California Environmental Protection Agency

Air Resources Board

Updated Economic Analysis of California's Climate Change Scoping Plan

Staff Report to the Air Resources Board

March 24, 2010

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1. EXECUTIVE SUMMARY

The Climate Change Scoping Plan provides California's blueprint for reducing its greenhouse gas (GHG) emissions to 1990 levels by 2020 as directed by AB 32, California's Global Warming Solutions Act of 2006. In approving the Scoping Plan, the California Air Resources Board (ARB) directed ARB staff to update the analysis of the economic effects of implementing the Plan. That updated economic analysis, documented in this report, profited from consultation with members of the Economic and Allocation Advisory Committee (EAAC), appointed by California Environmental Protection Agency (Cal/EPA) Secretary Linda Adams and ARB Chairman Mary Nichols. EAAC consists of top economists, business and financial leaders.

The Scoping Plan contains measures designed to reduce greenhouse gas emissions by increasing the efficiency with which California uses all forms of energy and by reducing its dependence on the fossil fuels that produce greenhouse gases. This analysis confirms that successful implementation of these measures will mean that we can achieve the goals of AB 32 without adversely affecting the growth of California's economy over the next decade, especially as the state recovers from the current economic downturn.

The updated economic analysis presented here indicates that these policies can shift the driver of economic growth from polluting energy sources to clean energy and efficient technologies, with little or no economic penalty. These results are consistent with most other economic analyses of AB 32 and of proposed federal climate-change legislation.

The Scoping Plan provides a framework for achieving the goals of AB 32 in a cost-effective manner by relying on a wide range of approaches, including:

- Expanding and strengthening existing energy-efficiency programs as well as the standards that apply to buildings and appliances
- Achieving a statewide renewable-energy contribution of 33 percent
- Developing a California cap-and-trade program that links with other Western Climate Initiative partner programs to create a regional market system
- Establishing targets for transportation-related GHG emissions for regions throughout California, and pursuing policies and incentives to achieve those targets
- Adopting and implementing measures that were already in progress, including California's clean-car standards, goods-movement measures, and Low Carbon Fuel Standard

The measures in the Plan will reduce GHG emissions from key sources and activities while putting the state on a path toward meeting the long-term 2050 goal of reducing California's greenhouse gas emissions to 80 percent below 1990 levels. ARB evaluated a comprehensive array of approaches to achieving these emissions reductions, and the

Scoping Plan includes both a greenhouse gas cap-and-trade program and a number of “complementary measures.” This combination is intended to achieve cost-effective reductions in the short and medium terms while accelerating the necessary transition to the low-carbon economy required for meeting the 2050 target.

This report provides an update on the expected economic effects of Scoping Plan implementation, taking into consideration the recent downturn in global economic activity and the progress on key federal policies designed to help achieve California’s and the country’s climate-change policy goals. The analysis also examines the potential outcomes should some of the ambitious measures included in the Plan not achieve the level of reductions currently expected.

Key complementary measures in the Scoping Plan include expanding and strengthening energy-efficiency programs, increasing the use of renewable energy in the electricity sector, increasing the use of combined heat and power, developing the next generation of vehicle GHG standards, implementing the Low Carbon Fuel Standard, reducing emissions of high global warming potential gases, and decreasing vehicle miles traveled through improved land-use planning. These measures are examined individually and collectively in this analysis.

The reference case in this analysis shows that if the Scoping Plan were not implemented, California’s economy would grow at an annual average rate of 2.4 percent between 2006 and 2020, with fuel expenditures increasing at an annual rate of 1.7 percent. By contrast, when the Scoping Plan measures are in place, increased investment in efficient buildings and technologies and in advanced fuels pays off: the economic growth rate remains 2.4 percent per year but fuel expenditures are reduced 4.9 percent and GHG emissions reduced by 15 percent relative to the reference case. The emissions reductions achieved through the complementary measures also help limit the allowance price in the cap-and-trade program to $21 per metric ton. Moreover, the analysis shows that success in reducing GHG emissions from the passenger-transportation sector can translate into savings both in investment and fuel expenditures.

ARB staff also conducted sensitivity analyses that considered the potential economic effects of achieving the AB 32 emission-reduction goals should some of the key reduction measures in the electricity, natural gas, and transportation sectors not provide the anticipated reductions. These sensitivity cases, including one in which all the major measures other than the cap-and-trade program deliver fewer reductions than planned, show only a small decrease in California’s economy in 2020 relative to the reference case. These results underscore the importance both of ensuring that these other measures remain on track and of developing rules for the cap-and-trade program that help ensure that allowance prices remain within a reasonable range.

The Costs of Inaction

The updated economic analysis presented here focuses exclusively on the economic effects in California of taking the actions outlined in the Scoping Plan. The analysis does not consider the avoided costs of inaction. The potential effects of climate change on California that are expected to occur could cause severe economic impacts. While California has developed a Climate Adaptation Strategy to help alleviate these potential costs, the risk of potentially high economic costs from climate change in California remains real.

While California acting alone cannot reduce emissions sufficiently to change the course of climate change worldwide, our leadership has played and continues to play a critical role in moving federal and international climate policy forward. Successful implementation of the AB 32 Scoping Plan, in particular, has the potential to help move federal climate policy in a positive direction during the coming years. The magnitude of the impacts that California could face from climate change provide a useful context for understanding the significance of the relatively modest economic costs associated with taking the actions described in the Scoping Plan.

The actions proposed in the Scoping Plan can also help mitigate the economic consequences of continued reliance on fossil fuels. Experience in recent decades, such as the spike in world oil prices in the summer of 2008, has illustrated the economic costs of volatile energy prices on California's economy. While this report does not attempt to quantify the insurance benefits of reduced dependence on fossil fuels in the face of continued volatility of world energy prices, it does show that California can significantly reduce its dependence on these fuels and, therefore, its vulnerability to future price spikes.

Analytic Approach

This analysis begins with an updated economic and energy forecast, based on the 2009 Integrated Energy Policy Report's estimates adopted by the California Energy Commission. This forecast takes into account the recent downturn in the global economy and projects a slower rate of growth than was assumed in developing the Scoping Plan in 2008. Because some of the emissions-reduction policies in the Scoping Plan are now being implemented at the federal level, ARB has incorporated them into the reference case for the updated analysis. These policies include the Pavley I vehicle standards and the energy-efficiency programs included in the 2007 Federal Energy Independence and Security Act (EISA). ARB has also included as part of the reference case the California 20-percent Renewable Portfolio Standard and actions being taken under the State Implementation Plan for criteria pollutants. Together, these changes mean that California's projected 2020 greenhouse gas emissions before considering the remaining measures from the Scoping Plan are estimated at 525 million metric tons (MMT), compared to the 600 MMT in the 'business-as-usual' case developed for the Scoping Plan.

This analysis relied on the use of models. It is important to remember that modeling of any kind is inherently uncertain, but even with uncertainties modeling is useful in policy evaluation. Modeling results, such as those presented here, can be useful tools in evaluating design elements of the measures as they are implemented. As ARB and other agencies move forward on individual measures, the results of this and more focused economic analyses can be used to help avoid potential adverse consequences.

The analysis presented here relied on two primary tools: the Energy 2020 model and the Environmental Dynamic Revenue Assessment Model (E-DRAM). Energy 2020 is a multi-region energy model that provides complete and detailed simulations of the demand and supply for all fuels. Models such as Energy 2020 are useful for investigating the impacts of GHG emissions constraints on the portfolio of technologies that make up the supply and demand components of the energy system, in order to identify low-cost abatement opportunities or to design technology based subsidies or emission standards.

E-DRAM is a computable general equilibrium (CGE) model of the California economy. CGE models are standard tools of empirical analysis, and they are widely used to analyze the aggregate impacts of policies whose effects may ripple through multiple markets. In the current analysis, the two models are used in tandem. The combination provides a more complete picture of the economic effects of AB 32 implementation than could be achieved using either model alone.

These two models help answer different key questions relating to the economic effects of implementing AB 32. Energy 2020 provides insights into GHG emissions reductions, changes in fuel expenditures, changes in investment by year and by sector, and shifts in the allowance price for the cap-and-trade program. E-DRAM complements these results by providing insights into changes in statewide output and in income and employment across different socioeconomic groups.

In addition to using Energy 2020 and E-DRAM to evaluate the overall economic effects of implementing AB 32, ARB staff conducted a number of additional evaluations. They included: an analysis of the potential effects on small business and on job creation; and an examination of the economic valuation of the reduction in criteria pollutants that may be associated with the GHG emissions-reduction measures.

Work with the Economic and Allocation Advisory Committee

ARB staff has been working closely with the members of the Economic and Allocation Advisory Committee (EAAC), which was appointed in the summer of 2009 by Cal\EPA Secretary Adams and ARB Chairman Nichols in part to advise ARB on the updated economic analysis. EAAC established an economic impacts subcommittee to consult with ARB staff while the analysis described in this report was being developed. Subcommittee members have informally commented on earlier drafts of this report, and they have written a companion report, included with this report as an appendix, that describes both their working relationship with ARB staff and their comments on the report. The subcommittee will first report to the Board at the March 2010 meeting where this updated analysis is presented. ARB is planning a more extensive public discussion in April of this report and related analyses of GHG mitigation plans. ARB staff will continue to consult with the EAAC subcommittee members as the analysis is refined and expanded as part of cap-and-trade rulemaking.

Impact on the Economy

The combination of Energy 2020 and E-DRAM provides a more complete look at the economic effects of the measures in the Scoping Plan than is possible with either model alone. However, this modeling effort conservatively estimates the effects that the Plan's implementation will have on California's economy. One of the key reasons to adopt a policy like the cap-and-trade program, which puts a price on GHG emissions, is to provide incentives throughout the economy for companies and inventors to seek out new technologies that increase efficiency or enable lower-polluting fuels to be used. While Energy 2020 captures the potential for increased investment in more efficient technologies or alternative fuels, it cannot fully account for the technological innovation that a long-term price on GHG emissions is intended to spur.

In the main policy case, which reflects implementation of the Scoping Plan as currently expected, the analysis shows that the overall rate of California's economic growth will be virtually unchanged through 2020, though shifts within the economy will mean a cleaner and more efficient future for the state. Gross State Product, one of the broadest measures of California's economic activity, income and labor demand would essentially remain the same (see Table ES-1).

While Energy 2020 modeling results show an increase in energy prices (i.e., cost per unit), the increases in efficiency throughout the economy helps reduce fuel expenditures in California relative to the reference case by 4.9 percent by 2020. These results suggest that the increases in energy prices in California from the measures in the Scoping Plan are offset by the resulting decreases in fuel use.

Table ES-1. Modeling Results for 2020—Scoping Plan Policy Case (Case 1)

(2007 Dollars)	**Reference Case**	**Scoping Plan Policy Case**	**Change from Reference Case**
Gross State Product ($ Billions)	2,502	2,498	-0.2%
Personal Income ($ Billions)	2,027	2,029	0.1%
Income Per Capita ($ Thousands)	46.06	46.09	0.1%
Labor Demand (Millions)	18.41	18.42	0.1%
Allowance Price in 2020	NA	21	NA
Annual Average Growth (2007-2020)			
Gross State Product	2.4%	2.4%	
Personal Income	2.4%	2.4%	
Income Per Capita	1.2%	1.2%	
Labor Demand	0.9%	0.9%	

Sensitivity Analysis

In addition to the main policy case representing the implementation of the Scoping Plan, ARB analyzed four sensitivity cases. The first of these examined an alternative design feature within the cap-and-trade program:

- No offsets case (Case 2): This case considered the effects of not allowing offsets in the cap-and-trade program. (Offsets in this context are credits for emissions reductions that can be achieved by outside sources.)

The no-offsets case examines a cap-and-trade program design that does not allow lower-cost offset credits to substitute for the most expensive emission-reduction options otherwise available. Because the price of allowances reflects the cost of the most expensive emissions reductions needed to meet the cap, not allowing offsets has a large effect on allowance prices. The results of this case show that offsets can help contain costs within the cap-and-trade program and prevent higher energy prices for California's businesses and residents, allowing continued economic growth (see Table ES-2).

The other three cases examine the impacts on California's economy should the complementary measures provide fewer reductions than assumed in the Scoping Plan:

- Reduced transportation measures case (Case 3): This case examines less effective implementation of the transportation-sector measures
- Reduced electricity/natural gas measures case (Case 4): This case examines less successful implementation of the electricity- and natural gas-sector measures
- Combined reduced measures case (Case 5): This case examines less successful implementation of both sets of measures

Successful implementation of the complementary measures has the effect of reducing emissions for sources covered by the cap-and-trade program, meaning that fewer emissions reductions need to be found through the cap-and-trade mechanism than would otherwise be the case. Less effective implementation of these measures results in a small negative effect on the economy both through increased allowance prices and through the lack of cost savings that derive from many of the complementary measures in the main policy case. However, even the most extreme case, which assumes reduced effectiveness of key measures in the transportation, electricity, and natural gas sectors, would result in just a 1.4-percent decrease in 2020 gross state product compared to the reference case (see Table ES-2). These findings highlight the importance of successful implementation of the complementary measures, and they also emphasize the need for design features and market-stability mechanisms in the cap-and-trade program so that costs can be contained and allowance prices can be kept at a moderate level.

Table ES-2. Modeling Results for 2020—Sensitivity Cases

				Sensitivity to Reduced Effectiveness of Complementary Policies		
(2007 Dollars)	**2020 Business as Usual Reference Case**	**Scoping Plan Case (Case 1)**	**No offsets in C&T Sensitivity (Case 2)**	**Reduced Transpor-tation Measures Sensitivity (Case 3)**	**Reduced Electricity/ Natural Gas Measures Sensitivity (Case 4)**	**Combined Reduced Measures Sensitivity (Case 5)**
Gross State Product ($ Billions)	2,502	2,498	2,480	2,477	2,483	2,467
Personal Income ($ Billions)	2,027	2,029	2,018	2,011	2,019	2,003
Income Per Capita ($Thousands)	46.06	46.09	46.00	45.84	46.00	45.79
Labor Demand (Millions)	18.41	18.42	18.19	18.27	18.22	18.09
Percent Change from Reference						
Gross State Product	-	-0.2%	-0.9%	-1.0%	-0.8%	-1.4%
Personal Income	-	0.1%	-0.4%	-0.8%	-0.4%	-1.2%
Income Per Capita	-	0.1%	-0.1%	-0.5%	-0.1%	-0.6%
Labor Demand	-	0.1%	-1.2%	-0.8%	-1.0%	-1.7%
Annual Average Growth (2007-2020)						
Gross State Product	2.4%	2.4%	2.3%	2.3%	2.3%	2.3%
Personal Income	2.4%	2.4%	2.4%	2.3%	2.4%	2.3%
Income Per Capita	1.2%	1.2%	1.2%	1.2%	1.2%	1.2%
Labor Demand	0.9%	0.9%	0.8%	0.9%	0.8%	0.8%

Note: All five modeling cases achieve the reduction goals of AB 32. The Scoping Plan case (Case 1) includes full implementation of all policies. Case 2 tests the economic effects of not allowing offsets in a cap-and-trade program but with full implementation of complementary policies. Cases 3-5 test the sensitivity of results from differing assumptions of the effectiveness of complementary policies. Case 3 includes no VMT reduction, and reduced effectiveness of the Low Carbon Fuel Standard and the Pavley II vehicle standards. Case 4 includes no 33% RPS (20% RPS is still in place) and reduced effectiveness of the electricity and natural gas energy efficiency, and the combined heat and power measure. Case 5 combines the reduced effectiveness of both cases 3 and 4.

Small Businesses

The report concludes that the Scoping Plan is unlikely to have a significant adverse or disproportionate effect on California's small businesses. Impacts on small businesses are less than those on the economy as a whole because small businesses are concentrated in sectors that primarily see only the indirect costs of AB 32. But in some sectors, such as wholesale trade and information, small businesses may expect to see an increase in employment and output as consumers invest in more efficient appliances and improve the energy efficiency of their homes.

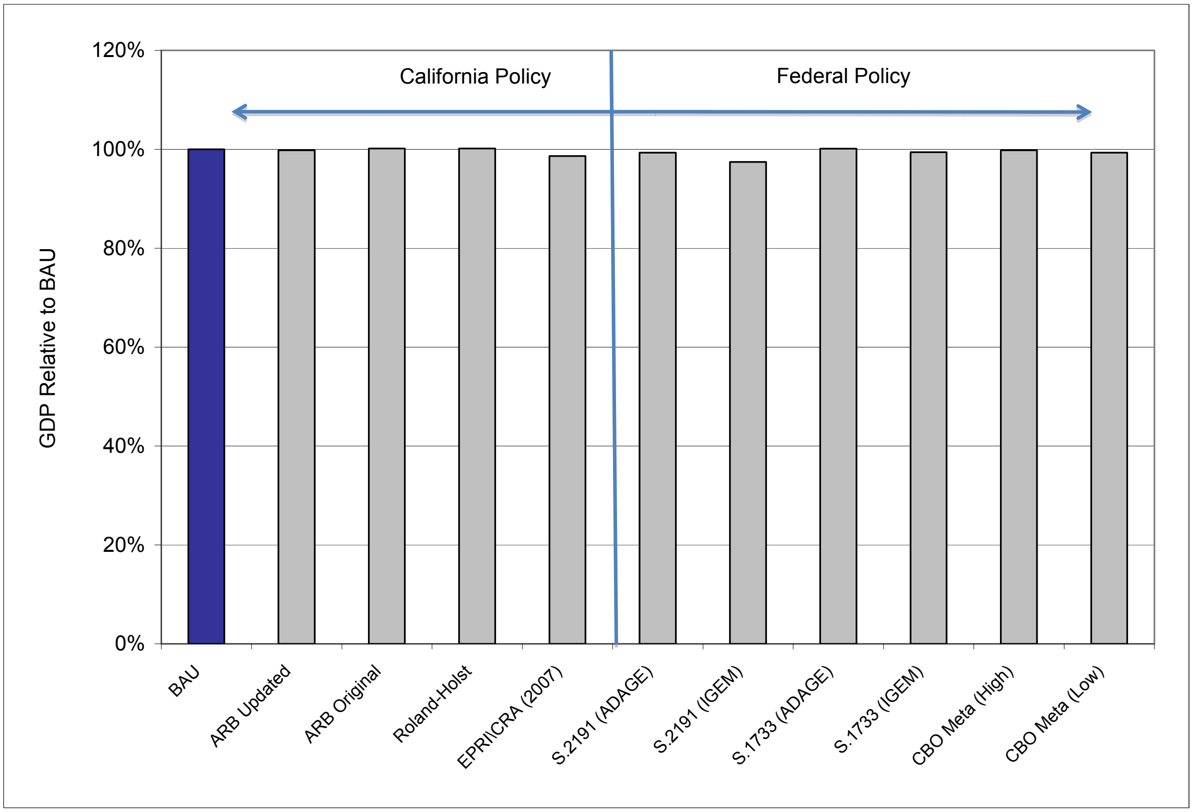
Because this analysis does not take into consideration the potential for increased energy efficiency by small businesses, the actual impact of the energy-cost increases is likely to be less than estimated here.[1] Higher energy costs tend to stimulate investment in energy-efficient products and equipment. Moreover, the Scoping Plan includes aggressive energy-efficiency targets that can be achieved expanding the range of programs available from utilities and third party providers, including significant outreach to and investment assistance for small businesses and households. As businesses invest in energy-efficient products and equipment, their annual energy consumption will decline.

Comparison of Updated Analysis with Other Economic Analyses

This report identifies several efforts to model AB 32 and similar federal climate-change legislation. Although the modeling approaches vary, the overall results are quite similar, with the aggregate impact on GSP expected to be small relative to overall GSP growth. Figure ES-1 compares the relative impact of the various analyses of climate policy with respect to business-as-usual for 2020.

[1] This statement is consistent with an independent study by the Brattle Group titled "The Economic Impact of AB 32 on California Small Business" (December 2009) http://www.ucsusa.org/assets/documents/global_warming/AB-32-and-CA-small-business-report.pdf

Figure ES-1: Comparison of Climate Policy Analysis Results for 2020



The results presented here are consistent with these other evaluations of AB 32 and of federal climate legislation. The findings of this report support the continued implementation of the Scoping Plan, while helping to highlight key issues that ARB and other state agencies must address as part of that implementation.

2. INTRODUCTION

The purpose of this report is to provide an update to the Air Resources Board (ARB) regarding the potential economic impacts of implementing the Climate Change Scoping Plan. Upon approving the Plan in December 2008, the Board directed ARB staff to provide an update of the analysis of the economic effects of implementing it. The update would include:

- Estimates of the overall costs, savings, and cost-effectiveness of the reductions, not only for greenhouse gases (GHGs) but also for co-pollutants
- Estimates of the timing of capital investments and the resulting savings
- Sensitivity of the results to changes in assumed conditions
- Impacts on small businesses.[2]

2.1. Economic and Allocation Advisory Committee

The Board also directed ARB staff to solicit input from experts on the continuing analysis of the economic effects of implementing the Scoping Plan. On May 22, 2009, California Environmental Protection Agency (CalEPA) Secretary Linda Adams and Air Resources Board Chairman Mary Nichols appointed a 16-member Economic and Allocation Advisory Committee (EAAC) to provide advice on the implementation of the state's landmark Global Warming Solutions Act of 2006 (AB 32). It would also advise on an associated cap-and-trade system designed to reduce California greenhouse gas emissions to 1990 levels by 2020 and provide expert input on the updated economic analysis of the Scoping Plan.

The EAAC, composed of top economists, financial and business leaders, and policy experts, has provided advice on the allocation of allowances and the implications of different allowance-allocation strategies. Its Economic Impacts Subcommittee has also given advice to ARB on how to perform the revised economic analysis presented here. On January 11, 2010, the EAAC presented its final allocation recommendations to the State.[3] Stanford Professor Lawrence Goulder, chairman of the EAAC, will attend the Air Resources Board meeting on March 25, 2010, both to present the EAAC's allocation recommendations and to provide the committee's perspective on the ARB staff's updated economic analysis of the Scoping Plan.

2.2. Collaborative Modeling Exercise

ARB and CalEPA arranged with Charles River Associates (CRA) to conduct a collaborative modeling exercise of the AB 32 policies. CRA's Multi-Region National-North American Electricity and Environment Model (MRN-NEEM) model fully integrates

[2] http://www.arb.ca.gov/cc/scopingplan/document/scopingplandocument.htm
[3] http://climatechange.ca.gov/eaac/documents/eaac_reports/2010-01-10_EAAC_Allocation_Report_Draft.pdf

a “computable general equilibrium” model of the U.S. economy and a bottom-up quadratic-programming model of the North American electric sector. The MRN-NEEM model has previously been used to investigate the impacts of climate and energy policies both for California and the United States as a whole.

The intent of this portion of the analysis was to examine the impact of modeling tools and frameworks on the conclusions drawn by ARB regarding the economic impacts of AB 32 policies. ARB staff provided CRA with model inputs, assumptions, and scenarios examined. In particular, CRA was able to use its models to examine the policy scenarios presented in this report.

While the CRA analysis is not included in this report—it will be released as a separate document—CRA has been invited to present and discuss its analysis at the March Board meeting.

3. DEFINITIONS

Allowance budget is the number of allowances issued in a given year, in millions of metric tons ($MMTCO_2E$) of CO_2-equivalent. The sum of allowance budgets over 2012-2020 is quantitatively equivalent to the cap-and-trade program's cap.

Allowance value is the allowance price in a given year multiplied by the allowance budget for that year.

Compliance periods are 2012-2014, 2015-2017, and 2018-2020.

Covered Sectors connotes the sectors covered by the cap-and-trade program in a given compliance period.

2012 is the first year of the first compliance period; it is also the starting year of the cap-and-trade program.

2015 is the first year of the second compliance period.

2020 is the final year of the third compliance period.

Compliance means that at the end of each compliance period the covered-sector emissions, summed over each year since 2012, are equal to or less than the cap, after accounting for offsets.

California target is that GHG emissions for the entire regional economy by 2020 will equal 1990 levels.

Narrow scope in the modeling connotes emissions in California from electric power generation, energy-intensive industries, other industry fuel-combustion processes, and electric power imported into the state.

Broad scope in the modeling means the narrow scope plus passenger-transport and freight-transport emissions and emissions from all remaining fossil-fuel combustion, including residential, commercial, agriculture, solid waste, and wastewater. Not included in the broad scope are process emissions from agriculture, solid waste, wastewater, and high-global-warming-potential gases (such as refrigerants).

Uncovered sources are emission sources that are not included in the program scope in a given year. Once the program is covering the broad scope, the uncovered sources include process emissions from agriculture, waste and wastewater, and high-global-warming-potential gases (such as refrigerants).

Banking means that allowances that are not required for compliance in one compliance period may be used for compliance in a subsequent compliance period.

Cap-setting precision means the degree to which the 2012 narrow-sector allowance budget and 2015 other-sectors allowance budget is close to the relevant capped-sector emissions in the Complementary Policies run.

Allowance-price trajectory connotes a series of allowance prices from 2012 to 2020 that is used to model rational banking behavior as part of the cap-and-trade program.

Reference case is the case against which the Scoping Plan policy cases are compared.

Complementary policies case builds on the reference case by including the complementary policies.

Cap-and-trade case builds on the complementary-policies case by imposing an allowance-price trajectory. All of the cap-and-trade cases include the complementary policies.

Abatement means the change in emissions in the capped sectors due to the cap-and-trade policy. In particular, it is the difference between the emissions in a cap-and-trade case and the emissions in the reference case. Abatement indicates efforts to decrease emissions in the capped sectors, whereas reduction refers to progress toward compliance.

Reduction means the difference between the emissions in the cap-and-trade case and the allowance budget in 2012 (for narrow scope) or 2015 (for other covered sectors in second and third compliance periods). Reduction refers to progress toward compliance, whereas abatement indicates decreased emissions in the capped sectors. Reductions are relevant to calculating the offset limit.

GHG benefit is the amount of CO_2e kept out of the atmosphere by the California cap-and-trade program.

4. MODELING FRAMEWORKS

Modeling of any kind is inherently uncertain, but even with uncertainties modeling is useful in policy evaluation. The intent of this analysis is to investigate how several of the major emission-reduction policies proposed in the Scoping Plan perform individually, as a group, and with cap and trade, and to do this investigation using a common set of data and assumptions. When making the many assumptions necessary, staff has tried to err on the side of caution so as to not make the goal of achieving emission reductions under AB 32 appear too easy. Specifically:

- The analysis was performed using economic-growth assumptions that might be considered too aggressive given the current state of the California economy thus potentially overstating the costs of compliance.
- The models used provide limited avenues for compliance, also potentially overstating the costs of compliance.
- Analysis was performed using a wide range of assumptions about the potential success of complementary policies, since many of the reductions from complementary policies come at low or negative costs.

This analysis does not compute an exact measure of economic impact but instead provides some sense of the magnitude and direction of the Scoping Plan's costs and benefits, as compared to the assumed reference case. Moreover, the analysis is not intended to serve as the economic basis for adopting any specific policy. Individual regulations implemented under AB 32 will need to be adopted on the basis of their own merits and supporting economic analysis, as part of a public rulemaking process.

The analysis is performed with the assumption that no Regional or Federal climate program is in place prior to 2020. Furthermore, the analysis does not speculate about polices that may be adopted to reach targets beyond the 2020 goal established in the Scoping plan.

Implementation of some Scoping Plan measures may shift emissions from sources in the state to those outside, resulting in emissions "leakage." AB 32 defines leakage as a reduction in emissions of greenhouse gases within the state that is offset by an increase in emissions of greenhouse gases outside the state, and the law requires that its mandated measures minimize leakage to the extent feasible and in furtherance of achieving the statewide emissions limit. ARB, which considers leakage in the context of each measure, is working closely with its partners in the Western Climate Initiative (WCI) and with the federal government to implement a larger climate-change program in order to reduce the risk of leakage. For example, the California Clean Car standard (referred to as Pavley I in the Scoping Plan) and the federal Corporate Average Fuel Efficiency standard are now equivalent for model years 2012-2016. ARB anticipates that current and future actions to reduce greenhouse gases in California will become adopted by other states and at the national level (as occurred with the California Clean Car standard), thereby reducing or eliminating the potential for leakage to occur.

An analysis of the economic impacts of the Scoping Plan requires the ability to represent the costs, savings, and emissions impacts of all of the Scoping Plan measures; the ability to estimate the responses by producers and consumers to changes in costs and prices; and the ability to estimate the impact on the overall economy to changes in all prices. The combined use of the Energy 2020 model and the E-DRAM model provides these capabilities. Models such as Energy 2020 are designed to investigate the impacts of GHG emissions constraints on the portfolio of technologies that make up the supply and demand components of the energy system; through their use, analysts can identify low-cost abatement opportunities and design technology-based subsidies or emission standards.[4] Models such as E-DRAM are designed to assess the regional costs of GHG emission limits and the feedbacks of these policies on prices, commodity and factor substitutions, and incomes. The two models are meant to act both as complements and alternative views of the potential impacts of AB 32 policies. Sections 4.1 through 4.3 provide a brief summary of each model.

4.1. Energy 2020

A brief description of the Energy 2020 model is provided here, and additional detail can be found in the Assumptions Book for Energy 2020 and the Energy 2020 technical documentation posted on the ARB Website.[5]

Energy 2020 is an integrated multi-region energy model that provides complete and detailed simulations of the demand and supply picture for all fuels. The model simulates demand by three residential categories, over 40 North American Industrial Classification System (NAICS) commercial and industrial categories, and three transportation services. There are approximately six end-uses per category and six technology/mode families per end-use. Currently the technology families correspond to six fuel groups (oil, gas, coal, electric, solar, and biomass) and 30 detailed fuel products.

Supply sectors include electricity, oil, natural gas, refined petroleum products, ethanol, landfill gas, and coal supply. For electricity, the model includes endogenous (i.e., calculated by the model) simulation of capacity expansion/construction, rates/prices, load-shape variation due to weather, and changes in regulation. For the other supply sectors the prices are set exogenously. The model includes pollution accounting for combustion (by fuel, end-use, and sector), non-combustion, and non-energy (by economic activity) for GHGs and other criteria pollutants (SO_2, NO_2, N_2O, CO, CO_2, CH_4, PMT, $PM_{2.5}$, PM_5, PM_{10}, VOC, CF_4, C_2F_6, SF_6, and HFC). In the present analysis, we consider only the GHG changes resulting from Energy 2020.[6]

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[4] I. Sue Wing (2006). The Synthesis of Bottom-Up and Top-Down Approaches to Climate Policy Modeling: Electric Power Technologies and the Cost of Limiting U.S. CO_2 Emissions, Energy Policy 34: 3847-3869. http://people.bu.edu/isw/papers/top-down_bottom-up_static.pdf

[5] http://www.arb.ca.gov/cc/scopingplan/economics-sp/models/models.htm

[6] The criteria-pollutant emissions reductions calculated in Section 9 result from changes in energy use, calculated by the Energy 2020 model, multiplied by independent emission factors (for criteria pollutants) and are not directly computed by Energy 2020.

The model simulates decisions by energy users by year for each end-use, including: fuel choice; investment in end-use efficiency (e.g., by purchasing devices that are more efficient than the minimum required by standards); and end-use utilization (i.e., how much the device is used). End-use-specific choices are simulated as needed, such as mode choice for freight movement and passenger transportation. Choices are simulated based on costs (e.g., increased capital costs versus the value of fuel saved) as well as on non-price attributes (e.g., convenience or the acceptance of the technology). Past purchasing behavior is used to calibrate the non-price choice parameters for each end-use. Additionally, outputs produced using Energy 2020 can be linked to a macroeconomic model to further determine the economic impacts of the AB 32 policies.

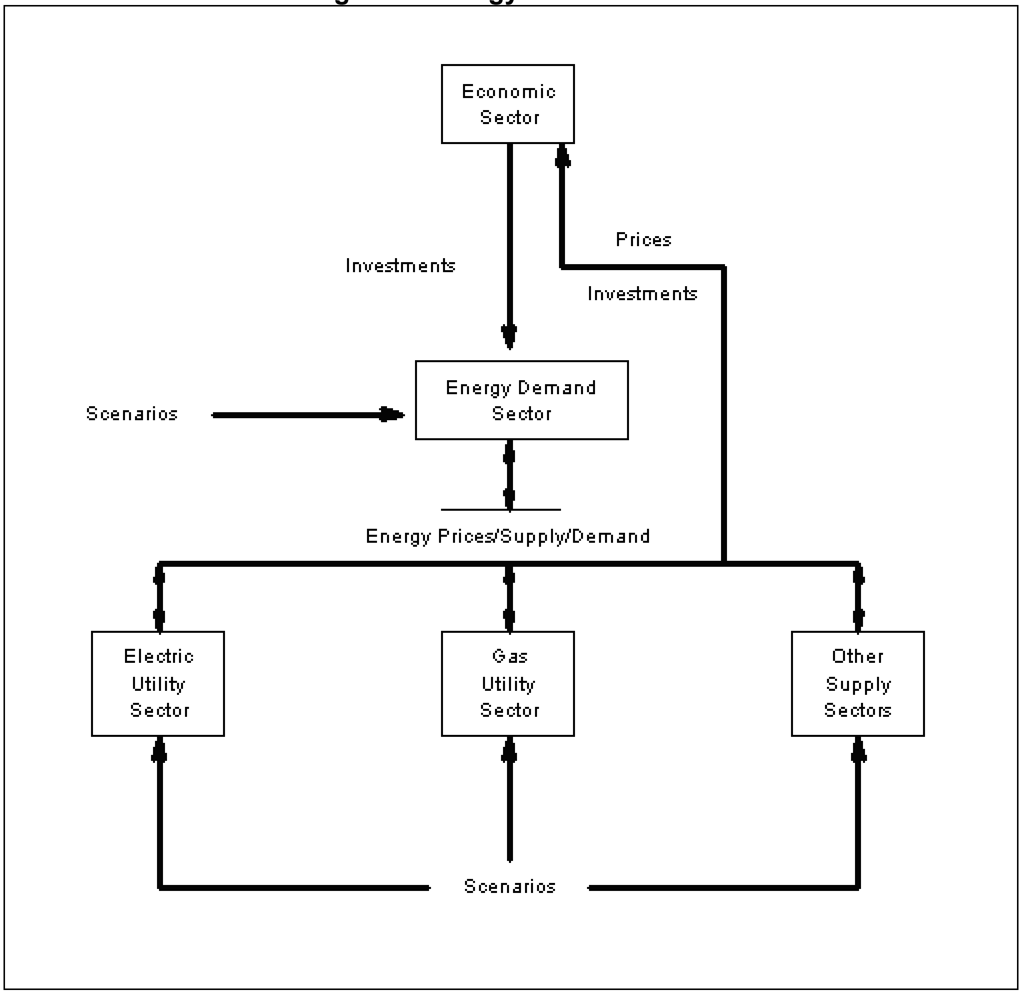
Energy 2020 can provide insight into the following:

- The cap-and-trade program allowance price
- Changes in fuel prices associated with allowance prices
- Emissions reductions by year and sector
- Changes in fuel expenditures by year and sector
- Changes in investment by year and sector

Energy 2020 does not estimate changes in state output, income, employment, or the redistribution of potential allowance revenue. These questions are addressed using the E-DRAM model, discussed in Section 4.3.

The general structure of Energy 2020 is provided in Figure 1. The Energy Demand Sector interacts with the Energy Supply Sector to determine the equilibrium levels of demand and energy prices. The Energy Demand Sector is driven by the Economic Sector, but it also feeds back inputs to the Economic Sector in terms of investments (in energy-using equipment and processes) and energy prices. The model has a simplified Economic Sector so as to capture the linkages between the energy system and the overall economy. However, the model is best run with integration with a macroeconomic model.

Figure 1. Energy 2020 Overview



The model assumes that energy demand results from using capital stock in the production of output. For example, the industrial sectors produce goods, which require energy for production; the commercial sectors require buildings in order to provide services; and the residential sector needs housing. The amount of energy consumed in any end-use is based on energy efficiencies. For example, the energy efficiency of a house, along with the efficiency of the furnace, determines how much energy the house uses to provide the desired warmth.

The model simulates investment in energy-using capital (e.g., buildings and equipment) from installation to retirement through three age classes, or vintages. This capital represents embodied energy requirements that will result in a specified energy demand as the capital is utilized, until it is retired or modified.

The size and efficiency of the capital stock, and therefore the energy demands, change over time as consumers make new investments and retire old equipment. Consumers determine which fuel and technology to use for new investments based on perceptions of cost and utility. Marginal tradeoffs between changing fuel costs and efficiency determine the capital cost of the chosen technology. These tradeoffs are dependent on perceived energy prices, capital costs, operating costs, risks, access to capital, regulations, and other imperfect information.

The model formulates the energy-demand causally using historical relationships of output, energy demand and technology. Rather than using price elasticities to determine how demand reacts to changes in price, the model explicitly identifies the multiple ways in which price changes influence the economics of alternative technologies and behaviors, which in turn determine consumers' demand. The model accurately recognizes that price responses vary over time, depending on factors such as the rate of investment, age and efficiency of the capital stock, and relative prices of alternative technologies.

The energy requirement embodied in the capital stock can be changed only by new investments, retirements, or retrofitting. The efficiency with which capital uses energy has a limit determined by technological or physical constraints. The efficiency of the new capital purchased depends on the consumer's perception of the trade-off between efficiency and other factors such as capital costs. For example, as fuel prices increase, the efficiency that consumers choose for a new furnace is increased despite higher capital costs. The amount of the increase in efficiency depends on the perceived price increase and its relevance to the consumer's cash flow. Cumulative investments determine the average "embodied" efficiency. The efficiency of new investments versus the average efficiency of existing equipment is one measure of the gap between realized and potential conservation savings.

The Energy 2020 model uses saturation rates for devices to represent the amount of energy services necessary to produce a given level of output. Saturation rates may change over time to reflect changes in standard of living or technological improvements.

Not all investment expenditures are allocated to the least expensive energy option. Uncertainty, regional variations, and limited knowledge make the perceived price a distribution. The investments allocated to any one technology are then proportional to the fraction of times it is perceived as less expensive (has a higher perceived value) than all others.

4.2. Energy 2020 Input Data, Assumptions, and Outputs

4.2.1. Energy 2020 Data and Assumptions

This section provides an overview of the data and assumptions required for Energy 2020 to perform the multi-sector analysis and generate the primary model outputs.

The Energy 2020 model calculates a reference case based on forecasts of key drivers across a range of topic areas, including economic developments, fuel and electric markets, and regulatory structures. The data inputs for Energy 2020 are required in five areas:[7]

1. Population and economic growth
2. Fuel prices
3. Energy use and consumption
4. Emissions and existing air quality regulations
5. Electricity generation capacity and operation

These categories are further subdivided as follows:

Geographic Coverage. This phase of the analysis covers the lower 48 states of the United States and all of Canada. By covering the entire electric grid, the impacts of the California program on electricity generation in the other Western Electricity Coordinating Council (WECC) states and provinces can be examined.

Sectors and Sources. This phase of the analysis includes energy use in all sectors as well as most industrial-process emissions. Landfill methane emissions and non-energy agriculture emissions are included in the total emissions estimates, but emissions reductions are not estimated for these sources.[8] The analysis is based on gross emissions, so that forestry emissions and sinks are excluded.

California Population Forecast. The model is driven by forecasts that include population growth and economic growth by detailed sector. The forecasts for California are from the California Department of Finance while forecasts for the other states are from the U.S. Census Bureau. Table 1 shows the population-growth forecasts.

Table 1. Population Forecast for California (Millions)

	2006	2012	2015	2020	Avg. Annual Growth Rate 2006-2020
Population	37.3	40.2	41.7	44.1	1.2%

California Economic Growth Forecast. The model is driven by forecasts of economic growth by detailed sector. For California, the economic forecasts used in this analysis are consistent with those used to produce the 2009 Integrated Energy Planning Report (IEPR).[9] Forecasts for the other states are from the U.S. Bureau of Economic Analysis. Table 2 details the economic forecasts.

[7] Data refers both to historical data as well as projections of future inputs.
[8] Examples of non-energy agriculture emissions are methane emissions from livestock, carbon and N_2O emissions from agricultural soils, and methane emissions from livestock manure management.
[9] http://www.energy.ca.gov/2007publications/CEC-100-2007-008/CEC-100-2007-008-CMF.PDF

Table 2. Gross State Product Forecast for California (Billions of 2000 dollars)

	2006	2012	2015	2020	Avg. Annual Growth Rate 2006-2020
Gross State Product	1,487	1,656	1,828	2,091	2.5%

Fuel Price Forecast. The model is also driven by forecasts of fuel prices for oil, coal, and natural gas. The model calculates electricity prices endogenously. Table 3 shows the forecasts used in the reference case.

Table 3. Fuel Price Forecast

	2006	2012	2015	2020
World Oil Price (2007 US$/barrel)	60.70	94.84	108.52	112.05
Natural Gas Wellhead Price (2007 US$/mmBtu)	6.91	6.75	6.90	7.43
Coal Price (2007 US$/ton)	25.29	27.69	27.77	27.38

Source: U.S. Energy Information Administration (EIA) Annual Energy Outlook 2008 revised reference price series.

Energy Demand Forecast. Growth in energy consumption by sector is targeted to be in line with energy demand in the 2009 IEPR for California and in the EIA State Energy Data System (SEDS) for the remaining states.[10]

Coal Plants. For modeling purposes, the coal plants already planned and committed to be built in the WECC are assumed to have been put in place. No additional coal plants in the WECC are assumed in the analysis.

Nuclear Plants. For modeling purposes, the cases assume that no new nuclear plants will be built by 2020 in the WECC.

Carbon capture and storage (CCS). For modeling purposes, no commercial-scale carbon capture and storage is assumed for electric power generation through 2020. Consequently, CCS does not play a role in the analysis.

Hydropower. For modeling purposes, the cases assume no new hydropower capacity built in the WECC by 2020.

Plug-in hybrids. For modeling purposes, the cases assume that plug-in hybrid and electric vehicles are not available in significant numbers through 2020. Consequently, electricity as a vehicle fuel does not play a role in the analysis.

Electrical Generation Costs. The costs and characteristics of new generation are adapted from information developed by Energy and Environmental Economics, Inc. (E3) as part of that company's modeling process for the California Public Utility

[10] http://www.eia.doe.gov/emeu/states/_seds.html

Commission.[11] For those plant types not reported by E3, default characteristics were used. The Assumptions Book contains the specific costs and characteristics used in the model for California and the rest of the WECC.

Allocation of Allowances. The cost of allowances is modeled explicitly for the electric sector, being reflected in electricity prices and paid for by ratepayers. For the other sectors, the opportunity cost of allowances is reflected in energy prices; in that way, investment decisions consider the price of carbon at the margin. This analysis did not use the model to examine the distributional impacts of alternative allowance-allocation methods or methods for returning allowance value.

4.2.2. Energy 2020 Outputs

Results from the Energy 2020 model include estimates of energy use, GHG emissions, electricity generation, fuel prices, and costs. Results are reported for California only and are shown as changes from a reference case. The following are brief explanations of the model outputs that are shown for the cases analyzed:

Greenhouse Gas Emissions. GHG emissions are presented in millions of metric tons of carbon dioxide equivalent ($MMTCO_2E$ CO_2e). Emissions are presented by major sector.

Compliance Summary. The compliance summary shows how GHG emissions are reduced to achieve the California emissions goal of 1990 levels by 2020. The compliance summary shows a compliance total, which is the calculated emissions less offsets used and adjusted for any allowances that are banked or used from the bank.[12]

Electricity Sector. Outputs for the electric sector include:

- *Generation Capacity* in units of megawatts (MW) by generation type. Note that estimated generation capacity grows with capacity additions but that capacity retirement is not calculated. Consequently, generation capacity does not decline in the model outputs.
- *Generation Output* in units of gigawatt-hours per year (GWh/year) by generation type.
- *Electricity Sales* in units of GWh/year.

Transportation Sector. Outputs for the transportation sector include vehicle miles traveled for passenger and freight vehicles, as well as miles traveled per person. The fleet average efficiency is reported in miles per gallon.

Fuel Prices. Fuel prices are reported for electricity, natural gas, coal, fuel oil, liquefied petroleum gas, gasoline, and diesel in 2007 dollars per million Btu (2007 $/mmBtu). The

[11] http://www.cpuc.ca.gov/PUC/energy/Renewables/hot/33implementation.htm.

[12] As explained in more detail in section 5.3.4, allowances issued in one compliance period may be saved, or "banked," for use in later compliance periods. A firm would be likely to bank allowances if it had current reduction options that were less expensive than the expected present value of future allowances.

prices include the forecasted energy prices as well as the costs of delivering the fuels to market. The prices reported for the modeling cases also include the calculated allowance price, reflecting the appropriate carbon content of the fuel.

Costs and Savings. Costs and savings are reported in millions of 2007 dollars per year ($M/Yr). Fuel expenditures are reported by major sector. Total costs, which also are reported by major sector, are the sum of changes in fuel expenditures and investment costs. Investment costs increase as more efficient devices, buildings, and processes are purchased in response to the limit on GHG emissions. The investment costs are annualized using a 5-percent real capital recovery factor over the life of the equipment. The estimates of total costs include both the change in fuel expenditures and the change in investment costs.

4.3. Environmental Dynamic Revenue Assessment Model (E-DRAM)

The Environmental Dynamic Revenue Assessment Model (E-DRAM) is a static computable general equilibrium (CGE) model of the California economy.[13] CGE models are standard tools of empirical analysis, and they are widely used to analyze the aggregate impacts of policies whose effects may be transmitted through multiple markets. The E-DRAM model was developed by Dr. Peter Berck of the University of California, Berkeley, in collaboration with the California Department of Finance and the Air Resources Board. The current model includes 188 distinct sectors: 120 industrial sectors, two factor sectors (labor and capital), 8 household sectors, nine consumption sectors, one investment sector, 45 government sectors, and one sector that represents the rest of the world.

The E-DRAM model does not a produce a forecast of the future. Rather, it constructs a future-year reference case from existing forecasts of income, population, and energy use. Together, income and energy growth imply an estimate of technical progress. In this analysis, growth in E-DRAM has been set so that it is in agreement with the growth assumptions used in Energy 2020.

The model solves for the set of commodity and factor prices, and the levels of industry activity and household income that clear all markets in the economy, given aggregate factor endowments, households' consumption technologies (specified by their utility functions) and industries' transformation technologies (specified by their production functions). The model derives a price for the output of each of the 120 industrial sectors, a price for labor (called the "wage"), and a price for capital services (the "rental rate").

To perform analysis with the E-DRAM model, AB 32 policies are imposed, the model is resolved and the effects are measured as changes from the Reference Case. Polices can be modeled in several ways such as adjusting model parameters, changing prices

[13] "Static" in this respect means that E-DRAM solves for a single year and that the solution in that year is not tied to decisions made in previous years.

through the use of fees or imposing technological change and the same policy could be represented in several different ways each providing a different perspective.[14] Section 4.4 provides examples of how policies are modeled using E-DRAM.

E-DRAM can provide insights into the following:

- Changes in statewide output, income, and employment
- Changes in income for different socioeconomic groups
- Effects of redistribution of allowance revenue

The basic relationships in E-DRAM are shown in Figure 2, called a “circular-flow diagram.” The outer set of flows, shown as solid lines, are the flows of “real” items, goods, services, labor, and capital. The inner flows, shown as broken lines, are monetary flows.

Households buy goods and services from the goods-and-services markets and give up their expenditure as compensation. They sell capital and labor services on the factor markets and receive income in exchange. There are eight separate household types distinguished by California marginal personal income tax brackets. A detailed description of the demand for goods and services is given in Chapter III of the DRAM report.[15]

Firms supply goods and services to the goods-and-services market in return for revenues. Firms demand capital and labor from the factor markets and in return pay wages and rents. Firms also purchase intermediate goods from other firms. The expense of buying the input is a cost of production. Chapter IV of the DRAM report contains the model specification for these types of transactions, which are based on a national input-output table.

California is an open economy, which means that it trades goods, services, labor, and capital readily with other states and countries. In this model, all agents outside California are aggregated into one group, called “Rest of World.” That is, no distinction is made between the rest of the United States and foreign countries. California interacts with two types of rest-of-world agents: foreign consumers and foreign producers.

Producers sell goods on the (final) goods-and-services markets and on the intermediate markets (i.e., they sell goods to both households and firms). The model takes these goods as being imperfect substitutes for the goods made in California. The degree to which foreign and domestic goods substitute for each other is very important, and the evidence is described in Chapter V of the DRAM Report. Foreign households buy California goods and services on the goods-and-services markets. They and foreign

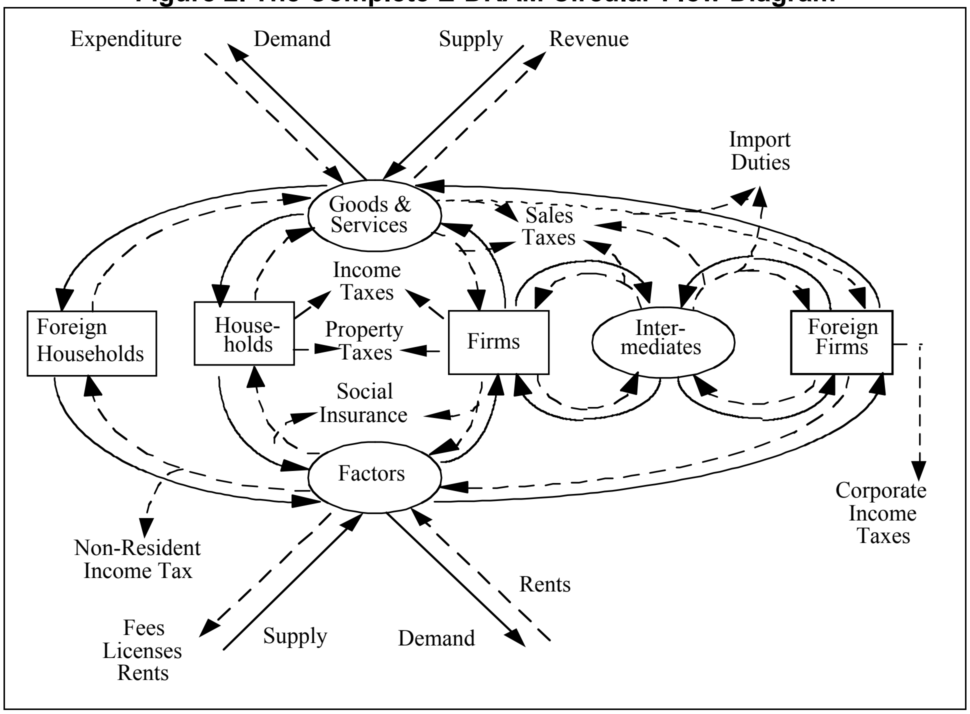
[14] Berck, Peter, and Hess, Peter. (2000). Developing a Methodology For Assessing The Economic Impacts of Large Scale Environmental Regulations. UC Berkeley: Department of Agricultural and Resource Economics, UCB. CUDARE Working Paper No. 924. available at http://escholarship.org/uc/item/51v1b6wm

[15] http://www.dof.ca.gov/HTML/FS_DATA/DYNA-REV/DYNREV.HTM

firms both can supply capital and labor to the California economy, and domestic migration patterns are described in Chapter VIII of the DRAM Reports.

Finally, government is considered by combining the taxing and spending effects of the three levels of government (federal, state, and local). Government buys goods and services and gives up expenditures. It supplies goods and services, for which it may or may not receive revenue. Government also supplies factors of production, such as roads and education. And government makes transfers to households, which are not shown in the diagram. Chapter II of the DRAM Report includes a detailed description of the government activities in the model.

Figure 2. The Complete E-DRAM Circular-Flow Diagram



The primary E-DRAM data, and sources for these data, are as follows:

- Industry intermediate demand is from the U.S. Bureau of Economic Analysis 2002 Make and Use table.
- Employment is from the California Employment Development Department for the year 2003.
- Energy use is corrected with data from the California Energy Balances database.
- Demand is estimated from the Consumer Expenditure Survey for the Western United States.
- State government data are derived from state records.
- Most model parameters (e.g., elasticities of substitution) are taken from the published literature.

4.4. Energy 2020 in Combination with E-DRAM

Results from Energy 2020 are used in combination with the E-DRAM model to further examine the potential economic impacts of the AB 32 policies. Figure 3 provides a summation of the information presented in the previous sections and highlights how further analysis can be preformed using Energy 2020 together with E-DRAM.

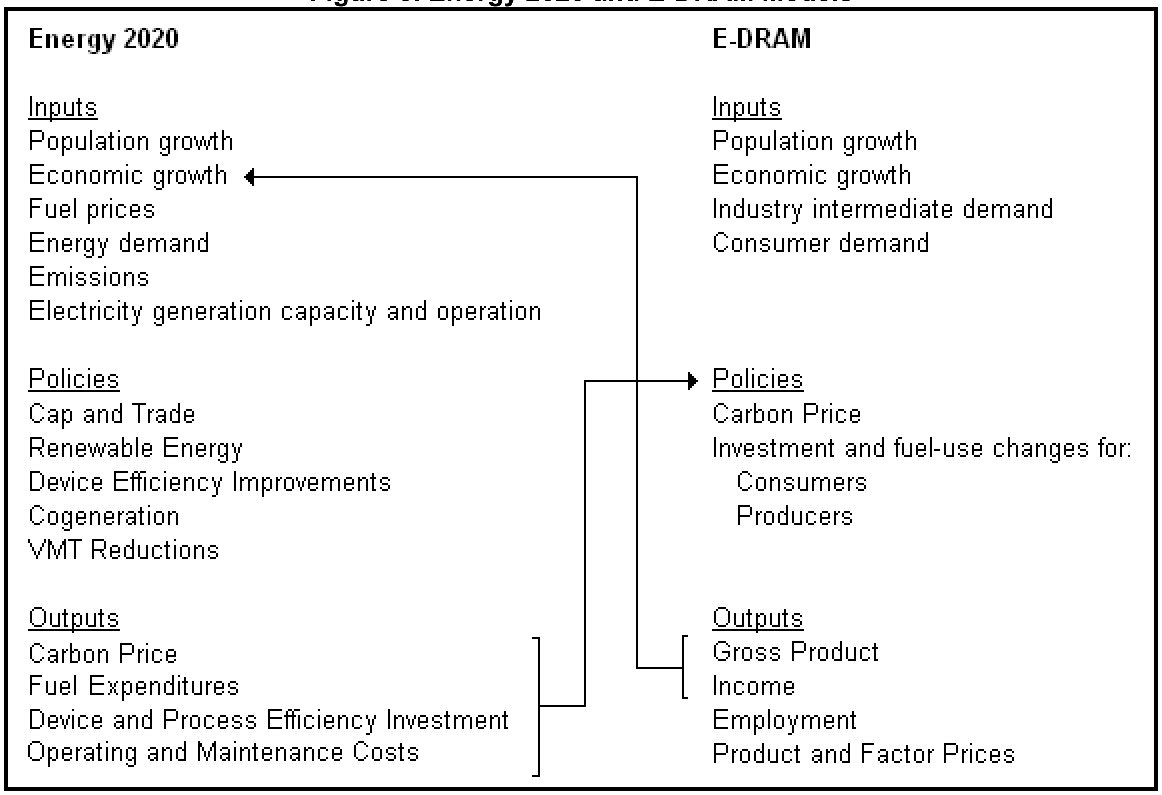
As shown, both models rely on some of the same input data, but Energy 2020 focuses more on energy supply and demand while E-DRAM concentrates on the economic relationships between producers, consumers, and government. The intent of this portion of the analysis is to use the information produced by the detailed energy model to further investigate the broader economic impacts of AB 32 policies, which are better estimated in E-DRAM.

The Energy 2020 model results that are passed on to E-DRAM include:

- CO_2 allowance prices
- Changes in device and process efficiency investment
- Changes in operating and maintenance costs
- Changes in fuel expenditures.

The linking can be in both directions, with Energy 2020 results passed to E-DRAM and E-DRAM results passed back to Energy 2020. Emissions reductions in Energy 2020 result from fuel switching and improvements in device and process efficiencies. Energy 2020 does not calculate the macroeconomic effects of a carbon price, as the model does not account for changes in economic growth and thus may overstate the amounts of investment and the CO_2 allowance price needed to achieve the AB 32 emissions target. Linking from E-DRAM back to Energy 2020 is necessary for estimating the full effect of AB 32 policies, which includes both increased investment and changes in economic growth.

Figure 3. Energy 2020 and E-DRAM Models



CO_2 Allowance Price. The allowance price is represented in E-DRAM by increasing the prices of electricity, natural gas, and transportation fuel by amounts that reflect the average carbon content of each fuel. For this analysis, all allowance value is assumed to remain in-state and is returned to the eight household categories in the same proportion that these households receive income from their labor. The return of income in this manner would be similar, though not exactly equivalent to, an adjustment to taxes on wages. Household types that supply more labor to the market would receive a greater share of the allowance revenue.

Investment and Fuel Expenditure Changes. The changes in investment and fuel expenditure generated by Energy 2020 are captured in the E-DRAM model as changes in technology and consumer-expenditure patterns.

The Energy 2020 model simulates energy demand and investment at the end-user, or consumer, level. Therefore, all Energy 2020 results must be applied in E-DRAM at the consumer level.[16] The consumer in this respect is both a household that consumes finished goods and a producer that consumes intermediate goods.

[16] In a vertical-market relationship the impacts of a policy can be measured at any stage of the marketing chain. See J.M.Alston, G.W. Norton, and P.G. Pardey. 1995. Science Under Scarcity: Principles and Practice for Agricultural Research and Priority Setting. Ithaca, NY: Cornell University Press. pp. 246-50. In general equilibrium, both vertical and horizontal relationships are represented, so the economy-wide impacts of displacements applied to any sector are fully captured.

Table 4 provides a picture of the Energy 2020 to E-DRAM model-to-model mapping of expenditures. Column 1 indicates the Energy 2020 expenditure category that will be passed on to E-DRAM. Column 2 indicates the level of aggregation that will be used in both models. The two models each have considerable detail, but to make the sharing of information tractable, it is preferable to deal with aggregations. In this analysis, the Energy 2020 investment and fuel-expenditure changes are applied in E-DRAM to six broad sector aggregations. These groupings are Residential, Commercial, Energy-Intensive Industrial, Other Industrial, Passenger Transportation, and Freight Transportation.[17] Column 3 provides information about the Energy 2020 end-uses, which are useful for determining the appropriate E-DRAM categories that are on the receiving end of the expenders (shown in Column 4).

For example, the Residential sector demands energy to operate different devices. Implementing AB 32 policies in Energy 2020 causes expenditures by the Residential sector on these devices and thereby the fuel needed to power these devices to change. In E-DRAM, these changes are represented as increases or decreases in spending by the Residential sector to the appropriate E-DRAM device and fuel sector.

[17] Industrial sectors are the goods-producing sectors, while commercial sectors are the non-goods-producing sectors such as wholesale trade, retail trade, or services.

Table 4. Energy 2020 Mapping to E-DRAM

Expenditure	Energy Consumer	End-use	E-DRAM Sector
Device	Residential Commercial	Air Conditioning Lighting Refrigeration Space Heating Water Heating Other Non-Subs* Other Subs**	Refrigeration and Air Conditioning Wholesale Durable Goods Machinery Manufacture
	Industrial - Energy-Intensive - Other	Motors Process Heat Other Subs Off Road Miscellaneous	Refrigeration and Air Conditioning Wholesale Durable Goods Machinery Manufacture
	Transportation - Passenger - Freight	Vehicle type	Retail Vehicles and Parts Automobile Manufacturing
Process	Residential Commercial Industrial - Energy-Intensive - Other	Building Efficiency	Retail Building Materials
Operating and Maintenance	Residential Commercial Industrial - Energy-Intensive - Other		General increase in all intermediate goods
Fuel	Residential Commercial Industrial - Energy Intensive - Other Transportation - Passenger - Freight	All end-uses	Electrical Power Distribution Natural Gas Distribution Retail Gasoline Stations

* Other Non-Subs = Other devices that operate only on electricity
** Other Subs = Other devices that operate on multiple fuel types

These expenditure changes are implemented in E-DRAM by adjusting the model's Social Accounting Matrix (SAM), which represents all of the economic transactions that take place within a regional economy during a particular benchmark period. The entries along a row in the SAM show each payment received by a particular sector. The entries down a column in the SAM show the expenditures made by a particular sector. For accounting purposes, a SAM must balance—that is, each row sum and corresponding column sum must be equal. This balancing ensures that all money received by firms is spent and that no money leaks out of the economy. The original SAM provides the basis for what the reference-case economy looks like, and the altered SAM indicates what the economy looks like with the imposition of AB 32 policies.

For example, the Pavley II vehicle-efficiency-improvement measure, as implemented in Energy 2020, increases the amount that the Passenger Transportation sector spends on vehicles while decreasing the amount that this sector spends on fuel. These types of expenditure change would be implemented in E-DRAM in the following manner: the Consumer Transportation sector increases its spending in the Retail Vehicle Sector to reflect the sector's increased spending on vehicles. Simultaneously, the Consumer Transportation sector decreases its spending in the Retail Gasoline sector to reflect the decrease in spending on fuels.

As shifts in expenditures are made, the SAM is rebalanced so that the sum of the rows equals the sum of the columns. In particular, the increase in Consumer Transportation sector spending for automobiles has the effect of reducing expenditures on all other Consumer Transportation goods. The decrease in fuel expenditures has the effect of increasing expenditures on all other Consumer Transportation goods. The model is then resolved for a new set of commodity and factor prices, and the levels of industry activity and household income that clear all markets—and their impacts—are measured as the change from the original SAM reference solution.

To fully cycle between the two models, the E-DRAM results are used to adjust the Energy 2020 growth assumptions and the entire process is repeated until a stable CO_2 price is reached. The iterative steps are:

1. Solve Energy 2020 to determine the CO_2 price and expenditure changes.
2. Solve E-DRAM to determine the change in economic growth resulting from the above CO_2 price and expenditure changes.
3. Adjust the Energy 2020 model drivers to reflect the new growth assumptions and determine the new CO_2 price and new expenditures.
4. Resolve E-DRAM to determine the change in economic growth.
5. Repeat Steps 3 and 4 until the prices converge.

Ideally, the Energy 2020 model drivers would be adjusted, fed back into the model, and the model would be resolved; however, such an outcome has not yet been fully accomplished. In this analysis, the reduction in emissions brought on by reduced economic growth is estimated outside of Energy 2020, based on values of emissions intensity from the Energy 2020 reference case (i.e., metric tons of emissions/$gross state product). Multiplying the intensity factor by the change in GSP from E-DRAM provides an estimate of the change in emissions from reduced economic growth. The new CO_2 price is then determined from the set of estimated price trajectories.[18] While this method for determining emission reductions is less sophisticated, it is far more manageable.

[18] A minor issue with this procedure is that the reductions from complementary policies would be overstated slightly, given that decreases in economic growth rates would affect the amount of reductions available through complementary policies.

5. CASES ANALYZED

This section describes the cases analyzed. The first is the reference case, which reflects GHG emissions reductions expected to occur in the absence of AB 32—that is, it reflects the assumed future growth path through 2020 in the absence of the cap-and-trade program and related Scoping Plan complementary GHG emissions-reduction policies. Because the world's economy has not remained on the same growth path in the two years since the original analysis was completed, the current reference case has been adjusted to reflect the global economic downturn, resulting in a lower estimate of 2007 economic activity and GHG emissions in California. The revised economic growth assumptions are based on those used by the California Energy Commission in the *2009 Integrated Energy Policy Report*. ARB staff estimates that this revised economic forecast has resulted in a reduction in projected 2020 emissions of approximately 25 million metric tons ($MMTCO_2E$) of CO_2 equivalent (CO_2E).

Additionally, because State and federal policy has moved beyond where they were in mid-2008, the new reference case incorporates a number of measures that were considered part of the policy case for the original analysis of the Scoping Plan. These measures include the 20-percent Renewable Portfolio Standard, the California Clean Car standards (Pavley I), and the federal Energy Independence and Security Act 2007. As a result of moving these now-standard measures into the reference case, projected 2020 emissions declined by approximately another 50 $MMTCO_2E$.

5.1. Reference Case Description

The Scoping Plan measures that are now assumed to be in place in the reference case that were not business-as-usual for the original Scoping Plan analysis include:

- 20-Percent Renewable Portfolio. The sales share of renewable electricity is increased to 20 percent by 2012. Such electricity is not required to be produced in state.

- Pavley I Vehicle Standards. The passenger transportation-fuel forecast presented in the 2009 Integrated Energy Planning Report and used in this analysis assumes an increase in passenger vehicle efficiency consistent with Pavley I Emissions Standards.[19]

- Federal Device Standards. The 2007 Energy Independence and Security Act (EISA) specifies new standards for residential boilers and furnace fans, walk-in coolers, electric motors, and lighting.

[19] California Energy Commision. Transportation Energy Forecasts and Analyses for the 2009 Integrated Energy Policy Report. Available at http://www.energy.ca.gov/2009publications/CEC-600-2009-012/CEC-600-2009-012-SD.PDF

- Federal Renewable Fuel Standards. The EISA sets out targets for increasing the percentage of biofuels derived from cellulosic and advanced biofuels. Thus the ethanol share of passenger ground-transportation fuels is increased to approximately 12 percent for light vehicles and the biodiesel share of freight ground-transportation is increased to approximately 4 percent by 2020. These targets have been reflected in the model by adjusting the full-cycle emissions factors associated with ethanol between 2010 and 2020. The effect of this adjustment is to reduce the full-cycle emissions factor for ethanol by about 40 percent from the initial level (the level for corn-based ethanol) by 2020.

Tables 5 through 9 present select model outputs for the Reference Case.

Table 5. Reference Case Greenhouse Gas Emissions

GHG Emissions (Mt)	**2006**	**2012**	**2015**	**2020**	**Avg. Annual Growth Rate 2006-2020**
Residential	27.3	27.0	27.9	29.7	0.6%
Commercial	14.0	12.4	12.1	12.1	-1.0%
Industrial	80.0	86.2	92.8	102.8	1.8%
Energy Intensive Industry	52.5	47.8	48.6	49.2	-0.5%
Other Industry	27.5	38.4	44.2	53.6	4.9%
Mining	13.2	13.0	13.0	12.2	-0.6%
Agriculture	27.4	29.1	29.8	31.0	0.9%
Transportation	213.3	211.5	222.7	227.8	0.5%
Passenger	167.6	162.0	168.5	168.8	0.1%
Freight	45.7	49.5	54.2	58.9	1.8%
Power Sector	102.0	89.1	93.1	100.0	-0.1%
Domestic Power Sector	43.2	40.0	37.7	39.1	-0.7%
Electricity Imports	58.8	49.1	55.3	60.8	0.2%
Waste and Other	9.8	10.9	11.5	12.4	1.7%
Total	**486.9**	**479.3**	**502.8**	**527.9**	**0.6%**

Table 6. Reference Case Energy Use

Total Primary Energy Use (TBtu/year)	**2006**	**2012**	**2015**	**2020**	**Avg. Annual Growth Rate 2006-2020**
Aviation Fuel	372	441	478	551	2.8%
Biomass	65	66	66	67	0.2%
Coal	83	79	79	77	-0.5%
Diesel	475	422	465	501	0.4%
Ethanol	79	91	103	122	3.2%
Landfill Gases/Waste	24	24	24	24	0.1%
LPG	313	275	278	281	-0.8%
Motor Gasoline	1,871	1,718	1,763	1,689	-0.7%
Natural Gas	1,952	1,824	1,790	1,828	-0.5%
Nuclear	319	319	319	319	0.0%
Oil, Unspecified	410	482	505	537	2.0%
Renewables	452	460	469	482	0.5%
Total	**7,324**	**7,126**	**7,291**	**7,485**	**0.2%**

Table 7. Reference Case Electric Sector Results

Generation Capacity (MW)	**2006**	**2012**	**2015**	**2020**	**Avg. Annual Growth Rate 2006-2020**
Gas/Oil	38,773	41,984	41,984	41,984	0.6%
Coal	557	557	557	557	0.0%
Nuclear	4,324	4,324	4,324	4,324	0.0%
Hydro	13,777	13,781	13,788	13,788	0.0%
Biomass	1,009	1,036	1,060	1,100	0.6%
Wind	2,225	2,601	2,967	3,577	3.5%
Other Renewable	2,476	2,758	3,040	3,510	2.5%
Total	**63,140**	**67,042**	**67,721**	**68,841**	**0.6%**

Generation Output (GWh/year)	**2006**	**2012**	**2015**	**2020**	**Avg. Annual Growth Rate 2006-2020**
Gas/Oil	81,355	75,393	70,086	73,296	-0.7%
Coal	2,986	2,925	2,925	2,925	-0.1%
Nuclear	31,560	31,560	31,560	31,560	0.0%
Hydro	48,114	48,140	48,199	48,199	0.0%
Biomass	5,674	5,861	6,030	6,312	0.8%
Wind	4,818	5,973	7,101	8,979	4.5%
Other Renewable	13,584	14,855	16,127	18,247	2.1%
Imported Power	104,842	113,556	125,156	135,094	1.8%
Total	292,934	298,265	307,185	324,613	0.7%

Sales (GWh/year)	**2006**	**2012**	**2015**	**2020**	**Avg. Annual Growth Rate 2006-2020**
Residential	89,626	91,854	96,542	106,681	1.3%
Commercial	112,757	112,945	114,974	119,295	0.4%
Industrial	61,533	63,258	64,271	65,063	0.4%
Transportation	2,632	2,982	3,389	4,039	3.1%
Street/Misc.	1,780	1,873	1,899	1,942	0.6%
Resale	-	-	-	-	-
Total	**268,327**	**272,912**	**281,074**	**297,021**	**0.7%**

Table 8. Reference Case Transportation Sector Results

Distance Traveled (millions of vehicle miles traveled)	**2006**	**2012**	**2015**	**2020**	**Avg. Annual Growth Rate 2006-2020**
Passenger	327,382	331,099	383,858	441,887	2.2%
Freight	29,292	25,212	28,608	31,928	0.6%
Passenger Miles/Person	8,768	8,228	9,205	10,012	1.0%

Average Vehicle Efficiency (miles/gallon)	**2006**	**2012**	**2015**	**2020**	**Avg. Annual Growth Rate 2006-2020**
Light Gasoline	23.2	25.8	28.9	34.3	2.8%
Medium Gasoline	23.2	25.8	28.8	34.2	2.8%
Heavy Gasoline	16.9	18.6	20.5	23.6	2.4%
Heavy Diesel	16.9	18.5	20.4	23.4	2.3%
Fleet Average (In-Use Vehicles)	21.1	23.6	26.5	31.5	2.9%

Marginal Vehicle Efficiency (miles/gallon)	**2006**	**2012**	**2015**	**2020**	**Avg. Annual Growth Rate 2006-2020**
Light Gasoline	24.0	31.3	39.8	42.7	4.2%
Medium Gasoline	24.0	31.3	39.8	42.7	4.2%
Heavy Gasoline	17.4	23.0	25.4	25.4	2.7%
Heavy Diesel	17.4	23.0	25.4	25.4	2.7%
Fleet Average (In-Use Vehicles)	21.5	28.0	34.1	35.9	3.7%

Table 9. Reference Case Fuel Prices

Prices (2007 $/mmBtu)	2006	2012	2015	2020	Avg. Annual Growth Rate 2006-2020
Residential					
Res Electricity Prices	40.1	40.8	41.2	42.1	0.4%
Res Natural Gas Prices	13.5	13.0	13.4	14.0	0.3%
Res Oil Prices	17.9	21.0	22.3	24.3	2.2%
Res LPG Prices	24.9	28.0	29.2	31.3	1.6%
Commercial					
Com Electricity Prices	37.3	38.9	39.4	40.3	0.6%
Com Natural Gas Prices	11.8	11.3	11.7	12.2	0.3%
Com Oil Prices	15.1	18.2	19.4	21.5	2.6%
Com LPG Prices	19.5	22.6	23.8	25.9	2.0%
Industrial					
Ind Electricity Prices	29.5	30.9	31.4	32.3	0.6%
Ind Natural Gas Prices	11.8	11.3	11.6	12.2	0.2%
Ind Coal Prices	2.4	2.5	2.4	2.4	0.0%
Ind Oil Prices	18.1	21.2	22.4	24.5	2.2%
Ind LPG Prices	20.2	23.3	24.5	26.6	2.0%
Transportation					
Gasoline Prices	21.2	24.3	25.5	27.6	1.9%
Diesel Prices	33.7	39.9	42.3	46.5	2.3%

5.2. Complementary Policies Description

Complementary policies are those that may be pursued whether a cap-and-trade program is implemented or not. They include:

- Pavley II Vehicle Standards. The marginal vehicle efficiency for passenger cars and light trucks is incrementally increased, beginning in 2017, to reach a new vehicle fleet of 42.5 mpg by 2020.[20] Policy impacts include increases in expenditure for vehicles of greater efficiency and decreases in fuel expenditures.

- Low-Carbon Fuel Standard (LCFS). The ethanol share of passenger ground transportation fuels is increased to approximately 18% for light vehicles and the biodiesel share of freight ground transportation is increased to approximately 15% to represent a 10% reduction in the carbon intensity of fuels by 2020.[21] For exposition purposes biofuels from the Federal RFS are included as part of the

[20] Comparison of Greenhouse Gas Reductions for the United States and Canada Under U.S. CAFE Standards and California Air Resources Board Greenhouse Gas Regulations. Available at http://www.climatechange.ca.gov/publications/arb/ARB-1000-2008-012/ARB-1000-2008-012.PDF. The 42.5 mpg represents a test efficiency and not an on-road efficiency.
[21] Initial Statement of Reasons Proposed Regulation to Implement the Low Carbon Fuel Standard Volume I available at http://www.arb.ca.gov/fuels/lcfs/030409lcfs_isor_vol1.pdf

LCFS policy. Biofuels have historically been priced above gasoline, although with federal tax credits, a maturing biofuels industry, and projected higher crude prices, the cost of producing biofuels relative to petroleum-based fuels is expected to decline within the next several years. Nevertheless, for this analysis, staff assumes that biofuels will continue to be priced above gasoline. Furthermore, it is assumed that a sufficient amount of the type of biofuels needed to comply with the standard will be available.[22]

- VMT-Reduction Measure. Vehicle miles traveled per year in California are assumed to be reduced by 4 percent by 2020. This measure is representative of changes that could occur through the implementation of SB 375—a 2008 state law to reduce GHG emissions from vehicles by redesigning communities. No assumptions are made with regard to exactly how this reduction would be achieved or the cost of achieving it.

- 33-Percent Renewable Portfolio Standard. The sales share of renewable electricity (not required to be in-state) is increased to 33 percent by 2020. The type of renewable generation built to meet this mandate was based on resource mix projections by the California Public Utilities commission.[23] The costs for any new transmission needed to comply with a 33-Percent Renewable Portfolio Standard are not accounted for in the Energy 2020 model.

- Residential and Commercial Energy Efficiency. Building and device efficiency standards and programs are assumed to reduce electricity sales by 24,200 GWh and natural gas sales by 800 million therms by 2020. [24] The efficiency is represented in the model as an increase in device and building efficiency standards. The increased costs of actual equipment upgrades associated with these efficiency gains are captured in the model; however, utility program and administration costs are not estimated.

  The availability of low-cost energy-efficiency potential is based on market failures that have prevented the penetration of energy-efficient devices among some customers. In this analysis, we assume that this efficiency potential exists without

[22] In this analysis it is assumed that the prices of biofuels remain at least 14 percent above the prices of gasoline or diesel through out the 2020 forecast period. The Annual Energy Outlook 2010 projects that the price of E85 could be comparable to the price of gasoline by 2016. http://www.eia.doe.gov/oiaf/aeo/supplement/supref.html. Other sources indicate that cellulosic ethanol costs could be equivalent to gasoline at a crude-oil price of $100/bbl. See Liquid Transportation Fuels from Coal and Biomass: Technological Status, Costs, and Environmental Impacts, National Academies Press. Available at http://www.nap.edu/catalog/12620.html. Current federal tax credits do make cellulosic ethanol more competitive at lower crude prices.

[23] http://www.cpuc.ca.gov/PUC/energy/Renewables/hot/33implementation.htm

[24] The Scoping Plan called for 32,000 GWh of end-use energy efficiency beyond what was included in the 2007 IEPR Demand Forecast. This amount has been reduced to reflect the 2009 IEPR forecast, which is lower than the 2007 IEPR and includes new efficiency programs that were formerly considered uncommitted. California Energy Commission correspondence.

being specific as to what market failures are being corrected by the policy intervention.

- Combined Heat and Power (CHP). This measure sets a target of an additional 4,000 MW of installed CHP capacity by 2020, enough to displace approximately 30,000 GWh of demand from other power-generation sources. It is assumed that the heat output of these facilities is used to serve existing or new heating loads.[25] Increasing the deployment of efficient CHP will require addressing these barriers and instituting incentives or mandates where appropriate.

- Heavy-Duty Vehicle and Marine Efficiency. This measure increases freight end-use efficiency in trucks to reflect the SmartWay program of the U.S. Environmental Protection Agency (EPA), and it increases the use of on-shore electricity for ships in port.

5.3. Cap and Trade Description

This section describes ARB's overall modeling approach for the cap-and-trade program, including how the cap, allowance prices, offsets, banking, and compliance are defined for use in Energy 2020. In general, the approach is first to set the cap, which in turn determines the number of offsets allowed in accordance with the Scoping Plan. ARB staff then models different allowance-price trajectories, analyzing how the various responses to the carbon price, by emitters and other market participants, reduce GHG emissions to achieve compliance from 2012 to 2020, given the ability to bank allowances and to use a limited number of offsets. Finding the "right" price trajectory requires running and analyzing many different trajectories.

5.3.1. The Cap

The cap annually limits the GHG emissions from sources that are covered by the cap-and-trade program.[26] Because most of the covered emissions result from fuel combustion, the Energy 2020 model is well suited for analyzing cap-and-trade because it estimates emissions from fuel combustion, as well as process emissions, from all sources. For the emissions sources not calculated by the model, emissions from ARB's greenhouse gas emissions inventory are used (e.g., for non-fuel agriculture and waste-management emissions). Also included in the cap are emissions from electricity imported to California from outside the state. For existing contracts, emissions are estimated based on actual sources, while for unspecified power the model assumes an emissions factor of 1,100 lbs/MWh.

The 2012 cap is set as the projected 2012 emissions for the narrow-scope sectors after the implementation of complementary policies. For the first compliance period, the cap

[25] The policy calls for a target of 30,000 GWh. However, the model did not find this level of self-generation potential to be available, so a lesser amount is actually achieved.
[26] This analysis does not replace or constrain ARB's work in setting the cap level in its cap-and-trade regulation. For the regulation, ARB staff are examining in detail the how the cap should be set.

declines linearly at the rate that would be required for the covered sources to reach their 2020 emissions target. The 2015 cap is set in two parts. The part is the continued trajectory of the narrow-scope emissions that started in 2012. The second part is set as the projected 2015 emissions for the remaining broad-scope sectors after the implementation of complementary policies. From 2015 to 2020 the cap follows a linear decline (i.e., a reduction of the same number of tons each year). It should also be noted that the modeling cases that reduce the effectiveness of the complementary policies, or that implement the complementary policies at a slower rate, result in higher caps in 2012 and 2015, but the caps still decline to the same 2020 target.

5.3.2. Allowance Prices

ARB's modeling approach utilizes exponentially rising allowance prices (i.e., prices rising at a fixed percentage each year), as implied by economic theory. A key feature of the cap-and-trade program is that the allowance budget declines over time. In the model, compliance in the early years is not as challenging as in later years. In the early years, relatively low-cost abatement opportunities are available. Thus a banking policy motivates emitters to overcomply in early years if those low-cost reductions can be credited against compliance obligations in later years.

Banked allowances are the result of net overcompliance by covered sources, which comes with its own opportunity cost. Allowance holders will expect a rate of return on a banked allowance similar to any other investment. So the effect of banking is to induce an exponential growth in the allowance price, whereby the growth rate reflects both the time value of money and the risk associated with financial offsets. In the early years, the allowance price for compliance with banking is higher than the no-banking price, as allowances are accumulated for future use. Later, as banked allowances are used, the price with banking is less than the no-banking price. The results presented in this analysis use a growth rate of 7 percent per year. For example, an allowance price trajectory of $30 in 2020 is a series of allowance prices that start out at $17.46 in 2012 and rise at 7 percent annually to $30.00 in 2020.[27]

5.3.3. Offsets

The cap-and-trade modeling incorporates an offset supply curve to calculate the number of offsets available under the allowance price trajectory. This curve is based on a 2005 report by the U.S. EPA.[28] Moreover, the analysis considers that at low allowance prices, offset providers might not sell offsets to those with cap-and-trade compliance obligations in California. Rather, they might find other markets more profitable. To approximate this phenomenon transparently, the analysis uses the following simple linear function, which determines the quantity of offsets available:

[27] The calculation is $\$30/(1+0.07)^{(2012-2020)}$ = \$17.46 for 2012.

[28] U.S. EPA, Greenhouse Gas Mitigation Potential in U.S. Forestry and Agriculture, 2005. Available at http://www.epa.gov/sequestration/pdf/greenhousegas2005.pdf

$$\text{Cumulative Offsets (MMT } CO_2E) = (2020 \text{ Allowance Price} - \$8.00)/0.15$$

$$\text{for Allowance Price} > \$8.00$$

The function's results are considered to be valid only in the range from zero up to the offset limit, which equals 49 percent of the reductions from the initial cap levels. Using the function outside of this range may produce nonsensical results. The price in the above equation refers to the allowance price in 2020, implying that no offsets are available if the 2020 allowance price is $8 or less. Based on this equation, with a 2020 allowance price of $20, 80 million offsets are available over the nine years (2012 through 2020) cumulatively. To help put such a number in context, the Climate Action Reserve (a national offsets program for the U.S. carbon market) has to date issued fewer than three million offsets, and the Clean Development Mechanism, the world's largest offset entity (the global program created by the Kyoto Protocol), has issued fewer than 400 million offsets in its history and is currently expected to have issued just over one billion offsets by the end of 2012.

As noted later in this report, the offset limit as described in the Scoping Plan would range between about 80 and 120 million offsets. That would mean a 2020 allowance price would have to be in the range of $20 to $26 for enough offsets to be supplied for the offset quantitative limit to become a binding constraint in the analysis. The number of allowed offsets depends on the level of the caps in 2012 and 2015. Because the offset limit is modeled as 49 percent of the reductions from the initial cap levels, higher initial cap levels mean more reductions are required to reach a given 2020 cap level, and consequently more offsets are also allowed. The number of offsets actually used is the minimum of the offsets available and the offset limit. After the offset limit is calculated, the offsets assumed to be used in each year are proportional to each year's GHG emissions.

Table 10 illustrates how the offset limit is computed and applied, assuming the allowance price is high enough that the maximum number of offsets is used. The cap numbers in Table 10 are illustrative only.[29]

[29] For another illustration, see http://www.arb.ca.gov/cc/capandtrade/meetings/121409/capcalc.xls

Table 10. Offset Limit Calculation Illustration

Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Narrow-Scope Cap	185	180	175	170	165	160	155	150	145	1,485
Broad-Scope Cap	-	-	-	270	260	250	240	230	220	1,470
Total Cap	185	180	175	440	425	410	395	380	365	2,955
Narrow-Cap Reductions	0	5	10	15	20	25	30	35	40	180
Broad-Cap Reductions	-	-	-	0	10	20	30	40	50	150
Total Cap Reductions	0	5	10	15	30	45	60	75	90	330
Offsetable Reductions[30]	0	2.5	4.9	7.4	14.7	22.1	29.4	36.8	44.1	161.7
Offsets/Emissions[31]	-	-	-	-	-	-	-	-	-	5.2%
Offsets Used[32]	10.1	9.8	9.6	24.1	23.3	22.4	21.6	20.8	20.0	161.7

5.3.4. Banking

The bank flow in any year is straightforward:

Bank Flow = Allowances – Capped Sector Emissions + Offsets Used,

with the number of banked allowances being the sum of bank flow from 2012 up to and including that year.

The modeled scenarios assume that there are no banked allowances remaining after 2020. Utilizing this assumption allows us to find the lowest carbon price that will achieve the emissions target.

One potential question about this approach is whether a scenario exhausting all banked allowances by 2020 is realistic. If a large number of banked allowances are required for compliance in 2020, how then would emitters reach the emissions target the following year in 2021? If one posits that the 2021 cap is not larger than the 2020 cap, that there are no new technologies to enable less-costly GHG reductions in 2021, that there are no remaining banked allowances from previous vintages, and there is no other new source of compliance units, then a higher price trajectory would be needed to achieve the 2021 emissions target.

As a practical matter, the modeler must make decisions regarding the time horizon to be modeled. Modeling through only 2020 was chosen in part because of the time horizon specified by the AB 32 and also because of the uncertainty about which technologies will be available after 2020. However, including banking as a cap-and-trade feature

[30] Offsetable Reductions is defined as 49 percent of Total Cap Reductions.
[31] This table assumes that emissions equal cap plus offsets.
[32] Offsets Used are calculated as emissions times 5.2 percent. Emissions are assumed to equal the cap plus offsets.

brings back into question what technologies will be available after 2020, as they affect the carbon price before 2020 due to banking.

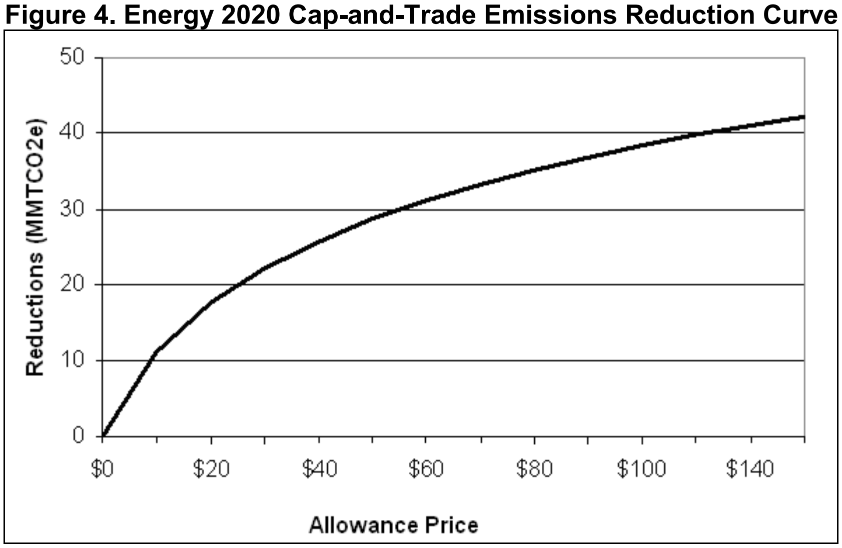
ARB staff concluded that the least arbitrary decision is to model banking such that no allowances are banked for use after 2020. The impact of this decision is noted in the results discussion (see Table 17). In general, this decision means that the analysis finds the minimum-cost solution, subject to the other modeling assumptions. Another possible avenue for modeling banking is to assume a carbon price in 2030. With allowance prices increasing at seven percent per year, the 2030 allowance price would be approximately double the 2020 allowance price. This analysis does not pursue that possibility.

5.3.5. Compliance

Compliance requires that the emissions in the capped sectors, summed over 2012-2020, equal no more than the allowances from each year plus offsets, summed over 2012-2020. High allowance prices tend to produce overcompliance, while low allowance prices yield insufficient reductions to reach compliance. Given the assumptions noted above about banking, and given that the allowance-price trajectory that achieves compliance is not obvious in advance of running Energy 2020, ARB staff modeled many different allowance-price trajectories to find the lowest one that achieved compliance with the GHG emissions caps.

Using price trajectories to model cap-and-trade has several advantages. First, the price trajectories make experimentation with different cap-setting details and offset supply curves possible without rerunning the Energy 2020 model. Second, banking follows logically from the interaction between the cap level, emissions, and offsets. The modeler is not required to make arbitrary assumptions about the price below which allowances enter the bank and above which they flow out of the bank. Lastly, this approach can be used to illustrate the responsiveness of emissions to different allowances prices in the Energy 2020.

Figure 4. Energy 2020 Cap-and-Trade Emissions Reduction Curve



But as seen in Figure 4, GHG emissions in the model show limited responsiveness to allowances prices. The results indicate that abatement does increase at higher carbon prices, but at a decreasing rate. In general, an increase of $10 in the allowance price reduces GHG emissions by about two million tons in the $10 to $70 range and reduces emissions by about one million tons in the $70 to $150. This lack of responsiveness results from the limited reduction opportunities that have been assumed to be available in the model. Such opportunities would include adoption of new technology, fuel switching, and reductions in non-CO_2 greenhouse gases.[33]

Before proceeding to a description of the modeling cases in the next section, we present Figure 5, which shows the emissions (and conversely, the amount of abatement) in each year using three different growth rates—0 percent, 7 percent, and 20 percent, which imply allowance prices in 2012 of $30, $17.46, and $6.98, respectively. In all three cases, the allowance price is $30 in 2020. The first panel in Figure 5—Panel A—graphically displays the three allowance-price trajectories. In the trajectory with the highest growth rate, the exponential rate at which the allowance price increases annually is most clearly visible.

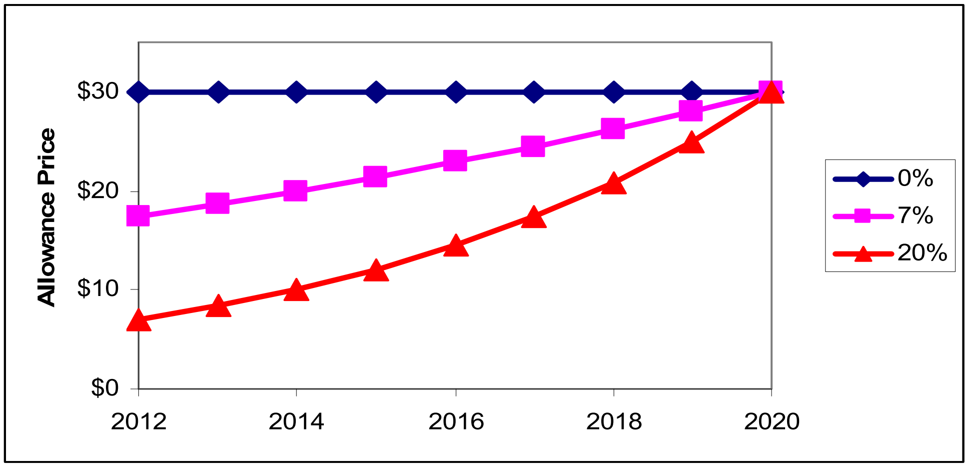
Panel B shows the annual abatement with each of the allowance-price trajectories; the reduced GHG emissions are relative to emissions in the reference-case scenario. The three lines plotting abatement are closely bunched together, suggesting that abatement differs little across these three trajectories. In each year, the emissions difference between the 0-percent and 20-percent allowance-price trajectories is less than three million tons. Total abatement between these two cases differs by 20 million tons, or 17 percent of abatement. It should also be noted that in 2020, when all three price trajectories have the same $30 price, their abatements still differ. This is because the trajectory with the highest price has motivated emitters to make marginally more low carbon-intensive investments in the early years.

Panel C presents an additional graphical display of the differences in abatement between price trajectories. In this case, each trajectory is normalized to the 7 percent trajectory. The graph shows that in the early years, the percentage difference in emissions is large but decreases over time. This is true for a couple of reasons. First, the difference in allowance prices is larger in the early years. Second, there is less abatement in the early years, so the denominator for the normalization is least in those years. The annual emissions between the 0 percent and 20 percent trajectories exceed 1.75 million tons in every year except 2012 (but they remain below three million tons, as previously stated), so there is little difference. In fact, the absolute difference in abatement is declining after 2017.

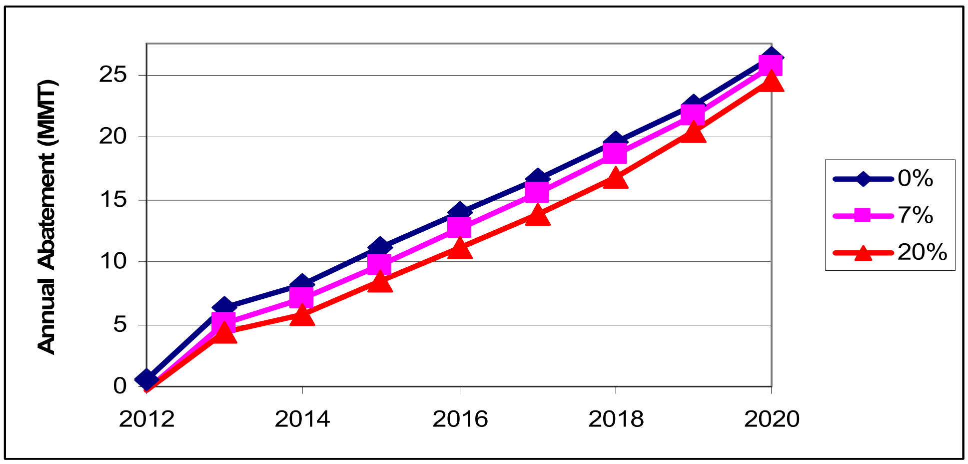
[33] The reduction opportunities for non-CO_2 gases are based on information from the U.S. EPA. See Global Mitigation of Non-CO_2 Greenhouse Gases, June 2006 (EPA Report 430-R-06-005). Available at http://www.epa.gov/climatechange/economics/downloads/GlobalMitigationFullReport.pdf

Figure 5. Emissions with Different Allowance-Price Trajectories

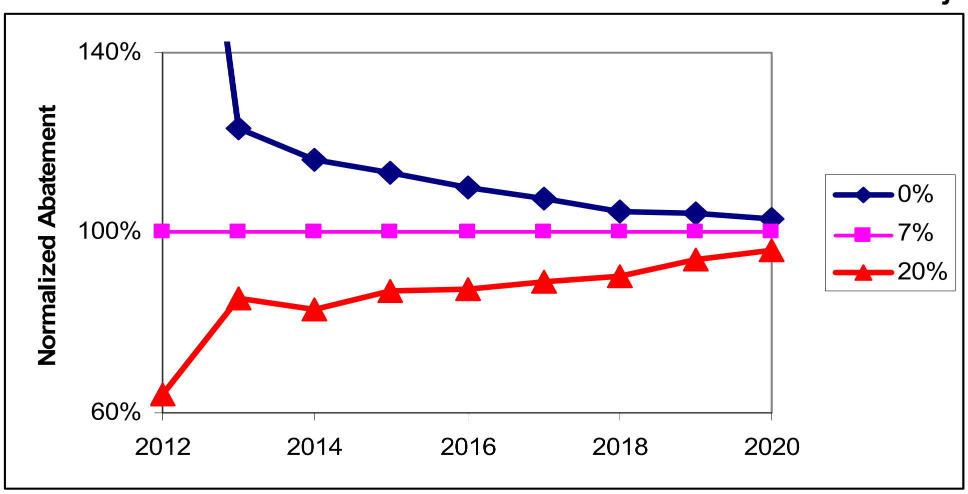
Panel A. Allowance-Price Trajectories



Panel B. Annual Abatement for Different Allowance-Price Trajectories



Panel C. Normalized Annual Abatement for Alternative Allowance-Price Trajectories



5.4. Modeling All Scoping Plan Policies

This section discusses the five cases examined for the updated economic analysis. These five cases represent the Scoping Plan as a whole, including the complementary policies and the cap-and-trade program. Three of the cases vary the effectiveness of the complementary policies to assess their impact. Table 11 presents the cap-and-trade elements that are common to all.

The reasons for focusing on the complementary measures are as follows:

- The complementary measures specify how a majority of the Scoping Plan emissions reductions are to be achieved (i.e., through investments in energy efficiency, low-carbon fuel, renewable electricity supply, and other actions).
- By motivating investments in emissions reductions that would not be undertaken in response to price alone, complementary policies reduce the demand for allowances, thereby lowering their market price. This effect is true regardless of whether individual complementary policies generate net savings (that is, when fuel savings exceed capital costs) or have positive per-ton abatement costs that exceed the allowance price.
- There is uncertainty regarding whether all of the targets expressed in the complementary policies can be fully achieved or achieved at their estimated cost.

Table 11. Common Cap-and-Trade Elements

1. Region	California
2. GHG Pollutants	CO_2, CH_4, N_2O, SF_6, PFC, and HFC
3. 2020 Goal	1990 emissions levels
4. Covered Sectors 2012-2014 2015-2020	 Electricity and large industrial Electricity, large industrial, transportation fuels, commercial and residential fuels, and small industrial
5. Banking	Allowed without limitation
6. Cap Trajectory	Linear phase-in
7. Allocation	100-percent Auction[34]
8. Offsets	Limited to 49% of emission reduction. An alternative case of no offsets is performed.

Table 12 describes the five cases analyzed. Cases 1 and 2 both assume full achievement of the complementary policy emission-reduction goals. The difference between these two cases demonstrates the possible range of allowance prices should offsets not be allowed. Cases 3 to 5 investigate how allowance prices vary under differing assumptions about the effectiveness of the complementary policies.

[34] In Energy 2020, the difference between auction and free allocation makes a difference for the electric sector only, as electric prices are determined endogenously.

Table 12. Cases Analyzed

	Case Descriptions	Complementary Policies					
		LCFS	Pavley II	VMT Reduction	Energy Efficiency	33% RPS	CHP
Case 1	Cap-and-Trade with Offsets	Full	Full	Full	Full	Full	Full
Case 2	Cap-and-Trade without Offsets	Full	Full	Full	Full	Full	Full
Case 3	Transportation Policy Sensitivity with Offsets	Half	Half	Excluded	Full	Full	Full
Case 4	Electricity and Natural Gas Policy Sensitivity with Offsets	Full	Full	Full	Half	Excluded	Half
Case 5	Combined Sensitivity with Offsets	Half	Half	Excluded	Half	Excluded	Half

"Full" means that the complementary policy fully achieves its emissions-reduction target by 2020.
"Half" means that the complementary policy achieves only one-half of its emissions-reduction target by 2020.
"Excluded" means that the complementary policy is absent from the analysis, thereby achieving none of its targeted emissions reduction by 2020.

6. RESULTS AND DISCUSSION

This section discusses the Energy 2020 and E-DRAM modeling outcomes. Section 6.1 details the Energy 2020 results for the complementary policies and for the complete Scoping Plan: complementary policies together with cap and trade. Section 6.2 presents the results of using E-DRAM and Energy 2020 in combination.

6.1. Energy 2020 Modeling

6.1.1. Energy 2020 Complementary Policy Results

This subsection presents key Energy 2020 results for the complementary policies individually and as a group. More detail can be found in Appendix B.

Table 13 shows results for the individual complementary policies, including the estimated changes in GHG emissions, fuel expenditures, and investment and operating costs. The changes, calculated relative to the reference case, reflect any secondary or indirect costs that a price change might have on fuel purchases and investments. For example, the energy-efficiency policy decreases the demand for electricity, which decreases the cost of investment for the 33-Percent Renewable Portfolio Standard.

Observations include:

- Most of the complementary-policy emissions reductions come from the options involving electricity and natural gas.
- While energy efficiency appears to be the least-cost policy, there may be market barriers that could increase its cost or reduce its effectiveness.
- Combined heat and power has the potential to displace a large portion of utility electricity generation, which would decrease the cost of implementing other electricity-sector policies, such as the 33-Percent Renewable Portfolio Standard. However, there may be market barriers, which also must be overcome, that could increase the cost or reduce the effectiveness of this policy.
- Fuel costs attributed to the Low Carbon Fuel Standard are the result of an ethanol price that is assumed to exceed the price of gasoline throughout the forecast period, although, as noted earlier, federal tax credits, a maturing biofuels industry, and projected higher crude prices are expected to reduce the cost of producing biofuels relative to petroleum-based fuels. Should biofuel prices turn out to be higher, or should the supply of such fuels not materialize, the cost of achieving this policy could increase or its effectiveness could be reduced.
- Policies that succeed at reducing VMT could reduce consumer investment in vehicles as well as transportation-fuel consumption. For example, concentration of new housing in central business districts could reduce the need for passenger-vehicle transportation, thereby reducing the need for multiple vehicles per household as well as extending the lifetimes of existing vehicles.

Table 13. 2020 Complementary Policy Direct and Indirect Expenditure Changes

2007 Dollars	33% RPS[1]	Energy Efficiency[2]	Combined Heat and Power	Pavley II	Low Carbon Fuel Standard	VMT
Total GHG Emissions Reduction (MMT)	20	12	5	4	14	5
Fuel Expenditures (2007 M$/Y)	$994	-$4720	-$864	-$1,722	$1,316	-$1,945
Annualized Investment and Operating Costs (2007 M$/Yr)[3]	$4,545	$1,073	$2,233	$279	$512	-$6,736

1. Costs do not include the cost of new transmission, which the E3/CPUC analysis estimates to be on the order of $1.8 billion ($2008) in 2020 for their 33% Reference case.
2. Costs include actual equipment upgrades associated with these efficiency gains but not utility program and administration costs.
3. Capital costs are annualized over the lifetime of the investment using a 5-percent real-capital-recovery factor.

6.1.2. Energy 2020 Results

This subsection provides an overview of modeling results from the five cases, involving various combinations of cap-and-trade and complementary policies, as defined in Table 12 above.

Emissions for the covered sources, cumulatively from 2012 through 2020, are 3,445 MMT before complementary policies.[35] For Cases 1 and 2, the cap for the covered sectors over 2012-2020 is 2,936 MMT.[36] To reduce emissions by more than 500 MMT, the Scoping Plan relies on three mechanisms:

- Abatement from complementary policies, which for Cases 1 and 2 accounts for 63 percent of the needed reductions.
- Abatement at covered sources from cap-and-trade (C/T) price effects, which for Case 1 accounts for 20 percent of the needed reductions.
- Abatement from offsets, which for Case 1 accounts for 17 percent of the needed reductions.

Table 14 shows how those percentages vary over the different cases. In Cases 1 and 2, complementary policies realize more than three-fifths of the needed reductions. The remaining reductions are achieved through cap-and-trade with reductions at covered sources and reductions from offsets. Because Cases 3 through 5 have lower reductions coming from the complementary policies, more reductions must come from the cap-and-trade program.

Table 14. Percentage of Abatement from Different Policies[37]

	Case 1	Case 2	Case 3	Case 4	Case 5
From complementary policies	63%	63%	49%	42%	30%
From covered sources due to C/T	20%	37%	30%	38%	46%
From offsets due to C/T	17%	0%	21%	20%	24%

The calculations in Table 14 assume that the maximum number of offsets allowed by the offset limit is used in each case (i.e., up to 49% of the reductions from cap-and-trade). Note too that the percentage of reductions achieved at covered sources remains appreciably higher than the percentage of reductions realized through offsets. This is because the offsets can help achieve only the reductions required by the cap, while the covered sources must internally abate all the emission increases

[35] The capped sources exclude Residential, Commercial, and Transportation in 2012-2014. Reductions for uncapped sources occur through complementary policies and repsosne to changes in the price of electricity.
[36] Because the caps in 2012 and 2015 are modeled as a function of the complementary policies, the varying effectiveness of complementary policies in the other cases causes the caps to differ.
[37] In this table, each case does not result in the same amount of abatement.

above the initial cap level that would occur from expected economic growth. When comparing Case 1 to Case 3, 4, or 5, it is worth noting that reducing the contribution of complementary policies results in offsets contributing more. But the additional offsets in Cases 3, 4, and 5 are small in comparison to the additional reductions needed at the covered sources for compliance.

Table 15 shows for Case 1 and Case 2 the amount of abatement achieved at different price trajectories, and it highlights whether allowance prices are high enough to achieve the abatement needed to meet the cap. None of the five allowance-price trajectories shown motivate enough internal reduction to meet the cap without offsets. Even with a $100 price in 2020, additional reductions are needed to meet the emissions target. With offsets, a carbon price in 2020 of $30 (or higher) results in enough internal emissions reductions to meet the emissions target.

Table 15. Abatement from Various Allowance Price Trajectories in Case 1 and Case 2

	Allowance Price Trajectory ($/ton in 2020)				
	20	**30**	**50**	**70**	**100**
Abatement 2012-2020, due to cap-and-trade (MMT)	98.7	108.7	121.0	139.7	166.9
Compliance shortfall in Case 2 (no offsets), 2012-2020 (MMT)	91.5	81.6	69.3	50.6	23.4
Offsets used, 2012-2020 (MMT)	80.0	86.8	86.8	86.8	86.8
Compliance shortfall in Case 1 (with offsets), 2012-2020 (MMT)	11.5	-5.1	-17.5	-36.2	-63.4

ARB's analysis has generally assumed that no allowances are banked for use after 2020, but the reader may also infer from Table 15 how high the allowance price would need to be in 2020 if emitters collectively wished to have some banked allowances still available for use after 2020. For example, in Case 1 (with offsets), a price of $40 in 2020 would yield over 17 million allowances banked for later use. A price of $70 in 2020 (i.e., which starts at $41 in 2012 given a 7% growth rate) would stimulate enough early reductions to bank more than 36 million allowances for later use.

Abatement increases with higher allowance prices, but the response is generally inelastic. In Cases 1 and 2, the elasticity of cumulative abatement with respect to the allowance price is 0.24 in the $20–$50 range and 0.48 in the $50–$100 range. Overall, in the $20–$100 range the elasticity is 0.38. This would generally imply that doubling the carbon price results in an increased abatement at the covered sources of roughly 38 percent.

Table 16 summarizes the basic market information, for each of the five cases, when the price trajectory achieves just enough abatement to reach California's emissions target.

Table 16. First Stage Energy 2020 Compliance Summary

	Case 1	Case 2	Case 3	Case 4	Case 5
Allowance Price in 2020	$25	$148	$71	$109	$162
Cumulative Abatement, 2012-2020 (MMT)					
From Complementary Policies	319.2	319.2	234.1	202.3	136.8
From Covered Sources due to C/T	103.8	190.2	141.7	184.4	212.4
From Offsets due to C/T	86.8	0	102.2	98.6	111.0
Levels in 2020 (MMT)					
Covered Emissions	405.5	389.7	413.4	413.3	421.1
Offsets[38]	11.6	0	13.8	13.3	15.1
Bank Flow[39]	-17.2	-13.0	-23.0	-23.3	-29.4

Observations include:

- After the offset limit has been reached, the allowance price rises rapidly to achieve any additional reductions. This is illustrated by the very different allowance prices in Cases 1 and 2.
- When complementary policies are less effective (Cases 3, 4, and 5), thereby increasing the demand for allowances, the allowance price rises accordingly.
- In all five cases, a substantial number of banked allowances are used for compliance in 2020. In that year, the amount of early reductions used to comply with the cap is approximately double the number of offsets used.
- The availability of offsets (in all cases but Case 2) facilitates early banking. Building a bank of allowances at the outset helps keep the allowance price lower in later years. However, the case without offsets (Case 2) uses the smallest amount of banked allowances among the different cases, and as a result it also has the lowest level of emissions in 2020.

There are other variations to the modeling cases that can be described, primarily regarding the amount of reduction needed to reach the cap. For example, the allowance price would change by the same amount under each of the following scenarios:

- The offset limit differs, with 15 million more offsets allowed cumulatively 2012 through 2020. (Because the cumulative cap is approximately 3,000 million tons, allowing 15 million more offsets is equivalent to raising the percentage of a firm's compliance obligation that may be met with offsets by half a percentage point—e.g., from 3.0 percent to 3.5 percent.)

[38] In each case (except Case 2 with no offsets), the offsets quantitative limit is reached. The differences in the numbers of offsets reflect the different cap levels that are set in each case in the initial years. Each case has the same cap in 2020, but the caps prior to 2020 are set differently according to the effectiveness of the complementary policies.

[39] The negative bank-flow numbers indicate that allowances are being withdrawn from the bank. Thus, cap = emissions – offsets + bank flow.

- The cap is set such that there are cumulatively 15 million more allowances 2012 through 2020.[40]
- The model considers linkage such that California covered sources make net purchases of 15 million allowances from California's linked partners (e.g., other WCI partner jurisdictions).[41]
- Covered sources are able to borrow 15 million allowances from post-2020 vintages.

The converses of the above examples may also be considered:

- The offset limit declines to allow 15 million fewer cumulative offsets.
- The cap is set with 15 million more cumulative allowances.
- California covered sources make net sales of 15 million allowances to California's linked partners.
- Covered sources bank 15 million allowances for use after 2020.

The number 15 million is chosen in these examples as equivalent to "loosening" (or "tightening") the cap by one million in the first three years during the narrow-scope coverage and by two million in the next six years during the broad-scope coverage. In general, the cap could be altered in just some years, but the flexible compliance mechanisms, most notably banking, imply that it does not usually matter how the cap is affected in individual years. Rather, it matters how the cap is affected cumulatively. The exception would be if the cap was set tighter in the earliest years of the program and borrowing was not a permitted flexible compliance mechanism.

Table 17 reports the 2020 allowance price for the different cases in which the cap is effectively tightened or loosened by a certain amount. The cap can be so altered because it is set differently in each year. Alternatively, it might be less costly to reach a given cap level if an additional number of compliance units (allowances or offsets) not considered in the main analysis were available to reach compliance.

Table 17. Allowance Prices in 2020 in Select Sensitivities

	Case 1	Case 2	Case 3	Case 4	Case 5
Cap "tightened" by 15 million	$46	$176	$86	$135	$187
Cap as previously reported	$25	$148	$71	$109	$162
Cap "loosened" by 15 million	$20	$117	$55	$91	$129
Cap "loosened" by 30 million	$18	$92	$33	$78	$105
Cap "loosened" by 45 million	$16	$75	$24	$64	$88

[40] Technically, the number of allowances is less than 15 million if more offsets are also allowed along with the additional allowances. This analysis considers a net increase of all compliance units (allowances and offsets) of 15 million.
[41] As above, this analysis considers just an increase in allowances of 15 million with no accompanying increase in offsets.

The effects of these cases on the allowance price differ in magnitude. Loosening the cap does reduce the allowance price in all cases. In Case 1, the allowance price falls by a relatively small amount. With the allowance price falling below $21, the offset limit is no longer reached. In the other cases, loosening the cap by 15 million decreases the allowance price by at least $15. In the cases with the highest prices (Case 2 and Case 5), the allowance price declines by more than $30.

Table 17 also shows the effect on the allowance price from further loosening of the cap by either 30 or 45 million allowances. In Case 1, there is little effect on the allowance price because the offset limit is no longer binding. In this price range, the supply of offsets effectively flattens the marginal abatement-cost curve. The availability of an additional 45 million compliance units approximately halves the allowance price in the cases with the highest prices (Case 2 and Case 5). Interestingly, the other cases see a different pattern, with the allowance price falling by two-thirds in Case 3 but by just one-third in Case 4.

The first row of Table 17 also reports the effect of tightening the cap by 15 million compliance units. Particularly noteworthy is the near doubling of the allowance price in Case 1. In this price range, the permitted supply of offsets has been exhausted, and meeting the emissions target requires a much higher allowance price in percentage terms, although the price does remain below $50 in 2020. By contrast, Case 3 (with reduced effectiveness of the transportation complementary policies) needs a relatively mild increase in its allowance price to realize the tightened emissions target. In this range of allowance prices and with the implemented policies, the elasticity of abatement with respect to the allowance price is relatively high.

Table 18 shows how GHG emissions differ with three alternative allowance-price growth rates. In this sensitivity, each case has the same allowance price in 2020, which is $25 based on the results from Case 1 in the main case previously presented. However, each case has a different growth rate and therefore different allowance prices in 2012 through 2019. In the main analysis, the 7-percent growth rate meant an allowance price of $14.55 in 2012. Alternative growth rates of 0 percent, 15 percent, and 30 percent imply 2012 allowance prices of $25.00, $8.17, and $3.06, respectively. Table 19 notes these different allowance prices and reports the difference in emissions as compared to the primary 7-percent case.

Table 18. GHG Emissions at Covered Sources with Different Allowance-Price Trajectories

	0% Case	15% Case	30% Case
Allowance Price in 2012	$25.0	$8.2	$3.1
Allowance Price in 2016	$25.0	$14.3	$8.7
Allowance Price in 2020	$25.0	$25.0	$25.0
Emissions 2012-2014 ($MMTCO_2E$)*	-1.9	1.3	3.9
Emissions 2015-2017 ($MMTCO_2E$)*	-3.1	2.4	6.2
Emissions 2018-2020 ($MMTCO_2E$)*	-2.6	2.2	5.5
Total Emissions (2012-2020, $MMTCO_2E$)*	-7.6	5.9	15.6

*Emissions are reported relative to Case 1 (with a 7% allowance-price trajectory).

In the case with a 0-percent growth rate (i.e., a constant $25 allowance price in all years), additional emission reductions are realized, although they average less than one million tons per year. Even in 2020, when the allowance price is $25 both in the 0- and 7-percent growth rate cases, the 0-percent case has fewer emissions, as the higher allowance price in earlier years has incentivized more low-carbon investments. Increasing the growth rate from 7 to 15 percent results in a lower initial allowance price and hence fewer reductions in all years. The increase in emissions relative to the 7-percent main case is less than six million tons cumulatively. These relatively small changes in emissions, even with the large changes in the growth rate, suggest that ARB's analysis is not sensitive to the growth-rate assumption. Table 18 also includes one more growth-rate case. With a 30-percent growth rate, the allowance price starts at just $3 in 2012 and does not rise above $10 until 2017 or above $20 until 2020. In this fairly extreme case, the difference in GHG emissions still averages less than two millions tons per year.

6.1.3. Sector Reductions and Price Changes

Table 19 displays the 2020 sector emissions and the percent change in emissions across the five cases. The greatest reductions in absolute terms come from the industrial, transportation and power sectors.

Emissions reductions from the power sector range from 16 to 37 percent. When complementary policies achieve all of their reduction targets, the power sector is responsible for about 40 percent of the total reductions. As the transportation complementary policy effectiveness is reduced, the power sector becomes responsible for almost 50 percent of the total reductions, with most of these reductions attributable to imported power. As the electricity and natural gas complementary policies are reduced, the power sector section reductions fall accordingly with very little of the total reductions coming from imported power.

Emissions reductions from the transportation sector range from 7 to 13 percent. The transportation sector is responsible for about 32 to 43 percent of the total reductions.

Across all cases the passenger transportation sector accounts for the majority of the transportation reductions.

Emission reductions from the industrial sectors range from 15 to 18 percent. The Other Industry sector makes up a considerable share of these reductions in all cases. This group of sectors includes the emissions from Ozone Depleting Substance Substitutes which are projected to increase substantially over the forecast period. These emissions should be divided across other Commercial and Industrial sectors; however insufficient information existed to distribute these emissions to their appropriate sectors. The reductions that occur are based on a reduction estimates developed by ICF International based on information from U.S. EPA.[42]

Emission reductions from the commercial and residential sectors range from 6 to 24 percent. However, reductions from these reductions only account for a small share of the total reductions: about 4 to 6 percent.

Table 18 displays price changes including the estimated allowance value. Price changes are the greatest in the no-offsets case and the cases where electricity targeted complimentary policies do not achieve their reduction goals. The average electricity price increase is relatively consistent across sectors: ranging from 0-20 percent across the five cases. Like electricity prices, Natural Gas prices increase changes are the greatest in the no-offsets case and the cases where natural gas targeted complimentary policies do not achieve their reduction goals. The natural gas price increases ranges from about 13-76 percent with the change appearing relatively consist across the sectors. Gasoline and diesel prices increase 6-47 percent and 4-31 percent respectively.

[42] U.S. EPA Climate Change - Climate Economics
http://www.epa.gov/climatechange/economics/international.html

Table 19. 2020 First-Stage Energy 2020 Modeling Results: Greenhouse Gas Emissions

California Total GHG Pollution (MT)	Reference	Case 1	Case 2	Case 3	Case 4	Case 5
Residential	29.7	27.0	25.6	26.6	26.5	26.3
Commercial	12.1	11.3	10.9	12.6	12.3	12.2
Industrial	102.8	87.9	85.4	86.8	84.9	84.6
Energy Intensive Industry	49.2	46.9	45.8	46.6	45.4	45.3
Other Industry	53.6	41.0	39.6	40.3	39.5	39.4
Mining	12.2	11.5	10.5	11.2	10.0	9.9
Agriculture	31.0	30.8	30.5	30.7	30.2	30.2
Transportation	227.8	200.1	197.6	212.4	198.1	210.6
Passenger	168.8	146.1	145.0	158.0	145.2	157.2
Freight	58.9	54.0	52.6	54.4	52.8	53.4
Power Sector	100.0	67.6	63.5	68.3	83.9	83.0
Domestic Power Sector	39.1	33.9	19.3	30.4	26.2	25.7
Electricity Imports	60.8	33.7	44.2	37.9	57.7	57.4
Waste and Other	12.4	12.4	12.4	12.4	12.4	12.4
Total	527.9	448.5	436.3	461.0	458.2	469.1
Percent Change from Reference Case						
Residential	-	-9%	-14%	-10%	-11%	-11%
Commercial	-	-7%	-10%	4%	1%	1%
Industrial	-	-15%	-17%	-16%	-17%	-18%
Energy Intensive Industry	-	-5%	-7%	-5%	-8%	-8%
Other Industry	-	-24%	-26%	-25%	-26%	-27%
Mining	-	-5%	-14%	-8%	-17%	-19%
Agriculture	-	-1%	-2%	-1%	-3%	-3%
Transportation	-	-12%	-13%	-7%	-13%	-8%
Passenger	-	-13%	-14%	-6%	-14%	-7%
Freight	-	-8%	-11%	-8%	-10%	-9%
Power Sector	-	-32%	-37%	-32%	-16%	-17%
Domestic Power Sector	-	-14%	-51%	-22%	-33%	-34%
Electricity Imports	-	-45%	-27%	-38%	-5%	-6%
Waste and Other	-	0%	0%	0%	0%	0%
Total	-	-15%	-17%	-13%	-13%	-11%

Table 20. 2020 First-Stage Energy 2020 Modeling Results: Price Changes

Fuel Prices Including Permits (2007 $/mmBtu)	Case 1	Case 2	Case 3	Case 4	Case 5
Residential					
Electric	0%	13%	2%	11%	22%
Gas	13%	70%	34%	41%	76%
Oil	9%	51%	25%	29%	56%
LPG	4%	22%	10%	13%	24%
Commercial					
Electric	1%	14%	0%	12%	24%
Gas	14%	80%	39%	47%	87%
Oil	10%	58%	28%	33%	63%
LPG	4%	26%	13%	15%	29%
Industrial					
Electric	1%	15%	2%	14%	29%
Gas	12%	64%	31%	37%	70%
Coal	89%	532%	255%	305%	578%
Oil	7%	41%	20%	23%	44%
LPG	5%	32%	15%	23%	34%
Transportation					
Light Gasoline	6%	38%	24%	22%	47%
Light Diesel	4%	22%	18%	12%	31%

6.2. E-DRAM Macroeconomic Analysis

This section presents results from the E-DRAM model and Energy 2020 model used interactively. As discussed in Section 4.4, the outputs of Energy 2020 can be passed to E-DRAM in order to assess macroeconomic impacts, and these impacts can in turn be passed back to Energy 2020 so as to assess how changes in economic growth affect the CO_2 price and level of expenditures originally estimated.

Because Energy 2020 does not directly account for any change in economic growth resulting from a CO_2 price, both the amount of investment and the CO_2 price needed to drive the investment will be overstated. Linking from E-DRAM back to Energy 2020 is necessary for estimating the full effect of the AB 32 policies, which include increased energy prices, increased amounts of investment and changes in economic growth.

The model-to-model iterative steps are:

1. Solve Energy 2020 to determine the CO_2 price and expenditure changes.
2. Solve E-DRAM to determine the change in economic growth resulting from that CO_2 price and those expenditure changes.
3. Adjust the Energy 2020 model drivers to reflect the new growth assumptions and determine a new CO_2 price and new expenditures.
4. Re-solve E-DRAM to determine the change in economic growth.
5. Repeat Steps 3 and 4 until prices converge.

The results from Energy 2020 used in conjunction with E-DRAM include the changes in device and process investments, changes in operating and maintenance costs, changes in fuel expenditures, and the CO_2 price. Table 21 presents the values used in the first stage (Step 2) of the E-DRAM analysis.[43]

[43] The E-DRAM analysis also includes the costs of the High Global Warming Scoping Plan measures, H-1 through H-7. See Climate Change Scoping Plan Appendices, Volume I: Supporting Documents and Measure Detail, pp. C-172 to C-192.
http://www.arb.ca.gov/cc/scopingplan/document/appendices_volume1.pdf

Table 21. 2020 Energy 2020 Expenditure Changes Used in First-Stage E-DRAM Analysis

Device, Process, and Operating Expenditures (2007 M$/Yr)	Case 1	Case 2	Case 3	Case 4	Case 5
Residential	$1,539	$2,486	$1,901	$2,363	$2,830
Commercial	$2,793	$3,689	$4,521	$4,633	$5,031
Energy-Intensive Industrial	$1,298	$1,351	$1,300	$1,111	$1,176
Other Industrial	$767	$641	$711	$432	$417
Passenger	($6,268)	($6,907)	($93)	($6,709)	($595)
Freight	$250	$262	$259	$258	$267
Total	$379	$1,522	$8,599	$2,088	$9,126
Residential	0.8%	1.3%	1.0%	1.3%	1.5%
Commercial	2.2%	2.9%	3.5%	3.6%	3.9%
Energy-Intensive Industrial	19.2%	20.0%	19.3%	16.4%	17.4%
Other Industrial	9.3%	7.7%	8.6%	5.2%	5.0%
Passenger	-4.1%	-4.5%	-0.1%	-4.4%	-0.4%
Freight	11.0%	11.6%	11.4%	11.4%	11.8%
Total	0.1%	0.3%	1.8%	0.4%	1.9%

Fuel Expenditures (2007 $/mmBtu)	Case 1	Case 2	Case 3	Case 4	Case 5
Residential	($2,269)	($1,001)	($2,270)	$229	$1,081
Commercial	($1,292)	$787	($254)	$2,270	$3,366
Energy-Intensive Industrial	$267	$530	$143	($430)	($279)
Other Industrial	$529	$885	$457	$317	$635
Passenger	($4,001)	($4,464)	($1,626)	($4,298)	($1,900)
Freight	($663)	($1,368)	($1,171)	($1,163)	($1,600)
Total	($7,429)	($4,632)	($4,721)	($3,077)	$1,303
Residential	-9.6%	-4.2%	-9.6%	1.0%	4.6%
Commercial	-6.7%	4.1%	-1.3%	11.8%	17.5%
Energy Intensive Industrial	1.5%	3.0%	0.8%	-2.5%	-1.6%
Other Industrial	6.3%	10.6%	5.5%	3.8%	7.6%
Passenger	-6.4%	-7.2%	-2.6%	-6.9%	-3.1%
Freight	-3.2%	-6.6%	-5.6%	-5.6%	-7.7%
Total	-4.9%	-3.1%	-3.1%	-2.0%	0.9%

Table 22 details the first-stage state-level E-DRAM results for the five cases. The reported measures of economic impact include: gross state product (GSP), personal income, and labor demand. Gross state product is the sum of all value added by industries within the state plus taxes on production and imports. Personal income is the sum of all earned income and transfer payments. All comparisons are made relative to the 2020 reference case.

The change in GSP is negative across all cases, ranging from -0.2 percent to -1.9 percent. Personal income exhibits a small positive change in Case 1 (0.1 percent) but is negative for all other cases, ranging from -0.5 percent to -1.6 percent. Labor demand exhibits a negative response in all cases, ranging from almost 0 in Case 1 to -2.5 percent in Case 5.

In general, the economic impacts from the AB 32 policies are the least in the cases where the complementary policies more fully achieve their targets. In these cases, fewer reductions are required by the cap-and trade-program, which helps keep allowance prices low. Additionally, with the exception of the 33-Percent Renewable Portfolio Standard, the Low-Carbon Fuel Standard, and the Combined Heat and Power policy, the complementary policies achieve their reductions at a net savings. These savings reduce some of the negative impacts brought on by the CO_2 price and the positive-cost complementary policies.

Table 22. 2020 First-Stage E-DRAM Modeling Results

(2007 Dollars)	**Reference**	**Case 1**	**Case 2**	**Case 3**	**Case 4**	**Case 5**
Gross State Product ($ Billions)	2,502	2,497	2,471	2,471	2,479	2,454
Personal Income ($ Billions)	2,027	2,029	2,011	2,008	2,016	1,995
Income Per Capita ($ Thousands)	46.1	46.1	45.9	45.8	46.0	45.7
Labor Demand (Millions)	18.4	18.4	18.1	18.2	18.2	17.9
Percent Change from Reference Case						
Gross State Product	-	-0.2%	-1.3%	-1.3%	-1.0%	-1.9%
Personal Income	-	0.1%	-0.7%	-0.9%	-0.5%	-1.6%
Income Per Capita	-	0.1%	-0.3%	-0.5%	-0.2%	-0.8%
Labor Demand	-	0.0%	-1.7%	-1.2%	-1.3%	-2.5%
Annual Average Growth (2007-2020)						
Gross State Product	2.4%	2.4%	2.3%	2.3%	2.3%	2.2%
Personal Income	2.4%	2.4%	2.3%	2.3%	2.3%	2.3%
Income Per Capita	1.2%	1.2%	1.2%	1.2%	1.2%	1.2%
Labor Demand	0.9%	0.9%	0.8%	0.8%	0.8%	0.7%

To estimate the reduction in emissions brought on by reduced economic growth, the changes in GSP shown in Table 22 were multiplied by emissions-intensity factors (i.e., metric tons of emissions/$gross state product) estimated in the Energy 2020 reference case. The new CO_2 allowance price was then determined from the set of estimated Energy 2020 price trajectories, and the process was repeated until the allowance price stabilized.[44]

Table 23 summarizes the basic market information for each of the five cases for the price trajectory that achieved just enough abatement to reach the California emissions target. This table is comparable to Table 16 in Section 6.1.2. The primary differences between Table 16 and Table 23 are in three rows ("Allowance Price in 2020," "From Reduced Economic Growth," and "From Covered Sources due to C/T"), with the results reported in the other rows remaining basically unchanged. Regarding the decline in the emissions needed at covered sources, some of the reductions are now realized through reduced economic growth, which was not considered in Table 16. This reduced growth results in a lower allowance price being needed to comply. It is evident from Table 23 that relatively small changes in emissions result in large changes in the CO_2 allowance price in the Energy 2020 model. For example, the price in Case 5 drops from $162 to $102, with about a 7.5 MMT 2020 reduction (32.3 MMT cumulative reduction).

Table 23. Final Energy 2020 Compliance Summary

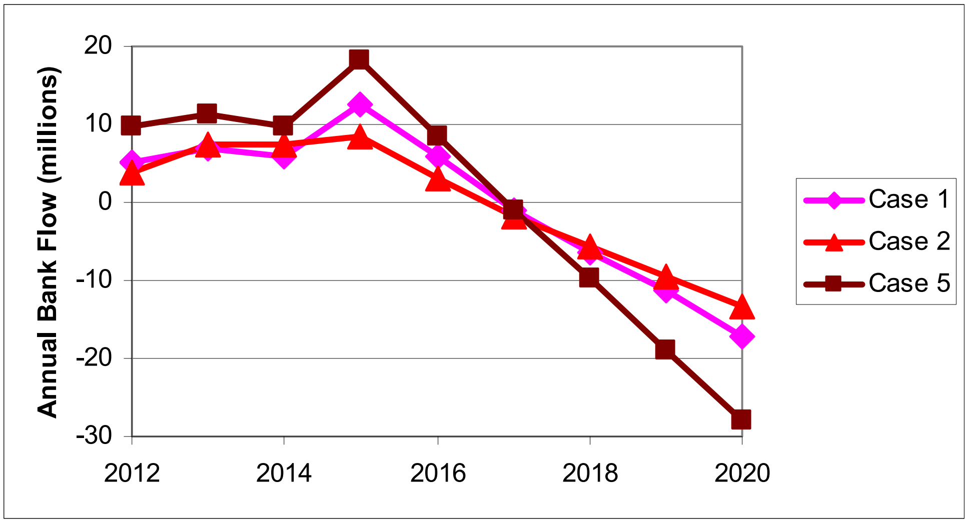
	Case 1	Case 2	Case 3	Case 4	Case 5
Allowance Price in 2020	$21	$106	$40	$87	$102
Cumulative Abatement, 2012-2020 (MMT)					
From Complementary Policies	319.2	319.2	234.1	202.3	136.8
From Reduced Economic Growth	4.1	20.3	23.9	18.0	32.3
From Covered Sources due to C/T	99.9	170.0	118.0	166.7	180.1
From Offsets due to C/T	86.8	0	102.2	98.6	111.0
Levels in 2020 (MMT)					
Covered Emissions	405.5	389.6	413.5	412.0	419.7
Offsets[45]	11.6	0	13.8	13.3	15.0
Bank Flow	-17.2	-13.4	-23.1	-22.0	-28.0

To offer further insights into the timing of emission reductions, Figure 6 shows when allowances are banked for future use and when banked allowances are

[44] In all cases, prices stabilized to within a dollar after four iterations between the models.
[45] In each case (except Case 2, with no offsets), the maximum number of offsets is reached. The differences in the number of offsets reflect the different cap levels that are set in the cases in the initial years. Each case has the same cap in 2020, but the caps prior to 2020 are set differently (except that Case 1 and Case 2 are the same), according to the effectiveness of the complementary policies. As a percentage of emissions, the offset limit is 2.9 percent in Case 1, 0.0 percent in Case 2, 3.3 percent in Case 3, 3.2 percent in Case 4, and 3.6 percent in Case 5.

subsequently used to meet compliance obligations. Recall that banking equals the cap (i.e., number of allowances) minus emissions plus offsets. In all cases, banking follows the same trend. In 2012 through 2016, emission reductions (including reductions from offsets) exceed those required by the cap, and so allowances are banked for future use. In 2017, emissions (including offsets) are approximately equal to the cap, so there is no banking. In 2018 through 2020, emissions (even after offsets) exceed the cap; so banked allowances are needed to meet compliance obligations.

Figure 6. Allowance Banking in Final Model Results



The primary difference between the cases is not the timing but the extent of banking. In Case 1, the banking through the first four years is approximately equal to the number of offsets used in each year. Case 2 banks a similar number of allowances in the early years. In contrast to Case 1, however, the banking is not because of offsets (which are not included in Case 2) but because the much higher allowance prices in Case 2 than in Case 1 motivate an approximately similar number of reductions as would have been provided by the offsets. Case 5 achieves nearly double the early reductions of Case 1 and Case 2, as it has both the offsets available in Case 1 and the early reductions in Case 2, given the similarly high allowance price. (It should be noted that the reductions in Case 5 are not exactly comparable to the reductions in Case 2, as the complementary policies and the cap levels in the initial years differ.)

The extent of banking in the final three years mirrors the banking in the early years as all of the banked allowances are used to meet compliance obligations. Case 1 and Case 2 rely on a smaller number of banked allowances in the final three years, while Case 5 uses nearly twice as many banked allowances as Case 1 and Case 2 in that period. As modeled, the 2020 allowance price does not appear to be a good predictor of how many banked allowances will be used (given the different levels of banked allowances used in Case 2 and Case 5 in 2020), though their 2020 allowance prices are very similar.

Table 24 displays the final price changes including the estimated allowance value. This table is comparable to Table 20. In general, the lower allowance prices lead to smaller increases in the price of fuels. Price changes are the greatest in the no-offsets case and the cases where electricity-targeted complementary policies do not achieve their reduction goals. The average electricity price increase is relatively consistent across sectors: ranging from 0-17 percent across the five cases. Like electricity prices, natural gas price increases change the most in the no-offsets case and the cases where natural gas-targeted complementary policies do not achieve their reduction goals. The natural gas price increases range from about 11-56 percent with the change appearing relatively consistent across the sectors. Gasoline and diesel prices increase 5-32 percent and 3-23 percent, respectively.

Table 24. Final Results: Fuel Prices, Including Permit Value

Fuel Prices, Including Permits (2007 $/mmBtu)	Case 1	Case 2	Case 3	Case 4	Case 5
Residential					
Electric	0%	4%	2%	11%	13%
Gas	11%	50%	20%	42%	49%
Oil	7%	36%	14%	30%	36%
LPG	3%	15%	6%	13%	15%
Commercial					
Electric	0%	3%	3%	12%	15%
Gas	12%	57%	22%	48%	56%
Oil	8%	41%	16%	34%	40%
LPG	4%	19%	7%	16%	18%
Industrial					
Electric	0%	5%	3%	14%	17%
Gas	10%	46%	18%	38%	45%
Coal	75%	377%	143%	312%	370%
Oil	6%	29%	11%	24%	28%
Transportation					
Light Gasoline	5%	27%	16%	22%	32%
Light Diesel	3%	15%	13%	13%	23%

Table 25 presents the expenditure values used in the final stage of the E-DRAM analysis. This table is comparable to Table 21 with the difference reflecting the effect of lower allowance prices on the timing and amount of investments and fuel expenditures.

Finally, Table 26 presents the final E-DRAM results. As should be expected, the lower CO_2 allowance price derived from using the two models together reduces the economic impacts brought about by the Scoping Plan policies. The difference is minimal in Case 1 where the allowance price was already low, but there is a much greater effect in the higher price cases.

It is important to note that none of the changes reflected in Table 26 consider additional design elements that could be made part of the cap-and-trade program to minimize the potential for high allowance prices. Recall from Table 15 that the addition of a small amount of additional allowances into the market had a substantial effect on the allowance price in Energy 2020.

The change in gross state product is negative in all cases, ranging from -0.2 percent to -1.4 percent. Personal income exhibits a small positive change in Case 1 but is negative for all other cases, ranging from -0.4 percent to -1.2 percent. Labor demand also exhibits a small positive change in Case 1 but is negative in all other cases, ranging from -0.8 to -1.7 percent.

Table 27 through Table 29 present the sector and household level impacts. At the sector level, results are largely as expected: the sectors with the greatest negative impacts are those that distribute fossil fuels such as the utilities; or those that consume large amounts of fossil fuels such as the Energy Intensive Industrials and Transportation and Warehousing. However, all sectors see some reduction in total value added labor demand.

At the household level, the assumption that 100 percent of the permit value remains in state and is returned to households helps ensure that the incomes of most household categories are not reduced. With the exception of Case 3, incomes remain relatively unchanged except for those at the highest income levels who see reductions of -0.2 to -1.2 percent across the five cases.

Observations include:

- Modeling results demonstrate that California's emissions target for 2020 could potentially be achieved with minimal negative economic impacts.
- The complementary policies lessen some of the impacts of the cap-and-trade program.
- Economic impacts could increase if complementary policies achieve fewer reductions or if measures are more costly.
- Economic impacts could decrease sharply should the economy grow at a slower rate, thereby producing lower emissions.
- Market-stability mechanisms, such as offsets, reduce the economic impact of AB 32 policies.

Table 25. 2020 Energy 2020 Expenditures Used in Final E-DRAM Analysis

Device, Process, and Operating Expenditures (2007 M$/Yr)	**Case 1**	**Case 2**	**Case 3**	**Case 4**	**Case 5**
Residential	$1,505	$2,148	$1,669	$2,177	$2,304
Commercial	$2,769	$3,255	$4,504	$4,475	$4,581
Energy-Intensive Industrial	$1,295	$1,284	$1,302	$1,114	$1,115
Other Industrial	$771	$660	$763	$439	$436
Passenger	($6,247)	($6,686)	$82	($6,594)	($268)
Freight	$249	$257	$256	$256	$262
Total	$342	$919	$8,576	$1,866	$8,428
Residential	0.8%	1.1%	0.9%	1.2%	1.2%
Commercial	2.2%	2.5%	3.5%	3.5%	3.6%
Energy-Intensive Industrial	19.2%	19.0%	19.3%	16.5%	16.5%
Other Industrial	9.3%	8.0%	9.2%	5.3%	5.3%
Passenger	-4.1%	-4.3%	0.1%	-4.3%	-0.2%
Freight	11.0%	11.4%	11.3%	11.3%	11.6%
Total	0.1%	0.2%	1.8%	0.4%	1.7%

Fuel Expenditures (2007 $/mmBtu)	**Case 1**	**Case 2**	**Case 3**	**Case 4**	**Case 5**
Residential	($2,301)	($2,042)	($2,058)	($145)	$102
Commercial	($1,345)	($845)	$170	$1,800	$2,111
Energy-Intensive Industrial	$267	$91	$256	($420)	($423)
Other Industrial	$519	$502	$609	$181	$269
Passenger	($3,984)	($4,337)	($1,476)	($4,223)	($1,699)
Freight	($635)	($1,154)	($987)	($1,043)	($1,325)
Total	($7,480)	($7,785)	($3,487)	($3,850)	($965)
Residential	-9.8%	-8.7%	-8.7%	-0.6%	0.4%
Commercial	-7.0%	-4.4%	0.9%	9.4%	11.0%
Energy Intensive Industrial	1.5%	0.5%	1.5%	-2.4%	-2.4%
Other Industrial	6.2%	6.0%	7.3%	2.2%	3.2%
Passenger	-6.4%	-7.0%	-2.4%	-6.8%	-2.7%
Freight	-3.1%	-5.6%	-4.8%	-5.0%	-6.4%
Total	-4.9%	-5.1%	-2.3%	-2.5%	-0.6%

Table 26. 2020 Final E-DRAM Modeling Results

All dollar values in 2007 dollars	**Reference**	**Case 1**	**Case 2**	**Case 3**	**Case 4**	**Case 5**
Gross State Product ($ Billions)	2,502	2,498	2,480	2,477	2,483	2,467
Personal Income ($ Billions)	2,027	2,029	2,018	2,011	2,019	2,003
Income Per Capita ($Thousands)	46.1	46.1	46.0	45.8	46.0	45.8
Labor Demand (Millions)	18.4	18.4	18.2	18.3	18.2	18.1
Percent Change from Reference Case						
Gross State Product	-	-0.2%	-0.9%	-1.0%	-0.8%	-1.4%
Personal Income	-	0.1%	-0.4%	-0.8%	-0.4%	-1.2%
Income Per Capita	-	0.1%	-0.1%	-0.5%	-0.1%	-0.6%
Labor Demand	-	0.1%	-1.2%	-0.8%	-1.0%	-1.7%
Annual Average Growth (2007-2020)						
Gross State Product	2.4%	2.4%	2.3%	2.3%	2.3%	2.3%
Personal Income	2.4%	2.4%	2.4%	2.3%	2.4%	2.3%
Income Per Capita	1.2%	1.2%	1.2%	1.2%	1.2%	1.2%
Labor Demand	0.9%	0.9%	0.8%	0.9%	0.8%	0.8%

Table 27. 2020 Sector Changes: Final E-DRAM Modeling Results (Value Added)

Billions of 2007 dollars	Reference	Case 1	Case 2	Case 3	Case 4	Case 5
Agriculture, Forestry, and Fishing	34.2	34.2	33.5	33.9	33.4	33.2
Mining	12.4	11.1	12.6	11.3	12.8	12.8
Construction	65.9	64.6	63.1	63.4	62.7	62.3
Utilities	32.0	28.8	22.1	28.1	23.5	23.3
Energy-Intensive Manufacturing	56.9	55.2	52.2	54.6	53.1	52.8
Other Manufacturing	245.9	242.8	241.8	242.2	242.8	242.6
Wholesale Trade	117.5	116.3	116.8	116.0	117.3	117.2
Retail Trade	149.5	147.8	146.7	148.1	146.7	147.5
Transportation and Warehousing	53.0	52.2	51.3	51.8	51.6	51.5
Information	115.7	115.2	116.3	115.3	116.4	116.6
Finance, Insurance, and Real Estate	376.3	376.4	373.0	373.6	372.8	370.8
Services	595.7	592.9	591.9	592.5	591.6	592.1
Total	**1,855**	**1,838**	**1,821**	**1,831**	**1,825**	**1,823**
Percent Change from Reference Case						
Agriculture, Forestry, and Fishing	-	0.1%	-1.9%	-0.8%	-2.3%	-2.7%
Mining	-	-10.5%	1.9%	-9.1%	3.1%	3.2%
Construction	-	-2.0%	-4.2%	-3.8%	-4.9%	-5.4%
Utilities	-	-10.0%	-31.0%	-12.3%	-26.6%	-27.3%
Energy-Intensive Manufacturing	-	-3.0%	-8.3%	-4.0%	-6.7%	-7.3%
Other Manufacturing	-	-1.2%	-1.7%	-1.5%	-1.3%	-1.4%
Wholesale Trade	-	-1.0%	-0.5%	-1.2%	-0.1%	-0.2%
Retail Trade	-	-1.1%	-1.9%	-0.9%	-1.8%	-1.3%
Transportation and Warehousing	-	-1.4%	-3.2%	-2.2%	-2.5%	-2.9%
Information	-	-0.4%	0.5%	-0.4%	0.7%	0.8%
Finance, Insurance, and Real Estate	-	0.0%	-0.9%	-0.7%	-0.9%	-1.5%
Services	-	-0.5%	-0.6%	-0.5%	-0.7%	-0.6%
Total	**-**	**-0.9%**	**-1.8%**	**-1.3%**	**-1.6%**	**-1.7%**

Table 28. 2020 Changes: Final E-DRAM Modeling Results (Labor Demand)

Thousands of jobs	**Reference**	**Case 1**	**Case 2**	**Case 3**	**Case 4**	**Case 5**
Agriculture, Forestry, and Fishing	448.7	453.4	441.4	446.5	439.8	435.0
Mining	25.9	22.2	23.3	22.1	24.2	23.8
Construction	928.6	920.1	893.6	898.7	887.9	875.9
Utilities	67.1	61.4	47.4	59.2	50.1	49.1
Energy-Intensive Manufacturing	857.6	849.5	835.4	839.6	842.0	832.2
Other Manufacturing	1,189.4	1,176.2	1,166.8	1,172.9	1,176.0	1,172.9
Wholesale Trade	791.4	791.1	789.3	784.5	793.0	786.5
Retail Trade	1,901.3	1,895.2	1,831.1	1,876.5	1,832.7	1,821.1
Transportation and Warehousing	503.4	500.1	484.1	491.5	487.0	480.7
Information	448.4	450.7	451.6	448.5	452.4	449.6
Finance, Insurance, and Real Estate	1,025.6	1,036.5	1,022.3	1,022.5	1,023.4	1,009.6
Services	6,728.5	6,753.4	6,713.9	6,713.9	6,714.8	6,675.3
Total	**14,916**	**14,910**	**14,700**	**14,776**	**14,723**	**14,612**
Percent Change from Reference Case						
Agriculture, Forestry, and Fishing	-	1.0%	-1.6%	-0.5%	-2.0%	-3.1%
Mining	-	-14.2%	-10.0%	-14.7%	-6.8%	-8.2%
Construction	-	-0.9%	-3.8%	-3.2%	-4.4%	-5.7%
Utilities	-	-8.5%	-29.3%	-11.8%	-25.3%	-26.7%
Energy-Intensive Manufacturing	-	-0.9%	-2.6%	-2.1%	-1.8%	-3.0%
Other Manufacturing	-	-1.1%	-1.9%	-1.4%	-1.1%	-1.4%
Wholesale Trade	-	0.0%	-0.3%	-0.9%	0.2%	-0.6%
Retail Trade	-	-0.3%	-3.7%	-1.3%	-3.6%	-4.2%
Transportation and Warehousing	-	-0.7%	-3.8%	-2.4%	-3.3%	-4.5%
Information	-	0.5%	0.7%	0.0%	0.9%	0.3%
Finance, Insurance, and Real Estate	-	1.1%	-0.3%	-0.3%	-0.2%	-1.6%
Services	-	0.4%	-0.2%	-0.2%	-0.2%	-0.8%
Total	-	**0.0%**	**-1.4%**	**-0.9%**	**-1.3%**	**-2.0%**

The sector total does not include public sector employment.

Table 29. 2020 Final E-DRAM Modeling Results (Household Income)

Thousands of 2007 dollars	Reference	Case 1	Case 2	Case 3	Case 4	Case 5
0.0% Marginal CA PIT	24.4	24.4	24.6	24.4	24.5	24.5
1.0% Marginal CA PIT	11.3	11.3	11.3	11.3	11.3	11.3
2.0% Marginal CA PIT	33.0	33.1	33.2	33.0	33.1	33.0
4.0% Marginal CA PIT	58.3	58.4	58.6	58.2	58.5	58.3
6.0% Marginal CA PIT	85.0	85.1	85.6	84.9	85.5	85.2
8.0% Marginal CA PIT	118.8	118.9	119.6	118.6	119.4	119.1
9.3% Marginal CA PIT Under 200k	197.4	197.6	198.3	196.9	198.1	197.5
9.3% Marginal CA PIT Over 200k	1,258.2	1,256.2	1,247.9	1,248.1	1,249.4	1,242.5
Percent Change from Reference Case						
0.0% Marginal CA PIT	-	0.3%	1.1%	0.2%	0.8%	0.7%
1.0% Marginal CA PIT	-	0.1%	0.2%	-0.2%	0.0%	-0.2%
2.0% Marginal CA PIT	-	0.1%	0.4%	-0.2%	0.3%	0.0%
4.0% Marginal CA PIT	-	0.1%	0.5%	-0.2%	0.4%	0.1%
6.0% Marginal CA PIT	-	0.1%	0.6%	-0.2%	0.5%	0.3%
8.0% Marginal CA PIT	-	0.2%	0.7%	-0.2%	0.6%	0.3%
9.3% Marginal CA PIT Under 200k	-	0.1%	0.4%	-0.3%	0.4%	0.1%
9.3% Marginal CA PIT Over 200k	-	-0.2%	-0.8%	-0.8%	-0.7%	-1.2%

CA PIT = California Personal Income Tax

7. TIMING OF CAPITAL INVESTMENTS

This section presents information about the timing of capital investments. As discussed in Section 6, the Energy 2020 model simulates investment in energy-using capital (i.e., buildings and equipment). This capital represents embodied energy requirements, resulting in particular energy demand as the capital is utilized.

The size and efficiency of the capital stock, and hence its energy demands, change over time as consumers make new investments and retire or modify old equipment. Consumers determine which fuel and technology to invest in, and marginal tradeoffs between changing fuel costs and efficiency determine the capital cost of the chosen technology. These tradeoffs are dependent on perceived energy prices, capital costs, operating costs, risk, regulations, and other imperfect information.

Investments, representing both device and process investments for all end-uses, are presented for Case 1 through Case 5 for the major sector levels: Residential, Commercial, Industrial, and Transportation (Passenger and Freight). Table 30 specifies the sector end-uses.

All expenditures for capital are on an annual basis, and they are recorded as the annual cost of capital services, taking depreciation and interest into account. An annual expenditure is the amount of money that when paid annually over the life of the capital item exactly recovers its cost, assuming a 5-percent capital recovery factor.[46] The complementary policies are phased in from 2010 to 2020 and the CO_2 price rises over time starting in 2012, so there are no changes in investment prior to 2010.

Table 30. Sector End-Uses

Residential and Commercial	**Industrial**	**Transportation (Passenger and Freight)**
• Space Heating • Water Heating • Other Substitutable[47] • Refrigeration • Lighting • Air Conditioning • Other Non-Substitutable	• Process Heat • Electric Motors • Other Substitutable • Miscellaneous	• Ground • Air/Water

[46] The capital recovery factor (CRF) is calculated with the formula $i(1+i)^n/[(1+i)^n-1]$ where i is the discount rate (5 percent in this case) and n is the lifetime of the capital. A real discount rate of 5 percent is chosen so as to match the rate of return on an inflation-adjusted 10-year Treasury security.

[47] Other Substitutable includes all other devices that can use multiple fuels. Other Non-Substitutable entails devices that use only electricity.

For passenger ground transportation, there are 16 transportation-technology types including light-, medium-, and heavy-duty vehicles. For freight ground transportation, there are seven transportation-technology types. Depending on capital costs and fuel prices, consumers substitute among these technologies.

Figures 7 through 11 detail the percentage changes in investment expenditures by sector for 2012, 2015, and 2020 across the five cases. Because there are both complementary policies and a CO_2 price in effect, it is not always apparent what drives a particular result.

Total

- The change in total investment ranges from -$463 million to $1.6 billion in 2012, increasing to $342 million to $8.6 billion in 2020.
- Investment in all years is greatest for Case 3 and Case 5, where the VMT policy is not in effect.
- Net expenditures range from -$6.8 billion to $7.5 billion.
- The commercial and industrial sectors are responsible for more of the increases in investment.
- By comparison, the original Scoping Plan looked at a single case with costs of $25 billion and savings of $40 billion, for a net savings of $15 billion.[48]

Residential

- The change in residential investment ranges from $77 to $139 million in 2012, increasing to $1.5 billion to $2.3 billion in 2020.
- Investment in the early years is greatest for Cases 1–3, most likely because of the phase-in of the energy-efficiency policy. Investment in later years is greatest for the high-price Cases (2, 4, and 5), as the CO_2 price effect drives additional investments.
- In Case 1 and Case 3 the decrease in fuel expenditure outweighs the increase in investment. In the high-price cases, fuel savings do not outweigh investment; thus net expenditure increases.

Commercial

- The change in commercial investment ranges from $597 million to $1 billion in 2012, increasing to $2.8 billion to $4.6 billion in 2020.
- Investment in the early years is greatest in Case 3, where fewer reductions in the transportation sector drive additional commercial reductions. Investment in 2020 is the greatest in Cases 3–5 because of the decreased complementary policy effectiveness and the higher CO_2 price.
- In all years and throughout the cases, the decrease in fuel expenditure is less than the increase in investment, so net expenditure increases.

[48] The Scoping Plan costs and savings included the California Clean Car standard (Pavley I).

Industrial

- The change in industrial investment ranges from $282 million to $465 million in 2012, increasing to $1.5 billion to $2.1 billion in 2020.
- In all years, industrial investment is least in Case 4 and Case 5, as high allowance prices drive presumably less-costly reductions in other sectors.
- In all years and throughout the cases, the decrease in fuel expenditure is less than the increase in investment, so net expenditure increases.

Passenger

- The change in passenger-transportation investment ranges from -$1.4 billion to $21 million in 2012, increasing to -$6.7 billion to $82 million.
- The decrease in passenger investment is driven by the VMT-reduction policy, which is in effect in Cases 1, 2, and 4. When the VMT policy is not active, passenger investment increases slightly because of the vehicle-efficiency policy. In Case 5 (the high-price case), technology-switching causes investment to fall as consumers switch to smaller, and therefore cheaper, vehicles.
- In Cases 1–3, the net expenditures decrease, while in Case 4 and Case 5 net expenditures increase slightly.

Freight

- The change in freight-transportation investment ranges from $22 million to $25 million in 2012, increasing to $249 to $257 million in 2020. The increase is primarily driven by the heavy-duty-vehicle efficiency policy and slightly by the CO_2 price effect.
- In all years and throughout the cases, the decrease in fuel expenditure exceeds the increase in investment, so net expenditure decreases.

Figure 7a. Case 1: Percentage Change in Investment Expenditures

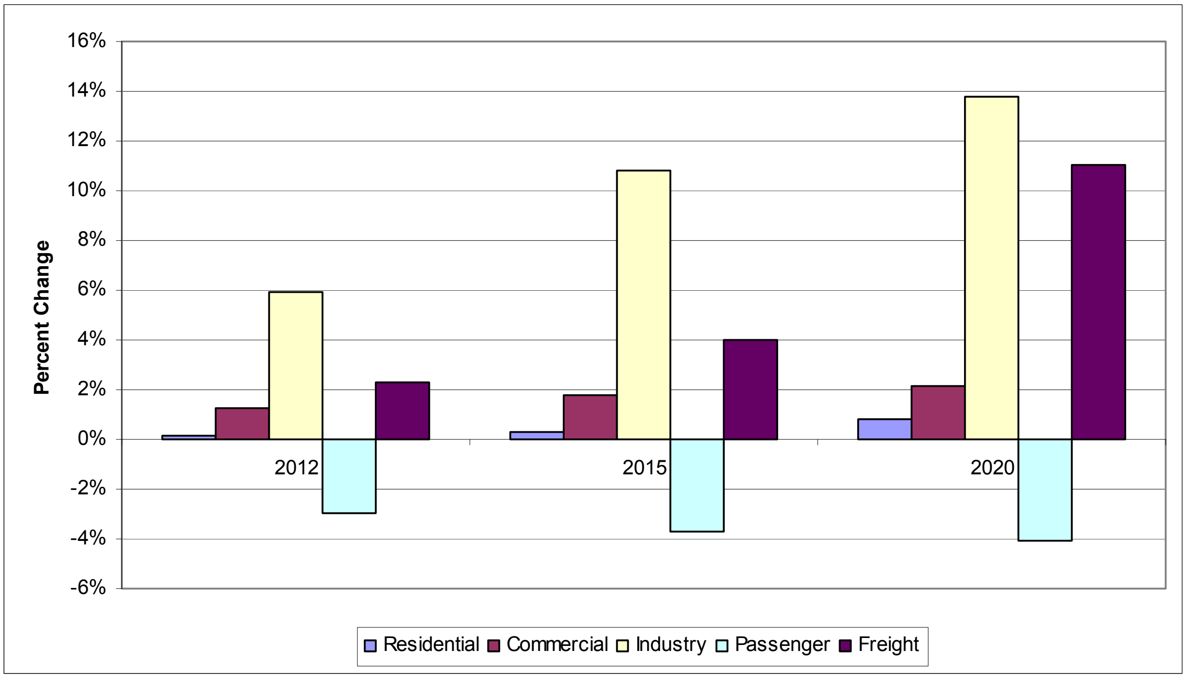


Figure 7b. Case 1: Percentage Change in Net Expenditures (Investments + Fuel Expenditures)

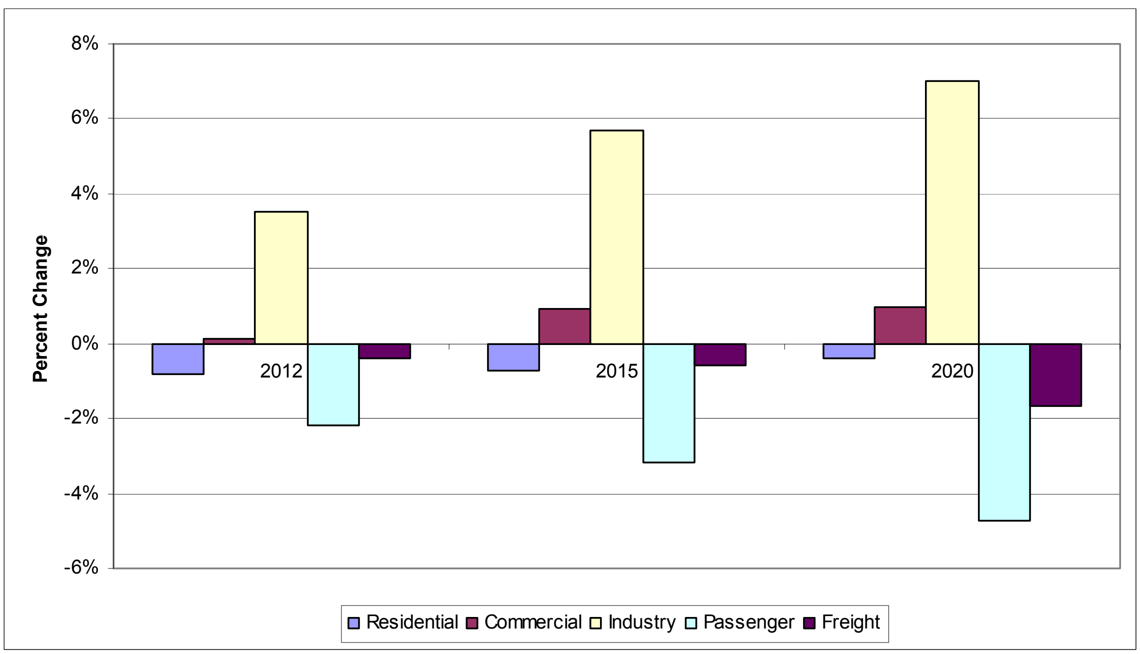


Figure 8a. Case 2. Percentage Change in Investment Expenditures

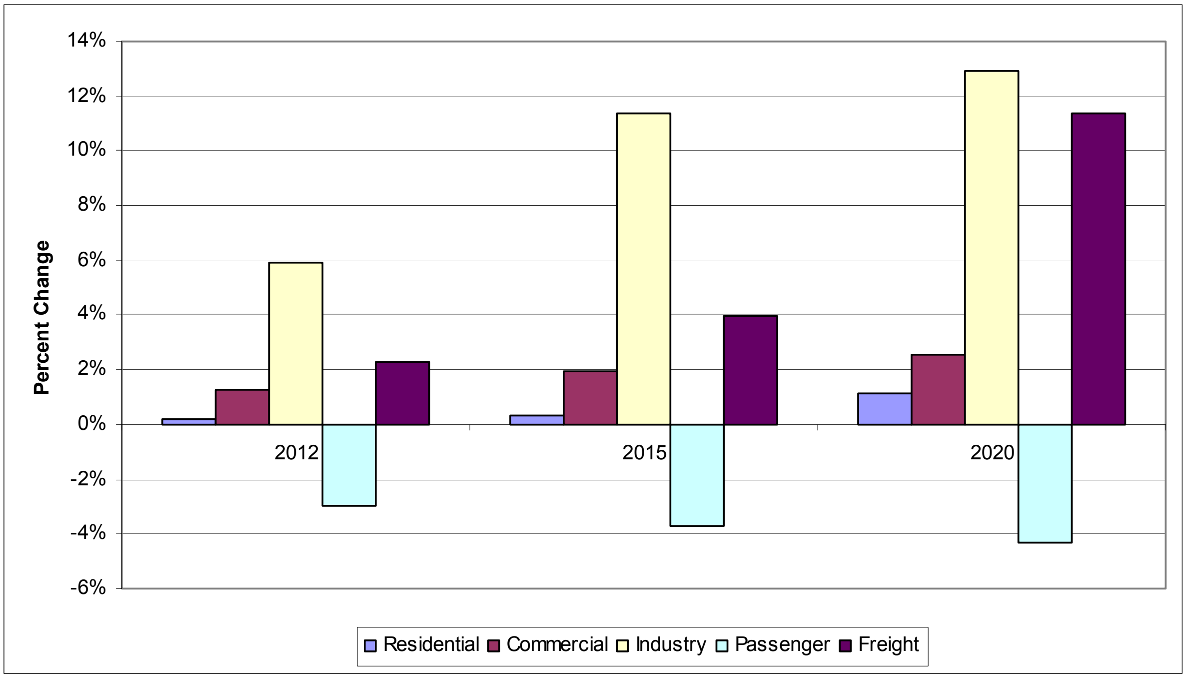


Figure 8b. Case 2. Percentage Change in Net Expenditures (Investments + Fuel Expenditures)

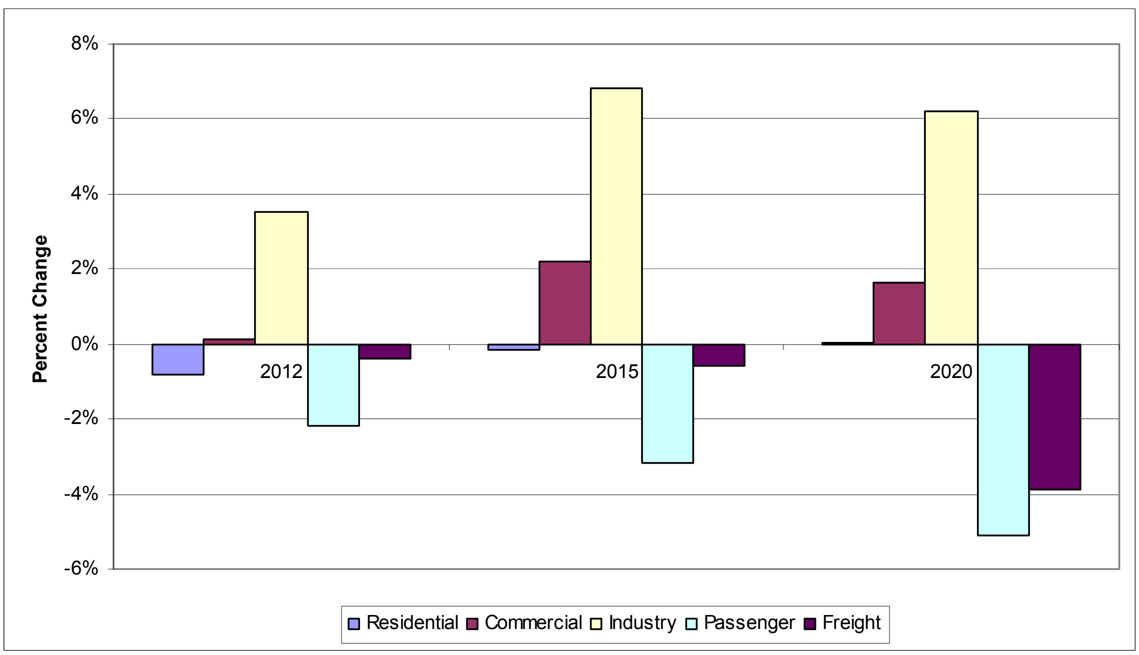


Figure 9a. Case 3: Percentage Change in Investment Expenditures

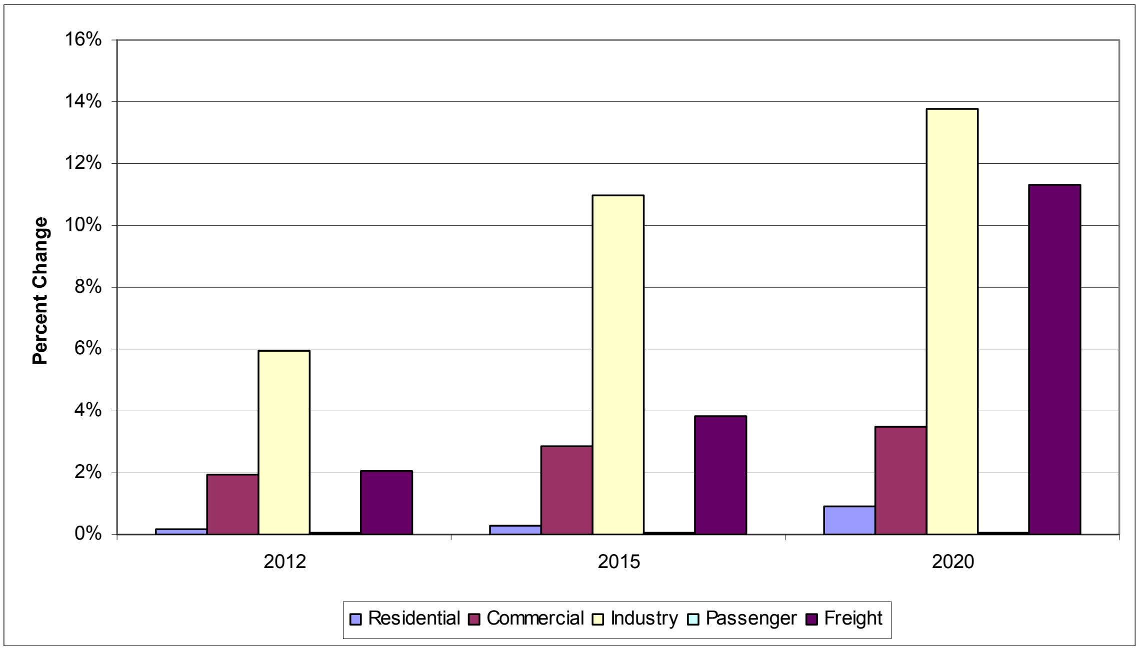


Figure 9b. Case 3: Percentage Change in Net Expenditures (Investments + Fuel Expenditures)

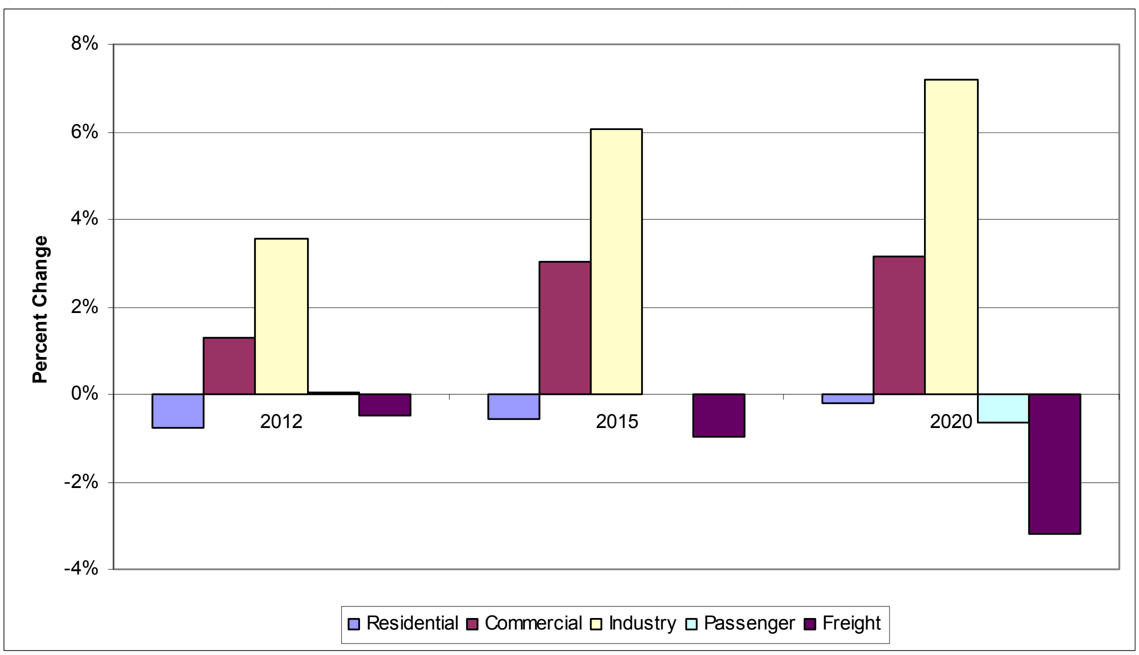


Figure 10a. Case 4: Percentage Change in Investment Expenditures

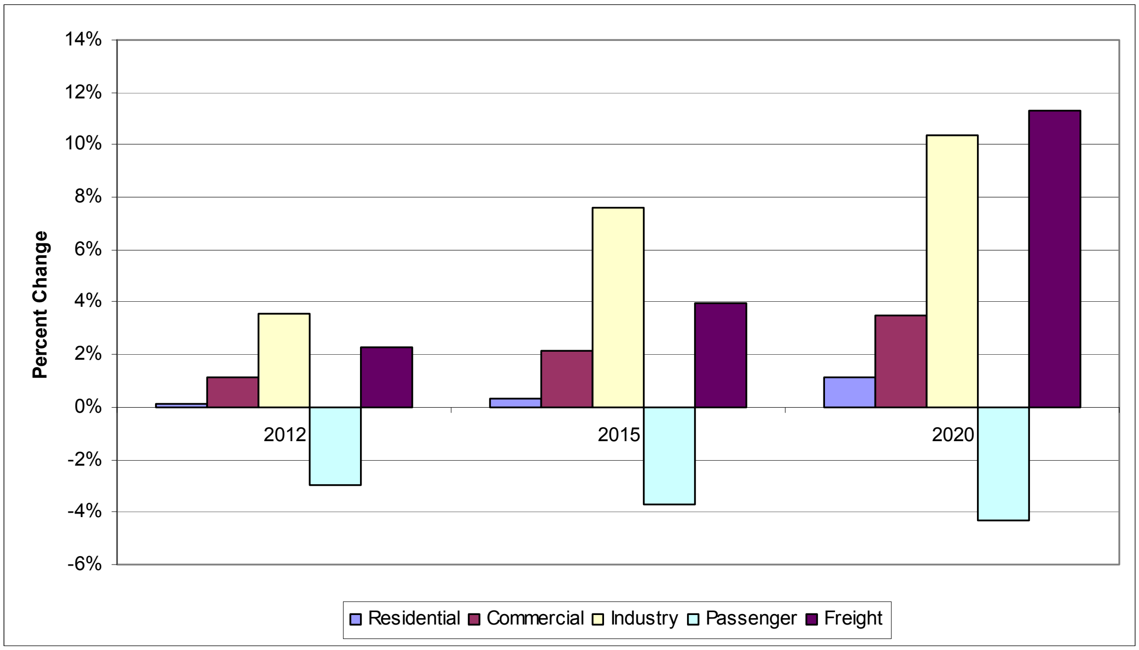


Figure 10b. Case 4: Percentage Change in Net Expenditures (Investments + Fuel Expenditures)

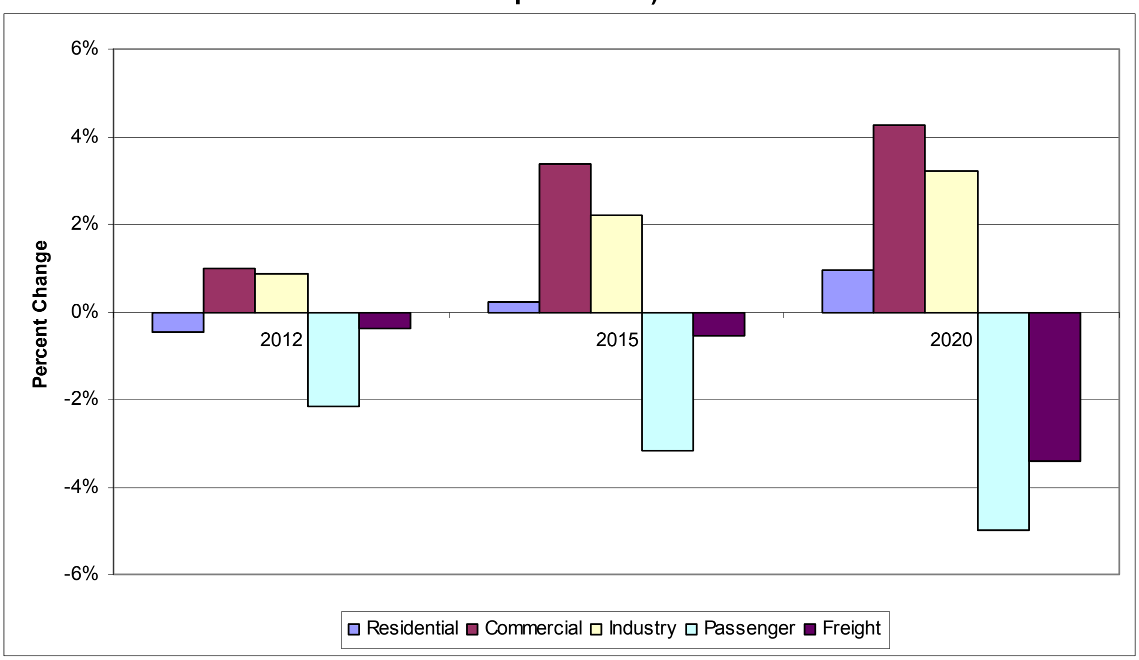


Figure 11a. Case 5: Percentage Change in Investment Expenditures

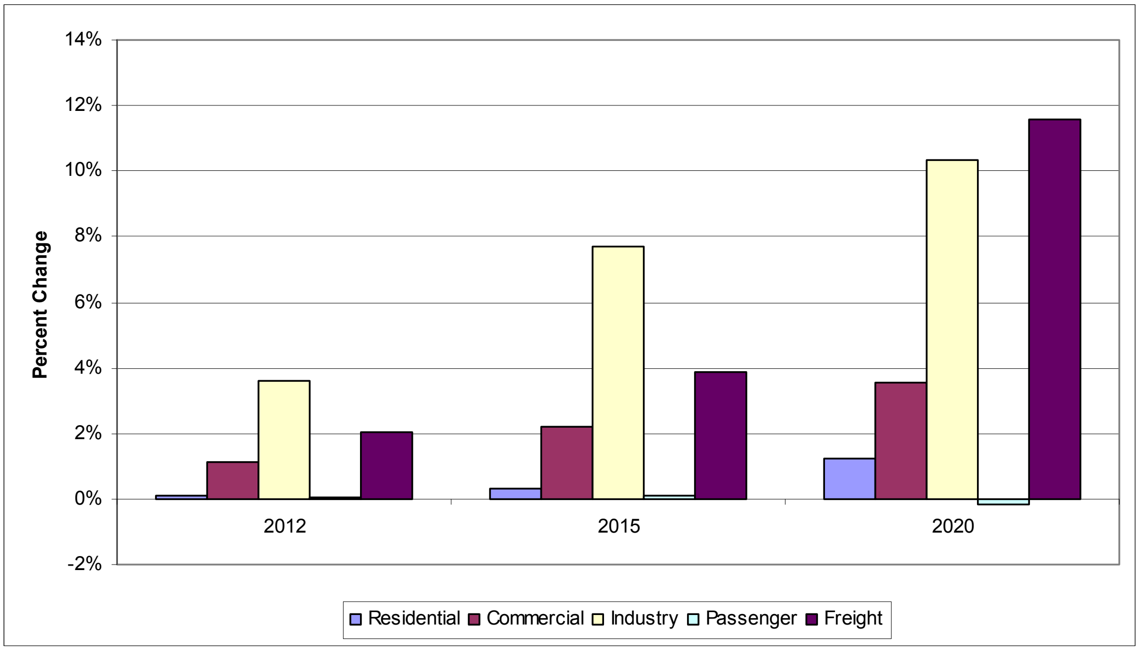
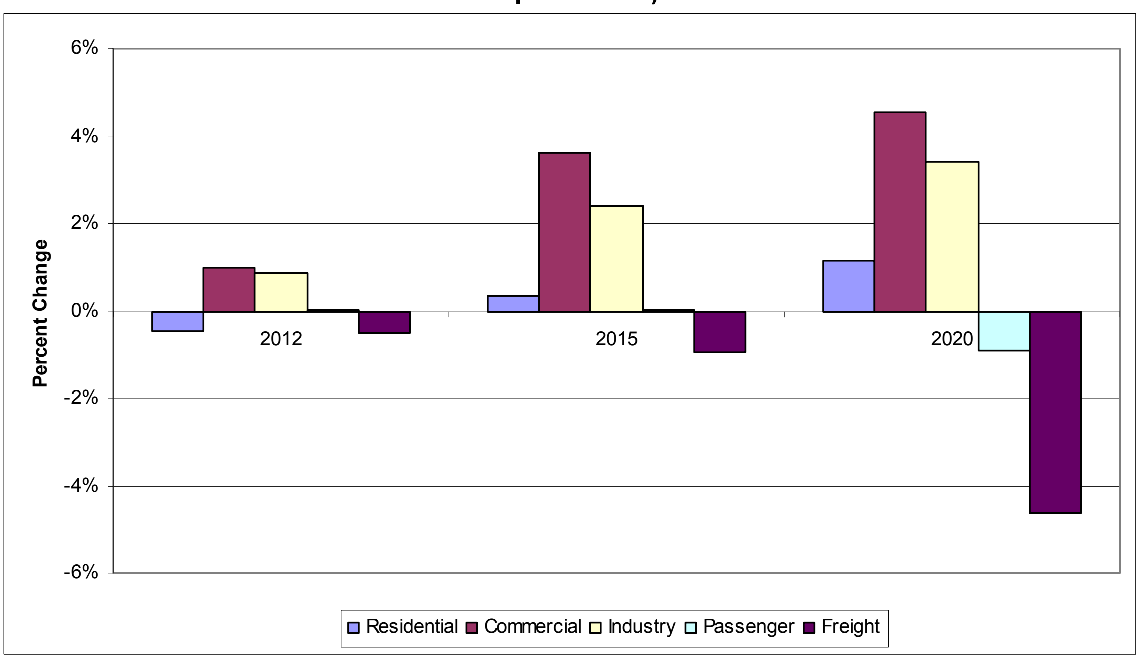


Figure 11b. Case 5: Percentage Change in Net Expenditures (Investments + Fuel Expenditures)



8. AB 32 AND SMALL BUSINESS

Section 38561(e) of AB 32 requires the Air Resources Board to consider the potential for adverse effects on small businesses when developing its Scoping Plan. What follows in this section is an update of the economic assessment of the likely impacts in that sector.

8.1. Small Business in California

There are many ways to define what it means to be a small business.[49] For the purposes of this analysis we adopt the definition of a small business chosen by the California Legislature and administered by the state's Department of General Services. California law requires that in order for a firm to be considered eligible for small-business status and the benefits afforded to small businesses, it:[50]

- Must be independently owned and operated
- Cannot be dominant in its field of operation
- Must have its principal office located in California
- Must have its owners (or corporate officers) domiciled in California
- Together with its affiliates, must be either:
  - A business with 100 or fewer employees and average annual gross receipts of $12 million or less over the previous three tax years; or
  - A manufacturer with 100 or fewer employees.

Under this definition of a small business, it is estimated that over 98 percent of California's 1,337,920 businesses are considered eligible for small-business status.[51]

[49] The U.S. Small Business Administration (SBA) has developed a schedule of definitions, differentiated by NAICS code, for which firms may be classified as small businesses. The schedule may be accessed on the SBA website at: http://www.sba.gov/idc/groups/public/documents/sba_homepage/serv_sstd_tablepdf.pdf. In general the definitions chosen by the SBA extend the definition of a small business to larger businesses than do California's rules.

[50] This definition and a description of the many benefits available to certified small and micro businesses may be accessed on the California Department of General Services Website: http://www.pd.dgs.ca.gov/smbus/sbcert.htm.

[51] This statistic was derived using Employment Development Department Table 1, which may be accessed at http://www.labormarketinfo.edd.ca.gov/?pageid=138.

8.2. Regulating Small Business Under AB 32

Small businesses in general will not be directly regulated by the measures recommended in the Scoping Plan. Most impacts will come from changes in the costs of goods and services that they procure—in particular, changes in energy expenditures. Therefore this analysis focuses on how implementation of the Scoping Plan could affect expenditures that small businesses make on energy and how such shifts could affect their profitability and overall economic competitiveness.

8.3. A Summary of Previous Analyses of Small-Business Impacts

For the Scoping Plan analyses, ARB staff assumed that the primary impacts on small business would come from changes in the price of energy. Staff based their assessment on the work of Energy and Environmental Economics, Inc. (E3). Prior to the adoption of the Scoping Plan, E3 estimated the impact of a package of GHG emissions reduction measures similar to those of the Scoping Plan. E3 estimated that the program could provide, in 2020, a 5 percent reduction in electricity expenditures (relative to business-as-usual) for the average California electricity customer.[52] This estimate was based largely on the assumption that increases in electricity prices would be more than offset by the continued expansion of energy-efficiency measures and that more efficient technologies would be developed and implemented.[53]

Accordingly, staff analysis indicated that implementation of the Scoping Plan's recommendations would likely have minor but positive impacts on small businesses in California. These benefits were primarily attributable to the measures in the Scoping Plan that were expected to deliver greater energy and fuel efficiencies. Thus, even when higher per-unit energy prices were taken into account, such efficiencies were expected to decrease overall energy expenditures for small businesses. Moreover, as the California economy was projected to experience continued economic growth associated with the implementation of AB 32, small businesses were expected to experience many of the benefits—more jobs, greater productive activity, and rising personal income—associated with that growth.

Since adoption of the Scoping Plan, several groups have attempted to revisit its impacts on small business. In June 2009, Professors Sanjay B. Varshney and Dennis H. Tootelian (both of California State University, Sacramento) estimated that the cost to each small business of implementing AB 32 would average $49,691.[54]

[52] Based on their GHG calculator, CPUC/CEC GHG Docket (CPUC Rulemaking.06.04.009, CEC Docket 07-OIIP-01), and may be accessed at http://www.ethree.com/cpuc_ghg_model.html.
[53] The E3 analysis focuses on direct programmatic measures and does not include the incremental price impact of a cap-and-trade regulation, which will depend on allowance price, allocation strategy, capped-industry response, and other decisions.
[54] Varshney and Tootelian's "Cost of AB 32 on California Small Business" may be accessed at: http://suspendab32.org/AB_32_Report071309.pdf

After reviewing several critiques by independent economists,[55] staff concluded that the Varshney and Tootelian estimate was unrealistic because it was driven primarily by two problematic assumptions—that AB 32 would not induce any cost-saving increases in energy or fuel efficiency; and that all investments resulting from AB 32 should be counted as losses to the California economy.

Subsequently, others have generated alternative estimates of the impact of AB 32 on small business. In August 2009, Professor Matthew Kahn (University of California at Los Angeles) conducted a point-by-point rebuttal of the Varshney and Tootelian analysis, using his calculations of the potential increases in energy and indirect costs. Kahn concluded that the net cost to small businesses was likely to be insignificant when accounting for the potential energy savings and new business opportunities brought about from the implementation of AB 32.

Most recently, the Union of Concerned Scientists (UCS) released an analysis, conducted for it by the Brattle Group, in which the estimated impact on small businesses was a “modest” 0.1–2.0 percent increase in costs.[56] The UCS analysis built on the work of E3 by including not only the costs of implementing direct measures but also ranges of associated indirect costs resulting from increases in the prices of inputs other than energy. UCS described its estimate as conservative because it assumed that small businesses do not take advantage of any efficiency improvements.

8.4. An Updated Methodology

As part of this updated analysis, the ARB has reviewed the following: comments made by peer reviewers of the original Scoping Plan analysis; comments made by stakeholders; and the body of recent impact studies regarding small business. Where appropriate, staff has incorporated this input into the updated analysis. Additionally, staff has worked with the Economic Impacts Subcommittee of the Economic and Allocation Advisory Committee to refine assumptions and develop a

[55] The independent critiques of the Varshney and Tootelian analysis include:
Frank Ackerman, “Daydreams of Disaster: An evaluation of the Varshney-Tootelian critiques of AB 32 and other regulations, Report to the California Attorney General 2009;
http://ww.sei-us.org/climate-and-energy/Ackerman Review Dec 2009.pdf
Chris Busch, “Climate Policy and Economic Growth in California: A Comparative Analysis of Different Economic Impact Projections,” December 3, 2009;
http://www.resource-solutions.org/pub_pdfs/Climate Policy and Economic Growth in California.pdf
Matthew Kahn, “A Review of Cost of AB 32 on California Small Businesses—Summary Report of Findings,” September 21, 2009;
http://www.arb.ca.gov/cc/scopingplan/economics-sp/matthew_kahn.pdf
James Sweeney, “Review of Varshney/Tootelian Report: Cost Of AB 32 On California Small Businesses—Summary Report Of Findings,” February 15, 2010;
http://www.stanford.edu/group/peec/cgi-bin/docs/policy/research/Sweeney%20Review%20of%20Varshney.pdf

[56] The Brattle Group analysis for UCS may be accessed at
http://www.ucsusa.org/assets/documents/global_warming/AB-32-and-CA-small-business-report.pdf.

methodology that can characterize the range of potential impacts on California small business from the implementation of AB 32.

Staff pursued three strategies for estimating the impacts of AB 32 on small business: a general equilibrium analysis; an energy price analysis; and a descriptive sensitivity analysis. While each of these analyses have distinct strengths and weaknesses, we believe that, used in conjunction, they provide a rich description of what small business may expect from AB 32.

8.5. The General Equilibrium Analysis

8.5.1. E-DRAM

The general equilibrium analysis captures both the direct and indirect impacts of each of the Scoping Plan measures. This analysis relies on the Environmental Dynamic Revenue Assessment Model (E-DRAM) for an estimation of the impacts by economic sector. More background on E-DRAM can be found in Section 4.3 of this report.

When identifying industry-level impacts, E-DRAM does not differentiate between small and large businesses. This fact prevents us from discerning the impacts of AB 32 on small business directly from E-DRAM output. In order to do so, the overall industry-level impacts must be combined with another data source that captures the distribution of economic activity by business size.

8.5.2. Employment Data

To estimate the distribution of economic activity, ARB staff used employment data from the California Employment Development Department (EDD). Employment data are used instead of alternative measures, such as the number of small businesses by size category, because we believe that employment is the best publicly available proxy for economic activities differentiated by size of business and industrial classification. For example, while over 98 percent of businesses may be classified as small businesses, it is clear that they do not produce anything approaching 98 percent of all economic output. Therefore, using the number of businesses would drastically overstate the impact of implementing AB 32 on small business.

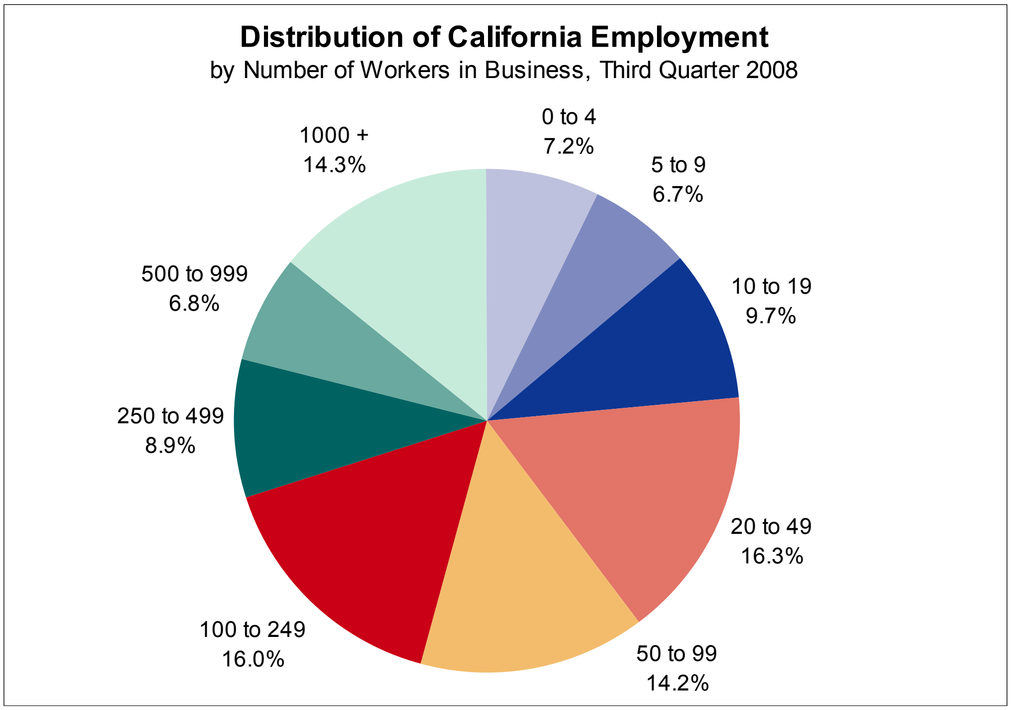
Employment data for 2008 were obtained from the EDD.[57] These data consist of third-quarter counts of employment by industrial classification and size of business. Industrial classification is in accordance with NAICS and is disaggregated to the three-digit level, which partitions the California economy into more than 90 industries such as Crop Production (111), Oil and Gas Extraction (211), and Residential Building Construction (236). Size of business is measured by employment and is

[57] 2008 is the most recent year for which employment data by industrial classification are available. Employment and business data for years 1994-2008 were obtained from EDD's Labor Market Information section and may be accessed at http://www.labormarketinfo.edd.ca.gov/?pageid=138.

partitioned into nine categories: 0-4, 5-9, 10-19, 20-49, 50-99, 100-249, 250-499, 500-999, and 1000+.[58]

Figure 12 is a pie chart representing the California employment, by size of business, in 2008. It shows, for example, that small business employed approximately 54 percent of the workforce.

Figure 12. Distribution of California Employment



8.5.3. Employment Share

Using the EDD data on total state employment partitioned by size of business and industrial classification, a small-business share is calculated for each industry. Equation (1) gives the formula for how each industry's small business share is calculated:

$$\text{Small Business Share}_i = \frac{\sum Employment\ at\ firms\ with\ fewer\ than\ 100\ employees}{\sum Employment\ at\ all\ firms} \qquad (1)$$

Table 31 reports employment and small-business share aggregated to the two-digit NAICS code level for each of the major economic sectors operating in California.

[58] For certain industrial classifications and business categories (always with more than 100 employees), exact counts are omitted. This is because data are considered confidential when, for example, there are fewer than three businesses in a category, when one employer makes up 80 percent or more of the employment in a category, or when confidential data could be inferred. This omission was observed in the partitions containing the largest employers, however, and did not affect our ability to calculate a small-business share for any industrial classification.

The two-digit level, which includes sectors such as services, retail trade, and transportation, differentiates between energy-intensive (EI) and non-energy-intensive (NEI) manufacturing. Each two-digit level is computed by taking the weighted average of each of the three-digit NAICS codes within the economic sector, using the formula from equation (1).

Table 31. California Employment and Small-Business Share by Industrial Sector

Industrial Sectors (EDD 2008 Data)	Total Employment	Small-Business Employment	Small-Business Share
Agriculture, Forestry, and Fishing	459,723	176,771	38.5%
Mining	26,698	10,339	38.7%
Construction	782,432	570,328	72.9%
Utilities	58,575	14,027	24.0%
EI Manufacturing	234,161	101,369	43.3%
NEI Manufacturing	1,191,064	479,404	40.3%
Wholesale Trade	705,036	490,238	69.5%
Retail Trade	1,615,574	1,056,518	65.4%
Transportation and Warehousing	432,622	196,370	45.4%
Information	472,152	159,917	33.9%
Finance, Insurance, and Real Estate	837,914	554,873	66.2%
Services	6,232,695	3,813,832	61.2%
Total	13,048,646	7,623,986	58.4%

Note: The partition of employment activities across sub-sectors is not identical between EDD and E-DRAM. Therefore, direct comparison of employment numbers between tables in this section is not possible. However, the classification difference has a similar impact on employment in small and large firms, so small business shares are unbiased by this difference.

Across the various economic sectors, small business makes up between 24 percent and 73 percent of employment. As expected, small business accounts for a smaller share of employment in energy-intensive sectors such as utilities (24 percent), information (34 percent), agriculture (38 percent), mining (39 percent), and manufacturing (NEI 40 percent, EI 43 percent). On the other hand, small business accounts for a majority of employment in labor-intensive and service-oriented sectors such as construction (73 percent), wholesale trade (70 percent), retail trade (65 percent), and finance, insurance, and real estate (66 percent). Given the fact that labor-intensive and service-oriented sectors are less energy- and emissions-intensive, it may be expected that small business will bear a less-than-proportional share of the direct economic costs of implementing AB 32.

8.5.4. Small Business Impacts

To estimate the impacts of implementing AB 32 on small business, staff chose to focus on employment and output, given these two metrics' descriptive importance and relatively constant relationship to employment share. That is, because the identification of economic impacts relies on relationships between employment and each of the chosen metrics, it was important that staff be confident in the stability of those relationships. Clearly, this held for the employment metric.

Throughout the remainder of this analysis, staff assumed that employment and output have a fixed relationship across small and large business. Staff believed that this was conservative in the sense that the resulting small-business shares calculated are almost certainly upper bounds. That is, because larger businesses tend to be more capital-intensive, it is likely that employment share overstates the productive activity of, and therefore impacts on, small business within a given industry.[59] Without the benefit of confidential data on production by size of business and industrial classification, this assumption yielded the best estimate of the likely share of economic output generated by small business.

Sector-level changes in employment and output were generated by E-DRAM, with small-business impacts calculated by using the E-DRAM results from the iterated analysis. For each of the five modeling cases, impacts were calculated by multiplying the change in 2020 sector-level employment (output) by the sector's calculated small-business share,[60] as shown in Equation (2):

$$\text{Sector Level Impact}_i = \textit{(Sector Small Business Share) x (Change in E-DRAM Output)} \quad (2)$$

The aggregate impacts on small business were then calculated by summing all of the sector-level changes. Thus, the difference between the aggregate impacts of implementing AB 32 on small business, as compared to the whole of the California economy, results directly from the different sector-level concentrations of small business. That is, because small business is more heavily concentrated in construction and retail trade than in utilities and mining, the impacts of implementing AB 32 on the construction and retail-trade sectors are going to more strongly determine the aggregate impacts on small business.

Tables 32 and 33 report employment and output impacts aggregated to the two-digit NAICS level for each of the major economic sectors operating in California.

[59] Staff expect the difference between the estimated and true share of small business output to be most pronounced in capital-intensive sectors such as manufacturing and utilities. Because these sectors are expected to bear a disproportionate share of the costs, staff conclude that the estimate may overstate the total cost to small business.
[60] See Section 5 for a detailed description of what is included in each of the cap-and-trade cases.

Table 32. E-DRAM Small-Business Employment Changes for Modeling Cases

Small Business Employment 2020	Reference	Case 1	Case 2	Case 3	Case 4	Case 5
Agriculture, Forestry, and Fishing	172,537	174,337	169,741	171,700	169,106	167,260
Mining	10,040	8,613	9,032	8,560	9,354	9,219
Construction	676,885	670,681	651,334	655,067	647,222	638,438
Utilities	16,061	14,697	11,356	14,170	12,005	11,769
EI Manufacturing	371,253	367,755	361,654	363,484	364,521	360,274
NEI Manufacturing	478,721	473,423	469,624	472,082	473,339	472,108
Wholesale Trade	550,264	550,104	548,799	545,467	551,417	546,905
Retail Trade	1,243,348	1,239,407	1,197,456	1,227,157	1,198,524	1,190,915
Transportation and Warehousing	228,506	226,977	219,733	223,094	221,074	218,205
Information	151,855	152,657	152,963	151,893	153,223	152,279
Finance, Insurance, and Real Estate	679,132	686,370	676,952	677,107	677,729	668,557
Services	4,117,225	4,132,439	4,108,313	4,108,271	4,108,809	4,084,641
Small Business Total	8,695,827	8,697,461	8,576,955	8,618,051	8,586,323	8,520,572
All Business Total	14,915,745	14,909,831	14,700,195	14,776,316	14,723,406	14,611,776
Percent Change from Reference Case						
Agriculture, Forestry, and Fishing	-	1.0%	-1.6%	-0.5%	-2.0%	-3.1%
Mining	-	-14.2%	-10.0%	-14.7%	-6.8%	-8.2%
Construction	-	-0.9%	-3.8%	-3.2%	-4.4%	-5.7%
Utilities	-	-8.5%	-29.3%	-11.8%	-25.3%	-26.7%
EI Manufacturing	-	-0.9%	-2.6%	-2.1%	-1.8%	-3.0%
NEI Manufacturing	-	-1.1%	-1.9%	-1.4%	-1.1%	-1.4%
Wholesale Trade	-	0.0%	-0.3%	-0.9%	0.2%	-0.6%
Retail Trade	-	-0.3%	-3.7%	-1.3%	-3.6%	-4.2%
Transportation and Warehousing	-	-0.7%	-3.8%	-2.4%	-3.3%	-4.5%
Information	-	0.5%	0.7%	0.0%	0.9%	0.3%
Finance, Insurance, and Real Estate	-	1.1%	-0.3%	-0.3%	-0.2%	-1.6%
Services	-	0.4%	-0.2%	-0.2%	-0.2%	-0.8%
Small Business Total	-	0.1%	-1.4%	-0.9%	-1.3%	-2.0%
All Business Total	-	-0.1%	-1.5%	-0.9%	-1.3%	-2.0%

Table 33. E-DRAM Small-Business Output Changes for Modeling Cases

Small Business Output 2020 (Millions of 2007 $)	**Reference**	**Case 1**	**Case 2**	**Case 3**	**Case 4**	**Case 5**
Agriculture, Forestry, and Fishing	36,490	36,851	35,600	36,085	35,499	34,932
Mining	10,236	9,472	10,829	9,547	10,903	10,785
Construction	101,455	100,797	96,595	97,488	96,086	93,919
Utilities	21,157	19,236	14,486	18,460	15,403	15,043
EI Manufacturing	77,833	74,807	66,027	72,136	68,039	66,177
NEI Manufacturing	262,255	262,025	256,214	257,692	257,438	253,329
Wholesale Trade	119,051	119,344	117,830	117,412	118,502	116,637
Retail Trade	211,175	207,310	198,326	204,577	200,377	198,573
Transportation and Warehousing	56,886	56,665	54,529	55,445	55,029	53,993
Information	79,755	80,298	79,726	79,356	79,927	78,924
Finance, Insurance, and Real Estate	370,492	374,061	365,299	366,900	365,706	359,059
Services	556,946	561,552	550,926	553,286	551,446	543,271
Small Business Total	1,903,730	1,902,419	1,846,388	1,868,384	1,854,356	1,824,640
All Size of Business Total	3,505,000	3,496,000	3,383,000	3,433,000	3,401,000	3,346,000
Percent Change from Reference Case						
Agriculture, Forestry, and Fishing	-	01.0%	-2.4%	-1.1%	-2.7%	-4.3%
Mining	-	-7.5%	5.8%	-6.7%	6.5%	5.4%
Construction	-	-0.7%	-4.8%	-3.9%	-5.3%	-7.4%
Utilities	-	-9.1%	-31.5%	-12.8%	-27.2%	-28.9%
EI Manufacturing	-	-3.9%	-15.1%	-7.3%	-12.6%	-15.0%
NEI Manufacturing	-	-0.1%	-2.3%	-1.7%	-1.8%	-3.4%
Wholesale Trade	-	0.3%	-1.0%	-1.4%	-0.5%	-2.0%
Retail Trade	-	-1.8%	-6.2%	-3.1%	-5.1%	-6.0%
Transportation and Warehousing	-	-0.4%	-4.1%	-2.5%	-3.3%	-5.1%
Information	-	0.7%	0.0%	-0.5%	0.2%	-1.0%
Finance, Insurance, and Real Estate	-	1.0%	-1.4%	-1.0%	-1.3%	-3.1%
Services	-	0.8%	-1.2%	-0.7%	-1.0%	-2.5%
Small Business Total	-	-0.1%	-3.0%	-1.9%	-2.6%	-4.2%
All Size of Business Total	-	-0.3%	-3.4%	-2.0%	-3.0%	-4.5%

Observations include:

- As a percentage, aggregate impacts on small business are relatively modest in comparison to the impacts on the whole economy. This is in large part because small businesses are generally not regulated by AB 32 policies or because small businesses are able to pass through costs due to the nature of their market.
- In some sectors, small business may expect to see an increase in employment and output as consumers invest in more efficient appliances and improve the energy efficiencies of their homes.
- Some uncertainty remains as to the actual impacts on small business. This uncertainty comes from the relationships that were assumed between employment and output and output and energy use.

8.6. Energy Price Analysis

8.6.1. Methodology

The energy price analysis uses proprietary data from Dun & Bradstreet on the energy-use profiles of small businesses to estimate a range of potential direct effects. This analysis is a useful complement to the general equilibrium analysis because it does not rely on the assumption that inputs to small businesses are similar to those of larger businesses. However, because it does not capture indirect effects it is a partial analysis.

Changes in energy prices are an output of Energy 2020. And according to that model, Scoping Plan measures are expected to increase the energy prices to businesses in California. Because we assume throughout this analysis that businesses are not able to change their energy-use profile in the short run, each business may expect an increase in energy expenditure. This spending increase among California businesses may reduce their profitability if they are unable to pass on the cost increase. Therefore estimating the increase in energy spending by businesses provides an upper bound on the direct impact that higher energy prices may have on small businesses in California.

8.6.2. Shares of Revenue Spent on Electricity and Natural Gas

Table 34 provides a list of California industries with the greatest expenditures on retail electricity as a percentage of their revenue. These industries are mostly service-related. To the extent that small businesses predominate in these industries, small business may expect to see a greater direct effect from increased energy prices. Each industry's small-business share, as calculated using the EDD employment data, is also reported.

Table 34. List of Industries with Highest Percentage of Revenue Spent on Electricity

SIC	Industry Description	Revenue on Electricity	Small-Business Share (EDD)
8641	Civic and Social Associations	8.6%	71%
7032	Sporting and Recreational Camps	8.2%	54%
7033	Trailer Parks and Campsites	8.2%	N/A*
7021	Rooming and Boarding Houses	7.4%	40%
7219	Laundry and Garment Services	6.9%	78%
7041	Membership-Basis Organization Hotels	6.9%	40%
8231	Libraries	6.9%	44%
7241	Barber Shops	6.9%	78%
5461	Retail Bakeries	6.9%	66%
6719	Holding Companies	6.6%	78%
5813	Drinking Places	6.4%	86%
7011	Hotels and Motels	6.4%	40%
7215	Coin-Operated Laundries and Cleaning	6.2%	78%
7231	Beauty Shops	6.2%	78%
7217	Carpet and Upholstery Cleaning	6.1%	91%
5441	Candy, Nut, and Confectionery Stores	6.0%	66%
4941	Water Supply	6.0%	24%
0259	Poultry and Egg Houses	5.9%	87%
8351	Child Day-Care Services	5.9%	78%
8361	Residential Care	5.8%	49%

*Data on this industry are not reported by the Employment Development Department

Table 35 provides a description of California industries that spend the greatest percentage of their revenue on retail natural gas. As shown, this measure varies greatly, from a high of 15.89 percent to a low of 1.81 percent. Small-business share is also reported.

Table 35. List of Industries with Highest Percentage of Revenue Spent on Natural Gas

SIC	Industry Description	Revenue on Natural Gas	Small-Business Share (EDD)
7215	Coin-Operated Laundries and Cleaning	15.9%	78%
7219	Laundry and Garment Services	8.4%	78%
7021	Rooming and Boarding Houses	6.9%	40%
7041	Membership-Basis Organization Hotels	6.8%	40%
8641	Civic and Social Associations	5.8%	71%
6719	Holding Companies	5.2%	78%
7033	Trailer Parks and Campsites	5.1%	N/A*
7241	Barber Shops	5.0%	78%
7011	Hotels and Motels	4.9%	40%
8351	Child Day-Care Services	4.4%	78%
7231	Beauty Shops	3.7%	78%
5813	Drinking Places	3.6%	86%
8231	Libraries	3.3%	44%
5461	Retail Bakeries	3.2%	66%
8361	Residential Care	3.14%	49%
7032	Sporting and Recreational Camps	2.8%	54%
4941	Water Supply	2.7%	24%
7217	Carpet and Upholstery Cleaning	1.9%	91%
5441	Candy, Nut, and Confectionery Stores	1.8%	66%

*Data on this industry are not reported by the Employment Development Department

8.6.3. Energy 2020 Price Changes

From Energy 2020 we estimate that the Scoping Plan control measures may be expected to increase the commercial electricity price in California by up to 13 percent (Case 5) and to increase the commercial natural gas price by 50 percent (Case 2), relative to the reference case. Using the change in energy prices, ARB staff estimated the change in percentage of revenue spent on energy by California firms in the industries that spend the greatest share of their revenue on commercial energy, as shown in Equation (3). Table 36 reports the results, along with each industry's small-business share.

Spending Change = *(Change in 2020 prices) x (% of revenue spent on energy)* (3)

Table 36. Range of Impact on Average Percentage of Revenue Spent on Energy

SIC	Business Category	SB Share	Total Energy	Case 1	Case 2	Case 3	Case 4	Case 5
7215	Coin-Operated Laundries and Cleaning	78%	22.1%	1.8%	8.2%	3.3%	7.4%	8.6%
7219	Laundry and Garment Services	78%	15.3%	0.9%	4.5%	1.8%	4.3%	5.0%
8641	Civic and Social Associations	71%	14.4%	0.6%	3.3%	1.3%	3.4%	4.0%
7021	Rooming and Boarding Houses	40%	14.2%	0.8%	3.7%	1.5%	3.7%	4.3%
7041	Membership-Basis Organization Hotels	40%	13.6%	0.7%	3.7%	1.5%	3.6%	4.2%
7033	Trailer Parks and Campsites	N/A*	13.3%	0.6%	2.9%	1.2%	3.0%	3.6%
7241	Barber Shops	78%	11.8%	0.6%	2.8%	1.1%	2.8%	3.3%
6719	Holding Companies	78%	11.8%	0.6%	2.9%	1.2%	2.9%	3.4%
7011	Hotels and Motels	40%	11.3%	0.5%	2.7%	1.1%	2.8%	3.3%
7032	Sporting and Recreational Camps	54%	10.9%	0.3%	1.7%	0.7%	2.1%	2.4%
8351	Child Day-Care Services	78%	10.2%	0.5%	2.4%	1.0%	2.5%	2.9%
8231	Libraries	44%	10.1%	0.4%	1.9%	0.8%	2.1%	2.5%
5461	Retail Bakeries	66%	10.1%	0.4%	1.9%	0.8%	2.1%	2.5%
5813	Drinking Places	86%	10.0%	0.4%	2.1%	0.9%	2.2%	2.6%
7231	Beauty Shops	78%	9.9%	0.4%	2.1%	0.9%	2.2%	2.6%
8361	Residential Care	49%	9.0%	0.4%	1.8%	0.7%	2.0%	2.3%
4941	Water Supply	24%	8.6%	0.3%	1.6%	0.7%	1.8%	2.1%
7217	Carpet and Upholstery Cleaning	91%	8.0%	0.2%	1.2%	0.5%	1.5%	1.7%
5441	Candy, Nut, and Confectionery Stores	66%	7.8%	0.2%	1.2%	0.5%	1.4%	1.7%

*Data on this industry are not reported by the Employment Development Department

Observations include:

- Most of these business classes are in the service sector. They are predominantly comprised of small businesses and likely constitute a representative sample of small business activity.
- In general, these business classes may expect a modest increase in the percentage of revenue spent on electricity and natural gas consumption.
- In the most expensive case, only nine of these business classes can expect an increased expenditure of more than 3 percent of revenue.
- In the mildest case, only one of these business classes can expect an increased energy expenditure of more than 1 percent of revenue.

8.7. Small Business Energy-Use Patterns

This section of the analysis uses Dun & Bradstreet data to generate descriptive statistics, which are meant to serve as a form of sensitivity analysis. To the extent that energy-use patterns among small businesses are different from larger businesses, this analysis should capture those differences.

The Dun & Bradstreet classification of business spending on electricity by employee size shows that small businesses tend to spend a greater share of their business costs on electricity than do larger businesses. In general, the smaller a business, the larger its expenditure on electricity. As shown in Figure 13, small businesses with a single employee spend 3.3 percent of each dollar generated from sales on electricity, while businesses with 500 or more employees spend only 0.3 percent.

Figure 13. Percentage of Revenue Spent on Electricity by Business Employee Size

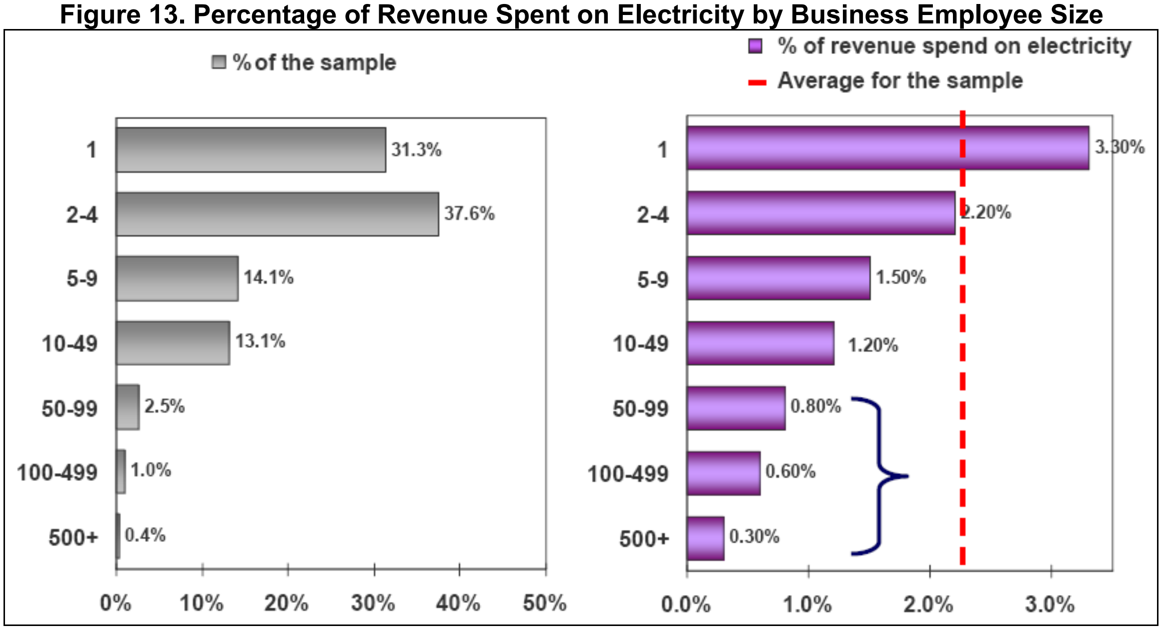


Figure 14 shows that businesses with smaller sales spend much higher percentages on electricity than do larger businesses. Small businesses with less than $50,000 in sales spend 34 times more on electricity as a percentage of revenue than larger businesses with $10 million or more in sales.

Figure 14. Percentage of Revenue Spent on Electricity by Business Revenue

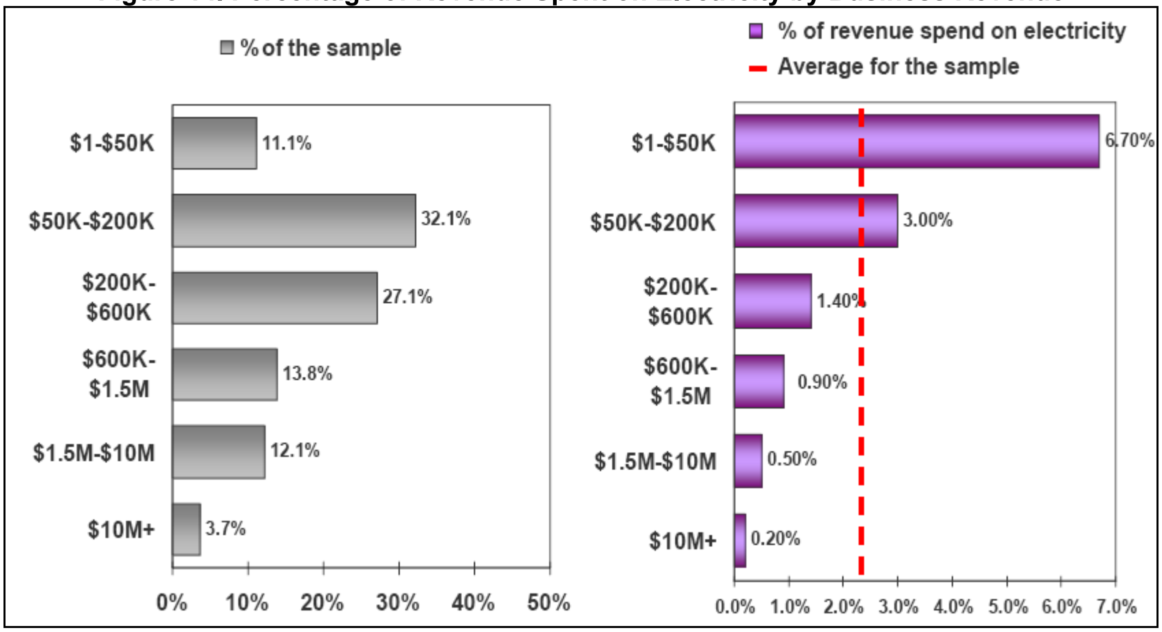


Figure 15 shows that younger businesses' spending on electricity as a percentage of revenue is about twice as great as older businesses' spending. Note that most young businesses are small businesses.

Figure 15. Percentage of Revenue Spent on Electricity by Business Age

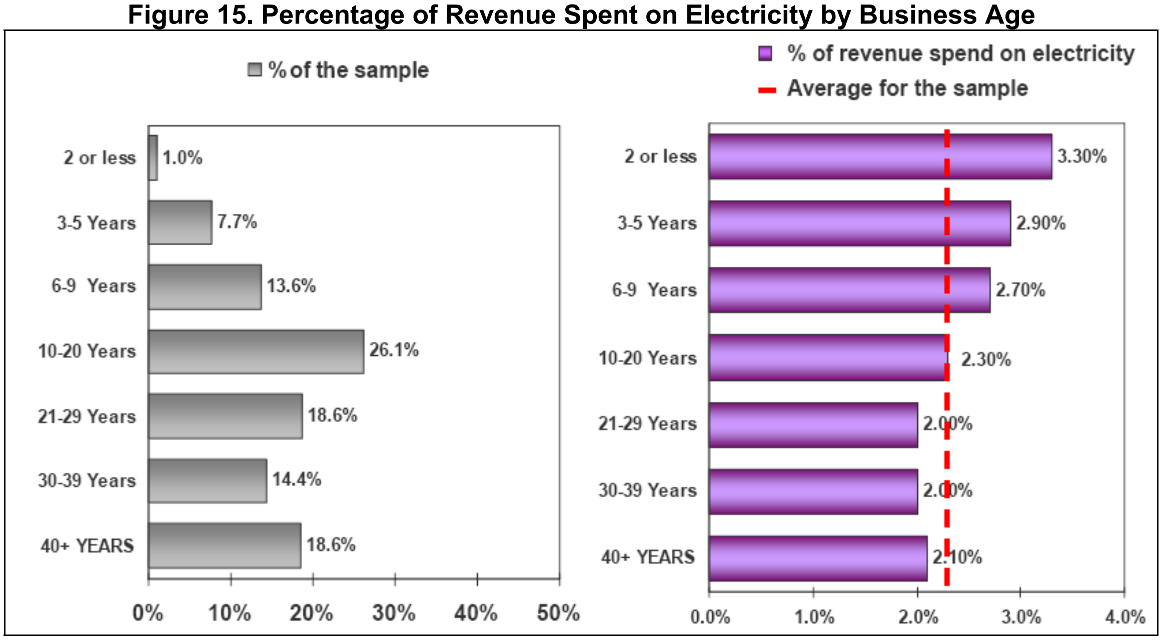


Figure 16 shows that the businesses that own their places of work spend almost as much on electricity as the businesses that rent their places of work. Both of these types of businesses, however, spend a smaller percentage of revenue on electricity than businesses that operate from home. The ownership status was not available for about 41 percent of businesses in the Dun & Bradstreet database.

Figure 16. Percentage of Revenue Spent on Electricity by Ownership Type

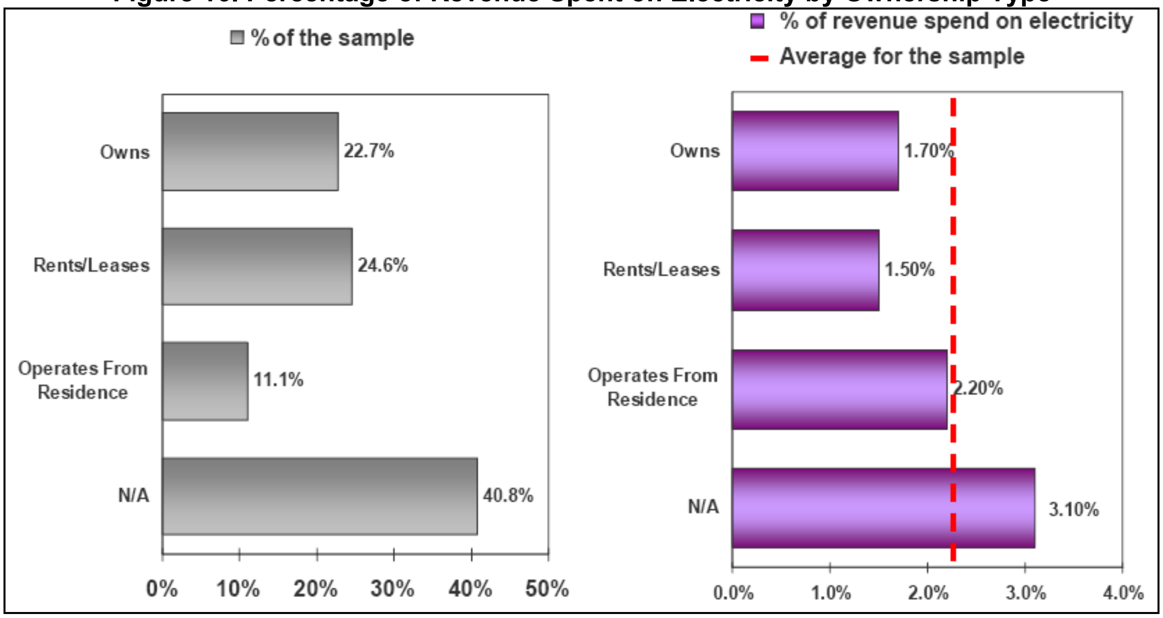


Figure 17 shows that nonprofit organizations much more on electricity than other business categories do. Corporations spend the lowest percentage of revenue on electricity; they also tend to be larger than other types of businesses.

Figure 17. Percentage of Revenue Spent on Electricity by Business Legal Status

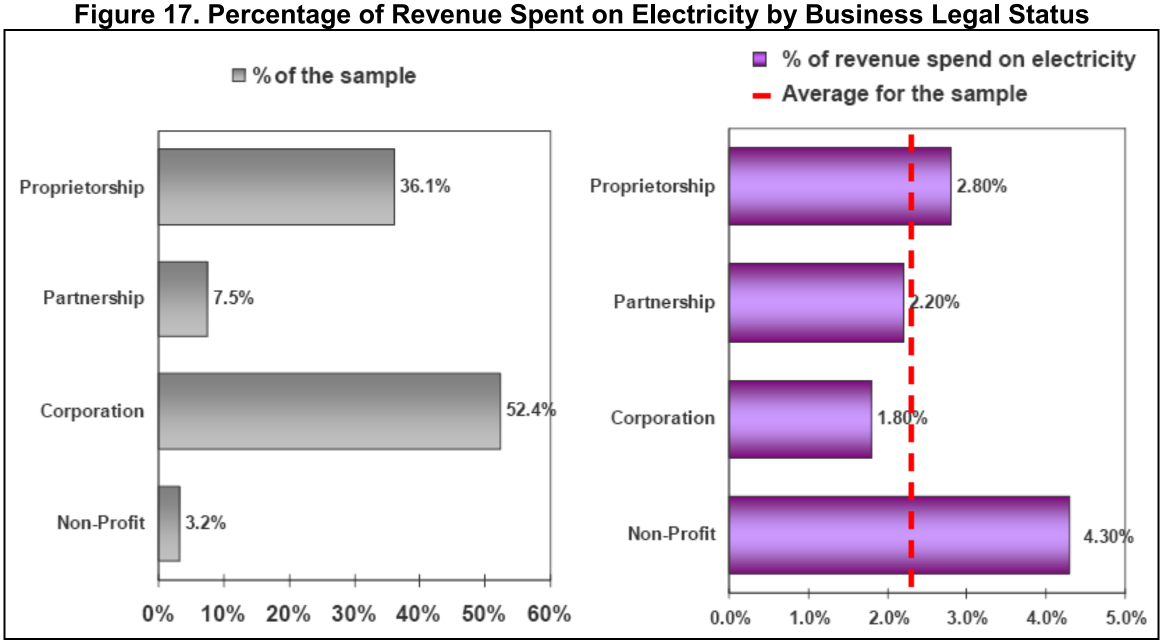
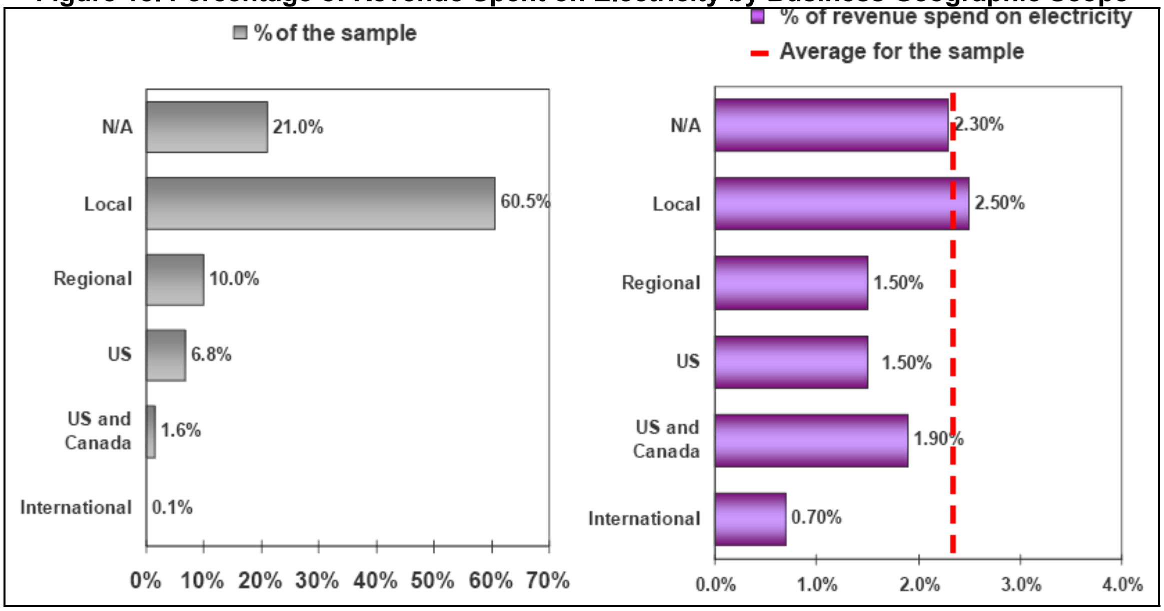


Figure 18 shows that local businesses tend to spend a larger percentage of revenue on electricity than businesses that operate regionally, nationally, or internationally. Local businesses also tend to be smaller businesses.

Figure 18. Percentage of Revenue Spent on Electricity by Business Geographic Scope



8.8. Section Conclusions

In aggregate, the Scoping Plan is unlikely to have a disproportionate impact on California's small businesses. Actually, the impact on small business is expected to be somewhat lower than the impact on the whole economy. This may be due to the fact that the cost to small businesses of implementing AB 32 will fall on them *indirectly*—through increases in energy prices. In particular, small businesses that operate in some service industries may expect to experience modest increases in their energy costs.

The majority of small businesses serve local markets and compete with entities that face similar costs. Thus, these businesses may be better able to pass on energy cost increases than those that compete regionally, nationally, and internationally. In any case, the actual impacts of energy-cost increases are likely to be lower than estimated in this analysis. Elevated energy costs tend to stimulate investment in energy-efficient products and equipment. To the extent that businesses invest in such products and equipment, their annual energy consumption will decline, thus easing the impacts of the energy-cost increases.

9. VALUATION OF THE POTENTIAL REDUCTIONS OF CRITERIA-POLLUTANT EMISSIONS

The primary objective of the AB 32 Climate Change Scoping Plan is to reduce greenhouse gas emissions. However, many of the Scoping Plan's measures also reduce criteria-pollutant emissions. We provide in this report's analysis an estimate of those latter reductions, and we estimate their economic value in terms of reduced costs of control.

9.1. Methodology

This analysis is not intended to re-create the California State Implementation Plan inventory or to estimate total statewide changes in criteria pollutants from implementing the Scoping Plan. Rather, the analysis provides a conservative estimate of the criteria-pollutant emissions reductions that could be expected to result from changes in energy demand—as stimulated by the Scoping Plan—in a subset of sectors of the California economy. As such, it gives a conservative estimate of the changes in criteria pollutants that may result from implementing the Scoping Plan.

Combined with the Energy 2020 model, which produces estimates of energy demand by economic sector and fuel type, the estimated change in criteria-pollutant emissions was estimated for 11 fuel categories: biomass, coal (electricity generation only), diesel, ethanol, motor gasoline, natural gas (electricity generation, residential use, and CHP/Other), PET coke, still gas, and biodiesel.

To estimate reductions in criteria pollutants, statewide emissions factors were multiplied by the energy demand in the sector and fuel categories that exhibited the greatest changes. Emissions reductions were not calculated for sectors or fuels that exhibited incidental changes or for which emission factors were not available. Finally, the estimated reductions in emissions were multiplied by dollars-per-ton values to estimate the avoided costs of control that could be realized under each scenario.[61]

9.2. Scenarios

This analysis evaluates the differences between a 2020 reference case and three cases representing various configurations of GHG regulations and measures. Those three scenarios are the complementary policies, the previously described Case 1 (complementary policies plus cap-and-trade with offsets), and the previously described Case 2 (complementary policies plus cap-and-trade without offsets). These three scenarios are more fully described in Sections 5.1, 5.2, and 5.3.

[61] This portion of the analysis focuses solely on the avoided costs of control and does not attempt to estimate the avoided damages that might result (e.g., avoided health costs).

Although California is a member of the Western Climate Initiative (WCI), the scenarios used in this analysis are for California alone and do not consider measures, policies, or offsets outside of California.

9.3. Fuel Equivalents

The Energy 2020 model uses trillion British thermal units (TBtu) as the universal unit of energy demand. To provide a more familiar context, however, the predicted changes in energy demand have been converted into more familiar units, such as gallons of gasoline, cubic feet of natural gas, and pounds of biomass. Most conversion values were obtained from the ARB Compendium of Emission Factors and Methods to Support Mandatory Reporting of Greenhouse Gas Emissions. Conversion values not contained in the compendium were obtained from online conversion calculators and websites. The conversion values used in this analysis are presented in Table 37.

Table 37. Conversion Values: Common Units of Fuel Measure

Fuel	Btu per gallon
Oil, unspecified	138,690
Still Gas	142,857
Motor Gasoline	124,238
Aviation Gasoline	120,190
Diesel	138,690
Ethanol (E85) [1]	90,500
Biodiesel [2]	130,000
Fuel	**Btu per pound**
Coal	9,985
Petroleum Coke	15,060
Biomass	7,690
Fuel	**Btu per cubic foot**
Natural Gas	1,027

1. University of Wisconsin, Stephens Point, Conversion Factors: Average Energy Content of Various Fuels. Available at http://www.uwsp.edu/cnr/wcee/keep/Mod1/Whatis/energyresourcetables.htm
2. North Dakota State University, Biodiesel Fuel http://www.ag.ndsu.edu/pubs/ageng/machine/ae1240w.htm

9.4. Emissions-Factor Estimates

To estimate criteria-pollutant emissions changes that could occur under the examined scenarios, ARB staff had to develop emissions factors. Because the Energy 2020 model presents energy demand for economic sectors and fuel types that are not directly comparable to more traditional ARB inventories and analyses, emissions factors were developed specifically for this analysis and should not be used for more general applications. The emissions factors used in this analysis were obtained by dividing the average statewide emissions for a given sector by the fuel consumed for each fuel type in that sector. As a result, the emissions-factor estimates do not consider regional or local conditions and thus are not appropriate for application at those levels.

The emissions factors developed for this analysis were based on data obtained from the following sources:

- The California Emission Inventory Development and Reporting System, which was queried to obtain area- and point-source average statewide emissions.
- The California Emission Factors Model, which was used to obtain estimates of on-road emissions and fuel use for both light- and heavy-duty vehicles.
- California Energy Commission (CEC) fuel databases, which contain data from the Quarterly Fuel and Energy Reporting requirements and the Petroleum Industry Information and Reporting Act. These CEC databases provided estimates of area- and point-source fuel use.

9.5. Estimated Changes in Criteria-Pollutant Emissions

To estimate the changes in 2020 criteria-pollutant emissions, the predicted changes in energy demand from the reference case and each scenario were multiplied by appropriate criteria-pollutant emissions factors.

As noted above, these estimated changes were on altered energy demand in 11 fuel categories. The changes in TBtu from these fuel categories represent more than 90 percent of the estimated change in energy demand, calculated by the Energy 2020 model, from fuel categories that have the potential to change criteria emissions.

The complementary policies alone are estimated to reduce the 2020 energy demand by 1 percent for the source categories considered in this analysis and to reduce the corresponding criteria-pollutant emissions by 126 tons per day. Case 1 would reduce 2020 energy demand by 4 percent and the corresponding criteria-pollutant emissions by 159 tons per day total. Case 2 would reduce 2020 energy demand by 6 percent and corresponding criteria-pollutant emissions by 211 tons per day.

The primary sources of the predicted reductions in energy use include increased energy efficiency for all fuels, reduced vehicle miles traveled, and increased use of sustainable energy sources such as solar and wind. The greatest reductions are predicted to occur in motor vehicle gasoline, natural gas used for electricity generation, and ethanol. Reduced emissions from gasoline are attributed to more efficient vehicles, alternative-fuel vehicles, and reduced vehicle miles traveled. Natural gas emissions could increase as a result of increased use of combined heating and power. However, in all scenarios the Energy 2020 model predicts an overall decrease in emissions from natural gas attributable to increased efficiency of natural gas use and replacement of natural gas with sustainable sources.

9.6. Value of Avoided Costs

The estimated avoided costs that result from implementation of the examined scenarios were calculated by multiplying the reductions in tons of criteria-pollutant emissions by their respective values (expressed as dollars per ton). For comparison purposes, two sources were referenced: the South Coast Air Quality Management District (AQMD) Best Available Control Technology (BACT); and the California EPA (Cal/EPA) Climate Action Team's Updated Macroeconomic Analysis of Climate Strategies (presented in the March 2006 Climate Action Team Report and in its Final Report).

Values obtained from the AQMD's BACT guidelines are the average maximum cost-effectiveness value, expressed as control costs (dollars) per ton of air-pollutant emissions reduced. Average maximum cost-effectiveness considers the difference in cost and emissions between a proposed minor-source BACT and an uncontrolled case. It is important to note that the values of emissions reductions vary widely, depending on region and attainment status. This valuation overestimates value because it assesses all reductions (avoided control costs) at the same price, but in attainment areas no further action is needed and additional costs are not incurred.

The values from the Cal/EPA Climate Action Team's Updated Macroeconomic Analysis of Climate Strategies were calculated by ARB and represent the weighted-average cost per ton of the criteria-pollutant reductions from the 2007 State Implementation Plan measures.

Depending on the scenario examined and the selected cost-per-ton value, the estimated savings in 2020 resulting from not having to implement control actions (on avoided emissions) range from $140 million per year (complementary policies scenario, using Cal/EPA values) to $518 million per year (Case 2, using AQMD BACT values). The estimated values for all scenarios are presented in Table 38.

Table 38. Estimated Value of Avoided Costs Statewide (2007 Dollars)

Statewide Difference Between Reference Case and Complementary Policies

		AQMD MSBACT Guidelines		Cal/EPA Updated Macroeconomic Analysis	
Criteria Pollutant	Estimated Statewide Change (TPD)	$/Ton	Value ($Millions/Yr)	$/Ton	Value ($Millions/Yr)
Reactive Organic Gases (ROG)	-10.2	$22,297	($83.0)	$12,813	($47.7)
Oxides of Nitrogen (NO_x)	-9.5	$21,083	($72.9)	$21,320	($73.8)
Oxides of Sulfur (SO_x)	-0.7	$11,149	($2.7)		
Carbon Monoxide (CO)	-102.8	$442	($16.6)		
Particulate Matter (PM10)	-2.4	$4,967	($4.4)	$20,500	($18.2)
Total			($179.7)		($139.7)

Statewide Difference Between Reference Case and Cap-and-Trade With Offsets

		AQMD MSBACT Guidelines		Cal/EPA CAT Updated Macroeconomic Analysis	
Criteria Pollutant	Estimated Statewide Change (TPD)	$/Ton	Value ($Millions/Yr)	$/Ton	Value ($Millions/Yr)
Reactive Organic Gases (ROG)	-11.7	$22,297	($95.0)	$12,813	($54.6)
Oxides of Nitrogen (NO_x)	-24.4	$21,083	($187.9)	$21,320	($190.0)
Oxides of Sulfur (SO_x)	-3.4	$11,149	($14.0)		
Carbon Monoxide (CO)	-115.3	$442	($18.6)		
Particulate Matter (PM10)	-3.9	$4,967	($7.1)	$20,500	($29.2)
Total			($322.5)		($273.7)

Statewide Difference Between Reference Case and Cap-and-Trade With No Offsets

		AQMD MSBACT Guidelines		Cal/EPA CAT Updated Macroeconomic Analysis	
Criteria Pollutant	Estimated Statewide Change (TPD)	$/Ton	Value ($Millions/Yr)	$/Ton	Value ($Millions/Yr)
Reactive Organic Gases (ROG)	-14.4	$22,297	($117.4)	$12,813	($67.5)
Oxides of Nitrogen (NO_x)	-44.6	$21,083	($343.0)	$21,320	($346.9)
Oxides of Sulfur (SO_x)	-5.7	$11,149	($23.3)		
Carbon Monoxide (CO)	-140.2	$442	($22.6)		
Particulate Matter (PM10)	-6.4	$4,967	($11.7)	$20,500	($48.1)
Total			($518.1)		($462.5)

10. COMPARISON OF OTHER MODELING EFFORTS OF CLIMATE POLICY

This section provides a brief review of other economic analyses of California climate policy and of similar federal climate change proposals. The primary conclusion of this review is that although the modeling approaches vary, the overall results are similar—notably that the aggregate impact of climate policies is likely to be small relative to expected overall growth.

10.1. Identification of Modeling Efforts

There have been several efforts to model California climate policy.[62] They include: the original ARB Scoping Plan analysis using the E-DRAM model; analysis by Prof. David Roland-Holst of UC, Berkeley, using the Berkeley Energy and Resources (BEAR) model; and analysis by Charles River Associates for the Electric Power and Research Institute, using the Multi-Region National-North American Electricity and Environment Model (MRN-NEEM).

At the regional level, the Western Governors' Association (WGA) used the Energy 2020 model to perform an analysis of the Western Climate Initiative (WCI) cap-and-trade program. This effort was enabled by a contract with ICF International and Systematic Solution Inc. No further analysis has been performed to date, though the WGA is continuing to evaluate the economic impacts of the WCI cap-and-trade program.

At the federal level, both the U.S. Environmental Protection Agency (USEPA) and the Congressional Budget Office have each performed analyses of several pieces of proposed federal climate legislation, which include the Lieberman-Warner Climate Security Act of 2008 (S. 2191), the American Clean Energy and Security Act of 2009 (H.R. 2454), and the Clean Energy Jobs and American Power Act of 2009 (S. 1733). Although the federal legislation differs from AB 32 in geographic scope and complementary policies, the emissions reduction targets are similar enough to warrant comparison.

The USEPA analyses used a suite of models, including two computable general-equilibrium (CGE) models, a detailed electricity-sector model, and four auxiliary models that provided inputs to the CGE models. These CGE models used were the Applied Dynamic Analysis of the Global Economy (ADAGE) model developed by Martin T. Ross of RTI International and the Inter-Temporal General Equilibrium Model (IGEM) developed by Dale Jorgenson of Harvard University and other associates under contract with the USEPA.

[62] Another was performed, by Professors Sanjay B. Varshney and Dennis H. Tootelian of California State University, Sacramento, for the California Small Business Roundtable. But it is not discussed in this document because of the many problems that have been identified in its analysis.

10.2. Brief Model Description

The previous modeling exercises were performed using different models, as noted, and they used different assumptions about growth and assessed different program designs. All of these elements affected the results of the analyses.

The models share many common elements but differ in several areas, including:

- Geographic scope
- Sector detail
- Time dynamics
- Energy substitution possibilities.

Analyses differed in program-design elements such as:

- Sector coverage
- Greenhouse gas inclusion
- Programmatic flexibilities, such as offsets

Results were also influenced by growth assumptions, such as those related to:

- Population
- Economic activity
- Emissions levels

The following is a brief description of the modeling tools used in these analyses:

E-DRAM is a static computable general equilibrium (CGE) model of the California economy. E-DRAM was originally developed to assess the revenue impacts of tax policies and other state policies for the Department of Finance. E-DRAM has subsequently been used by the California Energy Commission and ARB to assess impacts of reducing petroleum dependency (AB 2076) and by ARB for the Vehicle Climate Change Standards, the State Implementation Plan analysis, and the previous Climate Action Team analysis. E-DRAM has considerable sectoral detail and provides a good representation of California government, but it offers limited opportunities for energy substitution.

MRN-NEEM is a fully integrated model that combines a top-down general equilibrium model (MRN) of the entire economy with a bottom-up quadratic-programming model (NEEM) of the electricity sector. The MRN (Multi-Regional National) model is a forward-looking dynamic CGE model of the United States. The NEEM (North American Electricity and Environment Model) is a partial equilibrium model of the continent's electricity market that can simultaneously model system expansion and environmental compliance. The model employs detailed information on all of the generating units in the United States and large portions of Canada.

BEAR is a dynamic CGE model designed to support a broad spectrum of policy analysis, including responses to climate change such as trading and offset mechanisms. BEAR is similar to E-DRAM in some respects, such as sector detail and representation of the California government, but it differs in terms of additional components designed to evaluate technological change, energy and emissions policy, and transportation policy. The BEAR model has previously been used in the Climate Action Team analysis in order to assess the economic impacts of California GHG-control policies.

ADAGE is a dynamic CGE model capable of examining many types of economic, energy, environmental, climate change mitigation, and trade policies at the international, national, U.S. regional, and U.S. state levels.

IGEM is a dynamic model of the U.S. economy that describes growth due to capital accumulation, technological change, and population change. It is a multi-sector model that tracks changes in the composition of industry output as well as in the input mix, including energy, used by each industry.

Energy 2020 is an integrated multi-region energy model that provides complete and detailed simulation of the demand and supply pictures for all fuels. The model employs unit-level information on all of the generating units in the United States and large portions of Canada. The model simulates decisions by energy users regarding fuels; investments in end-use efficiency (e.g., by purchasing devices that are more efficient than the minimum required by standards); and end-use utilization (i.e., how much the device is used).

10.3. Main Results of the Modeling Exercises

Table 39 compares the carbon prices and estimated changes in GDP/GSP of the various modeling efforts. Changes in employment were estimated only by E-DRAM and BEAR. Most of these analyses produced results for several cases or variations on cases, but only the primary case results are presented in the table.

Although the models and modeling approaches differ, the overall impacts are not drastically different. The CO_2 price ranges from $10 to $101 per metric ton, with only one price greater than $51 per metric ton. The aggregate GSP/GDP impacts are small relative to the business-as-usual (BAU) growth assumptions; the changes range from -2.5 percent to 0.1 percent, with only two estimates falling below -0.7 percent. These differences in results can be related back to the differences in model designs, economic growth assumptions, and program designs highlighted in the previous section.

The federal analyses provide a good means for comparisons of the effects of such differences. With respect to model design, in both the S. 2191 analysis and H.R. 2454/S. 1733 analysis the IGEM-estimated price and resulting change in GDP estimated are greater than the ADAGE estimates. The IGEM model is implemented econometrically, meaning that the parameters governing the behavior of producers and consumers are statistically estimated over a time-series data set that is constructed specifically for this purpose. This manner of estimation is in contrast to many other multi-sector models, such as ADAGE, that are calibrated to the economy of one particular year.

With respect to economic growth assumptions, the H.R. 2454/S. 1733 analyses entailed slower rates of growth than the S. 2191 analysis, which resulted in lower prices and smaller changes in GDP.

The case that best illustrates how program design elements affect the carbon price is the EPRI analysis. The price estimated in the EPRI analysis was much greater than those of the other California studies; however, the $101 price estimate was based on a program design that did not allow for the use of offsets. While the EPRI analysis did not provide an allowance price with offsets, it stated that the use of offsets could provide a cost savings of $33 billion (14 percent) through 2050.

Table 39. Main Outputs for 2020 Results of Economic Models

Analysis	Model	Model Type	2020 Carbon Price	BAU GDP/GSP Growth	2020 GDP/GSP Change	2020 Employment Change
California						
AB 32 Scoping Plan	E-DRAM	CGE	$10	43% (2007-2020)	0.1%	0.6%
AB 32 Scoping Plan	BEAR	CGE	$12	43% (2007-2020)	0.1%	0.1%
AB 32 General (EPRI)	MRN-NEEM	CGE/Electric Sector	$101	51% (2006-2020)	-1.3%	N/A
Regional						
WCI	Energy 2020	Energy sectors	$20	53% (2006-2020)	N/A	N/A
Federal						
S. 2191	ADAGE	CGE	$37	60% (2005-2020)	-0.7%	N/A
S. 2191	IGEM	CGE	$51	48% (2007-2020)	-2.5%	N/A
H.R. 2454/S. 1733	ADAGE	CGE	$16	32% (2010-2020)	0.1%	N/A
H.R. 2454/ S. 1733	IGEM	CGE	$30	35% (2007-2020)	-0.6%	N/A
CBO	Meta-analysis	CGE and others	$26	N/A	-0.2% to-0.7%	N/A

EPRI = Electric Power Research Institute
CBO = Congressional Budget Office

SOURCES

The Estimated Costs to Households From the Cap-and-Trade Provisions of H.R. 2454. Congressional Budget Office. June 19, 2009. Available at: http://www.cbo.gov/ftpdocs/103xx/doc10327/06-19-CapAndTradeCosts.pdf

Climate Change Draft Scoping Plan: Economic Analysis Supplement Pursuant to AB 32, the California Global Warming Solutions Act of 2006. Prepared by the California Air Resources Board for the State of California. Available at http://www.arb.ca.gov/cc/scopingplan/document/economic_analysis_supplement.pdf

Design Recommendations for the WCI Regional Cap-and-Trade Program. September 23, 2008. Appendix B: Economic Modeling Results. Available at http://www.westernclimateinitiative.org/component/remository/func-startdown/33/.

Economic Impacts of S. 1733: The Clean Energy Jobs and American Power Act of 2009. October 23, 2009. U.S. Environmental Protection Agency, Office of Atmospheric Programs. Available at http://www.epa.gov/climatechange/economics/pdfs/EPA_S1733_Analysis.pdf.

EPA Analysis of the American Clean Energy and Security Act of 2009, H.R. 2454 in the 111th Congress. June 23, 2009. Available at http://www.epa.gov/climatechange/economics/pdfs/HR2454_Analysis.pdf.

EPA Analysis of the Lieberman-Warner Climate Security Act of 2008, S. 2191 in 110th Congress. March 14, 2008. Available at http://www.epa.gov/climatechange/downloads/s2191_EPA_Analysis.pdf.

Program on Technology Innovation: Economic Analysis of California Climate Initiatives: An Integrated Approach. Volume 1: Summary for Policymakers (No. 1014641). EPRI. June 2007. Available at http://mydocs.epri.com/docs/public/000000000001014641.pdf.

APPENDICES

Appendix A. Assumptions Book for Energy 2020

The latest version of the ICF report "Modeling of Greenhouse Gas Reduction Measures to Support the Implementation of the California Global Warming Solutions Act (AB 32): Energy 2020 and Model Inputs and Assumptions" is available at: http://www.arb.ca.gov/cc/scopingplan/economics-sp/models/book1002.pdf

Background information on Energy 2020 and E-DRAM is available at: http://www.arb.ca.gov/cc/scopingplan/economics-sp/models/models.htm

Appendix B. Detailed Energy 2020 Modeling Results

First-Stage Results

Table B-1. 2020 First-Stage Results: Greenhouse Gas Emissions

California Total GHG Pollution (% Change from Reference)	Case 1	Case 2	Case 3	Case 4	Case 5
Residential	-9%	-15%	-12%	-12%	-13%
Commercial	-7%	-11%	1%	0%	-2%
Industrial	-15%	-17%	-16%	-18%	-18%
Energy Intensive Industry	-5%	-8%	-6%	-8%	-9%
Other Industry	-24%	-26%	-26%	-27%	-27%
Mining	-6%	-17%	-11%	-19%	-23%
Agriculture	-1%	-2%	-1%	-3%	-3%
Transportation	-12%	-14%	-7%	-13%	-8%
Passenger	-14%	-14%	-7%	-14%	-7%
Freight	-9%	-12%	-9%	-11%	-11%
Power Sector	-33%	-38%	-34%	-17%	-19%
Domestic Power Sector	-17%	-57%	-41%	-36%	-46%
Electricity Imports	-43%	-26%	-30%	-6%	-1%
Waste and Other	0%	0%	0%	0%	0%
Total	-15%	-18%	-14%	-14%	-12%

Table B-2. 2020 First-Stage Results: Energy Supply and Demand

California Total Primary Demands (% Change from Reference)	Case 1	Case 2	Case 3	Case 4	Case 5
Aviation Fuel	-4%	-7%	-5%	-6%	-7%
Biomass	12%	12%	12%	0%	0%
Coal	-20%	-64%	-49%	-60%	-64%
Diesel	-18%	-20%	-12%	-20%	-14%
Ethanol	-7%	-7%	-2%	-7%	-2%
Landfill Gases/Waste	0%	0%	0%	0%	0%
LPG	-2%	-1%	-1%	-3%	-2%
Motor Gasoline	-18%	-18%	-8%	-18%	-9%
Natural Gas	-11%	-30%	-21%	-20%	-25%
Nuclear	0%	0%	0%	0%	0%
Oil, Unspecified	-3%	-6%	-4%	-6%	-7%
Renewables	74%	73%	49%	53%	27%
Total	-6%	-12%	-8%	-10%	-11%

California Generating Capacity by Plant Type (% Change from Reference)	Case 1	Case 2	Case 3	Case 4	Case 5
Gas/Oil	0%	0%	0%	0%	0%
Coal	0%	0%	0%	0%	0%
Nuclear	0%	0%	0%	0%	0%
Hydro	0%	0%	0%	0%	0%
Biomass	31%	31%	31%	0%	0%
Wind	101%	101%	101%	0%	0%
Other Renewable	185%	185%	185%	0%	0%
Total	15%	15%	15%	0%	0%

California Electricity Generation by Primary Fuel (% Change from Reference)	Case 1	Case 2	Case 3	Case 4	Case 5
Gas/Oil	-32%	-70%	-54%	-38%	-52%
Coal	-21%	-98%	-72%	-88%	-95%
Nuclear	0%	0%	0%	0%	0%
Hydro	0%	0%	0%	0%	0%
Biomass	38%	38%	38%	0%	0%
Wind	125%	125%	125%	0%	0%
Other Renewable	100%	100%	100%	0%	0%
Power Imports	-46%	-22%	-29%	-5%	1%
Specified	0%	-42%	-18%	-25%	-37%
Unspecified	-60%	-16%	-33%	1%	12%
Total	-17%	-16%	-15%	-11%	-12%

California Electricity Sales (% Change from Reference)	Case 1	Case 2	Case 3	Case 4	Case 5
Residential	-11%	-11%	-11%	-6%	-7%
Commercial	-18%	-18%	-15%	-9%	-11%
Industrial	-27%	-23%	-25%	-26%	-27%
Transportation	21%	20%	25%	20%	24%
Street/Misc.	0%	0%	0%	0%	0%
Resale	0%	0%	0%	0%	0%
Total	-17%	-16%	-15%	-11%	-12%

Table B-3. 2020 First-Stage Results: Transportation

California Passenger: Average Device Efficiency (% Change from Reference)	Case 1	Case 2	Case 3	Case 4	Case 5
Light Gasoline	2%	2%	1%	2%	1%
Medium Gasoline	2%	2%	1%	2%	1%
Heavy Gasoline	7%	7%	3%	7%	3%
Heavy Diesel	8%	8%	4%	8%	4%
Fleet	4%	4%	2%	4%	2%

California Passenger: Marginal Device Efficiency (% Change from Reference)	**Case 1**	**Case 2**	**Case 3**	**Case 4**	**Case 5**
Light Gasoline	10%	10%	6%	10%	6%
Medium Gasoline	10%	10%	6%	10%	6%
Heavy Gasoline	24%	24%	11%	24%	11%
Heavy Diesel	24%	24%	11%	24%	11%
Fleet	15%	15%	8%	15%	8%

California Distance Traveled (% Change from Reference)	**Case 1**	**Case 2**	**Case 3**	**Case 4**	**Case 5**
Passenger	-4%	-4%	0%	-4%	0%
Freight	2%	0%	0%	0%	-2%

Table B-4. 2020 First-Stage Results: Fuel Prices, Including Permit Value

Fuel Prices, Including Permits (% Change from Reference)	**Case 1**	**Case 2**	**Case 3**	**Case 4**	**Case 5**
Residential					
Electric	0.3%	12.9%	1.8%	14.3%	21.7%
Gas	12.9%	70.3%	34.4%	52.1%	76.4%
Oil	8.7%	51.3%	24.6%	37.8%	55.8%
LPG	3.7%	21.8%	10.5%	16.1%	23.7%
Commercial					
Electric	0.6%	14.5%	0.5%	15.6%	23.5%
Gas	14.4%	80.3%	39.1%	59.4%	87.3%
Oil	9.8%	58.1%	27.9%	42.8%	63.2%
LPG	4.5%	26.4%	12.7%	19.4%	28.7%
Industrial					
Electric	0.7%	15.4%	2.4%	17.9%	29.0%
Gas	11.6%	63.9%	31.1%	47.4%	69.6%
Coal	89.5%	531.5%	254.6%	391.3%	578.3%
Oil	6.9%	40.7%	19.5%	30.0%	44.3%
Transportation					
Light Gasoline	6.4%	38.0%	24.0%	28.0%	47.1%
Light Diesel	3.7%	21.7%	17.9%	16.0%	31.1%

Final Results

Table B-5. 2020 Final Results: Greenhouse Gas Emissions

California Total GHG Pollution (% Change from Reference)	Case 1	Case 2	Case 3	Case 4	Case 5
Residential	-9%	-14%	-10%	-11%	-11%
Commercial	-7%	-10%	4%	1%	1%
Industrial	-15%	-17%	-16%	-17%	-18%
Energy Intensive Industry	-5%	-7%	-5%	-8%	-8%
Other Industry	-24%	-26%	-25%	-26%	-27%
Mining	-5%	-14%	-8%	-17%	-19%
Agriculture	-1%	-2%	-1%	-3%	-3%
Transportation	-12%	-13%	-7%	-13%	-8%
Passenger	-13%	-14%	-6%	-14%	-7%
Freight	-8%	-11%	-8%	-10%	-9%
Power Sector	-32%	-37%	-32%	-16%	-17%
Domestic Power Sector	-14%	-51%	-22%	-33%	-34%
Electricity Imports	-45%	-27%	-38%	-5%	-6%
Waste and Other	0%	0%	0%	0%	0%
Total	-15%	-17%	-13%	-13%	-11%

Table B-6. 2020 Final Results: Energy Supply and Demand

California Total Primary Demands (% Change from Reference)	Case 1	Case 2	Case 3	Case 4	Case 5
Aviation Fuel	-4%	-6%	-5%	-6%	-6%
Biomass	12%	12%	12%	0%	0%
Coal	-12%	-60%	-36%	-52%	-57%
Diesel	-17%	-19%	-12%	-19%	-13%
Ethanol	-7%	-7%	-2%	-7%	-2%
Landfill Gases/Waste	0%	0%	0%	0%	0%
LPG	-3%	-1%	-2%	-3%	-2%
Motor Gasoline	-18%	-18%	-8%	-18%	-8%
Natural Gas	-10%	-26%	-12%	-18%	-19%
Nuclear	0%	0%	0%	0%	0%
Oil, Unspecified	-3%	-5%	-3%	-6%	-6%
Renewables	74%	73%	49%	53%	28%
Total	-6%	-11%	-5%	-10%	-9%

California Generating Capacity by Plant Type (% Change from Reference)	Case 1	Case 2	Case 3	Case 4	Case 5
Gas/Oil	0%	0%	0%	0%	0%
Coal	0%	0%	0%	0%	0%
Nuclear	0%	0%	0%	0%	0%
Hydro	0%	0%	0%	0%	0%
Biomass	31%	31%	31%	0%	0%
Wind	101%	101%	101%	0%	0%
Other Renewable	185%	185%	185%	0%	0%
Total	15%	15%	15%	0%	0%

California Electricity Generation by Primary Fuel (% Change from Reference)	Case 1	Case 2	Case 3	Case 4	Case 5
Gas/Oil	-30%	-62%	-36%	-36%	-37%
Coal	-7%	-91%	-51%	-73%	-83%
Nuclear	0%	0%	0%	0%	0%
Hydro	0%	0%	0%	0%	0%
Biomass	38%	38%	38%	0%	0%
Wind	125%	125%	125%	0%	0%
Other Renewable	100%	100%	100%	0%	0%
Power Imports	-47%	-26%	-40%	-6%	-5%
Specified	0%	-27%	0%	-19%	-24%
Unspecified	-62%	-25%	-53%	-2%	0%
Total	-17%	-16%	-16%	-11%	-11%

California Electricity Sales (% Change from Reference)	Case 1	Case 2	Case 3	Case 4	Case 5
Residential	-11%	-10%	-11%	-6%	-6%
Commercial	-18%	-18%	-15%	-9%	-9%
Industrial	-27%	-23%	-27%	-27%	-27%
Transportation	21%	20%	25%	20%	25%
Street/Misc.	0%	0%	0%	0%	0%
Resale	0%	0%	0%	0%	0%
Total	-17%	-16%	-16%	-11%	-11%

Table B-7. 2020 Final Results: Transportation

California Passenger, Average Device Efficiency (% Change from Reference)	Case 1	Case 2	Case 3	Case 4	Case 5
Light Gasoline	2%	2%	1%	2%	1%
Medium Gasoline	2%	2%	1%	2%	1%
Heavy Gasoline	7%	7%	3%	7%	3%
Heavy Diesel	8%	8%	4%	8%	4%
Fleet	4%	4%	2%	4%	2%

California Passenger, Marginal Device Efficiency (% Change from Reference)	Case 1	Case 2	Case 3	Case 4	Case 5
Light Gasoline	10%	10%	6%	10%	6%
Medium Gasoline	10%	10%	6%	10%	6%
Heavy Gasoline	24%	24%	11%	24%	11%
Heavy Diesel	24%	24%	11%	24%	11%
Fleet	15%	15%	8%	15%	8%

California Distance Traveled (% Change from Reference)	Case 1	Case 2	Case 3	Case 4	Case 5
Passenger	-4%	-4%	0%	-4%	0%
Freight	2%	0%	1%	1%	-1%

Table B-8. Final Results: Fuel Prices, Including Permit Value

Fuel Prices, Including Permits (% Change from Reference)	Case 1	Case 2	Case 3	Case 4	Case 5
Residential					
Electric	0%	4%	2%	11%	13%
Gas	11%	50%	20%	42%	49%
Oil	7%	36%	14%	30%	36%
LPG	3%	15%	6%	13%	15%
Commercial					
Electric	0%	3%	3%	12%	15%
Gas	12%	57%	22%	48%	56%
Oil	8%	41%	16%	34%	40%
LPG	4%	19%	7%	16%	18%
Industrial					
Electric	0%	5%	3%	14%	17%
Gas	10%	46%	18%	38%	45%
Coal	75%	377%	143%	312%	370%
Oil	6%	29%	11%	24%	28%
Transportation					
Light Gasoline	5.4%	27%	16%	22%	32%
Light Diesel	3%	15%	13%	13%	23%

Appendix C. Criteria-Pollutant Valuation Spreadsheets

Spreadsheets used to calculate the potential criteria pollutant reductions in Section 9 based on Energy 2020 modeling outputs are available at:
http://www.arb.ca.gov/cc/scopingplan/economics-sp/updated-analysis/criteria_pollutant_appendix.pdf

Appendix D. EAAC Economic Impacts Subcommittee Report

The report of the Economic Impacts Subcommittee of the Economic and Allocation Advisory Committee (EAAC) on this Updated AB 32 Scoping Plan Analysis is available at:
http://www.arb.ca.gov/cc/scopingplan/economics-sp/updated-analysis/EAAC_appendix.pdf