Appendix E

ECONOMIC ANALYSIS

1. Introduction

This 2030 Target Scoping Plan proposes actions to achieve California's climate target: a 40 percent reduction in greenhouse gas (GHG) emissions by 2030 compared to 1990 levels. The proposed emission reduction path relies 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 draft analysis presented here indicates that the SB 32 target can be achieved with minimal impact on the growth of California's economy, and that the Proposed Plan is preferred to the alternatives examined.

This appendix summarizes the draft economic analysis of the Proposed Plan and the two alternatives presented in the 2030 Target Scoping Plan Discussion Draft which were suggested by the Environmental Justice Advisory Committee and stakeholders: Alternative 1, No Cap-and-Trade; and Alternative 2, Carbon Tax.[1] Each of these three policy scenarios is evaluated relative to a Reference (or no action) scenario as outlined in Chapter III. The economic analysis is continuing, and additional information will be included in an updated version of this appendix with the final release of the 2030 Target Scoping Plan. Additional analyses underway include: sensitivity analysis of GHG emission reduction and cost estimates; and analysis of the distribution of economic impacts across regions of the state, including disadvantaged communities.

This appendix is organized as follows. Section 2 describes the modeling framework used in the analysis, Section 3 summarizes the scenarios analyzed, Section 4 discusses the modeling results, and Section 5 presents proposed additional modeling and concludes.

2. Modeling Framework

This analysis uses two models to examine how proposed actions 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 represents the buildings and equipment throughout the 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

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[1] https://www.arb.ca.gov/cc/scopingplan/2030target_sp_dd120216.pdf

economy, focusing on how changes in expenditures and prices can affect economic growth, employment, and income. The REMI Model takes as input the cost estimates that come from PATHWAYS.

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 Proposed 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 necessarily has important limitations. This analysis focuses exclusively on the economic effects in California of taking action to reduce GHG emissions. The analysis does not consider the economic, environmental, and health benefits of avoiding climate change by taking action to reduce emissions. These issues are discussed in Chapter III. Also, the analysis does not include the dollar value of criteria and toxic pollutant emission reductions, which are 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 net cost of reducing future reliance on fossil fuels is strongly influenced by the uncertain future price of fossil fuels. Similarly, progress will depend on the pace of innovation and commercialization that improves equipment efficiency and reduces cost. New disruptive technologies and business models are possible, but by their nature are not known in advance. Also influential will be consumer acceptance of new technologies, particularly the zero-emitting vehicles that are significant in all the scenarios examined.

To better understand how uncertainty affects the magnitude and direction of the costs and savings of the Proposed Plan and the alternatives, sensitivity analysis is continuing. The sensitivity analysis is expected to provide additional insight into the factors that most significantly affect the cost and benefit estimates. Also, the analysis should help assess the robustness of the conclusions regarding the relative merits of the Proposed Plan and the alternatives.

Finally, this analysis does not serve as the economic basis for adopting any specific policy or measure. Individual regulations implemented as a result of the Proposed 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 ARB 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 population, building square footage, and other energy demand forecasts. Energy and infrastructure costs are tracked, and greenhouse gas emissions are calculated based on energy demand and energy supply choices. The basic model does not include macroeconomic analysis, price feedback effects or impacts, nor are the scenarios determined by optimization. Rather, the scenarios are the result of input assumptions determined by the users of the model.

PATHWAYS calculates GHG emissions from 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. In most cases, an emission-reduction measure results in increases in capital expenditures which are offset to varying degrees by savings in energy consumption. PATHWAYS incorporates interrelationships 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 Renewable Portfolio Standard. The increased use of electricity for transportation also interacts with the Low Carbon Fuel Standard. Therefore, PATHWAYS estimates costs and savings for the combined set of measures included in each scenario.

For this analysis, California PATHWAYS calculates annual costs for a policy scenario by comparing the scenario to the Reference scenario. The costs calculated for each policy scenario can be compared, reflecting the different

mixes of technology investments, fuel savings, and emission reductions associated with each. To enable 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 are realized. All costs and savings are calculated in real 2012 dollars, but are adjusted by ARB to 2015 dollars for consistency with other modeling results.[2] Estimated results from PATHWAYS are detailed in section 4.

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 s 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 costs inputs used in PATHWAYS are informed by external sources (as outlined in Appendix D) as well as from the economic analyses of regulations and plans at ARB. Available cost information varies across sector and technology. Where the Proposed Plan relies on the extension of existing programs and regulations for GHG reductions, better cost data is generally available than for new 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[3], 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 ARB and external research. However, since there are currently no 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 implemented. In addition, there are policies and measures contained in the policy scenarios for which cost information is less well developed. For example, the costs associated with the proposed efficiency measures for refineries, oil and gas, and industrial sources are based on estimated mitigation costs from a study of industrial energy efficiency costs by LBNL.[4] There are also measures for which no costs are available including anticipated vehicle miles traveled (VMT) reductions due to smart growth as called for in SB 375.

California PATHWAYS is not an optimization model and is not designed to determine the most cost-effective way to achieve a policy objective. The input scenarios define the manner in which the capital stock and fuel supplies will

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[2] 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.
[3] https://www.arb.ca.gov/planning/sip/2016sip/2016mobsrc.pdf.
[4] Cost inputs to the PATHWAYS model are detailed in Appendix D.

evolve over time. PATHWAYS does not consider micro- or macroeconomic effects in its calculations. Consequently, price changes are not modeled in PATHWAYS. Rather, the REMI Model is used to assess the impacts of costs and savings on economic growth, employment and income. The 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 Version 1.7.2 is used to estimate the impact of policy scenarios on the California Economy. ARB 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[5]:

- 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.[6]
- 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.

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.[7]

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[5] http://www.remi.com/the-remi-model
[6] https://www.bls.gov/emp/ep_data_input_output_matrix.htm
[7] A detailed explanation of each block in the REMI model is available at: http://www.remi.com/resources/technical

Figure 1: Structure of the REMI Model
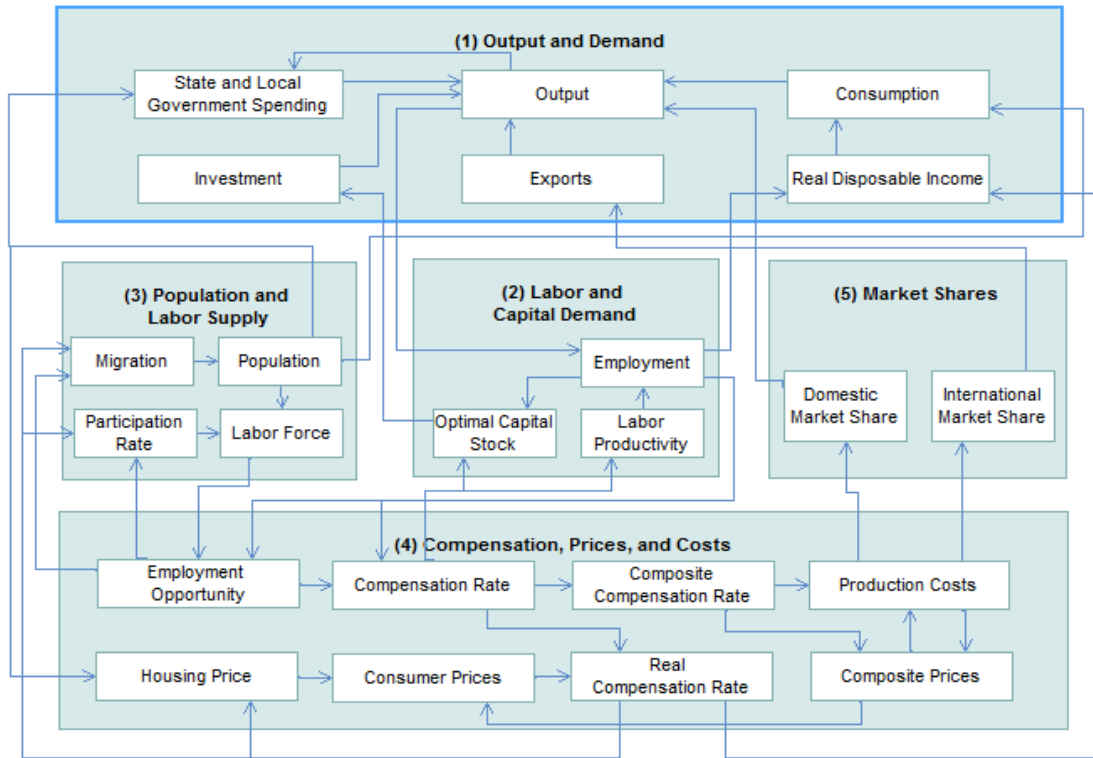
Within Figure 1, the rectangles represent a variable with arrows representing the equations that link the pieces of the model together. Block 1 represents macroeconomic impacts and includes components of Gross Domestic Product (GDP) often used as a proxy for economic growth. Block 2 contains firm and 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 policy scenarios 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 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 three policy scenarios on the California economy is estimated by inputting into REMI the PATHWAYS estimates of the costs and savings to households and businesses of achieving the SB 32 target. The impact of carbon pricing on businesses and households is evaluated in REMI directly (without additional input 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. As such, estimated costs and savings from PATHWAYS must be aggregated for use in REMI. This aggregation does not change the overall costs calculated in PATHWAYS, but it does impact how some costs may be categorized by sector in REMI.

The PATHWAYS model output that is used in the REMI model consists of capital expenditures and spending on fuel categorized into household, commercial, industrial and transportation designations. The industrial category is further divided into agriculture and waste, oil and gas extraction, refining, transportation communication and utilities (TCU) and other industrial. The categories of changes in capital expenditures and fuel purchases are presented in Table 1 for each sector. For example, policies may result in changes in household expenditures related to water heating, space heating, or lighting, while policies may shift expenditures in the commercial sector may be due to purchase of ventilation devices. Capital expenditures are levelized over the useful life of the device. 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
End-use Capital Expenditure	Consumer Price - Household appliances
	Consumer Price - Household maintenance
	Consumer Price - New motor vehicles*
Fuel Expenditure	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	Residual (Industrial Sectors) Fuel Cost
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 and Waste	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
Passenger Transport	Aerospace product and parts manufacturing
	Motor vehicle manufacturing
	Railroad rolling stock manufacturing
Freight Transport	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

3. Policy Scenarios

The economic impact of three policy scenarios is estimated using the California PATHWAYS and REMI models. Chapter III provides an overview of the three scenarios, while details related to the economic modeling of the scenarios in this analysis are presented below.

Proposed Plan

The Proposed 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 Proposed Plan ensures that the SB 32 target is achieved at the lowest cost to the California economy.

The costs and savings of the prescriptive measures included in the Proposed Plan are calculated in PATHWAYS as changes in energy use and capital investment relative to the PATHWAYS Reference scenario (detailed in Chapter III). Depending on the ability of ambitious measures to deliver anticipated GHG reductions, the prescriptive measures in the Proposed Plan may achieve 50 to 70

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 should 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 to the price of fuel. Other policy factors that also impact the allowance price include the return of auction proceeds from the sale of State-owned allowances and linkage with other jurisdictions.

This analysis includes a range of allowance prices bounded by the 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 is made available and is the highest anticipated price under the Program. 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 ARB 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 $60 above the C+T Floor Price from 2020 through 2030. Table 5 outlines the projected allowance prices used in this analysis. The values in 2025 and 2030 are modeled including the $60 difference between the C+T Floor Price and C+T Reserve Price and all values are reported in 2015 dollars.

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[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.

Table 5. Estimated Range of Cap-and-Trade Allowance Prices 2020 – 2030

($2015)	2020	2025	2030
C+T Floor Price	$15.4	$19.7	$25.2
C+T Reserve Price	$72.1	$73.0	$78.4

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, and the return of auction proceeds from the sale of State-owned allowances.

Entities covered by the Cap-and-Trade Program comply by surrendering allowances and offsets 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 REMI modeling, the sectors in Table 6 are disaggregated across forty-four 2- to 4-digit NAICS code sectors.

Table 6. 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. Under the current Cap-and-Trade Regulation, 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. 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. The allowance allocation in this analysis is based on the sector allocation in the 2016 Proposed Amendments to the Cap-and-Trade Regulation available at: https://www.arb.ca.gov/regact/2016/capandtrade16/attachb.pdf.

Under the current Cap-and-Trade Regulation, the value associated with the auction of State-owned allowances is directed to the Greenhouse Gas Reduction Fund (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.

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. 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, are approximations for this analysis. 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
Sustainable Communities and Clean Transportation	Consumer & new motor vehicles	$250 Million
	Rail transportation	$1 Billion
	Truck transportation	$250 Million
Energy Efficiency and Clean Energy	Consumer household maintenance	$400 Million
	Water, sewage, & other systems	$40 Million
Natural Resources and Waste	Forestry; fishing, hunting, trapping	$20 Million
	Waste management and remediation services	$40 Million
Total per Year		$2 Billion

Under the current Cap-and-Trade Regulation, investor-owned electric and gas utilities are provided allowances on behalf of their ratepayers. The value of these allowances must be used for ratepayer benefit, for example the biannual California Climate Credit received by customers of investor-owned utilities. 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. This methodology approximates the requirement that the value of these allowances be used for the benefit of ratepayers in California.

In this analysis, any allowance value that remains after allocation of free allowances to industrial entities, distribution of funds to consumers representing the allocation of allowances to electric and natural gas utilities, and distribution of funds to GGRF is returned to California consumers.

Alternative 1

Alternative 1 relies solely on prescriptive measures to achieve the SB 32 target and does not include any carbon pricing mechanism. The measures included in Alternative 1 are outlined in Chapter III 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

Alternative 2 includes the same set of prescriptive measures as the Proposed
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 should 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 of 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.[10] Additional information on
the carbon tax alternative is presented in Chapter II.

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.[11] 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 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 U.S. EPA and other federal
agencies in regulatory impact assessments. As shown in Chapter III, there is a
range of SC-CO_2 estimates across different discount rates, which measures the
value of money over time. Table 6 outlines the SC-CO_2 at a discount rate of 3
percent, in both 2007$ (as reported by U.S. EPA) and inflated to 2015$. As

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[10] 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
[11] For more information see: https://www.arb.ca.gov/regact/2016/capandtrade16/appc.pdf

modeled, the carbon tax increases over time from $48 in 2020 to $57 in 2030 (in $2015).[12]

Table 8. Social Cost of Carbon 2020 - 2030[13]

	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.

4. 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

California PATHWAYS estimates the costs and savings of the prescriptive measures in the scenarios. As modeled, the Proposed 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 Proposed 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.[14] Table 9 assumes that all prescriptive measures deliver the anticipated GHG reductions, and does not include any uncertainty in GHG reductions or cost.[15]

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[12] Information on the Social Cost of Carbon values is available at: https://www.epa.gov/climatechange/social-cost-carbon. 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.
[13] More information is available at: https://www.epa.gov/climatechange/social-cost-carbon.
[14] Additional information on the fuels included in PATHWAYS is available at: https://www.arb.ca.gov/cc/scopingplan/meetings/1142016/e3pathways.pdf.
[15] More information on the inputs to the California PATHWAYS model is available at: https://www.arb.ca.gov/cc/scopingplan/scoping_plan_scenario_description2016-12-01.pdf.

The prescriptive measures result in incremental capital investments of $5.1 billion per year in 2030, but these annual capital costs are nearly offset by annual fuel savings of $4.1 billion in 2030. The incremental net cost of prescriptive measures in the Proposed Plan is estimated at $1 billion in 2030, which represents 0.03 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. Agriculture and transportation sectors will see a net cost increase from the implementation of the prescriptive measures. The transportation sector sees higher capital costs due to the purchase of more efficient equipment and a reduction in fuel costs due to reduced vehicle miles traveled, more efficient equipment, and fuel-switching from fossil to electric fuels, relative to the Reference scenario. In the agriculture sector, capital expenditures are due to investments in more efficient lighting and the mitigation of agricultural methane and nitrogen oxides. As modeled, agricultural fuel costs increase due to higher electricity and liquid biofuel costs.

Table 9. Proposed Plan/Alternative 2: Change in PATHWAYS Sector Costs in 2030 Relative to the Reference Scenario (Billion $2015)[16]

End Use Sector[17]	Capital Cost	Fuel Cost	Total Cost
Residential	$0.1	-$0.8	-$0.7
Commercial	$0.5	-$0.9	-$0.4
Transportation	$3.7	-$3.2	$0.5
Industrial	$0.3	$0.2	$0.4
Oil & Gas Extraction	$0.0	$0.1	$0.1
Petroleum Refining	$0.1	-$0.2	$0.0
Agriculture	$0.3	$0.5	$0.8
TCU[18]	$0.1	$0.2	$0.3
Total	**$5.1**	**-$4.1**	**$1.0**

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[16] 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.
[17] Information on the end use sectors are available in the California PATHWAYS documentation available at: https://www.arb.ca.gov/cc/scopingplan/meetings/1142016/technicalappendix.pdf.
[18] Transportation, communications and utilities (TCU) energy supports public infrastructure including street lighting and waste treatment facilities.

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 (Proposed Plan) or the carbon tax (Alternative 2). The additional direct costs and savings associated with these scenarios are presented in Table 11 and 12.

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 with the exception of the industrial, oil & gas extraction, and petroleum refining sectors. Under Alternative 1, efficiency measures specifically target these sectors achieving a 25% reduction in GHGs for the oil & gas and industrial sectors and a 30% reduction in refinery GHGs. While these measures are anticipated to result in significant fuel cost savings, the capital costs of these measures are highly uncertain which may result in artificially low cost estimates.[19] 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.

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[19] Cost assumptions for PATHWAYS are detailed in Appendix D.

Table 10. Alternative 1: Change in PATHWAYS Sector Costs in 2030 Relative to the Reference Scenario (Billion $2015)[20]

End Use Sector	Capital Cost	Fuel Cost	Total Cost
Residential	$0.9	$2.7	$3.6
Commercial	$1.3	$1.0	$2.3
Transportation	$7.1	$0.9	$7.9
Industrial	$0.7	-$0.9	-$0.2
Oil & Gas Extraction	$0.1	-$0.4	-$0.3
Petroleum Refining	$0.2	-$0.2	$0.0
Agriculture	$1.4	$1.0	$2.4
TCU	$0.1	$0.6	$0.7
Total[21]	**$11.8**	**$4.7**	**$16.4**

In addition to uncertainty in measure costs, there is also uncertainty in costs embedded within the Reference scenario including the price of oil, other energy costs, and technology costs. The PATHWAYS cost results are sensitive to fossil fuel price assumptions. Altering the fuel price trajectory in the Reference scenario directly impacts the incremental cost of achieving GHG reductions as the costs of the Proposed Plan, Alternative 1, and Alternative 2 are measured relative to the Reference scenario.

The PATHWAYS scenarios use fossil fuel price projections from the Annual Energy Outlook (AEO) 2015 reference case.[22] To estimate the impact of changes in future fuel prices on the estimated incremental cost of the scenarios, two sensitivities were conducted. In the low fuel price sensitivity, the AEO low oil and natural gas price case is used to project the future cost of fuels in the Reference scenario. The cost of the scenarios, relative to the Reference scenario, increases under these conditions, since fuel savings are less valuable when fuel prices are low. A second sensitivity shows that high future oil and natural gas prices (as projected in the AEO high oil price case) reduce the net

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[20] 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.
[21] Values may not sum due to rounding.
[22] 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.

cost of the scenarios, relative to the Reference scenario. This is because avoided fuel savings are more valuable when fuel prices are high.

Table 11 outlines the costs and savings from the prescriptive measures in the Proposed Plan, Alternative 1, and Alternative 2 under the varying fuel price sensitivities.

Table 11. Change in PATHWAYS Cost in 2030 Relative to the Reference Scenario Under Varying Fuel Price Sensitivities (Billion $2015)

Scenario	Proposed Plan/ Alternative 2	Alternative 1
Reference Oil Price	$1.0	$16.4
Low Oil Price Sensitivity	$4.0	$21.5
High Oil Price Sensitivity	-$5.0	$5.5

Across the fuel price sensitivities, the prescriptive measures in the Proposed Plan and Alternative 2 range from a net cost of $4 billion to a *net savings* of $5 billion in 2030. The estimated cost of Alternative 1, meanwhile, varies from a net cost of $5.5 to $16.4 billion depending on the fuel price assumption. Additional sensitivity modeling will be included in the final release of the 2030 Target Scoping Plan and will also address the GHG and cost uncertainty of specific measures.

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 is estimated by multiplying the quantity of reductions needed to achieve the SB 32 target by the range of allowance prices in 2030.   This analysis includes a range of allowance prices bounded by the C+T Floor Price and the C+T Reserve Price. Similarly, the direct cost of reductions achieved through a carbon tax is calculated by multiplying the GHG anticipated GHG reductions by the carbon tax.

Table 12 shows the estimated direct cost (including prescriptive measures and the Cap-and-Trade Program) of the Proposed Plan across the fuel price sensitivities. As presented in Table 12, the costs of the prescriptive measures are calculated in PATHWAYS, but the costs associated with the Cap-and-Trade Program are calculated outside of the model. Changes in fuel prices may affect the price of Cap-and-Trade allowances, but the price is highly unlikely to go outside the range of prices bounded by the C+T Floor Price and C+T Reserve Price. The final column in Table 12 presents the estimated total cost of the Proposed Pan, reflecting future oil and allowance price uncertainty. The total cost ranges from an annual savings to California of $3.8 billion to an annual cost

of $7.6 billion. The net climate benefits, as estimated by the SC-CO_2, outweigh these direct costs.[23]

Table 12. Proposed Plan: Change in PATHWAYS Cost in 2030 Relative to the Reference Scenario Under Varying Fuel Price Sensitivities (Billion $2015)

Scenario	Prescriptive Measures	C+T Floor Price	C+T Reserve Price	2030 Total Cost
Reference Oil Price	$1.0	$1.2	$3.6	$2.2 to $4.6
Low Oil Price Sensitivity	$4.0	$1.2	$3.6	$5.2 to $7.6
High Oil Price Sensitivity	-$5.0	$1.2	$3.6	-$3.8 to -$1.4
Range of Climate Benefits (SC-CO_2)				$2.4 to $11.0

Fuel price sensitivity is directly modeled in PATHWAYS, resulting in a range of impacts from prescriptive measures. The range of costs labeled "2030 Total Cost" includes the cost of prescriptive measures estimated in PATHWAYS and the 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).

As there is no carbon pricing in Alternative 1, the cost of all GHG reductions is calculated in PATHWAYS and the total cost of the scenario with different fuel price sensitivities is presented in Table 11.

Table 13 presents the estimated direct costs of Alternative 2, including the cost of prescriptive measures and the carbon tax, across fuel price sensitivities. The SC-CO_2, which represents the carbon tax in this analysis, falls within the range of analyzed allowance prices under the Proposed Plan. Thus, the impacts of varying fuel prices under Alternative 2 fall within the anticipated range of impacts estimated under the Proposed Plan. This modeling assumes that a carbon tax at the SC-CO_2 will realize precisely the quantity of GHG reductions required to achieve the SB 32 target, which is very unlikely to occur. Under the fuel price sensitivities, the cost of Alternative 2 ranges from a net savings of $2.4 billion to net cost of $3.6 billion.

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[23] Climate benefits are estimated using the Social Cost of Carbon in 2030 across the range of discount rates from 2.5 to 5 percent. All values are reported in $2015. Additional information on the Social Cost of Carbon is available at: https://www3.epa.gov/climatechange/Downloads/EPAactivities/social-cost-carbon.pdf.

Table 13. Alternative 2: Change in PATHWAYS Cost in 2030 Relative to the Reference Scenario Under Varying Fuel Price Sensitivities (Billion $2015)

Scenario	Prescriptive Measures	Carbon Tax	2030 Total Cost
Reference Oil Price	$1.0	$2.6	$3.6
Low Oil Price Sensitivity	$4.0	$2.6	$6.6
High Oil Price Sensitivity	-$5.0	$2.6	-$2.4

Comparing the three scenarios, Table 14 presents the range of direct costs as estimated in PATHWAYS (for prescriptive measures) and calculated outside of the model (cost of Cap-and-Trade and the carbon tax). While there are potential cost savings under both the Proposed Plan and Alternative 2 depending on the future fuel price, the flexibility of the Proposed Plan results in the lowest potential cost across the fuel price sensitivities.

Table 14: Range of PATHWAYS Cost in 2030 Relative to the Reference Scenario Under Varying Fuel Price Sensitivities (Billion $2015)

Scenario	Range of 2030 Total Cost
Proposed Plan	-$3.8 to $7.6
Alternative 1	$5.5 to $21.5
Alternative 2	-$2.4 to $6.6

REMI

The macroeconomic impacts of the three scenarios are estimated using the REMI model. As detailed in section 2, 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) 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 15 outlines the macroeconomic impacts of implementing the Proposed Plan, based on the range of anticipated allowance prices.

Table 15. **Proposed Plan: REMI Macroeconomic Indicators in 2030 Relative to the Reference Scenario**

	Absolute Change	Percentage Change
California GDP (Billion $2015)	-$11.4 to -$20.7	-0.3% to -0.6%
Employment (Jobs)	-62,100 to -99,400	-0.3% to -0.4%
Personal Income (Billion $2015)	-$5.8 to -$4.1	-0.2% to -0.1%

In 2030, under the Proposed 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 3.

It is important to put the results of Table 15 into context. First, reducing GHG emissions 40 percent below 1990 levels under the Proposed Plan will lead to avoided social damages from climate change on the order of $2.4 to $11 billion, as estimated using the SC-CO$_2$ and presented in Table 12, 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. Even without including the potentially significant economic benefits of emissions reductions in the Proposed Plan, implementation of the Plan is not estimated to change the annual GDP growth across the range of allowance prices. Based on this analysis, in 2030 the California economy would take only three months longer to get to the GDP anticipated in the Reference scenario.

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 Proposed 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. In this analysis, implementing the Proposed Plan would change that growth of employment by less than one-half of one percent.

Estimated personal income in California is relatively unchanged under the Proposed 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 16 outlines the percentage change in value added by sector, i.e. a sector's contribution to California's economy, under the Proposed Plan. The sectors presented in Table 16 are defined in REMI by NAICS code at the 2-digit (or economic sector) level.[24] The range of results for each sector represents the estimated impact of the Proposed 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 Proposed 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 Proposed Plan.

Generally, sector value add grows more slowly under the higher allowance price, relative to the lower allowance price. However some sectors see reduced impact under the higher allowance price as more Cap-and-Trade auction proceeds are returned to consumers. The sector "other services sector" sees increased consumer spending resulting from the return of more auction proceeds from the sale of allowances under the higher allowance price.

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[24] 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 16. Proposed 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	-2.8% to -5.8%
Utilities	-1.8% to -5.02%
Construction	-0.6% to -1.2%
Manufacturing	-0.4% to -0.9%
Wholesale Trade	-0.5% to -1.1%
Retail Trade	-0.8% to -0.9%
Transportation and Warehousing	-1.0% to -1.7%
Information	-0.1% to -0.2%
Finance and Insurance	-0.2% 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 -0.4%
Educational Services	-0.2% to –0.1%
Health Care and Social Assistance	-0.1% 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	0.0% to 0.2%

Table 17 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 less than one percent relative to the Reference scenario. As modeled, Alternative 1 will not change the growth of GDP in California but will result in the slowing of

employment from 0.2 percent per year to 0.1 percent. Relative to the Proposed Plan, Alternative 1 has higher costs to the California economy and may result in additional job losses relative to the Proposed Plan.

Table 17. Alternative 1: REMI Macroeconomic Indicators in 2030 Relative to the Reference Scenario

	Absolute Change	Percentage Change
California GDP (Billion $2015)	-$24.6	-0.7%
Employment (Jobs)	-190,500	-0.8%
Personal Income (Billion $2015)	-$18.4	-0.6%

Table 18 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 "forestry, fishing, and related activities" sector which is estimated to see a decline of 5.4% under Alternative 1. As defined in REMI, this sector includes activities associated with forestry and agriculture. As modeled, the "utilities" sector is also sees declines in value add due to increased energy efficiency and demand response in Alternative 1. Relative to the Proposed 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.

Table 18. 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	-2.4%
Utilities	7.2%
Construction	-2.1%
Manufacturing	-0.7%
Wholesale Trade	-1.0%
Retail Trade	-1.9%
Transportation and Warehousing	-1.2%
Information	-0.5%
Finance and Insurance	-0.7%
Real Estate and Rental and Leasing	-0.7%
Professional, Scientific, and Technical Services	-0.6%
Management of Companies and Enterprises	-0.6%
Administrative and Waste Management Services	-0.9%
Educational Services	-0.7%
Health Care and Social Assistance	-0.7%
Arts, Entertainment, and Recreation	-0.7%
Accommodation and Food Service	-0.8%
Other Services, Except Public Administration	-0.9%

The macroeconomic impact of Alternative 2 lies within the range of impacts estimated under the Proposed Plan, as the SC-CO$_2$ lies within the anticipated range of allowance prices from 2021 through 2030. Table 19 presents the impact on California GDP, employment, and personal income resulting from Alternative 2. 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 does highlight the impact that different mechanisms for the return of tax revenue or allowance value can have on California consumers and the California economy.

Table 19. Alternative 2: Macroeconomic Indicators in 2030 Relative to the Reference Scenario

	Absolute Change	Percentage Change
California GDP (Billion $2015)	-$19.7	- 0.6%
Employment (Jobs)	-97,800	- 0.4%
Personal Income (Billion $2015)	-$2.0	-0.1%

The macroeconomic modeling of Alternative 2 does differ from the modeling of the Proposed Plan in the distribution of allowance value or tax revenue. Under the Proposed 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 20 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 20. 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	-7.1%
Utilities	-4.0%
Construction	-1.4%
Manufacturing	-0.9%
Wholesale Trade	-0.9%
Retail Trade	-0.8%
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	-0.4%
Management of Companies and Enterprises	-0.4%
Administrative and Waste Management Services	-0.4%
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%

Table 21 compares the percentage change in macroeconomic indicators for the three scenarios relative to the Reference scenario. Across all scenarios, the estimated economic impacts are negligible relative to the size of the California economy. Under all scenarios, California will continue to grow and will see less than a one percent decline in GDP, employment, or personal growth.

Comparing the three scenarios, the Proposed Plan has the lowest overall cost to California – when measured by California GDP, employment, and personal income. Alternative 1 has the largest relative impact on the economy with reductions in employment estimated as 190,000 jobs in 2030. This is double the employment impact of the other scenarios. Alternative 1 is expensive and among the three scenarios analyzed does the least to promote growth in employment and personal income. Alternative 2 has an economic impact that falls within the range of the Proposed Plan for impacts to GDP, employment, and personal income. Please note that the modeling results of Alternative 2 are a construct of the assumption that a carbon tax at the SC-CO$_2$ will achieve the GHG reductions needed to meet the SB 32 target.

Table 21. Comparison of Macroeconomic Indicator Growth in 2030 Relative to the Reference Scenario

	Proposed Plan	Alternative 1	Alternative 2
California GDP (Billion $2015)	-0.3% to -0.6%	-0.7%	- 0.6%
Employment (Jobs)	-0.3% to -0.4%	-0.8%	- 0.4%
Personal Income (Billion $2015)	-0.2% to -0.1%	-0.6%	-0.1%

Household Impacts

Consumer spending also shifts in response to implementation of the three scenarios relative to the Reference scenario. As presented in Table 21, there is a negligible impact to consumer income, but small changes in income can alter the distribution of consumer spending among categories. In 2030, consumer spending is lower under the all three scenarios compared to the Reference scenario. Consumers spend less on fuels, electricity, natural gas, and capital as a result of measures that reduce demand, increase efficiency, and drive technological innovations.

The estimated impact to California households is also modest in 2030, as outlined in Table 22. In 2030, the average annual cost per household of the Proposed Plan ranges from $30 to $215, depending on the price of reductions under the Cap-and-Trade Program.[25]

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[25] Household projections were obtained from California Department of Finance. They are available at: http://www.dof.ca.gov/Forecasting/Demographics/projections/.

Table 22. Household Impacts: Cost per Household in 2030 Relative to the Reference Scenario

Scenario	2030 Cost per Household
Proposed Plan	$30 to $215
Alternative 1	$240
Alternative 2	$130

Implementing the prescriptive measures in the Proposed Plan will change household fuel and equipment expenditures and is estimated to result in a $45 savings per household in 2030. The additional reductions needed to achieve the SB 32 target, obtained through the Cap-and-Trade Program, result in a cumulative annual cost of $30 to $215 to households in 2030, relative to the Reference scenario. The household impact of the Cap-and-Trade Program assumes that all costs of GHG reductions in the Cap-and-Trade Program are passed to consumers and therefore represents the upper bound of the estimated household impact. It does not account for benefits from reduced climate impacts, health savings from reduced air pollution impacts, or lower petroleum dependence costs that might otherwise impact households.

The estimated cost of Alternative 1 to households in 2030 is $240, reflecting the increased cost of prescriptive measures relative to the Cap-and-Trade Program. The estimated cost to households of Alternative 2 is $130, which is within the anticipated range of impacts under the Proposed Plan and also assumes that all costs of the carbon tax are passed directly to consumers.

While not significant, the range of household impacts represents net changes in fuel expenditures and capital investment as a result of the prescriptive measures and Cap-and-Trade component of the Proposed Plan. As modeled, the household impact of the Proposed Plan comprises less than one percent of average household expenditures in 2030. To ensure that vulnerable populations and low-income households are not 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 Proposed Plan. Researchers at the University of California, Los Angeles (UCLA) are 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. The Cap-and-Trade Program will also continue to provide benefits to disadvantaged communities through the disbursement of GGRF funds.

5. Additional Modeling and Conclusion

The economic analysis of the 2030 Target Scoping Plan is continuing and work is underway to finalize additional sensitivity analyses that will address uncertainty in the Reference scenario as well as the impact of cost uncertainty and GHG reductions from measures among the three scenarios. An additional analysis is also underway that will estimate the regional distribution of changes in California GDP, employment, and personal income as modeled in REMI. The regional analysis will be used to estimate the impact of the scenarios on disadvantaged communities and different regions throughout the State.

Additional modifications may also be made to incorporate stakeholder feedback and well as comments provided by the Environmental Justice Advisory Committee, and the Economic Reviewers to the Scoping Plan. The Economic Reviewers are a group of academic economists and researchers that are under contract with ARB to provide input on the tools and modeling assumptions, and the overall economic analysis used to evaluate the economic impact of the 2030 Target Scoping Plan. The Economic Reviewers and their academic affiliation are presented in Table 22.

Table 22: Economic Reviewers to the 2030 Target Scoping Plan

Economic Reviewer	Affiliation
Max Auffhammer	UC Berkeley
Jim Bushnell	UC Davis
Duncan Callaway	UC Berkeley
Meredith Fowlie	UC Berkeley
Christopher Knittel	MIT

The Proposed Plan achieves the SB 32 target at the lowest cost across the three modeled scenarios. The Proposed Plan outlines a path to achieve the SB 32 target that requires less reliance on fossil fuels and increased investment in low-carbon fuels and clean energy technologies. Through this shift, California can lead the world in developing the technologies needed to reduce the global risks of climate change. Innovation in low-carbon technologies will open growth opportunities for investors and businesses in California. This analysis suggests that the cost of transitioning to this lower carbon economy are small, even without accounting for the potential opportunities for new industries and innovation in California. Under the Proposed Plan, the California economy, employment, and personal income will continue to grow as California businesses

and consumers make clean energy investments and improve efficiency and productivity to reduce energy costs.

The investments made in implementing the Proposed Plan will have long-term benefits and present significant opportunities for California investors and businesses as upfront capital investments will result in long-term fuel and energy efficiency savings, the benefits of which will continue into the future. The California economy will continue to grow under the Proposed Plan, but it will grow more resilient, more sustainable, and will be well positioned to reap the long-term benefits of lower carbon investments.