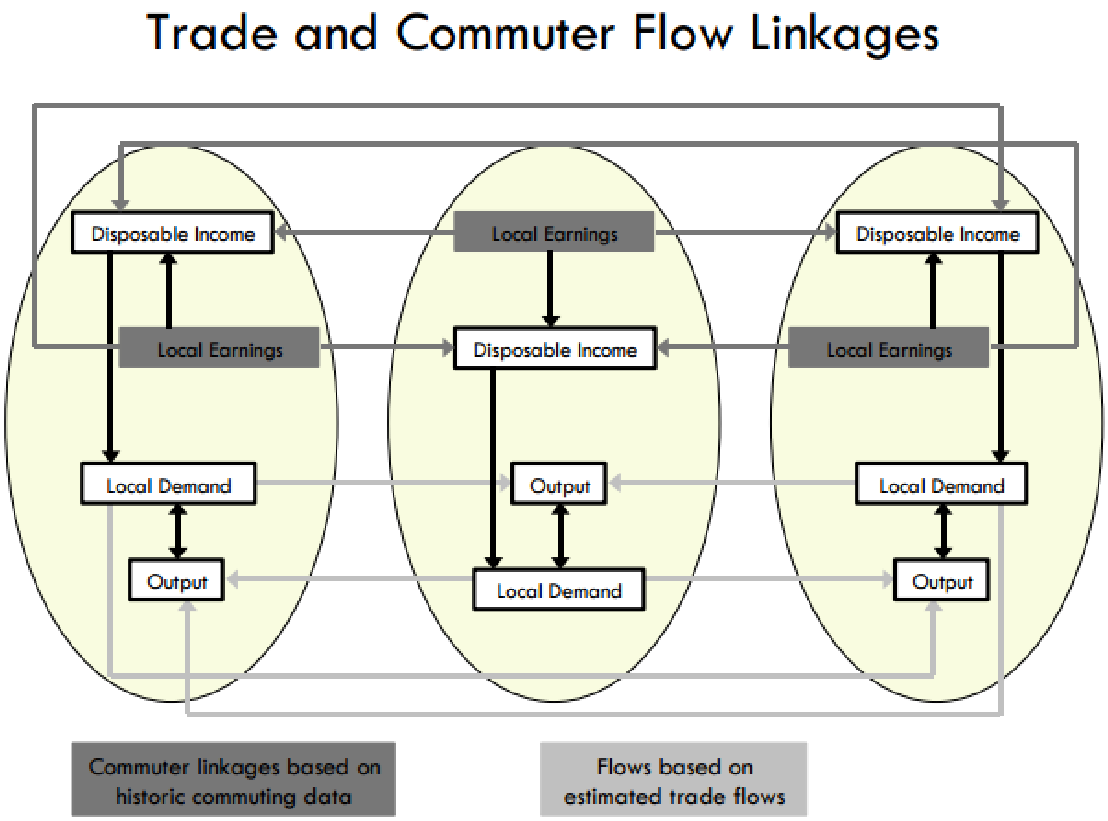
Implementing the Scoping Plan is projected to have a small impact on the Statewide California economy through 2030. However, shifting from fossil fuels can disproportionately affect specific geographic regions whose local economies rely on fossil fuel intensive industries. These regions can also include vulnerable populations and disadvantaged communities who may be disproportionately impacted by poor air quality and climate.

The regional impacts of the Scoping Plan and alternatives, including the impact to disadvantaged communities, are estimated using the REMI California County model which represents the 58 counties and 160 sectors of the California economy. Utilizing the same inputs used for modeling the statewide impact of the five policy scenarios relative to the Reference Scenario, the California County model estimates how measures will affect employment, value added, and other economic indicators at the county level across the state.

The Scoping Plan and alternatives are modeled in the REMI California County model through a series of input variables. These variables are representative of changes in capital and fuel costs, as modeled in PATHWAYS, as well as the costs of carbon pricing calculated outside the PATHWAYS model. The REMI California County model functions similarly to the REMI California model, but accounts for regional differences in both economic and demographic characteristics. Regional effects on individuals are accounted for using parameter coefficients that adjust for local differences in consumption using data from the Bureau of Economic Analysis (BEA) and the Census Bureau. For example, the regional effect on consumption for household appliances could be more significant in some counties and less significant in others. Similarly, economic characteristics are distinctive in each county, including economic variables such as industry output, personal income, GDP, and price indexes for housing and energy.

Unlike the statewide REMI model, this multi-regional model allows for many interactions between California counties, as seen in Figure 5. Some examples of flow linkages include trade flows from each individual county to each of the other counties as a response to local demand and any corresponding changes in disposable income.

Figure 5: Structure of California County Interactions in REMI California County Model



When modeling the five policy scenarios in the REMI California County model, changes to industry equipment costs are modeled as an increase in capital expenditures unique to each industry and are distributed to the counties proportional to industry output by county. Represented industries include those at the 2- to 4-digit NAICS code level. The change in capital purchases is modeled as a change in demand, distributed proportional to industry output by county. Fuel costs and savings are modeled proportional to industry consumption in each fuel category at the county level, using industry output multiplied by a consumption coefficient.[44]

GGRF funds are the same dollar amounts assumed for the statewide analysis of, but unique values have been calculated for each county when running the regional analysis. The modeling methodology attempts to allocate GGRF funds representatively by injecting dollars at the county level and is modeled as a change in demand for goods and services distributed proportionally to industry output by county, with the exception of any change in demand for motor vehicles which are allocated proportional to REMI's baseline forecast of out-county output under NAICS 3361, and rail program spending

[44] Coefficients are static in the REMI California County model, and are organized in an input-output table that represents interdependencies between industries at the county level.

assumptions where spending is directed to specific counties as reported in the 2016 California Climate Investments Annual Report of Cap-and-Trade Auction Proceeds.[45] A complete list of input translations modified for the REMI California County model can be seen in Table 31. The modeling may not reflect the true flow of GGRF funds, as those investment dollars realistically flow at a higher rate to disadvantaged communities, as opposed to an even distribution of investment dollars across the state by regional output. Thus, as modeled, the benefits of GGRF funds in disadvantaged communities may be underestimated.

Table 31. Input Translations for Inputs to the REMI California County Model

REMI Policy Variable	County Conversion
Capital Cost, by industry	Proportional to industry output at the county level
Fuel Cost, for all industrial sectors	Proportional to industry consumption in each fuel category at the county level, using industry output multiplied by a consumption coefficient.[46]
Exogenous Final Demand, by industry	Proportional to industry output by county*
Consumer Spending, for reduced fuel purchases	Proportional to personal consumption expenditure in each spending category at the county level
Production Cost, by industry	Proportional to industry output at the county level
Transfer Payments	Proportional to population by county
Consumer Price	Proportional to county personal consumption expenditures in each category

* Demand for motor vehicles is distributed proportional to REMI's baseline forecast of out-county output under NAICS 3361. Rail program spending is unique to county spending reported in Appendix A of the 2016 California Climate Investments Annual Report of Cap-and-Trade Auction Proceeds: https://CARB.ca.gov/cc/capandtrade/auctionproceeds/cci_annual_report_2016_final.pdf.

[45] 2016 California Climate Investments Annual Report of Cap-and-Trade Auction Proceeds available at: https://arb.ca.gov/cc/capandtrade/auctionproceeds/cci_annual_report_2016_final.pdf.

[46] Coefficients are static in the REMI California County model, and are organized in an input-output table that represents interdependencies between industries at the county level.

Disadvantaged Communities

The output from the REMI California County model allows for estimating some economic impacts on disadvantaged communities. The California Communities Environmental Health Screening Tool (CalEnviroscreen) 2.0[47] is a screening tool developed by the Office of Environmental Health Hazard Assessment that is used to identify California communities that are disproportionately burdened by multiple sources of toxics and criteria pollutants. The tool considers the pollution burden for each census tract[48] in California across multiple sources of pollution including potential exposure to pollutants, adverse environmental conditions, socioeconomic factors and prevalence of certain health conditions. CalEPA uses the CalEnviroscreen tool to identify disadvantaged communities. In this analysis, disadvantaged communities are defined as the 25 percent highest scoring census tracts using results of CalEnviroscreen 2.0.

For this analysis, disadvantaged community impacts are determined through a 2-step process. County estimates of occupational employment, from the American Community Survey (ACS),[49] provide census tract-level data on jobs by occupation, which are matched to the output of county-level forecasts of jobs by occupation provided by the REMI California County model – providing an estimate of occupational employment by census tract across California.

The employment impact in disadvantaged communities is estimated by matching the ACS census tract-level employment data to disadvantaged communities as identified by CalEPA using CalEnviroscreen 2.0. REMI county-level output of jobs by occupation is then used to estimate impacts on disadvantaged communities by allocating county impacts proportional to the disadvantaged communities (as identified by census tracts) share of jobs. Figure 6 outlines the methodology used to estimate the impacts allocated to disadvantaged communities.

[47] More information about CalEnviroscreen 2.0 and the tool's technical documentation can be accessed at: http://oehha.ca.gov/calenviroscreen/report/calenviroscreen-version-20. While CalEnviroscreen 3.0 is now available, it was not finalized in time for this analysis.
[48] Census tracts are small geographic areas within greater metropolitan areas that usually have a population between 2,500 and 8,000 persons. More information on the composition of census tracts available here: https://www.census.gov/geo/reference/gtc/gtc_ct.html.
[49] American Community Survey: https://www.census.gov/programs-surveys/acs/.

Figure 6: Determination of Disadvantaged Community Impacts

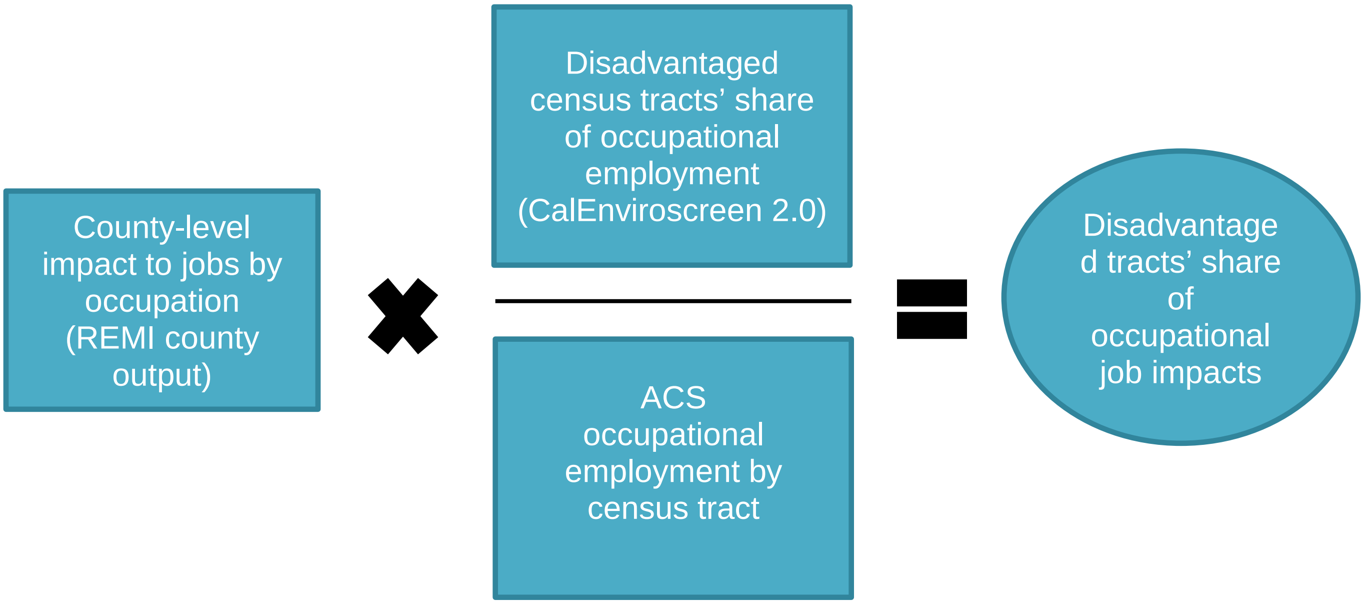


Table 32. California Regional Impacts of the Scoping Plan in 2030 Relative to the Reference Scenario

		Value Added	Wages	Employment
	Central Coast	-0.2% to -0.5%	-0.2% to -0.3%	-0.2% to -0.3%
	North Coast	-0.4% to -0.8%	-0.3% to -0.6%	-0.3% to -0.4%
	Northeast	-0.2% to -0.4%	-0.2% to -0.3%	-0.2% to -0.3%
	Sacramento Valley	-0.2% to -0.3%	-0.1% to -0.2%	-0.2% to -0.2%
	San Francisco Bay	-0.4% to -0.6%	-0.3% to -0.4%	-0.2% to -0.4%
	San Joaquin Valley	-0.6% to -1.0%	-0.5% to -0.8%	-0.4% to -0.6%
	Sierra Nevada	-0.2% to -0.4%	-0.2% to -0.3%	-0.2% to -0.2%
	Southern California	-0.4% to -0.6%	-0.4% to -0.6%	-0.3% to -0.4%
	Statewide	**-0.4% to -0.6%**	**-0.3% to -0.5%**	**-0.3% to -0.5%**

Regional output suggests that the impacts of the Scoping Plan are distributed evenly across California counties. Table 32 shows the range of impacts of the Scoping Plan relative to the Reference Scenario. The regional results are not significantly different and there is no discernable difference in the regional results compared to the statewide results for value add, wages, and employment. Tables 33 through 36 show that there is no discernable difference in the impacts across regions for all scenarios.

Table 33. California Regional Impacts of Alternative 1 in 2030 Relative to the Reference Scenario

		Value Added	Wages	Employment
	Central Coast	-0.7%	-0.8%	-0.9%
	North Coast	-0.9%	-1.0%	-1.1%
	Northeast	-0.6%	-0.6%	-0.7%
	Sacramento Valley	-0.8%	-0.9%	-0.9%
	San Francisco Bay	-1.0%	-0.9%	-0.9%
	San Joaquin Valley	-1.2%	-1.2%	-1.0%
	Sierra Nevada	-0.8%	-0.9%	--0.9%
	Southern California	-1.4%	-1.5%	-1.3%
	Statewide	**-1.2%**	**-1.2%**	**-1.2%**

Table 34. California Regional Impacts of Alternative 2 in 2030 Relative to the Reference Scenario

		Value Added	Wages	Employment
	Central Coast	-0.5%	-0.4%	-0.3%
	North Coast	-0.7%	-0.5%	-0.3%
	Northeast	-0.4%	-0.3%	-0.3%
	Sacramento Valley	-0.3%	-0.2%	-0.2%
	San Francisco Bay	-0.6%	-0.4%	-0.4%
	San Joaquin Valley	-1.1%	-0.9%	-0.6%
	Sierra Nevada	-0.4%	-0.3%	-0.3%
	Southern California	-0.6%	-0.5%	-0.4%
	Statewide	**-0.6%**	**-0.5%**	**-0.4%**

Table 35. California Regional Impacts of Alternative 3 in 2030 Relative to the Reference Scenario

		Value Added	Wages	Employment
	Central Coast	-0.2% to -0.4%	-0.1% to -0.3%	-0.1% to -0.3%
	North Coast	-0.3% to -0.7%	-0.2% to -0.4%	-0.2% to -0.3%
	Northeast	-0.2% to -0.4%	-0.1% to -0.2%	-0.1% to -0.2%
	Sacramento Valley	-0.1% to -0.2%	-0.1% to -0.1%	-0.1% to -0.1%
	San Francisco Bay	-0.2% to -0.5%	-0.1% to -0.3%	-0.1% to -0.2%
	San Joaquin Valley	-0.3% to -0.7%	-0.2% to -0.6%	-0.2% to -0.4%
	Sierra Nevada	-0.1% to -0.3%	-0.1% to -0.1%	-0.1% to -0.1%
	Southern California	-0.2% to -0.5%	-0.2% to -0.4%	-0.1% to -0.3%
	Statewide	**-0.2% to -0.5%**	**-0.2% to -0.3%**	**-0.2% to -0.3%**

Table 36. California Regional Impacts of Alternative 4 in 2030 Relative to the Reference Scenario

		Value Added	Wages	Employment
	Central Coast	-2.8%	-2.8%	-2.2%
	North Coast	-2.5%	-2.2%	-1.8%
	Northeast	-1.2%	-1.1%	1.1%
	Sacramento Valley	-1.7%	-1.8%	-1.5%
	San Francisco Bay	2.4%	-2.2%	-1.8%
	San Joaquin Valley	-4.6%	-4.3%	-3.1%
	Sierra Nevada	-1.8%	-1.8%	-1.6%
	Southern California	-2.6%	-2.8%	-2.1%
	Statewide	**-2.7%**	**-2.6%**	**-2.1%**

While there is no discernable difference in the economic impact across regions in California for the Scoping Plan, Alternative 1, Alternative 2, and Alternative 3, there is a larger regional impact in the San Joaquin Valley under Alternative 4. As Alternative 4 (as modeled) includes a reduction in industrial production, declines in employment, wages, and value add are anticipated in regions with strong industrial sectors. In addition, the overall impact of Alternative 4 on the California economy is much more significant than the Scoping Plan and other alternatives.

The same findings hold when estimating the impact on disadvantaged communities. There is no discernable difference between the impact to disadvantaged communities relative to the overall region in which they are located for the Scoping Plan and all alternatives with the exception of Alternative 4. Tables 37 through 41 show the employment impacts of each policy scenario for each region as well as disadvantaged communities within those regions. Under Alternative 4, the slowing of employment growth in the San Joaquin Valley as well as in disadvantaged communities in the San Joaquin Valley is higher (though still a relatively small impact) than for other regions.

Table 37. Employment Impacts of Scoping Plan on DACs in 2030 Relative to the Reference Scenario

		Overall Impact	Disadvantaged Communities
	Central Coast	-0.2% to -0.3%	-0.1% to -0.2%
	North Coast	-0.3% to -0.4%	--
	Northeast	-0.2% to -0.3%	--
	Sacramento Valley	-0.2% to -0.2%	-0.2% to -0.2%
	San Francisco Bay	-0.2% to -0.4%	-0.3% to -0.4%
	San Joaquin Valley	-0.4% to -0.6%	-0.3% to -0.5%
	Sierra Nevada	-0.2% to -0.2%	--
	Southern California	-0.3% to -0.4%	-0.3% to -0.5%
	Statewide	**-0.3% to -0.5%**	**-0.3% to -0.4%**

Table 38. Employment Impacts of Alternative 1 on DACs in 2030 Relative to the Reference Scenario

		Overall Impact	Disadvantaged Communities
	Central Coast	-0.9%	-0.9%
	North Coast	-1.1%	--
	Northeast	-0.7%	--
	Sacramento Valley	-0.9%	-1.0%
	San Francisco Bay	-0.9%	-1.1%
	San Joaquin Valley	-1.0%	-1.0%
	Sierra Nevada	--0.9%	--
	Southern California	-1.3%	-1.3%
	Statewide	**-1.2%**	**-1.2%**

Table 39. Employment Impacts of Alternative 2 on DACs in 2030 Relative to the Reference Scenario

		Overall Impact	Disadvantaged Communities
	Central Coast	-0.3%	-0.3%
	North Coast	-0.3%	--
	Northeast	-0.3%	--
	Sacramento Valley	-0.2%	-0.2%
	San Francisco Bay	-0.4%	-0.5%
	San Joaquin Valley	-0.6%	-0.5%
	Sierra Nevada	-0.3%	--
	Southern California	-0.4%	-0.5%
	Statewide	**-0.4%**	**-0.4%**

Table 40. Employment Impacts of Alternative 3 on DACs in 2030 Relative to the Reference Scenario

	Overall Impact	Disadvantaged Communities
Central Coast	-0.1% to -0.3%	-0.1% to -0.2%
North Coast	-0.2% to -0.3%	--
Northeast	-0.1% to -0.2%	--
Sacramento Valley	-0.1% to -0.1%	-0.1% to -0.1%
San Francisco Bay	-0.1% to -0.2%	-0.1% to -0.3%
San Joaquin Valley	-0.2% to -0.4%	-0.2% to -0.3%
Sierra Nevada	-0.1% to -0.1%	--
Southern California	-0.1% to -0.3%	-0.1% to -0.3%
Statewide	**-0.2% to -0.3%**	**-0.1% to -0.3%**

Table 41. Employment Impacts of Alternative 4 on DACs in 2030 Relative to the Reference Scenario

	Overall Impact	Disadvantaged Communities
Central Coast	-2.2%	-2.2%
North Coast	-1.8%	--
Northeast	1.1%	--
Sacramento Valley	-1.5%	-1.6%
San Francisco Bay	-1.8%	-2.2%
San Joaquin Valley	-3.1%	-2.9%
Sierra Nevada	-1.6%	--
Southern California	-2.1%	-2.3%
Statewide	**-2.1%**	**-2.3%**

4. Uncertainty Analysis

This section presents an uncertainty analysis that examines the range of cost and emissions that could result under the Scoping Plan and each alternative. The analysis was conducted by first characterizing the major sources of uncertainty and then evaluating the combined effects of the uncertainties using Monte Carlo analysis methods.[50] The estimates from the Monte Carlo analysis are referred to as "simulated values."[51] The analysis provides insight into the range of outcomes that could occur for each scenario, and enables the ranges to be compared across the scenarios. The analysis also highlights which of the uncertainties are potentially most influential on the outcomes. The simulated range of outcomes may be instructive for designing policy approaches for future midcourse policy adjustments to address simulated conditions that may be considered unacceptable, such as insufficient emission reductions being achieved.

The uncertainty analysis relies on the PATHWAYS estimates to characterize the Reference scenario emissions and the cost and emission reduction associated with each prescriptive measure under the Scoping Plan and under each alternative. The PATHWAYS values are taken as "point estimates" around which uncertainty is applied in this analysis. The performance of the emission pricing mechanisms (cap-and-trade and carbon taxes) is characterized using a range of prices based on the proposed Cap-and-Trade Program Auction Reserve Price (C+T Floor Price) and Allowance Price Containment Reserve (APCR) price (C+T Reserve Price), described above.

Major Sources of Uncertainty

Reference Scenario and Cumulative Emission Reductions: The Reference Scenario defines the emissions anticipated in the absence of the measures in the Scoping Plan and the alternatives. The cumulative emission reductions required to achieve the 2030 emission limit is the difference between the Reference scenario emissions and a straight line emissions decline to the 2030 emissions limit for the period 2021 to 2030. The PATHWAYS Reference scenario and the straight line decline are shown in Figure 7. The cumulative emission reductions required are the area between the blue Reference scenario and the red straight line for the period 2021 to 2030, which is estimated to be 680 $MMTCO_2e$ in the PATHWAYS analysis.

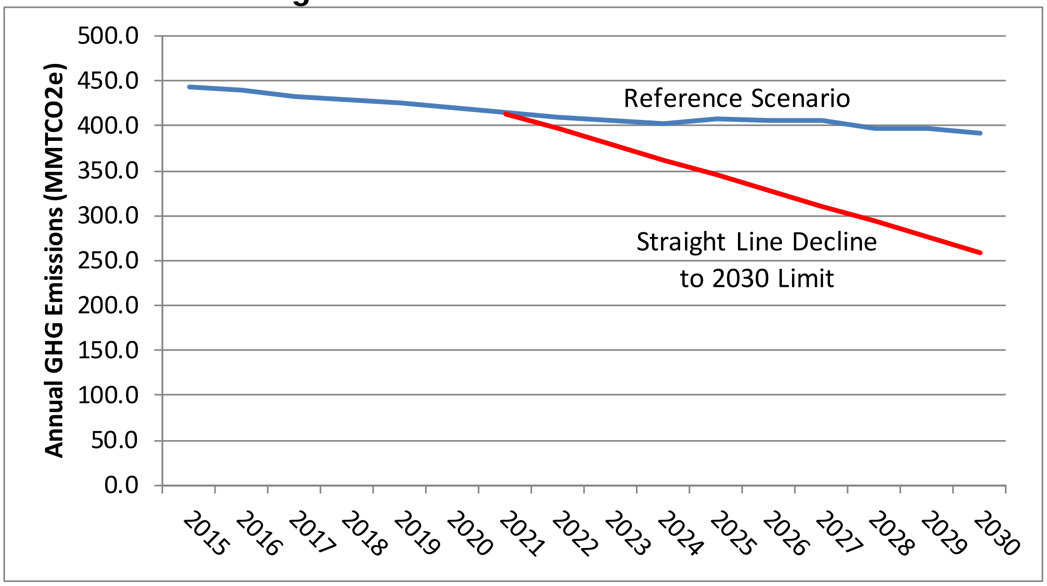
The Reference scenario emissions are uncertain. The economy could grow faster or slower than expected and the emission intensity of the economy could be higher or lower than expected. These uncertainties in the Reference scenario translate into

[50] The spreadsheet used in the sensitivity analysis can be accessed at: https://www.arb.ca.gov/cc/scopingplan/meetings/meetings.htm.

[51] Monte Carlo analysis simulates a range of outcomes that reflect the uncertainty in the analysis input variables. The uncertainty of each input variable is characterized using a probability distribution. A simulated value for each input variable is generated by randomly drawing from the distribution. The simulation is repeated for multiple iterations, which form the range of outcomes that quantifies the combined effect of the uncertainty in the input variables.

uncertainty in the cumulative emission reduction needed to achieve the 2030 emission limit.

Figure 7: PATHWAYS Reference Scenario Emissions and Straight Line Decline to 2030 Emission Limit



To characterize the uncertainty in the rate of economic growth, CARB examined California Gross Domestic Product (GDP) growth rates for all 15-year periods from 1987 to 2015. Data from the Bureau of Economic Analysis show that the fastest growth rate experienced over any 15-year stretch was 3.8 percent per year, and the slowest was 2.1 percent per year.[52] The REMI Reference scenario has a 2.4 percent growth rate for 2015 to 2030. To simulate the economic growth rate, the historical range was used as bounds for the uncertainty as follows: the simulated rate was given an equal likelihood of being below or above the REMI Reference scenario rate of 2.4 percent; if the rate is below 2.4 percent it is uniformly distributed (i.e., equally likely) between 2.1 percent and 2.4 percent; if the rate is above 2.4 percent it is uniformly distributed between 2.4 percent and 3.8 percent. The average simulated GDP growth rate using these inputs was 2.7 percent per year for 2015 to 2030.

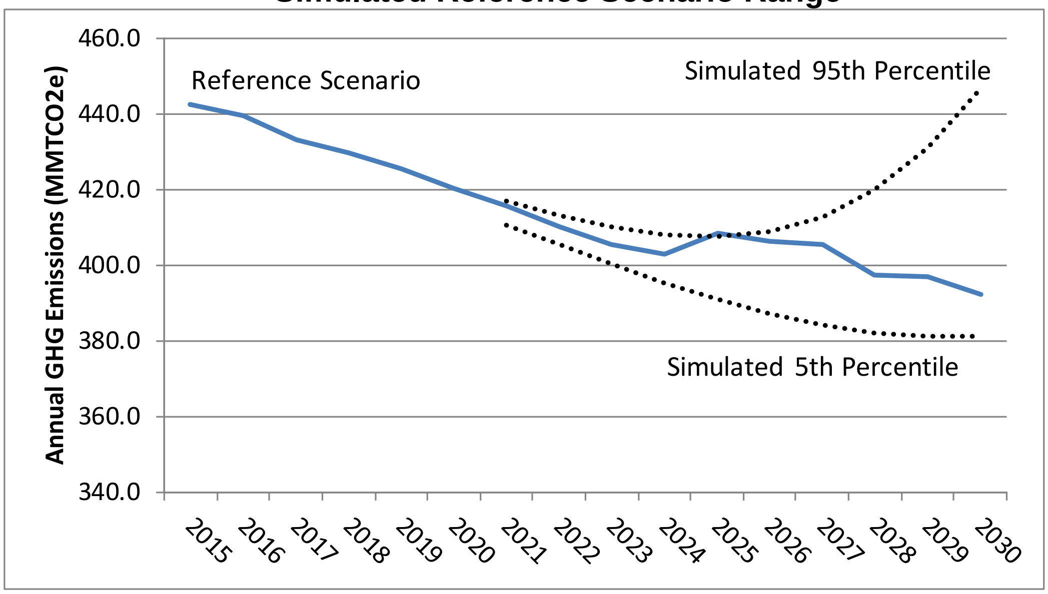
The next step for simulating the Reference scenario emissions was to characterize the emission intensity of the economy, in terms of emissions per GDP. Using the PATHWAYS Reference scenario emissions and the REMI Reference scenario GDP, the emission intensity of the economy was calculated. The analysis showed that emission intensity is expected to be lower at higher levels of GDP, which is consistent with the observation that the emission intensity of the California economy has declined historically as the economy grew. This relationship between emission intensity and GDP can be applied to the simulated values of GDP to simulate an emission intensity that is consistent with the simulated level of GDP in each year.

[52] The GDP data were in real chained dollars. The Bureau of Economic Analysis data were accessed at: https://www.bea.gov/iTable/iTable.cfm?reqid=70&step=1&isuri=1&acrdn=2#reqid=70&step=1&isuri=1.

The emission intensity to GDP relationship is itself uncertain. To recognize this uncertainty, a range of uncertainty of $\pm$5 percent in the intensity was added. This uncertainty phases in during the period 2015 to 2030. The sensitivity of the results to this uncertainty assumption is described below.

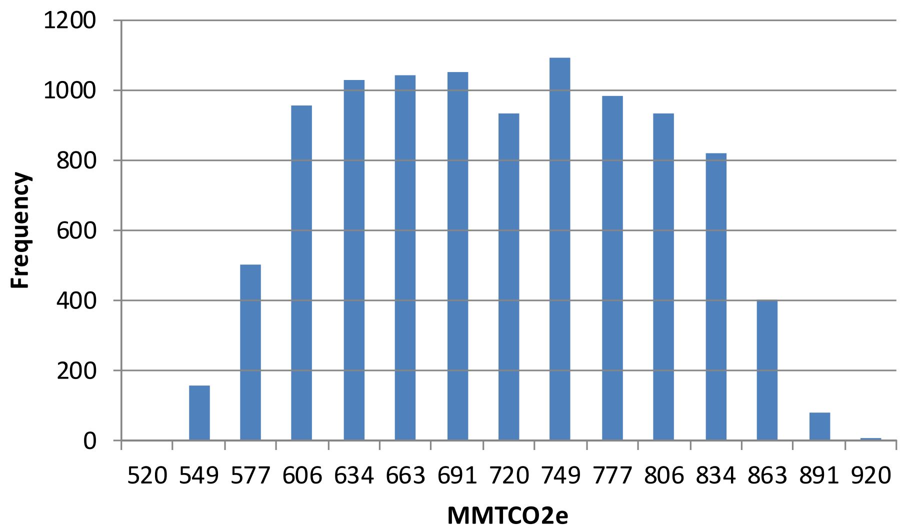
The combined impact of the GDP growth rate uncertainty and the emission intensity uncertainty is shown in Figure 8. The figure shows the 5^{th} and 95^{th} percentile simulated values for Reference scenario emissions, representing the range of 90 percent of the simulated values. As shown in the figure, the uncertainty assumptions indicate that there is opportunity for the Reference scenario emissions to be much larger in 2030 than the PATHWAYS-based point estimate.

Figure 8: PATHWAYS Reference Scenario and Simulated Reference Scenario Range



The simulated Reference scenario emissions were then used to estimate the cumulative emission reduction required to achieve the straight-line reduction to the 2030 emission limit (shown in Figure 7). The simulated required cumulative emission reduction averages 700 $MMTCO_2e$ with a 5^{th} and 95^{th} percentile range of $\pm$135 $MMTCO_2e$. Figure 9 shows the distribution of simulated cumulative emission reduction requirements. As shown in the figure, the distribution is fairly flat in the middle, meaning that the values are somewhat equally likely to be simulated between the 5^{th} and 95^{th} percentile values.

Figure 9: Simulated Cumulative Emission Reduction Required to Achieve 2030 Emission Limit
(n = 10,000 iterations)



Frequency is the number of observations out of the 10,000 simulated iterations that fall within the category. For example, the height of the bar above 606 $MMTCO_2e$ is about 950 observations, meaning that 950 simulated values are greater than 577 $MMTCO_2e$ and less than 606 $MMTCO_2e$.

From this simulation, there is nearly a 60 percent likelihood that cumulative emission reductions required to achieve the 2030 emission limit will be larger than the 680 $MMTCO_2e$ point estimate from the PATHWAYS analysis. While the 95^{th} percentile appears substantial (about 835 $MMTCO_2e$) compared to the point estimate (680 $MMTCO_2e$), the growth in California fossil fuel use during some past 15-year periods was rapid enough to lead to larger rates of emission increases. However, policies are currently in place that limit future growth in emissions, making comparisons with past emission growth rates less instructive. Existing policies that limit emissions growth include the 33 percent Renewable Portfolio Standard, the Advanced Clean Car Standards, the Low Carbon Fuel Standard, and SB 375 and regional Sustainable Community Strategies.

Nevertheless, unexpected emissions growth could occur, and could result from discrete events. For example, the Reference scenario incorporates the anticipated conversion of the Intermountain Power generating station from coal to natural gas by 2028. If that conversion were delayed, emissions could be about 5 $MMTCO_2e$ per year greater than expected, or about 15 $MMTCO_2e$ cumulatively for the three years 2028 through 2030. Similarly, an operating disruption at a nuclear generating station could result in higher than expected emissions. The Reference scenario already incorporates the closure of the Diablo Canyon generating station. However, if the electricity supplying California from the Palo Verde nuclear generating station unexpectedly needed to be replaced with natural gas generation, California emissions could be about 4 $MMTCO_2e$ higher each year, or about 40 $MMTCO_2e$ cumulatively if this occurred for all of the 10 years from 2021 to 2030. Large new industrial facilities could also increase emissions in ways not reflected in the Reference scenario. For example, a new liquefied natural gas (LNG) export terminal could have emissions on the order of 1 to 3 $MMTCO_2e$ per year (depending on size and technology), with cumulative emissions of 10 to 30 $MMTCO_2e$ over a 10-year period.[53] The simulated 95th percentile value appears to be more than large enough to incorporate the potential for events such as these to occur.

Fossil Fuel Prices: There is uncertainty in future oil and natural gas prices. The PATHWAYS analysis shows that the cost of reducing emissions is sensitive to these prices because the value of fuel savings is an important factor in the PATHWAYS cost estimates. The PATHWAYS scenarios use fossil fuel price projections from the Annual Energy Outlook (AEO) 2015 reference case. To estimate the impact of changes in future fuel prices on the incremental cost of the scenarios, the AEO low and high oil and natural gas price cases are used to create a range of future fuel costs.[54] To simulate fossil fuel prices, the AEO 2015 range was used as bounds for the uncertainty as follows: the simulated fossil fuel prices were given an equal likelihood of being below or above the AEO reference case; if the prices are below the reference case, they are uniformly distributed between the reference case and the low case; if the prices are above the reference case, they are uniformly distributed between the reference case and the high case. Using this approach, the average of the simulated fossil fuel prices is about 12.5 percent above the AEO reference case prices, with the 5th percentile value at 45 percent below the reference case and the 95th percentile at 90 percent above the reference case in 2030.

Prescriptive Measures Cost Per Metric Ton: The PATHWAYS analysis provides estimates of the costs of the prescriptive measures included in the Scoping Plan and each alternative. Uncertainty is applied to the PATHWAYS estimates to conduct this analysis.

The cost per ton for each measure was estimated for the period 2021 to 2030 as follows:

- The cost and emission impact of each measure for 2021 to 2030 was estimated using PATHWAYS.
- The annual costs of each measure were discounted to 2021 using the discount rate used in PATHWAYS to levelize capital costs (10 percent). This discounted cost is therefore the total investment required to achieve the measure's emission

[53] See, for example, *LNG Production in British Columbia: Greenhouse Gas Emissions Assessment and Benchmarking*, Delphi Group, May 2013, accessed at: http://www2.gov.bc.ca/assets/gov/environment/climate-change/ind/lng/lng_production_in_british_columbia_-_ghg_emissions_assessment_and_benchmarking_-_may_2013.pdf.

[54] The high and low fuel price sensitivity ranges are derived from the AEO 2016 reference case, and are applied as ratios to the base case fuel price assumptions. The AEO 2015 report is available at: http://www.eia.gov/outlooks/aeo/pdf/0383(2015).pdf and the AEO 2016 report is available for download at: http://www.eia.gov/outlooks/aeo/pdf/0383(2016).pdf.

reduction from 2021 to 2030 (including both incremental capital costs and incremental fuel savings/expenditures).

- Each measure's discounted cost is divided by its cumulative emission reduction from 2021 to 2030. The resulting value for each measure is the cost per ton used in the sensitivity analysis.

Multiplying this cost per ton estimate for each measure by each measure's cumulative emission reductions from 2021 to 2030 results in the total discounted cost of achieving the emission reductions over the 10-year period. Because this cost per ton estimate covers the entire period 2021 through 2030 and includes discounting, this cost per ton estimate is not comparable to the single year 2030 cost per ton values reported elsewhere in the Scoping Plan.

As described above, Alternative 4 includes reductions in industrial output in order to achieve the individual facility emission caps. The cost of the reduced output was estimated in REMI as the lost "value added" from the affected industry sectors. This value-added cost was discounted to 2021 and added to the PATHWAYS measure cost estimates for Alternative 4.

Two types of uncertainty were considered in the cost per ton estimates. First, the uncertainty in fossil fuel prices was incorporated into the cost per ton estimates by calculating the change in the cost per ton as a function of the change in fossil fuel prices. Because the uncertainty range for fossil fuel prices is large, the uncertainty in the cost per ton estimates for some measures is also large. For each iteration of the simulation, fossil fuel prices were simulated once from its distribution so that all measures would be subject to the same fossil fuel prices in the iteration.

Second, uncertainty in the capital costs of each measure was included by assuming capital costs could be ±20 percent of the estimates used in the PATHWAYS analysis. The capital cost uncertainty was applied to each measure individually and phased in through 2030.

Table 42 summarizes the simulated costs per ton for the set of prescriptive measures in the Scoping Plan and each alternative. As shown in the table, the ranges in cost per ton within each scenario can be substantial. The comparison across scenarios is also instructive. The Scoping Plan and Alternative 2 have identical prescriptive measures, so they have the same cost per ton estimates. Alternative 3 omits the refining sector prescriptive measure and does not increase the LCFS carbon intensity above the current 10 percent requirement in 2020. Alternative 1 and Alternative 4 have the most aggressive prescriptive measures, which result in the highest simulated measure cost per ton. Alternative 4 was evaluated with and without the cost of the lost value added from reductions in industrial output. As shown in the table, the cost per ton of the lost value added is much larger than the cost per ton of the prescriptive measures themselves.

Prescriptive Measures Emission Reductions: The PATHWAYS analysis provides estimates of the cumulative emission reduction achieved by each prescriptive measure included in the Scoping Plan and the alternatives for the period 2021 to 2030. To apply uncertainty to the PATHWAYS estimates, two factors were considered:

- Each prescriptive measure has the potential to underperform or overperform relative to the PATHWAYS estimates of cumulative emission reductions achieved.
- The emission reduction achieved by each prescriptive measure may be affected by how the economy grows, and whether emissions addressed by the measure are growing faster or slower than expected.

Table 42: Simulated Cost Per Ton for Prescriptive Measures: Discounted Costs Divided by Cumulative Emission Reductions

Scenario	Average	5th Percentile	95th Percentile
Scoping Plan	$2	-$18	$16
Alternative 1	$69	$59	$82
Alternative 2	$2	-$18	$16
Alternative 3	-$9	-$34	$9
Alternative 4[a]	$56	$43	$65
Alternative 4[b]	$355	$278	$436

a. Alternative 4 (Cap-and-Tax) costs simulated without the cost of the lost value added from reductions in industrial output.
b. Alternative 4 (Cap-and-Tax) costs simulated with the cost of the lost value added from reductions in industrial output.
Simulation of 10,000 iterations. See text for definition of cost per ton.

Generally, the PATHWAYS estimates of the measure emission reductions assume that the regulatory programs motivating the emission reductions are fully implemented in a timely manner. Consequently, the opportunity for measures to overperform and reduce emissions more than the PATHWAYS estimates may be limited, given the amount of time required for measure implementation. The potential overperformance was therefore limited to be a 5 percent or 10 percent increase in the emission reduction achieved by each measure.

The risk of underperformance may be greater, and could have a more significant impact on the ability of the Scoping Plan and the alternatives to achieve the cumulative emission reductions needed to achieve the 2030 emission limit. Underperformance estimates were assigned that range from -10 percent for the Renewable Portfolio Standard (i.e., emission reduction 10 percent lower than expected) to -20 percent for the LCFS to -50 percent for most of the industrial measures. The most aggressive industrial measures were assigned a potential underperformance of -75 percent. The single largest prescriptive measure, the Short Lived Climate Pollutant Plan, was assigned an underperformance risk of -25 percent and a potential overperformance value of 5 percent.

The performance of each measure was simulated as being uniformly distributed between its underperformance value and its overperformance value. For example, the Short Lived Climate Pollutant Plan was simulated to perform uniformly between -25 percent and +5 percent of the PATHWAYS estimate for this measure. Because the underperformance risk is assumed to be greater than the overperformance potential for each measure, the measures individually and collectively underperform on average compared to the PATHWAYS estimates. This underperformance bias in the uncertainty analysis reduces the simulated likelihood that the Scoping Plan and the alternatives will reduce emissions sufficiently to achieve the 2030 emission limit. The simulated results indicate the potential magnitude of midcourse policy adjustments that could be needed to compensate for the underperformance of prescriptive measures.

The second uncertainty factor is the manner in which economic growth affects the performance of the measures. When Reference scenario emissions are simulated to be higher than expected, measures may reduce emissions more than otherwise expected. For example, if economic growth pushes up the emissions from passenger vehicles in the Reference scenario, the reductions from the transportation measures may also be larger than expected because the measures would apply to larger Reference scenario emissions. Unfortunately, a quantitative basis for assessing the relationship between measure performance and Reference scenario emissions was not available. The following assumptions were used to characterize this relationship:

- A "scaling factor" was assigned to each measure to relate its emission reduction potential to the extent to which the simulated Reference Scenario emissions deviated from the PATHWAYS Reference scenario emissions. A scaling factor of 0.5 means that at 10 percent change in the Reference scenario emissions leads to a 5 percent change in the expected emission reduction from the measure.
- Scaling factors were assigned as follows:
    - For industrial measures, the scaling factor was assumed to be 0.25, so that a 10 percent increase in the Reference scenario emissions results in a 2.5 percent increase in the industrial measure emission reductions. This value was assigned based on the expectation that industrial measures apply primarily to existing facilities.
    - For electricity and energy efficiency measures, the scaling factor was assumed to be 0.5, so that a 10 percent increase in the Reference Scenario emissions results in a 5 percent increase in the measure emission reductions. This value was assigned based on the expectation that faster economic growth could affect the rate of electrification in the Reference scenario.
    - For transportation measures, the scaling factor was assumed to be 0.75, so that a 10 percent increase in the Reference scenario emissions results

in a 7.5 percent increase in the measure emission reductions. This value was assigned based on the expectation that faster economic growth could lead to more passenger and freight vehicle use.
- For the Short Lived Climate Pollutant Plan, the scaling factor was assumed to be zero. This value was assigned based on the expectation that economic growth will not affect significantly the emissions sources covered by this measure.

Because the scaling factors are all less than 1.0, the measures adjust by less than the changes in the Reference scenario. Consequently, when the Reference scenario emissions are simulated to be higher than expected, the prescriptive measures do not compensate proportionately to address the increased emissions.

Finally, as described above, Alternative 4 was modeled to include reductions in industrial output. Because this alternative includes individual facility emission caps, the amount by which output is simulated to be reduced is adjusted to reflect the underperformance or overperformance of the industrial prescriptive measures. If the industrial prescriptive measures are simulated to overperform, the industrial output reductions are simulated to be less than expected by a compensating amount. The opposite is simulated if the industrial prescriptive measures underperform. Because the prescriptive measures underperform on average, the simulated industrial output reductions are larger on average.

Table 43 presents the combined impact of these uncertainties on the emission reductions achieved by the prescriptive measures in each scenario. The simulated emission reductions are summarized relative to the emission reductions calculated in PATHWAYS. As shown in the exhibit, on average the measures underperform by about 6 percent to 8.5 percent. Within each scenario, the performance range is roughly ±10 percent relative to the average.

Table 43: Simulated Prescriptive Measure Emission Reductions Relative to the Reductions Calculated in PATHWAYS

Scenario	Average	5th Percentile	95th Percentile
Scoping Plan	-6.9%	-16.2%	2.6%
Alternative 1	-8.1%	-16.8%	0.6%
Alternative 2	-6.9%	-16.2%	2.6%
Alternative 3	-6.1%	-15.8%	3.5%
Alternative 4[a]	-8.5%	-17.1%	0.4%

Simulated emission reductions over the period 2021 through 2030.
Simulation of 10,000 iterations.

For the Scoping Plan, PATHWAYS calculated that the prescriptive measures would reduce emissions by about 501 $MMTCO_2e$ cumulatively from 2021 through 2030. The average simulation for the Scoping Plan was 6.9 percent less, or about 466 $MMTCO_2e$, confirming that the uncertainty assumptions result in the prescriptive measures underperforming on average. The 5th percentile was 16.2 percent less, or about 420 $MMTCO_2e$, whereas the 95th percentile was 2.6 percent more, or about 514 $MMTCO_2e$.

Emissions Pricing Mechanisms: Four of the five scenarios include emissions pricing, either through a Cap-and-Trade Program or a carbon tax. The cumulative emission reduction motivated by these pricing mechanisms can be important contributors to the total emission reduction achieved in the scenarios. The estimates of the emission reductions achieved through pricing are uncertain.

As discussed above, in the Scoping Plan and Alternative 3, the Cap-and-Trade Program is expected to deliver the emission reduction, over and above the reduction achieved by the prescriptive measures, needed to reach the 2030 emission limit. Because the emission reduction achieved by the prescriptive measures is uncertain, the emission reduction demanded of the Cap-and-Trade Program is also uncertain. The cost and ability of the Cap-and-Trade Program to deliver emission reductions as a component of the Scoping Plan is characterized as follows in this uncertainty analysis.

- The allowance price is assumed to range between the C+T Price Floor and C+T Reserve Price as described above.
- Based on the PATHWAYS analysis, the point estimate of the cumulative emission reduction required of the Cap-and-Trade Program as part of the Scoping Plan is about 179 $MMTCO_2e$. Based on this expectation, emission reduction of 180 $MMTCO_2e$ was assumed to be achievable at allowance prices midway between the floor and ceiling prices.
- If allowance prices remained at the floor price from 2021 through 2030, cumulative emission reductions were assumed to be 80 $MMTCO_2e$, or 10 $MMTCO_2e$ less than half the point estimate.
- If allowance prices remained at the ceiling price from 2021 through 2030, cumulative emission reductions were assumed to be 350 $MMTCO_2e$, or 10 $MMTCO_2e$ less than double the point estimate.

These assumptions specify the emission reduction response to allowance prices in this analysis. This characterization of the Cap-and-Trade Program relies on best estimates of the expectation that the necessary emission reductions can be achieved by the Cap-and-Trade Program within the range of the C&T Floor Price and the C&T Reserve Price, and should not be used as a forecast of emission responses to allowance prices. The sensitivity of the uncertainty analysis results to these estimates is discussed below.

To characterize the uncertainty in these values, a uniform range of $\pm$20 percent is applied to each of the achievable emission reduction values. For example, the maximum emission reduction achievable at the C&T Reserve Price is uniformly distributed between 280 $MMTCO_2e$ and 420 $MMTCO_2e$. The sensitivity of the results to this assumed uncertainty range of ±20 percent is discussed below.

The performance of the Cap-and-Trade Program in the Scoping Plan is simulated in each iteration as follows:

- The cumulative emission reduction required of the Cap-and-Trade Program is calculated as the simulated cumulative emission reduction required to achieve the 2030 emission limit minus the cumulative emission reduction simulated for the prescriptive measures.
- The emission reduction achievable at the C&T Floor Price, C&T Reserve Price, and midway is simulated from the ±20 percent uncertainty range.
- If the emission reduction required is less than the simulated emission reduction achievable at the C&T Floor Price, then the allowance price is estimated to be the C&T Floor Price and the emission reduction achievable at the C&T Floor Price is taken as the simulated emission reduction. Under this circumstance, the Cap-and-Trade Program delivers more emission reduction than is needed to achieve the 2030 emission limit.
- If the emission reduction required is greater than the simulated emission reduction achievable at the C+T Reserve Price, then the allowance price is estimated to be the C+T Reserve Price and the emission reduction achievable at the C+T Reserve Price is taken as the simulated emission reduction. Under this circumstance, the Cap-and-Trade Program delivers fewer emission reductions than needed to achieve the 2030 emission limit.
- If the emission reduction required falls between the simulated emission reduction achievable at the C+T Floor Price and C+T Reserve Price, then the allowance price is estimated assuming emission reductions are achieved linearly within the C+T Floor Price, midway, and C+T Reserve Price. Under this circumstance, the Cap-and-Trade Program delivers exactly the emission reduction needed to achieve the 2030 emission limit.

As discussed above, the uncertainty in the Reference scenario emissions was simulated on average to require greater cumulative emission reductions from 2021 through 2030 to achieve the 2030 emission limit than was calculated in the PATHWAYS analysis. Also, the prescriptive measures were simulated on average to underperform compared to the PATHWAYS analysis estimates. As a result of these two factors, the emission reductions required from the Cap-and-Trade Program within the Scoping Plan was simulated to be 233 $MMTCO_2e$ on average, with a 5^{th} percentile estimate of 123 $MMTCO_2e$ and a 95^{th} percentile estimate of 346 $MMTCO_2e$. The simulated average is about 30 percent larger than the 179 $MMTCO_2e$ required of the Cap-and-Trade Program based on the PATHWAYS analysis, and the 95^{th} percentile estimate is nearly double. Given that the Cap-and-Trade Program emission reduction has an upper bound ranging from 280 $MMTCO_2e$ to 420 $MMTCO_2e$, the Cap-and-Trade Program was simulated to be unable to deliver the necessary emission reduction in a portion of the simulated iterations.

The simulated shortfall in emission reduction by the Cap-and-Trade Program in the Scoping Plan is caused by the limited range of allowance prices examined in the analysis. If higher allowance prices were included, additional emission reduction would be achieved by the Program. However, for this analysis the maximum simulated the allowance price was set at the C+T Reserve Price. Consequently, the likelihood of delivering insufficient emission reductions can also be interpreted as the likelihood that the allowance price could exceed the C+T Reserve Price. Additionally, in the context of this modeling, the results could be considered an indication of the likelihood that midcourse policy adjustments may be needed to maintain allowance prices below the C+T Reserve Price. These results are presented below and highlight the tradeoff between achieving greater emission reductions and allowance price.

Like the Scoping Plan, Alternative 3 also relies on a Cap-and-Trade Program. Because Alternative 3 has fewer prescriptive measures, the Cap-and-Trade Program is called upon to deliver more emission reductions: 286 $MMTCO_2e$ on average, with a 5th percentile value of 172 $MMTCO_2e$ and a 95th percentile value of 402 $MMTCO_2e$. These values are about 50 $MMTCO_2e$ greater than the emission reductions required from cap-and-trade under the Scoping Plan.

Because fewer prescriptive measures are included in Alternative 3, some of the emission reductions that could have been achieved by the prescriptive measures may be achieved by the Cap-and-Trade Program. To reflect these potential additional emission reductions, the achievable emission reductions at the floor price, ceiling price and midway were increased as follows: emission reductions achievable at the C+T Floor Price increase by 8.0 $MMTCO_2e$; emission reductions achievable at the midway price increase by 18 $MMTCO_2e$; and emission reductions achievable at the C+T Reserve Price increase by 35 $MMTCO_2e$. These assumed increases in achievable emission reductions compared to the Scoping Plan assumptions are smaller than the increase in the emission reduction demanded of the Cap-and-Trade Program in Alternative 3.

The performance of the Cap-and-Trade Program in Alternative 3 proceeds in the same manner as in the Scoping Plan. The uncertainty range of $\pm$20 percent is also applied to the Cap-and-Trade Program achievable emission reductions in Alternative 3.

Alternative 2 and Alternative 4 both include a carbon tax. The achievable emission reductions at the range of prices used in the Scoping Plan and Alternative 3 are used as the basis for simulating the performance of the carbon tax.

Alternative 2 includes the same prescriptive measures as the Scoping Plan, so the achievable emission reductions at the range of carbon prices are assumed to be the same. As discussed above, the Alternative 2 carbon tax could be set to mirror exactly the emission reductions achieved by the Cap-and-Trade Program in the Scoping Plan. Under those assumptions, the Alternative 2 uncertainty analysis results would be identical to the Scoping Plan. To provide a contrast, a carbon tax was examined in Alternative 2 that is set to mirror the SC-CO_2 and starts at $33.80 per metric ton in 2021 and increase by 10 percent per year through 2030 (all in 2015 dollars). This 10-year period of carbon prices discounts to the same present value as a constant carbon price of $50 per metric ton, representing the SC-CO_2 value in 2030.[55] The carbon tax in Alternative 2 does not adjust based on the emission reduction required to be achieved by the pricing mechanism. Rather, it is used for all iterations in the simulation. The cumulative emission reduction achieved by the Alternative 2 carbon tax is simulated using the price response defined in the Scoping Plan, including the ±20 percent uncertainty applied to the price-motivated achievable emission reductions.

Alternative 4 includes a carbon tax in combination with aggressive prescriptive measures. The carbon tax in Alternative 4 is simulated to be $52 per metric ton (2015 dollars). The tax rate does not adjust based on other simulated values. Because Alternative 4 includes aggressive prescriptive measures, the expectation is that there is less emission reduction likely to be motivated by the carbon tax than would otherwise be expected. A cumulative emission reduction of 50 MMTCO_2e is assumed to be achieved by the carbon tax under Alternative 4. The achievable emission reduction is subject to the ±20 percent uncertainty applied in the other scenarios.

The cost of each pricing mechanism is estimated as the simulated emission reduction achieved by the mechanism times the simulated price necessary to motivate the emission reduction. This cost estimate is almost certainly an over-estimate because the carbon price would reflect the cost of the most expensive action taken to reduce emissions. An upward-sloping marginal abatement cost curve would indicate that the average cost would be less than the marginal cost. By using the simulated price to calculate the cost of reducing emissions, this analysis biases the costs of the pricing mechanisms upward.

Uncertainty Analysis Results

The results of the uncertainty analysis are presented in terms of emission reductions achieved and the costs of achieving the emission reductions. The sensitivity of the results to key input assumptions is discussed throughout.

Figure 10 presents the simulated cumulative emission reduction achieved by the Scoping Plan. On average, the Scoping Plan is simulated to achieve about 700 MMTCO_2e of cumulative emission reductions from 2021 to 2030, with a 5th percentile estimate of 570 MMTCO_2e and a 95th percentile estimate of about 824 MMTCO_2e. At this level of performance, the Scoping Plan is simulated to achieve the emission reduction needed to reach the 2030 emission limit with a likelihood of about 92 percent. This means that in about 8 percent of the simulated iterations, cumulative emission reductions were not sufficient to achieve the straight-line emission reduction in Figure 4. As discussed above, the limit on the maximum allowance price leads to the shortfall in emission reductions needed to achieve the 2030 emission limit.

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[55] The representation of the Alternative 2 Carbon Tax in the uncertainty analysis differs from the approach used for the REMI analysis. Because the uncertainty analysis is performed on cumulative basis, the differences in representation do not significantly affect the results.

In the context of this analysis, midcourse policy adjustments, such as enhancing the effectiveness of the prescriptive measures or enabling higher allowance prices, could be designed to ensure that the emission reductions needed to reach the 2030 emission limit are achieved.

Figure 11 shows the performance of the four alternative scenarios. Alternative 3, All Cap-and-Trade, shows the broadest range of emission reduction achieved. Among the alternative scenarios, Alternative 3 is most responsive to the uncertain range of emission reduction required to achieve the 2030 emission limit, which accounts for its range being the broadest.

Alternative 2, Carbon Tax, has the narrowest emission reduction range among the alternatives. The carbon tax is assumed not to adjust in response to the simulated estimate of the cumulative emission reduction needed to achieve the 2030 emission limit. Alternative 1 (in red) and Alternative 4 (in green) are in the middle of the distribution shown in the figure. The emission reduction ranges for these alternatives are driven by the uncertainty in the performance of the prescriptive measures. Alternative 4 has the added emission reduction due to its carbon tax.

Table 44 summarizes the simulated emission performance of the scenarios. The Scoping Plan and Alternative 3 have the highest likelihood of achieving the 2030 emission target, due to the manner in which the Cap-and-Trade Program performs in each. Consequently, these options would be least likely to require midcourse policy adjustments to achieve the 2030 emission target. As discussed above, Alternative 2 could be designed to adjust its carbon tax to mirror the performance of the Scoping Plan. However, in this uncertainty analysis the carbon tax is not responsive to emission reduction requirements.

The impact of several input assumptions on these simulation results was examined. Increasing the emission intensity uncertainty from $\pm$5 percent to $\pm$10 percent widens the range of potential Reference scenario emissions. Figure 12 shows the increased range. At this level of uncertainty, the range of the cumulative emission reduction needed to achieve the 2030 emission limit is about 700 $MMTCO_2e$ $\pm$250 $MMTCO_2e$. As a result of this increased range, the simulated likelihood of achieving the 2030 emission limit is reduced, as shown in Table 45.

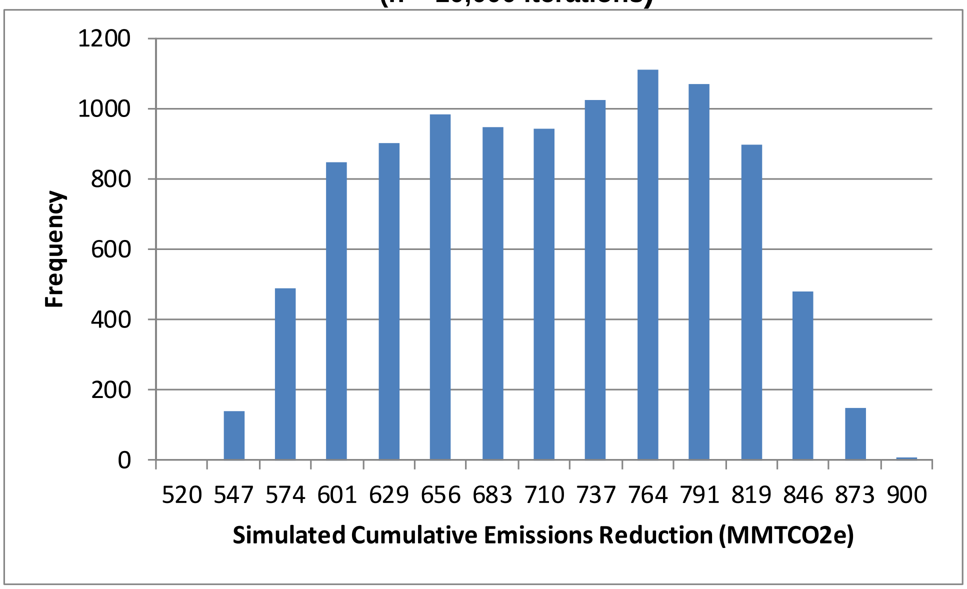
The impact of increasing the economic growth rate to 3.8 percent in all iterations increases the simulated cumulative emission reduction needed to achieve to 2030 emission limit to about 760 $MMTCO_2e$ $\pm$130 $MMTCO_2e$. This 3.8 percent growth rate is the fastest rate observed in California in any 15-year stretch from 1987 to 2015. Table 45 shows the likelihood of achieving the 2030 emission limit under the Scoping Plan and each alternative with this input assumption.

The sensitivity of the emission results to the ability of carbon prices to motivate emission reductions is examined with two input assumptions, the uncertainty in the price response and the maximum achievable emission reduction at the ceiling price.

Increasing the uncertainty in the price response from ±20 percent to ±40 percent mostly affects the scenarios that rely on cap and trade, including the Scoping Plan and Alternative 3. Similarly, reducing the maximum achievable emission reduction at the C+T Reserve Price from carbon pricing from 350 $MMTCO_2e$ to 250 $MMTCO_2e$ reduces the likelihood that the scenarios that rely on the Cap-and-Trade Program will achieve the 2030 emission limit. This input assumption has the largest impact on the likelihood of achieving the 2030 emission limit among those examined. The results are shown in Table 45.

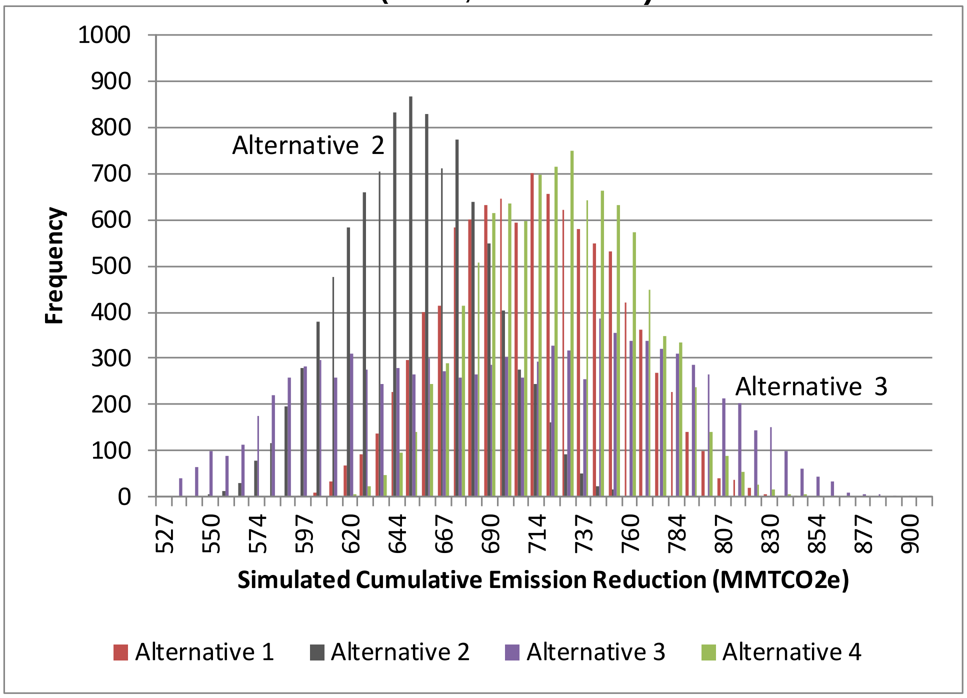
Figure 10: Simulated Cumulative Emission Reduction Achieved Under the Scoping Plan

(n = 10,000 iterations)



Frequency is the number of observations out of the 10,000 simulated iterations that fall within the category. For example, the height of the bar above 629 MMTCO2e is about 900 observations, meaning that 900 simulated values are greater than 601 $MMTCO_2e$ and less than 629 $MMTCO_2e$.

Figure 11: Simulated Cumulative Emission Reduction Achieved Under the Four Alternatives
(n = 10,000 iterations)



Frequency is the number of observations out of the 10,000 simulated iterations that fall within the category.

Table 44: Simulated Cumulative Emission Reduction Achieved and Likelihood of Reaching 2030 Emission Limit
(n = 10,000 iterations)

Scenario	Cumulative Emission Reduction ($MMTCO_2e$)			Likelihood of Achieving 2030 Limit
	Mean	5th %	95th %	
Scoping Plan	700	570	824	92%[a]
Alternative 1	710	642	778	55%[b]
Alternative 2	650	591	709	30%[c]
Alternative 3	697	569	818	87%[a]
Alternative 4	722	659	786	62%[b]

a. For the Scoping Plan and Alternative 3, the limit on the simulated Cap-and-Trade maximum allowance price leads to the shortfall in emission reductions needed to achieve the 2030 emission limit. Higher allowance prices would enable the necessary emission reductions to be achieved.

b. For Alternative 1 and Alternative 4, the shortfall in emission reductions needed to achieve the 2030 emission limit is due to the underperformance of prescriptive measures and uncertainty in the Reference scenario emissions.

c. For Alternative 2, the shortfall in emission reductions needed to achieve the 2030 emission limit is due to the carbon tax being set too low to motivate the necessary emission reduction given the uncertainty in the Reference scenario emissions.

Figure 12: PATHWAYS Reference Scenario and Increased Range of the Simulated Reference Scenario with 10% Emission Intensity Uncertainty

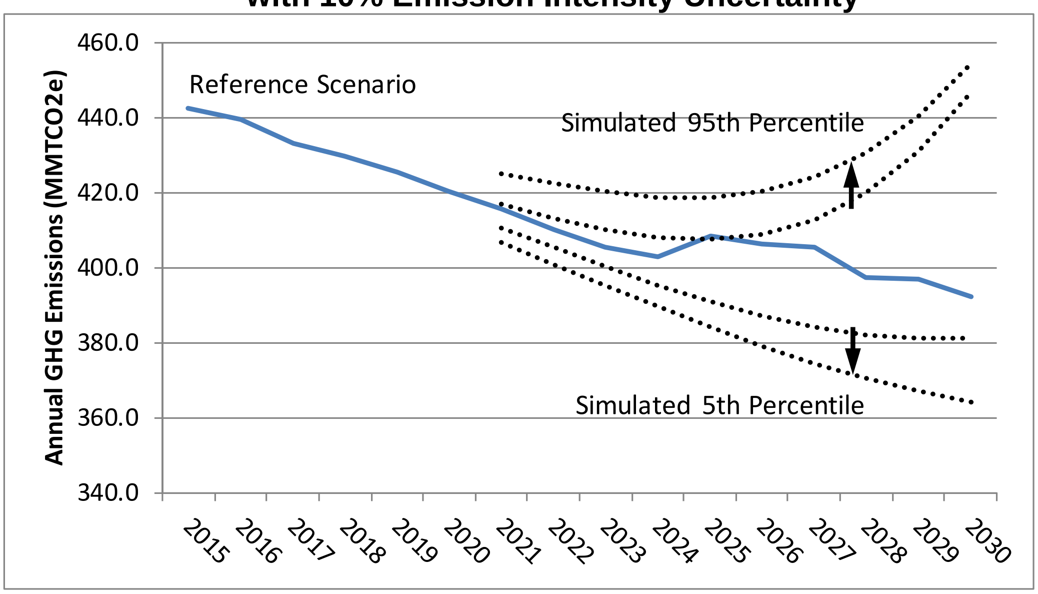


Table 45: Simulated Likelihood of Reaching 2030 Emission Limit For Several Alternative Input Assumptions
(n = 10,000 iterations)

Scenario	Base Input Assumptions	Alternative Input Assumptions			
		10% Intensity Uncertainty	3.8% Growth Rate	40% Uncertainty in Price Response	Lower Max Price Response by 100 MMT CO_2e
Scoping Plan[a]	92%	76%	78%	85%	58%
Alternative 1[b]	55%	53%	34%	55%	55%
Alternative 2[c]	30%	41%	13%	32%	29%
Alternative 3[a]	87%	71%	70%	80%	49%
Alternative 4[b]	62%	56%	40%	62%	62%

a. For the Scoping Plan and Alternative 3, the limit on the simulated Cap-and-Trade maximum allowance price leads to the shortfall in emission reductions needed to achieve the 2030 emission limit. Higher allowance prices would enable the necessary emission reductions to be achieved.

b. For Alternative 1 and Alternative 4, the shortfall in emission reductions needed to achieve the 2030 emission limit is due to the underperformance of prescriptive measures and uncertainty in the Reference scenario emissions.

c. For Alternative 2, the shortfall in emission reductions needed to achieve the 2030 emission limit is due to the carbon tax being set too low to motivate the necessary emission reduction given the uncertainty in the Reference scenario emissions.

Figure 13 presents the simulated total cost of the Scoping Plan. The total cost is the annual cost from 2021 to 2030 discounted to 2021. On average, the Scoping Plan is simulated to cost about $8.8 billion over the 10-year period, with a 5th percentile estimate of -$2 billion and a 95th percentile estimate of about $19 billion. In other words, the collective impact of the uncertainty indicates that the cost could range from approximately zero to approximately double the average cost estimate. As shown in the figure, the distribution of simulated costs is concentrated near the average estimate, meaning that the cost is simulated to most likely be near the average. About half the simulated cost estimates are within ±50 percent of the average cost.

To put the simulated range of cost in perspective, the REMI Reference scenario California gross domestic product (GDP) is forecast at about $20 trillion for 2021 to 2030, discounted to 2021. Consequently, even the 95th percentile cost estimate for the Scoping Plan is less than 0.1 percent of expected GDP over the period.

Figure 14a shows the simulated costs for Alternatives 1, 2, and 3. Figure 14b shows the cost estimates for Alternative 4. The figures show that Alternative 2 and Alternative 3 have similar distributions of simulated costs, which are also of a similar magnitude to the costs simulated for the Scoping Plan. Alternative 1 has costs that are simulated to be much higher (Figure 14a) and Alternative 4 has costs that are about five times higher than Alternative 1 (Figure 14b). As discussed above, the lost value added due to the reduction in industrial output is the primary reason for the much higher simulated costs of Alternative 4.

Table 46 summarizes the simulated cost estimates for the Scoping Plan and alternatives. The Scoping Plan, Alternative 2, and Alternative 3 have comparable costs. However, Alternative 2's low cost is the result of not achieving the cumulative emission reduction needed to reach the 2030 emission limit. As shown in the table, the simulated costs for Alternative 1 and Alternative 4 are much higher.

The distributions of simulated costs for the Scoping Plan and alternatives are not particularly sensitive the input variables examined above for the emissions simulation. Increasing the emissions intensity uncertainty increases slightly the range of costs, but has little effect on the simulated average costs. Assuming a 3.8 percent economic growth rate for all iterations increases the mean and 95th percentile estimates, but not appreciably. Finally, the simulated costs are not sensitive to the range of assumptions examined regarding price responsiveness for the range of prices examined.

As discussed above, the prescriptive measure cost estimates are sensitive to fossil fuel prices. The full range of expected fuel prices is reflected in the simulated costs. If the fuel price distribution were narrower, the range of simulated costs would also be narrower. The opposite would occur if the fuel price distribution were broader.

Uncertainty Analysis Conclusion

The results of the uncertainty analysis indicate that at 92 percent, the Scoping Plan has the greatest likelihood of achieving the 2030 emission limit among the options examined. Consequently, the Scoping Plan has the lowest likelihood that midcourse policy adjustments will be needed to ensure that the 2030 emission limit is achieved. Annual emission reporting enables progress toward the emission reductions needed to achieve the 2030 emission limit to be tracked. Based on this tracking, measures and programs may be modified through regulatory amendments and updates to the Scoping Plan (required every five years), providing opportunity to design and implement midcourse policy adjustments needed to ensure the 2030 emission limit can be achieved.

The uncertainty analysis highlights that the Cap-and-Trade Program achieves the necessary emission reductions in most cases, even if the prescriptive measures underperform. The Scoping Plan and Alternative 3 outperform the other alternatives across a range of input assumptions.

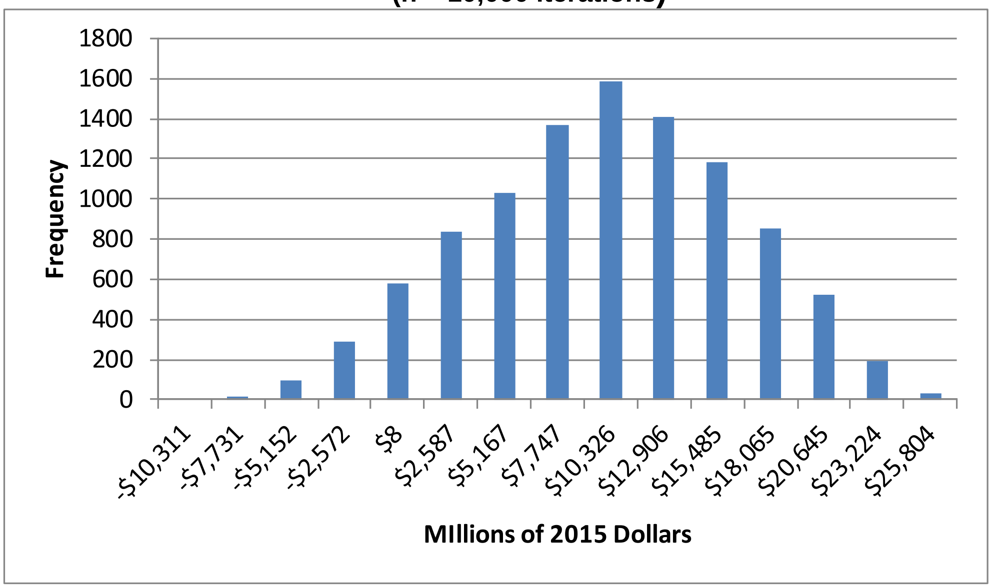
If carbon pricing is unable to motivate the emission reduction expected in the base set of input assumptions, the likelihood of the Scoping Plan and Alternative 3 achieving the 2030 emission limit is reduced. Under these alternate input assumptions, the likelihood for the Scoping Plan and Alternative 3 may be similar to the likelihood that Alternative 1 and Alternative 4 achieve the 2030 emission limit.

The Scoping Plan and Alternative 3 are also simulated to have the lowest cost for achieving the 2030 emission limit. This outcome is robust across all the input assumptions examined.

In terms of scenario emission reductions, the uncertainty analysis shows that because the Scoping Plan and Alternative 3 rely on a Cap-and-Trade Program, these scenarios are unlikely to overperform and reduce emissions more than needed to achieve the 2030 emission limit. This outcome is the result of the Cap-and-Trade Program adjusting to reduce just those emissions needed to achieve the 2030 emission limit. Alternative 1 and Alternative 4 have greater potential to overperform and reduce emissions more than required to achieve the 2030 emission limit, but with higher costs. This outcome is robust across all the input assumptions examined, as detailed in Table 45.

Figure 13: Simulated Total 2021 to 2030 Cost of the Scoping Plan (millions of 2015 dollars discounted to 2021)

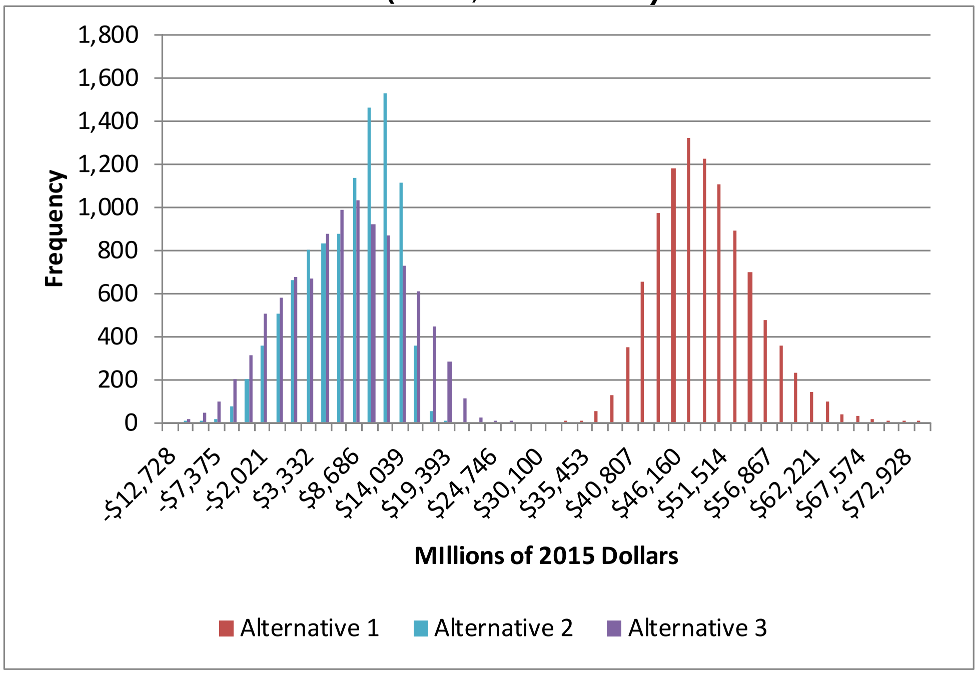
(n = 10,000 iterations)



Frequency is the number of observations out of the 10,000 simulated iterations that fall within the category. For example, the height of the bar above $5,167 is about 1,000 observations, meaning that 1,000 simulated values are greater than $2,587 and less than $5,167.

Figure 14a: Simulated Total 2021 to 2030 Cost of Alternatives 1, 2, and 3 (millions of 2015 dollars discounted to 2021)

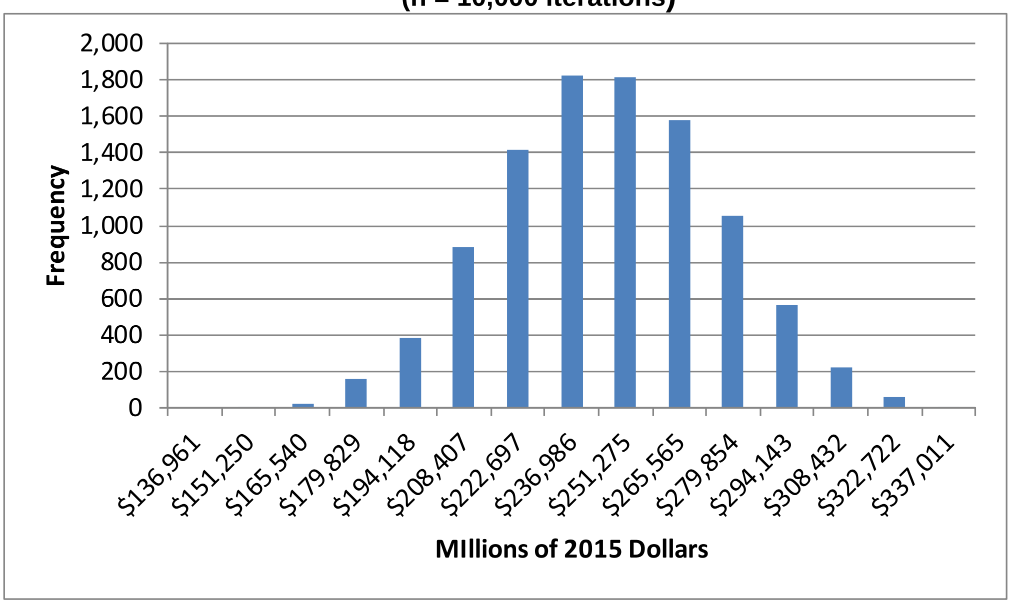
(n = 10,000 iterations)



Frequency is the number of observations out of the 10,000 simulated iterations that fall within the cost category shown on the horizontal axis.

Figure 14b: Simulated Total 2021 to 2030 Cost of Alternative 4 (millions of 2015 dollars discounted to 2021)

(n = 10,000 iterations)



Frequency is the number of observations out of the 10,000 simulated iterations that fall within the cost category shown on the horizontal axis.

Table 46: Simulated Total 2021 to 2030 Cost and Likelihood of Reaching 2030 Emission Limit
(n = 10,000 iterations)

Scenario	2021 to 2030 Cost (millions of 2015 dollars)			Likelihood of Achieving 2030 Limit
	Mean	5th %	95th %	
Scoping Plan	$8,800	-$2,000	$19,000	92%[a]
Alternative 1	$49,000	$40,500	$59,000	55% [b]
Alternative 2	$7,000	-$2,500	$14,000	30% [c]
Alternative 3	$6,500	-$5,100	$17,100	87%[a]
Alternative 4	$240,000	$192,000	$288,000	62% [b]

a. For the Scoping Plan and Alternative 3, the limit on the simulated cap-and-trade maximum allowance price leads to the shortfall in emission reductions needed to achieve the 2030 emission limit. Higher allowance prices would enable the necessary emission reductions to be achieved.

b. For Alternative 1 and Alternative 4, the shortfall in emission reductions needed to achieve the 2030 emission limit is due to the underperformance of prescriptive measures and uncertainty in the Reference Scenario emissions.

c. For Alternative 2, the shortfall in emission reductions needed to achieve the 2030 emission limit is due to the carbon tax being set too low to motivate the necessary emission reduction given the uncertainty in the Reference Scenario emissions.

Appendix E2

1. Updated Modeling Results

The scenarios and modeling assumptions analyzed in Appendix E2 have been updated since release of the January 2017 Proposed Plan based on stakeholder comments, the requirements under AB 398, and other technical refinements. As detailed in Appendix D, the updated Reference Scenario requires cumulative reductions of 621 $MMTCO_2e$ from 2021 through 2030 (as compared to 680 in the January 2017 Proposed Plan). Appendix E2 includes updated incremental impacts for the Scoping Plan scenario relative to the updated cumulative reduction requirement.

Alternative 1, Alternative 2, Alternative 3, and Alternative 4 are not included in the updated modeling results and are only analyzed relative to the pre-AB 398 Reference Scenario. The modifications in the updated Reference Scenario impact the magnitude of the economic impacts across scenarios but would not result in a change in the ordering of scenarios by economic impact or compliance with AB 398. However, the different cumulative emissions reductions under the two Reference Scenarios, and the different resulting energy mix, do not allow for the results in Appendix E2 to be compared to the results in Appendix E1. The analysis in Appendix E1 is based on measures achieving 680 $MMTCO_2e$ in cumulative reductions while Appendix E2 requires 621 $MMTCO_2e$ of cumulative reductions to achieve the emission reduction target. Therefore, the incremental economic impacts will be greater in Appendix E1 with all else equal.

The following section outlines the results of the updated economic analysis for the Scoping Plan. All results are reported in 2015 dollars and represent the costs and savings measured against the updated Reference Scenario in 2030. Additional information on the modeling changes in presented in Appendix D.

PATHWAYS Results

Table 47 presents the changes in capital and fuel expenditures in 2030 relative to the updated Reference Scenario. The overall direct costs have decreased to $100 million in 2030 (relative to $800 million as estimated in Appendix E1). Changes in direct costs can be seen in a few sectors, notably the petroleum refining sector due to the removal of the refinery measure. Again, the direct costs in Table 47 do not include any cost impacts related to carbon pricing.

Table 47. Scoping Plan: Change in PATHWAYS Sector Costs in 2030 Relative to the Updated Reference Scenario (Billion 2015$)[56]

End Use Sector[57]	Capital Cost	Fuel Cost	Total Cost
Residential	$0.1	-$1.2	-$1.1
Commercial	$1.8	-$1.8	$0.1
Transportation	$3.5	-$3.8	-$0.3
Industrial	$0.8	-$0.3	$0.5
Oil & Gas Extraction	$0.0	$0.0	$0.1
Petroleum Refining	$0.0	$0.0	$0.0
Agriculture	$0.3	$0.2	$0.5
TCU[58]	$0.1	$0.1	$0.2
Total[59]	**$6.7**	**-$6.6**	**$0.1**

REMI Results

The updated PATHWAYS cost results and calculated carbon pricing impacts are input into the REMI model to estimate the impact of the Scoping Plan and Alternative 3 on the California economy. Table 48 presents the macroeconomic impacts of the Scoping Plan relative to the updated Reference Scenario.

[56] PATHWAYS costs are calculated in real 2012$. For this analysis, all costs are reported in 2015$. The PATHWAYS costs are inflated using Bureau of Economic Analysis (BEA) data available at: https://www.bea.gov/iTable/iTable.cfm?ReqID=9#reqid=9&step=1&isuri=1&903=4.
[57] Information on the end use sectors are available in the California PATHWAYS documentation available at: https://www.arb.ca.gov/cc/scopingplan/meetings/meetings.htm.
[58] Transportation, communications and utilities (TCU) energy supports public infrastructure including street lighting and waste treatment facilities.
[59] Values may not sum due to rounding.

Table 48. Scoping Plan: REMI Macroeconomic Indicators in 2030 Relative to the Updated Reference Scenario

	Absolute Change	Percentage Change
California GDP (Billion 2015$)	-$9.7 to -$19.4	-0.3% to -0.6%
Employment (Jobs)	-43,400 to -81,300	-0.2% to -0.3%
Personal Income (Billion 2015$)	-$4.2 to -$1.7	-0.1% to -0.1%

The overall macroeconomic impacts of the Scoping Plan are slightly reduced when compared to the updated results due to modifications and fewer required reductions under the updated Reference Scenario, 621 $MMTCO_2e$ relative to 680 $MMTCO_2e$ in the January draft. Macroeconomic impacts are lower across all major metrics, including California GDP, employment, and personal income.

Table 49 presents the impact to value add by sector for the Scoping Plan relative to the updated Reference Scenario. Many sectors see a smaller magnitude reduction in value add relative to the January draft, however the utility sector see a larger reduction in value add.

Table 49. Scoping Plan: Sector Value Add in 2030 by Category Relative to the Updated Reference Scenario

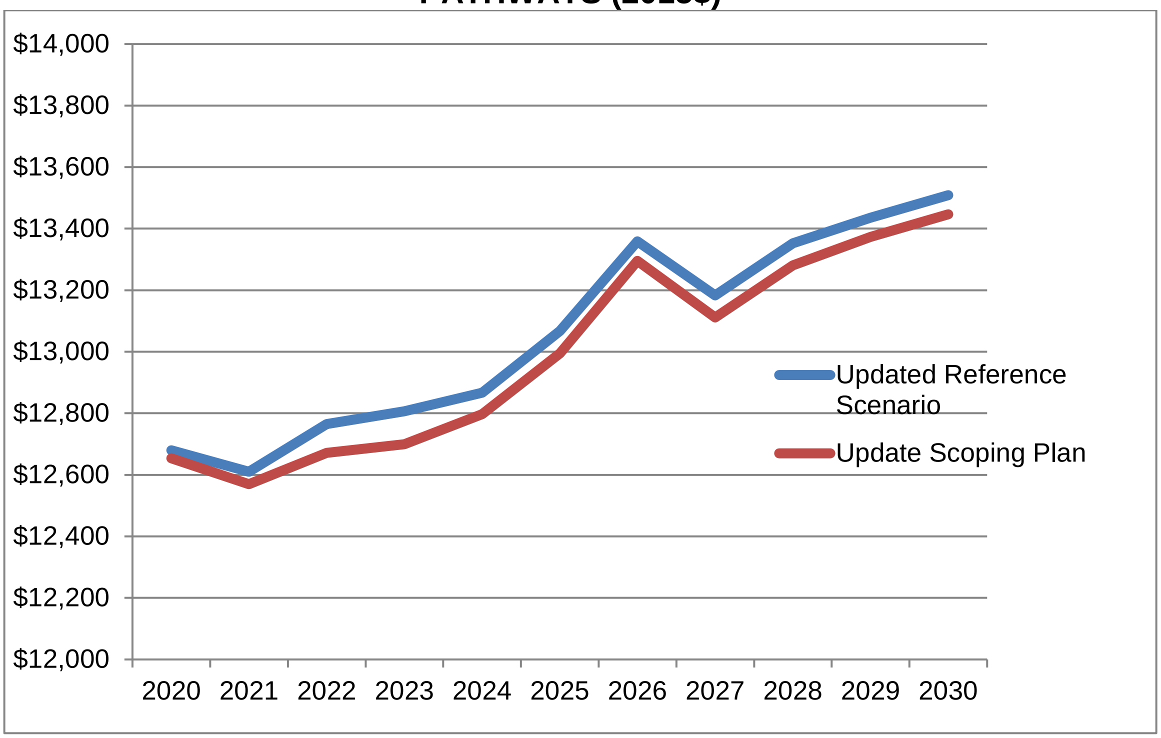
Sector Value Add by Category	Percentage Change
Forestry, Fishing, and Related Activities	-0.9% to -1.0%
Mining	-3.1% to -6.6%
Utilities	-3.6% to -7.0%
Construction	-0.4% to -0.9%
Manufacturing	-0.3% to -0.9%
Wholesale Trade	-0.5% to -1.0%
Retail Trade	-0.6% to -0.8%
Transportation and Warehousing	-0.9% to -1.6%
Information	-0.1% to -0.2%
Finance and Insurance	-0.5% to -0.1%
Real Estate and Rental and Leasing	-0.1% to -0.2%
Professional, Scientific, and Technical Services	-0.2% to -0.4%
Management of Companies and Enterprises	-0.1% to -0.4%
Administrative and Waste Management Services	-0.1% to -0.3%
Educational Services	-0.1% to –0.0%
Health Care and Social Assistance	-0.1% to 0.1%
Arts, Entertainment, and Recreation	-0.1% to -0.0%
Accommodation and Food Service	-0.1% to -0.0%
Other Services, Except Public Administration	0.1% to 0.3%

Household Impacts

Household Impacts Modeled in PATHWAYS

Household impacts, as estimated using capital and fuel expenditures from PATHWAYS, are virtually unchanged under the updated modeling. Capital costs in the updated Reference Scenario are slightly lower while they are unchanged from 2020 through 2030 under the Scoping Plan. Fuel cost impacts to households vary from year to year but do not result in a significant net impact to California households when compared to the results in Appendix E1. The annual household expenditures, including fuel and capital, are presented in Figures 15 through 17 for the updated Reference and Scoping Plan scenario. The results in Figure 15 through 17 do not include any household costs associated with carbon pricing.

Figure 15: Estimated Household Expenditures on Capital and Fuel as Modeled in PATHWAYS (2015$)[60]



[60] Figure 15 does not include any household impact resulting from carbon pricing in the Scoping Plan.

Figure 16: Estimated Household Capital Expenditures as Modeled in PATHWAYS (2015$)[61]

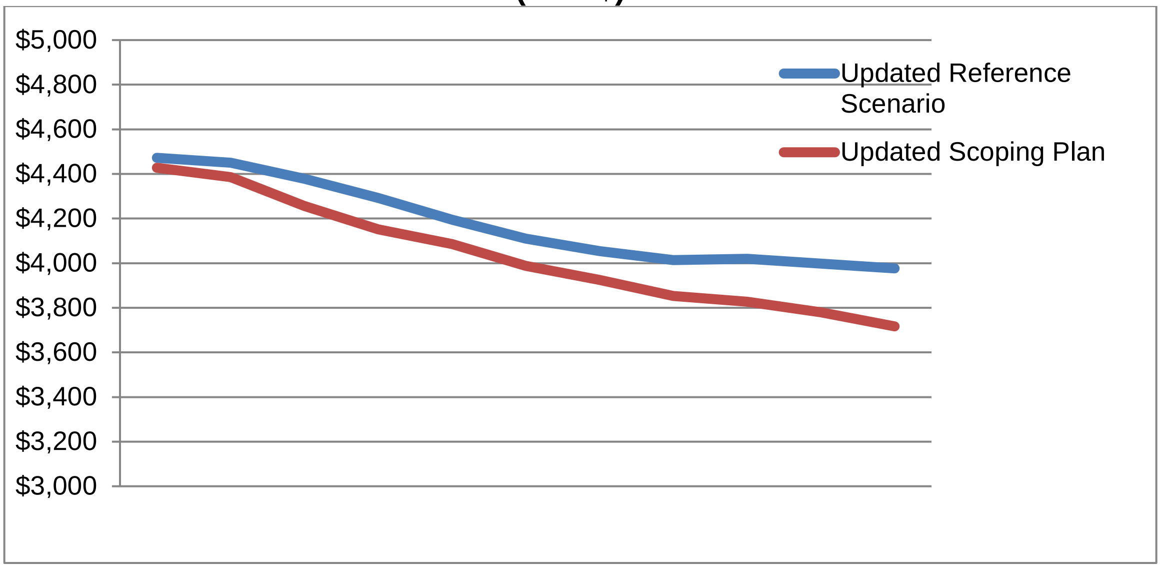
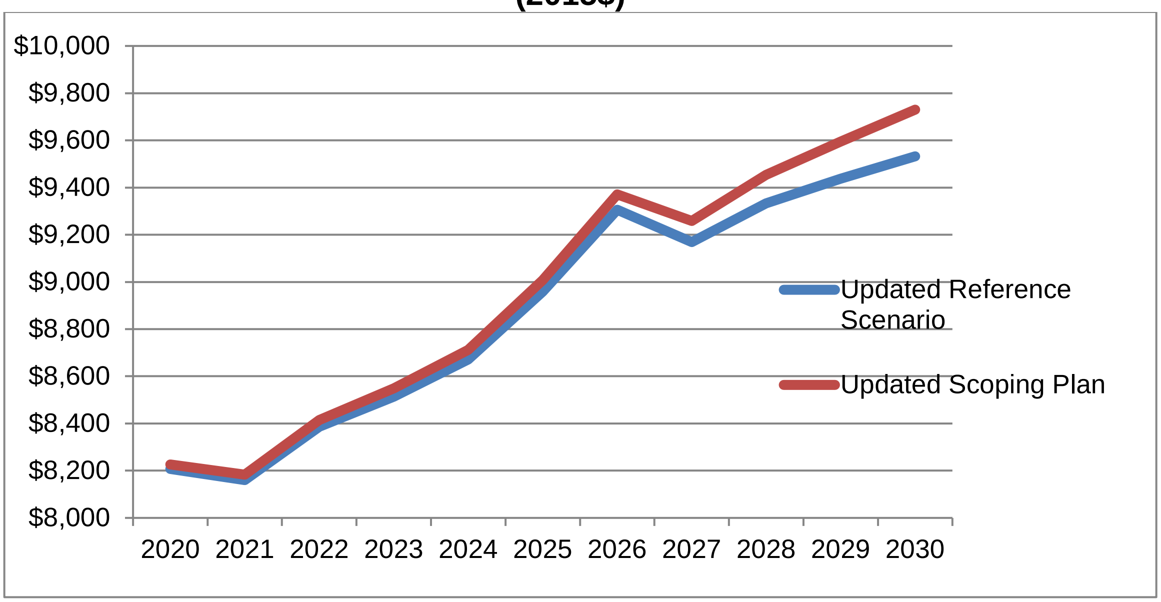


Figure 17: Estimated Household Fuel Expenditures as Modeled in PATHWAYS (2015$)[62]



Under the updated modeling, the per household impact of the Scoping Plan is unchanged relative to the updated Reference Scenario. Table 50 presents the annual household cost of the Scoping Plan.

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[61] Figure 16 does not include any household impact resulting from carbon pricing in the Scoping Plan.
[62] Figure 17 does not include any household impact resulting from carbon pricing in the Scoping Plan.

Table 50. Household Impacts: Annual Household Cost of the Scoping Plan Relative to the Updated Reference Scenario as Modeled in PATHWAYS (2015$)[63]

Scenario	2020 HH Fuel and Capital Costs	2025 HH Fuel and Capital Costs	2030 HH Fuel and Capital Costs
Updated Scoping Plan	-$5	-$80	-$60

Household Impacts Modeled in REMI

Table 51 presents the impact of the Scoping Plan on personal income, a metric that captures not only the capital and fuel expenditures modeled in PATHWAYS but also the indirect impact of carbon pricing on households. Under the Scoping Plan, personal income increases relative to the updated Reference Scenario in 2020 and declines slightly in 2030.

Table 51. Household Impacts: Scoping Plan Personal Income Relative to the Updated Reference Scenario as Modeled in REMI (Billion 2015$)[64]

Scenario	2020 Personal Income	2025 Personal Income	2030 Personal Income
Updated Scoping Plan	$0.7 to $15.8 0.0% to 0.7%	-$1.5 to $5.7 -0.1% to 0.2%	-$4.2 to -$1.7 -0.1% to -0.1%

When compared to the updated Reference Scenario, the Scoping Plan has a small overall impact on households. As shown in Table 52, in 2030 the estimated household impact ranges from $115 to $280. This impact is approximately half the modeled results in Appendix E1, shown in Table 25a.

Table 52. Reduction in Annual Household Personal Income Relative to the Updated Reference Scenario in 2030 (2015$)[65]

Scenario	Estimated Household Cost in 2030
Updated Scoping Plan	$115 to $280

[63] Numbers may not add due to rounding. Table 50 does not include any household impact resulting from carbon pricing in the Scoping Plan.

[64] The range of results for the Scoping Plan represents the estimated impact of the Cap and-Trade Program calculated at the C+T Floor Price (the lower bounds) and the C+T Reserve Price (the upper bounds).

[65] The range of results for the Scoping Plan represents the estimated impact of the anticipated Cap and-Trade Program calculated at the C+T Floor Price (the lower bounds) and the C+T Reserve Price (the upper bounds). The C+T Floor Price and C+T Reserve Price projections reflect the Cap-and-Trade Regulation which went into effect October 1, 2017,

Economic Valuation of Health Impacts

Consistent with the health modeling methodology presented in Appendix G, the mortality and morbidity incidences have been updated based on the updated Reference Scenario and Scoping Plan. Table 52a presents the estimated health impacts of the Scoping Plan in 2030.

Table 52a. Estimated Reduction in Premature Mortality and Morbidity in 2030 Under the Scoping Plan Relative to the Updated Reference Scenario

Number of Avoided Incidences	Updated Scoping Plan
Premature Mortality	140 to 210
All Hospitalizations	20 to 31
ER Visits	58 to 88

Table 53 presents the estimated valuation of the avoided health impacts, using the valuations outlined in Table 29. As the number of avoided incidences has been reduced under the updated modeling, so have the monetary impacts associated with health impacts, with a decline in total valuation from the range of $2.2 to $2.7 billion in 2030 to the updated range of $1.2 to $1.8 billion. This decline in avoided health impacts represents the lower cumulative emissions reductions required under the updated Reference Scenario. While a difference of an estimated $1 billion in avoided health impacts appears large, the updated economic valuation of avoided health impacts does not impact the macroeconomic modeling results of the Scoping Plan. There is no noticeable impact to state-level indicators like California GDP, employment, or personal income as a result of the updated health impact valuation (as detailed in Table 30).

Table 53. Estimated Economic Valuation of Avoided Health Impacts in 2030 Under the Scoping Plan Relative to the Updated Reference Scenario

Million 2015$	Scoping Plan
Premature Mortality	$1,200-$1,800
All Hospitalizations	$1.0 to $1.5
ER Visits	$0.04 to $0.07
Total	$1,200-$1,800

https://www.arb.ca.gov/regact/2016/capandtrade16/capandtrade16.htm, but do not reflect harmonization with AB 398, a process which began in October 2017,

Distributional Impacts

The updated modeling results continue to suggest that the impacts of the Scoping Plan are distributed evenly throughout California. As measured through changes in value add, wages, and employment, the updated modeling also suggests that overall impact on these variables will be modest across all regions of California. Table 54 presents the regional impacts of the Scoping Plan relative to the updated Reference Scenario. The regional results are not significantly different and there is no discernable difference in the regional results compared to the statewide results for value add, wages, and employment.

Table 54. California Regional Impacts of the Scoping Plan in 2030 Relative to the Updated Reference Scenario

		Value Added	Wages	Employment
	Central Coast	-0.2% to -0.5%	-0.1% to -0.3%	-0.1% to -0.3%
	North Coast	-0.6% to -1.0%	-0.4% to -0.7%	-0.3% to -0.4%
	Northeast	-0.3% to -0.5%	-0.2% to -0.3%	-0.2% to -0.2%
	Sacramento Valley	-0.2% to -0.3%	-0.2% to -0.2%	-0.2% to -0.2%
	San Francisco Bay	-0.2% to -0.5%	-0.1% to -0.3%	-0.1% to -0.2%
	San Joaquin Valley	-0.4% to -0.9%	-0.2% to -0.6%	-0.1% to -0.3%
	Sierra Nevada	-0.3% to -0.4%	-0.2% to -0.3%	-0.2% to -0.2%
	Southern California	-0.3% to -0.5%	-0.2% to -0.4%	-0.2% to -0.3%
	Statewide	**-0.3% to -0.5%**	**-0.2% to -0.4%**	**-0.2% to -0.3%**

The same findings hold when estimating the impact of the Scoping Plan on disadvantaged communities. There is no discernable difference between the impact to disadvantaged communities relative to the overall region in which they are located under the updated modeling for the Scoping Plan. Table 55 shows that there is no change in the impact to a DAC relative to the overall region.

Table 55. Employment Impacts of Scoping Plan on DACs in 2030 Relative to the Updated Reference Scenario

		Overall Impact	Disadvantaged Communities
	Central Coast	-0.1% to -0.3%	-0.1% to -0.2%
	North Coast	-0.3% to -0.4%	--
	Northeast	-0.2% to -0.2%	--
	Sacramento Valley	-0.2% to -0.2%	-0.2% to -0.2%
	San Francisco Bay	-0.1% to -0.2%	-0.1% to -0.2%
	San Joaquin Valley	-0.1% to -0.3%	-0.1% to -0.3%
	Sierra Nevada	-0.2% to -0.2%	--
	Southern California	-0.2% to -0.3%	-0.2% to -0.3%
	Statewide	**-0.2% to -0.3%**	**-0.2% to -0.3%**

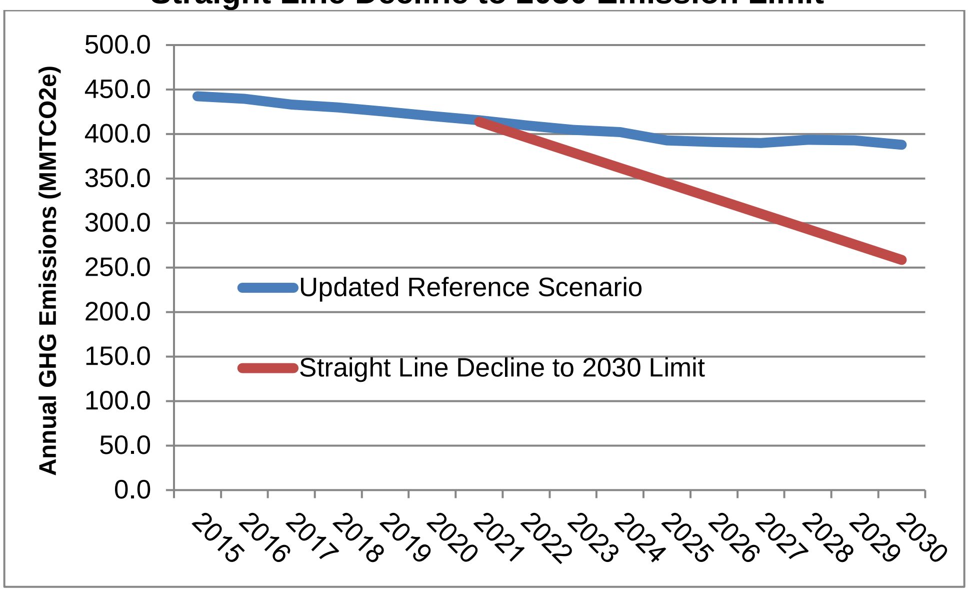
2. Uncertainty Analysis

The uncertainty analysis described in detailed in Appendix E1 has also been updated to reflect the changes in the Reference Scenario and Scoping Plan. The methodology of the analysis is unchanged, but updates have been made to reflect the changes in the Reference Scenario and the Scoping Plan.

This section outlines the changes that have been made to the uncertainty analysis and summarize the modified results for the Scoping Plan.

Reference Scenario and Cumulative Emission Reductions: The analysis has been modified to include the updated Reference Scenario. Figure 18 shows the updated PATHWAYS Reference Scenario and the straight-line decline to the 2030 target. The cumulative emissions reductions required to achieve the 2030 target from the updated Reference Scenario are estimated as 621 MMTCO_2e from 2021 through 2030.

Figure 18: Updated PATHWAYS Reference Scenario Emissions and Straight Line Decline to 2030 Emission Limit



As detailed in Appendix E1, the average simulated GDP growth rate from 2015 to 2030 (2.7 percent) was used to simulate Reference Scenario emissions. The simulated Reference Scenario emissions were then used to estimate the cumulative emission reduction required to achieve the 2030 emissions limit (shown in Figure 18). In the updated analysis, the simulated required cumulative emission reduction averages 660 $MMTCO_2e$ with a 5th and 95th percentile range of ±130 $MMTCO_2e$.

From this updated simulation, there is nearly a 65 percent likelihood that cumulative emission reductions required to achieve the 2030 emission limit will be larger than the 621 $MMTCO_2e$ point estimate from the PATHWAYS analysis.

Prescriptive Measures Cost Per Metric Ton: The cost per ton for each measure was estimated using the methodology outlined in Appendix E1. As the refinery measure was removed from the PATHWAYS modeling, that cost per ton is eliminated from this analysis. In addition, the flexible load measure was removed from the Scoping Plan (previously attributed emission reductions from this measure are now included in the updated Reference Scenario - as detailed in Appendix D) and the cost per ton of the 50 percent RPS was modified as discussed in Chapter 3 of the Scoping Plan.

Table 56 summarizes the simulated costs per ton for the set of prescriptive measures in the updated Scoping Plan. With the updated modeling in PATHWAYS, the prescriptive measures result in cost savings. The average cost per ton of the prescriptive measures declined from an average cost of $2 per ton to an average savings of $28 per ton. Appendix D provides additional context on the PATHWAYS modeling modifications that led to this change in cost.

Table 56: Updated Simulated Cost Per Ton for Prescriptive Measures: Discounted Costs Divided by Cumulative Emission Reductions

Scenario	Average	5th Percentile	95th Percentile
Scoping Plan	-$28	-$64	-$1

Table 57 presents the combined impact of these uncertainties on the emission reductions achieved by the prescriptive measures in the Scoping Plan. The simulated emission reductions are summarized relative to the emission reductions calculated in PATHWAYS. As shown in Table 57, on average the measures underperform by about 6 percent.

Table 57: Updated Simulated Prescriptive Measure Emission Reductions Relative to the Reductions Calculated in PATHWAYS

Scenario	Average	5th Percentile	95th Percentile
Updated Scoping Plan	-6.2%	-16.9%	4.2%

Simulated emission reductions over the period 2021 through 2030.
Simulation of 10,000 iterations.

For the Scoping Plan, PATHWAYS calculated that the prescriptive measures would reduce emissions by about 385 $MMTCO_2e$ cumulatively from 2021 through 2030. The average simulation for the Scoping Plan was 6.9 percent less, or about 361 $MMTCO_2e$, confirming that the uncertainty assumptions result in the prescriptive measures underperforming on average. The 5th percentile was 16.9 percent less, or about 320 MMTCO_2e, whereas the 95th percentile was 4.2 percent more, or about 401 MMTCO_2e.

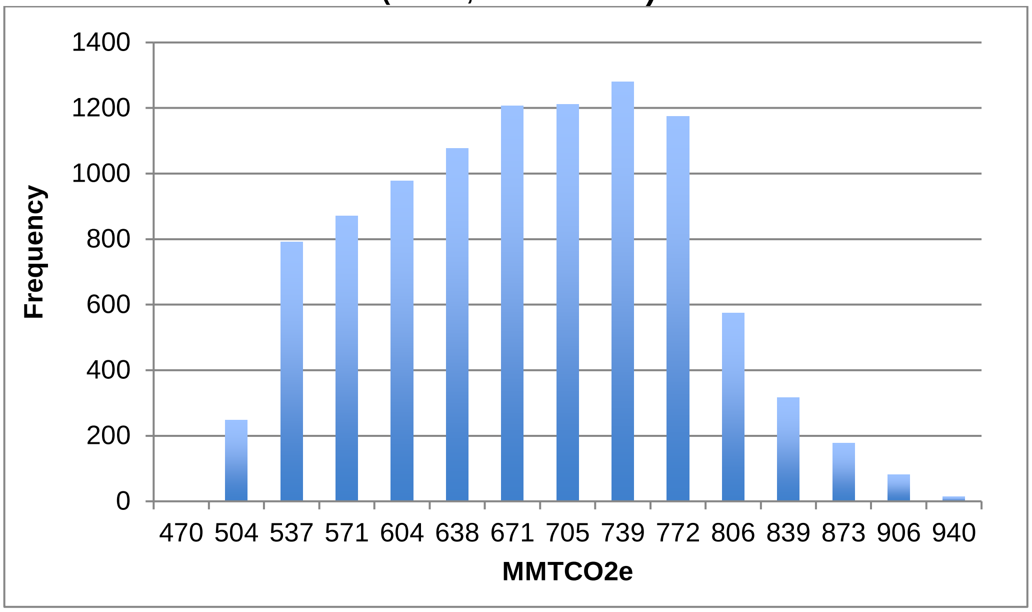
Emissions Pricing Mechanisms: Based on the updated PATHWAYS analysis, the point estimate of the cumulative emission reduction required of the Cap-and-Trade Program as part of the Scoping Plan is about 236 MMTCO_2e. Based on this updated expectation, an emission reduction of 237 MMTCO_2e was assumed to be achievable at allowance prices midway between the floor and ceiling prices. If allowance prices remained at the floor price from 2021 through 2030, cumulative emission reductions were assumed to be 106 MMTCO_2e and if allowance prices remained at the ceiling price from 2021 through 2030, cumulative emission reductions were assumed to be 462 MMTCO_2e, or approximately 10 MMT less than double the point estimate of 236 MMTCO_2e.
No other changes to the methodology related to emissions pricing was modified in the updated uncertainty analysis.

Uncertainty Analysis Results

This section presents the updated results of the uncertainty analysis in terms of emission reductions achieved and the costs of achieving the emission reductions under the Scoping Plan.

Figure 19 presents the simulated cumulative emission reduction achieved by the Scoping Plan. On average, the Scoping Plan is simulated to achieve about 660 MMTCO_2e of cumulative emission reductions from 2021 to 2030, with a 5th percentile estimate of 525 MMTCO_2e and a 95th percentile estimate of about 790 MMTCO_2e. At this level of performance, the Scoping Plan is simulated to achieve the emission reduction needed to reach the 2030 emission limit with a likelihood of about 96 percent. This means that in about 4 percent of the simulated iterations, cumulative emission reductions were not sufficient to achieve the straight-line emission reduction in Figure 18.

Figure 19: Updated Simulated Cumulative Emission Reduction Achieved Under the Scoping Plan
(n = 10,000 iterations)



Frequency is the number of observations out of the 10,000 simulated iterations that fall within the category. For example, the height of the bar above 648 $MMTCO_2e$ is about 1200 observations, meaning that 1200 simulated values are greater than 614 $MMTCO_2e$ and less than 648 $MMTCO_2e$.

Table 58 summarizes the updated simulated emission performance of the Scoping Plan. For the Scoping Plan, the limit on the simulated Cap-and-Trade maximum allowance price leads to the shortfall in emission reductions needed to achieve the 2030 emission limit. Higher allowance prices would enable the necessary emission reductions to be achieved.

Table 58: Updated Simulated Cumulative Emission Reduction Achieved and Likelihood of Reaching 2030 Emission Limit
(n = 10,000 iterations)

Scenario	Cumulative Emission Reduction ($MMTCO_2e$)			Likelihood of Achieving 2030 Limit
	Mean	5^{th} %	95^{th} %	
Scoping Plan	660	525	789	96%

Table 59 summarizes the impact of several input assumptions on the updated results. Increasing the emission intensity uncertainty from ±5 percent to ±10 percent widens the range of potential Reference Scenario emissions. At this level of uncertainty, the range of the cumulative emission reduction needed to achieve the 2030 emission limit is about 660 $MMTCO_2e$ ±225 $MMTCO_2e$. As a result of this increased range, the simulated likelihood of achieving the 2030 emission limit is reduced to 84 percent.

The impact of increasing the economic growth rate to 3.8 percent in all iterations increases the simulated cumulative emission reduction needed to achieve to 2030 emission limit to about 660 $MMTCO_2e$ $\pm$155 $MMTCO_2e$. This 3.8 percent growth rate is the fastest rate observed in California in any 15-year stretch from 1987 to 2015.

The sensitivity of the emission results to the ability of carbon prices to motivate emission reductions is examined with two input assumptions, the uncertainty in the price response and the maximum achievable emission reduction at the ceiling price. Reducing the price response at the price ceiling has the largest impact on the likelihood of achieving the 2030 emission target. The updated results are shown in Table 59. Overall, the likelihood of reaching the 2030 emission limit has increased under the updated Reference Scenario and Scoping Plan.

Table 59: Updated Simulated Likelihood of Reaching 2030 Emission Limit For Several Alternative Input Assumptions
(n = 10,000 iterations)

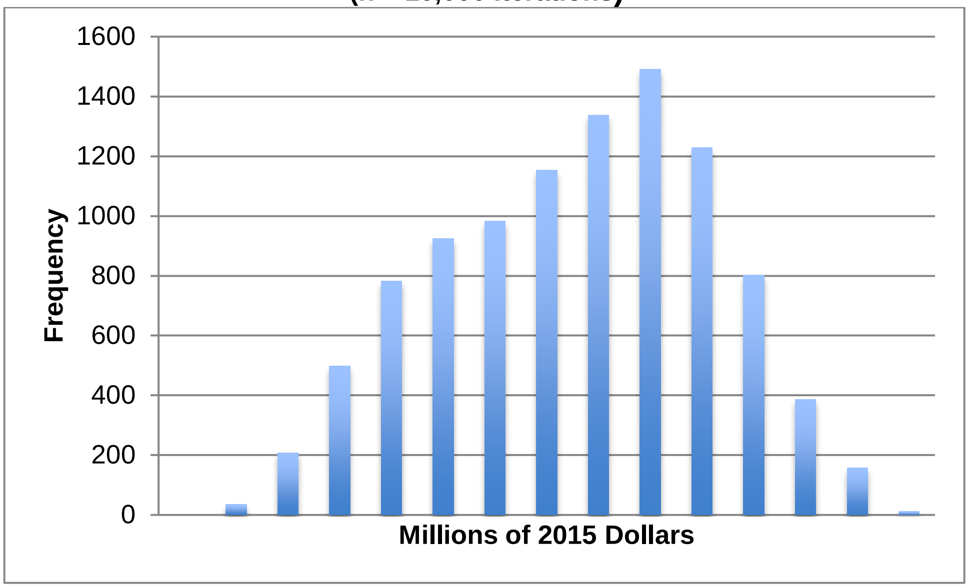
Scenario	Base Input Assumptions	Alternative Input Assumptions			
		10% Intensity Uncertainty	3.8% Growth Rate	40% Uncertainty in Price Response	Lower Max Price Response by 100 MMT CO_2e
Scoping Plan	96%	84%	94%	85%	75%

Figure 20 presents the updated simulated total cost of the Scoping Plan. The total cost is the annual cost from 2021 to 2030 discounted to 2021. As modeled, on average, the Scoping Plan is simulated to result in a savings of $8 million over the 10-year period, with a 5th percentile estimate of -$13.9 billion and a 95th percentile estimate of $12.5 billion. In other words, the collective impact of the uncertainty indicates that the cost could range over $25 billion. As shown in the figure, the distribution of simulated costs is concentrated near the average estimate, meaning that the cost is simulated to most likely be near the average.

The average simulated cost of achieving the 2030 emission limit has declined significantly as a result of the updated PATHWAYS modeling of the Reference Scenario and Scoping Plan. These savings result from the lower required emission reductions and a greater reliance on the Cap-and-Trade Program to achieve the required reductions.

This uncertainty analysis is highly sensitive to assumptions related to carbon pricing, specifically the amount of reductions that can be achieved at the price ceiling. It is important to note that this analysis is based on the Cap-and-Trade Program in place in 2017 and therefore any changes to the Regulation to harmonize with the requirements of AB 398 (a process which began in October 2017 and will include a hard price ceiling) would greatly impact the results of this analysis. As modeled, the likelihood of achieving the SB 32 target decreases with lower price responsiveness at the price ceiling. Price responsiveness will be directly impacted by the choice of price ceiling under AB 398. A lower price ceiling will likely result in lower price responsiveness and an increased probability of missing the SB 32 target.

Figure 20: Updated Simulated Total 2021 to 2030 Cost of the Scoping Plan (millions of 2015 dollars discounted to 2021)
(n = 10,000 iterations)



Frequency is the number of observations out of the 10,000 simulated iterations that fall within the category. For example, the height of the bar above -$3,343 is about 1,000 observations, meaning that 1,000 simulated values are greater than $-6,448 and less than -$3,343.

Table 60: Updated Simulated Total 2021 to 2030 Cost and Likelihood of Reaching 2030 Emission Limit
(n = 10,000 iterations)

Scenario	2021 to 2030 Cost (millions of 2015 dollars)			Likelihood of Achieving 2030 Limit
	Mean	5th %	95th %	
Scoping Plan	-$8	-$13,900	$12,500	96%[a]

a. For the Scoping Plan, the limit on the simulated cap-and-trade maximum allowance price leads to the shortfall in emission reductions needed to achieve the 2030 emission limit. Higher allowance prices would enable the necessary emission reductions to be achieved.

Under the Scoping Plan, annual emission reporting enables progress toward the emission reductions needed to achieve the 2030 emission limit to be tracked. Based on this tracking, measures and programs may be modified through regulatory amendments and updates to the Scoping Plan (required every five years), providing opportunity to design and implement midcourse policy adjustments needed to ensure the 2030 emission limit can be achieved.