DRAFT

CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY
AIR RESOURCES BOARD

STAFF PROPOSAL REGARDING THE MAXIMUM FEASIBLE AND COST-EFFECTIVE REDUCTION OF GREENHOUSE GAS EMISSIONS FROM MOTOR VEHICLES

This report has been reviewed by the staff of the California Air Resources Board and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Air Resources Board, nor does the mention of trade names or commercial products constitute endorsement or recommendation for use.

June 14, 2004

EXECUTIVE SUMMARY

California has a long history of environmental leadership. This tradition of environmental leadership continues to this day. In 2002, recognizing that global warming would impose compelling and extraordinary impacts on California, the legislature adopted and the Governor signed AB 1493. That bill directs the California Air Resources Board (Board) to adopt regulations to achieve the maximum feasible and cost-effective reduction of greenhouse gas emissions from motor vehicles. This Draft Initial Statement of Reasons presents a preview of the staff proposal that will be considered by the Board at its September 2004 public hearing.

This document describes the conceptual outlines of the staff proposal, including the specific details of the proposed approach, its rationale, and an assessment of its environmental and economic consequences. The reader should bear in mind that this document is a draft. The various elements of the staff proposal as well as the methodology used to evaluate its environmental and economic impacts are all subject to change, due to work in progress as well as comments received from the public.

This draft does not include proposed regulatory language. Staff is in the process of developing specific regulatory language and will release a draft for public comment prior to the September hearing.

Climate Change Overview

The earth's climate is changing because human activities are altering the chemical composition of the atmosphere through the buildup of greenhouse gases (GHGs), primarily carbon dioxide (CO_2), methane, nitrous oxide, and hydrofluorocarbons.

The heat-trapping property of GHGs is undisputed. Although there is uncertainty about exactly how and when the earth's climate will respond to enhanced concentrations of GHGs, observations indicate that detectable changes are under way. There most likely are and will continue to be changes in temperature and precipitation, soil moisture, and sea level, all of which could have significant adverse effects on many ecological systems, as well as on human health and the economy.

California Actions to Address Climate Change

The State of California has traditionally been a pioneer in efforts to reduce air pollution, dating back to 1963 when the California New Motor Vehicle Pollution Control Board adopted the nation's first motor vehicle emission standards. California likewise has a long history of actions undertaken in response to the threat posed by climate change. Beginning with 1988 legislation that directed the

California Energy Commission, in consultation with the Air Resources Board and other agencies, to study the implications of global warming on California's environment, economy, and water supply, and continuing on over the years through Governor Schwarzenegger's April 2004 Executive Order outlining his vision for the California Hydrogen Highway Network, California state government has consistently recognized the necessity for state action on climate change to protect California's interests. At the Air Resources Board, attention to the mechanisms and effects of climate change dates back to 1989, when staff first updated the Board on the emerging science.

Maximum Feasible and Cost-Effective Technologies

A key part of the staff's technical work is an assessment of technologies and fuels that can contribute to a reduction of climate change emissions in passenger vehicles from the 2009 model-year and beyond. The staff technology assessment reviews baseline vehicle attributes and their contribution to atmospheric climate change emissions, and evaluates technologies that have the potential to decrease these emissions. The technologies explored are currently available on vehicles in various forms, or have been demonstrated by auto companies and/or vehicle component suppliers in at least prototype form. The report then examines the lifetime cost of these technologies to vehicle owner-operators. This approach is consistent with the AB 1493 directive to require climate change reduction technologies that are economical to an owner or operator of a vehicle, taking into account the full life-cycle costs of a vehicle.

There are near-term, or off-the-shelf, technology packages in each of the vehicle classes evaluated (small and large car, minivan, small and large truck) that results in a reduction of CO_2 emissions of at least 15-20% from baseline 2009 values. Several technologies stood out as providing significant reductions in emissions at favorable costs. These include discrete variable valve lift, dual cam phasing, turbocharging with engine downsizing, automated manual transmissions, and camless valve actuation. Potential improvements in the air conditioning system include an improved variable displacement compressor, reduced leakage systems, and the use of an alternative refrigerant (HFC-152a). Packages containing these and other technologies provided substantial emission reductions at prices that ranged from a saving to several hundreds of dollars. Nearly all technology combinations modeled provided reductions in lifetime operating costs that exceeded the retail price of the technology.

Climate Change Emission Standards

Vehicle climate change emissions comprise four main elements: (1) CO_2, CH_4 and N_2O emissions resulting directly from operation of the vehicle, (2) CO_2 emissions resulting from operating the air conditioning system (indirect AC emissions), (3) refrigerant emissions from the air conditioning system due to either leakage, losses during recharging, or release from scrappage of the vehicle at end of life (direct AC emissions, and (4) upstream emissions associated with the production of the fuel used by the vehicle. The climate change emission standard incorporates all of these elements.

Staff elected to incorporate the CO_2 equivalent emission standards into the current LEV program along with the other light and medium-duty automotive emission standards. Accordingly, there would be a CO_2 equivalent fleet average emission requirement for the passenger car/light-duty truck 1 (PC/LDT1) category and another for the light-duty truck 2 (LDT2) category, just as there are fleet average emission requirements for criteria pollutants for both categories of vehicles in the LEV program.

Determination of the specific climate change emission standards for each category involved several steps. First, the maximum feasible emission reductions were modeled for five vehicle types (small and large car, minivan, small and large truck) with various technology packages. These technology packages were then categorized with respect to their technology readiness (i.e. near-, mid-, or long-term). Secondly, manufacturer specific data was collected for the California fleet in order to evaluate individual manufacturer product mix. The emission standards for each category were then determined based on the manufacturer with the highest average weight vehicles (as opposed to the average of all the manufacturers) to ensure that all manufacturers can comply with the standards.

Staff proposes setting near-term standards, phased in from 2009 through 2011, and mid-term standards, phased in from 2012 through 2014. The proposed standards, expressed in terms of CO2 equivalent grams per mile, are as follows:

Tier	Phase-in	Year	CO_2-equivalent emission standard by vehicle category (g/mi)	
			PC/LDT1	LDT2
Near-term	30%	2009	315	422
	60%	2010	284	385
	100%	2011	242	335
Mid-term	30%	2012	233	328
	60%	2013	223	321
	100%	2014	211	311

Staff estimates that the average fleetwide incremental cost of control to meet these standards, taking into account the phase-in of the standard and the specific starting point of the individual manufacturers, will be as follows:

Year			All major 6
2009	Near-term phase-in	PC/LDT1	$25
		LDT2	$69
2010		PC/LDT1	$96
		LDT2	$176
2011		PC/LDT1	$241
		LDT2	$326
2012	Mid-term phase-in	PC/LDT1	$294
		LDT2	$421
2013		PC/LDT1	$382
		LDT2	$584
2014		PC/LDT1	$539
		LDT2	$851

Thus when fully phased in the near term standards will result in an estimated average cost increase of $241 for PC/LDT1, and $326 for LDT2. The fully phased in mid term standards will result in an estimated average cost increase of $539 for PC/LDT1 and $851 for LDT2. The staff analysis concludes, however, that these increased costs will be more than offset by operating cost savings over the lifetime of the vehicle.

Looking at the cost of the technology on a per vehicle basis, staff estimates that applying the maximum feasible near term technology to an individual vehicle would cost an average of $328 for the PC/LDT1 category and $363 for the LDT2 category, compared to the 2009 baseline vehicle. The estimated average cost to apply the maximum feasible mid term technology is $1047 for PC/LDT1 and $1210 for LDT2. These costs are higher than the fleet average shown above because not all vehicles will need to be controlled to the maximum level. Rather, the proposed standard is set at a level that is feasible for the manufacturer in the worst starting position. Therefore the average cost across the fleet will be less than the maximum cost of the technology on a per vehicle basis.

The staff analysis concludes that these standards, when applied to the fleet of the “major six” automakers (GM, Ford, DaimlerChrysler, Toyota, Honda, Nissan), would result in the following emission reductions by year. The reductions needed by individual automakers will vary depending on their initial starting position.

Year			All major 6
2009	Near-term phase-in	PC/LDT1	-2.3%
		LDT2	-5.1%
2010		PC/LDT1	-8.8%
		LDT2	-13.1%
2011		PC/LDT1	-22.2%
		LDT2	-24.3%
2012	Mid-term phase-in	PC/LDT1	-25.3%
		LDT2	-25.9%
2013		PC/LDT1	-28.3%
		LDT2	-27.6%
2014		PC/LDT1	-32.3%
		LDT2	-29.8%

The proposed standards also address upstream emissions (emissions due to the production and transportation of the fuel used by the vehicle). Staff proposes to use the upstream emission levels for conventional fuel vehicles as a yardstick against which to compare the relative emissions of alternative fuel vehicles. This approach simplifies the regulatory treatment of gasoline vehicles, while at the same time allowing for appropriate consideration of differences in upstream emissions from alternative fuel vehicles.

AB 1493 directs that emission reduction credits be granted for any reductions in greenhouse gas emissions achieved prior to the operative date of the regulations. ARB staff proposes that the baseline against which manufacturer emissions are measured should be the fully phased in near term standards, and that credit for early emission reductions should be available for model years 2000 through 2008. Thus under the staff early credit proposal, manufacturer fleet average emissions for model years 2000 through 2008 would be compared to the near term standards on a cumulative basis. Manufacturers that had cumulative emissions below the near term standards would earn credit.

AB 1493 also requires that the regulations "provide flexibility, to the maximum extent feasible consistent with this section, in the means by which a person subject to the regulations ... may comply with the regulations. That flexibility shall include, but is not limited to, authorization for a person to use alternative methods of compliance with the regulations." Thus the use of alternative compliance strategies must not undercut the primary purpose of the regulation, which is to achieve greenhouse gas reductions from motor vehicles. Accordingly, the ARB's alternative compliance program will be limited to the vehicles that are regulated through AB 1493, and their fuels. This is to ensure that the program does not dilute the technology-forcing nature of the regulation, since the goal is to reduce emissions from the vehicles themselves. The major features of the staff proposal are:

- Projects must be located in California to be eligible as alternative methods of compliance.

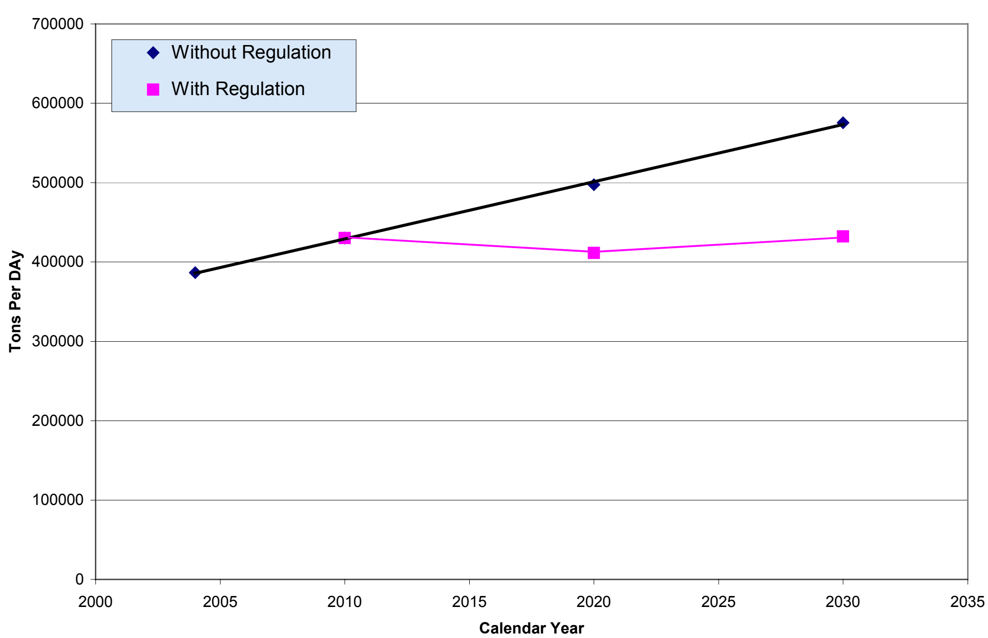
- Only companies regulated by AB 1493 (automakers) will be permitted to apply for alternative compliance credits.
- Only those vehicles regulated under AB 1493 are eligible for alternative compliance credits. This includes model year 2009 and later passenger vehicles and light-duty trucks and other vehicles used for noncommercial personal transportation in California.
- Staff proposes that eligible projects be limited to those that achieve greenhouse gas reductions through documented increased use of alternative fuels in eligible vehicles.

Environmental Impacts

Taking into account the penetration of 2009 and later vehicles meeting the new standard into the fleet, staff estimates that the proposed regulation will reduce climate change emissions by an estimated 85,900 CO_2 equivalent tons per day statewide in 2020 and by 143,300 CO_2 equivalent tons per day in 2030. This translates into a 17% overall reduction in climate changes emissions from the light duty fleet in 2020 and a 25% overall reduction in 2030.

Staff estimates that baseline emissions today (2004) are 386,600 CO_2 equivalent tons per day. With the regulation 2020 emissions will be lower than today's, and 2030 will be approximately the same, as shown below.

Motor Vehicle Greenhouse Gas Emissions



Cost Effectiveness

Typically, emission control regulations impose a cost. Cost effectiveness is a measure of the cost imposed per ton of reduction achieved, and thus is a useful tool to compare various possible approaches. In this instance, however, AB 1493 requires that the regulations be economical to the consumer over the life cycle of the vehicle. Consistent with this direction, the technology packages that provide the basis for the standard result in operating cost savings that exceed the initial capital cost, resulting in a net savings to the consumer over the lifecycle of the vehicle. This translates to a "negative" cost effectiveness value (there is a cost savings per ton reduced). Thus staff estimates that the cost effectiveness of the staff proposal, in terms of dollars per ton of CO_2 equivalent emissions reduced, is -$143 in 2020 and -$136 in 2020.

Economic Impacts

The climate change regulation may impact several sectors of the economy. The steps that manufacturers will need to take to comply with the regulatory standards are expected to lead to price increases for new vehicles. Many of the technological options that manufacturers choose to comply with the regulation are also expected to reduce operating costs. These two responses to the regulation have combined positive and negative impacts on California businesses and consumers. The vehicle price increase will be borne by purchasers and may negatively affect businesses. However, the operating cost savings from the use of vehicles that comply with the regulation will positively impact consumers and most businesses. Based on the staff analysis, the net effect of the regulation on the economy is expected to be small but positive. The proposed climate change regulation is not expected to cause any significant adverse impact on the State's economy. It is very likely that savings from reduced vehicle operating costs would end up as expenditures for other goods and services. These expenditures would flow through the economy, causing expansion or creation of new businesses in several sectors. Staff's economic analysis shows that as the expenditures occur, jobs and personal income increase. There will not be any impacts on the ability of California business to compete with businesses in other states. State and local agencies will not be adversely impacted and are likely to realize a net reduction in their cost of fleet operations.

Impacts on Low Income and Minority Communities

The ARB has made the achievement of environmental justice an integral part of its activities. The Board approved Environmental Justice Policies and Actions (Policies) on December 13, 2001. These Policies establish a framework for incorporating environmental justice into the ARB's programs consistent with the directives of State law.

As the ARB developed the climate change regulations, staff worked closely with community leaders involved with environmental justice as well as with environmental and public health organizations to maintain an ongoing dialogue and thus successfully implement the ARB's environmental justice policies.

Staff has undertaken an evaluation to investigate if low-income and minority communities (communities) may be impacted disproportionately by the climate change regulation. The primary direct mechanism identified was the potential effect on used car prices. Because the vehicle price increases caused by the proposed regulation may, over time, increase the price of used vehicles that low-income households tend to purchase, the staff focused on analyzing the potential impacts of the vehicle price increase on low-income purchasers of used vehicles. The analysis showed that the expected impacts of any price increase are minor, and would be more than outweighed by a reduction in operating cost. Thus the proposed regulation should not have a significant impact on low-income purchasers of used vehicles.

Staff has not identified any mechanisms by which the climate change regulation would result in disproportionate impact on low income or minority communities

Other Considerations

Staff also is investigating several approaches that supplement the standard economic analysis. The methods used rely on recent tools and studies that provide additional insight into the potential impacts of the regulation. Using those tools and studies to investigate possible secondary impacts of the regulation, this report presents additional perspectives on the potential impact of the proposed regulation on fleet mix, emissions, the State’s economy, small businesses, and low-income households. The methods discussed are in the early stages of development relative to the standard analysis. As such, it is expected that these methods will be further refined.

The economic impact analysis is based on the staff assessment that the reduced vehicle operating cost resulting from the regulation will be sufficiently attractive to new car buyers to compensate for the vehicle price increase, which results in vehicle sales that are unchanged from the levels that would have been the case without the regulation. Staff also, however, assessed what the consequences would be if one assumes that the changes in vehicle price and other attributes do affect sales. Staff analyzed the potential effect of price and operating cost changes on sales, fleet size, and fleet age using a consumer choice model developed by University of California, Davis. The results show that the net result of increased new vehicle prices and lower operating costs is a tendency to increase sales in the near term, and slightly decrease sales in the longer term as the more stringent second step of the regulation is fully phased in.

Staff also evaluated potential adverse environmental impacts associated with increased VMT due to lower operating costs. Our analysis indicates that the benefits of reduced climate change emission from the regulation will not be affected significantly by any increase in driving attributable to lower operating cost.

The staff assessment concludes that communities with low income and minority households are expected to have increased jobs as a result of the regulation. Future employment growth in some sectors may be reduced, but an increase in overall economic activity because of increased purchasing power due to lowered operating costs of vehicles would be expected to create a sufficient number of jobs to more than offset any losses.

Staff will continue to refine these approaches and will consider public comment received before issuing the final staff report.

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1 INTRODUCTION

California has a long history of environmental leadership. Motivated by the stunning natural beauty of our coastline, inland valleys, forests and mountains, as well as by the public health and environmental challenges brought about increasing levels of pollution, California's citizens have repeatedly called for and supported measures to protect California's environmental heritage. Our political leadership and governmental institutions have responded with a variety of initiatives that restore, protect and enhance the environment, to ensure public health, environmental quality and economic vitality. Often these California initiatives have provided a benchmark and template for further action both nationally and internationally.

This tradition of environmental leadership continues to this day. In 2002, recognizing that global warming would impose compelling and extraordinary impacts on California, the legislature adopted and the Governor signed Assembly Bill (AB) 1493. That bill directs the California Air Resources Board (Board) to adopt regulations to achieve the maximum feasible and cost-effective reduction of greenhouse gas emissions from motor vehicles. This Draft Initial Statement of Reasons presents a preview of the staff proposal that will be considered by the Board at its September 2004 public hearing.

1.1 Status of This Document

Staff typically does not provide a draft report of its staff analysis in advance of the release of an Initial Statement of Reasons, 45 days prior to the Board's public hearing. In this case, however, due to the complexity and controversy of the issue and the investigation of several new tools and approaches, staff thought that the rule development process would be best served by giving interested parties an early opportunity to look at the full range of analyses being undertaken by staff and how they will be integrated into a final staff proposal.

This document thus describes the complete staff proposal, including the specific details of the proposed approach, its rationale, and an assessment of its environmental and economic consequences. The reader should bear in mind that this document is a draft. The various elements of the staff proposal as well as the methodology used to evaluate its environmental and economic impacts are all subject to change, due to work in progress as well as comments received from the public.

In addition, please note that different portions of the analysis may use slightly different assumptions. This reflects the fact the staff analysis continues to be refined on an ongoing basis. As a result, the inputs provided to the various elements of the economic and emission modeling may differ slightly depending on when the work was undertaken. These variations will be reconciled and updated analyses will be prepared in all areas as staff prepares for the release of the final staff proposal on August 6, 2004.

This document does not include proposed regulatory language. Staff is in the process of developing specific regulatory language and will release a draft for public comment prior to the release of the final staff report.

1.2 Organization of the Report

The report begins (Section 2) with an overview of the scientific evidence regarding climate change and its potential effects in California. Section 3 outlines the long history of previous actions that California has taken to understand and address the threat of climate change. Section 0 briefly summarizes the proposed regulation. Section 5 presents the results of staff's detailed technology assessment, which identifies the technologies available to achieve the maximum feasible and cost-effective reduction. Section 6 describes how the vehicle-level reductions outlined in the technology assessment were translated into a standard that can be applied at the manufacturer fleet level. This section also discusses staff's proposed approach towards alternative compliance and credits for early action. Section 7 summarizes the environmental impact of the proposed regulation, and Section 8 provides staff's estimate of its cost-effectiveness. Section 9 presents staff's evaluation of the impact of the regulation on California's businesses and economy. Section 10 looks more specifically at potential impacts on minority and low-income communities. Section 11 discusses the status of staff work to evaluate several other considerations, such as the possible effect of changes in vehicle attributes on vehicle purchase or vehicle miles traveled.

2 CLIMATE CHANGE OVERVIEW

The earth's climate is changing because human activities are altering the chemical composition of the atmosphere through the buildup of greenhouse gases (GHGs), primarily carbon dioxide (CO_2), methane, nitrous oxide, and hydrofluorocarbons. Climate research scientists are also suggesting that climate change in recent decades may have been mainly caused by non-CO_2 greenhouse gases, particularly tropospheric ozone, methane, hydrofluorocarbons, and black carbon particles. Thus it appears that an effective response to the threat of climate change ultimately will need to address both CO2 and other greenhouse gases.

The heat-trapping property of GHGs is undisputed. Although there is uncertainty about exactly how and when the earth's climate will respond to increasing concentrations of GHGs, observations indicate that detectable changes are under way. There most likely are and will continue to be changes in temperature and precipitation, soil moisture, and sea level, all of which could have significant adverse effects on many ecological systems, as well as on human health and the economy.

This chapter first presents an overview of climate change (Section 2.1) as well as a brief discussion of topics that convey the understanding of scientists on related issues. The chapter then discusses climate change pollutants (Section 2.2), concepts and definitions associated with climate change (Section 2.3), pollutants addressed under the proposed regulation (Section 2.4), indicators of climate change in California (Section 2.5), and potential impacts of climate change on California (Section 2.6). The chapter concludes with a brief discussion of abrupt climate change (Section 2.7).

2.1 Climate Change Overview

Climate change is a shift in the "average weather" that a given region experiences. This is measured by changes in the features that we associate with weather, such as temperature, wind patterns, precipitation, and storms. Global climate change means change in the climate of the Earth as a whole. Global climate change can occur naturally; an ice age is an example of naturally occurring climate change. The Earth's natural climate has always been, and still is, constantly changing. The climate change we are seeing today, however, differs from previous climate change in both its rate and its magnitude.

The temperature on Earth is regulated by a system known as the "greenhouse effect". Naturally occurring GHGs, primarily water vapor, carbon dioxide, methane, and nitrous oxide, absorb heat radiated from the Earth's surface. As the atmosphere warms, it in turn radiates heat back to the surface, to create what is commonly called the "greenhouse effect". Without the effect of these naturally occurring gases, the average temperature on the Earth would be –18 °C (-0.4 ^{o}F), instead of the current average of 15 °C (59 ^{o}F). Life as we know it would be impossible.

Human activities are exerting a major and growing influence on some of the key factors that govern climate by changing the composition of the atmosphere and by modifying the land surface. The human impact on these factors is clear. The concentration of CO_2 in the atmosphere has risen about 30 percent since the late 1800s (NAST, 2001). This increase has resulted from the burning of coal, oil, and natural gas, and the destruction of forests around the world to provide space for agriculture and other human activities. Rising concentrations of CO_2 and other GHGs are intensifying the Earth's natural greenhouse effect. Global projections of population growth and assumptions about energy use indicate that the CO_2 concentration will continue to rise, likely reaching between two and three times its late-19th-century level by 2100 (Figure 2-1, Source: NAST, 2001).

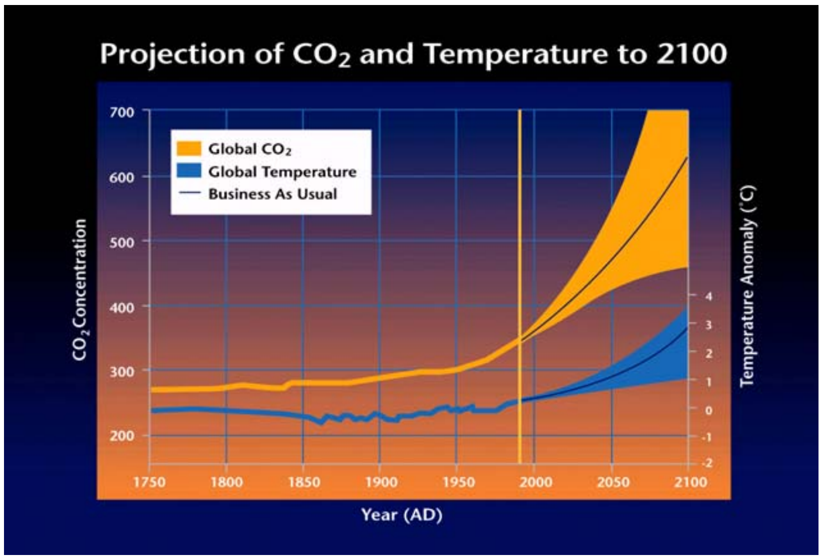


Figure 2-1. **Projection of Carbon Dioxide and Temperature to 2100 (Source: NAST, 2001).** Note: Temperature anomaly is the projected changes in temperature due to anthropogenic effects.

The Third Assessment Report of the International Panel on Climate Change (IPCC, 2001) and the National Research Council of the National Academies (NRC, 2001) conclude that the global climate is changing at a rate unmatched in the past one thousand years. The IPCC Assessment cites new and stronger evidence that most of the global warming observed over the last fifty years is attributable to human activities and that anthropogenic climate change will persist for many centuries. However, while the NRC Report generally agrees with the IPCC Assessment, it does not rule out that some significant part of these changes is also a reflection of natural variability. The observed changes over the last fifty years and those projected for the future include higher maximum air temperatures, more hot days, fewer cold days, greater extremes of drying and heavy rainfall, and sea level rise (IPCC, 2001).

Many sources of data indicate that the Earth is warming faster than at any time in the previous 1,000 years. The global mean surface temperature has increased by 1.1 ^{o}F since the 19th century (IPCC, 2001). The 10 warmest years of the last century all occurred within the last 15 years. For example, 2002 and 2003 are tied as the second warmest years on record, according to a year-end review of climate data by the National

Oceanic and Atmospheric Administration. The NAST (2001) report indicates that the warming in the 21st century will be significantly larger than in the 20th century. Scenarios examined in that Assessment, which assume no major interventions to reduce continued growth of world GHG emissions, indicate that temperatures in the US will rise by about 5-9°F (3-5°C) on average in the next 100 years, which is more than the projected *global* increase. This rise is very likely to be associated with more extreme precipitation and faster evaporation of water, leading to greater frequency of both very wet and very dry conditions. Warming or cooling of the earth will impact public health, air quality, water resources, agriculture, ecological resources, and California's economy. As a result, global climate change issues are receiving increasing national and international attention from governments, business and industry, the research community, environmental interests, and the public (IPCC, 2001).

2.2 Climate Change Pollutants

Naturally occurring GHGs include water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and ozone (O_3). Several classes of halogenated substances that contain fluorine, chlorine, or bromine are also GHGs, but they are, for the most part, solely a product of industrial activities. Chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) are halocarbons that contain chlorine, while halocarbons that contain bromine are referred to as bromofluorocarbons (i.e., halons). Because CFCs, HCFCs, and halons are substances, which deplete stratospheric ozone, they are covered under the Montreal Protocol on Substances that Deplete the Ozone Layer. The United Nations Framework Convention on Climate Change (UNFCCC) defers to this earlier international treaty; consequently these gases are not included in national GHG inventories. Some other fluorine containing halogenated substances—hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6)—do not deplete stratospheric ozone but are potent GHGs. These latter substances are addressed by the UNFCCC and accounted for in State and national GHG inventories. In addition, there are a number of other pollutants such as carbon monoxide, nitrogen oxides, and aerosols that have direct or indirect effects on terrestrial or solar radiation absorption. They are discussed later in this section.

In September 2000, the California Legislature passed Senate Bill 1771 (SB1771, 2000), requiring the California Energy Commission (CEC), in consultation with other state agencies, to update California's inventory of GHG emissions in January 2002 and every five years thereafter. The CEC (2002) report includes emissions of six GHGs: CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6. Although the first three gases are also emitted from natural sources, the CEC report primarily focuses on emissions due to human activities (anthropogenic emissions). The report concluded that there were major uncertainties associated with the inventory of GHG emissions, and recommended that future GHG inventories could be improved by: (1) incorporating improved data; (2) updating emissions estimates; and, (3) presenting a discussion of the uncertainty in emissions estimates from key sources.

Figure 2-2 shows the distribution of California's emissions by GHG.

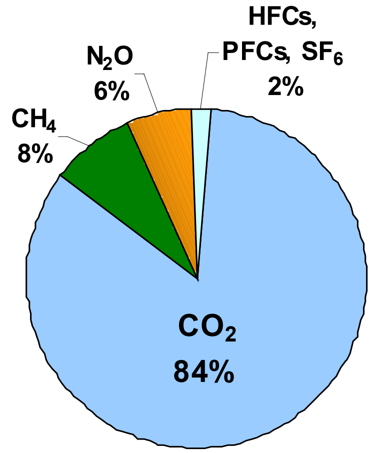


Figure 2-2. Distribution of California greenhouse gas emissions by gas in 1999, expressed in terms of CO_2 equivalent (adapted from CEC, 2002).

Individual climate change species are briefly discussed in the following sections. Detailed discussions of GHG emissions are given in the CEC (2002) report.

2.2.A Carbon Dioxide (CO_2)

In the atmosphere, carbon generally exists in its oxidized form, as CO_2. Increased CO_2 concentrations in the atmosphere have been primarily linked to increased combustion of fossil fuels.

Fossil fuel combustion accounted for 98 percent of gross California CO_2 emissions. California's total CO_2 emissions from fossil fuel combustion in 1999 were 356 million metric tons of CO_2 equivalent ($MMTCO_2$ Eq), which accounts for approximately 7 percent of the U.S. emissions from this source. The transportation sector accounted for the largest portion of emissions, averaging 59 percent of the total CO_2 emissions from fossil fuel combustion in California for the period 1990-1999. Within the transportation sector, gasoline consumption accounted for the greatest portion of emissions. Figure 2-3 presents the contribution of each sector to CO_2 emissions from fossil fuel combustion in 1999.

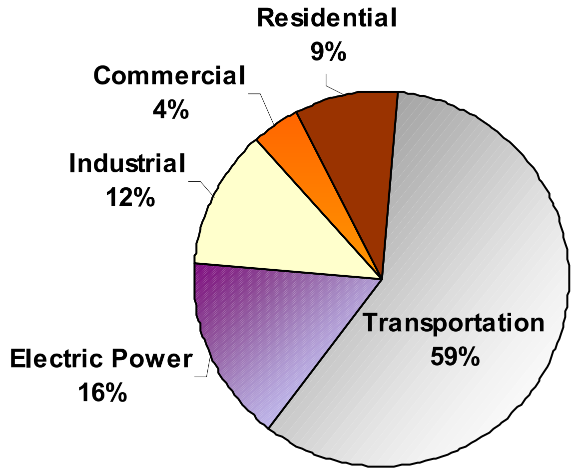


Figure 2-3. **CO2 Emissions from the Combustion of Fossil Fuels by Sector for 1999 (adapted from CEC, 2002).**

The CEC (2002) report indicates that CO_2 emissions from fossil fuel combustion tracked economic and population growth in the early 1970s. Emissions remained flat through 1986, and then started to grow through the end of the decade. Economic and population growth both outpaced the growth in emissions during this period.

2.2.B Methane (CH_4)

Methane accounted for approximately 8 percent of gross 1999 GHG emissions in California, in terms of equivalent CO_2 emissions. Methane is produced during anaerobic decomposition of organic matter in biological systems. Decomposition occurring in landfills accounts for the majority of anthropogenic CH_4 emissions in California and in the United States as a whole. Agricultural processes such as enteric fermentation, manure management, and rice cultivation are also significant sources of CH_4 in California.

While it is well established that exhaust from vehicles using hydrocarbon fuels contains CH_4, there are few published data concerning the magnitude of CH_4 emissions from the modern, and likely future, vehicle fleet. Metz (2001) concluded that the anthropogenic contribution of road transport to the global CH_4 budget is less than 0.5 percent. Three-way catalyst emission control systems installed on all modern vehicles are effective in removing CH_4 from vehicle exhaust (Nam et al., 2004). It seems highly likely that the future will bring increasingly stringent regulations concerning the effectiveness and durability of vehicle emission control systems. Hence, it is likely that emissions of CH_4 from gasoline- and diesel-powered vehicles will be reduced from their already low values. A possible exception to this trend would be the increased use of compressed natural gas (CNG) powered vehicles. However, based on the emission measurements reported in Nam et al., (2004) even assuming a substantial fraction of CNG-powered vehicles, the tailpipe CH_4 emissions from CNG vehicles can be controlled such that they are likely to have negligible environmental impact. While refueling losses would be another source of CH_4 emissions from CNG vehicles, safety considerations would mandate effective control of such emissions. It seems reasonable to conclude that the environmental impact of CH_4 emissions from vehicles is negligible and is likely to remain so for the foreseeable future.

2.2.C Nitrous Oxide (N_2O)

Nitrous oxide emissions accounted for nearly 6 percent of GHG emissions (CO_2 equivalent) in California in 1999. The primary sources of anthropogenic N_2O emissions in California are agricultural soil management and fossil fuel combustion in mobile sources. Nitrous oxide is a product of the reaction that occurs between nitrogen and oxygen during fuel combustion. Both mobile and stationary combustion emit N_2O, and the quantity emitted varies according to the type of fuel, technology, and pollution control device used, as well as maintenance and operating practices. For example, some types of catalytic converters installed to reduce motor vehicle pollution can promote the formation of N_2O. USEPA (2003) estimates suggest that, in 2001, N_2O emissions from mobile combustion were 13 percent of U.S. N_2O emissions, while stationary combustion accounted for 3 percent. From 1990 to 2001, combined N_2O emissions from stationary and mobile combustion increased by 9 percent, primarily due to increased rates of N_2O generation from on road vehicles.

Behrentz et al., (2004) conducted a pilot study to measure exhaust emissions of N_2O. Their results indicate that the average N_2O emissions factor for the 37 vehicles tested was 20 ± 4 mg/km, significantly lower than previous reports of average values of ~35 mg/km (Dasch, 1992; Ballantyne et al., 1994; Barton and Simpson, 1994; Michaels et al., 1998). The difference between the previously reported emission factors and those presented in the pilot study could be related to the introduction of new technologies on some of the vehicles tested since they play a significant role in the amount of N_2O emitted by the vehicles. The differences could also be related to difference in the vehicle fleets studied. This issue will be resolved with ARB's future analysis of a much larger database of N_2O emissions. However, It is generally expected that N_2O emissions from light-duty vehicles will continue this pattern of decreasing emissions due to increasingly stringent NOx control technologies.

2.2.D Hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6)

HFCs are primarily used as substitutes for ozone-depleting substances (ODS) regulated under the Montreal Protocol. PFCs and SF_6 are generally emitted from various industrial processes including aluminum smelting, semiconductor manufacturing, electric power transmission and distribution, and magnesium casting. There is no aluminum or magnesium production in California; however, the rapid growth in the semiconductor industry leads to greater use of PFCs.

For vehicular HFC emissions, four emission sources, all related to air conditioning, should be considered: emissions leaking from the hoses, seals and system components of vehicle air conditioning system, and emissions that are released when the air conditioning system is opened for servicing. HFC emissions can also occur when the vehicle is scrapped at the end of its useful life or due to sudden releases (e.g., traffic accident refrigerant releases). R-134a, also known as HFC-134a is presently the vehicle refrigerant of choice among vehicle manufacturers. The assessment of mobile air conditioning system technology and associated cost analysis are included in later chapters.

2.2.E Other Radiatively Important Gases

In addition, there are a number of man-made pollutants, emitted primarily as byproducts of combustion (both of fossil fuels and of biomass), that have indirect effects on terrestrial or solar radiation absorption by influencing the formation or destruction of other GHGs. These include carbon monoxide (CO), nitrogen oxides (NO_X), non-methane volatile organic compounds (NMVOCs), and sulfur dioxide. These compounds, regulated in the United States and California pursuant to the Clean Air Act, are often referred to as “criteria pollutants.” The criteria pollutants are reactive compounds, and they tend to remain in the atmosphere for a much shorter time than the previously discussed gases. As shown in Table 2.3-1 below, CO_2, N_2O, CH_4, and HFC-134a have atmospheric lifetimes ranging from a century to ten years. Reactive compounds typically last only hours or days. The sequence of reactions that removes CO, NO_X, and NMVOCs from the atmosphere, however, tends to promote the formation of ozone. Ozone in the stratosphere protects life on Earth from ultraviolet radiation, but ozone at ground level causes respiratory distress in people and animals and, also, is a potent (though short-lived) GHG. The lifetime of criteria pollutants in the atmosphere varies from weeks to months, which imparts an element of uncertainty in estimating tropospheric ozone radiative forcing effects.

It is generally difficult to make an accurate determination of the contribution of ozone precursors to global warming. The reactions that produce ozone are strongly affected by the relative concentrations of various pollutants, the ambient temperature, and local weather conditions. California’s unique emissions and fuel standards for cars, trucks, buses, motorcycles, and other motor vehicles have dramatically reduced criteria pollutant emissions, as have controls on non-automotive pollution sources that are administered by the State’s 35 local air pollution control districts. California has achieved these improvements despite the State’s substantial growth in population, vehicle use, and business activities.

Molecular hydrogen (H_2) is a trace component of the lower atmosphere. Hydrogen is not radiatively-active and therefore does not have a direct impact on climate; however, it has an indirect impact on climate change as (a) it is involved in the production of tropospheric ozone, and (b) it can modify the concentration of methane through its affect on the concentration of the hydroxyl radical.

Since the 1980s, alternative options for fulfilling the global energy demand have been developed. The use of H_2 produced with renewable energy sources currently appears to be a promising option, in particular for non-stationary energy uses. Although H_2 fuel cells themselves are a "clean" technology, producing water vapor (a GHG) as exhaust, emissions of GHGs and ozone precursors associated with the production of H_2 must be considered (Schultz et al., 2003). Furthermore, the release of molecular hydrogen may increase because of leakage attributable to the production, transport, storage, and end use of H_2 (Zittel and Altmann, 1996). At present, the average leak rate to be expected in a full-scale hydrogen-driven economy is very uncertain (Schultz et al., 2003).

2.2.F Aerosols

Aerosols are extremely small particles or liquid droplets found in the atmosphere. Various categories of aerosols exist, including naturally produced aerosols such as soil dust, sea salt, biogenic aerosols, sulfates, and volcanic aerosols, and anthropogenically manufactured aerosols such as industrial dust and carbonaceous aerosols (e.g., black carbon or organic carbon) from transportation, coal combustion, cement manufacturing, waste incineration, and biomass burning. Aerosols affect radiative forcing in both direct and indirect ways: directly by scattering and absorbing solar and thermal infrared radiation, and indirectly by increasing droplet counts that modify the formation, precipitation efficiency, and radiative properties of clouds.

Understanding the role of aerosols in climate change requires inclusion of realistic representations of aerosols and their radiative forcings in climate models. Compared to GHGs with long atmospheric residence times, however, the optical properties and temporal and spatial patterns of aerosols are poorly understood. Uncertainty in aerosol radiative forcing arises because neither emission factors, which determine atmospheric concentrations, nor optical properties are fully known. The IPCC (2001) and the NACIP (2002) have identified radiative forcing due to aerosols, and in particular light absorbing aerosols, as one of the most uncertain components of climate change models.

2.3 Global Warming Potentials

Radiative forcing is often specified as the net change in energy flux in the atmosphere, and is expressed in watts per square meter (W/m^2), i.e. heat per area of the Earth's surface. Radiative forcing of the surface-troposphere system, resulting, for example, from a change in GHG concentrations, is the change in the balance between radiation coming into the atmosphere and radiation going out. A positive radiative forcing tends, on average, to warm the surface of the Earth, and negative forcing tends, on average, to cool the surface. The impact of GHG emissions upon the atmosphere is related not only to radiative properties, but also to the length of time the GHG remains in the atmosphere. Radiative properties control the absorption of radiation per kilogram of gas present at any instant, but the lifetime of the gas controls how long an emitted kilogram remains in the atmosphere and hence its cumulative impact on the atmosphere's thermal budget. The climate system responds to changes in the thermal budget on time-scales ranging from the order of months to millennia depending upon processes within the atmosphere, ocean, and biosphere.

Gases in the atmosphere can contribute to the greenhouse effect both directly and indirectly. Direct effects occur when the gas itself is a GHG. Indirect radiative forcing occurs when chemical transformations of the original gas produce other GHGs, when a gas influences the atmospheric lifetimes of other gases, and/or when a gas affects atmospheric processes that alter the radiative balance of the Earth (e.g., cloud formation). The concept of a Global Warming Potential (GWP) has been developed to compare the ability of each GHG to trap heat in the atmosphere relative to another gas. CO_2 was chosen as the reference gas to be consistent with IPCC guidelines. GWP is defined as the ratio of the time-integrated radiative forcing from the instantaneous release of 1 kg of a trace substance relative to that of 1 kg of a reference gas (IPCC 2001). While any time period can be selected, the 100-year GWPs are recommended by the IPCC and will be employed by the ARB for policy making and reporting purposes.

GWP values allow a comparison of the impacts of emissions and reductions of different gases. According to the IPCC (2001), GWPs typically have an uncertainty of ±35 percent. In addition to communicating GHG emissions in units of mass, we have also chosen to use GWPs to reflect their inventories in CO_2 equivalent terms because it places all of the GHGs on the same comparative scale. Table 2.3-1 lists GWPs for CO_2, CH_4, N_2O, and HFC-134a for the 20, 100, and 500 years time frames. It should be noted that when the lifetime of the species in question differs substantially from the response time of CO_2 (nominally about 150 years), then the GWP becomes very sensitive to the choice of time horizon. Thus, the GWP concept is only relevant for compounds that have sufficiently long lifetimes to become globally well-mixed. Therefore, short-lived gases and aerosols with vertical or horizontal variations pose a serious problem in the simple GWP framework.

Table 2.3-1. Numerical Estimates Of Global Warming Potentials Compared With CO2 (Kilograms Of Gas Per Kilogram Of CO2 -- Adapted From IPCC 2001).

Climate Pollutants	Lifetime (years)	Global Warming Potential		
		20 years	100 years	500 years
CO_2	~150	1	1	1
CH_4	12	62	23	7
N_2O	114	275	296	156
HFC-134a	~14	3,300	1,300	400

2.4 Pollutants Included in the Proposed Regulation

Assembly Bill 1493 calls for reductions in GHGs, which are defined in the bill as carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. The first four of these identified global climate change pollutants are clearly associated with motor vehicle use in California. Perfluorocarbons and sulfur hexafluoride are not known to be associated with motor vehicle emissions in California and therefore are not addressed further in the staff report.

Black carbon and criteria pollutant emissions from motor vehicles are also known to have global climate change impacts. Although these pollutants are not specifically defined as greenhouse gases in AB 1493, the authority for ARB to regulate these pollutants currently exists in the Health and Safety Code (Section 39014). AB 1493 does not limit that authority; rather it supports the need to address the impacts of climate change pollutants.

The 2001 IPCC states that in addition to the gases targeted in the Kyoto Protocol, the contribution of tropospheric O_3 to the greenhouse effect is also important. The report further states that in order to curb global warming it is necessary to reduce the emissions of both GHGs and other gases that influence the concentration of GHGs. Air pollutants such as NO_X, CO, and NMVOC produce OH radicals, that affect tropospheric O_3 and CH_4 levels, and hence they are called indirect GHGs. Due to the basic uncertainties regarding the actual impact of criteria pollutant emissions on climate, however, it is impossible at this time to have confidence in any numerical prediction of the climate effect of their emissions from light-duty motor vehicles. Because the uncertainties associated with the impact of criteria pollutants on climate change are large, at this time the ARB has chosen not to consider the potential climate change effects when regulating CO, NO_X, VOC or aerosols. As more definite scientific evidence becomes available, the ARB will, if appropriate, consider the climate change impacts of these criteria pollutants in its regulatory decisions.

2.5 Indicators of Climate Change In California

The climate is changing under the influence of human activity. Climate change indicators can be used to illustrate trends, measure the suitability of particular actions in certain areas and encourage public awareness of the climate change impacts. Several potential climate change indicators have been suggested, including anthropogenic GHG emissions, air temperature, annual Sierra Nevada snow melt runoff, and sea level rise in California (EPIC, 2002).

Time series of historical emissions of anthropogenic GHGs have been produced for a number of geographic regions. The GHGs emissions trends illustrate that, although California has been able to moderate its GHG emissions, total GHG emissions are still increasing and continue to remain above 1990 levels. With a relatively temperate climate, California uses relatively less energy for heating and cooling energy than other states. California leads the nation in vehicle miles traveled, however, which leads to a concomitant increase in carbon dioxide emissions in the transportation sector. Tracking California's trends in motor vehicle-related GHGs emissions will allow an assessment of the State’s contributions to global GHG emissions.

Increases in the concentrations of GHG are predicted to change regional and global climate-related parameters such as temperature, precipitation, soil moisture, and sea level. Temperature data have been collected at many weather stations in the State for almost a century. The air temperature indicator can be used to track trends in statewide surface air temperatures and regional variations, allowing for a comparison of temperature changes in California with those occurring globally.

The warming of global climate could increase evaporation rates, thereby potentially increasing precipitation and storms in the State. Snowmelt and runoff volume data can be used as a climate change indicator to document changes in runoff patterns. These changes are, at least in part, due to increased air temperatures and climate changes. In California, large accumulations of snow occur in the Sierra Nevada and southern Cascade Mountains from October to March. Each winter, at the high elevations, snow accumulates into a deep pack, preserving much of California's water supply in cold storage. If the winter temperatures are warm, more of the precipitation falls as rain instead of snow, and water directly flows from watersheds before the spring snowmelt. Thus, there is less buildup of snow pack; as a result, the volume of water from the spring runoff is diminished. Lower water volumes of the spring snowmelt runoff may indicate warmer winter temperatures or unusually warm springtime temperatures. Figure 2-4 shows that throughout the 20th century, annual April to July spring runoff in the Sierra Nevada has been decreasing. This decreased runoff was especially evident after mid-century; since then the water runoff has declined by about ten percent.

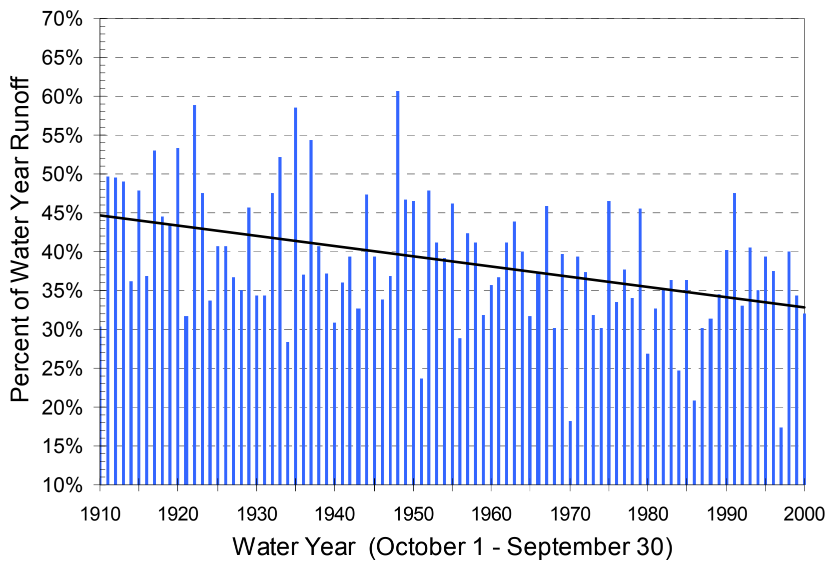


Figure 2-4. Sacramento River Runoff (1910-2000) - April to July as a Percent of Total Runoff (Roos, 2002).

Sea level rise also provides a physical measure of possible oceanic response to climate change. The rise in sea level may be associated with increasing global temperatures. Based on results from modeling, warming of the ocean water will cause a greater volume of sea water because of thermal expansion. This is expected to contribute the largest share of sea level rise, followed by melting of mountain glaciers and ice caps (IPCC, 2001). Along California's coast, sea level already has risen by three to eight inches over the last century. Long-term data from 10 of 11 California stations show increases in sea level (Figure 2-5, using San Francisco as an example).

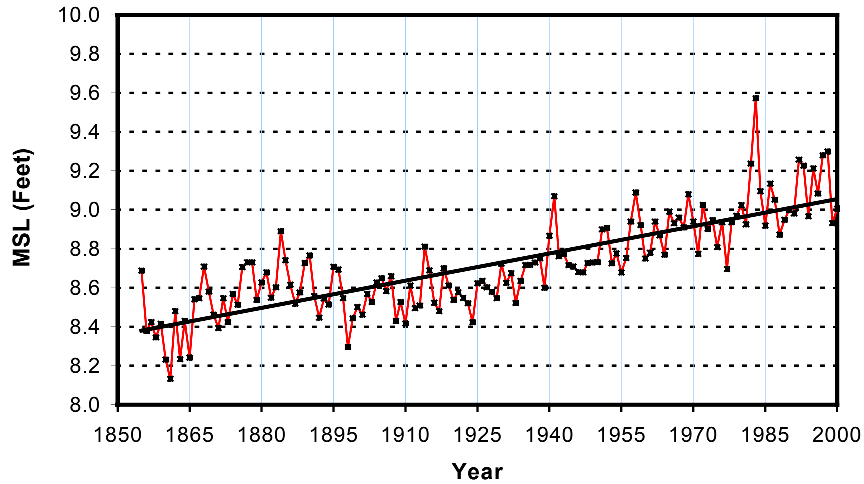


Figure 2-5. **1855-2000 San Francisco yearly mean sea level (Roos, 2002).**

The climate change indicators described in this report represent key properties of the climate system that are considered sensitive to climate change. Many additional potential indicators remain to be explored. For example, climate change may influence the frequency of extreme weather events, ecosystem structures and processes, and species distribution and survival. It may affect forestry, energy and other industries, insurance and other financial services, and human settlements. In addition, the impacts can vary from one region, ecosystem, species, industry, or community to the next. Research into the regional impacts of climate change is ongoing, and the potential climate change indicators will be updated and expanded as new information becomes available.

2.6 Potential Impacts on California

Climate is a central factor in Californian life. It is at least partially responsible for the State's rapid population growth in the past 50 years, and largely responsible for the success of industries such as agriculture and tourism. The potential effects of climate change on California have been widely discussed from a variety of perspectives (Lettenmaier and Sheer 1991; Gleick and Chalecki 1999; Wilkinson 2002). The signs of a global warming trend continue to become more evident and much of the scientific debate is now focused on expected rates at which future changes will occur. Rising temperatures and sea levels, and changes in hydrological systems are threats to California's economy, public health, and environment. The following section discusses evidence of a changing climate in California and provides examples of why the State is particularly at risk from an increasingly warmer and more variable climate.

2.6.A Human Health and Air Pollution

Human health in California is likely to be impacted by climate change. Several recent studies have addressed potential implications for human health at the national and international levels (Patz et al., 2000). Greater climate variability and changes in climate patterns would potentially cause both direct and indirect health effects. Direct health impacts due to climate change include extreme events, such as heat waves, droughts, increased fire frequency, and increased storm intensity resulting in flooding and landslides. Secondary or indirect health effects include damages to infrastructure causing, for example, sanitation and water treatment problems leading to an increase in water-borne infections. Air quality impacts such as increases in tropospheric (i.e., ground-level) ozone due to higher temperatures may also cause secondary health impacts.

The most obvious direct impact of climate change is higher temperatures and increased frequency of heat waves that may increase the number of heat-related deaths and the incidence of heat-related illnesses. Studies of heat waves in urban areas have shown an association between increases in mortality and increases in heat, measured by maximum or minimum temperature, heat index (a measure of temperature and humidity), or air-mass conditions (Semenza et al., 1996). For example, after a 5-day heat wave in 1995 in which maximum temperatures in Chicago ranged from 93 to 104°F, the number of deaths increased 85 percent over the number recorded during the same period of the preceding year. At least 700 excess deaths (deaths beyond those expected for that period in that population) were recorded, most of which were directly attributed to heat (Semenza et al., 1999).

Until recently, excess deaths occurring during heat waves have been attributed entirely to heat-induced stress. However, analyses in the Netherlands (Fischer et al., 2004) and the United Kingdom (Stedman, 2004) conclude that a substantial portion of the mortality is actually due to elevated O_3 and particulate matter levels. Air quality has a very real and direct effect on the health of many Californians who experience the worst air quality in the nation. Over 90 percent of Californians are living in areas that violate the State ambient air quality standard for ozone and/or particulate matter. In the Los Angeles area, population density and sprawl, cars, climate, and geography conspire to create some of the nation's worst air quality. A study by Kinney and Ozkaynak (1991) of urban air pollution in Los Angeles County found a significant association between daily mortality and ozone levels. Other California cities including Bakersfield and Fresno are also struggling with severe air quality problems as the San Joaquin Valley suffers from air pollution from various sources.

Climate change can lead to changes in weather patterns that can influence the frequency of meteorological conditions conducive to the development of high pollutant concentrations. High temperatures, strong sunlight, and stable air masses tend to increase the formation of ozone and secondary organic carbon particles – weather conditions associated with warmer temperatures increase smog. Figure 2-6 shows the relationship between ozone and temperature in the South Coast Air Basin, and indicates that ozone air quality can be profoundly affected by changes in climate and meteorology.

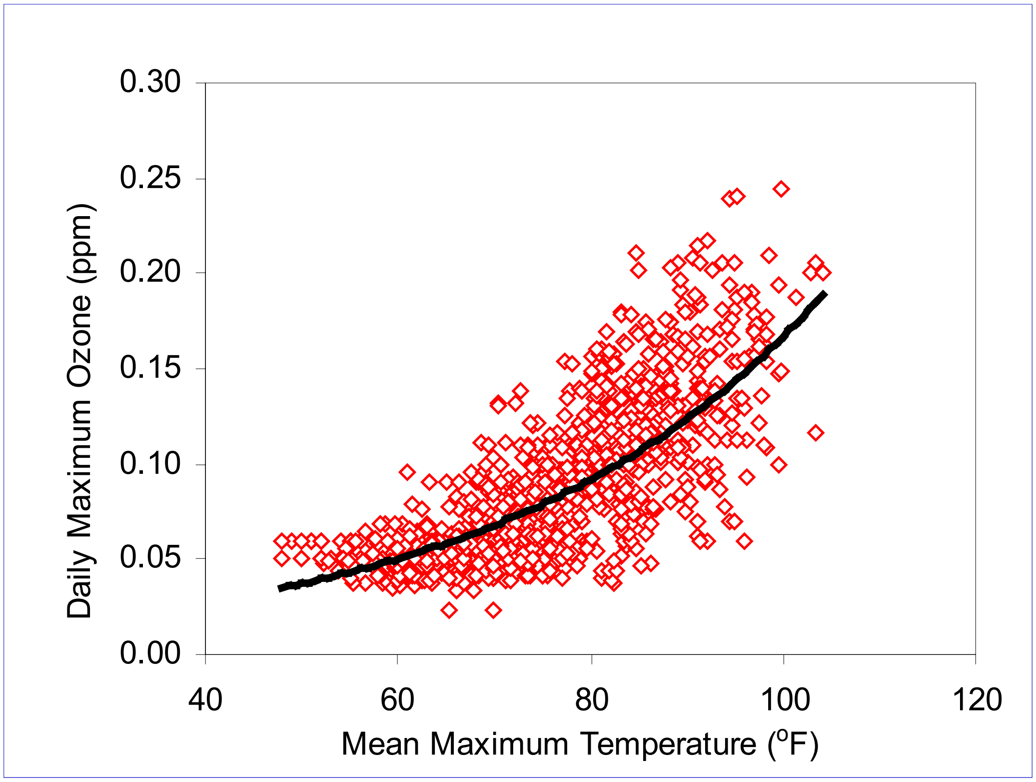


Figure 2-6. Relationship between ozone and temperature in the South Coast Air Basin, 1996-1998.

Climate change may alter the frequency, timing, intensity, and duration of extreme weather events (meteorological events that have a significant impact on local communities). Injury and death are the direct health impacts most often associated with natural disasters. Indirect health effects of climate change include increases in the potential transmission of vector-borne infectious diseases caused by the extensions of ranges and seasons of some vector organisms and acceleration of the maturation of certain infectious parasites. Most vector-borne diseases exhibit a distinct seasonal pattern that clearly suggests that they are weather sensitive. Rainfall, temperature, and other weather variables affect in many ways both the vectors and the pathogens they transmit. In California, as in much of the world there is concern that increased heat and moisture will facilitate the spread of emerging infectious diseases, many of which are vector-borne. It has also been suggested that climate change will increase exposure to natural allergens. Fungi have adapted to virtually all environments, but fungal growth is often enhanced at increased temperature and/or humidity (Bernard et al., 2001).

In summary, serious effects on human health may result from climate change. It is clear that heat waves and other extreme events pose serious public health concerns. Higher temperatures are also likely to negatively affect health by exacerbating air pollution. The elderly, infirm, and poor are most at risk because these conditions can exacerbate pre-existing disease. Lack of access to air conditioning increases the risk of heat-related illness. Secondary or indirect effects of changes in climate such as changes in disease vectors may also pose concerns. Poor and immigrant populations (residence in urban areas where the heat island effect actually increases warming and the consequent effects of heat) are more vulnerable to climate change as they are often without adequate resources to control their environment with appliances such as air conditioners, or to seek medical attention. Thus, these communities are the first to experience negative climate change impacts like heat death and illness, respiratory illness, infectious disease, and economic and cultural displacement.

2.6.B Water Resources

Much of California is semi-arid and, thus, water resources are a key factor in the State’s economic and environmental well being. Water resources are affected by changes in precipitation as well as by temperature, humidity, wind, and sunshine. Water resources in drier climates, such as California, tend to be more sensitive to climate changes. Because evaporation is likely to increase with warmer climate, it could result in lower river flows and lake levels, particularly in the summer. In addition, changes in meteorology could result in more intense precipitation, which could increase flooding. If stream flow and lake levels drop, groundwater also could be reduced. The seasonal pattern of runoff into California’s reservoirs could be susceptible to climatic warming. Winter runoff most likely would increase, while spring and summer runoff would decrease. This shift could be problematic, because the existing reservoirs are not large enough to store the increased winter flows for release in the summer. Increased winter flows to San Francisco Bay could increase the risk of flooding (Gleick and Chalecki 1999; Miller, et al., 2001; Roos 2002).

California is home to about 35 million people. Using the California Department of Finance projections, it is estimated that California's population will grow by an average of 1.4 percent per year over the next 20 years. This projection translates to approximately 10 million more Californians by 2020. The combination of population growth and climate warming could impose serious environmental challenges. Increased water demands and decreased water availability raise substantially the costs of providing water to urban, agricultural, and hydropower users. It is possible that California’s water system could adapt to the population growth and climate change impact. However, even with new technologies for water supply, treatment, and water use efficiency, widespread implementation of water transfers and conjunctive use, coordinated operation of reservoirs, improved flow forecasting, and the close cooperation of local, regional, State, and federal government, this adaptation most likely will be costly.

2.6.C Agriculture

If California’s water resource systems face challenges from climate change and variability, so will the State's agricultural sectors. While agricultural production is potentially vulnerable to climate change risks associated with adverse water system impacts, this sector also faces other risks that come with increasingly unpredictable variations in both temperature and precipitation. For example, increases in the frequency of extreme weather at inopportune times can cause significant declines in agricultural productivity (Wilkinson, 2002).

The impacts of global warming on crop yields and productivity will vary considerably by region. But several studies, including one by the US Department of Agriculture, show that maintaining today's levels of agricultural productivity would be difficult. At best, this would require expensive adaptation strategies. Farmers will likely need to change crops and cultivation methods because warming generally hinders crop yields, although the beneficial effects of elevated CO_2 in fertilizing plant growth may cancel out the effects of warming. If climate warming is accompanied by increased drought, however, the detrimental effects would be intensified.

In California, 87 percent of the crop area is irrigated, and increased drought could be countered by human management. Yet there are severe constraints on increased irrigation since 100 percent of the surface water is already allocated. Agricultural water users in the Central Valley are the most vulnerable to climate warming. While wetter hydrologies could increase water availability for these users, the driest climate warming hydrology could significantly reduce agricultural water deliveries in the Central Valley. If the climate shifts toward a severe drought, not only will more irrigation be needed, but also the snow pack at higher elevations will be lacking. This can be disastrous for producers that grow fruit trees and vines that will require years to reestablish production.

2.6.D Ecological Impacts

California is an ecologically diverse state, with 134 endangered and threatened species, including the sea otter, the California condor, and the American bald eagle. California's unique ecosystems include 25,000 square miles of desert. California's mountain ecosystems in the Sierra Nevada, including Yosemite National Park, contain alpine wilderness areas with large numbers of sequoia trees. The ranges of many species of plants and animals are restricted and fragmented because of both natural and human causes. Many invading species have colonized large areas and displaced native species in the wake of environmental changes in recent centuries (Wilkinson and Rounds, 1998).

Climate change could have an impact on many of California's species and ecosystems. For example, aquatic habitats are likely to be significantly affected by climatic changes. Most fish have evolved to thrive in a specific, narrow temperature range. As temperatures warm, many fish will have to retreat to cooler waters. Species differ significantly in their abilities to disperse and to become established in new locations with more suitable climates. Poorly dispersed species such as oak trees and related species, and amphibians, may not be able to survive the predicted rapid climatic changes if they have narrow tolerances for specific environmental conditions. Even for easily dispersed species, such as grasses and birds, other biological interactions (i.e., new predators, missing pollinators, lack of specific food sources) or physical environments (i.e., different soils, roads, lack of suitable intervening habitat) may block the success of migration.

With changes in climate, the extent of forested areas in California could also change. The magnitude of change depends on many factors, including whether soils become drier and, if so, how much. Hotter, drier weather could increase the frequency and intensity of wildfires, threatening both property and forests. Along the Sierras, drier conditions could reduce the range and productivity of conifer and oak forests. Farther north and along the northern coast, drier conditions could reduce growth of the Douglas fir and redwood forests. A significant increase in the extent of grasslands and chaparral throughout the State could result. These changes would affect the character of California forests and the activities that depend on them.

2.6.E Impact on Economy

California produces more than one-eighth of total U.S. economic output, which makes it equivalent to the sixth largest economy in the world. Increased climate variability and long-term climate change potentially will affect the state's sectors in important and different ways. Some activities and enterprises will be impacted directly through changes in natural resource and ecosystem services. Water shortages and increased insect damage to crops due to relatively rapid changes in insect populations, for example, will have direct impacts on the State's diverse agricultural sector. While field crops may be switched by the season, perennial crops including vineyards and orchards are long-term investments. The reported damages from the El Niño storms in 1997-98 for agricultural losses approached $100 million. From dairy farmers losing cows to exhaustion as they try to escape the mud, or are attacked by diseases, to strawberry growers losing crops to the rain, farmers have experienced significant losses due to strong climate variability (Wilkinson and Rounds, 1998).

Precipitation falling as rain instead of snow will pose major problems for water managers, as the existing capture will become inadequate, and distribution system designed for the current supply and demand areas will develop bottlenecks. Higher summer temperatures will cause more rapid deterioration of asphalt and concrete, impacting the highway and rail systems. Sea level increases of up to three feet over the next century, with consequent implications for coastal erosion, inundation of wetlands, salt water intrusion of coastal and delta aquifers, and impacts on developed areas would clearly be extremely costly to mitigate, and devastating to some ecosystems and urban communities. Climate change has the potential to affect many aspects of California—the survival of its unique ecosystems, its ability to produce electricity, its supply of water and agricultural products, and the resources that support its economy.

2.7 Abrupt Climate Change

When most people think about climate change, they imagine gradual increases in temperature and only marginal changes in other climatic conditions, continuing indefinitely or even leveling off at some time in the future. It is assumed that human societies can adapt to gradual climate change. However, recent climate change research has uncovered a disturbing feature of the Earth's climate system: it is capable of sudden, violent shifts. This is a critically important realization. Climate change will not necessarily be gradual, as assumed in most climate change projections, but may instead involve relatively sudden jumps between very different states. A mounting body of evidence suggests that continued GHG emissions may push the oceans past a critical threshold and into a drastically different future. Abrupt climate change is the subject of a report commissioned by the U.S. Department of Defense (Schwartz and Randall, 2003). The report stated that abrupt climate change could destabilize the geo-political environment, leading to skirmishes, battles, and even war due to resources constraints such as food shortage, decreased availability and quality of fresh water, and disrupted access to energy supply.

Change in any measure of climate or its variability can be abrupt, including a change in the intensity, duration, or frequency of extreme events. For example, single floods, hurricanes, or volcanic eruptions are important for humans and ecosystems, but their effects generally would not be considered abrupt climate changes. A rapid, persistent change in the number or strength of floods or hurricanes might, however, be an abrupt climate change. Although more regionally limited, the apparent change in El Niño behavior (Graham, 1994; Trenberth and Hoar, 1996) could also be considered an abrupt change. El Niño is characterized by a large-scale weakening of the trade winds and warming of the surface layers in the eastern and central equatorial Pacific Ocean. El Niño is notorious worldwide for causing catastrophic disruptions in weather patterns. Floods in California are countered by droughts in Australia.

Societies have faced both gradual and abrupt climate changes for millennia and have learned to adapt through various mechanisms, such as developing irrigation for crops, and migrating away from inhospitable regions. Nevertheless, because climate change will likely continue in the coming decades, denying the likelihood or downplaying the relevance of past abrupt events could be costly. Thus, in addition to the gradual (albeit accelerated) climate changes projected by current climate models, Californians need to be aware of the possibility of much more sudden climate shifts. These shifts have a scientifically well-founded place among the possible futures facing the State and should be among the possibilities accommodated in planning and adaptation measures.

3 CALIFORNIA ACTIONS TO ADDRESS CLIMATE CHANGE

The State of California has traditionally been a pioneer in efforts to reduce air pollution, dating back to 1963 when the California New Motor Vehicle Pollution Control Board adopted the nation's first motor vehicle emission standards. California likewise has a long history of actions undertaken in response to the threat posed by climate change. Beginning with 1988 legislation that directed the California Energy Commission, in consultation with the Air Resources Board and other agencies, to study the implications of global warming on California's environment, economy, and water supply, and continuing on over the years through Governor Schwarzenegger's April 2004 Executive Order outlining his vision for the California Hydrogen Highway Network, California state government has consistently recognized the necessity for state action on climate change to protect California's interests.

At the Air Resources Board, attention to the mechanisms and effects of climate change dates back to 1989, when staff first updated the Board on the emerging science.

3.1 Summary of California Activities

Listed below is a chronology of major California activities to address climate change. The noted activities illustrate the depth and breadth of California's commitment. The sections that follow provide more detail on major activities, beginning with state legislation and concluding with administrative initiatives.

Chronology of California Activities Addressing Global Climate Change

1988
AB 4420—Directs California Energy Commission (CEC), in consultation with the Air Resources Board and other agencies, to study and report on how global warming trends may affect California's energy supply and demand, economy, environment, agriculture, and water supplies.

1989
CEC reports—*Comparing the Impacts of Different Transportation Fuels on the Greenhouse Effect; The Impacts of Global Warming on California*
ARB—Board agenda item on global warming

1990
CEC releases *1988 Inventory of California Greenhouse Gas Emissions*

1991
CEC report—*1991 Global Climate Change Report*
CEC sponsors *Symposium on Global Climate Change*
CEC report—*Global Climate Change: Potential Impacts and Policy Recommendations*

1998
CEC report—*1997 Global Climate Change Report: Greenhouse Gas Emission Reduction Strategies for California*

1999
CEC sponsors *Global Climate Change Science Workshop*
California Fuel Cell Partnership established

2000
CEC sponsors *Global Climate Change Strategies Workshop*
SB 1771—Establishes California Climate Action Registry, and designates CEC and ARB with advisory functions
Executive Order D-16-00—directs Secretary for State and Consumer Services to facilitate sustainable building practices
ARB— Public Meeting to Consider an Informational Report on Air Pollution Trends: Past Progress and Future Challenges; included discussion of global warming

2001
SB 1170—cites global warming as one of the public health and environmental problems associated with petroleum use. To mitigate such effects the bill required the commission, the Air Resources Board and the Department of General Services to develop and adopt fuel-efficiency specifications governing the purchase by the state of motor vehicles and replacement tires.
California Stationary Fuel Cell Collaborative established

2002
CEC report—*Inventory of California Greenhouse Gas Emissions and Sinks: 1990-1999*
California Climate Action Registry launched
CEC reports—*Guidance to the California Climate Action Registry: General Reporting Protocol; Guidance to the California Climate Action Registry: Certification Protocol*
AB 1493—directs Air Resources Board to adopt regulations that achieve the maximum feasible and cost effective reduction of greenhouse gas emissions from motor vehicles
SB 812—directs California Climate Action Registry to include forest management practices
SB 1078—establishes *California Renewable Portfolio Standard Program*
SB 1389—directs CEC to adopt *Integrated Energy Policy Report* every two years
AB 857—directs Governor to prepare comprehensive *State Environmental Goals and Policy Report*

2003
CEC, California Power Authority and Public Utilities Commission issue *Energy Action Plan for the State of California*
West Coast Governors adopt Global Warming Initiative
Office of Planning and Research issues *Governor's Environmental Goals and Policy Report*, which included discussion of climate change impacts
CEC submits first *Integrated Energy Policy Report* to Governor, including supporting document entitled *Climate Change and California*

CEC Public Interest Energy Research Program creates *California Climate Change Research Center*
CEC Public Interest Energy Research Program reports—*Global Climate Change and California: Potential Implications for Ecosystems, Health and the Economy; Climate Change Research, Development and Demonstration Plan*

2004
CalTrans issues *California Transportation Plan (DRAFT)*
Executive Order S-7-04—outlines Governor Schwarzenegger's vision for the *California Hydrogen Highway Network*
Staff releases draft action plans for first five project topics in West Coast Governor's Global Warming Initiative

3.2 Legislation

This section provides a brief description of significant legislative actions taken to address climate change in California.

AB 4420 (Chapter 1506, Statutes of 1988, Sher)
Assembly Bill 4420 was signed on September 28, 1988 and directed the Energy Commission, in consultation with the Air Resources Board and other agencies, to "study and report…on how global warming trends may affect California's energy supply and demand, economy, environment, agriculture, and water supplies". Furthermore, "the study shall include recommendations for avoiding, reducing, and addressing the impacts." In approving the bill the Legislature declared that "recent projections regarding global warming trends raise long-range energy, economic, environmental planning issues for the State of California."

SB 1771 (Chapter 1018, Statutes of 2000, Sher)
Senate Bill 1771 was signed on September 30, 2000. This bill established the California Climate Action Registry and designated the Energy Commission and the Air Resources Board with advisory functions. It also required the Energy Commission to periodically update the State's greenhouse gas inventory, to "acquire and develop information on global climate change," to "convene an interagency task force consisting of state agencies with jurisdiction over matters affecting climate change to ensure policy coordination at the state level for those activities," and to "establish a climate change advisory committee." The Legislature stated that "it is in the best interest of the State of California, the United States of America, and the earth as a whole, to encourage voluntary actions to achieve all economically beneficial reductions of greenhouse gas emissions from California sources." The bill's stated purpose was to "encourage voluntary actions to increase energy efficiency and reduce greenhouse gas emissions."

SB 527 (Chapter 769, Statutes of 2001, Sher)
SB 1771 was followed by Senate Bill 527, which was signed on October 11, 2001. This clean-up legislation authorized administrative penalties for certain violations of air pollution laws and clarified and added language to SB 1771. In the bill the Legislature repeated its statement that it "finds and declares [that it] is in the best interest of the

State of California, the United States of America, and the earth as a whole, to encourage voluntary actions to achieve all economically beneficial reductions of greenhouse gas emissions from California sources."

SB 1170 (Chapter 912, Statutes of 2001, Sher)
Senate Bill 1170 was signed on October 14, 2001. The bill cited global warming as one of the "public health and environmental problems" associated with petroleum use. Specifically, the bill mentioned "air pollution, acid rain, global warming, and the degradation of California's marine environment and fisheries." To mitigate such effects, the bill required the commission, the Air Resources Board and the Department of General Services to develop and adopt fuel-efficiency specifications governing the purchase by the state of motor vehicles and replacement tires.

AB 1493 (Chapter 200, Statutes of 2002, Pavley)
Assembly Bill 1493, the subject of this draft staff report, was signed on July 22, 2002. It required that the State Air Resources Board "develop and adopt regulations that achieve the maximum feasible and cost-effective reduction of greenhouse gases from motor vehicles". In the bill the Legislature declared that "global warming is a matter of increasing concern for public health and the environment in the state" and that "the control and reduction of emissions of greenhouse gases are critical to slow the effects of global warming". The bill also directed the California Climate Action Registry to adopt protocols for reporting "reductions in greenhouse gas emissions from mobile sources".

SB 812 (Chapter 423, Statutes of 2002, Sher)
Assembly Bill 812 was signed on September 7, 2002. It instructed the California Climate Action Registry to include forest management practices as a mechanism to achieve emission reductions and "to adopt procedures and protocols for the reporting and certification of greenhouse gas emission reductions resulting from a project" and for "the monitoring, estimating, calculating, reporting, and certifying of carbon stores and carbon dioxide emissions resulting from the conservation and conservation-based management of native forest reservoirs in California"

SB 1078 (Chapter 516, Statutes of 2002, Sher)
Senate Bill 1078 was signed on September 12, 2002 and established the California Renewable Portfolio Standard Program. In the bill the Legislature finds that "[t]he development of renewable energy resources may ameliorate air quality problems throughout the state and improve health by reducing the burning of fossil fuels and the associated environmental impacts."

SB 1389 (Chapter 568, Statutes of 2002, Bowen)
Senate Bill 1389 was signed on September 14, 2002 and required that the Energy Commission compile and "adopt an integrated energy policy report" every two years. In the report the Commission shall develop public interest energy strategies that include "reducing statewide greenhouse gas emissions and addressing the impacts of climate change on California".

AB 857 (Chapter 1016, Statutes of 2002, Wiggins)
Assembly Bill No. 857 was signed on September 28, 2002 and instructed the Governor to prepare a "comprehensive State Environmental Goals and Policy Report". The bill sets out the State's planning priorities as being "to promote equity, strengthen the economy, protect the environment, and promote public health and safety". After approval of the report it shall serve as a guide for state expenditures.

3.3 Administrative Initiatives

This section provides more detail on climate change initiatives that have been undertaken by state agencies.

3.3.A Governor's Office

A number of activities have been undertaken at the Governor's Office level, as outlined below.

Sustainable Building Practices. In 2000 Governor Gray Davis signed Executive Order D-16-00, which directed the Secretary for State and Consumer Services to facilitate the incorporation of sustainable building practices into the planning, operations, policymaking, and regulatory functions of State entities. The Integrated Waste Management Board mitigates emissions through actions contained in the "Sustainable Building Implementation Plan."

West Coast Governor's Global Warming Initiative. On September 22, 2003 Governor Davis announced the formation of the West Coast Governor's Global Warming Initiative in cooperation with the governors of Oregon and Washington. The three states intend to reduce greenhouse gas emissions through six initial projects areas. These areas include (1) using the states' purchasing power to purchase fuel-efficient vehicles and low-rolling resistance tires for motor pool fleets, (2) reducing emissions from diesel generators in ships at west coast ports, and create a system of emission-free truck stops along the Interstate 5 corridor, (3) encouraging the development of renewable electricity generation resources and technologies, (4) improving efficiency standards, (5) developing consistent and coordinated greenhouse gas emission inventories, protocols for standard accounting and reporting methods for greenhouse gas emissions, and (6) promoting a hydrogen fuel infrastructure for transportation. In April 2004 the staff of the three states released draft initiatives covering the first five project areas for public comment. The hydrogen fuel infrastructure draft initiative will be completed in the near future.

Environmental Goals and Policy Report. In November of 2003 the *Governor's Environmental Goals and Policy Report* was published by the Governor's Office of Planning and Research. The report details the significant impact of potential climate change on California's public health, agriculture, water supply, ecosystems, and economy. The report encouraged the establishment of "achievable targets for greenhouse gas emissions that are incorporated into regulatory programs and reflected in subsequent investments in greenhouse gas reduction." Analyses to estimate the "cumulative effects of proposed government actions on total greenhouse gas emissions and require feasible mitigation measures that would achieve greenhouse gas emission and fossil fuel use reduction targets" should also be undertaken.

California Hydrogen Highway Network. Governor Arnold Schwarzenegger signed Executive Order (EO) S-7-04 on April 20, 2004. This EO acknowledged that hydrogen, a non-carbon energy carrier, is ideally suited to address global, regional and local energy and environmental challenges. The EO designated California's 21 interstate freeways as the "California Hydrogen Highway Network". The EO directed the California Environmental Protection Agency (Cal/EPA), in concert with the State Legislature, and in consultation with the California Energy Commission and other relevant state and local agencies, to develop the California Hydrogen Economy Blueprint Plan (Blueprint Plan) for the rapid transition to a hydrogen economy. The Blueprint Plan is due to the Governor and the Legislature in January 2005 and must include recommendations that promote environmental benefits, including global climate change benefits.

Cal/EPA has established a Hydrogen Highways Implementation Advisory Panel (Panel) to direct the Blueprint Plan effort. The Panel Chair will be chaired by Cal/EPA Agency Secretary Terry Tamminen and is made of up high-level executives from the public and private sector, including representatives from environmental organizations, the California Fuel Cell Partnership, the California Stationary Fuel Cell Collaborative, and a representative of environmental justice organizations. The Panel will be advised by Topic Teams that include experts in specific hydrogen-related issues. The Blueprint Plan will undergo review by a Senior Review Committee that includes Cabinet members and Legislators prior to going to the Governor and the full Legislature.

3.3.B California Energy Commission

As a result of AB 4420 the Energy Commission initiated several research efforts to clarify the consequences of global warming on California. In April of 1989 a report *Comparing the Impacts of Different Transportation Fuels on The Greenhouse Effect* surveyed how crude oil, compressed natural gas, natural gas and coal transportation fuels affected greenhouse gas emissions. In August of the same year another report *The Impacts of Global Warming on California* examined the risk of significant global warming upon water resources, electrical energy, agriculture, forestry, rising ocean level, natural habitat, regional air quality and human health, and the California economy.

The efforts to complete an inventory of California's greenhouse gas emissions were concluded in October of 1990 with the release of the *1988 Inventory of California Greenhouse Gas Emissions*. It inventoried emissions of CO_2, CH_4, N_20 and halocarbons, and included estimates of emissions from some out-of-state electricity fuel supplies.

In January of 1991 the Energy Commission reported to the Governor and Legislature with the *1991 Global Climate Change Report* detailing the greenhouse gas emissions inventory, greenhouse gas reduction strategies and recommended policies to avoid and reduce global warming impacts. The following month leading climate scientists presented information on climate change science, global climate change models, and the importance of California public policy at *A Symposium on Global Climate Change.* At the end of 1991 the Energy Commission compiled the findings of the earlier reports and recommended actions to reduce greenhouse gas emissions and adapt to potential global climate change in the *Global Climate Change: Potential Impacts & Policy Recommendations.*

In January of 1998 the emissions inventory was updated, and emission forecasts were presented along with an overview of the progress of the policies recommended in 1991. A follow-up to the global climate change symposium was conducted in 1999 with presentations by ten of the nation's leading climate scientists on the latest scientific data and information on global climate change potential impacts at the *Global Climate Change Science Workshop*.

In June of 2000 a *Global Climate Change Strategies Workshop* included presentations by California, national and international businesses who have adopted "early actions" to reduce greenhouse gas emissions and elicited suggestions for strategies that could be cooperatively undertaken by the State government and the private sector.

The *Inventory of California Greenhouse Gas Emissions and Sinks: 1990-1999* was presented in 2002. In addition to emission estimates it included an examination of trends in greenhouse gas emissions over the decade of the 1990s.

<u>Integrated Energy Policy Report</u>. The California Energy Commission adopted the 2003 Integrated Energy Policy Report on November 12, 2003. This document contains numerous recommendations to the Governor about current and potential energy issues confronting the state. Recommendations on the topic of climate change focused on the need to partner with neighboring states to take leadership positions in addressing global warming. Specific actions mentioned include required reporting of greenhouse gas (GHG) emissions as a condition of state licensing of new electric generating facilities; use of sustainable energy and environmental designs in all state buildings; and a requirement for all state agencies to incorporate climate change mitigation and adaptation strategies in planning and policy documents.

<u>Public Interest Energy Research Program</u>. The California Energy Commission's Public Interest Energy Research Environmental Area (PIER-EA) is engaged in a variety of activities to address both the causes and impacts of global climate change. These collaborative activities leverage public and private research expertise and funding, from within California and throughout the world.

In 2003, the Energy Commission's PIER Staff created the California Climate Change Research Center (CCCRC) to initiate and implement climate-related research, development, and demonstration projects. The CCCRC has three components. The first, located at Scripps Institution of Oceanography, concentrates on scientific research related to climate variability and change. The second, located at the University of California at Berkeley, focuses on the economic and social aspects of climate change.

The third, located at the University of California's Office of the President (UCOP), manages a competitive grant program that funds research related to climate change.

Also, in 2003, PIER-EA released two major climate-related reports. *Global Climate Change and California: Potential Implications for Ecosystems, Health, and the Economy* discusses various affects of climate change on the state. The *Climate Change Research, Development, and Demonstration Plan* outlines the need for state-sponsored climate change research, identifies research gaps, and prioritizes research activities to address climate change and its impacts in a number of disciplines.

These interrelated programs and projects are building a strong foundation that enables PIER-EA to collaborate with other organizations to address climate change issues that are affecting the environmental and economic health of the state and the region.

Energy Efficiency Activities. The Energy Commission adopted 2005 building energy efficiency standards in November 2003. These standards have growing positive effects. The savings that these standards are expected to yield for each year of construction are 180 megawatts of electric demand, 475 giga-watt hours of electric energy and 8.8 million therms of natural gas. These energy savings will yield significant reductions in criteria pollutant and greenhouse gas emissions.

CO2 Reporting in Power Plant Licensing. The Energy Commission staff is examining the feasibility and advisability of CO2 reporting in power plant licensing. This information would allow staff to estimate the amount of greenhouse gas emissions that will be emitted by the project, and would prove useful in establishing a more comprehensive and accurate inventory of greenhouse gas emissions from the electric generation sector within the state. In addition, by identifying and quantifying these emissions strategies can be developed, if appropriate, addressing the feasibility and cost-effectiveness of potential mitigation measures. The staff will also examine whether it should recommend that the Commission require power plant applicants, as a condition of certification, to submit actual monthly operational emissions data for greenhouse gases.

The staff also expects to study the issue of whether it would be advisable to require power plant applicants to obtain carbon dioxide (CO_2) emission offsets, as is currently done in Oregon. If it were decided that a California CO_2 emission offset market had merit, this issue would be reviewed in cooperation with the Air Resources Board and local air districts and would be the subject of public hearings.

3.3.C California Air Resources Board

Prior to being designated as lead role for implementation of AB 1493, the California Air Resources Board had already taken a number of actions to better understand climate change mechanisms and effects and encourage low greenhouse gas emission technologies. The Board's focus on the issue dates back to 1989, when staff provided to the Board a presentation on the emerging science. At a Board hearing in 2000 staff updated the scientific evidence and highlighted ARB and state actions on global climate change as an air pollution challenge. Specific initiatives are summarized below.

Zero Emission Vehicle Regulation. This regulation, first adopted in 1990 and most recently modified in 2003, requires manufacturers to offer for sale in California specified numbers of zero and near-zero emitting vehicles. Although the regulation focuses most directly on criteria pollutants, the emerging technologies encouraged by the regulation, such as battery electric, fuel cell and hybrid electric vehicles, also offer significant greenhouse gas benefits.

California Fuel Cell Partnership. The California Fuel Cell Partnership, established in 1999, is a unique collaborative of auto manufacturers, energy companies, fuel cell technology companies, and government agencies. The Partnership is committed to promoting fuel cell vehicle commercialization as a means of moving towards a sustainable energy future, increasing energy efficiency and reducing or eliminating criteria pollutants and greenhouse gas emissions.

California Stationary Fuel Cell Collaborative. The mission of the California Stationary Fuel Cell Collaborative, which was established in 2001, is to promote stationary fuel cell commercialization. One of the Collaborative's key objectives to be achieved through commercialization of stationary fuel cell technology is the reduction or elimination of air pollutants and greenhouse gas emissions. The Collaborative envisions fuel cell installations pursued by state, local and public organizations as well as private entities. The Collaborative will take specific actions to promote a wide variety of fuel cell technologies, sizes and applications for installation in California.

Research. Global air pollution issues are specifically highlighted in the 10-year research strategy adopted by the Board in 2001. The purpose of the ARB's global climate research program is to assess the effects of greenhouse gas emissions, global climate change, and global transport of pollutants, especially as they impact the public health and environment of California. This comprehensive scientific research and assessment will help policymakers design the most appropriate control strategies to deal with these very complex issues. Important research questions concerning global air pollution and global climate change include the following:

- How can the greenhouse gas emission inventory be improved?
- What is the true contribution of motor vehicles to N2O emissions?
- What is the role of aerosols in climate change?
- What will be the effects of global climate change on human health?
- What are the possible economic impacts of global climate change on California?

One example of climate change related research is a study entitled *Global Radiative Effect of Particulate Black Carbon*. The goal of this project, which is underway, is to provide the Air Resources Board with state-of-the-science global radiative forcing estimates for black carbon (BC) and other aerosols. Quantitative understanding of the absorbing aerosol's role in the climate change is required to accurately evaluate the radiative forcing impacts of PM emissions. Such information is needed in order to determine whether PM should at some point be incorporated into climate change regulations.

A second study, entitled *Climate Change - Characterization of Black Carbon and Organic Carbon Air Pollution Emissions and Evaluation of Measurement Methods*, is under consideration. This project will result in an improved understanding of the effect of different combustion sources and their particle emissions, in particular black carbon and organic carbon, on air pollution and climate change.

ARB staff are currently reviewing climate change research proposals as part of the 2004/2005 research solicitation. The climate change proposals as well as those addressing other air quality-related needs will be considered by the Research Screening Committee. It is expected that the highest-ranking proposals will be presented to the Board with the recommendation that they be funded.

Innovative Clean Air Technologies Program. The Innovative Clean Air Technologies (ICAT) program provides co-funding for companies that are developing technologies supporting ARB's clean air objectives for California. This program has funded several projects on hydrogen, fuel cells, and hybrids, primarily for their GHG emission reductions.

3.3.D California Climate Action Registry

Legislation passed in 2000 called for creation of the California Climate Action Registry (CCAR), a non-profit organization with the primary function of promoting voluntary annual reporting of GHG emissions inventories by California entities. In 2002 the California Climate Action Registry was launched and several recommendations were provided by the Energy Commission to the Registry's Board of Directors. These included the *Guidance to the California Climate Action Registry: General Reporting Protocol* and *Guidance to the California Climate Action Registry: Certification Protocol*. The Registry has over 35 participants from business, industry, government, and other types of organizations. Emissions data by Registry members are reported at the facility level, and are verified by state approved certifiers.

Under the enabling legislation, the State of California agrees to provide “appropriate consideration” of certified emissions that result in the future, when possible regulatory regimes may be implemented to reduce greenhouse gas emissions at the international, national, or state level. A forestry protocols workgroup has been convened and a power generator/utility sector workgroup is currently being formed to draft industry-specific GHG reporting and certification protocols. In addition, there is an effort underway to establish oil and gas industry reporting protocols. Lastly, there is an effort underway to quantify the “asset value” of greenhouse gas emissions reductions and move toward a market-based system for recording actual emissions savings. The Oregon Climate Trust has been instrumental in this effort.

3.3.E California Department of Transportation

The California Department of Transportation (CalTrans) is working on a *California Transportation Plan* which "is a policy plan designed to guide transportation investments and decisions at all levels of government and the private sector to enhance [California's] economy…and safeguard [California's] environment for the benefit of all." In a draft version of the plan CalTrans stated that "the use of fossil fuels to transport people and goods leads to air emissions that contribute to the warming of earth's atmosphere". The report cites "potential adverse impacts to public health, agriculture, forest, and other systems, storm frequency and intensity, mountain snow pack, smog, and rising sea levels resulting from climate change."

CalTrans also has a Director's Policy entitled "Energy Efficiency and Conservation Policy." This policy promotes environmental stewardship, sustainable transportation, reductions in greenhouse gas emissions, and educational programs.

3.3.F California Department of Water Resources

The California Department of Water Resources (DWR) has recognized that climate change and variability can have important consequences for the state's water resource systems. As a result the Scripps Institution of Oceanography is partnering with DWR and the PIER Program to improve data collection and regional climate modeling in an effort to reduce the uncertainty surrounding predictions of how precipitation patterns may change in California. DWR has also been documenting sea levels that dates back to the mid-1800s measured at San Francisco Bay. DWR is evaluating these risks and considering adaptive measures as part of the state's planning process related to water resources.

3.3.G Department of General Services

SB 1170 highlighted global warming as one of the public health and environmental problems associated with petroleum use. In response to the bill the Department of General Services (DGS) has developed "green" specifications for the procurement of all new passenger and light duty vehicles. The DGS solicits bids and publishes annual purchasing contracts for new passenger cars, pickups, passenger and cargo vans, and utility vehicles. Currently, all new passenger and light duty vehicles offered for purchase by state and local governmental fleets meet and in some cases exceed the Ultra Low Emission Vehicle (ULEV) requirements as established by the CARB.

3.3.H Multi-Agency Initiatives

<u>Renewable Portfolio Standard (RPS).</u> The California Public Utilities Commission (CPUC) and the Energy Commission have established a collaborative process to implement the state's RPS. Legislation currently requires retail sellers to increase percentage of renewable energy sources in their portfolio by 1% of sales per year, up to 20% by the year 2017. Additional legislation provides up to $135 million per year to help achieve the objectives of the RPS and other renewable energy policies of the state.

A plan has been developed for the proceedings and workshops have been held to discuss implementation topics. A final document entitled "Renewable Resources Development Report" was prepared for the Legislature that describes the renewable resource potential in California and other states in the Western Electricity Coordinating Council.

Energy Action Plan – 2003. In 2003 the Energy Commission, the California Power Authority, and the Public Utilities Commission joined to create an Energy Action Plan for the State of California. One of the proposed actions was for "California [to] decrease its per capita electricity use through increased energy conservation and efficiency measures. This would minimize the need for new generation, reduce emissions of toxic and criteria pollutants and greenhouse gases, avoid environmental concerns, improve energy reliability and contribute to price stability." The plan also argues that the state should "encourage companies that invest in energy conservation and resource efficiency to register with the state's Climate Change Registry." The plan states that "the agencies will each take into account the effect the action will have on energy expenditures, the environment and climate change, and the overall economy." The state's Energy Action Plan also calls for an accelerated RPS goal of 20% renewable energy electricity by the year 2010.

West Coast Regional Carbon Sequestration Partnership. In August 2003, the U. S. Department of Energy selected the West Coast Regional Carbon Sequestration Partnership as one of seven regional groups to evaluate a range of carbon sequestration options. The partnership (which consists of the Western Governor's Association; various state agencies in California, Oregon, and Washington; and oil and gas companies) is focusing on terrestrial and geological sequestration. California and neighboring states will examine opportunities to capture and store CO_2, including issues related to transport, permitting, monitoring, verification, and public outreach. This regional partnership approach is a cooperative effort between federal, state, and private organizations and described as "the centerpiece" of federal efforts to understand the potential of carbon sequestration to help mitigate greenhouse gas emissions.

The Energy Commission is managing the task-related working groups that are addressing issues relating to CO_2 transport, permitting, monitoring, verification, and public outreach. Phase I projects are developing the framework, tools, and methods for a regional assessment and identifying regional sequestration options and candidate projects. In Phase II, participants will conduct terrestrial and geologic sequestration pilot demonstrations to provide information for full-scale demonstrations.

Forest Management Practices. In response to SB 812 the Energy Commission and the Department of Forestry and Fire Protection are participating in the Registry's efforts to develop guidance for protocols estimating emissions storage in forests. The Energy Commission, the Department of Forestry and Fire Protection and the Department of Food and Agriculture are also working to improve methods of establishing an extensive inventory of carbon currently stored within California's landscapes.

4 SUMMARY OF PROPOSED REGULATION

4.1 Climate Change Emission Reduction Standard

Vehicle climate change emissions comprise four main elements: (1) CO_2, CH_4 and N_2O emissions resulting directly from operation of the vehicle, (2) CO_2 emissions resulting from operating the air conditioning system (indirect AC emissions), (3) refrigerant emissions from the air conditioning system due to either leakage, losses during recharging, or release from scrappage of the vehicle at end of life (direct AC emissions, and (4) upstream emissions associated with the production of the fuel used by the vehicle. The climate change emission standard incorporates all of these elements.

The staff proposal recommends that one standard be established for passenger cars and the lightest trucks (PC and LDT1), and a separate standard for heavier trucks (LDT2). Staff proposes setting near-term standards, phased in from 2009 through 2011, and mid-term standards, phased in from 2012 through 2014. The proposed standards, expressed in terms of CO2 equivalent grams per mile, are as follows:

Tier	Phase-in	Year	CO_2-equivalent emission standard by vehicle category (g/mi)	
			PC/LDT2	LDT2
Near-term	30%	2009	313	420
	60%	2010	282	383
	100%	2011	240	333
Mid-term	30%	2012	231	326
	60%	2013	221	319
	100%	2014	209	309

To maintain simplicity, staff proposes to use the upstream emissions for vehicles that use conventional fuels as a “baseline” against which to compare the relative merits of alternative fuel vehicles. Therefore, the emissions standards as shown above do not directly reflect upstream emissions. Rather, when certifying gasoline or diesel-fuel vehicles manufacturers would report only the “direct” or, “on vehicle” emissions. For alternative fuel vehicles, exhaust CO_2 emissions values will be adjusted in order to compensate for the differences in upstream emissions. This approach simplifies the regulatory treatment of gasoline vehicles, while at the same time allowing for appropriate treatment of alternative fuel vehicles.

4.2 Early Credits

AB 1493 directs that emission reduction credits be granted for any reductions in greenhouse gas emissions achieved prior to the operative date of the regulations. ARB staff proposes that credit for early emission reductions should be available for model years 2000 through 2008, and that the baseline against which manufacturer emissions are measured should be the fully phased in model year near term standards. Thus under the staff early credit proposal, manufacturer fleet average emissions for model years 2000 through 2008 would be compared to these standards on a cumulative basis.

4.3 Alternative Compliance

AB 1493 requires that the regulations “provide flexibility, to the maximum extent feasible consistent with this section, in the means by which a person subject to the regulations ... may comply with the regulations. That flexibility shall include, but is not limited to, authorization for a person to use alternative methods of compliance with the regulations.” Thus the use of alternative compliance strategies must not undercut the primary purpose of the regulation, which is to achieve greenhouse gas reductions from motor vehicles. Accordingly, the ARB's alternative compliance program will be limited to the vehicles that are regulated through AB 1493, and their fuels. This is to ensure that the program does not dilute the technology-forcing nature of the regulation, since the goal is to improve the vehicles themselves. The major features of the staff proposal are:

- Projects must be located in California to be eligible as alternative methods of compliance.
- Only companies regulated by AB 1493 (automakers) will be permitted to apply for alternative compliance credits.
- Only those vehicles regulated under AB 1493 are eligible for alternative compliance credits. This includes model year 2009 and later passenger vehicles and light-duty trucks and other vehicles used for noncommercial personal transportation in California.
- Staff proposes that eligible projects be limited to those that achieve greenhouse gas reductions through documented increased use of alternative fuels in eligible vehicles.

5 MAXIMUM FEASIBLE AND COST-EFFECTIVE TECHNOLOGIES

A key part of the staff's technical work, and the focus of this section, is an assessment of technologies and fuels that can contribute to a reduction of climate change emissions in passenger vehicles from the 2009 model-year and beyond. The relevant portions of AB 1493 that guide this technology and economic assessment read -

> 43018.5. (a) No later than January 1, 2005, the state board shall develop and adopt regulations that achieve the maximum feasible and cost-effective reduction of greenhouse gas emissions from motor vehicles…. [where] (i) For the purposes of this section, the following terms have the following meanings: (1) ''Greenhouse gases'' means those gases listed in subdivision (g) of Section 42801.1. (2) ''Maximum feasible and cost-effective reduction of greenhouse gas emissions'' means the greenhouse gas emission reductions that the state board determines meet both of the following criteria: (A) Capable of being successfully accomplished within the time provided by this section, taking into account environmental, economic, social, and technological factors. (B) Economical to an owner or operator of a vehicle, taking into account the full life-cycle costs of a vehicle. (Stats. 2002, Ch. 200, §3)

5.1 Background

5.1.A Development of Staff Technology Assessment

Since passage of AB 1493, ARB has hosted several meetings to provide an update on the process of formulating climate change emission standards and to solicit feedback and public comment from relevant stakeholders, interested parties, and technology developers. ARB hosted the International Technology Symposium in March of 2003 in an effort to bring together international experts on climate change emission reduction technologies. Leading researchers from the auto industry, vehicle component suppliers, academia, and vehicle simulation firms were invited to speak, covering numerous technologies and their potential to reduce climate change emissions of vehicles in the 2009-2015 timeframe. Additional feedback on developing a climate change regulation came from an update to the Board on November 20, 2003. ARB staff presented its early findings on the individual technologies that are likely to be available in the 2009 timeframe and the potential for climate change emission reductions from these technologies.

Building on the work presented at the earlier public meetings, on April 1, 2004 staff released the <u>Draft Technology and Cost Assessment for Proposed Regulations to Reduce Vehicle Climate Change Emissions Pursuant to Assembly Bill 1493</u>. That report provided a comprehensive assessment of the technologies considered by the ARB staff in formulating targets for the "maximum feasible and cost-effective reduction of greenhouse gases." ARB then hosted a public workshop on April 20, 2004 to receive public comment on the draft technology assessment.

This section presents the ARB staff technology results that are used to derive the proposed regulatory standards. The results presented here restate the findings from the draft technology assessment, updated as appropriate due to public comment and additional staff analysis.

5.1.B Research Method Overview

The vehicle technology results presented in this report are derived primarily from a comprehensive vehicle simulation modeling effort and a thorough cost analysis performed for the Northeast States Center for a Clean Air Future (NESCCAF). The participants in the study include AVL List Gmbh (AVL), Martec, and Meszler Engineering Services. ARB staff has been monitoring progress of this independent study and has been afforded various opportunities to provide comments on the analysis. ARB staff believes the NESCCAF study is the most advanced and accurate evaluation of vehicle technologies that reduce greenhouse emissions yet performed. ARB staff also monitored a separate Tiax, LLC analysis of the greenhouse gas benefits of alternative fuel vehicles, including upstream benefits, and the cost associated with alternative fuel vehicle technologies. ARB staff also met with representatives from EPA, the Society of Automotive Engineers, the Mobile Air Conditioning Society, and the National Renewable Energy Laboratory to develop its approach for reducing the effects of air conditioning refrigerant emissions and excess CO_2 emissions from air conditioning use on climate change.

A key part of the ARB staff's technical work is to assess technologies that will be available to reduce greenhouse gases for model year 2009 and later light-duty passenger vehicles. As directed by AB 1493, the technologies assessed need to "achieve the maximum feasible and cost-effective reduction of greenhouse gas emissions from motor vehicles." This section provides a brief overview of the methodology used in the NESCCAF study that serves as the basis of the ARB staff assessment of the potential greenhouse gas reductions and the cost of various available and emerging vehicle technologies.

In Section 5.2, the "Technology Assessment" section, we review NESCCAF's 2002 baseline vehicle attributes, their contribution to atmospheric climate change emissions, and evaluate technologies that have the potential to decrease these emissions. The technologies being explored are currently available on vehicles in various forms or have been demonstrated by auto companies and/or vehicle component suppliers in at least prototype form. Brief generalized descriptions of the technologies and their level of current and potential commercial deployment are provided. Results for climate change emission reductions from more detailed analyses, with specific engine and drivetrain technologies applied to specific vehicles, are presented and summarized. Mobile air-conditioning systems are investigated to determine potential climate change emission reductions from improved efficiency air-conditioning compressors, reduced refrigerant leakage systems, and the use of alternative refrigerants. An assessment of technology options to reduce climate change emissions with the use of alternative fuel vehicles is provided, including analysis of both exhaust and fuel-cycle-related (i.e. "upstream") emissions. Lastly, potential climate change reductions from improved exhaust catalyst technologies are considered.

Many different data sources were used for this analysis. U.S. Environmental Protection Agency data (EPA, 2003) was used to estimate baseline vehicle characteristics, and vehicle systems modeling simulations were used to analyze the potential benefits of various technologies. As indicated before, staff has relied extensively on the NESCCAF 2004 study “Reducing Greenhouse Gas Emissions from Light-Duty Motor Vehicles” for our analysis. It was tailored specifically for the task of formulating a cost-effective vehicular greenhouse gas regulation, and offers the most definitive, contemporary, and relevant research results to date.

The NESCCAF assessment of the costs and benefits of potential climate change reduction technologies relies on vehicle computer modeling simulations in order to reduce the potential error involved with overcounting the potential benefits of clusters of technologies used simultaneously on vehicles. This study also projected 2009 baseline vehicle performance using current trend lines and results of interviews with manufacturers and suppliers concerning production plans relative to performance and weight (the latter being constrained by pending implementation of a Corporate Average Fuel Economy (CAFE) increase for light-duty trucks), and the subsequent modeling maintained those outcomes. The vehicle simulation data used in this assessment rely on a validated model used by the auto industry that includes systems level analyses of the subsystems of the vehicle, including the various types of fuel intake systems, engines, drivetrain configurations, electrical systems, and overall vehicle drag and resistance parameters.

Section 5.3, “Incremental Cost of Technologies,” examines the incremental cost of the climate change reduction technologies of Section 5.2. The analysis includes a collection of cost data for the technology packages modeled by NESCCAF. Our cost estimates associated with the technologies of the previous section again rely to a large extent on the portion of the NESCCAF study conducted by Martec, which specifically analyzes the costs associated with the vehicle technology packages that were examined in the vehicle simulation modeling. Determination of the costs of these technologies involved a detailed investigation of all of the components involved in implementing them in baseline vehicles, with inclusion of the effects of the new technologies on other vehicle systems. The level of detail in the cost analysis again raises the bar relative to any other cost study that we have seen to date. However, there are some aspects of the cost analysis that ARB staff believes need to be modified to meet our long-term cost projection guidelines. Specifically, ARB staff applied additional cost reduction factors for some emerging technologies that account for additional innovation and higher volume learning than was assumed by Martec. In some cases, cost estimates from various other sources were also included in our assessment. California-specific vehicle use data, such as average annual vehicle use and vehicle lifetime, were obtained from the California Department of Motor Vehicles and the ARB’s EMFAC emission model.

Section 5.4, "Lifetime Cost of Technologies to Vehicle Owner-Operator," includes a net present value analysis of climate change emission reduction technologies. This assessment is under the direction of AB 1493 to demonstrate climate change reduction technologies that are "Economical to an owner or operator of a vehicle, taking into account the full life-cycle costs of a vehicle." Here we apply the initial incremental retail price of the technologies, average vehicle use data, and the resulting lifetime cost benefits to the consumer from the technologies to determine whether technology packages are economical over the life of the vehicle.

5.2 Technology Assessment

NESCCAF established baseline vehicle characteristics and assessed technologies with potential to reduce greenhouse gas emissions for carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), and hydrofluorocarbons (HFCs). This was done for five current representative vehicles. These five base vehicles were established in order to compare the differences of various greenhouse gas reduction technologies on various vehicle platforms (e.g. cars, minivans, trucks) with differing characteristics (e.g., maximum power, acceleration).

U.S. Environmental Protection Agency data (from EPA, 2003) was used to establish five representative current vehicles using data from 2002 model year light-duty vehicles. Representative vehicles were chosen to correspond to each of five passenger vehicle classes – small cars, large cars, minivans, small trucks, and light trucks. Separating the fleet into these five subdivisions was done to group vehicles that have similar attributes (e.g. weight, size), have comparable performance (e.g., acceleration), have similar technologies (e.g., transmission types, valvetrain designs), and that are functionally similar. This approach makes the modeling exercise affordable by limiting the number of modeling runs. The approach also acknowledges that some greenhouse gas-reducing technologies may be more applicable to different vehicle classes than others, and each vehicle modeling platform starts from a vehicle that is commercially viable with compatible subsystems.

Table 5.2-1 shows each of the five representative vehicles that was chosen to represent its vehicle class in terms of the following attributes: engine type, number of cylinders, transmission type, maximum power, engine displacement, curb weight, number of transmission speeds, driveline type, and cam type. The table also includes average vehicle class performance characteristics from the EPA (2003) data, including power and acceleration characteristics. Instead of making idealized composite vehicles that had the average or most common sales-weighted vehicle attributes, five actual 2002 model year vehicles were chosen based on closeness of fit to their class average attributes, average performance parameters, and dominant technologies. By choosing existing vehicles, not all characteristics are the exact average of their class. Instead, all the characteristics closely match the class averages, and the vehicles have the advantage of being based on actual existing vehicle platforms.

Table 5.2-1: Representative 2002 Vehicles (NESCCAF, 2004)

		Vehicle class				
		Small car	Large car	Minivan	Small truck	Large truck
EPA-defined vehicle types included		Sub-compact and compact sedans	Mid-size and large sedans	Minivans	Small sport utility vehicles and small pick-ups	Standard pick-ups and large sport utility vehicles
Class average vehicle attributes	Curb weight (lbs)	2762	3380	3980	3714	4826
	GVWR (lbs)				4867	7167
	Engine displacement (liters)	2.27	3.18	3.42	3.41	5.01
	Engine Type	L4	V6	V6	V6	V8
	Charge Type	NA	NA	NA	NA	NA
	Cam Type	DOHC	DOHC	OHV	DOHC	OHV
	Driveline	FWD	FWD	FWD	4WD	4WD
	Transmission Type	Automatic	Automatic	Automatic	Automatic	Automatic
	Number of Transmission Speeds	4	4	4	4	4
	Rated power (hp)	148	194	199	195	257
Performance characteristics	Peak Torque (lb-ft)	152	208	222	218	311
	Power/weight ratio (HP/lb)	0.0530	0.0569	0.0498	0.0524	0.0537
	Torque/weight ratio (lb-ft/lb)	0.0545	0.0610	0.0558	0.0586	0.0649
Representative vehicles for vehicle class		Chevrolet Cavalier 2.2 L I-4	Ford Taurus 3.0 L V-6	Daimler Chrysler Town & Country 3.3 L V-6	Toyota Tacoma 3.4 L V-6	GMC Sierra 5.3 L V-8

Baseline exhaust CO_2 emissions for each of five vehicle classes were based on a combined EPA driving cycle. The EPA combined cycle includes a driving schedule of specific speeds over time to simulate city driving, called the Federal Test Procedure (FTP, also known as the Urban Dynamometer Driving Schedule (UDDS)), and another cycle to simulate highway driving (HWY). Because the resulting emissions from the FTP and HWY cycles are used to determine California vehicle emission certification compliance, using a weighted combination of the CO_2 emissions results from both cycles was deemed appropriate for this assessment.

The greenhouse gas emissions of interest in this report impact the atmospheric radiation budget differently due to their distinct chemical and physical properties. For the purpose of this report, they are expressed in terms of their CO_2 equivalent global warming potential (GWP). Table 5.2-2 lists the GWP value for these gases. The emission rate of 0.005 grams of CH_4 per mile for 2009 baseline vehicles is derived using EMFAC. The emission rate of 0.006 grams of N_2O per mile driven was derived from the ratio of N_2O to oxides of nitrogen derived from emission test data generated at ARB's vehicle test facility.

Table 5.2-2: Global Warming Potential

Greenhouse Gas Compound	Global Warming Potential
Carbon Dioxide	1
Methane	23
Nitrous Oxide	296
HFC 134a	1300
HFC152a	120

Source: IPCC, Third Assessment Report, 2003

Mobile air conditioning has an environmental impact because of both "direct" refrigerant releases and "indirect" exhaust CO_2 emissions. Direct emissions include refrigerant releases from vehicles through air conditioning system leakage (a slow process, sometimes called "regular emissions"), during accidents or other events that suddenly breach containment of the system refrigerant (sometimes called "irregular emissions"), during service events, and when vehicles are dismantled without recovery of the refrigerant. The dominant refrigerant used in vehicle air conditioning systems is 1,1,1,2-tetrafluoroethane, which is a hydrofluorocarbon commonly referred to as HFC-134a. The NESCCAF study also included modeling runs to estimate the total amount of "indirect" CO_2 exhaust emissions that is associated with the use of the air conditioning system. Both the "indirect" CO_2 emissions and the CO_2-equivalent "direct" HFC emissions are summarized in Table 5.2-11 and Table 5.2-12.

In the following subsections (5.2.A) through (5.2.E), technologies with potential to achieve net reductions in total baseline vehicle greenhouse gas emission levels are investigated. The technologies involved are briefly described and the potential emission reduction benefits are quantified. The assessment of technology options to reduce these emissions is split into the five generalized technology areas:

5.2.A <u>Engine, Drivetrain, and Other Vehicle Modifications</u> – valvetrain, transmission, vehicle accessory, hybrid-electric, and overall vehicle modifications designed to reduce engine exhaust CO_2 emissions from conventional vehicles
5.2.B <u>Mobile Air-Conditioning System</u>– air conditioning unit modifications to reduce vehicle CO_2 emissions and refrigerant modifications to reduce emissions of HFC refrigerants, such as HFC-134a
5.2.C <u>Alternative Fuel Vehicles</u> – the use of vehicles that use fuels other than gasoline and diesel to reduce the sum of exhaust emissions and "upstream" fuel-delivery emissions of climate change gases
5.2.D <u>Exhaust Catalyst Improvement</u> – exhaust aftertreatment alternatives to reduce tailpipe emissions of CH_4 and N_2O

5.2.A Engine, Drivetrain, and Other Vehicle Modifications

This section includes research into the potential to reduce tailpipe carbon dioxide emissions with the introduction of various available or emerging valvetrain, engine, transmission, vehicle accessory and body improvement technologies on conventional gasoline and diesel vehicles by model year 2009. The assessment relies primarily on the NESCCAF (2004) analysis, which establishes baseline 2009 vehicle characteristics and evaluates the potential CO_2 reductions from individual technologies and packages of multiple technologies. Many of these technologies could also be applied to alternative fuel vehicles, which would further increase their greenhouse gas emission benefits.

5.2.A.1 Carbon Dioxide Reduction Technologies

This subsection provides brief, generalized descriptions of the carbon dioxide reduction technologies and their levels of commercial deployment. The technologies being explored for carbon dioxide emission reductions are currently available on vehicles in various forms or have been demonstrated by auto companies or vehicle component suppliers in prototype form, so as to conform to the 2009 – 2015 timeframe of the assessment. Although general estimates for potential CO_2 reductions can be found in the technical literature, they are not reported here because improved and more detailed estimates are obtained from the vehicle simulation modeling results below for one or more of these technologies on specific vehicles. These technologies are contained either in or around the engine itself, pertain to the transfer of motive force between the engine and the wheels through the drivetrain, or involve overall vehicle changes. Those technologies contained in the engine include modifications to the functioning of the intake and exhaust valves, the charge type, or the injection and preparation of the fuel or fuel-air mix into the cylinders. Drivetrain technologies that could reduce greenhouse gases include modifications to the transmission and various degrees of hybridization. This section offers a brief description of these technology options. Abbreviations for each of the technologies within each description in this section are used to refer to the technologies in shorthand in later sections of this report.

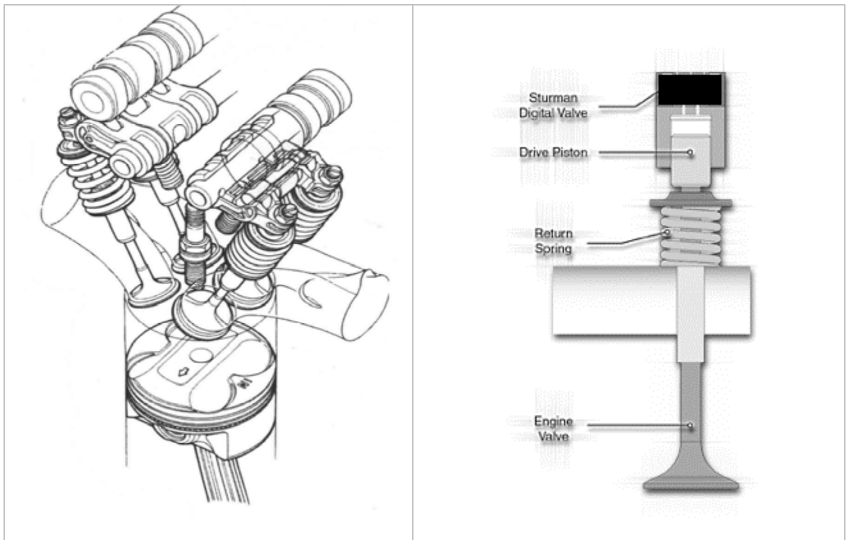
Factors that affect CO_2 emissions from an engine include friction of internal components and the presence of a throttle that restricts airflow into the engine, thereby resulting in pumping losses. The remainder of the driveline also contributes to higher CO_2 emissions due to frictional and hydraulic losses in the transmission and differential or transaxle. Further, CO_2 emissions are increased due to the work performed by the engine to run accessories needed to maintain the electrical system, operate the power steering and air conditioning compressor, or from operation of other devices. CO_2 emissions are further increased when the engine has to work to overcome inertial forces due to vehicle weight during acceleration or hill climbing, to overcome wind resistance, or to overcome tire rolling resistance. Shutting off the engine when possible during idling reduces CO_2 emissions and using a regenerative braking system for capturing otherwise lost energy to assist in relaunching a vehicle from a stop also minimizes CO_2 emissions production.

Engine Valvetrain Modification
Valve timing and lift have historically been fixed for most manufacturers regardless of vehicle load demand. Variable valve timing, also known as “cam phasing,” and variable valve lift can improve engine carbon dioxide emissions by more optimally managing

precisely when the valves open and close and exactly how much they open and close. Cam phasing can be varied either by linking the intake and exhaust cams together and rotating them with one phaser (CCP) or independently using dual cam phasers (DCP) for varying engine operation conditions. Valve lift technologies can be introduced to make continuous variations in lift (CVVL) or make discrete valve height lift increments (DVVL). These technologies can also be introduced either singly or in combination, providing reduced engine pumping losses, improved power output that permits engine downsizing, and substantial CO_2 reductions.

Increased control of intake and exhaust valves also provides for selective cylinder deactivation (DeAct) by closing both sets of valves. The selective deactivation of cylinders allows each of the other still-active cylinders to operate in more optimal regions of higher loads (higher torque and/or engine speeds) and reduces pumping losses. The technology has been found to be better suited for vehicles with relatively high engine displacement to weight ratios and engines with at least six cylinders.

More advanced and offering even greater improvements are camless valve actuation (CVA) systems that replace a belt, chain- or gear-driven camshaft system with variable electrohydraulic or electromagnetic actuation of the valves. Electrohydraulic actuation systems provide greater potential to reduce CO_2 emissions than electromagnetic systems since less power is required for system operation throughout the engine speed range. As shown in Figure 5-1, electrohydraulic camless valve systems are relatively simple in their design and operation. Electromagnetic systems continue to have issues with valve closing force and attendant noise, but progress is being made according to some. Also, electrohydraulic systems can incorporate variable valve lift more readily. However, there are proponents for both systems who strongly believe they will be in volume production in the 2012 timeframe. Camless valve actuation is the ultimate goal of engine designers to achieve optimum valve position and lift for maximum engine performance and lowest CO_2 emissions over the full range of engine operation. Engines with CVA systems do not need a throttle and can deactivate cylinders at anytime as opportunity exists. Staff is aware of significant development activity taking place in Europe and Japan. Manufacturers that develop this technology such that they are first to market will have a strong competitive advantage. It also represents a more logical next step for manufacturers of overhead valve engines than going to overhead cam designs that might be short-lived should camless valve actuation come to fruition as early as the 2010 timeframe as is now predicted.



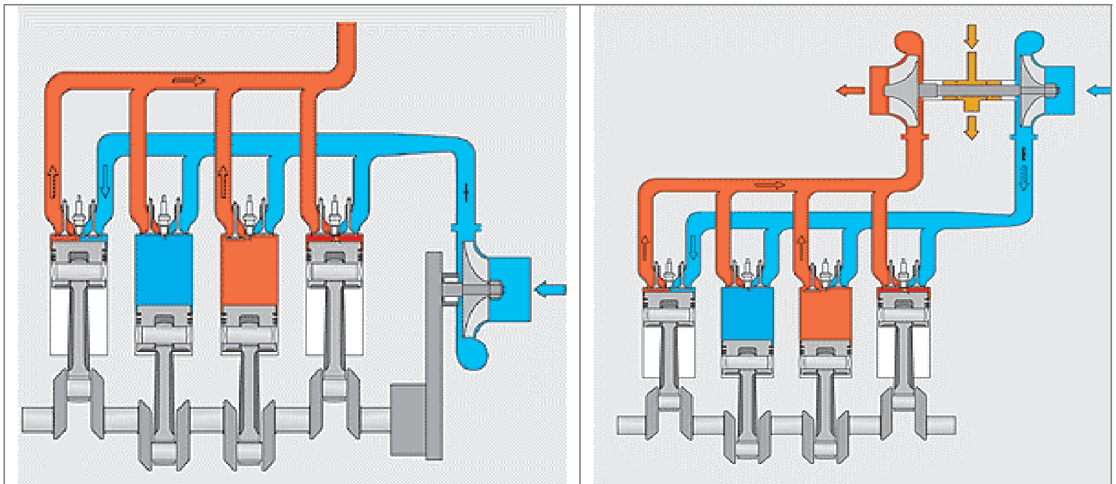
Variable valve timing and lift
(Honda V-tec system)

Electrohydraulic valve actuation
(Sturman DHOS Valve Technology)

Figure 5-1: **Two Variable Valve Systems**

Charge Modification

In conventional gasoline-fueled passenger vehicles, air-fuel mixture (i.e. “charge”) enters the cylinders near ambient pressure. Increasing, or “boosting”, the pressure of the air-fuel mix in the cylinder results in a higher specific power output from the engine. Therefore, the use of a supercharging or turbocharging compressor to increase the charge entering the cylinders improves engine power output and offers the opportunity to downsize the engine without compromising vehicle performance, thereby allowing operation of the engine in more optimal, low-CO_2 regions. A supercharger (Super) offers this advantage by using mechanical power directly off the main engine. A turbocharger system (Turbo) utilizes the otherwise lost thermal energy of the exhaust to operate a turbine, which then drives a compressor. Both of these systems are shown schematically in Figure 5-2. Superchargers were not modeled in the NESCCAF study since they do not offer the level of CO2 benefits achieved from turbochargers and are generally more costly. Current state of the art turbochargers incorporate a variable geometry feature that provides quicker boost at all speeds to maintain performance from downsized engines, especially at lower speeds where “turbo lag” can otherwise result in sluggish performance.



Mechanical power supercharging (BorgWarner Turbo Systems) | Exhaust gas turbocharging (BorgWarner Turbo Systems)

Figure 5-2: **Schematics for Supercharged and Turbocharged Engines**

Variable Compression Ratio
Engine compression ratio is a key determining factor for optimal engine operation and lower CO_2 emissions. Current gasoline engines generally use a compression ratio of about ten-to-one and are limited from using higher ratios by pre-ignition or “knocking” at high loads. Because knocking generally increases with engine load, overall CO_2 emissions can be improved with the use of higher compression ratios at lower loads and lower compression ratios under higher loads with the use of variable compression ratio (VCR) technology that can vary cylinder geometry. This technology, however, is relatively expensive to implement given its current state of development and greater CO_2 reductions can be obtained from other approaches at less cost. Therefore, the NESCCAF study did not include modeling of this technology.

Gasoline Direct Injection
Carbon dioxide reductions can be achieved through modifications of the fuel injection system of gasoline vehicles to directly inject the fuel into the cylinder where the air is already compressed (conventional engines inject fuel into the intake manifold ahead of the intake valve, wherein fuel evaporates and is inducted into the cylinder with the incoming air). This can be done under stoichiometric (i.e., using only enough air to burn the fuel) or “lean burn” (i.e., excess air) conditions. Due to thermodynamic improvements, lean burn GDI (GDI-L) systems can offer substantial CO_2 reductions, but with some complications involved in controlling oxides of nitrogen (NO_x) emissions. Advances in lean burn aftertreatment devices similar to those being developed for diesel engines may offer a solution. Stoichiometric GDI (GDI-S) systems offer smaller CO_2 reductions than GDI-L technology, but without NO_x aftertreatment concerns.

Homogeneous Charge Compression Ignition
Through precise control of the temperature and pressure in the combustion chamber, spontaneous and homogeneous ignition of the air fuel mixture can occur. Since combustion occurs simultaneously throughout the combustion chamber without forming a flame front and at lower temperatures than conventional spark ignited engines,

engine-out particulate matter (PM) and NO_x emissions are very low. Homogeneous charge compression ignition (HCCI) can offer substantial CO_2 emission reductions and can be applied to engines using a variety of fuels, including gasoline and diesel. While significant effort is being directed to its development, some technical challenges remain before it becomes commercially applicable. At present, HCCI operation is possible only in a portion of the engine operating range. Therefore gasoline engines with this capability are based on a direct injection engine wherein its spark ignition capability is retained for the non-HCCI operating modes that will continue to require a spark to ignite the mixture.

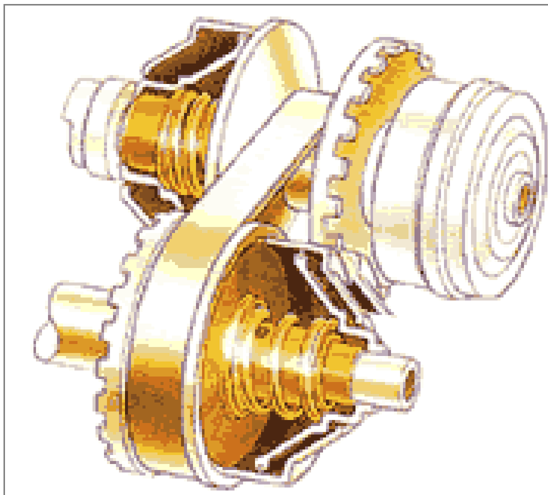
Diesel Fuel
High speed direct injection (HSDI) diesel vehicles have improved with the advancement of several technologies. Diesel compression-ignition engines, with higher compression ratios, turbocharging, and lean air-fuel ratios provide significant CO_2 reductions compared with conventional gasoline engines. Advancements in small diesel engines running at high speeds (over 4000 rpm compared to heavy-duty diesel engines at less than 2000 rpm) in the areas of fuel injection, emissions, noise, and vibration have addressed many of the more objectionable aspects of these vehicles, making them more acceptable to the public. Diesel vehicles are becoming popular in Europe but face a substantial challenge meeting more stringent emission standards in the U.S. Advanced multi-mode diesel engines combine homogeneous charge compression ignition operation at lower engine speeds and loads to minimize particulate matter (PM), NO_x and CO_2 emissions compared to conventional diesels and revert to conventional diesel engine operation at higher speeds and loads to ensure expected power levels. Maximum use of homogeneous charge combustion operation reduces CO_2 emissions and lessens the burden of aftertreatment of NO_x and PM emissions.

Engine Accessory Improvement
Improvements to various electrical components on vehicles can provide significant improvements in CO_2 emissions. Electrification (eACC) of engine accessory subsystems, such as coolant pumps and other accessories, can reduce the overall losses associated with powering them mechanically. Electrifying the power steering for most cars or utilizing an electro-hydraulic power steering system for larger cars and trucks is also being considered for its contribution to total vehicle CO_2 emissions. Improvements in the vehicle alternator (ImpAlt) that would power these accessories can also provide benefits.

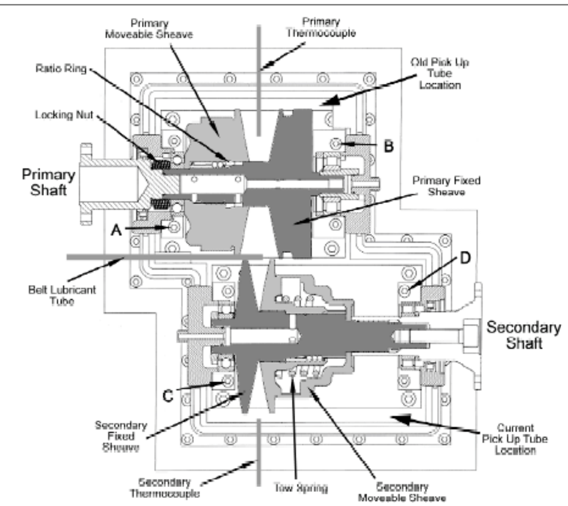
42 Volt Systems
Upgrading of vehicle electrical systems to 42 volts (42V), a step many manufacturers are currently contemplating, is an enabling technology for more diverse electrical opportunities. The 42-volt electrical system can accommodate more powerful electrical accessories on-board the vehicle and an integrated starter generator. An integrated starter-generator 42-volt vehicle system (ISG 42v) recoups energy while decelerating through regenerative braking and provides instantaneous engine restart to avoid engine idling; some variants can provide power assist in vehicle acceleration.

Transmissions

Automatic transmissions on today's vehicles generally have 4 gear ratios, or speeds. Increasing the number of gears to 5- or 6-speeds, as has already been done in numerous vehicle models, allows the engine to operate in more optimum operating ranges for lowest CO_2 emissions during the drive cycle. Each increase in number of speeds corresponds approximately to a two percent reduction in CO_2 emissions. More advanced transmissions may offer more substantial improvements. The automated manual transmission (AMT) acts like a conventional automatic transmission in that shifting is performed automatically, but no torque converter used. AMTs operate with either one or two electronically controlled clutch mechanisms. Some of the transmissions are in production in Europe. These transmissions may need some additional refinement to achieve the shift quality of conventional automatic transmissions and to improve driveline vibration. Just as increasing the number of gears from 4 to 5 speeds or more allows the engine to operate closer to its ideal operating point at any given time, the continuously variable transmission (CVT) provides engines a greater ability to operate at precisely the optimal speed for the required load. The CVT effectively acts as a transmission with an infinite number of gears, using either a belt or chain on a system of two pulleys (see Figure 5-3). At this time, however, manufacturers seem to be obtaining most of the CO_2 emission reductions of a CVT by using a 6-speed automatic transmission at significantly less cost. Therefore, few of the modeling runs incorporated CVTs.



Honda CVT



Schematic for CVT developed by General Motors and Southwest Research Institute

Figure 5-3: Continuously Variable Transmissions

Hybridization

Hybridization, or use of both combustion engines and electric motors for propulsion, is being actively explored by all major auto manufacturers. Hybridization of current and planned vehicles varies widely from "mild" hybrids, which tend to be more similar to conventional gasoline passenger vehicles to fully-integrated "advanced" hybrids that use and store more electric energy on-board. Differentiating the mild system from more advanced hybrids is the increased extent to which electrical power is stored on the vehicle and used during driving. In a fully integrated hybrid (e.g., Toyota Prius), the electric motor approaches the same size as the on-board combustion engine and therefore can be used exclusively to power the vehicle during low-load, low speed conditions. In the moderate "motor-assist" hybrid configuration, such as the Honda Civic Hybrid, the maximum power output of the engine is substantially greater than that of the electric motor. The electric motor then is generally used for times of higher load demands, such as acceleration or hill climbing, providing for engine downsizing and optimization for low load conditions such as cruising. Mild hybrids generally offer only idle off capability. Compared with similar performing conventional vehicles, moderate to aggressive hybrids can achieve improvements of over thirty percent in CO_2 emissions. Along with the commercially available Toyota and Honda hybrid vehicles, every major automaker has introduced plans to mass produce hybrid vehicles in the next few years. EPA is investigating the potential of hydraulic hybrids and has published an interim report on their progress.

Engine Friction Reduction
Due to the large number of internal parts in today's engines coupled with numerous accessory drives, improvements in the design of engine components and subsystems can continue to drive friction reductions, resulting in improved engine operation and reduced climate change emissions. Friction reductions in and around the engine can result from such measures as engine component weight reduction, use of different materials, more optimal thermal management, and improved computer-aided understanding of component dynamics under various engine load and vibration conditions. Further friction reductions result from the use of advanced multi-viscosity engine and transmission oils.

Aerodynamic Drag and Rolling Resistance Reduction
Improvements in the overall force required to propel a vehicle reduces engine load thereby leading to a reduction in vehicle exhaust CO_2 emissions. Two ways to reduce the engine load for a given vehicle are to reduce the opposing resistance or frictional forces that act against the motion of the vehicle. Two prominent resistance forces are aerodynamic drag and rolling resistance at the tires. The most obvious areas for potential aerodynamic drag improvements are reducing the frontal area of the vehicle or improving the shape of the body, with skirts, air dams, underbody covers, and other features that have less aerodynamic friction. The rolling resistance force due to friction between the tires and the road can be improved via shoulder design improvements or with design and material modifications to the tire tread pattern, tire belts, or the traction surface.

Aggressive Shift Logic
Shifting schedules, or the engine speed at which automatic transmissions switch from one gear ratio to another, can have a substantial impact on CO_2 emissions. Using a more aggressive shift logic allows more flexible shifting of gears and thus allows for operation of the engine at more optimal low CO_2 emission regions of the engine maps. Generally, aggressive shift logic entails moving transmission upshift points to lower speeds and reducing the amount of downshifting. Driveability and acceleration concerns must be accounted for carefully in these alterations of shifting schedules.

Early Torque Converter Lock-up
Conventional automatic transmissions employ a torque converter between the engine and transmission. This is a fluid coupling with hydraulic torque multiplication capability that helps provide a brisk “launch feel” to vehicles so-equipped. They also dampen engine vibrations in the driveline and allow engines to remain at idle speeds with the transmission engaged in a forward or reverse gear. Unfortunately, the torque multiplication at launch and the other features result in higher CO_2 emissions compared to a manual transmission. In order to reduce slip, virtually all of today’s automatic transmissions offer some degree of lock-up capability during some light accelerations and during cruise conditions (this means the torque converter no longer slips needlessly and provides direct or near-direct mechanical transmission of power to the drive wheels much like a manual transmission). The conditions under which lock-up operation occurs can be improved by doing so earlier than at present, especially when the number of transmission speeds increases, thereby reducing CO_2 emissions. As with early shift speeds, however, care must be exercised to ensure smooth, responsive driveability and low noise, vibration, and harshness. AVL was conservative in its modeling of these features to ensure good driveability and minimum vibration.

Weight Reduction
Although ARB staff efforts will not rely on weight reductions in setting its climate change emission standards, manufacturers would still have the option of lowering weight to improve CO_2 emission performance. Lower weight results in lower CO_2 emissions by lowering the forces needed to accelerate the vehicle and climb grades. Lower weight can be achieved by substitution of lighter materials, better packaging, and shifting to a smaller platform. Besides the use of high strength low alloy steels, some manufacturers are relying on more use of aluminum and magnesium alloys and plastics to achieve greater weight savings, although at somewhat higher cost than steel.

5.2.A.2 Summary of Vehicle Simulation Modeling Results

As was alluded to above, a detailed vehicle simulation model was used in the NESCCAF study to predict baseline 2002 CO_2 emissions and to estimate CO_2 emission reductions from applying various combinations of technologies to the baseline vehicles. The year 2002 is held as a base year for the calculations because it is the year that the modeling platforms were built upon and it is most recent year for which extensive and actual knowledge on the vehicle fleet was available. Moreover, emissions are reported using the 2002 model year as a baseline because it is likely to be the year that will later be used in quantifying pre-2009 climate change reduction credits. Because the pending regulation would be applicable for model year 2009 and later vehicles, potential reductions for 2009 vehicles are also provided in the summary.

The modeling presented here (and in the NESCCAF report) utilizes the vehicle simulation model developed by AVL Powertrain Engineering, Inc. called CRUISE. The modeling software is designed for the advanced study of various vehicle platforms to provide estimates of vehicle performance, emissions, and fuel usage. The modular systems-based nature of the CRUISE software allows for investigation of sophisticated and detailed analyses of each vehicle component, from the fuel intake system and engine through the drivetrain to the tires. An advantage of systems modeling such as this is to allow a wide diversity of combinations of technologies to be modeled together and examine how they interact together when simulating a vehicle driving on various driving cycles.

The AVL CRUISE model was first used to create the five 2002 representative vehicle simulation models with representative attributes and to validate these models with the known actual vehicle performance characteristics. In addition to modeling the 2002 representative vehicles, separate 2009 baseline vehicles were characterized through analysis of vehicle trends and market research in order to quantify costs and benefits of vehicle technologies. The NESCCAF study uses EPA data on vehicle trends to characterize vehicle class characteristics and market research by Martec to forecast vehicle technology platforms that will dominate the base case, or "business-as-usual," (i.e. absence of new regulations) 2009 model year vehicles. With the use of historical trends from the EPA (EPA 2003b) dataset, the baseline vehicle characteristics of acceleration and weight were examined. The 0-60 miles-per-hour acceleration changes for the five vehicle classes were projected to increase by seven to sixteen percent for the 2009 model year. Averaged vehicle inertia weights were projected to hold constant for all the classes except for small cars due to historical trends and pending implementation of federal CAFE regulations for light duty trucks.

The NESCCAF study highlights several key technology changes for their "business-as-usual" scenario for the 2009 model year. The Martec market research projected the technologies that are likely to enter the vehicle fleet to deliver the power and acceleration requirement for 2009 for each of the five vehicle classes. The primary differences from the 2002 fleet are the widespread introductions of emerging engine valvetrain and transmission technologies. Introducing cam phasing technology to alter the timing of intake and/or exhaust valves during engine operation is forecasted to dominate in each vehicle class, and all classes but the large truck are expected to have some form of variable valve lift technology. Each vehicle class is expected to increase the number of transmission gears from four to either five (for small cars and minivans) or six (large cars, small trucks, and large trucks). All vehicles were then modeled on a combined EPA driving cycle. Using a weighted combination of the emissions from the FTP and HWY cycles was deemed appropriate for the assessment because the emissions from these cycles are used to determine California vehicle emission certification.

The technologies for reducing CO_2 emissions were modeled both individually and in various technology packages by AVL. A summary of the modeling results for individual technologies from the NESCCAF study is shown in Table 5.2-3. In the table, the baseline 2002 CO_2 emission rates, in grams per mile, for each vehicle class are shown, and the results from the other modeling runs are shown as percentage reductions from these baseline values. Modeling of single technologies often was accomplished through partial CRUISE modeling or use of other abbreviated simulation techniques to save cost in the study. This seems reasonable since this step was only intended to provide an estimate of the benefits in order to provide a basis for selecting the technology combinations for full CRUISE modeling.

Table 5.2-3: Potential Carbon Dioxide Emissions Reductions from Individual Technologies (from NESCCAF, 2004)

	Vehicle Class				
	Small car	Large car	Minivan	Small truck	Large truck
Baseline 2002 CO_2 emissions (g/mi)	291.4	344.6	395.4	444.7	511.6
Technologies	*Percent reduction from 2002 baseline*				
Near Term Technologies 2009-2012					
Intake Cam Phasing	-2%	-1%	-1%	-1%	-2%
Exhaust Cam Phasing	-2%	-3%	-2%	-2%	-3%
Dual Cam Phasing (DCP)	-3%	-4%	-2%	-3%	-4%
Coupled Cam Phasing (CCP)	-3%	-4%	-2%	-2%	-4%
Discrete Variable Valve Lift (DVVL)	-4%	-4%	-3%	-4%	-4%
Continuous Variable Valve Lift (CVVL)	-5%	-6%	-4%	-5%	-5%
[2]Turbocharging (Turbo)	-6%	-8%	-6%	-6%	
[3]Electrically Assisted Turbocharging (EAT)	-6%	-8%	-6%	-6%	
[2]Cylinder Deactivation (DeAct)	-3%	-6%	-5%	-6%	-4%
[1]Variable Charge Motion (CBR)	-3%	-4%	-2%	-3%	-4%
[5]Variable Compression Ratio	-7%	-7%	-7%	-7%	-7%
[5]Gasoline Direct Injection - Stochiometric (GDI-S)	0%	-1%	1%	1%	0%
[2]4-Speed Automatic Transmission	0%	0%	0%	0%	0%
[2]5-Speed Automatic	-2%	-1%	-1%	-1%	-1%
[2]6-Speed Automatic	-3%	-3%	-3%	-3%	-2%
[6]6-Speed Automated Manual	-8%	-7%	-8%	-8%	-5%
[2]Continuously Variable Transmission (CVT)	-4%	-3%	-4%		
[2]Electric Power Steering (EPS)	-1%				-1%
[3]Electro-Hydraulic Power Steering (E-HPS)	-1%				-1%
[2]Improved Alternator (Higher efficiency)	-1%				0%
[2]Electric Accessories	-3%				-2%
[3]Aggressive Transmission Shift-Logic	-1.5%	-1.5%	-1.5%	-1.5%	-1.5%
[3]Early Torque Converter Lock-up	-0.5%	-0.5%	-0.5%	-0.5%	-0.5%
[2]Variable Displacement AC Compressor	-10%	-9%	-7%	-9%	
[2]Aerodynamic Drag Coefficient (% CO_2 / % Cd)	0.165				0.192
[2]Improved Tire Rolling Resistance (% CO_2 / % TRR)	0.180				0.204
Mid Term 2013-2015					
[1]Electromagnetic Camless Valve Actuation (emCVA)	-11%	-11%	-11%	-11%	-11%
[2]Electrohydraulic Camless Valve Actuation (ehCVA)	-11%	-16%	-11%	-13%	-12%
[5]Gasoline Direct Injection - Lean-Burn Stratified (GDI-L)	-6%	-9%	-4%	-5%	-8%
[5]Gasoline Homogeneous Compression Ignition (gHCCI)	-4%	-6%	-3%	-4%	-5%
[2]Electric Water Pump (EWP)	0%				0%
[2]42-Volt 10 kW ISG (Start Stop)	-7%	-4%	-4%	-4%	-5%
[2]42-Volt 10 kW ISG (Motor Assist)	-10%	-6%	-6%	-6%	-5%
[2]Diesel – HSDI	-20%	-22%	-24%	-27%	-23%
Long Term 2015-					
[6]Moderate Hybrid-Electric Vehicle (HEV)	29%	29%	29%	29%	29%
[6]Advanced Hybrid-Electric Vehicle (HEV)	54%	54%	54%	54%	54%
[2]Diesel – Advanced Multi-Mode	-13%	-15%	-18%	-21%	-17%

[1] Based on Literature Search; [2] Based on Full AVL CRUISE Simulation; [3] Based on Combined Literature/AVL CRUISE Simulation; [4] Estimated Value; [5] Additional Reduction due to Downsizing is not Included; [6] HEV numbers based on internal ARB analysis (not from NESCCAF, 2004), See Technical Support Document

This report relies on Martec's analysis of hybrid electric vehicle costs and ARB staff assessment of hybrid vehicle benefits based on current production vehicle data. Although the NESCCAF (2004) report did study the effect of moderate and advanced hybrid-electric vehicles, the analysis was less detailed and less comprehensive than their intricate modeling of the other technologies due to cost and time constraints. As a result, the ARB staff opted to do an independent review of HEV CO_2 emission reduction capability, using real-world data from currently available vehicle platforms.

Given the multitude of technologies available for reducing vehicle CO_2 emissions, there needs to be some engineering guidelines for choosing combinations that would be economical to the consumer. Generally it is important to avoid combining technologies that tend to address the same categories of losses or technologies that may not complement each other from a driveability standpoint. For example, it would not be advisable to combine cylinder deactivation capability with a lean burn gasoline direct injection engine design since both technologies address reductions in pumping losses within an engine. Also, when transitioning in and out of the deactivation mode, operating in a lean burn mode at the same time could make the transitions more noticeable to the driver since larger throttle changes would be needed to ensure constant engine torque than if the vehicle were operating in a stoichiometric mode.

Some technologies are attractive to combine because their features enhance each other. For example, combining cylinder deactivation with stoichiometric gasoline direct injection makes sense since the transitions in and out of the deactivation mode tend to introduce fuel control challenges due to the abrupt changes in operating modes that occur. By using a direct injection concept where fuel is introduced directly into the combustion chamber, control of transient fueling is much more precise. This is because fuel preparation and wall wetting issues in the intake passages encountered with conventional engines introduce fueling errors in transient engine operation. The more precise control afforded by direct injection would therefore be an enabler for some engines to meet the lowest emission categories in the Low-Emission Vehicle program when utilizing cylinder deactivation.

Some technologies are attractive because they provide elegant solutions to minimizing CO_2 emissions. One such technology is electrohydraulic camless valve actuation combined with stoichiometric gasoline direct injection. This technology permits operating the engine in modes that generate the lowest CO_2 emissions at all times with minimum complexity. It would allow operation without a throttle to minimize pumping losses, could employ cylinder deactivation whenever it was useful, and would provide the maximum flexibility necessary to achieve maximum performance from a given engine displacement, thereby enabling smaller engine displacements. Again, stoichiometric gasoline direct injection would further complement this technology because it permits higher compression ratios due to the cooling effect of fuel evaporation in the combustion chamber, thereby affording more optimal engine operation from a low CO_2 emission standpoint.

AVL provided a chart summarizing the most appropriate engine technologies to group for achieving the most cost effective CO_2 emission reductions (Figure 5-4). The chart is read first across and then down (as illustrated by the arrow) to determine which technologies are compatible. For example, turbocharging is considered compatible with all technologies except GDI lean burn, since both technologies address the same engine pumping losses. Therefore, it is unlikely that a manufacturer would combine these two technologies. This figure was used by NESCCAF participants when they constructed their technology combinations.

Feasible Technology Combinations	Cam Phaser - Single (Intake Cam)	Cam Phaser - Single (Exhaust Cam)	Cam Phaser - Dual	Cam Phaser - Coupled	Variable Valve Lift - Discrete	Variable Valve Lift - Continuous	Camless Valve Actuation - Electrohydraulic	Turbocharging	Electrically Assisted Turbocharging (EAT)	Cylinder Deactivation	Variable Charge Motion (CBR)	GDI Stochiometric	GDI Lean Burn Stratified	Gasoline HCCI	Diesel – HSDI	Diesel – Advanced Multi-Mode
Cam Phaser - Single (Intake Cam)																
Cam Phaser - Single (Exhaust Cam)	NO															
Cam Phaser - Dual	NO	NO														
Cam Phaser - Coupled	NO	NO	NO													
Variable Valve Lift - Discrete	YES	YES	YES	YES												
Variable Valve Lift - Continuous	YES	YES	YES	YES	NO											
Camless Valve Actuation - Electrohydraulic	NO	NO	NO	NO	NO	NO										
Turbocharging	YES	YES	YES	YES	YES	YES	YES									
Electrically Assisted Turbocharging (EAT)	YES	YES	YES	YES	YES	YES	YES	NO								
Cylinder Deactivation	YES	YES	YES	YES	YES	NO	YES	NO	NO							
Variable Charge Motion (CBR)	YES	YES	YES	YES	YES	YES	YES	NO	NO	YES						
GDI Stochiometric	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES					
GDI Lean Burn Stratified	YES	YES	YES	YES	NO	NO	NO	NO	NO	NO	NO	NO				
Gasoline HCCI	YES	YES	YES	NO	YES	NO	YES	NO	NO	NO	NO	NO	NO			
Diesel – HSDI	NO	NO	NO	NO	NO	NO	YES	YES	YES	NO	NO	NO	NO	NO		
Diesel – Advanced Multi-Mode	NO	NO	NO	NO	NO	NO	YES	YES	YES	NO	NO	NO	NO	NO	NO	

Figure 5-4. **Feasible Technology Combinations**

Having selected a variety of engine technologies, further choices are available relative to the rest of the driveline for enhancing low CO_2 performance. Transmissions with more gear ranges allow the engine to operate more of the time in a low CO_2 mode, and continuously variable transmissions provide an unlimited number of ratios for achieving improvements. Use of a 6 speed automated manual transmission affords further reductions in CO_2 since it allows elimination of the torque converter utilized in a conventional automatic transmission or continuously variable transmission. CO_2 savings also result from use of integrated starter generators that permit shutoff of the engine when the vehicle is not in motion. Further, more capable integrated starter generators permit capture of braking energy that can be redeployed during relaunch of the vehicle to further minimize production of CO_2.

Engine accessories can also be designed to reduce CO_2 emissions through such technologies as variable displacement air conditioning compressors described later plus such features as electric power steering and improved efficiency alternators.

With these guidelines in mind, participants in the NESCCAF study assembled a wide variety of combined technologies to evaluate through simulation modeling those combinations that would provide the greatest CO_2 reductions. ARB staff provided some suggested technology combinations for full simulation modeling.

Table 5.2-4. Impacts and Costs of Additional CO_2 Reduction Technologies

Technology		Transmission Type		
		Automatic	Automated Manual	CVT
Improved Tires	Impact	10% reduction in rolling resistance = 2% reduction in CO_2		
	Cost	$20 to $90 RPE		
Engine Friction Reduction or Improved Lubricating Oil	Impact	Reduced internal friction/lower viscosity oil, 0.5% CO_2 reduction		
	Cost	$5 to $15 RPE		
Aerodynamic Drag Reduction	Impact	8-10% reduction in drag = 1.5-2% reduction in CO_2		
	Cost	$0 to $125 RPE		
Aggressive Shift Logic	Impact	1.5% CO_2 reduction	0.5% CO_2 reduction	None
	Cost	$0 to $50 RPE	$0 to $20 RPE	
Improved Torque Converter or Early Lockup	Impact	0.5% CO_2 reduction	None	
	Cost	$0 to $10 RPE		
Total Potential (Excludes Weight Reduction)	Impact	6% to 6.5% CO_2	4.5% to 5% CO_2	4% to 4.5% CO_2
	Cost	$25 to $290 RPE	$25 to $250 RPE	$25 to $230 RPE
Average RPE per Percent CO_2		$25	$29	$30
Assumed Improvement	Impact	5% CO_2 reduction	5% CO_2 reduction	4% CO_2 reduction
	Cost	$125 RPE	$145 RPE	$120 RPE

Notes: from NESCCAF, 2004

Table 5.2-4 lists the CO_2 improvements that can be achieved through various technologies such as lower rolling resistance tires and aerodynamic drag reduction. These improvements are included in the CO_2 benefits listed in Table 5.2-5 through Table 5.2-9 below containing the simulation modeling results for various combinations of individual technologies using the 2002 vehicle platforms.

Guidelines contained in Table 5.2-3, as well as cost, served as the basis for the selections in the following tables. The study participants also wanted to cover the full spectrum of CO_2 reductions that would be possible. We have partitioned the results into three categories for near-, mid-, and long-term *volume* application. Thus, while hybrid vehicles are available now in several models, they were nonetheless grouped with the long-term strategies since high volumes of moderate to aggressive hybrids probably would not occur until the long term. Additional time is needed to sort out the level of consumer acceptance, suitability in various applications, long term durability and other issues that include investment resources across the industry to accomplish large scale conversion to a significantly different technology than currently exists in the vehicle fleet.

In the following tables, CO_2 emission reductions and package costs are shown relative to both the 2002 and 2009 baselines that were established in the NESCCAF report. When describing the results following each table, the text highlights the CO_2 reductions relative to the 2002 baseline because this is the reference most studies use. For describing the costs, however, staff cites them relative to the 2009 baseline because those would be the actual increment that the consumer would see when purchasing a

2009 and subsequent vehicle (i.e., NESCCAF predicted that even without regulations, industry will be making some improvements to vehicles that could reduce CO_2 emissions and will increase their cost).

Table 5.2-5. Potential Carbon Dioxide Emissions Reductions from Small Car (NESCCAF, 2004)

Small Car	Combined Technology Packages	CO_2 (g/mi)	Potential CO_2 reduction from 2002 baseline	Retail Price Equivalent 2002	Potential CO_2 reduction from 2009 baseline	Retail Price Equivalent 2009
Near Term 2009-2012	DVVL,DCP,A5 (2009 baseline)	284	-2.6%	$308	0%	$0
	DCP,CVT,EPS,ImpAlt	270	-7.6%	$570	-5.1%	$262
	DCP,A4,EPS,ImpAlt	269	-7.6%	$360	-5.2%	$52
	DCP,A5,EPS,ImpAlt	260	-10.7%	$494	-8.3%	$186
	DCP,A6	260	-10.8%	$346	-8.4%	$38
	DVVL,DCP,AMT,EPS,ImpAlt	233	-19.9%	$465	-17.8%	$157
	GDI-S,DCP,Turbo,AMT,EPS, ImpAlt	215	-26.4%	$1128	-24.4%	$820
Mid Term 2013-2015	gHCCI,DVVL,ICP,AMT,EPS,ImpAlt	229	-21.6%	$673	-19.6%	$365
	CVVL,DCP,AMT,ISG-SS,EPS, ImpAlt	216	-25.7%	$869	-23.8%	$651
	gHCCI,DVVL,ICP,AMT,ISG, EPS,eACC	204	-29.9%	$1570	-28.1%	$1262
Long Term 2015-	dHCCI,AMT,ISG,EPS,eACC	217	-25.5%	$2536	-23.5%	$2228
	ModHEV	213	-26.9%	$1705	-25.0%	$1397
	HSDI,AdvHEV	147	-49.5%	$4589	-48.2%	$4281
	AdvHEV	138	-52.6%	$2538	-51.4%	$2230

Notes: Costs are included here to place the technology benefits in context. Costs and their derivation are discussed in greater detail in Section 5.3; Reductions and costs for all scenarios except the baseline include benefits and costs listed in Table 5.2-4 and benefits and costs from improved air conditioning systems from NESCCAF (2004).

For the small car category, CO_2 reductions were greatest using a turbocharged engine that was downsized such that overall performance was maintained. Gasoline stoichiometric direct injection engine technology was also included in this package because it affords a higher compression ratio than would otherwise be possible in order to further reduce CO_2 emissions. Dual cam phasers provide additional flexibility relative to optimum intake and exhaust valve timing and the use of a six speed automated manual transmission, electric power steering and a more efficient alternator all contribute to lower vehicle CO_2 emissions as well. A lower cost runner-up approach in terms of CO_2 reductions for small cars was a package utilizing discrete variable valve lift and dual cam phasers that also affords some engine downsizing and reduced pumping losses, again combined with the same transmission and improved auxiliaries as the previous case. For this approach, there would be a small cost savings relative to the 2009 baseline. These packages achieved CO_2 reductions of about 20-26 percent relative to the 2002 baseline. For the mid-term, technologies that combine gasoline homogeneous charge compression ignition engines with or without an integrated starter generator plus use of electrical engine water pump and more could reduce CO_2 emissions approximately 22-30 percent. Instead of the 42 volt integrated starter generator, a lower cost 12 volt belt assisted start-stop starter-alternator system could also be incorporated, but with somewhat lower reductions in CO_2 emissions. In the longer term, use of diesel homogeneous charge compression ignition engines and hybrids could provide CO_2 reductions of approximately 26-50 percent.

Table 5.2-6. **Potential Carbon Dioxide Emissions Reductions from Large Car (NESCCAF, 2004)**

Large Car	Combined Technology Packages	CO_2 (g/mi)	Potential CO_2 reduction from 2002 baseline	Retail Price Equivalent 2002	Potential CO_2 reduction from 2009 baseline	Retail Price Equivalent 2009
Near Term 2009-2012	DVVL,DCP,A6 (2009 baseline)	322	-6.6%	$427	0%	$0
	DCP,A6	304	-11.5%	$479	5.6%	$52
	DCP,CVT,EPS,ImpAlt	303	-12.1%	$708	-6.0%	$281
	CVVL,DCP,A6	290	-15.9%	$864	-10.0%	$437
	DCP,DeAct,A6	286	-16.9%	$662	-11.0%	$235
	DCP,Turbo,A6,EPS,ImpAlt	279	-19.2%	$266	-13.5%	-$161
	CVVL,DCP,AMT,EPS,ImpAlt	265	-23.2%	$873	-17.8%	$446
	GDI-S,DeAct,DCP,AMT,EPS, ImpAlt	265	-23.2%	$931	-17.8%	$504
	GDI-S,DCP,Turbo,AMT,EPS, ImpAlt	251	-27.2%	$369	-22.1%	-$58
Mid Term 2013-2015	gHCCI,DVVL,ICP,AMT,EPS,ImpAlt	272	-21.0%	$880	-15.5%	$453
	DeAct,DVVL,CCP,A6,ISG,EPS, eACC	259	-24.7%	$1721	-19.4%	$1294
	ehCVA,AMT,EPS,ImpAlt	250	-27.4%	$929	-22.2%	$502
	ehCVA,GDI-S,AMT,EPS,ImpAlt	242	-29.9%	$1188	-24.9%	$761
	gHCCI,DVVL,ICP,AMT,ISG,EPS, eACC	231	-32.9%	$1796	-28.2%	$1369
	GDI-S,Turbo,DCP,A6,ISG,EPS, eACC	224	-35.1%	$1196	-30.5%	$769
Long Term 2015-	dHCCI,AMT,ISG,EPS,eACC	277	-19.7%	$1978	-14.0%	$1551
	ModHEV	252	-27.0%	$2146	-21.8%	$1719
	AdvHEV	163	-52.6%	$3126	-49.3%	$2699
	HSDI,AdvHEV	157	-54.4%	$4253	-51.1%	$3826

Notes: Costs are included here to place the technology benefits in context. Costs and their derivation are discussed in greater detail in Section 5.3; Reductions and costs for all scenarios except the baseline include benefits and costs listed in Table 5.2-4 and benefits and costs from improved air conditioning systems from NESCCAF (2004).

For the large car class, a turbocharged engine approach similar to the one modeled in the small car class again provided maximum CO_2 reductions in the near term of about 27 percent. Since the base engine was a 6 cylinder design, staff assumed that downsizing to a 5 cylinder engine (for costing purposes) would maintain most of the smoothness of a V6 configuration and remain attractive to consumers. Even then, there was a projected savings relative to a 2009 baseline model. CO_2 emission reduction results of about 23 percent were obtained (but at a small net cost relative to a 2009 baseline vehicle this time) using cylinder deactivation in conjunction with a gasoline stoichiometric direct injection engine with dual cam phasers (plus the same 6 speed automated manual transmission, electric power steering, and an improved efficiency alternator). Another similar performing package (23.2 percent CO_2 reduction) for the near term utilized continuously variable valve lift and dual cam phasers plus the same additional equipment at an additional cost in 2009 of $446. For the mid-term, a number of alternatives provide substantial reductions in CO_2 emissions. One of the more effective technology clusters includes electrohydraulic camless valve actuation in conjunction with gasoline stoichiometric direct injection plus the 6 speed automated manual transmission, electric power steering and more efficient alternator, yielding up to about 30 percent reduction in CO_2 emissions at a cost increment of $761 in 2009. To obtain even further reductions, integrated starter generators could also be utilized. Other combinations that could be used with integrated starter generators to achieve over a 30 percent reduction include gasoline homogeneous charge compression ignition engines and again turbocharged engines with gasoline direct injection systems. For the long term, moderate and advanced hybrids can achieve around 30-50 percent reductions in CO_2 emissions.

Table 5.2-7. Potential Carbon Dioxide Emissions Reductions from Minivan (NESCCAF, 2004)

Minivan	Combined Technology Packages	CO_2 (g/mi)	Potential CO_2 reduction from 2002 baseline	Retail Price Equivalent 2002	Potential CO_2 reduction from 2009 baseline	Retail Price Equivalent 2009
Near Term 2009-2012	DVVL,CCP,A5 (2009 baseline)	370	-6.4%	$315	0%	$0
	DCP,A6	348	-12.0%	$671	-5.9%	$356
	GDI-S,CCP,DeAct,AMT,EPS, ImpAlt	328	-17.0%	$781	-11.2%	$466
	DVVL,CCP,AMT,EPS,ImpAlt	325	-17.7%	$494	-12.1%	$179
	CCP,AMT,Turbo,EPS,ImpAlt,	325	-17.8%	$1042	-12.2%	$727
	DeAct,DVVL,CCP,AMT,EPS, ImpAlt	317	-19.9%	$624	-14.4%	$309
	CVVL,CCP,AMT,EPS,ImpAlt	316	-20.2%	$916	-14.7%	$601
	GDI-S,DCP,Turbo,AMT,EPS, ImpAlt	307	-22.3%	$1397	-17.0%	$1082
Mid Term 2013-2015	ehCVA,GDI-S,AMT,EPS,ImpAlt	300	-24.1%	$1431	-18.9%	$1116
	GDI-S,CCP,AMT,ISG,DeAct,EPS, eACC	297	-25.0%	$1716	-19.8%	$1401
Long Term 2015-	dHCCI,AMT,EPS,ImpAlt	313	-20.8%	$1635	-15.3%	$1320
	Mod HEV	389	-26.8%	$2271	-21.8%	$1956
	Adv HEV	188	-52.6%	$3251	-49.3%	$2936

Notes: Costs are included here to place the technology benefits in context. Costs and their derivation are discussed in greater detail in Section 5.3; Reductions and costs for all scenarios except the baseline include benefits and costs listed in Table 5.2-4 and benefits and costs from improved air conditioning systems from NESCCAF (2004).

Essentially the same technologies emerged as most effective in reducing CO_2 emissions for the minivan as for the large car group.

Table 5.2-8. Potential Carbon Dioxide Emissions Reductions from Small Truck (NESCCAF, 2004)

Small Truck	Combined Technology Packages	CO_2 (g/mi)	Potential CO_2 reduction from 2002 baseline	Retail Price Equivalent 2002	Potential CO_2 reduction from 2009 baseline	Retail Price Equivalent 2009
Near Term 2009-2012	DVVL,DCP,A6 (2009 baseline)	404	-9.0%	$427	0%	$0
	DCP,A6	379	-14.7%	$479	-6.3%	$52
	DCP,A6,Turbo,EPS,ImpAlt	371	-16.7%	$283	-8.4%	-$144
	DCP,A6,DeAct	366	-17.7%	$656	-9.5%	$229
	GDI-S,DCP,DeAct,AMT,EPS, ImpAlt	334	-24.9%	$928	-17.5%	$501
	DeAct,DVVL,CCP,AMT,EPS, ImpAlt	330	-26.2%	$736	-18.9%	$309
	GDI-S,DCP,Turbo,AMT,EPS, ImpAlt,DCP-DS	318	-28.4%	$367	-21.3%	-$60
Mid Term 2013-2015	DeAct,DVVL,CCP,A6,ISG,EPS, eACC	316	-29.0%	$1757	-22.0%	$1330
	ehCVA,GDI-S,AMT,EPS,ImpAlt	309	-30.5%	$1186	-23.6%	$759
	HSDI,AMT,EPS,ImpAlt	307	-31.0%	$1585	-24.2%	$1158
Long Term 2015-	dHCCI,AMT,EPS,ImpAlt	331	-25.6%	$912	-18.3%	$485
	Mod HEV	325	-27.0%	$2271	-19.7%	$1844
	Adv HEV	210	-52.7%	$3251	-48.0%	$2824

Notes: Costs are included here to place the technology benefits in context. Costs and their derivation are discussed in greater detail in Section 5.3; Reductions and costs for all scenarios except the baseline include benefits and costs listed in Table 5.2-4 and benefits and costs from improved air conditioning systems from NESCCAF (2004).

Once again, the same technology clusters that were most effective in reducing CO_2 emissions in the large car and minivan classes were also effective in the small truck class. Of interest, high speed direct injection diesel engines using the same driveline and accessory improvements didn't achieve significantly lower CO_2 emissions than the electrohydraulic camless valve actuation/gasoline direct injection system that was modeled in this class. This outcome is due largely to diesel fuel's relatively high carbon content that results in relatively higher CO_2 emissions. Given the higher cost of diesels and their attendant emission cleanup challenges, they are not necessarily clear CO_2 emission improvement strategies.

Table 5.2-9. Potential Carbon Dioxide Emissions Reductions from Large Truck (NESCCAF, 2004)

Large Truck	Combined Technology Packages	CO_2 (g/mi)	Potential CO_2 reduction from 2002 baseline	Retail Price Equivalent 2002	Potential CO_2 reduction from 2009 baseline	Retail Price Equivalent 2009
Near Term 2009-2012	CCP,A6 (2009 baseline)	484	-5.5%	$126	0%	$0
	DVVL,DCP,A6	442	-13.6%	$549	-8.6%	$423
	CCP,DeAct,A6	433	-15.4%	$550	-10.5%	$424
	DCP,DeAct,A6	430	-15.9%	$916	-11.0%	$790
	DeAct,DVVL,CCP,A6,EHPS,ImpAlt	418	-18.4%	$779	-13.6%	$653
	DeAct,DVVL,CCP,AMT,EHPS, ImpAlt	396	-22.6%	$667	-18.1%	$541
Mid Term 2013-2015	CCP,DeAct,GDI-S, AMT,EHPS,ImpAlt	416	-18.6%	$872	-13.9%	$746
	DeAct,DVVL,CCP,A6,ISG, EHPS,eACC	378	-26.2%	$1710	-21.9%	$1584
	ehCVA,GDI-S,AMT,EHPS,ImpAlt	381	-25.5%	$1684	-21.2%	$1558
Long Term 2015-	GDI-L,AMT,EHPS,ImpAlt	354	-24.4%	$1901	-20.0%	$1775
	Mod HEV	372	-27.3%	$2565	-23.1%	$2439
	dHCCI,AMT,ISG,EPS,eACC	362	-29.3%	$3031	-25.2%	$2905
	GDI-L,AMT,ISG,EPS,ImpAlt	354	-30.7%	$2800	-26.7%	$2674
	HSDI,AdvHEV	244	-52.2%	$6902	-49.5%	$6776
	AdvHEV	241	-52.9%	$4008	-50.2%	$3882

Notes: Costs are included here to place the technology benefits in context. Costs and their derivation are discussed in greater detail in Section 5.3; Reductions and costs for all scenarios except the baseline include benefits and costs listed in Table 5.2-4 and benefits and costs from improved air conditioning systems from NESCCAF (2004).

For large trucks, cylinder deactivation strategies in conjunction with flexible valve timing and lift strategies were the most effective in the near term, offering a CO_2 reduction of about 18 percent (also included 6 speed automated manual transmission, electrohydraulic power steering, and an improved alternator). Strategies relying on turbocharging and engine downsizing were avoided since large trucks may be more likely to encounter periods of sustained high load operation where cylinder pressures and temperature would be much higher than in non-turbo applications. In order to retain adequate engine durability under such conditions, significant engine upgrades would likely be needed, which were difficult to quantify. For the mid-term adding an integrated starter generator and electric engine water pump brought the potential CO_2 reduction to about 26%. Use of electrohydraulic camless valve actuation coupled with gasoline stoichiometric direct injection achieved about the same CO_2 reduction *without* an integrated starter generator. Use of the latter would improve the CO_2 reductions even more, though this was not specifically modeled. For the long term, gasoline lean burn direct injection or use of diesel multi-mode technology, both coupled with an integrated starter generator could allow about a 30 percent reduction in CO_2, but both technologies have aftertreatment issues remaining. Otherwise, moderate or aggressive hybrids that rely on a downsized engine coupled with an electric motor for assist could achieve around about a 30-50 percent CO_2 reduction. However, some believe that the short lived motor assistance based on battery storage capacity would limit the attractiveness of such large truck hybrids when sustained high load operation might be more likely. Perhaps an approach such as in the Lexus RX400H, wherein the base engine stays constant and the hybrid system is added to boost short-term acceleration and significantly improve CO_2 emissions during normal driving, would be a better approach for large trucks.

5.2.B Mobile Air Conditioning System

5.2.B.1 Improved Air Conditioning Systems

Mobile air conditioning contributes to greenhouse gas emissions through “direct” refrigerant releases and “indirect” exhaust CO_2 emissions. Direct emissions are due to releases from vehicles through air conditioning system leakage (a slow process, sometimes called “regular emissions”), during accidents or other events that suddenly breach containment of the system refrigerant (sometimes called “irregular emissions”), during service events, and when vehicles are dismantled without proper recovery of the refrigerant. In new vehicles, the potential for reduction of direct emissions is considerable. Industry sources estimate that existing systems can be cost-effectively improved to achieve up to 50 percent reduction in refrigerant leakage, also referred to as "regular emissions." Strategies for reducing direct emissions and estimates of the corresponding emission reductions are presented in this section.

Although current emission certification testing procedures do not include operation of vehicle air conditioning systems, their operation contributes significantly to exhaust CO_2 emissions, also known as "indirect emissions." These emissions are largely attributed to the added load on the engine from operation of the air conditioning system. It has been estimated that CO_2 emission reductions from 30 to 50 percent of the fraction attributable to air conditioning use may be achievable by reducing the engine load requirements of air conditioning systems. Potential measures for reducing indirect emissions are presented in this section. The associated emission reductions were estimated through vehicle simulation modeling performed by NESCCAF (2004). Again, these technologies can be applied to air conditioner system operation in alternative fuel vehicles, thus increasing their greenhouse gas reduction benefits.

5.2.B.2 Estimating Direct Emissions

Modern mobile air conditioning systems that enhance travel comfort and safety include features such as integrated cooling, heating, demisting, defrosting, air filtering, and humidity control. The basic components of a typical system are shown in Figure 5-5.

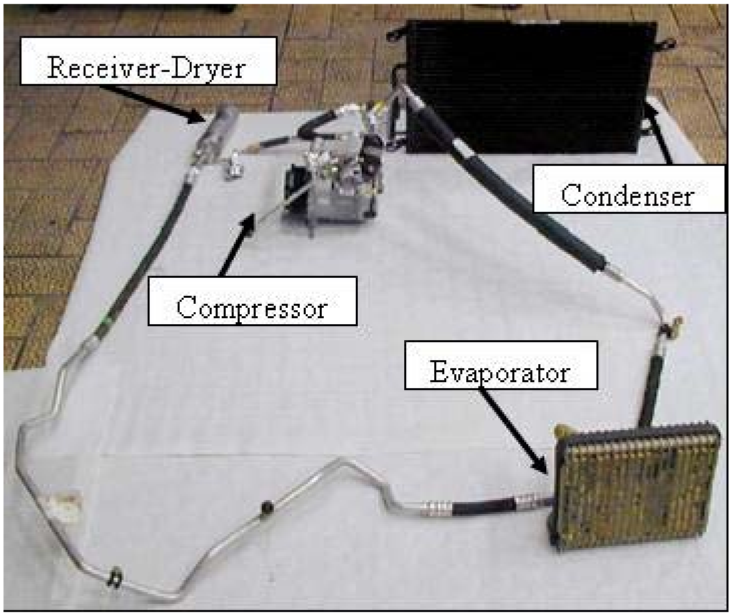


Figure 5-5. Typical Mobile Air-Conditioning System Components (Clodic et al, 2003)

The current refrigerant in new vehicles is HFC-134a (1,1,1,2-tetrafluoroethane), which has a global warming potential (GWP) of 1,300. Direct lifetime emissions of HFC-134a from vehicular air conditioning systems in California have been estimated using a method developed by ARB staff based on 1) HFC-134a consumption data by nine government and commercial fleets, 2) surveys of 966 vehicle owners on their air conditioning system repair incidence, 3) data on repair incidence among 12,000 fleet vehicles in California, and 4) information from automobile dismantlers. The data were used to provide estimates of the averages of the parameters in a mass balance model that equates vehicular lifetime emissions to lifetime inputs of HFC-134a. The analysis yielded lifetime direct emissions of approximately 1.36 kg of HFC-134a for a typical vehicle in the current California fleet, which has a 16-year median lifetime. This is equivalent to emissions of 85 grams of HFC-134a per year of life per vehicle, although the emissions may not be uniform over the vehicle's life. The limited data available suggest that about 72% of the lifetime refrigerant emissions are due to leakage ("regular emissions"), 22 percent are due to sudden or accidental releases ("irregular emissions"), and 6 percent are due to releases during dismantling. Assuming 200,000 lifetime miles driven, this breaks down into approximately 6 CO_2-equivalent grams per mile from "regular" emissions, 2 CO_2-equivalent grams per mile from "irregular" emissions and 0.5 CO_2-equivalent grams per mile from dismantling emissions.

5.2.B.3 Possible Measures to Reduce Direct Emissions

Reduction of direct emissions can be achieved through system improvements such as the use of low-permeability hoses and improved elastomer seals and connections. Work is in progress to define a component-specific blueprint for a baseline (current) air conditioning system and to identify key components for potential improvement (reduced leakage). It is anticipated that upgrades to a few key components (e.g., compressor shaft seal) would result in a low-leak system that can achieve a 50 percent reduction in “regular” emissions. However, improved containment would not reduce accidental releases or releases during scrapping. A 50 percent reduction in “regular” leakage emissions by a low-leak system translates into a reduction of approximately 3 CO_2-equivalent grams/mile, for an incremental increase in cost to the manufacturer of approximately twelve dollars. Table 5.2-10 illustrates the principal components of interest for upgrading to a low-leak system that halves "regular" emissions.

Table 5.2-10. Preliminary components of interest in a low-leak HFC-134a air conditioning system.

Component	Approximate Contribution to Leakage Emissions
Flexible hose (high and low pressure) construction and dimensions	25%
System component connections (type and number)	25%
Compressor shaft seal	50%
Leakage emissions prior to component improvements	6 CO_2-equiv (g/mi)
5.2.B.3.1 50% Reduction in Leakage	**~3 CO_2-equiv (g/mi)**

While low-cost improvements to current systems for reducing refrigerant leakage appear feasible, other alternatives can achieve greater benefits. As mentioned earlier, HFC-134a is the current refrigerant in vehicles manufactured during and since the 1995 model year. HFC-134a has a GWP of 1,300. Emissions of HFC-134a could be avoided completely by using an alternative refrigerant with a lower GWP. The leading alternatives are HFC-152a (1,1-difluoroethane), with a GWP of 120, and CO_2, with a GWP defined as one. HFC-152a could be introduced as a vehicular refrigerant on a schedule that appears to be consistent with the requirements of AB 1493.

For systems equipped with HFC-152a, total refrigerant emissions would be reduced by 91 percent (on a CO_2-equivalent mass basis). However, since HFC-152a is mildly flammable under certain conditions, mitigation options are being considered. Specifically, industry representatives report that they are currently evaluating technical solutions for mitigating potential safety concerns associated with HFC-152a, including the use of charge evacuation technologies that could be invoked in vehicle crash situations. The schedule for which CO_2 systems could be deployed is uncertain. For systems that use CO_2, the relative global warming impact of refrigerant emissions would be virtually eliminated. Safety issues related to high system pressures and in-cabin releases are currently under evaluation.

Table 5.2-11 presents estimates of emission reductions to be achieved from upgrading to a low-leak HFC-134a system, a low-leak HFC-152a system, and a carbon dioxide system. Note that it is only "regular" (leakage) emissions that would be impacted by the upgrade of a current HFC-134a system, not all the lifetime emissions. That is, approximately 72% of the lifetime emissions from a current HFC-134a system are due to leakage. For a low-leak system, the relative proportions of "regular", "irregular", "service events" and "dismantling" emissions are altered by factors consequential to reduced leakage (e.g. increase in "dismantling" emissions due to a larger refrigerant volume during dismantling). It is recommended that the reader consult the Technical Support Document (emissions quantification) for the methodology used to estimate emissions for low-leak systems.

A reduction of approximately 3 CO_2-equivalent grams per mile is estimated for upgrading to a low-leak HFC-134a system that achieves a 50 percent reduction in leakage. In contrast, the use of alternative refrigerants with lower GWPs can result in greater benefits because they reduce total lifetime emissions (i.e., regular, irregular, and end-of-life releases). For upgrading to a low-leak HFC-152a system or a CO_2 system, the benefits are approximately 8.5 or 9 CO_2-equivalent grams per mile, respectively.

Table 5.2-11: Direct Climate Change Emissions from Baseline and Alternative Mobile Air Conditioning Systems

	Air Conditioning System			
	HFC-134a Baseline Technology	Low-Leak HFC-134a	Low-Leak Primary Expansion HFC-152a[1]	Carbon Dioxide[2]
Total refrigerant emissions (g/yr)	85	70	70	85
Total refrigerant emissions, in CO_2 eq. (g/mi)	9	7	0.7	0.007
Refrigerant leakage emissions, in CO_2 eq. (g/mi)	6	3	0.3	0.005
Reduction in CO_2 eq (g/mi)	**Baseline**	**3**	**8.5**	**9**

[1] *Assuming same mass leak rate as a low-leak HFC-134a system*
[2] *Assuming same mass leak rate as a baseline HFC-134a system*

5.2.B.4 Efforts by the European Union to Reduce Direct Emissions

In August of 2003, the European Commission advanced a proposal mandating the future phaseout of HFC-134a for vehicle air conditioning systems. Beginning in 2005, annual leakage rates would be limited for refrigerants with a GWP of 150 or higher. Effectively, this action targets reductions for HFC-134a. A system of credits was also proposed that would ultimately accomplish a phaseout by 2019 of any refrigerant with a GWP of 150 or higher (Meszler, 2004). At the time of this report, the direction of the proposed regulation appears to be shifting towards elimination of a credit system and a future ban for new vehicles with a refrigerant having a GWP greater than 50. This would remove HFC-152a as a refrigerant option, and require substitution with other refrigerants, such as CO_2 or hydrocarbons. While there are significant advantages to substitution with CO_2, including the fact that it has the lowest GWP of the leading technologies, there are also disadvantages. Some characteristics of CO_2 air conditioning systems are: 1) significantly higher pressures and associated leak tendency, 2) high component costs, 3) new service training would be needed, 4) an internal heat exchanger would be necessary, 5) lower performance at higher ambient temperature conditions, and 6) timing for deployment is uncertain.

The European Union regulation is not final, and the ultimate outcome remains uncertain. However, because both the European Union and the United States each comprise about one third of worldwide vehicle sales, it is likely that there will be some uniformity in air conditioning system design. Note that the European Union's efforts did not result in a proposal to address indirect emissions due to a lack of consensus on how to address these emissions.

5.2.B.5 Possible Measures to Reduce Indirect Emissions

The contribution of mobile air conditioning systems to exhaust CO_2 (indirect) emissions can be attributed to transportation of the unit's mass and operation of the system. It is estimated that reducing the engine load requirements from air conditioning systems can reduce these emissions up to 50 percent. This can be accomplished by utilizing more efficient variable displacement compressors (VDC) with better control systems, and condensers and evaporators with improved heat transfer.

The engine load requirements for externally controlled VDCs are lower than those of fixed displacement compressors (FDCs) because, rather than providing a constant flow of refrigerant with on/off cycling, VDCs with appropriate controls modulate compressor displacement, allowing refrigerant flow to vary to meet cooling demands. As cooling demands increase, the benefits of VDCs decrease relative to those of FDCs. For the limited conditions that require maximum compressor displacement, the benefit of VDCs over FDCs approaches zero.

VDCs are a currently available technology. Though not yet commonly employed in the United States, VDCs are more prevalent in the European Union. The on/off cycling associated with FDCs noticeably impacts the driveability of smaller engines. Consequently, in the European Union, where the average engine displacement is less than two liters, VDCs provide significant improvement to engine driveability.

Another means to enhance air conditioning system operation is to reduce the amount of outside air admitted to the passenger compartment relative to recirculated air. This reduces the amount of hot air from outside that needs to be cooled by the system. This strategy can be applied to either manually or automatically controlled air conditioning systems and is also currently feasible.

Additionally, performance can be improved by the elimination of "air reheat". A characteristic of air conditioning systems equipped with FDCs is the tendency in mild conditions to overcool and then reheat the air to provide a moderate level of cooled air. Because VDCs modulate refrigerant flow, they can be adapted to eliminate air reheat. However, because elimination of air reheat requires automatic climate controls, and manual controls are most prevalent in the United States, this feature was not assumed for modeling the benefits of improved vehicle air conditioning systems (Meszler, 2004).

As mentioned previously, substitution with the refrigerant HFC-152a appears to have significant near-term potential for reducing CO_2-equivalent emissions associated with the refrigerant. In addition, because HFC-152a transfers heat slightly more efficiently than HFC-134a, there are also gains to be made with HFC-152a substitution from a CO_2 emission reduction (indirect emissions) standpoint. While the driving force behind substitution with HFC-152a may be the reduction in direct emissions, the likelihood of near-term implementation is favorable and therefore the indirect benefits were included in the vehicle simulation modeling.

Other air conditioning system CO_2 reduction strategies aim to reduce the vehicle solar load. Use of solar reflective glass, modified glass angles, improved cabin insulation, altering interior and exterior colors, and other measures can significantly reduce the solar load and consequently ease the engine load from air conditioning systems. However, these strategies are independent of air conditioning design and were not incorporated into the simulation modeling. In the future, benefits from these types of measures may be credited through the incorporation of whole vehicle testing that simulates solar load. However, presently such testing is neither reliable nor accurate, and needs further development.

Vehicle simulation modeling was performed to estimate the CO_2 benefits from the use of an improved air conditioning system for each of the five vehicle classes. Details of the modeling inputs are provided in the Technical Support Document. Given the considerations discussed in this section, operation with a conventional FDC was compared to that of a system comprised of a VDC with external controls, air reuse strategy, and substitution with HFC-152a refrigerant. Results are presented in Table 5.2-12 and have been adjusted to reflect data from an extensive study by the National Renewable Energy Laboratory (NREL). This study indicates that within California, vehicle air conditioning is operated for cooling or demisting during 29% of the vehicle miles traveled (Johnson, 2002; Rugh and Hovland, 2003). Consequently, failure to adjust the modeling results would have overestimated the benefits of upgrading the air conditioning system.

Table 5.2-12: Indirect CO_2 Emissions from Baseline and Improved Mobile Air Conditioning Systems

		Vehicle class				
		Small Car	Large Car	Minivan	Small Truck	Large Truck
Emissions (g/mi)	With no A/C system operation	277.9	329.2	376.4	425.7	492.6
	With baseline A/C system[1]	291.4	344.6	395.4	444.7	511.6
	Due to baseline air conditioning	13.5	15.4	19.0	19.0	19.0
	With improved A/C system[2]	284.4	336.6	385.6	434.9	501.8
Reductions Due To Improved A/C System	(g/mi)	7.1	8.1	10.0	10.0	10.0
	In A/C emissions	52%	52%	52%	52%	52%
	From baseline A/C system	2.4%	2.3%	2.5%	2.2%	1.9%

[1] *Utilizes fixed displacement compressor*
[2] *Equipped with a variable displacement compressor, air recirculation, and HFC-152a as the refrigerant*

For upgrading to a VDC with external controls, air recirculation, and HFC-152a as the refrigerant, the estimated indirect emission reduction is 7 CO_2–equivalent grams per mile for a small car, 8 CO_2–equivalent grams per mile for a large car, and 9.8 CO_2–equivalent grams per mile for minivans, small trucks, and large trucks.

5.2.C Alternative Fuel Vehicles

Alternative fuel vehicles have been used for many years as a means of providing reductions of smog-forming emissions. Alternative fuel vehicles may also provide reductions of climate change pollutants, in two ways. First, during the combustion process, alternative fuels burn more cleanly than conventional gasoline or diesel and therefore produce lower climate changes emissions. Second, alternative fuels have different upstream emissions than conventional gasoline or diesel. The upstream emissions are the "well-to-tank" emissions, and include extraction, transport, processing, distribution, and marketing. Tiax, LLC evaluated upstream emissions from conventional and dedicated alternate fuel vehicles for cases that are most likely to be available in the 2009 timeframe. This section describes the estimated benefits of various alternative fuel vehicles (both combustion and upstream benefits).

Under the staff proposal, the regulatory treatment of alternative fuel vehicles will vary depending on whether the vehicle is a "dedicated" vehicle, which uses only alternative fuel, or has the capability to use multiple fuels. For dedicated alternative fuel vehicles, the staff proposed methodology for dealing with relative differences in upstream emissions is presented in section 6.4, which describes the basic regulatory standard. For bi-fuel or flexible-fuel vehicles, the emissions benefits achieved are dependent on the extent to which the alternative fuel is used. Under the basic regulatory standard, emissions from such vehicles will be calculated assuming that the vehicle uses the "dirtier" fuel. If a manufacturer can demonstrate that the vehicle uses an alternative fuel with lower climate change emissions, the manufacturer can earn credit under the alternative compliance mechanism described in section 6.6.

The following sections describe the climate change emission characteristics of various alternative fuel vehicles.

Compressed Natural Gas (CNG) Vehicles
Compressed natural gas (CNG) has been effectively utilized to achieve NOx and PM emission benefits from both light-duty and heavy-duty vehicles. Manufacturers market a variety of CNG vehicles, including passenger cars, pick-up trucks, shuttle buses, school buses, refuse haulers, and transit buses. In addition, a natural gas vehicle was the first vehicle to be certified to the ARB's lowest emissions category (partial zero-emission vehicle or PZEV).

With regard to climate change emissions, current CNG vehicles have lower CO_2 emissions than comparable gasoline vehicles, but higher emissions of methane (CH_4). Methane has a relatively high global warming potential, which could significantly increase the overall climate change emissions of CNG vehicles. However, recent studies have shown that the high methane emissions of CNG vehicles can be significantly reduced through improved catalysts (increasing the cell density of the catalyst). Since CNG vehicles have inherently lower CO_2 emissions than gasoline vehicles, staff believes manufacturers would incorporate the improved catalyst technology on their future vehicles. With improved catalyst technology, CNG vehicles will provide a climate change emission reduction of approximately 30% as compared to conventional gasoline vehicles.

Liquid Petroleum Gas (LPG Vehicles)
More than 33,000 LPG vehicles are currently operating in California. These vehicles are popular in fleet applications where central refueling is possible. LPG is the most cost-effective alternative fuel option identified. LPG provides modest combustion benefits and significant upstream benefits of over 60 percent, compared to conventional gasoline vehicles. Overall, LPG provides climate change emission reductions of approximately 30 percent relative to gasoline vehicles.

Ethanol
Currently, approximately 2% of new vehicles sold in California are capable of running on a blend of up to 85% ethanol and 15% gasoline (E85). Almost all of these vehicles use primarily, if not exclusively, conventional gasoline. The reasons for this are the high cost of ethanol, and the resulting lack of consumer demand, the lack of fueling infrastructure, and E85 availability. As previously discussed, for purposes of compliance with the basic regulation, emissions from flex-fuel vehicles will be calculated assuming that they are running on gasoline. If a manufacturer can demonstrate that the vehicle is using E85 then the manufacturer can earn credit under the Alternative Compliance Strategies program. Ethanol derived from corn has negative upstream climate change emissions because corn crops will remove significant CO_2 from the ambient air. Overall, dedicated E85 vehicles provide an climate change emission reduction of approximately 35 percent.

Electricity
Both electricity and hydrogen are unique among alternative fuels in that they are generally converted from hydrocarbon fuel feedstocks and energy sources into a transportation fuel.

Battery electric vehicles (BEVs) have the largest potential to reduce climate change emissions relative to any other alternative fuel vehicle or conventional technology option under consideration. These vehicles can provide greater than 50% emission reductions, depending upon how the electricity used by these vehicles is produced. Unfortunately, building and marketing cost-effective “full function” BEVs remains a significant cost challenge. With near-term cost projections and technology options, staff believes that only relatively small neighborhood and “City” BEVs have the potential to be built at attractive enough prices to be viable in the 2009 timeframe.

Grid-connected hybrid electric vehicles (GHEVs) have the ability to operate on battery power alone for some distance. Researchers studying GHEVs have been focusing on those with zero emission range capabilities of 20-60 miles. For a GHEV, once the battery is depleted to a given threshold, these vehicles operate similar to a conventional non-grid HEV, with the engine being used for acceleration and cruise conditions. GHEVs are analogous to bi-fuel vehicles in that their emissions benefit is dependent on the extent to which the alternative fuel (electricity) is used. Therefore, these systems are also considered as part of the discussion in Section 6.6, Alternative Compliance Strategies.

Hydrogen
As stated above hydrogen is generally converted from hydrocarbon fuel feedstocks and energy sources into a transportation fuel. Hydrogen also has the potential to be generated from renewable resources, which would result in zero upstream climate change emissions. The most likely near-term method of producing hydrogen in the 2009 timeframe is steam-reformation of natural gas.

Automobile manufacturers are currently aggressively pursuing the commercialization of hydrogen fuel cell vehicles, which can provide transportation with zero greenhouse gas or criteria pollutant tailpipe emissions. Hydrogen internal combustion engine vehicles also offer significant potential for climate change emission reductions as their climate change tailpipe emissions are near zero and the upstream emissions are the equivalent to those from hydrogen fuel cell vehicles.

Availability of cost-effective vehicles and lack of fueling infrastructure make hydrogen fuel cell and internal combustion engine vehicles challenging for consideration in the 2009 timeframe. However, a small number of vehicles are expected to be produced in that timeframe in order to comply with the zero-emission vehicle requirements. To the degree that auto manufacturers choose to produce hydrogen fuel cell vehicles or hydrogen internal combustion engine vehicles, the benefits will be large.

Summary of Alternative Fuel Vehicle Emissions Benefits
Listed below are estimated CO_2 emissions for current conventional vehicles and several alternative fuels, as discussed above. The estimates assume a sales-weighted mix of small and large passenger cars. The table clearly indicates that each alternative fuel vehicle technology analyzed will provide significant climate change benefits relative to comparable gasoline-fueled vehicles.

Table 5.2-13. Potential Carbon Dioxide Equivalent Emissions Reductions with Alternative Fuel Vehicle Technologies for Passenger Cars

Vehicle type	Exhaust CO_2 equivalent emissions (g/mi)	Upstream CO_2 equivalent emissions (g/mi)	Total CO_2 emissions (g/mi)	Lifetime CO_2 equivalent emissions (ton)	Lifetime CO_2 equivalent emissions reduced from 2002 baseline[5] (ton)	Percent reduction of CO_2 equivalent emissions from 2002 baseline
Conventional vehicles[1]	311	98	409	91	0.0	0%
Compressed natural gas (CNG) [2,3]	205	75	280	65	25.5	-28%
Liquid propane gas (LPG) [2]	240	35	275	64	26.7	-29%
Ethanol (E85) [2]	260	-10	250	58	32.5	-36%
Plug-in Hybrid [2]	65	130	195	45	45.3	-50%
Hydrogen combustion [2,4]	13	185	198	46	44.6	-49%

[1] numbers for conventional vehicle baseline use approximated California sales-weighted average of baseline vehicle emission from small car and large car classes from above and 24% upstream CO_2 equivalent estimate; [2] Unnasch, 2004; [3] CNG vehicle assumed to have catalyst equipment; [4] Compressed hydrogen from steamed reformed natural gas; [5] based on EMFAC number for average vehicle lifetime (See Technical Support Document)

5.2.D Exhaust Catalyst Improvement

Potential reduction of passenger vehicle greenhouse gas contribution could result from improved exhaust catalysts to reduce emissions of methane (CH_4) and nitrous oxide (N_2O). Catalysts would reduce N_20 and CH_4 emissions from the tailpipe, as other air contaminants, including criteria air pollutants, have been controlled for decades. Both of these gases, although their mass emissions are much less than CO_2 emissions from vehicles, have significant overall contributions to global climate change. Each of these gases, due to their distinct chemical properties, impacts the atmospheric energy balance differently than CO_2, such that a ton of CH_4 in the atmosphere is estimated to have the same net warming effect over 100 years as 23 tons of CO_2. Emissions of N_2O have an even more potent effect on the atmosphere, with an estimated effect 296 times greater than CO_2.

Methane is a component of the unburned hydrocarbons emitted by motor vehicles. Since it has a very low potential to form ozone in the atmosphere, vehicular CH_4 emissions are not specifically regulated. Methane emissions are generally proportional to vehicle hydrocarbon (HC) and non-methane organic gas (NMOG) emissions. However, as NMOG fleet average emissions approach near-zero levels by 2010 (i.e., 0.035 grams/mile for passenger cars), CH_4 emissions are also expected to be extremely low. The expected CH_4 emission rates for 2009 vehicles less than 8,500 lbs is 0.005 grams/mile (EMFAC, 2003).

Nitrous oxide emissions are a by-product of a vehicle's aftertreatment catalyst and are primarily formed during catalyst warm-up. Similar to CH_4 emissions, N_2O emissions are generally proportional to vehicle oxides of nitrogen (NO_x) emissions. In addition, as fleet average NO_x emissions approach near-zero levels by 2010, N_2O emissions are also expected to be extremely low. Since it is not specifically a regulated pollutant, catalyst manufacturers are not currently pursuing strategies to reduce vehicle N_2O emissions. However, inclusion of N_2O emissions in the proposed vehicle climate change regulations may encourage more development work if a cost-effective solution can be identified.

Table 5.2-14 shows estimates of the total contribution of N_2O and CH_4 emissions to the climate change emission inventory for average light-duty vehicles. Although it is conceivable that these emissions could be reduced through faster catalyst heating at vehicle start-up and enhanced catalyst systems with either higher surface density or higher and/or revised catalyst loadings, staff is not aware of such efforts at this time.

Table 5.2-14. Contribution of Nitrous Oxides and Methane to Vehicle Climate Change Emissions

	Nitrous oxide (N_2O)	Methane (CH_4)
Emission rate[1] (g/mi)	0.006	0.005
Global warming impact (GWP)	296	23
Lifetime CO_2 equivalent emissions (tons/vehicle)	0.4	0.03
Emission rate in CO_2 equivalent g/mile	1.78	0.12

[1] Emission rates based on EMFAC, 2003 estimates for the 2019 vehicle fleet

5.2.E Summary of Technology Assessment Results

For the purpose of providing perspective regarding the various sources of CO_2 equivalent emissions that have been covered in this report, Table 5.2-15 itemizes the various contributions of CO_2 equivalent emissions and provides a total inventory. The table also provides an indication of the degree of reduction that an ARB climate change emission regulation could achieve.

Table 5.2-15. Summary of Technology Options and Potential Reductions

Vehicle/Fuel System	Climate Change Emission	Average lifetime GHG contribution (ton CO_2 equiv.)	Percent of lifetime GHG contribution	Technologies available for GHG reduction	Maximum percent GHG reduction studied here
Exhaust emissions	Carbon dioxide	100.6	74.64%	Engine, drivetrain, alternative fuels technologies	up to 60%
	Nitrous Oxide	0.4	0.30%	Improved exhaust catalyst	negl.
	Methane	0.03	0.02%	Improved exhaust catalyst	negl.
Fuel-Delivery "Upstream"	CO_2, N_2O, and CH_4	31.8	23.59%	Alternative fuels	up to 80%
Refrigerant leakage	Hydrofluorocarbons (HFCs)	1.95	1.45%	Tighter A/C system, R-152	Up to 95%
Total		134.78	100.0%		

5.3 Incremental Costs Of Technologies

This section includes an analysis of the incremental cost of the climate change emission technologies of Section 5.2 in reducing climate change emissions.

The initial cost is the incremental cost of the climate change reduction technology, or package of technologies. These technology costs are discussed for specific technologies in the sections below. Along with the initial cost of the new technology, there are additional mark-up costs to account for the profit and overhead for the companies that research, develop, and manufacture those technology components. Our analysis uses a 40% mark-up rate, i.e. each of the technology costs is multiplied by 1.4 to determine its retail price equivalent. This is between the conventionally utilized retail price equivalent (RPE) multipliers for general environmental technology assessments of 1.26 (EPA, 2004) and research studies of particular vehicle components with factors of 1.5 and above (Vyas, et al, 2000).

5.3.A Engine, Drivetrain, and Hybrid-Electric Vehicle Technologies

Estimates of the incremental cost to the manufacturer for each of the technologies considered were taken primarily from those supplied by Martec for the NESCCAF (2004) study. Some of the key aspects of the methodology used in the NESCCAF report for determining the costs of the engine and drivetrain technologies are summarized here. For further documentation see NESCCAF (2004). The main source of the price estimates were field interviews with representatives from automotive and component manufacturing industries that are involved with the engineering, production, product planning, and purchasing of new technologies. The costing assumes long term learned-out production volumes of at least 500,000 units for each of the technologies, and assumes a highly competitive purchasing environment including several suppliers.

Some deviations were made from the Martec cost estimates. For some of the emerging technologies, Martec did not account for additional cost reductions resulting from unforeseen innovations in design and manufacturing. While this may be adequate for technologies that are well defined and primarily mechanical in nature, staff expects that further cost reductions for emerging technologies that incorporate electromechanical and electronic components are highly probable. Based on our experience in the Low Emission Vehicle program, it is inevitable that consolidation of parts and further simplifications in production processes will take place when volumes reach into the millions per year per supplier and numerous suppliers are competing. The prices that ARB projects normally reflect components that have become commodity items. One example is the dramatic cost reductions for consumer electronic devices a few years after the first ones go on sale. Another example is the reduction in costs from initial estimates for emission control components developed by manufacturers for Low-Emission Vehicles. For example, there were projections of the need for multiple close-coupled catalysts to meet the SULEV emission levels when the Low Emission Vehicle program was adopted and yet we now have at least one manufacturer utilizing only one underfloor catalyst to meet these emission levels.

Usually, ARB estimates themselves tend to be high when high volume production is achieved. The Martec costs for these emerging technologies, we believe, will ultimately cost less in high volume production due to improvements from innovative design changes and manufacturing techniques. Accordingly, they have been discounted by 30%, to make them consistent with ARB's experience in estimating costs in the Low Emission Vehicle program. In discussions with some suppliers, it was their opinion that such costs might be reduced as much as 50% depending on the level of utilization of the part at present and the type of system in which it is utilized.

In addition, ARB staff reduced the cost of converting from an overhead valve engine to a dual overhead cam system by the cost of the aluminum block that was included by Martec. Although manufacturers may switch to an aluminum block when making such a changeover, staff believes it is not a necessary step to accomplish the conversion. Manufacturers may utilize an aluminum block to save weight or perhaps for competitive marketing reasons, or others. Staff, therefore, reduced the conversion cost by $250 for a V-6 engine and $300 for a V-8 engine relative to Martec’s estimates. For cylinder deactivation, Martec indicated that they did not include cost for controlling driveline noise when in the cylinder deactivation mode since the systems to accomplish this were in a state of flux. Staff included an additional $50 for a long term solution that involves modifications to the current exhaust system rather than inclusion of a special valve in the exhaust or active engine mounts since at least one vehicle in current production utilizes the more simple approach successfully. Regarding hybrids, ARB staff had earlier conducted its own analysis of their costs, but the latest Martec data is close enough to our own that for purposes of this report we will rely on Martec’s latest hybrid cost estimates.

ARB staff continues to assess costs with individual suppliers, and in those cases where we find that the Martec estimates might not contain the latest information, revisions will be made in our final report. Table 5.3-1 lists the estimated RPE costs of the individual technologies considered by this study.

Table 5.3-1. Estimated Cost of Individual Technologies

Technologies	Vehicle Class				
	Small car	Large car	Minivan	Small truck	Large truck
	Retail Price Equivalent ($)				
Intake Cam Phasing	49	98	49	98	49
Exhaust Cam Phasing	49	98	49	98	49
Dual Cam Phasing (DCP)	98	196	388	196	409
Coupled Cam Phasing (CCP)	70	161	49	161	49
Discrete Variable Valve Lift (DVVL,ICP)	154	259	210	259	259
Discrete Variable Valve Lift (DVVL,DCP)	203	357	549	357	619
Discrete Variable Valve Lift (DVVL,CCP)	175	322	210	322	259
Continuous Variable Valve Lift (CVVL,ICP)	259	483	626	483	764
Continuous Variable Valve Lift (CVVL,DCP)	280	581	773	581	911
Continuous Variable Valve Lift (CVVL,CCP)	308	546	626	546	764
Electromagnetic Camless Valve Actuation (emCVA)	676	764	1078	764	1274
Electrohydraulic Camless Valve Actuation (ehCVA)	564	637	882	637	1078
Turbocharging (Turbo)	560	(150)	490	(150)	-
Cylinder Deactivation (DeAct)	-	183	183	183	217
Cylinder Deactivation (DeAct,DVVL)	-	266	266	266	325
Cylinder Deactivation (DeAct,DVVL,ICP)	-	364	315	364	374
Cylinder Deactivation (DeAct,DVVL,DCP)	-	462	635	462	524
Cylinder Deactivation (DeAct,DVVL,CCP)	-	427	315	427	374
Variable Charge Motion (CBR)					
Gasoline Direct Injection - Stochiometric (GDI-S)	189	259	259	259	294
Gasoline Direct Injection - Lean-Burn Stratified (GDI-L)	728	959	1043	1057	1554
Gasoline Homogeneous Compression Ignition (gHCCI)	560	840	840	-	-
Diesel – HSDI	2100	1225	2152	1260	2943
Diesel – Advanced Multi-Mode	1323	735	1310	568	1791
4-Speed Automatic Transmission	0	0	0	0	0
5-Speed Automatic	140	140	140	140	140
6-Speed Automatic	70	105	105	105	112
6-Speed Automated Manual	0	0	0	0	0
Continuously Variable Transmission (CVT)	210	245	245	245	-
12-volt 2kW BAS (Start Stop)	280	-	-	-	-
42-Volt 10 kW ISG (Start Stop)	609	609	609	609	659
42-Volt 10 kW ISG (Motor Assist)	902	902	902	902	902
Electric Power Steering (EPS)	20	39	39	39	-
Electro-Hydraulic Power Steering (E-HPS)	-	-	-	-	60
Improved Alternator (Higher efficiency)	56	56	56	56	56
Electric Water Pump (EWP)	70	70	70	70	70
Improved AC	88	88	88	88	88
ModHEV	1617	2058	2058	2058	2352
AdvHEV	2450	3038	3038	3038	3920

Listed below in Table 5.3-2 through Table 5.3-6 are the incremental cost to the manufacturer and the RPE cost to the consumer for the technology combinations modeled for each vehicle class. Again these technologies are separated into near-, mid-, and long-term according to their relative readiness for potential widespread market penetration. The package costs listed here include credit for the elimination of duplicate technologies such as the exhaust gas recirculation (EGR) valve that can be eliminated when using variable valve timing or cam phasing, elimination of the conventional starter and alternator when using ISG systems, or engine downsizing when using turbocharging. Note that these costs are relative to the incremental cost for the 2009 baseline vehicle in each vehicle class. Each of the technology packages, along with the technologies listed, also includes the improved variable-displacement compressor air-conditioning systems, aggressive shift logic, improved rolling resistance tires, and engine friction reduction technologies.

Table 5.3-2. Estimated Incremental Costs for Carbon Dioxide Reduction Technologies for Small Car Relative to 2009 Baseline

Small Car	Combined Technology Packages	Technology cost ($)	Retail Price Equivalent ($)
Near Term 2009-2012	DCP,EPS,A4,ImpAlt	37	52
	DCP,CVT,EPS,ImpAlt	187	262
	DVVLd,A5 (2009 baseline)	0	0
	DCP,A6	27	38
	DCP,A5,EPS,ImpAlt	133	186
	DVVL,DCP,AMT,EPS,ImpAlt	112	157
	GDI-S,DCP,Turbo,AMT,EPS,ImpAlt	586	820
Mid Term 2013-2015	gHCCI,DVVLi,AMT,EPS,ImpAlt	261	365
	gHCCI,DVVL,ICP,AMT,ISG,EPS,eACC	901	1262
	CVVL,DCP,AMT,ISG-SS,EPS,ImpAlt	771	1079
Long Term 2015-	ModHEV	998	1397
	dHCCI,AMT,ISG,EPS,eACC	1591	2228
	AdvHEV	1593	2230
	HSDI,AdvHEV	3058	4281

Table 5.3-3. Estimated Incremental Costs for Carbon Dioxide Reduction Technologies for Large Car Relative to 2009 Baseline

Large Car	Combined Technology Packages	Technology cost ($)	Retail Price Equivalent ($)
Near Term 2009-2012	DCP,A6	37	52
	DCP,CVT,EPS,ImpAlt	201	281
	DVVL,DCP,A6 (2009 baseline)	0	0
	CVVL,DCP,A6	312	437
	DCP,DeAct,A6	168	235
	DCP,Turbo,A6,EPS,ImpAlt	(161)	(161)
	CVVL,DCP,AMT,EPS,ImpAlt	319	446
	GDI-S,DeAct,DCP,AMT,EPS,ImpAlt	360	504
	GDI-S,DCP,Turbo,AMT,EPS,ImpAlt	(58)	(58)
Mid Term 2013-2015	gHCCI,DVVL,ICP,AMT,EPS,ImpAlt	324	453
	DeAct,DVVL,CCP,A6,ISG,EPS,eACC	924	1294
	ehCVA,AMT,EPS,ImpAlt	359	502
	ehCVA,GDI-S,AMT,EPS,ImpAlt	544	761
	gHCCI,DVVL,ICP,AMT,ISG,EPS,eACC	978	1369
	GDI-S,Turbo,DCP,A6,ISG,EPS,eACC	549	769
Long Term 2015-	dHCCI,AMT,42V,EPS,eACC	1108	1551
	ModHEV	1228	1719
	AdvHEV	1928	2699
	HSDI,AdvHEV	2733	3826

Table 5.3-4. Estimated Incremental Costs for Carbon Dioxide Reduction Technologies for Minivan Relative to 2009 Baseline

Minivan	Combined Technology Packages	Technology cost ($)	Retail Price Equivalent ($)
Near Term 2009-2012	DVVL,CCP,A5 (2009 baseline)	0	0
	DCP,A6	254	356
	GDI-S,CCP,DeAct,AMT,EPS,ImpAlt	333	466
	DVVL,CCP,AMT,EPS,ImpAlt	128	179
	CCP,AMT,Turbo,EPS,ImpAlt	519	727
	DeAct,DVVL,CCP,AMT,EPS,ImpAlt	221	309
	CVVL,CCP,AMT,EPS,ImpAlt	429	601
	GDI-S,DCP,Turbo,AMT,EPS,ImpAlt	773	1082
Mid Term 2013-2015	GDI-S,CCP,AMT,ISG,DeAct,EPS,eACC	1001	1401
	ehCVA,GDI-S,AMT,EPS,ImpAlt	797	1116
Long Term 2015-	ModHEV	1397	1956
	AdvHEV	2097	2936
	dHCCI,AMT,EPS,ImpAlt	943	1320

Table 5.3-5. Estimated Incremental Costs for Carbon Dioxide Reduction Technologies for Small Truck Relative to 2009 Baseline

Small Truck	Combined Technology Packages	Technology cost ($)	Retail Price Equivalent ($)
Near Term 2009-2012	DCP,A6	37	52
	DVVL,DCP,A6 (2009 baseline)	0	0
	DCP,A6,Turbo,EPS,ImpAlt	(144)	(144)
	DCP,A6,DeAct	164	229
	GDI-S,DCP,Turbo,AMT,EPS,ImpAlt, DCP-DS	(60)	(60)
	DeAct,DVVL,CCP,AMT,EPS,ImpAlt	221	309
	GDI-S,DCP,DeAct,AMT,EPS,ImpAlt	358	501
Mid Term 2013-2015	DeAct,DVVL,CCP,A6,ISG,EPS, eACC	950	1330
	ehCVA,GDI-S,AMT,EPS,ImpAlt	542	759
	HSDI,AMT,EPS,ImpAlt	827	1158
Long Term 2015-	ModHEV	1317	1844
	AdvHEV	2017	2824
	dHCCI,AMT,EPS,ImpAlt	346	485

Table 5.3-6. Estimated Incremental Costs for Carbon Dioxide Reduction Technologies for Large Truck Relative to 2009 Baseline

Large Truck	Combined Technology Packages	Technology cost ($)	Retail Price Equivalent ($)
Near Term 2009-2012	CCP,A6 (2009 baseline)	0	0
	DVVL,DCP,A6	302	423
	CCP,DeAct,A6	303	424
	DCP,DeAct,A6	564	790
	DeAct,DVVL,CCP,A6,EHPS,ImpAlt	466	653
	DeAct,DVVL,CCP,AMT,EHPS,ImpAlt	386	541
Mid Term 2013-2015	CCP,DeAct,GDI-S, AMT,EHPS,ImpAlt	533	746
	DeAct,DVVL,CCP,A6,ISG,EPS, eACC	1131	1584
	ehCVA,GDI-S,AMT,EHPS,ImpAlt	1113	1558
Long Term 2015-	GDI-L,AMT,EHPS,ImpAlt	1268	1775
	dHCCI,AMT,ISG,EPS,eACC	2075	2905
	ModHEV	1742	2439
	AdvHEV	2773	3882
	HSDI,AdvHEV	4840	6776
	GDI-L,AMT,42V,EPS,ImpAlt	1901	2674

Figure 5-6 through Figure 5-10 show the results of the incremental cost assessments of each technology package for the five different vehicle types. These figures plot each packages' incremental costs versus the resulting greenhouse gas reduction from the technology packages. These determinations are based on the information provided in this interim document and do not necessarily represent the final values to be recommended by staff.

The diagonal lines in the figures show, for given economic assumptions, the break-even cut-off for the technologies. Thus the furthest right-most point that is under the "break-even" line is the maximum potential cost-effective reduction of greenhouse gases for that vehicle class. Almost all of the greenhouse gas reduction technologies evaluated are below the break even lines, which means that they result in lifetime operating cost savings that exceed their incremental cost. The methodology to determine the "break-even" point is outlined below in section 5.4. More detailed results in tabular form are summarized at the end of the section in Table 5.3-8.

The data points have been shaped differently to denote their expected market readiness. Near-term technology packages are diamonds, mid-term are triangles, and long-term are "X"s.

For the small cars (see Figure 5-6), the near-term technologies have incremental costs ranging from $38 to $820. Of these near-term technologies, the maximum reduction technology package was the one with a turbocharged stoichiometric gasoline direct injection (GDI-S) engine with dual cam phasing (DCP) and an automated manual transmission (AMT), and various other technology improvements. This package yielded a 24% CO_2 emission reduction for an incremental cost of $820 from the 2009 small car baseline. Due to the reduction in operating cost that is also achieved by this package, the package results in a net present value (lifetime savings) of $1,133. That is, over the life of the vehicle, the operating cost savings is sufficient to entirely pay for the initial cost of the technology, and provide an additional $1,133 in savings to the owner. The next highest near-term package CO_2 reduction came from discrete variable valve lift (DVVL), dual cam phasing (DCP), and an automated manual transmission (AMT). This package yielded an 18% CO_2 reduction with respect to the 2009 baseline small car at an incremental cost of $157, with a lifetime savings of $1,267. The highest mid-term technology scenario for small cars included homogeneous combustion compression ignition (HCCI) technology and offered a 28% CO_2 emission reduction for an additional cost of $1262, with a lifetime savings of $984. Some of the longer-term (beyond 2009) technologies, such as advanced hybrid-electrics and diesels, resulted in higher potential CO_2 reductions, but had incremental costs ranging from $2230 to $4809. Many of these technologies nevertheless resulted in lifetime savings.

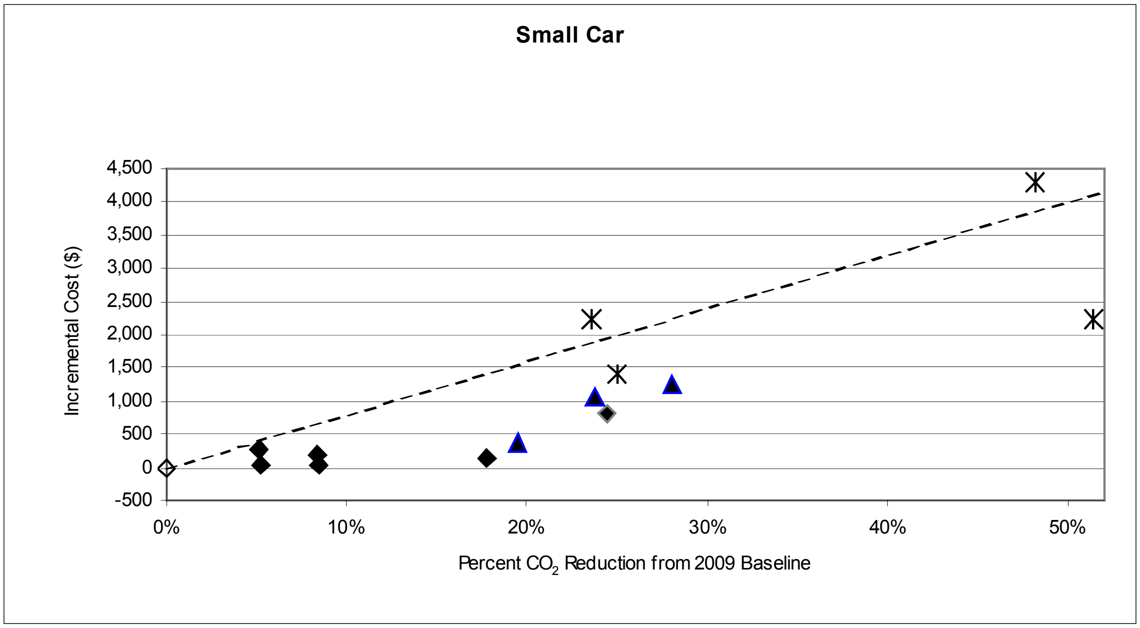


Figure 5-6. Incremental Costs for Technology Packages on 2009 Baseline Small Cars

For large cars (see Figure 5-7), the incremental costs to the consumer for the near-term technology scenarios ranged from a cost savings of \$161 to a cost increase \$504. The maximum reduction from a near-term technology was from the turbocharged stoichiometric gasoline direct injection (GDI-S) engine with dual cam phasing (DCP), and an automated manual transmission (AMT). This package yielded a 22% reduction in exhaust CO_2 emissions for a cost savings of \$58 compared to the 2009 baseline large car technology package, with a lifetime savings of \$2,060. The maximum reduction mid-term technology package in the analysis had a very similar technology package – a turbocharged stoichiometric gasoline direct injection (GDI-S) engine with dual cam phasing (DCP), a 6-speed automatic transmission (A6), and also had an integrated starter generator (ISG). This package yielded a 31% reduction in exhaust CO_2 emissions for an increased initial cost of \$769 from the 2009 large car baseline, with a lifetime savings of \$1,497.

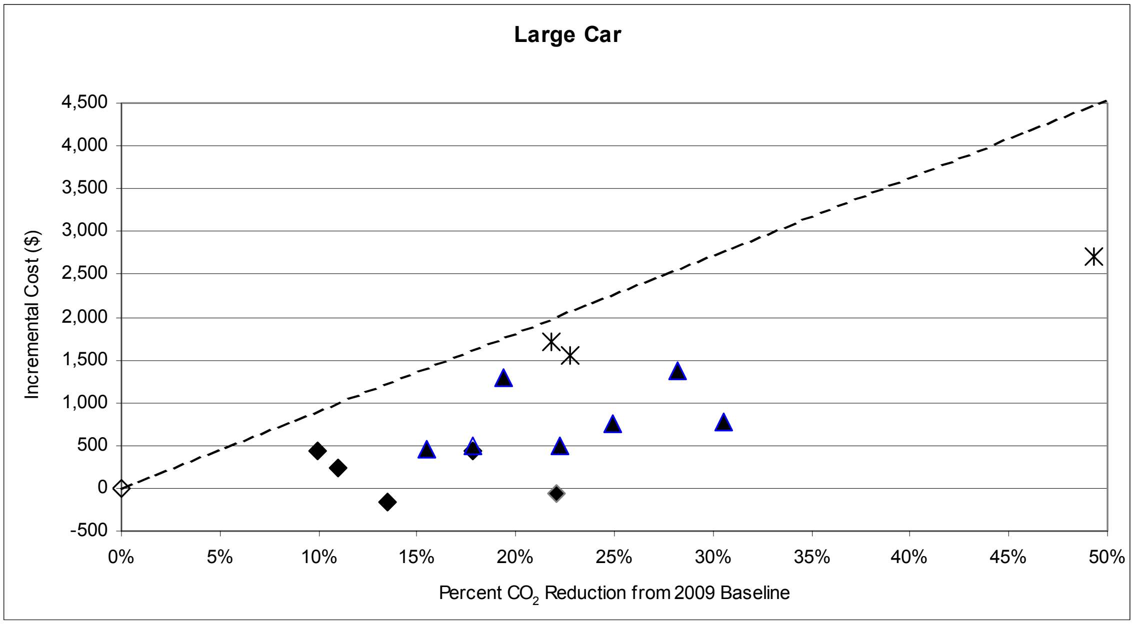


Figure 5-7. Incremental Costs for Technology Packages on 2009 Baseline Large Cars

For the minivan (see Figure 5-8), the maximum reduction from a near-term technology package in the analysis was determined to be the stoichiometric gasoline direct injection (GDI-S) engine with dual cam phasing (DCP), turbocharging, and an automated manual transmission (AMT). This package yielded a 17% reduction in exhaust CO_2 emissions for an increased initial cost of $1,082 from the 2009 large car baseline, with a lifetime savings of $819. A similar package that also included cylinder deactivation (DeAct) and a 42-volt integrated starter-generator (ISG) resulted in a 20% CO_2 reduction at an initial cost of $1401, with a lifetime savings of $816.

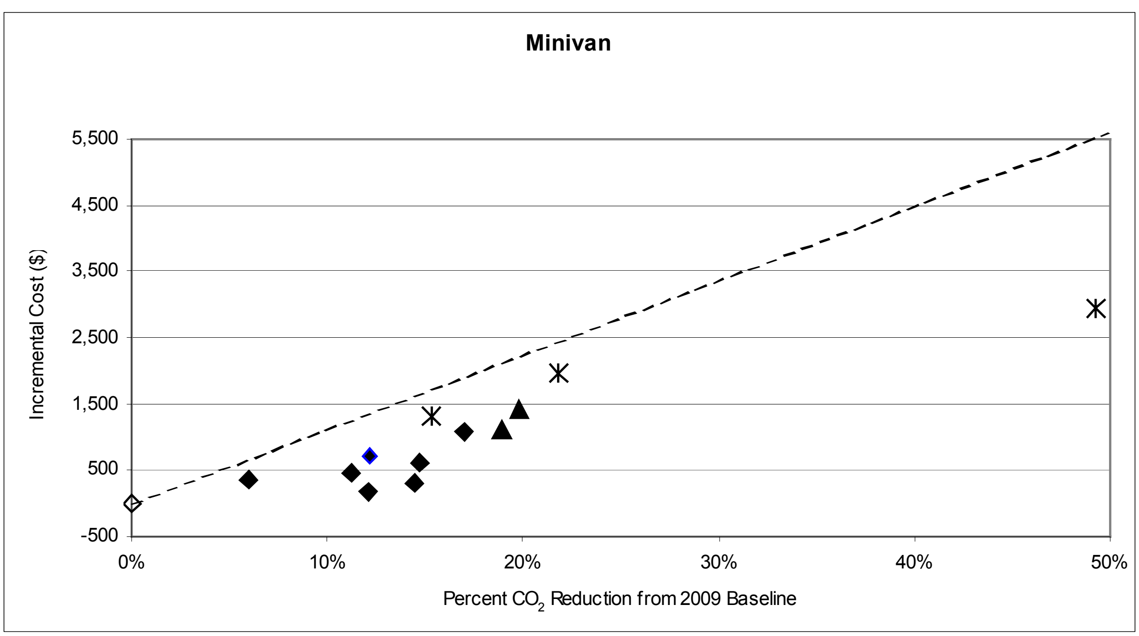


Figure 5-8. Incremental Costs for Technology Packages on 2009 Baseline Minivans

For the small truck vehicle type (see Figure 5-9), the incremental costs for the near-term scenarios ranged from a cost savings of $144 to a cost increase of $501. The near-term scenario with turbocharging, stoichiometric gasoline direct-injection, dual cam phasing (DCP), and an automated manual transmission (AMT), yielded a 21% reduction in exhaust CO_2 emissions at a cost savings of $60 compared to the 2009 baseline, and a lifetime savings of $1,633. The stoichiometric gasoline direct-injection engine with electrohydraulic camless valve actuation and an automated manual transmission (AMT) offered a 24% CO_2 emission reduction at an additional cost of $759, and a lifetime savings of $2,130.

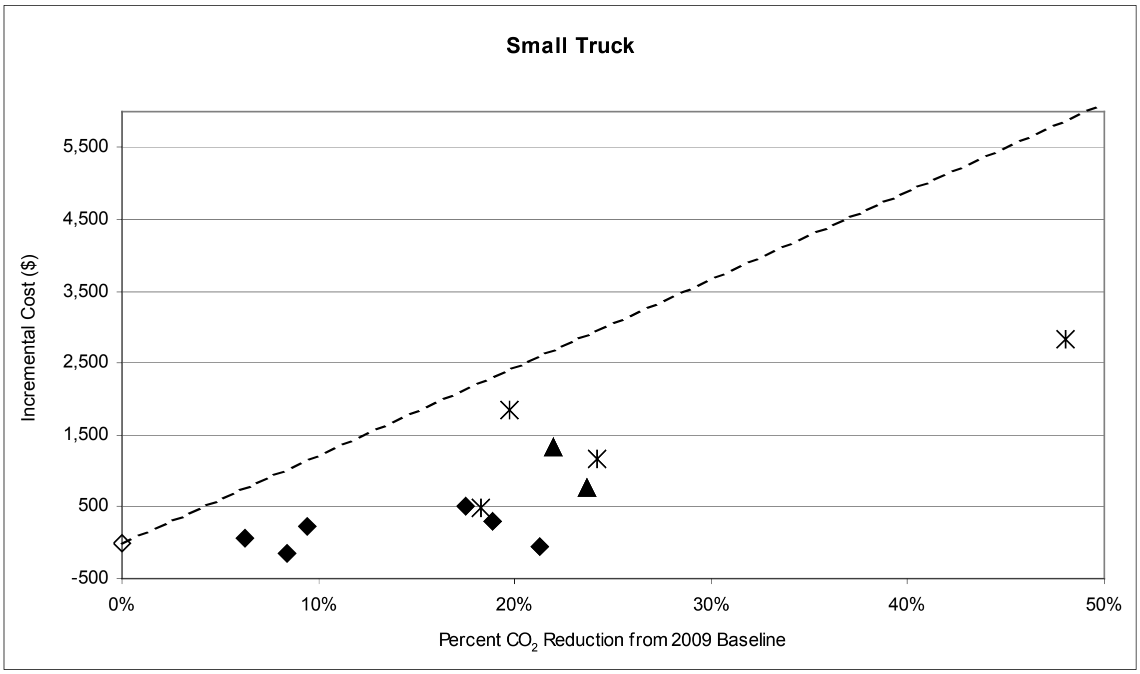


Figure 5-9. Incremental Costs for Technology Packages on 2009 Baseline Small Trucks

For the large trucks (see Figure 5-10), the maximum reduction near- and mid-term scenario packages involved cylinder deactivation, coupled cam phasing, and variable valve lift. The near-term version, which included an automated manual transmission (AMT), had an 18% CO_2 emission reduction and a cost increase of $541 relative to the 2009 baseline vehicle, with a lifetime savings of $2,106. The more advanced mid-term version of this package also included a 42-volt integrated starter-generator (ISG) and had a 22% CO_2 reduction with a $1,584 incremental cost from the 2009 large car baseline, with a lifetime savings of $1,620.

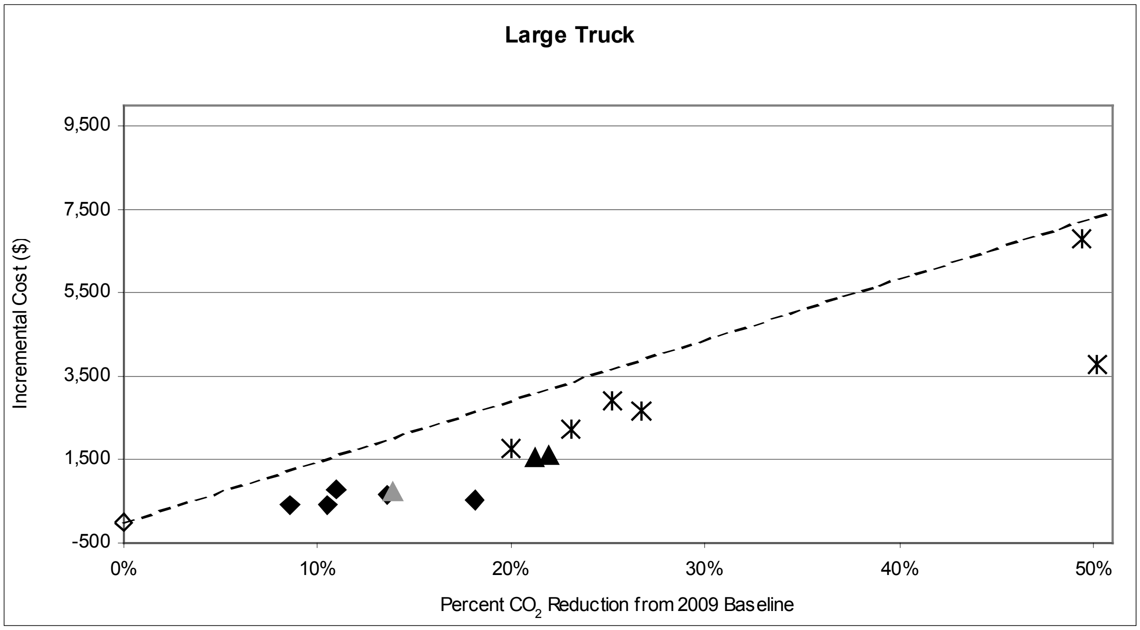


Figure 5-10. Incremental Costs for Technology Packages on 2009 Baseline Large Trucks

5.3.B Alternative Fuel Vehicles

This section presents ARB staff's assessment of the incremental costs of alternative fueled vehicles as compared to gasoline vehicles. The incremental cost estimates include only those costs directly related to the vehicle and while not exhaustive, provide a general sense of the relative cost of these vehicles. Thus, in the case of E85 where there are no additional costs to modify the vehicle, the incremental cost is zero.

Table 5.3-7. Incremental Costs of Alternative Fuel Vehicles

Vehicle type	Lifetime CO2 equivalent emissions (ton)	Lifetime CO2 equivalent emissions reduced from 2002 baseline (ton)	Percent reduction from Conventional Gasoline Vehicle	Incremental technology cost ($)
Conventional vehicles	99.9	0.0	0%	-
Compressed natural gas (CNG)	83.9	15.9	16%	3300
Liquid propane gas (LPG)	80.9	18.9	19%	370
HEV20	53.6	46.3	46%	4500
Ethanol (E85)	76.5	23.4	23%	0
Electric	38.0	61.9	62%	8800

5.3.C Summary of Incremental Cost Assessment

Technology improvements to vehicles' engine, drivetrain, and air-conditioning systems all result in incremental cost increases for light-duty vehicles. Improvements in the air conditioning system that included an improved variable displacement compressor, reduced leakage systems, and the use of an alternative refrigerant (HFC-152a) as well as incorporating other technologies such as improved aerodynamics and improved tires also resulted in an increase in vehicle costs. These costs are shown in Table 5.3-8. The table summarizes the key findings for the incremental costs of engine, drivetrain, and hybrid-electric vehicle technologies, improved air conditioning systems and the other technologies mentioned above. The table summarizes for each technology package the results for exhaust CO_2 emissions, the percentage change from the 2009 baseline emissions, the retail price incremental cost estimations for the installation of these technology packages on light-duty vehicles of the five vehicle classes that were studied here. There is a near-term, or off-the-shelf, technology package in each of the vehicle classes that resulted in a reduction of CO_2 emissions of at least 15-20% from baseline 2009 values. In addition, there is generally also a near-term technology package in each of the vehicle classes that results in an about 25% CO_2 emission reduction.

Table 5.3-8. Summary of Cost-Effectiveness Parameters for Climate Change Emission Reduction Engine, Drivetrain, and Hybrid-Electric Vehicle Technologies

Vehicle Class	Combined Technology Packages	Technology readiness	CO2 emissions (g/mi)	CO2 change from 2002 baseline	Lifetime CO2 reduced from 2002 baseline (ton)	CO2 change from 2009 baseline	Lifetime CO2 reduced from 2009 baseline (ton)	Retail cost incremental (2004$)	Cost incremental from 2009 baseline (2004$)	Lifetime Net Present Value (2004$)	Payback period (yr)
Small car	DVVL,DCP,A5	Near-term	284	-2.6%	1.7	0.0%	0.0	308	0	0	0
	DCP,A6	Near-term	260	-10.8%	7.0	-8.4%	5.3	346	38	635	1
	DCP,EPS,ImpAlt	Near-term	269	-7.6%	4.9	-5.2%	3.3	360	52	363	2
	DCP,A5,EPS,ImpAlt	Near-term	260	-10.7%	6.9	-8.3%	5.3	494	186	479	3
	DCP,CVT,EPS,ImpAlt	Near-term	269	-7.6%	4.9	-5.1%	3.2	570	262	149	8
	DVVL,DCP, AMT,EPS,ImpAlt	Near-term	233	-19.9%	12.9	-17.8%	11.3	465	157	1,267	2
	gHCCI,DVVL, ICP,AMT,EPS,ImpAlt	Mid-term	229	-21.6%	14.0	-19.5%	12.3	673	365	1,194	3
	GDI-S,DCP,Turbo, AMT,EPS,ImpAlt	Near-term	215	-26.4%	17.1	-24.4%	15.4	1,128	820	1,133	5
	gHCCI,DVVL,ICP, AMT,ISG,EPS,eACC	Mid-term	204	-29.9%	19.4	-28.1%	17.7	1,570	1,262	984	7
	dHCCI,AMT, ISG,EPS,eACC	Long-term	217	-25.5%	16.5	-23.5%	14.9	2,536	2,228	482	12
	HSDI,AdvHEV	Long-term	147	-49.5%	32.1	-48.2%	30.4	5,117	4,809	-396	>16
	CVVL,DCP,AMT, ISG-SS,EPS,ImpAlt	Mid-term	216	-25.7%	16.7	-23.8%	15.0	1,387	1,079	822	7
	Advanced HEV (ARB)	Long-term	138	-52.6%	34.1	-51.4%	32.5	2450	2142	1482	7
	Moderate HEV (ARB)	Long-term	213	-26.9%	17.5	-25.0%	15.8	1617	1309	1556	5
Large car	DVVL,DCP,A6	Near-term	322	-6.6%	5.1	0.0%	0.0	427	0	0	0
	DCP,DeAct,A6	Near-term	286	-16.9%	12.9	-11.0%	7.9	662	235	764	3
	CVVL,DCP,A6	Near-term	290	-15.9%	12.2	-10.0%	7.2	864	437	469	6
	DCP,A6	Near-term	304	-11.9%	9.1	-5.6%	4.0	479	52	459	1
	DCP,Turbo,A6,EPS,ImpAlt	Near-term	279	-19.2%	14.7	-13.5%	9.6	266	-161	1,381	0
	CVVL,DCP,AMT,EPS,ImpAlt	Near-term	265	-23.2%	17.8	-17.8%	12.7	873	446	1,166	3
	gHCCI,DVVL, ICP,AMT,EPS,ImpAlt	Long-term	272	-21.0%	16.1	-15.5%	11.1	880	453	949	4
	GDI-S,DCP,Turbo, AMT,EPS,ImpAlt	Near-term	251	-27.2%	20.9	-22.1%	15.8	369	-58	2,060	0
	DCP,CVT,EPS,ImpAlt	Near-term	303	-12.1%	9.3	-6.0%	4.3	708	281	259	6
	GDI-S,Turbo,DCP, A6,ISG,EPS,eACC	Mid-term	224	-35.1%	26.9	-30.5%	21.9	1,196	769	2,000	3
	DeAct,DVVL,CCP, A6,ISG,EPS,eACC	Mid-term	259	-24.7%	19.0	-19.4%	13.9	1,721	1,294	466	10
	gHCCI,DVVL,ICP, AMT,ISG,EPS,eACC	Mid-term	231	-32.9%	25.2	-28.2%	20.2	1,796	1,369	1,187	7
	dHCCI,AMT,ISG, EPS,eACC	Long-term	277	-19.7%	15.1	-14.0%	10.1	1,978	1,551	779	9
	HSDI,AdvHEV	Long-term	157	-54.4%	41.7	-51.1%	36.6	4,728	4,301	936	12
	GDI-S,DeAct,DCP, AMT,EPS,ImpAlt	Mid-term	265	-23.2%	17.8	-17.8%	12.8	931	504	1,111	4
	CVAeh,AMT,EPS,ImpAlt	Mid-term	250	-27.4%	21.0	-22.2%	15.9	929	502	1,514	3
	CVAeh,GDI-S, AMT,EPS,ImpAlt	Mid-term	242	-29.9%	22.9	-24.9%	17.8	1,188	761	1,497	4
	Advanced HEV (ARB)	Long-term	163	-52.6%	40.4	-49.3%	35.3	3038	2611	1894	7
	Moderate HEV (ARB)	Long-term	252	-27.0%	20.7	-21.8%	15.6	2058	1631	1809	6

Table 5.3-8 (cont.) Summary of Incremental Cost Parameters for Climate Change Emission Reduction Engine, Drivetrain, and Hybrid-Electric Vehicle Technologies

Vehicle Class	Combined Technology Packages	Technology readiness	CO_2 emissions (g/mi)	CO_2 change from 2002 baseline	Lifetime CO_2 reduced from 2002 baseline (ton)	CO_2 change from 2009 baseline	Lifetime CO_2 reduced from 2009 baseline (ton)	Retail cost incremental (2004$)	Cost incremental from 2009 baseline (2004$)	Lifetime Net Present Value (2004$)	Payback period (yr)
Minivan	DVVL,CCP,A5	Near-term	370	-6.4%	6.3	0.0%	0.0	315	0	0	0
	DCP,A6	Near-term	348	-12.0%	11.7	-5.9%	5.4	671	356	307	7
	DVVL,CCP,AMT, EPS,ImpAlt	Near-term	325	-17.7%	17.3	-12.1%	11.0	494	179	1,174	2
	CVVL,CCP,AMT, EPS,ImpAlt	Near-term	316	-20.2%	19.7	-14.7%	13.4	916	601	1,044	5
	GDI-S,DCP,Turbo, AMT,EPS,ImpAlt	Near-term	307	-22.3%	21.8	-17.0%	15.5	1,397	1,082	819	8
	DeAct,DVVL,CCP, AMT,EPS,ImpAlt	Near-term	317	-19.9%	19.4	-14.4%	13.2	624	309	1,305	2
	GDI-S,CCP,DeAct, AMT,EPS,ImpAlt	Mid-term	328	-17.0%	16.5	-11.2%	10.3	781	466	792	5
	CCP,AMT,Turbo, EPS,ImpAlt	Near-term	325	-17.8%	17.4	-12.2%	11.1	1,042	727	633	7
	dHCCI,AMT, EPS,ImpAlt	Long-term	313	-20.8%	20.2	-15.3%	14.0	1,635	1,320	1,678	6
	GDI-S,CCP,AMT,ISG, DeAct,EPS,eACC	Mid-term	297	-25.0%	24.3	-19.8%	18.1	1,716	1,401	816	9
	CVAeh,GDI-S, AMT,EPS,ImpAlt	Mid-term	300	-24.1%	23.5	-18.9%	17.2	1,431	1,116	999	7
	Advanced HEV (ARB)	Long-term	188	-52.6%	51.2	-49.3%	44.9	3038	2723	2789	6
	Moderate HEV (ARB)	Long-term	289	-26.8%	26.1	-21.8%	19.9	2058	1743	695	11
Small truck	DVVL,DCP,A6	Near-term	404	-9.0%	9.9	0.0%	0.0	427	0	0	0
	DCP,A6	Near-term	379	-14.7%	16.1	-6.3%	6.2	479	52	713	1
	DCP,A6,Turbo, EPS,ImpAlt	Near-term	371	-16.7%	18.3	-8.4%	8.4	283	-144	1,169	0
	DCP,A6,DeAct	Near-term	366	-17.7%	19.3	-9.5%	9.4	656	229	928	2
	GDI-S,DCP,Turbo, AMT,EPS,ImpAlt	Near-term	318	-28.4%	31.1	-21.3%	21.2	367	-60	2,663	0
	DeAct,DVVL,CCP, AMT,EPS,ImpAlt	Near-term	328	-26.2%	28.7	-18.9%	18.8	736	309	1,997	2
	DeAct,DVVL,CCP, A6,ISG,EPS,eACC	Mid-term	316	-29.0%	31.8	-22.0%	21.9	1,757	1,330	1,354	6
	GDI-S,DCP,DeAct, AMT,EPS,ImpAlt	Mid-term	334	-24.9%	27.3	-17.5%	17.4	928	501	1,633	3
	dHCCI,AMT, EPS,ImpAlt	Long-term	331	-25.6%	28.1	-18.3%	18.2	912	485	3,101	2
	HSDI,AMT, EPS,ImpAlt	Long-term	307	-31.0%	34.0	-24.2%	24.1	1,585	1,158	3,052	3
	CVAeh,GDI-S, AMT,EPS,ImpAlt	Mid-term	309	-30.5%	33.5	-23.6%	23.6	1,186	759	2,130	3
	Advanced HEV (ARB)	Long-term	210	-52.7%	57.7	-48.0%	47.8	3038	2611	3257	6
	Moderate HEV (ARB)	Long-term	325	-27.0%	29.5	-19.7%	19.6	2058	1631	777	10
Large truck	CCP,A6	Near-term	484	-5.5%	6.9	0.0%	0.0	126	0	0	0
	DVVL,CCP,A6	Near-term	442	-13.6%	17.1	-8.6%	10.2	549	423	829	2
	DCP,DeAct,A6	Near-term	430	-15.9%	20.0	-11.0%	13.1	916	790	816	4
	CCP,DeAct,A6	Near-term	433	-15.4%	19.4	-10.5%	12.5	550	424	1,112	1
	DeAct,DVVL,CCP, A6,EHPS,ImpAlt	Near-term	418	-18.4%	23.1	-13.6%	16.2	779	653	1,340	2
	DeAct,DVVL,CCP, AMT,EHPS,ImpAlt	Near-term	396	-22.6%	28.5	-18.1%	21.6	667	541	2,106	1
	GDI-L,AMT, EHPS,ImpAlt	Long-term	387	-24.4%	30.7	-20.0%	23.8	1,901	1,775	1,148	7
	DeAct,DVVL,CCP, A6,ISG,EPS,eACC	Mid-term	378	-26.2%	33.0	-21.9%	26.1	1,710	1,584	1,620	5
	dHCCI,AMT,ISG, EPS,eACC	Long-term	362	-29.3%	36.9	-25.2%	30.0	3,031	2,905	781	11
	HSDI,AdvHEV	Long-term	244	-52.2%	65.8	-49.5%	58.9	9,474	9,348	-1,119	>19
	GDI-L,AMT,ISG, EPS,ImpAlt	Long-term	354	-30.7%	38.7	-26.7%	31.8	2,800	2,674	1,230	9
	CVAeh,GDI-S, AMT,EHPS,ImpAlt	Mid-term	381	-25.5%	32.1	-21.2%	25.2	1,684	1,558	3,099	4
	CCP,DeAct,GDI-S, AMT,EHPS,ImpAlt	Mid-term	416	-18.6%	23.5	-13.9%	16.6	872	746	1,288	3
	Advanced HEV (ARB)	Long-term	241	-52.9%	66.7	-50.2%	59.8	3920	3794	3543	7
	Moderate HEV (ARB)	Long-term	372	-27.3%	34.4	-23.1%	27.5	2352	2226	1150	9

5.4 Lifetime Cost Of Technologies To Vehicle Owner-Operator

Following the direction of AB 1493 to demonstrate maximum cost-effective greenhouse gas reductions that are "economical to an owner or operator of a vehicle, taking into account the full life-cycle costs of a vehicle," this portion of the assessment provides estimations of the lifetime impact to vehicle operators for the greenhouse gas reduction technologies that were described previously. Such a detailed analysis has not been needed for previous California motor vehicle emission standards and regulations to meet federal requirements and is not needed here for that purpose; it is introduced here to satisfy AB 1493.

Applying estimations for the technology costs and assumptions for vehicle use and economic variables, estimations of the lifetime vehicle costs are quantified using a net present value (NPV) framework. This section conducts a NPV analysis on the engine, drivetrain, hybrid-electric, and alternative fuel vehicle technologies that were described in the technology section. The ARB staff is currently investigating ways to integrate the air conditioning cost-effectiveness work presented in the previous section with the engine, drivetrain, and other technologies into this section on lifetime costs. This NPV analysis involves an assessment of an initial consumer cost for the climate change reduction technologies and the potential net lifetime benefits in the future that result from the initial investment. If the sum of net future benefits outweighs the initial technology cost within the lifetime of the technology, the investment in the new technology is cost beneficial. The first year in which the net future benefits exceed the initial cost of the technology is called the break-even, or payback, period. The total initial cost to consumers, including the manufacturing cost plus the 40% mark-up for profit, and overhead, is K_0.

$$NPV_0 = -K_0$$

Future vehicle operator benefits and costs due to the new technology are discounted by the discount rate, or time value of money, *d,* to correct for the difference in the value of money in hand today versus money in the future (based primarily on interest rate and inflation). The NPV of the investment one year from now (in current dollars) is calculated,

$$NPV_1 = NPV_0 + \frac{\sum(Benefits,\ year\ 1) - \sum(Costs,\ year\ 1)}{(1+d)^1}$$

Or, more generally in any year *x*,

$$NPV_x = NPV_{x-1} + \frac{\sum(Benefits,\ year\ x) - \sum(Costs,\ year\ x)}{(1+d)^x}$$

Following historical trends, the analysis uses a real discount rate, or time value of money, of 5%. These values for the discount rate are based on ten-year averages of automobile interest rate and the general inflation rate.

The costs of the alternative fuels that are considered in this report were taken from the Tiax LLC alternative fuel vehicle study. For gasoline and diesel fuels, the prices are inflation adjusted from the values in the California Energy Commission (CEC) *Integrated Energy Policy Report* (CEC, 2004). For gasoline the price is $1.74 per gallon, and the diesel price is $1.73 per gallon (in 2004 dollars). These values are roughly consistent with the 3-yr historical California fuel prices.

5.4.A Engine, Drivetrain and Hybrid Electric Vehicle Technologies

The greenhouse gas reduction technologies evaluated in this report yield reductions in operating cost over the lifetime of the vehicle. The effects of the new engine and drivetrain technology systems on the lifetime vehicle maintenance costs are currently being investigated. For example, technologies that involve a reduction of the number of moving parts, like a camless valve actuation system, are expected to reduce lifetime maintenance costs. Similarly, lower leakage rate air conditioning systems should reduce maintenance costs. Without comprehensive data on these effects, maintenance costs are excluded here.

The costs and lifetime benefits for the technology packages were evaluated over the vehicle lifetime, using the same vehicle use parameters as Section 5.3. The results are shown in the “lifetime Net Present Value” and “Payback Period” columns in Table 5.3-8. Nearly all of the technologies evaluated provide a positive lifetime net present value, and thus are economical to the owner over the lifecycle of the vehicle.

5.4.B Alternative Fuel Vehicles

ARB staff has estimated the incremental costs of deploying alternative fuel vehicles to reduce greenhouse gases. This analysis compared the lifecycle costs of alternative fuel vehicles to the lifecycle cost of a conventional gasoline vehicle. The analysis is similar to the net present value analysis of engine and drivetrain technologies presented above. For this analysis, however, comprehensive data on how alternative fuel vehicle technologies differ among different vehicle types (e.g. small cars and large trucks) were not available. Therefore, the analysis compared a mid-sized alternative-fueled vehicle produced in volume production to a baseline conventional vehicle. The baseline conventional vehicle represents the California-specific sales weighting of 2009 small and large cars (i.e. trucks, minivans and SUVs are excluded).

ARB staff relied on modeling and cost information presented as part of the Tiax LLC analysis. This analysis included an evaluation of the incremental retail costs associated with equipping vehicles to operate on alternative fuels, and the costs of alternative fuels for 2009. The analysis does not include transitional costs such as vehicle development, certification or fuel transition infrastructure costs. Projecting fuel cost for 2009 is particularly difficult and can substantially affect the overall net present value. All cost estimates are presented in Table 5.4-1. Staff then estimated the net present value of the various alternative fuel vehicles using the same vehicle characteristics as given above.

The results demonstrate that two alternative fuel technologies can meet the life cycle costs of conventional gasoline vehicles. These include plug-in HEVs with an all-electric range of 20 miles, and LPG. Each of these technologies can also provide significant climate change emission reductions and thus provide automakers with additional cost effective compliance pathways in meeting the regulation.

Table 5.4-1. Life Cycle Cost of Alternative Fuel Vehicles

Vehicle-fuel systems	Distance per fuel usage (miles/fuel unit)	Sales-average fuel usage (fuel unit/mi)	fuel unit	Fuel cost ($/fuel unit)	Cost increment from 2009 baseline	Lifetime (16-yr) Net Present Value (2004$)	Payback period
Conventional vehicles	24.8	0.040	GGE	1.74	0	(0)	0
Compressed natural gas (CNG)	24.8	0.040	GGE	1.50	3300	(1,919)	>16
Liquid propane gas (LPG)	18.8	0.053	LPG gal	1.12	370	1,161	3
HEV20	2.96	0.337	kWh	0.074	-	-	-
	36.75	0.027	GGE	1.74	-	-	-
					4500	3,298	9
Ethanol (E85)	17.6	0.057	e85 gal	1.76	0	(4,203)	none
Electric	2.5	0.400	kWh	0.074	8800	(3,056)	>16

5.5 Conclusions

Identified in this analysis are a large number of technologies that reduce greenhouse gas emissions. The technologies range from low friction oils to advanced hybrid electric drive trains to alternative fuel vehicles. Many of the technologies, especially those involving the engine valve train and transmission, are used on some cars now, and could be in near universal use in the 2009 timeframe. Other technologies are still undergoing development, and can be expected to be available for widespread use after 2010. These include advanced valve trains and advanced hybrid electric drives.

Logical combinations of these technologies have been modeled to determine the potential to reduce greenhouse gas emissions from different size vehicles. The cost of the technology packages has also been determined, as has their impact on operating costs. Reductions in CO_2-equivalent emissions, compared to emissions of 2009 models in the absence of government regulation, vary widely, from a few percent to over 45 percent. In general the higher percentage reductions involve technologies that may not be widely available in 2009, but are expected to be available sometime after 2010.

Several technologies stood out as providing significant reductions in emissions at favorable costs. These include discrete variable valve lift, dual cam phasing, turbocharging with engine downsizing, automated manual transmissions, and camless valve actuation. Packages containing these and other technologies such as improved air conditioning compressors provided substantial emission reductions at prices that ranged from a saving to several hundreds of dollars. Nearly all technology combinations modeled provided reductions in lifetime operating costs that exceeded the retail price of the technology.

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6 CLIMATE CHANGE EMISSION STANDARDS

Vehicle climate change emissions comprise four main elements, 1) CO_2, CH_4 and N_2O emissions resulting directly from operation of the vehicle, 2) CO_2 emissions resulting from operating the air conditioning system (indirect AC emissions), 3) refrigerant emissions from the air conditioning system due to either leakage, losses during recharging, or release from scrappage of the vehicle at end of life (direct AC emissions), and 4) upstream emissions associated with the production of the fuel used by the vehicle. The climate change emission standard incorporates all of these elements.

This section also outlines the staff proposal with respect to credits for early action, and credit for alternative compliance projects.

Staff elected to incorporate the CO_2 equivalent emission standards into the current LEV program along with the other light and medium-duty automotive emission standards. The FTP urban and highway test cycles used as a basis in setting the existing LEV emission standards are also used in setting the climate change emission standards. Accordingly, there would be a CO_2 equivalent fleet average emission requirement for the passenger car/light-duty 1 (PC/LDT1) category and another for the light-duty truck 2 (LDT2) category, just as there are fleet average emission requirements for criteria pollutants for both categories of vehicles in the LEV program.

The fleet average requirements in the current LEV program rely on results of FTP urban cycle testing, with the highway test being used to ensure proper control of NOx emissions under all driving conditions. In the more distant past, when emission controls consisted primarily of engine modifications, it was possible to calibrate these controls to be effective in reducing emissions during FTP urban driving while being less effective during highway driving, especially relative to NOx emissions. With the advent of the LEV program, however, where emission control is dominated by effective aftertreatment devices, vehicles capable of passing the FTP test virtually always pass the highway test requirements with considerable margin. Hence the highway test serves more of a “capping” function to ensure that NOx emissions are well-controlled under all driving conditions.

In the case of CO_2 tailpipe emissions, however, there are no aftertreatment devices that can be applied to reduce engine out CO_2 emissions, so there is greater reliance on engine modifications to achieve these reductions (in concert with other powertrain and vehicle modifications). Accordingly it is important to ensure that vehicles are achieving maximum reductions under all driving conditions. Therefore, it is necessary to use both the FTP urban and highway cycles in determining the fleet average CO_2 equivalent emissions. In order to best reflect real world fleet emissions based on the two test cycles, the

NESCCAF study presented its findings in terms of a combined 55% urban/45% highway harmonic average. This split represents the national mix of urban and rural driving historically used by government agencies in reports that rely on this statistic. The statistic comes from the US Department of Transportation, Federal Highway Administration. However, more recent data from a December 1, 2003 summary by the agency shows a 62% urban/38% rural ratio of driving that may be more appropriate. ARB staff will consider using the updated ratio in setting our final CO_2 equivalent standards.

6.1 Determination of Maximum Feasible Emission Reduction Standard

For each of the vehicle classes, NESCCAF modeled numerous technology combinations in order to determine the most effective packages for reducing CO_2 emissions. This section outlines how the ARB staff utilized the NESCCAF modeling results to establish emission standards for the two LEV program vehicle classes – passenger cars and light duty trucks with test weights under 3751 lbs loaded vehicle weight (PC/LDT1), and light duty trucks with test weights between 3751 lbs. loaded vehicle weight and 8,500 lbs. gross vehicle weight (GVW) (LDT2). Medium-duty passenger vehicles (MDPVs) between 8,500-10,000 lbs. GVW would be included with manufacturers' LDT2 vehicles when determining compliance with the climate change emission standards.

Before describing the procedure used to determine the climate change emission standards below, it should be noted that different methodologies must be used when transitioning from an analysis of the potential benefits of the technology packages to setting emission standards based on these packages. First, in section 5 (Maximum Feasible and Cost-Effective Technologies) that describes the technology packages and their emission benefits relative to 2002, the baseline 2002 vehicle emissions include the indirect CO_2 emissions resulting from the use of an air conditioning system with a conventional fixed displacement compressor. The emission benefits listed in section 5 compare, against their respective baseline vehicles, the results from modeling vehicles using the chosen technology packages along with the additional benefits resulting from the use of an air conditioning system incorporating improved controls and a variable displacement compressor, and the CO_2 reductions that can be achieved from the use of lower friction tires, early lock-up torque converters, better aerodynamics and other technologies. This methodology is appropriate if the purpose of the analysis is to approximate the reductions that would be realized when the vehicles are operated under real world conditions.

Vehicles demonstrating compliance with the proposed emission standards, however, would not be tested under real world conditions but would be tested on a chassis dynamometer where the air conditioning system is not operated. Therefore, it is appropriate that the indirect air conditioning emissions not be included in the emissions for the respective baseline vehicles when setting a standard based on dynamometer testing. Consequently, the emission reductions listed in this section do not reflect the values listed in the tables in section 5.

While NESCCAF was able to predict the penetration of new technologies into the vehicle fleet in the 2009 timeframe using the projections from Martec, thereby enabling the construction of the appropriate baseline vehicles for 2009, staff is unable to translate these baseline vehicles into a representative California fleet for 2009. Individual manufacturer market share and consumer vehicle preferences may change depending on many factors. Accordingly, staff relied on its analysis of the 2002 fleet to determine climate change emission standards for 2009 and beyond.

Currently, minivans are classified as light-duty trucks and fall into the LDT2 category since their test weights are on the order of 4,000 lbs. However, these vehicles are generally based on a passenger car chassis and an examination of the NESCCAF data reveals that their CO_2 emissions are more properly aligned with passenger cars than trucks. Therefore, staff is evaluating whether these vehicles should be reclassified as passenger cars and has not included them in this analysis of the climate change emission standards.

Determination of the climate change emission standards involves several steps. First, the maximum feasible emission reductions were modeled (NESCCAF 2004) for the five vehicle types with various technology packages (e.g., engine, drivetrain, and air-conditioning systems). These technology packages were then categorized with respect to their technology readiness (i.e. near-, mid-, or long-term). Second, manufacturer specific data was collected for the California fleet in order to evaluate individual manufacturer product mix. The emission standards for each category were then determined based on the manufacturer with the highest average weight vehicles to ensure all manufacturers can comply with the standards (i.e. not simply according to the average of all the manufacturers).

To summarize the process, the steps taken to derive the climate change emission standards are:

1) Select appropriate technology packages from the NESCCAF study for setting the near and mid-term emission standards.
2) From the NESCCAF modeling results, determine average CO_2 exhaust emission values for each group of selected technology packages.
3) Adjust these values to reflect the CO_2 equivalent reductions achievable from improved mobile air conditioning systems, and include vehicle emissions of CH_4 and N_2O.
4) Using the resulting CO_2 equivalent emission values, derive the regression lines for setting the near and mid term climate change emissions standards.
5) Determine the baseline CO_2 emissions for California 2002 model year light-duty vehicles.

6) Using California baseline data, establish the baseline CO_2 emission rates for the PC/LDT1 and LDT2 classes from which the standards will be derived using the manufacturer with the heaviest fleet (this ensures that the proposed reductions are feasible for all manufacturers).
7) Derive the near and mid-term emission standards using the vertical intersection between the baseline emission rates for each vehicle class and the regression lines determined in step 6.

This process is explained in detail below.

6.1.A Selection of Technology Packages for Setting the Near- and Mid-Term CO_2 Equivalent Requirements

As a prelude to setting CO_2 equivalent emission standards, staff grouped the various packages into near, mid and long-term applicability based on the projected readiness of the individual technologies for implementation in large volumes in the given timeframes. A brief description of the chosen technology packages is offered here, and a tabular summary of the technologies and their CO_2 equivalent emission levels are shown below in Table 6.1-2 (for near-term) and Table 6.1-3 (for mid-term).

Near-term technologies were considered in assessing technological feasibility in the 2009 to 2011 timeframe. For the 2009 through the 2011 model years (MYs), staff developed the CO_2 equivalent emission standards based on the two packages in each of the five vehicle classes modeled in the NESCCAF study that yielded the greatest emission reductions. There was no need to further distinguish these packages on the basis of cost since each was relatively low (in fact, two of the packages yielded a cost savings). These packages generally include gasoline direct injection engines in conjunction with either turbocharging or cylinder deactivation, plus an automated manual 6-speed transmission and other technologies.

In assessing feasible reductions for 2012 and on, the mid-term technology package emission levels were utilized. For the 2012 and subsequent model years, staff developed CO_2 equivalent emission standards based on the top two or three potentially successful packages that yielded the greatest emission reductions while moderating costs. Selecting several packages provides manufacturers with greater flexibility to match technologies with their particular designs. Incremental costs for these packages ranged from \$761 to \$1584 as compared to the 2009 baseline. The technology packages generally included either electrohydraulic camless valve actuation in conjunction with gasoline direct injection, or various other engine technologies (e.g., turbochargers, advanced valvetrain systems, gasoline HCCI, cylinder deactivation, etc.) coupled with an integrated starter generator system providing regenerative braking and some launch assist.

6.1.B Inclusion of Mobile Air Conditioning CO_2 Equivalent Emissions in the Standard

Since no test protocol exists at this time to measure HFC emissions, either direct or indirect, these emissions have been included in the emission standards in the form of a credit such that manufacturers making improvements to their air conditioning systems can apply the credit towards their measured exhaust emissions when demonstrating compliance with the standard. Specifically, the emission reductions achievable from improved air conditioning systems have been subtracted from the emission values derived from the NESCCAF modeling of the near term and mid term technology packages used to set the climate change standards

Direct Air Conditioning System Emissions
Where a manufacturer demonstrates that their systems employ advanced leak reduction components such as improved seals, connections and hoses, the credit ranges from 3 grams per mile CO_2 equivalent emissions for systems using HFC 134a to 8.5 grams per mile CO_2 equivalent emissions for systems using HFC152a. Staff anticipates that manufacturers can readily incorporate low leak air conditioning systems in their vehicles for the near term (2009-2011), and will be converting to HFC 152a systems in the mid term (2012 and beyond). Therefore, staff has increased the stringency of the near term and mid term climate change emission standards accordingly.

Indirect Air Conditioning System Emissions
Indirect HFC emissions from conventional fixed displacement compressors and variable displacement compressors were modeled in the NECCAF study. The study demonstrated that using variable displacement compressors in conjunction with other system improvements can significantly reduce the exhaust CO_2 emissions associated with air conditioning use. Therefore, manufacturers incorporating improved air conditioning systems using variable displacement compressors and other features can apply a credit towards the measured exhaust emissions when demonstrating compliance to the emission standard. One comment staff received at its workshop indicated that fixed displacement compressors with improved thermal control can also reduce the indirect emissions associated with air conditioning operation. Manufacturers using improved air conditioning systems with fixed displacement compressors that can demonstrate comparable CO_2 reductions can also apply some portion of the credit towards meeting the CO_2 equivalent emission standard. Staff believes that these advanced systems can be readily incorporated in vehicles in the near-term and has, therefore, increased the stringency of the climate change emission standards accordingly. The reductions of indirect air conditioning CO_2 emissions from improved air conditioning systems range from 7.1 grams CO_2 per mile for small cars up to 10 grams CO_2 per mile for light trucks. Manufacturers that choose to incorporate other advanced climate change technologies to achieve

the standards may of course forego improvements to their air conditioning systems if they so choose.

The CO_2 equivalent emission values for indirect air conditioning system emissions from the NESCCAF study and direct CO_2 equivalent emissions from Table 5.2-11 used to adjust the chosen technology packages are listed in Table 6.1-1.

Table 6.1-1. Improved Air Conditioning System CO_2 Equivalent Emission Reductions

	Indirect CO_2 Equivalent Reduction from Advanced AC VDC system [1] (g/mi)	Direct CO_2 Equivalent Emission Reduction (g/mi)		Total A/C System Reduction [4] (g/mi)	
		Near-term[2]	Mid-term[3]	Near-term	Mid-term
Small car	7.1	3	8.5	10.1	15.6
Large car	8.1	3	8.5	11.1	16.6
Minivan	10.0	3	8.5	13.0	18.5
Small truck	10.0	3	8.5	13.0	18.5
Large truck	10.0	3	8.5	13.0	18.5

[1] improved efficiency air conditioning VDC or FDC system. [2] improved low leak HFC 134a system.
[3] improved low-leak HFC 152a. [4] sum of direct and indirect emission reduction credits.

As noted above, the air conditioning system credits were subtracted from the modeled gram-per-mile CO_2 levels for each of the different technology packages. The resulting CO_2 equivalent gram per mile values including CH_4 and N_2O are shown in Table 6.1-2 and Table 6.1-3 for the near- and mid-term, respectively. The average CO_2 gram-per-mile values of the selected technology packages were then used to determine the maximum feasible CO_2 equivalent reduction for each of the two LEV II vehicle classes.

Table 6.1-2. Maximum Feasible Near-Term CO_2 Reduction Levels

Vehicle Class	Combined Technology Packages	Test CO_2, without A/C (g/mi)	Test CO_2 equivalent with A/C credit (g/mi)	Maximum feasible reduction tested CO_2 equivalent with A/C credit for vehicle class (g/mi)
Small car	DVVL,DCP, AMT,EPS,ImpAlt	229	219	209
	GDI-S,DCP,Turbo, AMT,EPS,ImpAlt	210	200	
Large car	GDI-S,DeAct,DCP, AMT,EPS,ImpAlt	259	248	241
	GDI-S,DCP,Turbo, AMT,EPS,ImpAlt	245	234	
Minivan	CVVL,CCP,AMT, EPS,ImpAlt	299	287	283
	GDI-S,DCP,Turbo, AMT,EPS,ImpAlt	290	279	
Small truck	DeAct,DVVL,CCP, AMT,EPS,ImpAlt	321	308	303
	GDI-S,DCP,Turbo, AMT,EPS,ImpAlt	311	298	
Large truck	DeAct,DVVL,CCP, A6,EHPS,ImpAlt	410	398	387
	DeAct,DVVL,CCP, AMT,EHPS,ImpAlt	389	376	

Table 6.1-3. Maximum Feasible Mid-Term CO_2 Reduction Levels

Vehicle Class	Combined Technology Packages	Test CO_2, without A/C (g/mi)	Test CO_2 equivalent with A/C credit (g/mi)	Maximum feasible reduction tested CO_2 equivalent with A/C credit for vehicle class (g/mi)
Small car	CVVL,DCP,AMT, ISG-SS,EPS,ImpAlt	212	196	190
	gHCCI,DVVL,ICP, AMT,ISG,EPS,eACC	200	184	
Large car	CVAeh,GDI-S, AMT,EPS,ImpAlt	236	220	210
	gHCCI,DVVL,ICP, AMT,ISG,EPS,eACC	226	209	
	GDI-S,Turbo,DCP, A6,ISG,EPS,eACC	218	202	
Minivan	CVAeh,GDI-S, AMT,EPS,ImpAlt	282	266	265
	GDI-S,CCP,AMT,ISG, DeAct,EPS,eACC	280	263	
Small truck	DeAct,DVVL,CCP, A6,ISG,EPS,eACC	309	290	284
	CVAeh,GDI-S, AMT,EPS,ImpAlt	302	283	
	HSDI,AMT, EPS,ImpAlt	298	280	
Large truck	CVAeh,GDI-S, AMT,EHPS,ImpAlt	374	355	354
	DeAct,DVVL,CCP, A6,ISG,EPS,eACC	370	352	

6.1.C Light-Duty Vehicle Fleet Baseline

Characterizing California light-duty vehicle fleet baseline CO_2 emissions and vehicle weights by manufacturer is necessary in determination of feasibility of the standard for each manufacturer. That is, the maximum feasible standard must be set relative to the manufacturer with the highest average baseline emissions and/or average vehicle test weights.

The 2002 model year baseline is derived from California Department of Motor Vehicles records for registered 2002 model year vehicles adjusted to include the CO_2 equivalent emissions of CH_4 and N_2O. Table 6.1-4 shows sales-averaged CO_2 data, and sales-averaged test weight data for the six major light-duty vehicle manufacturers. Because the form of the climate change emission standard is structured similar to the LEV standard, the baseline for the California fleet is segmented into two light-duty classes (PC/LDT1 and LDT2) for each manufacturer. Smaller auto companies were grouped with their parent companies where applicable.

Table 6.1-4. 2002 Baseline CO_2 Equivalent Emissions and Test Weight by Manufacturer

Company[1]	Percent of vehicles for each auto (2002)		Sales-averaged test weight (lb)		Sales-averaged CO_2 (g/mi)	
	PC/LDT1	LDT2	PC/LDT1	LDT2	PC/LDT1	LDT2
Daimler Chrysler	45%	55%	3,644	4,729	346	451
Ford	44%	56%	3,569	4,909	334	445
General Motors	41%	59%	3,470	5,113	318	459
Honda	82%	18%	3,248	4,544	282	379
Nissan	61%	39%	3,369	4,393	305	447
Toyota	59%	41%	3,462	4,555	201	422
Average (6 major auto companies)	53%	47%	3457	4833	312	443

[1] The following models are included within each larger company name: Daimler Chrysler – Dodge, Chrysler, Mercedes, Jeep; Ford – Ford, Lincoln, Mercury, Jaguar, Rover, Mazda; General Motors – Chevrolet, Pontiac, Buick, GMC, Cadillac, Geo, Saturn; Honda – Honda, Acura; Nissan – Nissan, Infiniti; Toyota – Toyota, Lexus

Manufacturer data for sales-weighted averages of CO_2 emissions and test weight (from Table 6.1-4) are plotted along with the maximum feasible reduction CO_2 equivalent levels (from Table 6.1-2 and Table 6.1-3) in Figure 6.1-1 for the PC/LDT1 category and in Figure 6.1-2 for the LDT2 category. In these figures, the labeled points represent each manufacturer's average CO_2 emission level and test weight. The maximum feasible reduction levels are shown in the diagonal lines: solid black for the near-term, and dotted gray for the mid-term. The regression lines are based on the small and large car maximum feasible reduction CO_2-equivalent values in Table 6.1-2 and Table 6.1-3 for the PC/LDT1 category, and the small and large truck CO_2-equivalent values for the LDT2 category.

Setting the maximum feasible reduction level for each category that is feasible for all manufacturers according to their baseline fleet would call for setting the standard to the rightmost (i.e. heaviest) manufacturer point in each of the figures. Noting that the technology assessment indicated that for a given weight (within given vehicle classes) a certain gram-per-mile CO_2 is technically feasible, this would entail drawing a line straight down from the Daimler Chrysler point in Figure 6.1-1 until it intersects the black "near-term" line. That point, 242 grams of CO_2 equivalent per mile would be the near-term standard. Similarly, this would make 211 grams CO_2 equivalent per mile the mid-term standard.

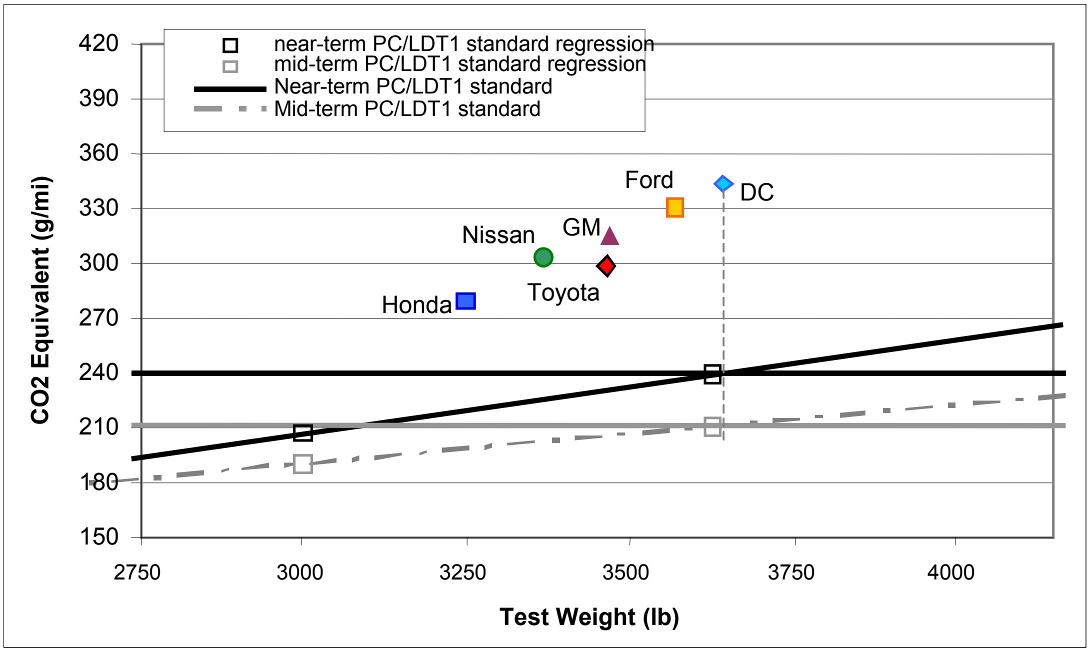


Figure 6.1-1. Manufacturer Baseline CO_2 and Maximum Feasible Regression Lines for PC/LDT1 Vehicle Category

Because trading between the two categories would be allowed for each manufacturer, the CO_2 equivalent standard for both the PC/LDT1 and the LDT2 categories need not be set according to the rightmost, heaviest manufacturer in *both* of the categories. Trading offers flexibility for each manufacturer to over-comply with one category's standard and trade those credits to compensate for a debit, or under-compliance, within the other category. Because of trading, each category's standard can be set using the same manufacturer, achieving greater total CO_2 equivalent emission reductions while still maintaining technical feasibility for all manufacturers. In this case, the maximum total emission reduction results from setting both standards according to the Daimler Chrysler CO_2 and test weight points of Figure 6.1-1 and Figure 6.1-2. Daimler Chrysler was chosen to set the standard because the majority of light-duty vehicles are in the PC/LDT1 category where Daimler Chrysler has the heaviest average weight vehicles. Graphically this is shown by the vertical gray dotted lines running down from the "DC" point in those figures. This equates to a PC/LDT1 standards of 242 g/mi CO_2 equivalent in the near-term and 211 g/mi CO_2 equivalent in the mid-term. The LDT2 standards are 335 g/mi in the near-term and 311 g/mi in the mid-term.

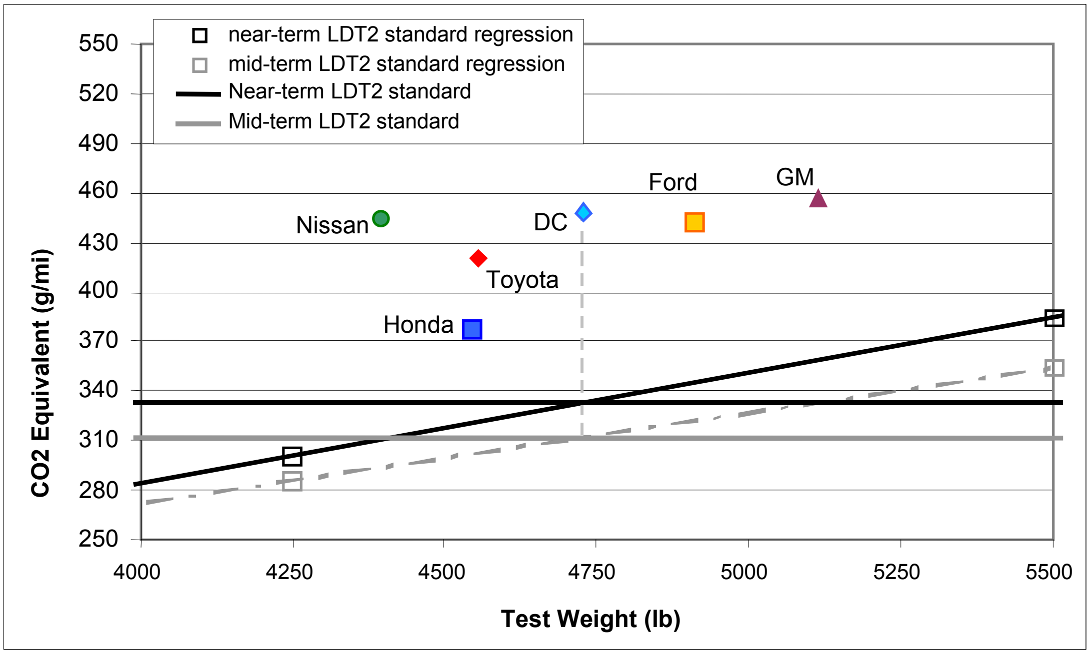


Figure 6.1-2. Manufacturer Baseline CO_2 and Maximum Feasible Regression Lines for LDT2 Vehicle Category

The proposed near-term and mid-term standards are to be phased-in by 30%, 60%, and 100% over three-year time periods. For the near-term, this entails phasing in the standard from MY 2009 through MY 2011. For example, in MY 2009, the standard is 30% of the way from the highest 2002 baseline CO_2 level for any of the major manufacturers (346 g/mi CO_2 equivalent/mi for PC/LDT1, 459 g/mi CO_2 equivalent/mi for LDT2) to the near-term standard. Similarly, for MY 2010 the standard is 60% of the way from the highest 2002 baseline CO_2 level to the near-term standard. The 2011 CO_2 equivalent standard emission levels then are set to the near-term standards shown above in Figure 6.1-1 and Figure 6.1-2.

The mid-term standards are phased-in from MY 2012 through 2014. The phase-in from the 2011 near-term standards to the 2014 mid-term standards is set with interim 30% and 60% steps in MY 2012 and 2013, respectively. A tabular summary of the proposed climate change emission standards is presented in Table 6.1-5.

Table 6.1-5. CO_2 Equivalent Emission Standards for Model Years 2009 through 2014

Tier	Phase-in	Year	CO_2-equivalent emission standard by vehicle category (g/mi)	
			PC/LDT1	LDT2
Near-term	30%	2009	315	422
	60%	2010	284	385
	100%	2011	242	335
Mid-term	30%	2012	233	328
	60%	2013	223	321
	100%	2014	211	311

6.2 Determination of Effect of Standard on the Fleet

Since the manufacturers start at baseline CO_2 emissions that are different, each manufacturer will have a different percentage of vehicles that are controlled by the regulation and different resulting average costs. This section provides an estimation of the percent of vehicles that will need to be controlled during the near- and mid-term phase-in periods in order to comply with the proposed climate change emission standards. It is assumed here that all of the major six manufacturers will be in compliance with the standard at all phases. Also, it is assumed that the use of the major six manufacturers offers a representative picture of the vehicle fleet for these emission reduction and control cost calculations.

6.2.A Emission Reduction by Model Year

The new manufacturer average CO_2 equivalent levels, resulting from compliance with the standard, are shown in Table 6.2-1. Because for the 2009 and 2010 model year phase-in some of the manufacturers' fleets are already in compliance (i.e., below the proposed standards), their CO_2 levels are assumed to remain the same as the 2002 baseline. For example, the average Honda CO_2 emission value is unchanged during 2009 and 2010 because its baseline emission values are already below each of those years' standards. The last column, "All major 6," in the following tables shows the sales-weighted averages based on 2002 California vehicle sales by the six major manufacturers.

Table 6.2-1. Average CO_2 Equivalent Emissions (g/mi) by Vehicle Model Year

Year			DC	Ford	GM	Honda	Nissan	Toyota	All major 6
2009	Near-term phase-in	PC/LDT1	315	315	315	282	305	301	304
		LDT2	422	422	422	379	422	422	420
2010		PC/LDT1	284	284	284	282	284	284	283
		LDT2	385	385	385	379	385	385	384
2011		PCT1	242	242	242	242	242	242	242
		T2	335	335	335	335	335	335	335
2012	Mid-term phase-in	PCT1	233	233	233	233	233	233	233
		T2	328	328	328	328	328	328	328
2013		PCT1	223	223	223	223	223	223	223
		T2	321	321	321	321	321	321	321
2014		PCT1	211	211	211	211	211	211	211
		T2	311	311	311	311	311	311	311

Table 6.2-2 tabulates the percent reduction from 2002 model year baseline emission values that each manufacturer must achieve to become compliant with the proposed emission standards.

Table 6.2-2. Average Percent CO_2 Emission Change by Vehicle Model Year

Year			DC	Ford	GM	Honda	Nissan	Toyota	All major 6
2009	Near-term phase-in	PC/LDT1	-9%	-6%	-1%	0%	0%	0%	-2.3%
		LDT2	-7%	-5%	-8%	0%	-6%	0%	-5.1%
2010		PC/LDT1	-18%	-15%	-11%	0%	-7%	-6%	-8.8%
		LDT2	-15%	-14%	-16%	0%	-14%	-9%	-13.1%
2011		PC/LDT1	-30%	-28%	-24%	-14%	-21%	-20%	-22.2%
		LDT2	-26%	-25%	-27%	-12%	-25%	-21%	-24.3%
2012	Mid-term phase-in	PC/LDT1	-33%	-30%	-27%	-17%	-24%	-23%	-25.3%
		LDT2	-27%	-26%	-29%	-14%	-27%	-22%	-25.9%
2013		PC/LDT1	-36%	-33%	-30%	-21%	-27%	-26%	-28.3%
		LDT2	-29%	-28%	-30%	-16%	-28%	-24%	-27.6%
2014		PC/LDT1	-39%	-37%	-34%	-25%	-31%	-30%	-32.3%
		LDT2	-31%	-30%	-32%	-18%	-31%	-26%	-29.8%

6.2.B Percent of Vehicles Controlled by Model Year

In order achieve the CO_2-equivalent emission reduction levels shown in Table 6.2-2, each manufacturer will need to deploy technology packages in their new vehicle fleet for years 2009 through 2014. To estimate the impact on manufacturers, it is assumed that the maximum feasible “near-term” technologies will first be used only on those vehicles necessary to comply with the proposed emission standards. The following scenarios assume that manufacturers will apply the lowest cost approaches to complying with the proposed emission standards. Daimler Chrysler, for example, with the highest PC/LDT1 2002 baseline CO_2 value, would need to install the near-term technology package on 30%, 60%, and 100% of PC/LDT2 vehicles from 2009 to 2011. Since some manufacturers' baseline values are closer to the 2011 standard, fewer of their vehicles would need to employ the same technology packages in order to be compliant. The baseline CO_2 value of Honda, for example, is closer to the PC/LDT1 standard for 2011 and, therefore, Honda would need to utilize the "near-term" technology packages on only 47% of its PC/LDT1 vehicles to become compliant by 2011. The estimated percentage of each manufacturers' vehicles equipped with near-term technology packages are shown in Table 6.2-3.

For the mid-term 2012-2014 phase-in, some manufacturers could not achieve the emission standards using only the "near-term" technology packages. Once a manufacturer's entire fleet has the near-term technology package installed and further reductions are needed, the mid-term technology packages are utilized to the extent necessary to comply with the 2012-2014 standards. Table 6.2-4 shows the projected use of mid-term technology packages. Table 6.2-5 sums the values of Table 6.2-3 and Table 6.2-4 to show the total number of vehicles that have some CO_2-reduction control technology.

Table 6.2-3. Percent of Vehicles Equipped with Near-Term Technology Package by Vehicle Model Year

Year			DC	Ford	GM	Honda	Nissan	Toyota	All major 6
2009	Near-term phase-in	PC/LDT1	30%	19%	3%	0%	0%	0%	8%
		LDT2	24%	19%	30%	0%	21%	0%	19%
2010		PC/LDT1	60%	50%	35%	0%	23%	20%	29%
		LDT2	55%	50%	60%	0%	52%	33%	48%
2011		PC/LDT1	100%	91%	79%	47%	69%	66%	73%
		LDT2	95%	92%	100%	43%	93%	77%	90%
2012	Mid-term phase-in	PC/LDT1	70%	97%	89%	58%	79%	76%	78%
		LDT2	94%	98%	70%	50%	99%	83%	84%
2013		PC/LDT1	40%	66%	99%	69%	89%	86%	76%
		LDT2	63%	81%	40%	57%	74%	89%	66%
2014		PC/LDT1	0%	25%	60%	84%	90%	99%	63%
		LDT2	22%	40%	0%	67%	33%	98%	37%

Table 6.2-4. Percent of Vehicles Equipped with Mid-Term Technology Package by Vehicle Model Year

Year			DC	Ford	GM	Honda	Nissan	Toyota	All major 6
2009	Near-term phase-in	PC/LDT1	0%	0%	0%	0%	0%	0%	0%
		LDT2	0%	0%	0%	0%	0%	0%	0%
2010		PC/LDT1	0%	0%	0%	0%	0%	0%	0%
		LDT2	0%	0%	0%	0%	0%	0%	0%
2011		PC/LDT1	0%	0%	0%	0%	0%	0%	0%
		LDT2	0%	0%	0%	0%	0%	0%	0%
2012	Mid-term phase-in	PC/LDT1	30%	3%	0%	0%	0%	0%	4%
		LDT2	6%	0%	30%	0%	0%	0%	10%
2013		PC/LDT1	60%	34%	0%	0%	0%	0%	13%
		LDT2	37%	19%	60%	0%	26%	0%	30%
2014		PC/LDT1	100%	75%	40%	0%	10%	1%	34%
		LDT2	78%	60%	100%	0%	67%	0%	61%

Table 6.2-5. Total Percent of Vehicles Equipped with Near- and Mid-Term Technology Packages by Vehicle Model Year

Year			DC	Ford	GM	Honda	Nissan	Toyota	All major 6
2009	Near-term phase-in	PC/LDT1	30%	19%	3%	0%	0%	0%	8%
		LDT2	24%	19%	30%	0%	21%	0%	19%
2010		PC/LDT1	60%	50%	35%	0%	23%	20%	29%
		LDT2	55%	50%	60%	0%	52%	33%	48%
2011		PC/LDT1	100%	91%	79%	47%	69%	66%	73%
		LDT2	95%	92%	100%	43%	93%	77%	90%
2012	Mid-term phase-in	PC/LDT1	100%	100%	89%	58%	79%	76%	82%
		LDT2	100%	98%	100%	50%	99%	83%	94%
2013		PC/LDT1	100%	100%	99%	69%	89%	86%	90%
		LDT2	100%	100%	100%	57%	100%	89%	96%
2014		PC/LDT1	100%	100%	100%	84%	100%	100%	97%
		LDT2	100%	100%	100%	67%	100%	98%	98%

6.2.C Cost of Control by Model Year

To translate the percent of vehicle fleet utilizing the near- and mid- term technology packages (from Table 6.2-3 and Table 6.2-4) into average cost-of-compliance estimations, the costs associated with the maximum feasible CO_2 reduction technologies are applied. These costs, directly associated with the technology packages of Table 6.1-2 and Table 6.1-3 above, are shown below in Table 6.2-6 and Table 6.2-7. The costs are shown as the incremental cost with respect to the 2009 baseline vehicle cost within each of the five vehicle classes. The costs are then aggregated into a sales-averaged cost for each of the two vehicle categories, PC/LDT1 and LDT2, according to the estimated percentage of the 2002 California fleet that each vehicle class represents. The average cost of control for maximum feasible climate change emission reductions for near-term technology packages on a vehicle in the PC/LDT1 category is found to be $328. The average cost of control for maximum feasible reductions for near-term technology packages on a vehicle in the LDT2 category is found to be $363.

These costs do not include any operating cost savings, which staff has determined to be more than sufficient to offset the upfront incremental cost.

Table 6.2-6. Technology Cost for Maximum Feasible Near-Term CO_2 Reduction by Vehicle Category

Category	Vehicle Class	Combined Technology Packages	Cost incremental from 2009 baseline (2004$)	Average cost incremental from 2009 baseline (2004$)	Estimated percentage of CA 2002 fleet	Average cost for near-term control technology for vehicle category ($)
PC/LDT1	Small car	DVVL,DCP, AMT,EPS,ImpAlt	157	489	21%	328
		GDI-S,DCP,Turbo, AMT,EPS,ImpAlt	820			
	Large car	GDI-S,DeAct,DCP, AMT,EPS,ImpAlt	504	223	32%	
		GDI-S,DCP,Turbo, AMT,EPS,ImpAlt	-58			
LDT2	Minivan	CVVL,CCP,AMT, EPS,ImpAlt	601	842	10%	363
		GDI-S,DCP,Turbo, AMT,EPS,ImpAlt	1082			
	Small truck	DeAct,DVVL,CCP, AMT,EPS,ImpAlt	309	125	29%	
		GDI-S,DCP,Turbo, AMT,EPS,ImpAlt	-60			
	Large truck	DeAct,DVVL,CCP, A6,EHPS,ImpAlt	653	597	9%	
		DeAct,DVVL,CCP, AMT,EHPS,ImpAlt	541			

Similar calculations were performed for the maximum feasible emission reductions for mid-term technology packages. The average cost of control to achieve the maximum feasible reduction for a vehicle in the PC/LDT1 category is found to be $1,047. The average cost of control to achieve the maximum feasible reduction for vehicles in the LDT2 category is found to be $1,210. Again, these costs do not include operating cost savings.

Table 6.2-7. Technology Package Cost for Maximum Feasible Mid-Term CO_2 Reduction by Vehicle Category

Category	Vehicle Class	Combined Technology Packages	Cost incremental from 2009 baseline (2004$)	Maximum feasible reduction tested CO2, with A/C credit for vehicle class (g/mi)	Estimated percentage of CA 2002 fleet	Average cost for mid-term control technology for vehicle category ($)
PC/LDT2	Small car	CVVL,DCP,AMT, ISG-SS,EPS,ImpAlt	1,079	1,171	21%	1,047
		gHCCI,DVVL,ICP, AMT,ISG,EPS,eACC	1,262			
	Large car	CVAeh,GDI-S, AMT,EPS,ImpAlt	761	966	32%	
		gHCCI,DVVL,ICP, AMT,ISG,EPS,eACC	1,369			
		GDI-S,Turbo,DCP, A6,ISG,EPS,eACC	769			
LDT2	Minivan	CVAeh,GDI-S, AMT,EPS,ImpAlt	1,116	1,259	10%	1,210
		GDI-S,CCP,AMT,ISG, DeAct,EPS,eACC	1,401			
	Small truck	DeAct,DVVL,CCP, A6,ISG,EPS,eACC	1,330	1,082	29%	
		CVAeh,GDI-S, AMT,EPS,ImpAlt	759			
		HSDI,AMT, EPS,ImpAlt	1,158			
	Large truck	CVAeh,GDI-S, AMT,EHPS,ImpAlt	1,558	1,571	9%	
		DeAct,DVVL,CCP, A6,ISG,EPS,eACC	1,584			

Multiplying the cost-of-control estimations (Table 6.2-6 and Table 6.2-7) with the corresponding percentages of the each manufacturer's fleet that has these packages installed to achieve compliance (Table 6.2-3 and Table 6.2-4) results in the average cost increase per vehicle manufacturer per model year under the proposed climate change regulation. These average costs per vehicle for each manufacturer for each model year are shown in Table 6.2-8. The final column "All major 6" shows the estimated cost increase averaged across all vehicle sales of the six manufacturers.

Table 6.2-8. Average Cost of Control by Vehicle Model Year ($)

Year			DC	Ford	GM	Honda	Nissan	Toyota	All major 6
2009	Near-term phase-in	PC/LDT1	98	62	9	0	0	0	25
		LDT2	87	70	109	0	77	2	69
2010		PC/LDT1	197	164	116	0	76	64	96
		LDT2	198	183	218	0	189	120	176
2011		PC/LDT1	328	300	259	153	225	215	241
		LDT2	346	333	363	157	338	278	326
2012	Mid-term phase-in	PC/LDT1	543	347	291	190	259	249	300
		LDT2	417	355	617	183	360	301	427
2013		PC/LDT1	759	571	324	226	293	283	390
		LDT2	675	522	871	209	584	325	603
2014		PC/LDT1	1047	869	614	275	399	333	561
		LDT2	1020	871	1210	243	931	356	871

6.3 Compliance with the Emission Standards

The proposed climate change emission standards incorporate the three elements listed above. Therefore, to demonstrate compliance with these standards, manufacturers will need to report the CO_2 equivalent emission values of their vehicles over the combined driving cycle. The structure of the standard can be expressed as follows:

Vehicle GHG emissions (gm/mi) = $CO_{2\ (exh)} + N_2O_{\ (exh)} + CH_{4\ (exh)} - HFC_{\ (dir)} - HFC_{\ (indir)}$

Where:

$CO_{2\ (exh)}$ = CO_2 exhaust emissions in grams per mile measured over the applicable test cycle.
$N_2O_{\ (exh)}$ = N_2O exhaust emissions in grams per mile measured over the applicable test cycle expressed as CO_2 equivalent (N_2O emissions times 296).
$CH_{4\ (exh)}$ = CH_4 exhaust emissions in grams per mile measured over the applicable test cycle expressed as CO_2 equivalent (CH_4 emissions times 23)
$HFC_{\ (dir)}$ = Credit in grams per mile CO_2 equivalent for low leak A/C system if applicable.
$HFC_{\ (indir)}$ = Credit in grams per mile CO_2 equivalent for improved A/C system if applicable.

The gram per mile CO_2 equivalent values for $HFC_{(dir)}$ for the PC/LDT1 and LDT2 classes are listed above in Table 6.1-1. These values are 3 grams per mile for the near term standard and 8.5 grams per mile for the mid term standard.

As mentioned above, the CO_2 equivalent reductions of A/C indirect emissions from improved systems were derived from the NESCCAF study. In the NESCCAF study, a factor was established for the exhaust CO_2 emission reductions determined by modeling the use of variable displacement compressors per 100cc displacement. The factor was then adjusted depending on the size of compressors in general use for each of the five vehicle categories. For example, the small car category was assumed to use a compressor with a 150cc displacement. Therefore, the calculated value was adjusted upward by a factor of 1.5. Staff is proposing that when certifying to the climate change emission standards, manufacturers use the factor derived from the NESCCAF study (adjusted for California A/C use) and adjust it according to the size of the A/C compressor used in their vehicles. In grams per mile CO_2 per 100cc of compressor displacement, the factor is equal to 32 for the UDDS cycle and 15 for the highway cycle.

Regarding emissions of N_2O and CH_4, preliminary emission rates for these gases are contained in the technical support document. Staff is proposing that manufacturers use these emission rates when demonstrating compliance, rather than measuring them when testing their vehicles. Manufacturers can retain the option to measure these gases if they believe that their vehicles emit at lower emission rates or they have incorporated technologies to reduce N_2O and/or CH_4 emissions.

Similar to the LEV II requirements, when complying with the climate change requirements, manufacturers must separately calculate the average fleet emissions for their PC/LDT1 and LDT2 classes to determine compliance with the standards. Also, similar to the LEV II non-methane organic gas fleet average requirement, debits in one vehicle class may be offset by credits earned in the other. In addition, overall debits occurring during the phase-in periods for both the near and mid-term standards need not be offset prior to one year after the applicable phase-in period has ended. Similarly, credits will be discounted by 50% the second year after accrual, another 50% the third year after accrual, and fully discounted in the fourth year.

Small Volume Manufacturers and Independent Low Volume Manufacturers need not comply with the climate change requirements until the final year of the phase-in. Furthermore, such manufacturers would need to meet the average percentage reduction for the six major manufacturers for the LDT2 class relative to their 2002 baseline model year CO_2 emissions. This value is listed in Table 6.2-2 above.

6.4 Treatment of Upstream Emissions

Historically, alternative fuel vehicles have been an important but small percentage of total light-duty vehicle sales. Therefore, staff originally considered treating all fuels as having the same upstream emissions until an alternative fuel reached a minimum sales threshold. The major benefit of such an approach was simplicity. Comments on the proposal, however, indicated that this approach did not appropriately account for the upstream benefits of the initial vehicles, and thus did not provide the proper incentives to manufacturers. Staff agrees that it is more accurate, and fair, to consider the relative upstream emissions for all vehicles produced, without consideration of a minimum threshold.

Approximately 24 percent of the total CO_2 emissions associated with conventional gasoline-fueled vehicles are a result of the upstream emissions. (Diesel-fueled vehicles result in approximately the same upstream emissions fraction as gasoline vehicles.) To maintain simplicity, staff proposes to use the upstream emissions fraction of conventional fuels as a “baseline” against which to compare the relative merits of alternative fuel vehicles. Therefore, the emissions standards as described in Table 6.1-5 above do not directly reflect upstream emissions. Rather, when certifying gasoline or diesel-fuel vehicles manufacturers would report only the “direct” or, “vehicle” emissions. For alternative fuel vehicles, however, exhaust CO_2 emissions values will be adjusted in order to compensate for the differences in upstream emissions. This approach simplifies the regulatory treatment of gasoline vehicles, while at the same time allowing for appropriate treatment of alternative fuel vehicles.

For vehicles other than zero emission vehicles, the exhaust CO_2 emissions will simply be multiplied by the CO_2 Adjustment Factor for the alternative fuel, as shown in Table 6.4-1. These factors reflect the upstream benefit (or disbenefit) of the alternative fuel, relative to conventional vehicles. Manufacturers may use different factors if they can demonstrate to the Executive Officer that the vehicle model being certified produces substantially different emission values.

Table 6.4-1. Upstream Adjustment Factor for Alternative Fuel Vehicles

Fuel	Fuel Cycle Emission Ratio (upstream g CO_2/ exhaust g CO_2)	Fuel Cycle Factor (g/g CO_2)	CO_2 Adjustment Factor - ratio to RFG (g/g CO_2)
Fuels with Direct CO_2 Emissions			
Conventional vehicles (RFG)	0.31	1.31	1.00
Compressed natural gas (CNG)	0.35	1.35	1.03
Liquid propane gas (LPG)	0.17	1.17	0.89
E85, corn	-0.04	0.96	0.74
No Direct CO_2 Emissions			
Electricity	n/a	n/a	130 g/mi
Hydrogen	n/a	n/a	210 g/mi

For example, assume that a mid-size LPG passenger car has measured exhaust emissions of 192.0 g/mile CO_2. The adjusted emissions value would then be:

192.0 g/mile * (0.89) = <u>170.9 g/mile Adjusted CO_2</u>

The manufacturer would use the value of 170.9 g/mile CO_2 to determine compliance with the applicable standards.

Several technologies require special consideration. First, since the CO_2 exhaust emissions of ZEVs (BEVs or hydrogen fuel cells) are zero, manufacturers would use the default values shown in Table 6.4-1. Second, emissions from vehicles that can operate on two alternate fuels, (e.g., a CNG-hydrogen internal combustion vehicle) will be calculated based on the worst-case fuel.

6.5 Early Reduction Credits

AB 1493 directs that emission reduction credits be granted for any reductions in greenhouse gas emissions achieved prior to the operative date of the regulations. Specifically, the bill states that in developing the regulations, the state board shall

> "Grant emissions reductions credits for any reductions in greenhouse gas emissions from motor vehicles that were achieved prior to the operative date of the regulations…to the extent permitted by state and federal law governing emissions reductions credits, by utilizing the procedures and protocols adopted by the California Climate Action Registry.

The bill further provides that:

> "the state board shall utilize the 2000 model year as the baseline for calculating emission reduction credits."

This section presents the ARB staff proposal for implementing this element of the legislation.

6.5.A Background

The early credit provision of the bill raises several complex issues that need to be addressed. First of all, how should the regulation take into account the fact that the various manufacturer fleets have different initial greenhouse gas emission levels? As noted in the technology assessment and standard development discussions above, greenhouse gas emissions are affected by the average size and weight of a manufacturer's fleet, and also by the level of technology employed on the vehicles. Thus the model year 2000 unregulated greenhouse gas emissions vary across the different manufacturers.

This in turn leads to a dilemma. If one uses each manufacturer's actual model year 2000 emissions as the base against which to measure reductions, then a manufacturer could earn early reduction credit even though it had higher emissions than another manufacturer that did not earn credit. Imagine, for example, that the model year 2000 fleet average emissions for manufacturer A are 400 grams per mile and for manufacturer B are 300 grams per mile. Using actual emissions as the base, then manufacturer A would earn credit for reducing its emissions to 350, even though it still had higher emissions than manufacturer B. Manufacture B would in effect be penalized for having lower initial emissions.

If one instead uses the average model year 2000 emissions across all manufacturers, however, other issues arise. Building on the previous example, imagine that average model year 2000 emissions across all manufacturers are 350 grams per mile. In that scenario, manufacturer A would earn no credit for reducing its emissions from 400 to 350, but manufacturer B would earn credit even if it did nothing and its emissions remained at 300.

This dilemma is related to the second issue to be addressed, which is should the early credit provision reward actions that were taken prior to the passage of the bill, or encourage manufacturers to make future changes? The answer to this question affects the "start date" for the granting of credits. If the intent is to encourage changes, then given the 2002 passage of the bill the earliest date by which changes could be reflected in the manufacturer's production vehicles would be the 2005 or 2006 model years. If on the other hand the intent is to reward past actions, then the granting of early credits could go back as far as one wanted to go.

Finally, careful consideration is needed to ensure that any apparent reductions are real. For example, one possible approach would be to provide credit to manufacturers for exceptional vehicles whose greenhouse gas emissions are below a certain threshold. Depending on what happens with the remaining vehicles in the manufacturer fleet, however, it is possible that a manufacturer could build large numbers of such low emission vehicles and still have an overall emission increase.

In attempting to sort through these and other issues, ARB staff began by evaluating alternative credit structures based on two basic approaches: generating credits based on industry-average levels, or generating credits based on automaker-specific emissions. Staff also explored the various issues related to program implementation start date.

As part of its background research, staff attempted to gain an understanding of legislative intent through review of documentary information and also through discussions with stakeholders familiar with the 2002 legislative debate. Staff also solicited comments regarding the various program design issues at a public workshop held on September 18, 2003. General comments received during this workshop suggested that the early credit program should meet existing state and federal early credit criteria. That is, in order to earn credit reductions must be real, surplus, verifiable, enforceable, and quantifiable. In addition, commenters suggested that the program should push technology development and only reward reductions achieved over an automaker's entire fleet. One automaker recommended that the early emission reduction credit program should be consistent with the form of the standard adopted for the 2009 model year.

Taking into account all of the information available, ARB staff has developed a proposed approach that is intended to meet the intent of the legislation while avoiding undesirable results. More specifically, the ARB staff has sought to ensure that early reduction emission credits are real, surplus, verifiable, enforceable, and quantifiable, while at the same time rewarding early actions taken that push commercialization of technologies to reduce climate change emissions.

6.5.B Early Credit Program Staff Proposal

ARB staff proposes that (1) credit for early emission reductions should be available for model years 2000 through 2008, and (2) the baseline against which manufacturer emissions are measured should be the fully phased in near term standard. As noted in Table 6.1-5 above, staff has proposed that the fully phased in near term standard for passenger cars and T1 trucks should be 240 grams per mile CO_2 equivalent, and for T2 trucks should be 333 grams per mile. Thus under the staff early credit proposal, manufacturer fleet average emissions for model years 2000 through 2008 would be compared to these standards on a cumulative basis. If a manufacturer has fleet average emissions below the standard for that cumulative period, the manufacturer would earn credit. Manufacturers whose emissions exceed the standard over the period would not earn credit. Any emission reduction early credits earned could be used in 2009 or later, or traded to another manufacturer.

The proposed program thus is consistent with the form of the standard proposed for 2009. Staff has chosen this approach because the two tier form of the standard represents staff's best thinking as to how to balance among a number of competing concerns, and as such it is appropriate to apply it during the early credit period as well.

Staff notes that the legislative language directs that the 2000 model year be used as the baseline for calculating early emission reduction credits. Staff believes that among the alternatives available, the proposed approach best meets the intent of the legislation. First of all, the staff proposal uses model year 2000 as the start date for the granting of credits. Second, staff's understanding of the legislative intent underlying the early credit proposal is that the legislature wanted to ensure that automakers would not be penalized for having taken aggressive steps to reduce climate change emissions prior to 2009. This would have been of particular concern if the 2009 standard required automakers to make a uniform percentage reduction against their own manufacturer-specific starting emissions.

Given that the proposed 2009 standards do not impose an automaker-specific uniform percent reduction, however, the concern that actions taken prior to the program's adoption would adversely affect an automaker's position is no longer warranted. Meanwhile, using model year 2000 data to set the standard against which early credits are measured can lead to undesirable outcomes no matter how the standard is structured.

Although there is value in rewarding credit for action taken before the operative date of the regulation, staff notes that the emission reductions achieved from 2009 and later vehicles may be reduced if manufacturers earn large amounts of early credit. While staff considered recommending approaches to reduce this concern (e.g. including a cap on the total credit that can be earned, discounting or deleting credits as they age, or limiting the use of credits for demonstration of compliance) the staff proposal at present does not include such provisions. This in part is due to the fact that based on staff's initial analysis, no manufacturer would earn early reduction credit given emissions to date. That is, no manufacturer at present has fleet emissions that are below the fully phased in 2009 standard. This is not surprising given the level of reduction embodied in the staff proposal. While this situation may change as we get closer to the 2009 effective date, it does not appear that manufacturers will earn significant amount of early credit on a cumulative 2000-2008 basis.

6.6 Alternative Compliance Strategies

This section describes the role of alternative compliance in the climate change regulation, the criteria proposed by staff to evaluate alternative methods of compliance, the types of projects that will be considered, and how emission reductions achieved by using an alternative compliance strategy can be used to earn credits for meeting the Climate Change regulation.

6.6.A Introduction

AB 1493 requires that the regulations:

> "provide flexibility, to the maximum extent feasible consistent with this section, in the means by which a person subject to the regulations ... may comply with the regulations. That flexibility shall include, but is not limited to, authorization for a person to use alternative methods of compliance with the regulations."

Proposed criteria and guidelines for alternative methods of compliance are described below. These guidelines provide additional flexibility for manufacturers, yet are also structured in a manner that safeguards against strategies that do not meet the goals of the legislation. These goals include:

- Achieving the maximum feasible reduction of climate change emissions from passenger vehicles and light-duty trucks and other vehicles used for noncommercial personal transportation in California,
- Providing flexibility, to the maximum extent feasible, in the means by which a manufacturer may comply with those reductions, and
- Ensuring that any alternative methods of compliance achieve equivalent or greater reductions in emissions of greenhouse gases as the regulations.

6.6.B Purpose of Alternative Compliance Strategies

Alternative compliance strategies are intended to provide auto manufacturers with flexibility in meeting the Climate Change regulations. Greenhouse gas emission reductions achieved using an alternative compliance strategy or project will be verified by the ARB in order to qualify as alternative compliance credits. A manufacturer can then use the credits to meet the Climate Change regulation. In addition, these credits can be banked for use in later years when a company foresees a shortfall in meeting the regulation.

As noted above, AB 1493 calls for the regulation to provide flexibility "to the maximum extent feasible consistent with this section." Thus the use of alternative compliance strategies must not undercut the primary purpose of the regulation, which is to achieve greenhouse gas reductions from motor vehicles. Accordingly, the ARB's alternative compliance program will be limited to the vehicles that are regulated through AB 1493, and their fuels. This is to ensure that the program does not dilute the technology-forcing nature of the regulation, since the goal is to improve the vehicles themselves.

6.6.C Elements of the Staff Proposal

The following sections discuss in turn the major features of the staff proposal:

- The primary flexibility provisions (aggregating, averaging, banking and trading)
- Criteria for awarding credit to alternative compliance projects
- Eligibility considerations
- The application process
- Issuance and use of alternative compliance credits
- Recordkeeping, auditing and enforcement requirements.

Aggregating, Averaging, Banking and Trading Greenhouse Gas Emissions
As required by the legislation, the staff proposal allows manufacturers significant flexibility in complying with the proposed emission standards. Specifically, the staff proposal would allow manufacturers to average emissions across their vehicle models, aggregate the different climate change pollutants, bank excess credits for later use, and trade credits in order to meet the climate change emission standards. In addition, manufacturers would have the ability to earn early compliance credits.

Criteria for Awarding Credit to Alternative Compliance Projects
Consistent with existing credit trading programs, prior to approval, any alternative compliance strategy must meet the criteria outlined below. Under such an approach, if any one criterion is not met, the project would not be approved. The criteria are:

Real or Additional. Real or additional emission reductions are those that have actually occurred, not emissions that could have been emitted but were not or are avoided emissions. This means that the emission reductions result from actions taken that are beyond the course of normal activity such that the emission reductions are not considered "business as usual."

Quantifiable. Quantifiable means that the amount of the emission reductions can be measured with reasonable certainty. This would involve determination of a baseline for each project. Quantification would then involve determining the emissions associated with the alternative compliance project.

Also, to ensure that the reductions significantly contribute to progress toward reducing climate change emissions, reductions generated using an alternative compliance strategy will be discounted by a certain percentage when applied towards a manufacturer's requirements under the climate change regulations. Details are described below.

Finally, because upstream emissions play a role in the greenhouse gas emissions from mobile sources, alternative compliance projects will use a baseline that accounts for upstream emissions before additional trade discounts are applied. For a discussion of these adjustment factors, see section 6.4. These values will be periodically reviewed in order to ensure that they reflect changes in fuel production and distribution.

Regulatory Surplus. Emissions reductions must be surplus of any reductions required by local, state or federal regulations or measures contained in a regional air quality plan or government commitment or agreement.

Alternative compliance credits will be determined, verified, and applied to a manufacturer's climate change obligation on an annual basis. If emission reductions are anticipated over multiple years, the emission reductions that are anticipated in future years cannot be used earlier than they are actually achieved.

Enforceable. Enforceable means that the reductions can be independently verified and are legally binding. Enforcement is an essential element of any alternative compliance strategy. Projects thus must be accessible to inspection by California staff. Following the initial application, annual verification will be needed to ensure that the activities that produce credits occur as planned. Details regarding enforcement and record keeping are described below.

Permanent. Permanent means that the life of the emission reductions is reasonably established and commensurate with the proposed use of the credits. Projects should be “irreversible”; that is, the reductions achieved should not be subject to backsliding or vulnerable to changes in external conditions. Emission reductions will be verified annually to ensure they continue to be real and permanent.

Evaluation of Non-Climate Change Emissions/Impacts. Staff will evaluate any potential negative environmental impacts due to an alternative compliance strategy. In order to receive approval for an alternative compliance project, it must not result in any increase in criteria or toxic emissions as well as cause any other negative environmental impacts especially in areas with environmental justice concerns.

Leakage. Leakage occurs when a project changes the availability or quantity of a product or service that results in changes in GHG emissions elsewhere [1]. Staff will explore ways to evaluate leakage and to ensure that alternative compliance strategies do not increase greenhouse gas emissions outside the boundaries of the alternative compliance project.

6.6.D Eligibility Considerations

Project Location. Projects must be located in California to be eligible as alternative methods of compliance. This is to ensure that the ARB can easily access the project location in order to verify compliance with the alternative compliance plan.

Applicant Eligibility. In order to ensure some level of prior project review, only companies regulated by AB 1493 (automakers) will be permitted to apply for alternative compliance credits. Thus automakers must partner with a fleet and/or a fuel provider to submit an application.

Vehicle Eligibility. To ensure maximum focus on improvements to vehicles, only those vehicles regulated under AB 1493 are eligible for alternative compliance credits. This includes model year 2009 and later passenger vehicles and light-duty trucks, and other vehicles used for noncommercial personal transportation in California. Projects involving commercial fleets, such as taxi or delivery services, that use 2009 and later passenger vehicles and light-duty trucks would be eligible.

Project Eligibility. The ARB views vehicles and fuels as a system. Therefore to provide maximum flexibility while still focusing on improvements to the new vehicle fleet, staff proposes that eligible projects be limited to those that achieve greenhouse gas reductions through documented increased use of alternative fuels in eligible vehicles.

Staff evaluated two such scenarios. The first, which we refer to as alternative fuel vehicle projects, involves increased use of alternative fuels in bi-fuel, flex fuel

[1] World Resources Institute/ World Business Council for Sustainable Development. The Greenhouse Gas Protocol. A Corporate Accounting and Reporting Standard - Revised Edition. March 2004. For more information, visit www.ghgprotocol.org

and grid connected hybrid vehicles. The second, referred to as alternative fuel projects, involves increased use of alternative fuels in conventional vehicles. Staff has concluded that it is appropriate to grant credit for the former (alternative fuel vehicle projects) but not the latter.

Alternative Fuel Vehicle Projects
Dedicated alternative fuel vehicles are vehicles that can only operate on an alternative fuel, such as CNG or hydrogen vehicles. Because such vehicles always use the alternative fuel, the calculation of their emissions is straightforward are they are included as part of a manufacturer's baseline fleet within the climate change regulation. Such vehicles earn greenhouse gas reduction credit based on their tailpipe and upstream emission characteristics, as discussed in section 6.

Bi-fuel vehicles are vehicles that can operate on two different fuels, typically gasoline and an alternative fuel. Such vehicles have two tanks, one for gasoline and one for either natural gas or propane, depending on the vehicle. The vehicles can switch between the two fuels. In the future, we may see bi-fuel vehicles that can switch between two alternative fuels.

Flex-fuel vehicles are vehicles that that can be fueled with gasoline or, depending on the vehicle, with either methanol (M85) or ethanol (E85). The vehicles have one tank and can accept any mixture of gasoline and the alternative fuel.

Currently, due to a lack of infrastructure and cost considerations most fleets do not use the alternative fuel in these types of vehicles. Therefore, in ARB emission control regulations the usual baseline assumption is that these vehicles are using the “dirtier” fuel and are not entitled to any credit for the use of alternative fuels.

Grid-connected hybrid electric vehicles (GHEVs) are similar to bi-fuel vehicles in that two "fuels" are used, gasoline and electricity. As with bi-fuel vehicles the climate change benefit of GHEVs is determined by the extent in which the alternative fuel (electricity) is used. There are no GHEVs in production today.

Staff proposes that a project that ensures and documents the use of an alternative, lower greenhouse gas emitting fuel in bi-fuel, flex fuel, or grid connected hybrid vehicles would be eligible for alternative compliance credits. Thus the alternative compliance program would encourage and reward fleets that use lower greenhouse gas alternative fuels rather than using conventional gasoline.

Staff recognizes that the greenhouse gas and criteria pollutant emissions associated with the production and use of alternative fuels will vary greatly depending on the specific feedstock used as well as the production and distribution methods employed. In addition, the use of crops as feedstock for alternative fuels has broader implications for land use, water supply, pesticide use, and other critical factors. It is clear that the evaluation of alternative fuel projects will need to encompass upstream as well as tailpipe emissions. Staff has not, however, developed a specific approach as to which alternative fuel feedstocks should be eligible for credit and how credit should be awarded.

In addition, the alternative compliance mechanism must prevent credits from being earned that are merely the result of shifting the same volume of fuel from one use to another. For instance, a fuel provider could take the same volume of fuel it would have used in blends and instead use it in bi-fuel vehicles. This does not achieve any net decrease in greenhouse gas emissions but could, if left unchecked, provide a manufacturer with a substantial number of credits.

Staff invites comment on these and other related issues.

Alternative Fuel Projects
Alternative fuel projects are those that use different conventional fuel blends, such as increased ethanol in gasoline, to decrease greenhouse gas emissions from model year 2009 and later conventionally fueled vehicles. The staff proposal would not award credit for such projects. Given the fact that the "business as usual" ethanol content in gasoline will vary according to economics, refinery strategies and the status of the oxygenate waiver, staff believes that it would be difficult if not impossible to ensure that reductions associated with the use of such blends are real and surplus, as required under the criteria outlined above. In addition the effect of such blends on criteria air pollutants is of concern. This uncertainty persuaded staff to recommend against such an approach.

6.6.E Application Process

In order to obtain alternative compliance credits, a manufacturer shall first submit a Climate Change Alternative Compliance Application to the ARB. The purpose of the application is to determine the fleet's baseline emissions as well as the projected reductions in greenhouse gas emissions anticipated from the alternative compliance project. The baseline emissions are those greenhouse gas emissions that would have been emitted in the absence of the alternative compliance project. ARB will use the information provided to calculate the baseline emissions and the greenhouse gas emission reductions that will result from the project. As stated earlier, staff will take into account both upstream and tailpipe emissions when doing this calculation.

6.6.F Issuance and Use of Alternative Compliance Credits

The proposed climate change regulations will apply to MY 2009 and later passenger cars and light duty trucks. Alternative compliance strategies can only be applied to vehicles subject to the climate change regulation, therefore, this program takes effect when these vehicles are available. Prior to that date, ARB staff will work with manufacturers to assist in developing project applications that meet the ARB's requirements.

Alternative compliance credits will be issued after the application is approved by the ARB and upon submittal and verification of the actual miles traveled and alternative fuel used for each bi- and flex-fuel vehicle. Each year the applicant must verify the emission reductions before receiving alternative compliance credits.

Interaction with Vehicle-Level Reductions. The emission reductions achieved by alternative compliance projects will be calculated in terms of tons of CO_2 equivalent. In order for alternative compliance tons to be used as an offset against otherwise required vehicle level reductions, the necessary vehicle level reductions will also be converted to tons. This will be achieved by taking the gram per mile reduction needed by a manufacturer and multiplying it by the expected lifetime VMT for the vehicle.

Discount Factor. To ensure that alternative methods of compliance achieve equivalent or greater reductions in emissions of greenhouse gases as the regulations, a proposed discount factor of 1.2 would be applied to the emission reductions. This discount factor is consistent with other air pollution credit/trading programs implemented by the State and local air pollution districts.

6.6.G Recordkeeping, Auditing, and Enforcement Requirements

Fleet operators will be responsible for storing and maintaining data records for each vehicle and the fuel used. The ARB must also be afforded access to audit any files or records created to comply with recordkeeping requirements or require vehicle operators to submit such records to the ARB upon request. The ARB must also be afforded access to inspect the vehicles at vehicle operators' facilities.

Ownership and Liability of Alternative Compliance Strategy Credits. Because an automaker will need to partner with a fleet and/or fuel provider to apply for alternative compliance credits, an ownership agreement must be worked out between the participating parties and included with the application.

A tracking system will need to be established to track the banking and trading of credits. The California Climate Action Registry may also be a resource for tracking alternative compliance strategy credits.

California Climate Action Registry. Senate Bill (SB) 1771 (Sher, Chapter 1018, Statutes of 2000) established the California Climate Action Registry (Registry) with technical changes being made to the statute in SB 527 (Sher, Chapter 769, Statutes of 2001). The Registry is a non-profit voluntary registry for greenhouse gas (GHG) emissions. The purpose of the Registry is to help companies and organizations with operations in the state to establish GHG emissions baselines against which any future GHG emission reduction requirements may be applied.

The Registry encourages voluntary actions to increase energy efficiency and decrease GHG emissions. Using any year from 1990 forward as a base year, participants can record their GHG emissions inventory. The State of California, in turn, will offer its best efforts to ensure that participants receive appropriate consideration for early actions in the event of any future state, federal or international GHG regulatory scheme. Registry participants include businesses, non-profit organizations, municipalities, state agencies, and other entities.

ARB is coordinating with the Registry and the California Energy Commission on our mobile source climate change regulations, in particular alternative compliance strategies. Projects certified by the Registry under their other programs are not automatically eligible to receive alternative compliance strategy credits under ARB's mobile source climate change regulations. However, staff is continuing to explore ways to involve the Registry in the alternative compliance strategy criteria and implementation

7 ENVIRONMENTAL IMPACTS

This chapter presents the emissions impacts of the proposed regulation, along with the baseline emissions inventory. Included is a discussion of the methods used to develop the inventory and assess impacts. Also included is an assessment of the impacts on upstream emissions and other environmental media.

7.1 Baseline Inventory Development

Staff has estimated the baseline climate change emissions from light duty vehicles for calendar years 2010, 2020 and 2030. These inventories are shown in Table 7.1-1. These inventories can also be expressed in terms of total CO_2 equivalent emissions based on the global warming potentials presented in Table 2.3-1 in section 2.3, Global Warming Potentials. Table 7.1-2 shows the total CO_2 equivalent emissions in tons per day. These inventories represent what emissions from the light duty fleet would be without the proposed regulation, and serve as a baseline from which to estimate the benefits of the proposed regulation. The following subsections describe how these inventories were developed and validated. Additional detail is presented in the Technical Support Document.

7.1.A CO2 and Methane

Staff has used the EMFAC2002 mobile source emissions model, version 2.2 (Apr03), to estimate the inventory for CO2 and methane. The EMFAC model estimates the emissions of CO2 and methane based on data collected from in-use vehicle testing at ARB's Haagen-Smit laboratory over various driving cycles that simulate real world conditions. Methane emission rates are derived from total hydrocarbon rates by the use of conversion factors based on speciation profiles.

7.1.B Nitrous Oxide

The ARB has collected N_2O emissions data from vehicles that have been tested as part of the ARB's 16th and 17th Vehicle Surveillance Projects (VSPs) at the Haagen-Smit Laboratory in El Monte, California. The purpose of the emissions testing effort is to gain a better understanding of the factors that lead to the formation of N_2O, and to develop applicable emission factors that can be used to develop an emissions inventory. The VSPs are conducted to measure in-use emissions from a fleet of light-duty gasoline vehicles including passenger cars and light-duty trucks up through 8,500 lb. GVWR. A total of approximately 120 light duty cars and trucks have been tested.

Table 7.1-1: Baseline Inventory for Light Duty Motor Vehicles

Calendar Year 2010 Emissions in Tons per Day[2]				
	CH_4	**CO_2**	**N_2O**	**HFCs**
PC/T1 *(Passenger Cars and Trucks 0-3750 lb. LVW[3])*	26	296,320	12	4
T2 *(Trucks 3751 lb. LVW[3]- 8500 lb. GVWR[5])*	11	120,760	8	1
Total Light Duty	**37**	**417,080**	**20**	**5**
Calendar Year 2020 Emissions in Tons per Day[2]				
	CH_4	**CO_2**	**N_2O**	**HFCs**
PC/T1 *(Passenger Cars and Trucks 0-3750 lb. LVW[3])*	12	341,640	7	5
T2 *(Trucks 3751 lb. LVW[3] - 8500 lb. GVWR[5])*	7	143,510	4	2
Total Light Duty	**19**	**485,150**	**11**	**7**
Calendar Year 2030 Emissions in Tons per Day[2]				
	CH_4	**CO_2**	**N_2O**	**HFCs**
PC/T1 *(Passenger Cars and Trucks 0-3750 lb. LVW[3])*	8	390,600	5	6
T2 *(Trucks 3751 lb. LVW[3] - 8500 lb. GVWR[5])*	5	171,670	4	2
Total Light Duty	**13**	**562,270**	**9**	**8**

[2] Annual average

[3] Loaded vehicle weight equals curb weight plus 300 lb.

[5] It is recognized that there are a few vehicle models over 8,500 lbs. gross vehicle weight rating (GVWR) that are used for noncommercial transportation and are thus subject to the climate change regulations. Likewise, there are some vehicles weighing less that 8,500 lbs. that are used in commercial service. It does not appear possible to accurately identify these two sets of vehicles from license registration records. Because both sets of vehicles make up a very small portion of the light duty fleet, we believe that no significant error is introduced by defining the inventory as all vehicles up to 8,500 lbs.

Table 7.1-2: CO_2 Equivalent Inventory for Light Duty Motor Vehicles

	2010 (tons per day)	2020 (tons per day)	2030 (tons per day)
PC/T1 *(Passenger Cars and Trucks 0-3750 lb. LVW[6])*	305,400	350,500	400,000
T2 *(Trucks 3751 lb. LVW[6] - 8500 lb. GVWR[8])*	124,800	146,900	175,500
Total Light Duty	**430,200**	**497,400**	**575,500**

Both the NOx and N_2O emission rates measured as part of the VSPs have been used to develop the N_2O inventory. Staff utilized statistical analysis software to develop a correlation between the grams per mile emission rate of NOx and the grams per mile emissions of N_2O. The resulting correlation equation was then applied to the model year specific grams per mile NOx emission rates estimated by EMFAC 2002, version 2.2 (Apr03), in order to develop model year specific grams per mile N_2O emission factors. Each model year's N_2O emission factor was then multiplied by an estimate of miles per day driven by those model year vehicles during the calendar year to yield a tons per day inventory for N_2O.

7.1.C Hydrofluorocarbons

ARB staff has developed a method to estimate direct emissions of HFC-134a from vehicular AC systems in California that is based on 1) data on HFC-134a consumption by nine government and commercial fleets, 2) surveys of 966 vehicle owners on their AC system repair incidence, 3) data on repair incidence among 12,000 fleet vehicles in California, and 4) information from dismantlers. The data were used to provide estimates of the averages of the parameters in a mass balance model that equates vehicular lifetime emissions to lifetime inputs of HFC-134a. That model is expressed by:

$$LE = C * (1 - g + N * f)$$

where: *LE* is the lifetime (16-year) mass of refrigerant emitted from a vehicle
C is the AC system capacity (mass) for HFC-134a
"*1*" represents the initial charge at the time of manufacture
g is the fraction of C recovered by the dismantler
N is the number of times the vehicle is recharged during its life
f is the fraction of charge C missing (leaked or released) before each recharging

[6] Loaded vehicle weight equals curb weight plus 300 lb.
[8] Gross vehicle weight rating

The values obtained for the model parameters are:

C -- 951 grams per vehicle
f -- 0.52
g -- .085 (assumes an average recovery of half the refrigerant present in vehicles reaching the dismantling yards)
N -- 1 recharge over 16 yrs

This analysis yields direct emissions of 1.36 kg of HFC-134a per 16-year average lifetime of an LDV in California. This is equivalent to 85 grams per year of life per vehicle, although the emissions may not be uniform through the average vehicular lifetime. However, since not all vehicles "last" 16 years, the actual average annual emission rate among in-use vehicles is slightly different. The ARB staff has estimated that rate by two methods. By taking into account the fractions of the on-road population by model year and (separately) by using HFC-134a consumption data, we arrived at 80 grams/year/vehicle.

All the numbers above reflect the vehicle fleet of 2003. Evolution in design or assembly of AC systems that may be occurring now, and may continue in the future as suggested by the industry, could lead to a different set of estimates if the analysis were repeated in some future year. The current data do not allow us to estimate how the future results would differ from those shown here.

These estimates reflect only emissions from vehicles and fugitive emissions incidental to professional servicing. They do not include emissions due to wastage during "do-it-yourself (DIY)" repairs of vehicles with HFC-134a systems or due to leakage from vehicles with older R-12 systems that are recharged with HFC-134a. These extra emissions may be substantial. Unfortunately, there are no substantiated estimates of the overall importance of the excess DIY emissions.

7.2 Emissions Benefits of Proposed Regulation

The emissions benefits are based on the projected reductions in CO_2 equivalent emission rates resulting from implementation of this proposed regulation. Using the emission reductions required under the standard, as outlined in section (insert cross-reference), and the proposed phase-in schedule for the regulation, ARB staff has estimated the percent reduction in CO_2 emissions rates by model year for those vehicles subject to the proposed regulation. Staff applied the percent reductions to the baseline CO_2 emissions by model year from the EMFAC2002 mobile source emissions model, version 2.2 (Apr03) for calendar years 2020 and 2030. The reductions in CO2 emissions were then subtracted from the baseline CO2 equivalent inventory for 2020 and 2030 to obtain the adjusted CO2 equivalent inventory reflecting the impact of the proposed regulation. Total CO2 equivalent benefits were estimated by subtracting the adjusted CO2 equivalent inventory from the baseline CO2 equivalent inventory.

Table 7.2-1 presents the baseline inventory from Table 7.1-2, the adjusted inventory with the proposed regulation in place, and the estimated benefits of the regulation.

Table 7.2-1: Light Duty Fleet CO_2 Equivalent Emissions and Reductions

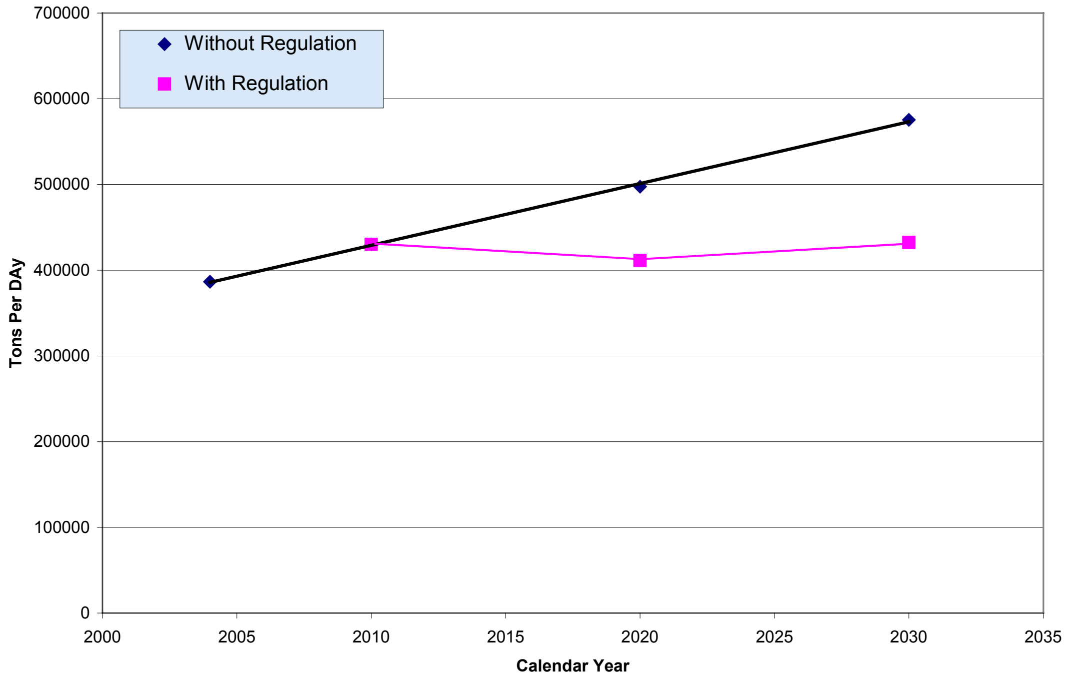
Baseline Inventory without Proposed Regulation		
	2020 (tons per day)	**2030 (tons per day)**
PC/T1 *(Passenger Cars and Trucks 0-3750 lb. LVW[9])*	350,500	400,000
T2 *(Trucks 3751 lb. LVW[9] - 8500 lb. GVWR[11])*	146,900	175,500
Total Light Duty	**497,400**	**575,500**
Adjusted Inventory with Proposed Regulation		
	2020 (tons per day)	**2030 (tons per day)**
PC/T1 *(Passenger Cars and Trucks 0-3750 lb. LVW[9])*	287,700	296,500
T2 *(Trucks 3751 lb. LVW[9] - 8500 lb. GVWR[11])*	123,800	135,700
Total Light Duty	**411,500**	**432,200**
Emissions Reductions for Proposed Regulation		
	2020 (tons per day)	**2030 (tons per day)**
PC/T1 *(Passenger Cars and Trucks 0-3750 lb. LVW[9])*	62,800	103,500
T2 *(Trucks 3751 lb. LVW[9] - 8500 lb. GVWR[11])*	23,100	39,800
Total Light Duty	**85,900**	**143,300**

The proposed regulation will reduce climate change emissions by an estimated 85,900 CO_2 equivalent tons per day statewide in 2020 and by 143,300 CO_2 equivalent tons per day in 2030. This translates into a 17% overall reduction in climate changes emissions from the light duty fleet in 2020 and a 25% overall reduction in 2030.

[9] Loaded vehicle weight equals curb weight plus 300 lb.
[11] Gross vehicle weight rating

Staff estimates that baseline emissions today (2004) are 386,600 CO_2 equivalent tons per day. Thus with the regulation 2020 emissions will be lower than today's, and 2030 will be approximately the same. Figure 7-1 shows this information in graphic form. Please note that there would also be a slight reduction due to the regulation in 2010, not accounted for in this figure.

Figure 7-1. Motor Vehicle Greenhouse Gas Emissions (excluding upstream emissions)



7.3 Fuel Cycle Emissions

The goal of the proposed regulation is to reduce climate change emissions from passenger cars and light-duty trucks. The ARB's efforts to reduce vehicular climate change emissions will also have a positive impact on the emissions that occur during the fuel cycle. These activities, which include refining, marketing and distribution of the gasoline, produce both climate change and criteria pollutant emissions.

Staff has quantified the marginal fuel cycle emissions from conventional vehicles using information from TIAX, LLC. The results show that the fuel cycle climate change emissions for gasoline vehicles are 31 percent of the vehicle emissions on a CO2 equivalent basis. Thus, for each gram of CO2 reduced per mile from the vehicle, an additional 0.31 gram of CO2 will be eliminated from the fuel cycle.

Table 7.3-1 estimates the reductions in total fuel cycle climate change emissions for 2020 and 2030.

Table 7.3-1: Climate Change Fuel Cycle Emission Reductions

(tons per day)

	2020	2030
CO_2 Equivalent Emissions	26,629	44,423

In terms of criteria pollutants, the proposed regulation will also provide fuel cycle benefits. The ARB staff has quantified the emission reductions of non-methane organic gases, oxides of nitrogen, and carbon monoxide for 2020 and 2030. The analysis calculates the reductions in criteria pollutant emissions using marginal fuel cycle emission factors based on an average vehicle. Table 7.3-2 shows the estimated reduction in criteria pollutant fuel cycle emissions. Please note that due to their smaller scale these reductions are show in terms of tons per year.

Table 7.3-2: Criteria Pollutant Fuel Cycle Emission Reductions

(tons per year)

	2020	2030
Non-Methane Organic Gases	2.8	4.0
Oxides of Nitrogen	0.2	0.3
Carbon Monoxide	0.1	0.2

7.4 Energy Cost and Demand

Recent disruptions in fuel supplies have at times greatly increased California fuel prices. Technologies and strategies required by the proposed regulation to reduce climate change emissions are also expected to reduce future demand for gasoline as compared to current trends. Reduced demand will mitigate the potential impacts from shortages of cleaner-burning gasoline and thus help stabilize fuel prices. To the extent that alternative-fueled vehicles are used, this will also help reduce gasoline demand and have a positive impact on fuel cost.

7.5 Other Environmental Media

At times, the refining, marketing and distribution of gasoline adversely affects water quality due to leaks, spills, and wastewater discharge. Any reduction in fuel use will reduce the opportunity for such occurrences. Consequently, the ARB staff projects that the proposed regulation will have a positive impact on water quality.

7.6 Other Considerations

Staff is investigating the possible effect of the regulation on consumer behavior. For example, a reduction in the operating cost of vehicles may cause consumers to drive more, which would tend to increase both climate change and criteria pollutant emissions above the levels estimated here. Changes in vehicle attributes, such as the initial price of the vehicle or the operating cost of the vehicle, may affect consumer purchases. This too could affect the emission consequences of the regulation for both climate change and criteria pollutant emissions. The results of the initial staff investigation are reported in section 11.

8 COST EFFECTIVENESS

This section presents the methodology used to calculate the cost effectiveness of the proposed regulation to reduce climate change emissions from light-duty vehicles. Staff has calculated the cost effectiveness for calendar years 2020 and 2030, based on a comparison of the cost (annualized costs minus annualized operating cost savings) and the emission reduction benefits.

Typically, emission control regulations impose a cost. Cost effectiveness is a measure of the cost imposed per ton of reduction achieved, and thus is a useful tool to compare various possible approaches. In this instance, however, AB 1493 requires that the regulations be economical to the consumer over the life cycle of the vehicle. Consistent with this direction, the technology packages that provide the basis for the standard result in operating cost savings that exceed the capital cost, resulting in a net savings to the consumer over the lifecycle of the vehicle. This translates to a "negative" cost effectiveness value (there is a cost savings per ton reduced).

8.1 Cost Data and Emission Reductions

ARB staff estimated the net costs of this proposed regulation primarily by using cost data from the 2004 study "Reducing Greenhouse Gas Emissions from Light-Duty Motor Vehicles" done for the Northeast States Center for a Clean Air Future (NESCCAF). The initial costs are based on the expected increases in vehicle cost resulting from the technology improvements needed to meet the standards in the proposed regulation. The proposed regulation includes a phase-in schedule whereby earlier model year vehicles will meet a less stringent standard and require less new technology than later model vehicles. ARB staff has estimated the cost increases by model year, using data from the NESCCAF study and other sources. Staff has used these cost data, along with the assumption that average vehicle life is 16 years, to calculate the total annualized costs by calendar year. The total annualized costs are estimated to be roughly $837 million for calendar year 2020 and $1,692 million for 2030.

Staff also estimated annual savings in operating cost, again based on information provided in NESCAFF as well as other sources. The annual savings are estimated to be $5,324 million in 2020 and $8,785 million in 2030, well in excess of the annualized cost. This results in an annual savings of $4,487 million in 2020 and $7,092 million in 2030.

The cost effectiveness in dollars per ton for a given calendar year is calculated by dividing the total annualized costs for that year by the total CO_2 equivalent emission reductions for that year. As detailed in section 7 of this report, the CO_2 equivalent emissions benefits of the proposed regulation are 85,900 tons per day in 2020 and 143,300 tons per day in 2030. Converting these figures to annual totals yields 31,338,165 tons per year in 2020 and 52, 311,800 tons per year in 2030.

8.2 Cost Effectiveness

Table 8.2-1 provides the cost effectiveness in calendar years 2020 and 2030 based on the annualized vehicle costs and the estimated benefits.

Table 8.2-1. Cost Effectiveness[12] of Proposed Regulation

	2020	2030
Net Annualized Costs (Savings)	$4,486,759,672	$7,092,415,806
Emissions Reduction (tons/year)	31,338,165	52,311,800
Cost effectiveness ($/ton)	**-143**	**-136**

[12] In 2003 dollars

9 ECONOMIC IMPACTS

The climate change regulation may impact several sectors of the economy. The steps that manufacturers will need to take to comply with the regulatory standards are expected to lead to price increases for new vehicles. Many of the technological options that manufacturers choose to comply with the regulation are also expected to reduce operating costs. These two responses to the regulation have combined positive and negative impacts on California businesses and consumers. The vehicle price increase will be borne by purchasers and may negatively affect businesses. However, the operating cost savings from the use of vehicles that comply with the regulation will positively impact consumers and most businesses. Based on the staff analysis, the net effect of the regulation on the economy is expected to be small but positive.

The major tool used for the analysis of the economic impact of the proposed regulation is a model of the California economy developed by the University of California, Berkeley, named the Environmental Dynamic Revenue Analysis Model (E-DRAM). This chapter explains the legal requirements for economic analysis, the methodologies employed, and the results obtained. Technical support documents to this report further explain the economic impact analyses.

9.1 Legal Requirements

The legal requirements for economic analysis are included in the Government Code and the Health and Safety Code. This section explains the requirements that must be satisfied for economic analyses of the proposed regulations.

Section 11346.3 of the Government Code, which applies to all agencies statewide and predates AB 1493, requires State agencies to assess the potential adverse economic impacts on California business enterprises and individuals when such agencies propose to adopt or amend any administrative regulation. The assessment shall include a consideration of the impact of the proposed regulation on California jobs, business expansion, elimination or creation, and the ability of California business to compete with businesses in other states. Health and Safety Code section 43018.5(c)(2), added by AB 1493, repeated many of these criteria. That section also added two criteria specific to this regulation, namely, to evaluate economic impacts on the State's automotive workers and affiliated businesses, and on minority and low income communities.

State agencies also are required to estimate the cost or savings to any State or local agency and school district, in accordance with instructions adopted by the Department of Finance (DOF). The estimate shall include any non-discretionary cost or savings to local agencies and the cost or savings in federal funding to the State.

Finally, Health and Safety Code section 57005 requires the Air Resources Board to perform an economic impact analysis of submitted alternatives to a proposed regulation before adopting any major regulation. A major regulation is defined as a regulation that will have a potential cost to California business enterprises in an amount exceeding ten million dollars in any single year.

9.2 Potential Impacts on Business Creation, Elimination, or Expansion

The climate change regulation affects only light duty vehicles whose primary use is noncommercial personal transportation. Therefore, many vehicles that businesses use would not be covered under the proposed regulation. However, if the businesses purchase the same vehicles as consumers, they would be expected to pay higher prices for the vehicles but save on operating costs, as is discussed in Section 5 above. As noted in that section, staff expects that reduced operating costs will more than outweigh the effect of the increase in price over the life cycle of the vehicle.

It is very likely that savings from reduced vehicle operating costs would end up as expenditures for other goods and services. These expenditures would flow through the economy, causing expansion or creation of new businesses in several sectors. Staff's economic analysis shows that as the expenditures occur, jobs and personal income increase. Jobs increase by 8,000 in 2010, by 57,000 in 2020, and 76,000 in 2030 compared to the baseline economy that excludes the proposed regulation. Similarly, income grows by $480 million in 2010, by $5.4 billion in 2020, and $7.7 billion 2030.

The E-DRAM model was used to assess the overall impact of the regulation on California's economy. Specifically, E-DRAM was used to estimate impacts on California's output of goods and services, personal income, and employment. The estimates of the regulation's impact on these economic factors are used to assess the potential impacts on business creation, elimination, or expansion in California. The next section describes E-DRAM.

9.2.A Environmental-Dynamic Revenue Analysis Model (E-DRAM)

The overall impact of all direct and indirect economic effects that may result from the proposed regulation are estimated using a computable general equilibrium (CGE) model of the California economy. A direct impact affects the automobile and oil industries, and their consumers. The proposed regulation may affect other economic sectors indirectly. For example, consumers may redirect the money from operating cost savings to spend on other sectors. In addition, the automobile industry would be expected to purchase goods and services from other sectors to comply with the proposed regulation. These expenditures caused by the regulation would indirectly affect the California economy.

A CGE model simulates various economic relationships in a market economy, where prices and production adjust in response to changes caused by regulations to establish an equilibrium in markets for all goods and services and factors of production (i.e., labor and capital). The CGE model used for this analysis is a modified version of the California Department of Finance's Dynamic Revenue Analysis Model (DRAM).[13] The DRAM has been used for several tax policy evaluations. The modified model accounts for environmental sectors and is called Environmental-DRAM (E-DRAM).[14] It has been used to assess the economic impacts of California's air quality State Implementation Plans, reformulated gasoline regulations, the petroleum dependency study required by AB 2076, and other regulations.

E-DRAM describes the relationships among California producers, California consumers, government, and the rest of the world. The model consists of over 1,000 equations designed to capture the interactions among over 100 industrial sectors, 2 factors of production sectors (labor and capital), 9 consumer good sectors, 7 household sectors (classified by income level), 1 investment sector, 45 government sectors (8 federal, 21 State, and 8 local), and the rest of the world.

The impacts of regulations are estimated by changing the inputs to the model that represent regulation effects on the industry or consumer sectors. Such changes to the model enable it to assess the economic impacts of large-scale environmental regulations. The economic impact results are estimated in terms of changes in the State output of goods and services, personal income, and employment.

The data for the industrial sectors originated with the Bureau of Economic Analysis of the U.S. Department of Commerce, based on the Census of Business – a detailed survey of companies conducted in the U.S. every five years, the most recent one done in 1999. The conversion of national data to updated California data is accomplished by Impact Analysis for Planning (IMPLAN), a program that primarily utilizes state-level employment data to scale national-level industrial data down to the size of a state.

In much the same way as firms, households are also aggregated. California households are divided into categories based upon their taxable income. There are seven such categories in the model, each one corresponding to a California personal income tax marginal tax rate (0, 1, 2, 4, 6, 8, and 9.3 percent). Thus, the income for the "one-percent" household is calculated by adding up the income from all households in the one-percent bracket.

[13] For a complete description of DRAM, see Peter Berck, E. Golan and B. Smith, "Dynamic Revenue Analysis for California", California Department of Finance, Summer 1996.

[14] Berck, Peter, "Developing a Methodology for Assessing the Economic Impacts of Large Scale Environmental Regulations", Prepared for California Air Resources Board, February 2000.

Similarly, the expenditure of the one-percent household on agricultural goods is calculated by adding up all expenditures on agricultural goods for these households. The total expenditure on agricultural goods is found by adding the expenditure of all households together.

Firms and households relate through factor markets and goods-and-services markets. Firms sell goods and services to households on the goods-and-services markets. Households sell labor and capital services to firms on the factor markets. There is a price in each of the factor and goods-and-services markets. Equilibrium in the factor markets and the goods-and-services markets means that prices adjust in response to changes caused by regulations to equate quantities supplied and demanded in all markets in about four years. That is, the full effects of a change take four years to work their way through the economy.

Compliance Cost Estimates
Based on the implementation of a combination of these technologies in different vehicle classes, staff estimates that the proposed near term (2009-2011) regulations would increase the average retail prices of passenger cars (PC) and small trucks (T1) from $25 to $241, and large trucks (T2) from $69 to $326. In the mid term (2012-2014) the price increases for PC/T1 vehicles as compared to the 2009 baseline would range from $294 to $539, and for T2 vehicles would range from $421 to $851. The incremental retail prices for all affected vehicles would remain unchanged after 2014. These increases are expected to be passed on to consumers in one form or another. This section annualizes these costs and estimates the corresponding operating cost benefits for the analysis of impacts on the California economy.

The new vehicles are expected to last 16 years, during which time they will provide transportation at lower operating costs, a benefit. To match the costs to the 16 years of benefits, we annualized the costs over the life of the vehicles. Annualized costs are estimated using a real discount rate of five percent based on an average of the past ten-year interest rates on car loans. Table 9.2-1 provides estimates of total annualized costs of the proposed climate change regulations from 2009 to 2030. The total cost was derived by multiplying new vehicle sales by the average cost increase per vehicle estimated in section 5. The total costs to consumers vary each year from 2009 to 2030. Annualized costs of the proposed regulations are estimated to be approximately $22 million in 2010, $837 million in 2020, and $1.7 billion in 2030. The annualized cost increases over time, due to additional sales of new cars at the higher price as multiple model years are annualized over the same period. For example, the annualized cost in 2011 of $59 million reflects the annualized costs of model years 2009, 2010, and 2011. Thus the annualized costs for each year are for cumulative sales of new cars since 2009. The annualized cost reaches about $1.7 billion in 2030. The $837 million in annualized cost in 2020 represents the cost, in 2020, of all complying vehicles sold from 2009 through 2020. The new vehicle sales totals are based on projected numbers of vehicles sold in that year as forecast by the EMFAC model.

Table 9.2-1. Estimates of Total Annual Costs of the Proposed Climate Change Regulations for 2009 through 2030 (millions of 2003 Dollars)

Model Year	Annualized Costs to Consumers of PC/T1	Annualized Costs to Consumers of T2	Incremental Annualized Costs to Consumers of MY 2009+ Vehicles	Cumulative Annualized Cost
2009	$ 3	$ 2	$ 5	$ 5
2010	$ 12	$ 5	$ 17	$ 22
2011	$ 28	$ 9	$ 37	$ 59
2012	$ 35	$12	$ 47	$ 106
2013	$ 46	$17	$ 63	$ 169
2014	$ 65	$26	$ 91	$ 260
2015	$ 66	$27	$ 93	$ 353
2016	$ 66	$27	$ 93	$ 446
2017	$ 67	$28	$ 95	$ 541
2018	$ 69	$28	$ 97	$ 638
2019	$ 70	$29	$ 99	$ 737
2020	$ 71	$29	$ 100	$ 837
2021	$ 69	$28	$ 97	$ 934
2022	$ 71	$29	$ 100	$ 1,034
2023	$ 72	$29	$ 101	$1,135
2024	$ 73	$30	$ 103	$ 1,238
2025	$ 74	$30	$ 104	$ 1,339
2026	$ 75	$31	$ 106	$ 1,434
2027	$ 76	$33	$ 109	$ 1,514
2028	$ 78	$34	$ 112	$ 1,589
2029	$ 79	$35	$ 114	$ 1,652
2030	$ 80	$35	$ 115	$ 1,692

Source: Sales data from ARB EMFAC model.

Many of the technologies that reduce climate change emissions will also reduce the operating costs of vehicles. Lifetime maintenance costs are also expected to remain the same or decline, depending on the technologies chosen by manufacturers. For example, improved containment of air conditioning refrigerant may reduce the need for mobile air conditioning servicing and therefore reduce maintenance costs to consumers. Due to a lack of comprehensive data, however, staff assumed no change in maintenance costs for the purpose of this analysis. Estimates of the average reduction in operating cost of the new vehicles range from about 2 percent to 27 percent for PC/T1, and about 5 percent to 25 percent for T2. Table 9.2-2 provides estimates of annual operating cost savings from 2009 through 2030. Data used to derive estimated reductions in operating cost are generated from the EMFAC model. The analysis assumes a gasoline price of $1.74 per gallon, taken from the 2004 California Energy Commission (CEC) Integrated Energy Policy Report.

Table 9.2-2. Estimates of Total Annual Value of New Vehicle Operating Cost Savings (in Millions)

Model Year	Annual Value of Operating Cost Savings (Millions of 2003 dollars)
2009	$ 64
2010	$ 276
2011	$ 747
2012	$1,239
2013	$1,762
2014	$2,331
2015	$2,881
2016	$3,405
2017	$3,913
2018	$4,402
2019	$4,872
2020	$5,324
2021	$5,771
2022	$6,164
2023	$6,537
2024	$6,890
2025	$7,218
2026	$7,612
2027	$7,922
2028	$8,220
2029	$8,508
2030	$8,785

Overall, purchasers of new vehicles in 2009 and beyond would experience a significant reduction in their operating cost. As shown in Figure 9-1, the annual value of the operating cost reduction is expected to exceed the annual cost increase by a ratio of about 13 to 1 in 2010, over 6 to 1 in 2020, and about 5 to 1 in 2030.

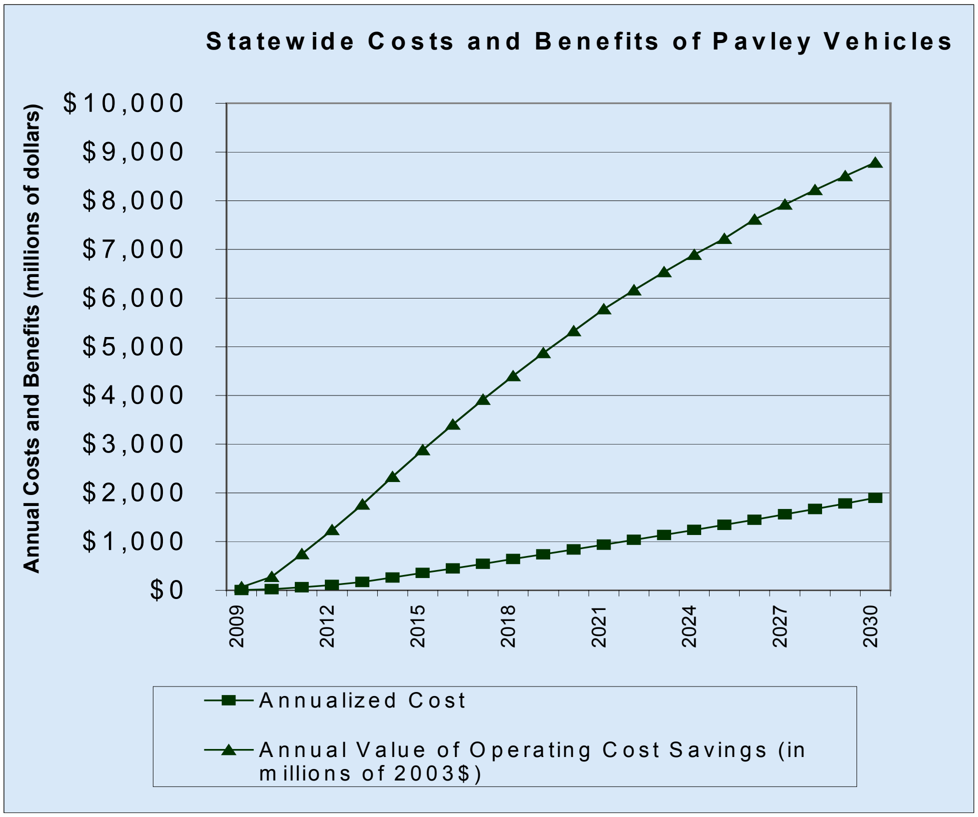


Figure 9-1. Statewide Costs and Benefits of the Proposed Climate Change Regulations

Economic Impacts
Higher vehicle prices provide a means to estimate the direct expenditures that will be incurred by California businesses, governments, and individuals to meet the requirements of the proposed climate change regulations. These expenditures would in turn bring about additional (indirect) changes in the California economy that may change the overall costs of the regulation to the economy. Increased vehicle prices, for example, may result in a reduction of demand for other goods and services as consumers use more of their money to pay for the price increase. California firms may respond by cutting back production and decreasing employment. On the other hand, in response to the proposed regulations automobile manufacturers are expected to choose technologies that reduce vehicle operating costs, leaving consumers with additional money to spend on products and services. This would, in turn, induce firms supplying those products and services to expand their production and increase their hiring of workers. A third type of effect occurs when purchase of the new vehicles directly lowers demand for the petroleum refining and gasoline distribution sectors.

The changes caused by the proposed regulations will affect industries both negatively and positively. The net effect on the California economy of these activities hinges on the extent to which products and services are obtained locally. Using the E-DRAM model of the California economy, staff estimated the net effects of these activities on affected industries and the overall economy. The California industries and individuals affected most by the proposed climate change regulations are those engaged in the production, distribution, sales, service, and use of light-duty passenger vehicles as well as the refining and distribution of gasoline.

Table 9.2-3, Table 9.2-4 and Table 9.2-5 summarize the impacts of the proposed climate change regulations on the California economy for fiscal years 2010, 2020, and 2030. Since the E-DRAM model is built to reproduce the economic conditions of fiscal year 1998/99, we first extrapolated the model out to 2010 based on State population, personal income, and industry-specific forecasts[15]. Higher vehicle prices were then adjusted to fiscal year 2010, 2020, and 2030.

The results of the E-DRAM simulation show that the changes caused by the proposed regulations would reduce the California economic output by roughly $90 million (0.004 percent) in 2010, $2.6 billion (0.08 percent) in 2020, and $4.7 billion (0.1 percent) in 2030. Personal income, however, would increase by roughly $480 million (0.03 percent) in 2010, $5.4 billion (0.3 percent) in 2020, and $7.7 billion (0.3 percent) in 2030. As a result, California net employment would also increase by over 8,000 jobs (0.05 percent) in 2010, 57,000 (0.3 percent) in 2020, and 76,000 (0.4 percent) in 2030.

Table 9.2-3. Economic Impacts of the Proposed Climate Change Regulations on the California Economy in Fiscal Year 2010 (2003$)

California Economy	Without Climate Change Regulations	With Climate Change Regulations	Difference	% of Total
Output (Billions)	$2,228.06	$2,227.97	- $0.09	- 0.004
Personal Income (Billions)	$1,451.01	$1,451.49	+ $0.48	+ 0.03
Employment (thousands)	16,354	16,362	+ 8	+ 0.05

Table 9.2-4. Economic Impacts of the Proposed Climate Change Regulations on the California Economy in Fiscal Year 2020 (2003$)

California Economy	Without Climate Change Regulations	With Climate Change Regulations	Difference	% Total
Output (Billions)	$3,078.02	$3,075.44	- $2.58	- 0.08
Personal Income (Billions)	$2,009.54	$2,014.92	+ $5.38	+ 0.30
Employment (thousands)	18,661	18,718	+ 57	+ 0.30

[15] For a more detail description of the E-DRAM extrapolation to "out years", see "Benefits of Reducing Demand for Gasoline and Diesel," a joint report to California Air Resources Board and California Energy Commission prepared by Arthur D. Little, Inc., March, 2002.

Table 9.2-5. Economic Impacts of the Proposed Climate Change Regulations on the California Economy in Fiscal Year 2030

California Economy	Without Climate Change Regulations	With Climate Change Regulations	Difference	% Total
Output (Billions)	$4,241.54	$4,236.83	- $4.71	- 0.1
Personal Income (Billions)	$2,781.44	$2,789.14	+ $7.71	+ 0.3
Employment (thousands)	21,763	21,839	+ 76	+ 0.4

These results indicate that higher vehicle prices cause consumers to redirect their expenditures. Consumers would now spend more on the purchase of motor vehicles, thus having less money to spend on the purchase of other goods and services. Since most automobile manufacturing occurs outside of the State, the increased consumer expenditures on motor vehicles would be a drain on the California economy. The reduction in operating costs that results from improved vehicle technology would, however, reduce consumer expenditures and would therefore leave California consumers with more disposable income to spend on other goods and services. Businesses that serve local markets are most likely to benefit from the increase in consumer expenditures. The increase would in turn boost the California economy, resulting in the creation of additional jobs.

9.3 Potential Impact on California Business Competitiveness

Automobile manufacturing in California represents a small fraction of the State's economy, about 0.27 percent. The California businesses impacted by this regulation tend to be the affiliated businesses such as gasoline service stations, automobile dealers, and automobile repair shops. Affiliated businesses are mostly local businesses. These businesses compete within the State and generally are not subject to competition from out-of-state businesses. Therefore, the proposed regulations are not expected to impose significant competitive disadvantages on affiliated businesses.

9.4 Potential Costs to Local and State Agencies

There are about 420,000 State and local agency-owned vehicles in California, or 1.74 percent of the total state fleet of about 24 million vehicles, according to a report from California Energy Commission[16]. A typical agency-owned vehicle is driven an average of 12,500 miles each year. This usage rate is very similar to those of private consumers. The staff analysis indicates that for individual consumers, the increased initial cost is more than offset by operating cost savings over the life of the vehicle. Therefore, staff expects that the same would hold true for public agencies--savings from the lowered operating costs of the proposed regulation would outweigh the higher price that the State and local agencies would pay for vehicles in 2009 and later.

9.5 Conclusion

The proposed climate change regulation has a net positive impact on the State's economy. The regulation may lead to a net creation or expansion of businesses, and could increase jobs in California. Because those businesses that are affected are local, there will not be any impact on the ability of California business to compete with businesses in other states. State and local agencies will not be adversely impacted and are likely to realize a net reduction in their cost of fleet operations.

[16] California Alternative Fuels Infrastructure Program Evaluation 2003, California Energy Commission Report # 600-03-018

10 IMPACTS ON MINORITY AND LOW INCOME COMMUNITIES

This section provides information on the ARB's activities to involve minority and low-income communities in the development of the climate change regulations. Staff also has assessed whether the regulation would impose economic or environmental impacts on minority or low income communities.

10.1 ARB Environmental Justice Policy

The ARB has made the achievement of environmental justice an integral part of its activities. State law defines environmental justice as the fair treatment of people of all races, cultures, and incomes with respect to the development, adoption, implementation, and enforcement of environmental laws, regulations, and policies.

The Board approved Environmental Justice Policies and Actions (Policies) on December 13, 2001. These Policies establish a framework for incorporating environmental justice into the ARB's programs consistent with the directives of State law. The Policies apply to all communities in California, but recognize that environmental justice issues have been raised more in the context of low-income and minority communities.

As the ARB developed the climate change regulations, staff worked closely with community leaders involved with environmental justice as well as with environmental and public health organizations to maintain an ongoing dialogue and thus successfully implement the ARB's environmental justice policies.

10.2 AB 1493 Requirements

Assembly Bill 1493 emphasizes the importance of considering the economic impacts of the climate change regulations on communities in an environmental justice context. The bill specifically directs ARB to,

> "consider the impact the regulations may have on the economy of the state, including, but not limited to…the ability of the state to maintain and attract businesses in communities with the most significant exposure to air contaminants, localized air contaminants, or both, including, but not limited to, communities with minority populations or low-income populations, or both."

In addition, the bill requires ARB to report to the Legislature and the Governor on:

> "the impact of the regulations on communities in the state with the most significant exposure to air contaminants or toxic air contaminants, or both, including, but not limited to, communities with minority populations or low-income populations, or both."

The bill also recognizes the importance of engaging these communities throughout the entire regulatory development process and includes specific requirements that the ARB

> "conduct public workshops in the state, including, but not limited to, public workshops in three of the communities in the state with the most significant exposure to air contaminants or localized air contaminants, or both, including, but not limited to, communities with minority populations or low-income populations, or both."

In order to accomplish the Board's over-arching environmental justice goals, the ARB has actively engaged communities with environmental justice concerns. These efforts have also served to meet the specific requirements set forth in the bill.

10.2.A Outreach to Minority and Low Income Communities

As ARB developed the climate change regulations, staff benefited from the support of community leaders working for environmental justice. Staff successfully identified a core group of leaders in communities with environmental justice concerns who were willing to work with staff to ensure the development of effective and defensible regulations. This core group of environmental justice representatives included environmental, health-based and environmental justice organizations. It was important to ensure that issues specifically impacting communities with environmental justice concerns were identified and addressed. Members of this core group regularly attended ARB workshops and Board hearings in order to have accurate information about our climate change activities. For those unable to attend the scheduled workshops and hearings, staff sent targeted emails with information prior to each workshop followed by a summary of the meeting specifically addressing issues that may be of concern to these communities.

In order to get communities intimately involved in the entire regulatory development process, staff made it a priority to attend local environmental justice community meetings. At these meetings, staff provided general background information on climate change and updated the groups on the ARB's climate change activities and potential issues that might arise. Below is a list of meetings staff attended:

Date	Organization
February 27, 2003	Los Angeles Environmental Justice Forum
July 22, 2003	Oakland Environmental Justice Meeting
October 30, 2003	California League of Conservation Voters Education Fund Environmental Justice Forum
May 13, 2004	Partnership for the Public Health, Environmental Justice Sub-Committee Meeting
May 20, 2004	Bluewater Network Environmental Justice Forum "Global Warming, Air Quality and Environmental Justice: Finding Common Ground"
June 10, 2004	3rd Street Celebration, North Richmond
June 26, 2004	Multi Cultural Celebration, North Richmond

Staff will continue to attend local environmental justice meetings in the Bay Area, Los Angeles area and the Central Valley. Staff has also worked with environmental and health based organizations to coordinate outreach messages and materials for communicating with these communities. In addition, all of the ARB climate change fact sheets were translated into Spanish and staff developed additional fact sheets and outreach materials that specifically address climate change in an environmental justice context.

10.2.B Public Workshops

Staff not only attended local community meetings, but also conducted a community-focused workshop in Huntington Park and will hold three additional workshops in communities with environmental justice concerns.

The first workshop allowed staff to receive input from community members prior to the development of a draft proposal. Working with our core group of stakeholders, a panel was put together for this workshop to provide attendees with an overview of climate change and how it may impact their community. This panel included staff from the Union of Concerned Scientists, Redefining Progress and a volunteer from the American Lung Association. In addition, staff invited Mr. Carlos Porras of Citizens for a Better Environment to emcee the workshop. This provided a good link between the panel, ARB staff and the community. Staff believes that this first workshop was beneficial and critical to making the following workshops an even greater success. State legislators and local elected officials were invited to this workshop and will be invited to all future workshops. Staff has continued to work with this group to plan upcoming workshops and ensure that they are effective and meet the needs of the specific audiences.

The dates of the first and future workshops are as follows:

Date	Location
February 18, 2004	Huntington Park
July 6, 2004	Oakland
July 8, 2004	Fresno
July 13, 2004	Pacoima

Each workshop will include a panel of experts on climate change, specifically health and community impacts. In addition, an emcee from each area that can relate to the community will be present.

10.3 Potential Environmental Impacts

The staff analysis concluded that the climate change regulation will have a negligible impact on criteria pollutant emissions. However, to the degree that there are upstream benefits associated with reduced petroleum shipping, storage and distribution, emissions will be reduced. Many of these shipping and storage facilities are located in low income and minority communities. Distribution of petroleum takes place along freeway corridors near communities often identified with environmental justice concerns. Staff therefore has not identified any mechanisms by which the climate change regulation would result in a disproportionate negative impact on low income or minority communities. In fact, the upstream emission reductions are likely to provide benefits to these communities.

10.4 Potential Economic Impacts

Staff has evaluated the economic effects of the climate change regulation on low-income and minority communities. For residents in these communities who purchase new vehicles, the economic effects of the regulations would be no different than in any other community. However, because residents in low-income communities tend to purchase used vehicles at a higher rate than residents in middle and high income communities, staff evaluated the effects of the regulation on the used vehicle market and, more specifically, on residents in low-income communities that purchase used vehicles. Staff invites comment on other possible economic impacts.

In section 11.5 of this report staff evaluated the broader impacts of the regulation on job and business creation in representative San Diego communities with environmental justice concerns. The evaluation concluded that the regulations would likely result in an increase in jobs and business creation.

10.4.A Potential Impact on Low Income Used Car Buyers

The proposed climate change regulation is likely to require changes in vehicle technology that will increase the price of new vehicles sold in California. This increase in turn is expected to eventually slightly increase the price of used vehicles. Low-income households often purchase used vehicles. According to the 2001 National Household Travel Survey, low-income households with an average annual income of $20,000 (closest bracket to poverty level of $15,000) tend to purchase vehicles with an average age of 10 to 12 years[17]. In this analysis, California households of three members with an annual family income of $15,000 or less are considered to be economically disadvantaged.[18]

The impact on low income used car buyers was assessed by using an annualized cost approach that considered the annual cost increase and operating cost savings as a percent of income. The analyses showed that the proposed regulation should not have a significant impact on low-income households that purchase used cars.

To estimate the potential impacts staff employed the following methodology:

Changes in prices of used vehicles caused by the proposed regulations for typical small and large vehicles were estimated, using historical retention value for various vehicles and trucks. For example, a $500 increase in the price of a small new vehicle is expected to increase the price of the vehicle when 10 years old vehicle by $80, assuming a historical retention value of 16 percent. Changes in prices of used vehicles were annualized over the remaining life of vehicles. For example, an $80 increase in the price of a 10-year-old small used vehicle is equivalent to a $16 annual cost increase of the vehicle over its remaining life of 8 years.

The resulting annualized cost increase was compared with the median income of typical low-income households to assess the extent of the impact on typical low-income household purchasers of used vehicles. Over the long term, the average new vehicle price increase due to the regulation is estimated to be a maximum of $540 for light duty vehicles and $850 for light duty trucks. Increases in the early years of the regulation would be smaller. As indicated, most low-income households purchase vehicles that are at least 10 years old, based on the information obtained from the 2001 National Household Travel Survey. Ten-year-old used small vehicles and trucks have retention values of about 16 and 27 percent, respectively.[19] Therefore the maximum estimated price increase for 10-year-old small vehicles and large trucks is $86 and $247, respectively.

To annualize the increased cost of the vehicles, a real 10 percent discount rate was used which is the total of a real discount rate of five, the historical

[17] 2001 National Household Travel Survey, the U.S. Department of Transportation, http://nhts.ornl.gov/2001/html_files/introduction.shtml

[18] U.S. Department of Labor and U.S. Department of Health and Human Services, Poverty Guidelines

[19] Communication with Institute of Transportation Studies at University of California, Davis. Data developed by the Institute for consumer choice models

automobile loan rate, and a five percent risk premium[20]. A five percent risk premium was added to the historical car loan rate to reflect higher risk associated with financing used vehicles and historical lending to low-income households. Based on the data from EMFAC, a 10-year-old car has a median remaining useful life of 8 years and a 10-year-old truck has a median remaining useful life of 11 years. These assumptions were used to annualize the increased cost.

Meanwhile, when used vehicles affected by the regulation are purchased by low-come households, they will yield benefits from reduced operating costs. These savings were also taken into account.

10.4.B Results

The impact of price increases for the 2009 model year vehicles on 10-year old cars is quite negligible. That is, the regulations are not expected to lead to a substantive increase in the price of older vehicles not subject to the regulation. Overall, the impact of higher new car prices on 10-year old cars is minimal. The impact of the price increase on low-income purchasers of used cars will begin in 2019 and later, at which point they also realize the benefits of lower operating costs.

Typical California low-income purchasers of used cars will be affected by the proposed climate change regulations to the extent that the implementation of the regulations would alter their annual income. Using the above assumptions, staff estimated that the maximum expected increase in annual costs of used vehicles ranges from 0.1 to 0.2 percent for a family with an annual family income of $15,000, as shown in Table 10.4-1.

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[20] Historical car loan data, Federal Reserve Statistical release, http://www.federalreserve.gov/releases/g19/hist/cc_hist_tc.html
Historical Consumer Price Index, U.S. Department of Labor, Bureau of Labor Statistics, http://research.stlouisfed.org/fred2/data/CPIAUCNS.txt

Table 10.4-1. Potential Impacts on Low-Income Purchasers of Used Cars

Description	**Small Car**	**Large Car**	**Small Truck**	**Large Truck**	**Minivan**
Maximum Increase in New Car Prices	$540	$850	$540	$850	$850
Maximum Increase in Used Car Value	$86	$213	$146	$247	$230
Median Remaining useful life (years)	8	8	11	11	11
Annualized Cost	$13	$33	$18	$30	$28
Poverty Income Level	$15,000	$15,000	$15,000	$15,000	$15,000
% Change	**0.1**	**0.2**	**0.1**	**0.2**	**0.2**

When vehicles affected by the regulation are purchased by low-income households, they will yield benefits from reduced operating costs that more than offset the price increase. Specifically, the small additional price of vehicles purchased by the low-income families is likely to be offset by operating cost savings. For example, for a 10-year-old small car with a 25 percent reduction in operating cost as a result of the regulation would provide an operating cost savings of about $124 per year. These savings far exceed the additional costs to the purchaser of $13 per year (see Table 10.4-1) for the small car and $18 for small trucks. For large cars and trucks the savings would be $193, well above the $33 and $30 additional cost shown.

The staff analysis assumes that low-income purchasers would be able to finance the increase in used car prices either from their own income or from borrowing. The increase in used car prices range from $86 for a small passenger car to $247 for a large truck. About 70 percent of vehicles owned by households with family income of less than $15,000 are passenger cars[21]. These households are likely to replace their vehicles with similar vehicles. Therefore, the maximum expected additional cost of used cars to most low-income used car purchasers would be about $86. This amounts to about 0.1 percent of their annual income. The low-income households who buy trucks or minivans would see a small additional cost of about 0.2 percent of their annual income. Overall, the monthly impact of the regulation on a low-income purchasers of 10-12 year-old vehicles impacted by the regulation (e.g., 2009 model year vehicles in 2020) vehicles in would be in the range of one to three dollars per month. On average, these costs to the low-income would begin to accrue in 2019.

The climate change regulation may cause vehicle prices to increase, but the low-income purchasers of used vehicles are not likely to face the increase for several years. When they do pay higher prices for their vehicle, they will see a significant reduction in vehicle operating costs. The savings far outweigh the annualized

[21] 2001 National Household Travel Survey.

cost of purchasing the vehicle (price increase spread over the years of ownership). Purchase costs may increase by a small percentage of their income, but will be more than offset by the operating costs savings. Given the wide margin of savings to costs, staff believes that the regulation is highly unlikely to have an adverse effect on low-income purchasers of used vehicles.

11 OTHER CONSIDERATIONS

This chapter describes several approaches that supplement the standard economic analysis presented in Section 9. The methods used in this chapter rely on recent tools and studies that provide additional insight into the potential impacts of the regulation. Using those tools and studies to investigate possible secondary impacts of the regulation, this section presents additional perspectives on the potential impact of the proposed regulation on fleet mix, emissions, the State's economy, small businesses, and low-income households. The methods discussed in this chapter are in the early stages of development relative to the standard analysis presented in Section 9. As such, it is expected that these methods will be further refined. ARB staff will continue to develop these lines of investigation and will consider any comments received before issuing the final staff report in early August.

11.1 Consumer Response Effects on Emissions and State Economy

The ARB's climate change regulation will increase new vehicle prices, starting with model year 2009. In addition to an increase in price, however, it is expected that many of the technologies that manufacturers employ to lower greenhouse gas emissions to comply with the regulation will, as an outgrowth, result in vehicles with lower operating costs than comparable pre-regulation vehicles. AB 1493 requires ARB to evaluate such operating costs as a component of owner or operator life-cycle costs. Changes in vehicle prices and other attributes may affect consumer purchase decisions and could affect how consumers subsequently use vehicles. For example, not all consumers would be willing to pay more for the vehicle that they might have otherwise purchased. Some may purchase a different vehicle commensurate with their budget. Others may wait until the following year, or respond in some other way. Still other consumers may highly value the reduction in operating cost, in which case the vehicle would be more attractive. Such decision changes, referred to as consumer response, can affect the California vehicle fleet mix and possibly emissions.

11.1.A Background

A model, known as CARBITS, was used to estimate consumer response (i.e., the estimated change in the type and number of vehicles sold) to changes in vehicle attributes. The model is fully explained in the Technical Support Document. The attribute changes considered are a vehicle price increase necessary to cover the estimated compliance costs of the climate change regulation, and a reduction in vehicle operating costs which is an outgrowth of the technology employed to reduce greenhouse gas emissions.

The CARBITS model is a consumer choice model and was developed by the Institute of Transportation Studies at the University of California, Davis. The ultimate objective of the modeling effort is to investigate the potential fleet mix changes and any criteria pollutant impact that may result as a side effect of the climate change regulation. The results show that even if there is a consumer response to potential price increases and changes in operating costs, the draft staff proposal would have a negligible effect on tailpipe criteria pollutant emissions.

Consumer response may manifest itself in different ways. The consumer response to the regulations is defined as the difference in the California fleet mix between the forecasted baseline and the regulation scenarios. The baseline scenario is a depiction of the passenger vehicle fleet in the absence of the climate change regulation.

While vehicle prices are likely to go up with respect to the regulatory scenarios, the operating costs are expected to be lower. As a consequence of the price increase, consumers could respond by purchasing fewer new vehicles and holding on to their current vehicles a bit longer. Such a shift in vehicle holdings would lead to aging of the vehicle fleet. The aging of the fleet could result in older, relatively higher polluting cars staying in service longer than they would have remained otherwise. This delay in fleet turnover could slow the progress that California is making in reducing criteria pollutant emissions from mobile sources. On the other hand, the reduction in operating cost could make new vehicles more attractive, creating a factor that would increase new vehicle sales. This would lessen and potentially more than offset the impact of any price effects. The purpose of the CARBITS model is to quantitatively investigate the possible magnitude and direction of such changes.

11.1.B Impacts on Vehicle Prices and Operating Costs

Using the cost estimates from section 5 of this report, staff developed a regulatory scenario to use as inputs to CARBITS in an effort to estimate consumer response to changes in price and operating cost. Table 11.1-1 shows the baseline vehicle prices for the fourteen vehicle classes that the model uses. Table 11.1-2 shows the estimated average price increase needed to cover manufacturer compliance cost. This estimated price increase takes into account the phase-in of the standard and the fact that not all vehicles will need to be modified in order for each manufacturer to comply with the standard. The derivation of these estimates is described in section 6. Table 11.1-3 shows the price increase in percentage terms. These price changes are calculated for the near-term phase (2009-2011) of the regulation as well as the mid-term (2012-2014) phase. A combination of near and mid-term price changes were calculated for some years based on the assumption that the regulation will be phased in over a period of years. Starting in 2014, when the mid-term technologies are fully phased in, the price changes remain the same.

The costs presented in section 5 were estimated for 5 vehicle classes. However, CARBITS uses 14 vehicle classes. To translate the costs from 5 to 14 classes, staff assumed that vehicles of similar size will have the same price and operating cost changes. For example, mini, sub-compact, and compact cars fit in the same class as the small car category in the cost estimates presented in section 5 and therefore see the same price change. Similarly, staff assumes that operating cost would decrease by the same percentage for the mini, sub-compact, and compact cars.

Table 11.1-1. Predicted Baseline Vehicle Prices by CARBITS Classes ($2003)

CARS:	Mini	Sub-compact	Compact	Midsize	Large	Luxury	Sport
2009	$14,787	$16,612	$16,830	$21,931	$25,195	$47,761	$22,129
2010	$14,850	$16,612	$16,910	$22,010	$25,274	$47,839	$22,193
2011	$14,899	$16,612	$16,975	$22,069	$25,333	$47,899	$22,241
2012	$14,931	$16,612	$17,022	$22,108	$25,372	$47,937	$22,274
2013	$14,947	$16,612	$17,054	$22,127	$25,392	$47,958	$22,290
2014	$14,947	$16,612	$17,070	$22,127	$25,392	$47,958	$22,290
2015	$14,947	$16,612	$17,070	$22,127	$25,392	$47,958	$22,290
2016	$14,947	$16,612	$17,070	$22,127	$25,392	$47,958	$22,290
2017	$14,947	$16,612	$17,070	$22,127	$25,392	$47,958	$22,290
2018	$14,947	$16,612	$17,070	$22,127	$25,392	$47,958	$22,290
2019	$14,947	$16,612	$17,070	$22,127	$25,392	$47,958	$22,290
2020	$14,947	$16,612	$17,070	$22,127	$25,392	$47,958	$22,290

Table 11.1-1. (Continued) Predicted Baseline Vehicle Prices by CARBITS Classes ($2003)

Trucks:	Small pickups	Large pickups	Minivans	Standard vans	Mid SUVs	Large SUVs	Mini SUVs
2009	$14,485	$19,816	$26,248	$23,817	$28,583	$37,054	$19,353
2010	$14,564	$19,858	$26,312	$23,859	$28,663	$37,096	$19,433
2011	$14,623	$19,890	$26,361	$23,891	$28,721	$37,127	$19,491
2012	$14,663	$19,911	$26,394	$23,912	$28,761	$37,149	$19,531
2013	$14,682	$19,921	$26,410	$23,922	$28,780	$37,158	$19,550
2014	$14,682	$19,921	$26,410	$23,922	$28,780	$37,158	$19,550
2015	$14,682	$19,921	$26,410	$23,922	$28,780	$37,158	$19,550
2016	$14,682	$19,921	$26,410	$23,922	$28,780	$37,158	$19,550
2017	$14,682	$19,921	$26,410	$23,922	$28,780	$37,158	$19,550
2018	$14,682	$19,921	$26,410	$23,922	$28,780	$37,158	$19,550
2019	$14,682	$19,921	$26,410	$23,922	$28,780	$37,158	$19,550
2020	$14,682	$19,921	$26,410	$23,922	$28,780	$37,158	$19,550

Table 11.1-2. Climate Change Regulation Scenario, Vehicle Price Changes 2009 – 2020 ($2003)

CARS:	Mini	Sub-compact	Compact	Midsize	Large	Luxury	Sport
2009	$65	$65	$65	$29	$29	$29	$65
2010	$185	$185	$185	$85	$85	$85	$185
2011	$395	$395	$395	$181	$181	$181	$395
2012	$475	$475	$475	$246	$246	$246	$475
2013	$585	$585	$585	$353	$353	$353	$585
2014	$772	$772	$772	$543	$543	$543	$772
2015	$772	$772	$772	$543	$543	$543	$772
2016	$772	$772	$772	$543	$543	$543	$772
2017	$772	$772	$772	$543	$543	$543	$772
2018	$772	$772	$772	$543	$543	$543	$772
2019	$772	$772	$772	$543	$543	$543	$772
2020	$772	$772	$772	$543	$543	$543	$772

Table 11.1-2 (Continued) Climate Change Regulation Scenario, Vehicle Price Changes 2009 – 2020 ($2003)

Trucks:	Small pickups	Large pickups	Minivans	Standard vans	Mid SUVs	Large SUVs	Mini SUVs
2009	$16	$79	$111	$79	$16	$79	$16
2010	$47	$226	$319	$226	$47	$226	$47
2011	$101	$484	$682	$484	$101	$484	$101
2012	$175	$589	$766	$589	$175	$589	$175
2013	$306	$743	$855	$743	$306	$743	$306
2014	$543	$1,006	$995	$1,006	$543	$1,006	$543
2015	$543	$1,006	$995	$1,006	$543	$1,006	$543
2016	$543	$1,006	$995	$1,006	$543	$1,006	$543
2017	$543	$1,006	$995	$1,006	$543	$1,006	$543
2018	$543	$1,006	$995	$1,006	$543	$1,006	$543
2019	$543	$1,006	$995	$1,006	$543	$1,006	$543
2020	$543	$1,006	$995	$1,006	$543	$1,006	$543

Table 11.1-3. Climate Change Regulation Scenario, Percentage Change in Vehicle Price 2009 - 2020

CARS:	Mini	Sub-compact	Compact	Midsize	Large	Luxury	Sport
2009	0.4%	0.4%	0.4%	0.1%	0.1%	0.1%	0.3%
2010	1.2%	1.1%	1.1%	0.4%	0.3%	0.2%	0.8%
2011	2.7%	2.4%	2.3%	0.8%	0.7%	0.4%	1.8%
2012	3.2%	2.9%	2.8%	1.1%	1.0%	0.5%	2.1%
2013	3.9%	3.5%	3.4%	1.6%	1.4%	0.7%	2.6%
2014	5.2%	4.6%	4.5%	2.5%	2.1%	1.1%	3.5%
2015	5.2%	4.6%	4.5%	2.5%	2.1%	1.1%	3.5%
2016	5.2%	4.6%	4.5%	2.5%	2.1%	1.1%	3.5%
2017	5.2%	4.6%	4.5%	2.5%	2.1%	1.1%	3.5%
2018	5.2%	4.6%	4.5%	2.5%	2.1%	1.1%	3.5%
2019	5.2%	4.6%	4.5%	2.5%	2.1%	1.1%	3.5%
2020	5.2%	4.6%	4.5%	2.5%	2.1%	1.1%	3.5%

Table 11.1-3 (Continued) Climate Change Regulation Scenario, Percentage Change in Vehicle Price 2009 - 2020

Trucks:	Small pickups	Large pickups	Minivans	Standard vans	Mid SUVs	Large SUVs	Mini SUVs
2009	0.1%	0.4%	0.4%	0.3%	0.1%	0.2%	0.1%
2010	0.3%	1.1%	1.2%	0.9%	0.2%	0.6%	0.2%
2011	0.7%	2.4%	2.6%	2.0%	0.4%	1.3%	0.5%
2012	1.2%	3.0%	2.9%	2.5%	0.6%	1.6%	0.9%
2013	2.1%	3.7%	3.2%	3.1%	1.1%	2.0%	1.6%
2014	3.7%	5.1%	3.8%	4.2%	1.9%	2.7%	2.8%
2015	3.7%	5.1%	3.8%	4.2%	1.9%	2.7%	2.8%
2016	3.7%	5.1%	3.8%	4.2%	1.9%	2.7%	2.8%
2017	3.7%	5.1%	3.8%	4.2%	1.9%	2.7%	2.8%
2018	3.7%	5.1%	3.8%	4.2%	1.9%	2.7%	2.8%
2019	3.7%	5.1%	3.8%	4.2%	1.9%	2.7%	2.8%
2020	3.7%	5.1%	3.8%	4.2%	1.9%	2.7%	2.8%

Section 5 presented data on operating cost reductions due to the proposed regulation. The reductions were translated to the 14 CARBITS classes and are presented in Table 11.1-4. Because the regulation is phased in over the years, the operating costs reductions account for the portion of the fleet that would become compliant with the proposed regulation in each year.

Table 11.1-4. Climate Change Regulation Scenario, Percentage Reduction in Fuel-related Operating Cost 2009 - 2020

CARS:	Mini	Sub-compact	Compact	Midsize	Large	Luxury	Sport
2009	3.7%	3.7%	3.7%	3.3%	3.3%	3.3%	3.7%
2010	10.6%	10.6%	10.6%	9.5%	9.5%	9.5%	10.6%
2011	22.7%	22.7%	22.7%	20.3%	20.3%	20.2%	22.7%
2012	25.1%	25.2%	25.2%	23.0%	23.0%	23.0%	25.2%
2013	27.5%	27.5%	27.5%	26.2%	26.1%	26.1%	27.5%
2014	31.0%	31.0%	31.0%	31.2%	31.1%	31.2%	31.0%
2015	31.0%	31.0%	31.0%	31.2%	31.1%	31.2%	31.0%
2016	31.0%	31.0%	31.0%	31.2%	31.1%	31.2%	31.0%
2017	31.0%	31.0%	31.0%	31.2%	31.1%	31.2%	31.0%
2018	31.0%	31.0%	31.0%	31.2%	31.1%	31.2%	31.0%
2019	31.0%	31.0%	31.0%	31.2%	31.1%	31.2%	31.0%
2020	31.0%	31.0%	31.0%	31.2%	31.1%	31.2%	31.0%

Table 11.1-4 (Continued) Climate Change Regulation Scenario, Percentage Reduction in Fuel-related Operating Cost 2009 - 2020

Trucks:	Small pickups	Large pickups	Minivans	Standard vans	Mid SUVs	Large SUVs	Mini SUVs
2009	3.3%	2.4%	2.9%	2.4%	3.3%	2.4%	3.3%
2010	9.5%	6.9%	8.3%	6.8%	9.5%	6.8%	9.5%
2011	20.3%	14.6%	17.8%	14.6%	20.3%	14.6%	20.3%
2012	22.3%	16.4%	19.7%	16.4%	22.3%	16.4%	22.2%
2013	24.0%	18.3%	21.4%	18.3%	23.9%	18.3%	23.9%
2014	26.3%	21.3%	23.9%	21.3%	26.3%	21.3%	26.3%
2015	26.3%	21.3%	23.9%	21.3%	26.3%	21.3%	26.3%
2016	26.3%	21.3%	23.9%	21.3%	26.3%	21.3%	26.3%
2017	26.3%	21.3%	23.9%	21.3%	26.3%	21.3%	26.3%
2018	26.3%	21.3%	23.9%	21.3%	26.3%	21.3%	26.3%
2019	26.3%	21.3%	23.9%	21.3%	26.3%	21.3%	26.3%
2020	26.3%	21.3%	23.9%	21.3%	26.3%	21.3%	26.3%

These percentage operating cost savings were then converted into cent per mile savings. The results are shown in Table 11.1-5.

Table 11.1-5. Operating Cost Savings, Cents Per Mile

CARS:	Mini	Sub-compact	Compact	Midsize	Large	Luxury	Sport
2009	0.2	0.2	0.2	0.2	0.2	0.2	0.3
2010	0.5	0.5	0.5	0.6	0.6	0.6	0.7
2011	0.9	0.9	1.0	1.1	1.2	1.2	1.3
2012	1.0	1.0	1.1	1.2	1.3	1.3	1.4
2013	1.1	1.1	1.2	1.3	1.5	1.5	1.5
2014	1.2	1.2	1.3	1.5	1.7	1.7	1.7
2015	1.2	1.2	1.3	1.5	1.7	1.7	1.7
2016	1.2	1.2	1.3	1.5	1.7	1.7	1.7
2017	1.2	1.2	1.3	1.5	1.7	1.7	1.7
2018	1.2	1.2	1.3	1.5	1.7	1.7	1.7
2019	1.2	1.2	1.3	1.5	1.7	1.7	1.7
2020	1.2	1.2	1.3	1.5	1.7	1.7	1.7

Table 11.1-5. (Continued) Operating Cost Savings, Cents Per Mile

Trucks:	Small pickups	Large pickups	Minivans	Standard vans	Mid SUVs	Large SUVs	Mini SUVs
2009	0.2	0.2	0.2	0.2	0.3	0.2	0.2
2010	0.6	0.6	0.6	0.7	0.7	0.7	0.6
2011	1.1	1.1	1.2	1.3	1.4	1.3	1.1
2012	1.2	1.2	1.3	1.4	1.5	1.5	1.2
2013	1.2	1.3	1.4	1.6	1.6	1.6	1.3
2014	1.3	1.5	1.5	1.8	1.7	1.8	1.4
2015	1.3	1.5	1.5	1.8	1.7	1.8	1.4
2016	1.3	1.5	1.5	1.8	1.7	1.8	1.4
2017	1.3	1.5	1.5	1.8	1.7	1.8	1.4
2018	1.3	1.5	1.5	1.8	1.7	1.8	1.4
2019	1.3	1.5	1.5	1.8	1.7	1.8	1.4
2020	1.3	1.5	1.5	1.8	1.7	1.8	1.4

11.1.C Impacts on Vehicle Sales, Fleet Size, and Average Age

The impacts of the proposed regulation were assessed by forecasting a baseline future fleet mix that assumes that, absent the regulation, vehicle prices and operating costs change only slightly in real terms. This baseline then is compared to a regulatory scenario that takes into account the estimated price and operating cost changes resulting from the regulation. Table 11.1-6 shows vehicle sales, the size of the fleet, and the average age of the fleet under the baseline and regulation scenarios.

Table 11.1-6. Results of Baseline and Climate Change Regulation Scenarios

Year	Baseline Scenario			Regulation Scenario		
	Vehicle Sales (x1000)	Fleet Size (x1000)	Average Age (years)	Vehicle Sales (x1000)	Fleet Size (x1000)	Average Age (years)
2009	1,687	26,875	9.17	1,694	26,875	9.17
2010	1,710	27,608	9.28	1,726	27,608	9.27
2011	1,728	28,302	9.38	1,752	28,302	9.36
2012	1,754	29,158	9.48	1,769	29,153	9.45
2013	1,775	29,837	9.59	1,771	29,834	9.56
2014	1,804	30,736	9.71	1,775	30,727	9.69
2015	1,849	31,805	9.84	1,819	31,788	9.82
2016	1,879	32,658	9.95	1,840	32,641	9.94
2017	1,926	33,677	10.05	1,880	33,650	10.06
2018	1,966	34,759	10.16	1,916	34,728	10.17
2019	2,005	35,629	10.25	1,948	35,583	10.26
2020	2,049	36,708	10.34	1,985	36,654	10.36

Table 11.1-7 shows the differences in sales, fleet mix, and average age of fleet between the baseline and regulation scenarios. The full analysis is presented in the Technical Support Document.

Table 11.1-7. Climate Change Regulation Impacts on Vehicle Sales, Fleet Size, and Fleet Age

Years	Changes in Sales		Changes in Fleet Size		Changes in Average Age (years)
	In Thousands	Percent Change	In Thousands	Percent Change	
2009	7	0.4%	0	0.0%	0.00
2010	16	0.9%	0	0.0%	-0.01
2011	24	1.4%	0	0.0%	-0.02
2012	15	0.9%	5	0.0%	-0.03
2013	-4	-0.2%	3	0.0%	-0.03
2014	-29	-1.6%	9	0.0%	-0.02
2015	-31	-1.7%	17	-0.1%	-0.02
2016	-39	-2.1%	17	-0.1%	-0.01
2017	-46	-2.4%	27	-0.1%	0.00
2018	-51	-2.6%	31	-0.1%	0.01
2019	-57	-2.9%	46	-0.1%	0.02
2020	-64	-3.1%	54	-0.1%	0.03

As can be seen by reviewing the table, in the initial years of the regulation the model predicts a sales increase. This implies that the negative effect on consumer demand brought about by the estimated price increase is more than offset by an increase in consumer demand due to the attractiveness of vehicles with reduced operating cost. As the more stringent second stage of the regulation is phased in, the model predicts that the combined effect of the changes in vehicle attributes would be a slight decrease in vehicle sales. As noted above, these are preliminary estimates and staff will continue to refine this work.

The changes in the fleet mix affect the average age of the fleet. If fewer new cars are sold and consumers hold on to their older cars, the fleet gets older. That is, the average age of vehicles on the road could increase. As Table 11.1-7 shows, the fleet aging associated with the regulatory scenario is minimal. It stays either unchanged, as illustrated by 2009 and 2017, or goes up or down by at most 0.03 years, or about 11 days.

The assumptions for this analysis do not consider other reductions in operating costs that may be associated with the regulation such as the potential elimination of a mobile air conditioning service event through improved refrigerant containment strategies that manufacturers may choose to employ. Further, the model does not consider the potential increase in the price of used vehicles in response to new vehicle price increases associated with the regulation. Both of these effects would be expected to translate into a further increase in the sales of new vehicles. Finally, the model does not take into account changes to other vehicle attributes associated with the regulation that consumers may value, such as the environmental benefits. Because the model does not take into account such factors that would serve to increase sales, ARB staff believes that the model may understate the sale of new vehicles with respect to the regulatory scenario.

11.1.D Impacts on Criteria Emissions

Changes in the fleet size and age would affect criteria emissions. Newer cars emit less, and will produce a steady decline in most vehicle pollutants as new vehicles replace existing ones. If the fleet ages, then the rate of emission reduction from the fleet could slow. Older cars tend to be driven less, however, implying that the emissions may not significantly change. The model results indicate small changes to the fleet. The small changes were input into EMFAC model to estimate the emissions. The emissions impacts assessments are shown in Table 11.1-8, Table 11.1-9, and Table 11.1-10 below. The tables show projected changes in ROG, NOx and PM10 emissions.

Table 11.1-8 Climate Change Regulation Consumer Response, Changes in ROG Emissions (tons/day)

Year	Vintages	Baseline ROG (tpd)	Regulation ROG (tpd)	Difference (tpd)
2020	1975-2008	197.70	197.39	**-0.31**
2020	2009-2020	33.26	33.46	**0.20**
2020	Total	230.96	230.85	**-0.11**

Table 11.1-9. Climate Change Regulation Consumer Response, Changes in NOx Emissions (tons/day)

Year	Vintages	Baseline NOx (tpd)	Regulation NOx (tpd)	Difference (tpd)
2020	1975-2008	157.24	157.03	**-0.21**
2020	2009-2020	32.96	32.99	**0.03**
2020	Total	190.20	190.02	**-0.18**

Table 11.1-10. Climate Change Regulation Consumer Response, Changes in PM10 Emissions (tons/day)

Year	Vintages	Baseline PM10 (tpd)	Regulation PM10 (tpd)	Difference (tpd)
2020	1975-2008	17.23	17.18	**-0.05**
2020	2009-2020	25.52	25.54	**0.02**
2020	Total	42.75	42.72	**-0.03**

As can be seen from the tables, the regulation is predicted to slightly decrease criteria pollutant emissions in 2020, but only by a very small amount. In considering and interpreting these results, staff believes that the increase in vehicle sales in the early years of the regulation results in a small acceleration in the retirement of higher polluting older cars from the pre-regulation period. This results in slightly lower fleet emissions. On the other hand, the slight projected decrease in sales in the later years of the regulation results in a longer average life for the much less polluting cars of 2009-2020 vintage. This will tend to increase emissions from that group, but to a lesser extent because the newer cars are cleaner than the older cars. The net effect is a very small, but positive, effect on emissions and air quality.

11.2 Alternative Approach to Assessing Consumer Response

The CARBITS model considers many factors at the household analytical level in predicting fleet change. Staff also is investigating a simplified alternative approach that uses an aggregate sales response factor, known as price elasticity of demand, to assess the consumer response and emission implications of vehicle price increases due to the proposed regulation. This simplified approach was developed as a screening tool and to provide a cross-check against the CARBITS results.

The ratio of a percentage change in sales to a percentage change in price is referred to as price elasticity of demand. Price elasticity of demand is the most commonly used measure of consumers' sensitivity to price. It measures the change in demand for a good or service caused by a given change in price. Table 11.2-1 provides estimates of the price elasticity of demand for automobiles by various sources.

Table 11.2-1. Estimated Price Elasticity of Demand for Automobiles

Estimator	Price Elasticity of Demand	Source
CARBITS	-1.4	ITS, UCD
NERA/Sierra	-1.0	GM Study of ZEV Mandate, Volume II
Mackinac	-1.2 to -1.5 (short-run) -0.2 (Long-run)	The Mackinac Center for Public Policy, Michigan
Patrick McCarty	-0.87	MIT Press, 1996
David Greene	-1.0	Kleit, Andrew 1990
Range	-0.2 to -1.5	

ARB staff, after reviewing a number of these studies, selected for this screening exercise a sales elasticity of minus one (-1) as an approximate average of the observed values. A sales elasticity of -1 means that the percentage decrease in new vehicle sales is equal to the percentage increase in price. Thus, for the percent increases in price given in Table 11.2-2, sales of new vehicles would decrease by the same amount.

Table 11.2-2. Percentage Price and Sales Changes by Vehicle Class

Vehicle Type	Change in Price	Change in Sales
Passenger Cars (All)	2.7	- 2.7
Trucks (0-3750 lb. Loaded Vehicle Weight[22])	3.1	- 3.1
Trucks (3751-5750 lb. Loaded Vehicle Weight[22])	2.5	- 2.5
Trucks (5751 lb. Loaded Vehicle Weight[22] - 8500 lb. GVWR[24]	2.2	- 2.2

[22] Loaded vehicle weight (LVH) equals curb weight plus 300 lb.

[24] Gross vehicle weight rating

A comparison of the sales changes projected by this screening analysis (from Table 11.2-2) versus the sales changes predicted by CARBITS (from Table 11.1-7) shows that the screening results are in general agreement with the CARBITS results for the fully phased in regulation (2015 and beyond).

It is important to note that this simplified approach assumes that the estimated price increase is applied to every vehicle in the fleet. In fact, as is shown in section 6.2, not all vehicles need to be modified in order for all manufacturers to comply with the regulation, particularly during the phase-in periods. Thus this methodology, which staff developed for screening purposed and to compare to the CARBITS results, is an overestimate of the actual impact. Staff also notes that this methodology does not take into account the effect of any desirable changes in vehicle attributes, such as a reduction in operating cost or more attractive environmental performance, that may be associated with the price increase.

11.3 Effects of Regulation on Vehicle Miles Traveled

The climate change regulation is designed to reduce emissions of greenhouse gases. As noted above, many of the technologies employed by manufacturers to reduce climate change emissions will, as an outgrowth, reduce the operating cost of the vehicle. All other factors being equal, economic theory suggests that people will drive more as operating costs decline. Thus a decrease in the cost of driving may lead to an increase vehicle miles traveled (VMT), lessening the greenhouse gas emission reductions associated with the climate change regulation as well as potentially increasing emissions of criteria pollutants relative to a baseline scenario. This section evaluates the possible impact of the draft proposed regulatory scenario with respect to increases in VMT due to reduced operating costs.

ARB staff has carried out two separate analyses of the effect of operating cost on vehicle miles traveled. The first incorporates the results to date of UC Irvine econometric studies, applying VMT increases to affected vehicles according to their ages in calendar years 2020 and 2030, then comparing these to a baseline case. The econometric analysis does not account for certain other factors that influence travel decisions, especially those related to the available transportation system in urban areas. The purpose of the second analysis is to estimate the change in travel demand when vehicle operating costs decline in the context of the transportation system in the South Coast Air Basin. The second analysis uses travel demand model outputs from the Southern California Association of Governments, comparing scenarios with changes in fuel cost assumptions to baseline cases in 2020 and 2030.

11.3.A Background

The phenomenon where measures designed to reduce the use of a product actually produce some incentives to increase its use is known as the "rebound effect". This effect has been studied in the context of energy efficiency, where, for example, more efficient air conditioners tend to be used more often. The economics literature also contains a number of studies of the effect of gasoline prices on driving, based on national data. The rebound effect associated with the cost of driving, however, is sensitive to household income and traffic conditions, and there are no California-specific studies of this effect. Staff does not believe that the national studies are necessarily representative of California. California has higher income and worse traffic conditions than other states, which would reduce the incentive for consumers to increase driving due to reduced operating costs. A few pennies of fuel savings per mile may not induce much driving in areas where people already drive all they need. If driving occurs in congested areas, the time cost of driving is high. It has been demonstrated that any cost savings must be quite large to compensate for the time cost. That is, people value their time highly enough that a few pennies in operating cost savings per mile is not going to encourage them to drive more.

To accurately reflect the rebound effect, if any, in emission calculations, myriad technical and analytical issues need to be addressed. The ARB and CEC commissioned a study by the University of California at Irvine (UCI). The purpose of the study is to evaluate the impact of reduced operating costs on vehicles miles traveled in California in response to a scenario consistent with the proposed regulation (i.e., increased prices for new vehicles with lower operating costs).

Most studies consider only the operating cost effects on VMT. They ignore the effects of increased initial cost of purchasing a vehicle. The increase in the purchase cost works in the opposite direction as the lower operating cost and can cancel additional driving. The results of the UCI study suggest that savings from reduced operating costs are directed towards the increased vehicle payments due to the higher vehicle price.

As noted above, the literature has addressed the "rebound effect" extensively, but the studies are generally national in scope and do not consider factors that are specific to California (e.g., very heavy traffic congestion and high personal income). Most studies attempt to explain VMT on the basis of a number of factors, including the fuel price per mile. These studies either use aggregate data or disaggregate data. Aggregate data are either in the form of pure time-series (one observation per year) or a combined cross-sectional and time series referred to as aggregate panel (e.g., one observation per state per year). Greene (1992) is a good example of an aggregate time series study. Using U.S. time series data for 1957-1989, Greene estimates the rebound effect to be between 5 and 15 percent for both the short-run and long-run, with a best estimate of 12.7 percent. He also finds some evidence that the rebound effect declines over time. Haughton and Sarkar (1996) provide an example of an aggregate panel study. This study uses both U.S. time series data from 1970-1991 and cross-sectional data for all of the 50 states plus the District of Columbia. They estimate a rebound effect of 16 percent in the short-run, and 22-23 percent in the long-run.

A number of recent studies have used disaggregate data to estimate the rebound effect. Disaggregate data are data on individuals, either in the form of a cross section of data in a single year or a panel covering multi-year observations on the same people. A review of the literature by Greene, Kahn, and Gibson (1999) finds that disaggregate studies show a wider range in their estimates of the rebound effect than aggregate studies. Estimates of the rebound effect from these studies range from zero to about 50 percent. Using disaggregate data, Goldberg (1998) finds a rebound effect of zero when accounting for simultaneity between the vehicle purchase and vehicle usage decision. Pickrell and Schimek (1999) estimate a rebound effect of 4 percent when controlling for ownership levels and hence for fuel efficiency. Using a series of large micro data sets covering six years from 1979 and 1994, Greene, Kahn, and Gibson (1999) find a long-run rebound effect of 23 percent, with a range of 17 percent for three-vehicle households to 28 percent for one-vehicle households.

The nationally-based literature thus offers an estimated range of zero to 50 percent for rebound effect. The UCI study found, however, that when California household income and transportation conditions are accounted for, the rebound estimate is very small. The study provided short-run and long-run estimates as well as a dynamic estimate which collectively considers the short-run (one year) and the long-run (two to four years) effects for a specific change in operating cost in a specific year. Table 11.3-1 reports the preliminary estimates of the rebound effect by UCI. They are subject to change and are stated in this draft report for illustrative purposes only. The table shows that if operating cost decreases by 25 percent in year 2009, VMT would increase by 0.17 percent (i.e., 25 X 0.0067) in 2009, 0.28 percent (i.e., 25 X 0.112) in 2010, and by 2020 the VMT will increase by 0.32 percent (i.e., 25 X 0.0127) in that year. These estimates are based on the model estimates which include income. Real income growth is assumed at 2 percent per year based on historical data, causing the short-run and long-run effects to diminish over the years. That is, operating costs become a smaller portion of the total income and any cost change becomes less significant with respect to driving decisions.

Table 11.3-1. Rebound Effect - Preliminary Estimates for California

Year	Income (2003$)	Short Run (%)	Long Run (%)	Dynamic (%)
2009	38,457	0.67	2.54	0.67
2010	39,077	0.62	2.35	1.12
2011	39,707	0.58	2.18	1.40
2012	40,349	0.53	2.02	1.56
2013	41,000	0.49	1.86	1.64
2014	41,661	0.46	1.72	1.66
2015	42,333	0.42	1.58	1.64
2016	43,015	0.39	1.45	1.59
2017	43,708	0.35	1.34	1.52
2018	44,414	0.32	1.23	1.44
2019	45,130	0.30	1.12	1.36
2020	45,857	0.27	1.03	1.27

The main concern for the rebound effect is its ability to reduce the intended effects of the climate change regulation. Increased driving would offset some of the greenhouse gas emission reductions. It also could offset some of the reductions in upstream criteria pollutant reductions because of the fuel savings effect of the regulation. To estimate the extent of the rebound effects on emissions, staff used ARB's EMFAC model.

11.3.B Analysis Using Econometric Study

As noted above, ARB has contracted with Dr. Kenneth Small at the University of California, Irvine (UC Irvine) to undertake a study of how changes in vehicle operating costs affect changes in travel. Dr. Small has developed initial values for the percent change in vehicle miles traveled (VMT) as a function of operating cost for California. The ARB staff used these initial findings to calculate that a potential 25 percent decrease in operating cost to the consumer would result in a 0.32 percent increase in VMT in 2020, and a 0.14 percent increase in VMT in 2030.

To examine the impact of the rebound effect on emissions, ARB staff ran the EMFAC model to reflect these adjustments to VMT. We used the EMFAC2002 mobile source emissions model, version 2.2 (April 2003), to estimate the emissions changes resulting from changes in travel brought about by the rebound effect. VMT in EMFAC is the product of vehicle population times accrual rate. The accrual rate is the miles traveled per year per vehicle for each vehicle class. Staff adjusted the accrual rates for model year 2009 and newer vehicles in the classes subject to the proposed regulation to reflect the rebound effect estimated by Dr. Small. The emissions from these runs were compared to baseline runs to assess the rebound impact. Results for the vehicle classes subject to the proposed regulation are shown in Table 11.3-2.

Table 11.3-2. Impacts of Rebound Effect, Total Light Duty Fleet ≤ 8500 lbs. GVWR[25] VMT and Emissions (tons per day)

	CY2020			CY2030		
	Baseline	**Adjusted**	**% Difference**	**Baseline**	**Adjusted**	**% Difference**
VMT[26]	1,020,478	1,022,778	0.23%	1,166,668	1,168,109	0.12%
ROG	230.95	230.90	-0.02%	155.95	155.91	-0.03%
NOx	190.20	190.49	0.15%	110.91	110.97	0.05%
PM10	42.74	42.86	0.28%	49.79	49.87	0.16%
CO	2096.98	2100.43	0.16%	1321.99	1323.45	0.11%
CO_2	485,150	486,210	0.22%	562,270	562,940	0.12%
CH_4	19.06	19.08	0.10%	13.48	13.49	0.07%

Again, this methodology assumes that all vehicles are modified in response to the regulation. Thus this approach will tend to overestimate the rebound impact.

11.3.C Analysis Using Travel Demand Model

The response of motorists to changes in vehicle operating cost occurs in the context of the transportation systems available to them. In California's urban areas, highway networks are often constrained by traffic congestion, which has bearing on decisions regarding when, where, how and even whether to travel. Many of the factors that affect these decisions are incorporated in travel demand models, which are the principal tools used by transportation planners to forecast travel activity within the limits of regional transportation systems.

Travel demand models contain a series of sequential calculations and iterative feedback loops through four principal steps: (1) the generation of person trips, (2) the distribution of trips among likely origins and destinations, (3) transportation mode choice, and (4) the assignment of vehicle trips to the transportation system. Among the variables considered in the mode choice step is the cost of motor vehicle operation, including the price of fuel. Because mode choice and travel time outputs are linked back to trip distribution, operating costs also affect the relative attractiveness of travel destinations and the miles driven to access goods and services. Fuel cost is one among the many variables affecting travel demand, and transportation modelers have found its impact to be relatively minor. Indeed the time cost involved with additional travel, especially in congested conditions, mitigates the travel-inducing effect of reduced operating cost.

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25 Gross vehicle weight rating
26 Vehicle miles traveled in thousands of miles

To examine the rebound effect in the context of urban travel demand, ARB worked with modeling staff at the Southern California Association of Governments (SCAG), who operate the travel demand model for the six-county region of southern California. Use of the SCAG model enabled staff to examine the emission impacts of changes in both the amount and the speed of motor vehicle travel, relative to the cost of gasoline per mile traveled. For purposes of this analysis, ARB staff used travel model outputs of vehicle miles of travel (VMT) and the distribution of speed by vehicle class for the South Coast Air Basin.[27]

For calendar years 2020 and 2030, SCAG staff ran the travel demand model for baseline cases that assume an automobile operating cost of 12.76 cents per mile in 1989 dollars. Automobile operating costs include gasoline at 8.14 cents per mile and maintenance costs at 4.62 cents per mile. SCAG staff then ran several separate scenarios for these years with varying decreases in the assumed cost of gasoline (maintenance costs were kept constant). Among the scenarios for 2020, a SCAG model run assumed a 17.3 percent reduction in gasoline cost. This figure represents a hypothetical 25 percent gasoline cost reduction applied to the 69 percent of light and medium duty VMT that will be driven in the (post-2008) vehicles subject to AB 1493 requirements in 2020. For 2030, when over 90 percent of miles will be driven in vehicles subject to proposed regulation's requirements, the alternative SCAG scenario assumed a full 25 percent reduction in fuel cost.

To estimate emissions, ARB staff applied the VMT and speed distribution outputs from these four SCAG model runs by vehicle class, through the scenario generator in EMFAC2002 (version 2.2, April 2003). EMFAC output was generated under each scenario for the South Coast Air Basin, annual average. Results for the light duty fleet affected by the proposed regulation are shown in Table 11.3-3.

[27] The SCAG travel models produce a distribution of VMT by speed for light and medium duty vehicles combined, and a separate distribution for heavy duty trucks. EMFAC2002 applies speed correction factors specific to vehicle class in its emissions calculation. Although heavy duty vehicles will not be directly affected by regulations established pursuant to AB 1493, their relative travel speed in urban areas, and thus their emissions, would be affected by additional light duty travel. Thus, a travel demand model analysis enables ARB staff to consider these broader emissions impacts.

Table 11.3-3. Impacts of Fuel Cost Reduction: Travel Demand Model Analysis South Coast Air Basin, Total Light Duty Fleet ≤8500 lbs. GVWR[28] VMT and Emissions (tons per day)

	CY2020			CY2030		
	Baseline	**Adjusted**	**% Difference**	**Baseline**	**Adjusted**	**% Difference**
VMTError! Bookmark not defined.	360,900	363,173	0.63%	382,373	385,840	0.91%
ROG	86.20	86.33	0.15%	55.84	55.92	0.14%
NOx	70.23	70.61	0.54%	37.65	37.97	0.85%
PM10	15.03	15.14	0.73%	16.23	16.40	1.05%
CO	772.35	776.70	0.56%	448.22	452.04	0.85%
CO_2	169,000	170,250	0.74%	181,280	183,280	1.10%
CH_4	6.97	7.04	1.00%	4.46	4.52	1.35%

Among vehicle classes affected by proposed regulation, the results from SCAG indicate an elasticity of VMT to fuel cost of about –0.04. Emissions impacts are minor, and vary from VMT impacts due to altered speed distributions and the emissions processes not tied to miles traveled.

In 2002, the Bay Area Metropolitan Transportation Commission (MTC) used its travel demand model to conduct a sensitivity test of the responsiveness of VMT to travel cost per mile, with similar results. In the MTC analysis the gasoline cost per mile was decreased by 25 percent in calendar year 2025. Daily VMT increased as a result by 0.66 percent, showing an elasticity of VMT to fuel cost of about –0.03.

11.4 Manufacturer Response

The economic impact analysis of the climate change regulation presented in section 9 provides conservative estimates. The results are conservative in that the analysis assumes that the compliance costs of the regulation will not change over time. It further assumes that the costs will be passed on to consumers in their entirety beginning the first year and continue on with no additional change due to innovation, no learning curve, and no distribution of costs to different vehicle classes or non-price methods of recovering costs.

Staff adopted this approach because there is a lack of quantitative information available to quantify the impact of the factors listed above. Nevertheless, there is ample evidence that automobile marketers use a variety of price and non-price tools in an effort to optimize sales. The purpose of this section is to provide a qualitative assessment of the options that are available to automobile

[28] Gross vehicle weight rating

manufacturers, and that they have used historically, to maintain sales while simultaneously complying with various regulatory requirements.

Staff reviewed consultant reports from ITS and the literature to assess the information available on these points. Staff believes, based on its review, that the increases in vehicle prices due to the regulation could well be less than the estimates provided in section 5 above. Staff's main findings with respect to strategies that automobile manufacturers may employ to comply with regulatory requirements are presented here and are discussed in more detail in the Technical Support Document to this report.

To comply with the climate change regulation, automobile manufacturers have a number of options. The option that they choose will depend on costs, sales strategy, market conditions, and consumer preferences. Whichever way they choose to respond, it is likely that the automobile manufacturers will employ methods that soften the impact of compliance costs on vehicle sales. They can use marketing tools and technology-based cost decreases over time to bring down the compliance costs to a fraction of what the consumer response analysis assumed. Manufacturers have complied in the past with regulations that increase vehicle production cost. Review of such cases helps to shed light on manufacture response. This section provides findings from a review of regulatory compliance costs in the automobile market over the past three decades.

The climate change regulations discussed in this draft staff proposal address automotive emissions. We therefore reviewed past compliance costs associated with emission control regulations. Because the industry response to other regulatory regimes may shed light on general trends, we also reviewed the response of automobile manufacturers and their customers to two other disparate cases of increased cost: the regulation of automotive safety and fuel consumption. We found that when put in a historical perspective, the economic impact analysis outlined in this draft can easily be characterized as a conservative scenario. Specifically, our historical review found that:

- Average, per-vehicle actual compliance costs are considerably higher in the initial years of regulatory implementation than in subsequent years. The cost of compliance tends to decline with passing years, due to the influence of economies of scale, learning curve effects and technological innovation. The cost of airbag systems, for example, dropped by 75 percent over the first 15 years of compliance.
- Automobile manufacturers do not typically pass along 100 percent of increased compliance costs as higher retail prices in the first year of compliance. One conservative estimate by an industry analyst indicates that automobile manufacturers absorb 100 percent of compliance cost increases in the first year, then pass along roughly two thirds of that cost in the following year, and the balance in later years.

- Automobile manufacturers do not recover the same proportion of compliance cost increases across all product lines. Instead, the relevant price increases focus on the vehicle classes and customers seen as least sensitive to such changes. Typically, higher price increases for popular and high-end models cross-subsidize lower price increases to "economy-class" models.
- Automobile manufacturers use methods other than price increases to recoup compliance cost increases, including changes in "standard" vehicle content and adjustments to incentive packaging and financing terms.
- If consumers regard compliance-related improvements as valuable, new vehicle sales may increase, despite increased prices. In the European Union, sales of diesel vehicles have doubled despite an average price that is $1567 higher than comparable gasoline-fueled vehicles.

These findings on the options available to manufacturers to comply with regulations help put the economic impact analysis into perspective. In short, the estimated impacts would likely be on the high side and furthermore do not consider the ongoing reductions due to further improvements.

11.5 Impact on Businesses in Low Income and Minority Communities

Businesses in low-income and minority communities (communities) in the State may be impacted by the proposed regulation. AB 1493 directs the Board to assess:

> "The ability of the State to maintain and attract businesses in the communities with the most significant exposure to air contaminants, localize air contaminants, or both, including, but not limited to, communities with minority populations, or low-income populations, or both."

In section 9 above staff presents its analysis of the direct effect of the regulation. Here staff again explores the use of new approaches to examine possible indirect impacts.

For the purposes of this analysis, communities in the San Diego area were used as a surrogate to characterize the potential impacts of the regulations on affiliated businesses in communities statewide. Specifically, communities as designated by the San Diego Air Quality Management District for environmental justice programs were selected as a surrogate to represent the impacts of the proposed climate change regulations on communities with minority population, or low-income population, or both across the State. San Diego County comprises 291 ZIP Code areas. Of these, 37 are designated by the San Diego Air Quality District as environmental justice communities. San Diego County is home to approximately 3 million Californians or about 8.3 percent of California's population in 2003[29]. The income distribution in the county roughly mirrors the income distribution for the entire State[30]. The potential economic impacts were assessed on businesses that are linked to automobiles, such as automobile dealers, gasoline stations, and automobile repair.

The reduction in operating cost due to the proposed regulation is expected to save consumers, including consumers in low income and minority communities, a significant amount of money. This analysis shows that the regulation may result in a reduction in employment growth in some businesses affiliated with the automobile industry, such as gasoline service stations. However, the potential reductions are likely to be more than offset by the creation of jobs elsewhere in unaffiliated (non-automotive) businesses, where consumers will spend their savings from the reduced operating costs of the new vehicles.

11.5.A Affiliated Businesses

Table 11.5-1 provides a list of the types of affiliated businesses used in this analysis. The businesses evaluated were selected as those determined to be most likely to be impacted due to their direct relationship with automobile sales, service, and operation.

Table 11.5-1. Socioeconomic Profile of Industries Affiliated with the Automobile Industry for the San Diego ZIP Codes Considered in our Analysis. (2003 Data)

SIC Code	Industry	Number of Businesses	Total Employment	Total Sales (million $)
5541	Gasoline service stations	293	1,964	287
5599	Automotive dealers	37	198	24
7537	Automobile transmission repair shops	91	342	23
7539	Automotive repair shops	342	1,431	114
7549	Automotive services	251	1,402	84
Total		**1,014**	**5,337**	**532**

Source: Dun and Bradstreet Marketplace Database, Dun and Bradstreet data were adjusted to reflect employment and sales data for all businesses.

Staff identified 1,014 businesses in communities in San Diego County that may be directly affected by the proposed climate change regulations. These businesses employ over 5,300 people and generate over $500 million in annual sales. These businesses, in aggregate, generate about $100,000 per employee as calculated by dividing total sales by total employment.

[29] California Statistical abstract, Department of Finance, 2003.
[30] 2000 Census Bureau, U.S. Department of Commerce.

To estimate the impacts of the regulation, changes in revenues caused by the proposed regulations for each affiliated industry were estimated. Then, profitability ratios published by Dun and Bradstreet[31] were used to estimate the impact on their profits. Sales-to-employment ratios were derived from the data, and used to estimate the impact on employment in each affected industry.

The affiliated business may experience some sales reduction because of vehicle price increases due to the proposed regulation. For purposes of this analysis staff used a price increase of $685 for 2014 and thereafter. This corresponds to roughly the average of the fully phased in estimated cost increases for PC/LDT1 and LDT 2 vehicles. This increase represents about 2.3 percent increase on an average new vehicle price of $25,000, which would reduce sales by 2.3 percent assuming a price elasticity of -1.0[32]. Staff chose the elasticity from literature reviews[33]. Further assumptions were made that new vehicles have 6 percent market penetration rate per year based on vehicle expected life of 16 years, and their operating cost declines by 25 percent. Because vehicle prices would increase, and people tend to maintain their cars more often in an attempt to retain the value of their car, staff assumed that the revenues of some of the affiliated business would increase such that the demand for automotive services and repairs increases by one percent.

11.5.B Potential Impacts on Affiliated Businesses

This section presents the estimated impact of the proposed regulation on the profitability of affiliated (automotive) businesses. As discussed below, staff expects that any negative impacts on affiliated businesses would be more than offset by positive impacts on the broader economy, due to increased purchasing power.

Using the assumptions noted above, staff estimated the impact on profitability of affiliated businesses. To provide a “maximum impact” estimate, this analysis assumes that the entire fleet is made up of regulated vehicles. Impacts in the initial years, as regulated vehicles enter into the fleet, would be less. As shown in Table 11.5-2, the impact on profitability would be the most severe on gasoline service stations. When regulated vehicles make up the entire fleet (which will not occur until 2020 and beyond) the affected service stations would experience an estimated decline of $72 million in revenues and $502,000 in profits as compared to the no regulation scenario. The profitability impact on other affiliated businesses would be negligible. No change is expected on the profitability of automotive dealers. That is because the loss in profit associated with a 2.3

[31] Industry Norms and Key Business Ratios, One Year desktop Edition, Dun and Bradstreet, 2003.

[32] See Klein, T.M., E. Hertz, and S. Borener (1991), A Collection of Recent Analyses of Vehicle Weight and Safety, Technical Report No. DOT HS 677, National Highway Traffic Safety Administration, Washington, DC.

[33] Paul S McCarthy, Market Price and Income Elasticities of New Vehicle Demands, The Review of Economics and Statistics, Vol. 78, No. 3 (August 1996), pp 543-547

percent loss of sales volume is estimated to be roughly equivalent to the increase in their profits associated with a 2.3 percent price increase.

Table 11.5-2. Impact on Profitability of Affiliated Businesses

Industry	Changes in Revenues	Profit as % of Revenues	Changes in Profitability
Service stations	($71,725,000)	0.7	($502,000)
Automotive dealers*	0	0.9	0
Automobile transmission repair shops	$227,000	4.3	$9,800
Automotive repair shops	$1,137,000	2.3	$26,100
Automotive services	$837,000	2.3	$19,300
Total	**($69,524,000)**		**($446,800)**

*Dealers' loss of sales volume was roughly compensated by the increase in vehicle prices.

11.5.C Potential Impact on Employment

This section discusses the potential impact on employment in affiliated businesses. It likewise provides a "maximum impact" analysis that assumes that the entire fleet consists of regulated vehicles. In addition, as noted below, any negative impacts are expected to be more than offset by gains in other sectors.

Table 11.5-3 provides ratios of revenue per employee and per business for affected businesses. For example, a typical service station in communities of San Diego County earns about $1 million in revenues annually or $146,000 per employee. On average, an affiliated business generated about $525,000 in revenues per year or about $100,000 per employee.

Table 11.5-3. Affiliated Businesses' Revenue Per Employee and Per Business in San Diego Communities

Industry	Revenue Per Employee	Revenue Per Business
Service stations	$146,000	$1,000,000
Automotive dealers	$123,000	$660,000
Automobile transmission repair shops	$66,000	$250,000
Automotive repair shops	$79,000	$330,000
Automotive services	$60,000	$330,000
Typical Business	**$100,000**[34]	**$525,000**[34]

Table 11.5-4 provides an assessment of the impact of the proposed regulations on jobs in affiliated businesses in communities in San Diego County. As shown in the table, when the entire fleet consists of regulated vehicles service stations

[34] Derived from the revenue and number of business data in Table 11.5-1.

are expected to have approximately 491 fewer jobs than in the no regulation scenario. This is not an actual loss of existing jobs, however, but rather a reduction from what the levels would otherwise in the future. This reduction is likely to be partially offset by the creation of 31 jobs in other affiliated businesses. In addition, the reduction in operating cost is expected to save consumers a significant amount of money. Depending upon where the consumers direct their expenditures, many unaffiliated businesses such as food service, wholesale trade, etc. will benefit from the proposed regulations, as discussed in section 9.

Staff believes that the numbers of jobs created by these unaffiliated businesses will significantly exceed the number of new jobs foregone at service stations. San Diego County has a population of 3,017,200 (8.3 percent of the state) according to California Department of Finance. To estimate the job gains in communities in San Diego, the 42,000 increased statewide jobs from the regulation, as estimated in section 9, can be apportioned to San Diego based on population. The communities have a population of about 2 million, or two-thirds of the total. Apportioning the total to these communities would mean a gain of 3,150 jobs. This more than outweighs the reduction of 460 in these communities and results in 2,690 new jobs created because of the proposed climate change regulation.

Table 11.5-4. Net Impact of the Proposed Regulations on Jobs and Affiliated Businesses In San Diego Communities

Industry	Number of Jobs Relative to No Regulation)	Business Creation (Elimination) Relative to No Regulation
Service stations	(491)	(72)
Automotive dealers	0	0
Automobile transmission repair shops	3	1
Automotive repair shops	14	3
Automotive services	14	3
Impact on affiliated businesses	(460)	(65)
Impact on other businesses	3,150	511
Net Impact	**2,690**	**446**

11.5.D Potential Impact on Business Creation, Expansion and Elimination

As shown in Table 11.5-4, the proposed regulations, when fully embodied in the fleet, are estimated to result in the equivalent of 72 fewer service stations in communities of San Diego County than under the no regulation scenario. Seven affiliated businesses, however, will be created. The proposed regulations are also expected to result in the creation or expansion of 511 unaffiliated equivalent businesses, depending upon where the consumers redirect their savings from the reduction in operating cost. Overall, the number of businesses created or expanded is expected to exceed the number of businesses eliminated by 446.

11.6 Summary and Conclusions

The economic impact analysis presented in section 9 considers vehicle price increases and operating cost decreases resulting from the climate change regulation. The economic impact analysis is based on the staff assessment that the lower vehicle operating cost resulting from the regulation will be sufficiently attractive to new car buyers to compensate for the vehicle price increase, and results in vehicle sales that are unchanged from the levels that would have been the case without the regulation.

In this section, staff assessed what the consequences would be if one assumes that the changes in vehicle attributes do affect sales. Staff analyzed the potential effect of price and operating cost changes on sales, fleet size, and fleet age using a consumer choice model, CARBITS, developed by University of California, Davis. The results show that the net result of increased new vehicle prices and lower operating costs is a tendency to increase sales in the near term, and slightly decrease sales in the longer term as the more stringent second step of the regulation is fully phased in. This effect had no significant impact on criteria pollutant emissions.

We also evaluated potential adverse environmental impacts associated with increased VMT due to lower operating costs. Our analysis indicates that the benefits of reduced climate change emission from the regulation will not be negated significantly by any increase in driving that lower operating costs may induce.

Automotive related businesses in communities with low income and minority households may be impacted and some future growth in those areas may be foregone. An increase in the overall economic activity because of lowered operating costs of vehicles would, however, be expected to create sufficient number of jobs to more than offset any reductions.

Staff concludes that the standard economic analysis presented in section 9 is a conservative one that errs on the side of overestimating the cost impacts of the regulation. We have also made an effort to apply additional tools in our analysis as discussed in this section. Though these tools are continuing to be further developed, they are valuable in providing further insight with respect to the proposed regulation. Specifically, considering other issues such as the impact of the regulation on vehicle sales via a consumer choice model as well as the rebound effect also suggests that the regulation would be expected to have an insignificant impact on the California economy and the consumer. Minority and low-income communities are expected to benefit from the operating cost savings that will be redirected to non-affiliated businesses. Generally, the economic impacts of the proposed climate change regulation tend to be positive.

Staff will continue to refine these approaches and will consider public comment received before issuing the final staff report.

LIST OF ACRONYMS AND ABBREVIATIONS

A4:	4-speed automatic transmission
A5:	5-speed automatic transmission
A6:	6-speed automatic transmission
AB 1493:	Assembly Bill 1493
AdvHEV:	Advanced hybrid
ARB:	California Air Resources Board
AMT:	Automated Manual Transmission
CCP:	Coupled cam phasing
CH_4:	Methane
CNG:	Compressed natural gas
CO_2:	Carbon dioxide
CVVL:	Continuous variable valve lift
CVT:	Continuously variable transmission
DCP:	Dual cam phasing
DeAct:	Cylinder deactivation
dHCCI	Diesel homogeneous charge compression ignition
DMV:	California Department of Motor Vehicles
DOHC:	Dual overhead cam
DVVL:	Discrete variable valve lift
DVVLd:	Discrete variable valve lift, includes dual cam phasing
DVVLi:	Discrete variable valve lift, includes intake valve cam phasing
eACC:	Improved electric accessories
EAT:	Electronically assisted turbocharging
EGR:	Exhaust gas recirculation
ehCVA:	Electrohydraulic camless valve actuation
emCVA:	Electromagnetic camless valve actuation
EHPS:	Electrohydraulic power steering
EPS:	Electric power steering
EMFAC:	ARB Emission Factors model (EMFAC2002 v.2.2 April 23, 2003)
EWP:	Electric water pump
FDC:	Fixed displacement compressor
FWD:	Front-wheel drive
GDI-S:	Stoichiometric gasoline direct injection
GDI-L:	Lean-burn gasoline direct injection
gHCCI	Gasoline homogeneous charge compression ignition
GVWR:	Gross vehicle weight rating
GWP:	Global warming potential
HC:	Hydrocarbons
HEV:	Hybrid-electric vehicle
HFC:	Hydrofluorocarbon
hp:	Horsepower
HSDI:	High-speed (diesel) direct injection
ICP:	Intake cam phaser
ImpAlt.	Improved efficiency alternator

ISG: Integrated starter-generator system
ISG-SS: Integrated starter-generator system with start-stop operation
L4: In-line four-cylinder
MAC: Mobile Air Conditioning
ModHEV: Moderate hybrid
NMOG: Non-methane organic gas
N_2O: Nitrous oxide
NO_x: Oxides of nitrogen
R-134a: Refrigerant 134a, tetrafluoroethane ($C_2H_2F_4$)
R-152a: Refrigerant 152a, difluoroethane ($C_2H_4F_2$)
RPE: Retail price equivalent
TRR: Tire rolling resistance
Turbo: Turbocharging
V6: Vee-formation six-cylinder
V8: Vee-formation eight-cylinder
VDC: Variable displacement compressor
4WD: Four-wheel-drive
42V ISG: 42-volt integrated starter-generator system

REFERENCES

Anderman, M., F.R. Kalhammer, and D. MacArther, 2000. Advanced Batteries for Electric Vehicles: An Assessment of Performance, Cost, and Availability, 2000.

Ballantyne, V.F., Howes, P., and Stephanson, L. Nitrous oxide emissions from light-duty vehicles. Society of Automotive Engineers (SAE) Paper No. 940304, 1994.

Barton, P., and Simpson, J. The effects of aged catalysts and cold ambient temperatures on nitrous oxide emissions. Mobile sources emissions division (MSED). Environment Canada, MSED Report #94-21, 1994.

Behrentz, E., Ling, R., Rieger, P., and Winer, A.M. Measurements of nitrous oxide emissions from light-duty motor vehicles: a pilot study. Submitted to Journal of Atmospheric Environment, April 2004.

Bernard, S.M., et al. The potential impacts of climate variability and change on air pollution-related health effects in the United States. Environ Health Perspect 109 Suppl 2: 199-209, 2001.

Bureau of Labor Statistics, 2004. "Consumer Price Index for All Urban Consumers: All Items." Updated February 20, 2004. http://research.stlouisfed.org/fred2/data/ CPIAUCNS.txt. Accessed March 1, 2004.

California Department of Water Resources, Division of Flood Management, California Cooperative Snow Surveys, 1929-present. Posted at: cdec.water.ca.gov/snow.

California Energy Commission (CEC). Inventory of California Greenhouse Gas Emissions and Sinks: 1990-1999 STAFF REPORT Publication Numbers: 600-02-001F & 600-02-001F-ES, November 2002. Available at: http://www.energy.ca.gov/reports/600-02-001F.

California Energy Commission (CEC), 2003. *Integrated Energy Policy Report.*

California Energy Commission (CEC), 2004. Fuels Division. Personal Communication

Clodic, Harnisch, Schwarz, 2003. "Refrigerant Emissions Along The Mac System Lifetime." Mobile Air Conditioning Summit, Brussels.

Dasch, J.M. Nitrous oxide emissions from vehicles. J. Air and Waste Management Association **42** (1):63-67, 1992.

Department of Energy (DOE). *Emissions of Greenhouse Gases in the United States 2001*. Office of Integrated Analysis and Forecasting U.S. Department of Energy, Washington, DC 20585. DOE/EIA-0573(2001/ES), 2003. Available at: www.eia.doe.gov/oiaf/1605/ggrpt/summary/index.html

Electric Power Research Institute (EPRI), 2001. Comparing the Benefits and Impacts of Hybrid Electric Vehicle Options. Palo Alto, CA: 2001 1000349.

Environmental Protection Agency (EPA). 2004. Progress Report on Clean and Efficient Automotive Technologies Under Development and EPA: Interim Report . Report EPA420-04-002. January.

Environmental Protection Agency (EPA). 2003. Light-Duty Automotive Technology and Fuel Economy Trends: 1975 Through 2003. http://www.epa.gov/otaq/fetrends.htm. Report EPA420-R-03-006. Washington, D.C. April.

Federal Reserve Statistical Release (FRSR), 2004. "G.19: Consumer Credit." Updated February 6, 2004. http://www.federalreserve.gov/releases/g19/hist/cc_hist_tc.html. Accessed March 1.

Fischer, P.H., Brunekreef, B., and Lebret, E. Air pollution related deaths during the 2003 heat wave in the Netherlands. Atmospheric Environment **38**: 1083-1085, 2004.

Forrest, W.O. and M.S. Bhatti, 2002. "Energy Efficient Automotive Air Conditioning System", Society of Automotive Engineers 2002-01-0229.

EMFAC, 2003. Version 2.2, Updated April 23, 2002.

Gleick, P.H., and Chalecki, E.L. "The Impact of Climatic Changes for Water Resources of the Colorado and Sacramento-San Joaquin River Systems," *Journal of the American Water Resources Association*, **35** (6): 429-1441, 1999.

Graham, N.E. Decadal-scale climate variability in the tropical and North Pacific during the 1970s and 1980s: Observations and model results. Climate Dynamics **10**: 135-162, 1994.

Harvell, C.D., Kim, K., Burkholder, J.M., Colwell, R.R., Epstein, P.R., Grimes, D.J., Hofmann, E.E., Lipp, E.K., Osterhaus, A.D., Overstreet, R.M., et al. Emerging marine diseases--climate links and anthropogenic factors. Science 285:1505-1510 (1999).

Intergovernmental Panel on Climate Change (IPPC), 2001. Climate Change 2001: The Scientific Basis. Working Group I of the IPCC, World Meteorological

Organization-U.N. Environment Program, Geneva, Switzerland. Available at: www.ipcc.ch.

Intergovernmental Panel on Climate Change. (IPCC), 2001. Third Assessment Report of the Intergovernmental Panel on Climate Change.

Johnson,V.H., 2002. "Fuel Used for Vehicle Air Conditioning: A State-by-State Thermal Comfort-Based Approach," Society of Automotive Engineers 2002-01-1957.

Kinney, P., and Ozkaynak, H. Associations of daily mortality and air pollution in Los Angeles County. *Environmental Research* **54:** 99–120, 1991.

Lettenmaier, D.P. and Sheer, D.P. Climatic Sensitivity of California Water Resources, Journal of Water Resources Planning and Management, **117** (1): 108-125, 1991.

Meszler Engineering Services, 2004. Light-Duty Vehicle Air Conditioning – Greenhouse Gas Impacts and Potential for Reduction, Draft report, prepared for Northeast States Center for a Clean Air Future.

Metz, N. Contribution of Passenger Cars and Trucks to CO_2, CH_4, N_2O, CFC, and HFC Emissions. *Soc. Automot. Eng.* 2001, *No. 2001-0103758*.

Michaels, H., Fulper, C., Kolowich, B. Nitrous oxide emission factors for mobile sources. Presented at the AWMA emission inventory conference, New Orleans, LA, 1998.

Miller, N. L., Bashford, K. E., and Strem, E. Climate Change Sensitivity Study of California Hydrology. A report to the California Energy Commission, LBNL Technical Report No. 49110, Berkeley, CA, November, 2001.

NACIP, National Aerosol-Climate Interactions Program. Available at: http://www-NACIP.ucsd.edu/NACIPWhitePaperMay2102.pdf , 2002.

Nam, E. K., Jensen, T. E., and Wallington, T. J. "Methane Emissions from Vehicles". Environ. Sci. Technol.; 2004; DOI: 10.1021/es034837g.

National Assessment Synthesis Team (NAST), 2001. *Climate Change Impacts on the United States.* Report for the United States Global Change Research Program. Cambridge University http://prod.gcrio.org/nationalassessment

National Research Council (NRC), Committee on Abrupt Climate Change, 2002. *Abrupt Climate Change: Inevitable Surprises*, National Academy Press, Washington, DC. Available at: http://www.nap.edu/catalog/10136.html

National Research Council (NRC), 2001. *Climate Change Science: An Analysis of Some Key Questions*. National Academy Press, Washington, DC. Available at: www.nap.edu.

Northeast States Center for a Clean Air Future (NESCCAF), 2004. Reducing Greenhouse Gases from Light-Duty Vehicles. Interim Report. http://bronze.nescaum.org/committees/mobile/rpt040316ghglightduty.pdf. Accessed March 15.

Office of Environmental Health Hazard Assessment. Environmental Protection Indicators for California (EPIC). Available at: http://oehha.ca.gov/multimedia/epic/index.html.

Patz, J.A., McGeehin, M.A., Bernard, S.M., Ebi, K.L., Epstein, P.R., Grambsch, A., Gubler, D.J., Reiter, P., Romieu, I., Rose, J.B., Samet, J.M., and Trtanj, J. The Potential Health Impacts of Climate Variability and Change for the United States: Executive Summary of the Report of the Health Sector of the U.S. National Assessment, Environmental Health Perspectives, Volume 108, Number 4, April 2000. Available at: http://ehis.niehs.nih.gov/topic/global/patzfull.htm.

Pavley, 2002. Assembly Bill No. 1493. Vehicular emissions: greenhouse gases. An act to amend Section 42823 of, and to add Section 43018.5 to, the California Health and Safety Code, relating to air quality.

Roos, M. The Effects of Global Climate Change on California Water Resources, A report to the California Energy Commission's Public Interest Energy Research Program (PIER), Sacramento, September 2002.

Rugh, J. and V. Hovland, "National and World Fuel Savings and CO2 Emission Reductions by Increasing Vehicle Air Conditioning COP." Presented at the SAE Alternate Refrigerants Symposium, Phoenix, Arizona, July 15-17, 2003

SB 1771 (Senator Sher, Chapter 1018, Statues of 2000). Greenhouse gas emission reductions: climate change, 2000.

Schwartz, P., and Randall, D. An Abrupt Climate Change Scenario and Its Implications for United States National Security. A report commissioned by the U.S. Defense Department, October 2003. Available at: http://www.fas.org/irp/agency/dod/schwartz.pdf

Schultz, M.G., Diehl, T., Brasseur, G.P., and Zittel W. Air pollution and climate-forcing impacts of a global hydrogen economy. Science, **302,** 624-627, 2003

Semenza, J.C., Rubin, C.H., and Falter, K.H. Heat-related deaths during the July 1995 heat wave in Chicago. N Engl J Med **335**: 84-90, 1996.

Semenza, J.C., McCullough, J., Flanders, D.W., McGeehin, M.A., and Lumpkin, J.R. Excess hospital admissions during the 1995 heat wave in Chicago. Am J Prev Med **16**: 269-277, 1999.

Stedman, J.R. The predicted number of air pollution related deaths in the UK during the August 2003 heatwave. Atmospheric Environment **38:** 1087-1090, 2004.

Trenberth, K.E., and Hoar, T.J. The 1990-1995 El Niño-Southern oscillation event: longest on record. Geophysical Research Letters **23**: 57-60, 1996.

Unnasch, Stefan, 2004. TIAX LLC. Personal communication. March.

Vyas, A., D. Santini, R. Cuenca, 2000. "Comparison of Indirect Cost Multipliers for Vehicle Manufacturing: Technical Memorandum in Support of Electric and Hybrid Vehicle Cost Estimation." Argonne National Laboratory, U.S. Department of Energy. April.

Wilkinson, R., and Rounds, T. Climate Change and Variability in California; White Paper for the California Regional Assessment. National Center for Ecological Analysis and Synthesis, Santa Barbara, California Research Paper No. 4, 1998. Available at http://www.nceas.ucsb.edu/papers/climate.pdf .

Wilkinson, R. Preparing for a Changing Climate: The potential consequences of climate variability and change – California, A report of the California Regional Assessment Group for the U.S. Global Change Research Program, Santa Barbara, CA, 2002.
..\..\2002GW\Final\AB_1493_(Pavley).ppt - 554,13,Slide 13
Zittel, W., and Altmann, M. in Proceedings of the 11th World Hydrogen Energy Conference, Stuttgart, Germany, June 1996 (Scho¨n & Wetzel, Frankfurt am Main, Germany, 1996), pp. 71–82.