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BEFORE THE
STATE OF CALIFORNIA
AIR RESOURCES BOARD

ENVIRONMENTAL AND ECONOMIC IMPACTS OF THE ARB STAFF PROPOSAL TO CONTROL GREENHOUSE GAS EMISSIONS FROM MOTOR VEHICLES

NERA ECONOMIC CONSULTING
AND
SIERRA RESEARCH, INC.

Prepared for

Alliance of Automobile Manufacturers

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Executive Summary

This study evaluates the economic and emissions impacts associated with proposed California regulations to control greenhouse gas emissions from motor vehicles. These proposed regulations ("Staff Greenhouse Gas Proposal") are described in an August 6, 2004 Initial Statement of Reasons ("August Staff Report") and a September 10, 2004 Addendum ("September Staff Addendum") The proposed regulations establish a set of greenhouse gas emission standards to implement AB 1493 (Pavley bill), which was passed by the legislature and signed by the Governor in 2002.

A. Background

The Staff Greenhouse Gas Proposal is contained in the August Staff Report. The proposed standards are expressed as model year fleet average emissions requirements for two categories of vehicles—a passenger car/light duty truck 1 ("PC/LDT1") category and a light-duty truck 2 ("LDT2") category—and set for a "near-term" period (2009 to 2012) and a "mid-term" period (2013 to 2016). The PC/LDT1 standard, expressed as a CO_2-equivalent emission standard, declines from 323 grams per mile in 2009 to 205 grams per mile in 2016; the equivalent LDT2 standard declines from 439 grams per mile in 2009 to 332 grams per mile in 2016. The September Staff Addendum alters the Staff's estimates of the underlying costs of the standards, but the Staff Greenhouse Gas Proposal is unchanged.

B. Objectives of This Study

This study develops a set of models that evaluate the effects of the Staff Greenhouse Gas Proposal on motor vehicle markets, consumer welfare, emissions, and the California economy. The models begin with detailed assessments of CO_2-reducing technologies that could be applied to various types of motor vehicles. These assessments result in estimates of the costs and effectiveness of CO_2-reducing technologies that differ from those developed by ARB Staff and reported in the September Staff Report. The set of estimates used in this study reflect our independent judgment about the feasibility, timing and effectiveness of various technologies. Because ARB Staff estimated the cost of the regulation based on the assumption that fuel economy technologies would be deployed on a nationwide basis, we have done so here as well.

However, it must be stressed that this approach understates the per vehicle costs that would be incurred if California-specific sales volumes were used. Given the limited amount of time available to respond to the proposed regulations, we were unable to assess the impact of the regulations if technologies were deployed only in California.

Specifically, this report develops estimates of the effects of the Staff Greenhouse Gas Proposal in five areas:

1. *Motor vehicle market effects.* These effects include the effects of the Staff Greenhouse Gas Proposal on the characteristics of new vehicles sold in California as well as related changes in the stock of vehicles and vehicle miles traveled.

2. *Emissions effects.* These are changes in emissions of Reactive Organic Gases (ROG), Oxides of Nitrogen (NO_x), Carbon Monoxide (CO) and Particulate Matter (PM_{10}) in California.

3. *Consumer welfare effects.* These effects measure the effects of the Staff Greenhouse Gas Proposal on the welfare of California households as a result of the vehicle market effects.

4. *State economic effects.* These effects include effects on the California economy, including employment, Gross Regional Product ("GRP"), and disposable personal income.

5. *State revenue effects.* These effects include effects on California state revenues, including sales tax revenues and income tax revenues.

The major results of our analyses are based on NERA/Sierra inputs regarding the initial costs and fuel efficiency effects of the Staff Greenhouse Gas Proposal. For fleet effects and emissions, we consider three other scenarios based upon the use of ARB staff inputs and the use of the fleet population model used by the ARB staff ("CARBITS"). Thus, a total of four scenarios were modeled for motor vehicle market and emissions effects:

- Scenario 1: NERA/Sierra inputs and NERA/Sierra modeling.
- Scenario 2: ARB Staff inputs and NERA/Sierra modeling.
- Scenario 3: NERA/Sierra inputs and CARBITS modeling.
- Scenario 4: ARB Staff inputs and CARBITS modeling.

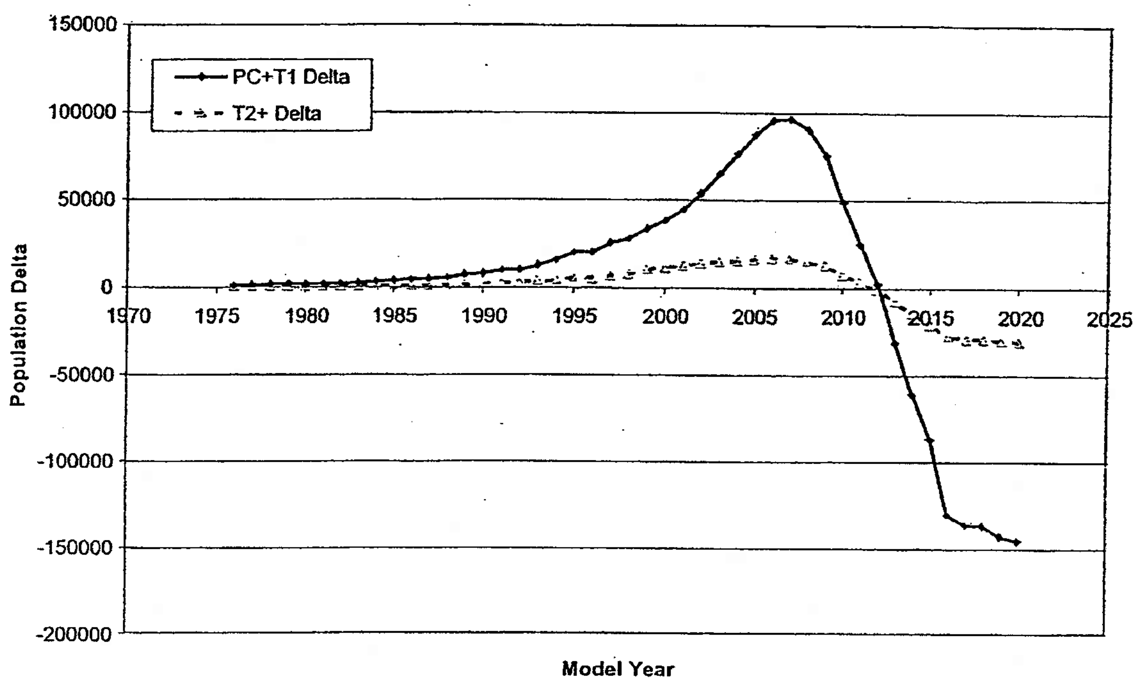
Results for consumer surplus, economic impacts and state revenue impacts are based upon Scenario 1.

C. Results of This Study

1. Motor Vehicle Market Effects

Figure ES-1 summarizes the effects on the vehicle market in 2020 based upon NERA/Sierra inputs and the NERA/Sierra modeling (Scenario 1) of the Staff Greenhouse Gas Proposal. The figure shows the changes in vehicle population relative to the baseline conditions (i.e., the projected vehicle population in 2020 without the effects of the Staff Greenhouse Gas Proposal). Separate results are provided for the PC/LDT1 and LDT2 categories. The Staff Greenhouse Gas Proposal has the effect of changing the age distribution of the vehicle population in both categories. In 2020, the numbers of motor vehicles in older vintages—those produced before 2012—are greater and the numbers of motor vehicles in more recent vintages—those produced after 2012—are smaller as a result of the Staff Greenhouse Gas Proposal. In 2020, new vehicle sales of PC/LDT1's and LDT2's combined are about 176,000 lower as a result of the Staff Greenhouse Gas Proposal. In contrast, the number of vehicles in the fleet with model years before the regulations would take effect (i.e., pre-2009 model year vehicles) is more than 1 million greater in 2020 as a result of the Staff Greenhouse Gas Proposal.

Figure ES-1. Change in Statewide 2020 Vehicle Population Estimates as a Result of the Staff Greenhouse Gas Proposal Using the NERA/Sierra Population Model with NERA/Sierra Input Assumptions (Scenario 1)



The table below summarizes motor vehicle market results in 2020 under all four scenarios. The table shows the *decrease* in new vehicle *sales* in 2020 along with the *increase* in the number of pre-2009 vehicles in the 2020 *fleet*. Thus, this table provides one summary of the shift in the age distribution of the vehicle stock in 2020 as a result of the Staff Greenhouse Gas Proposal, as predicted under the four different scenarios. The effects are broadly similar under all of the scenarios—the number of new vehicles sold in 2020 would be reduced and the number of pre-2009 vehicles in the 2020 fleet would be increased—although the magnitudes are different. The estimated number of reduced new vehicle sales in 2020 ranges from about 53,000 to more than 300,000. The estimated number of increased pre-2009 vehicles in 2020 ranges from about 64,000 motor vehicles to more than 1 million motor vehicles.

Table ES-1. Summary of the Changes in Statewide 2020 Vehicle Population Estimates as a Result of the Staff Greenhouse Gas Proposal

Scenario	New Vehicle Sales in 2020	Pre-2009 Vehicles in 2020 Stock
NERA/Sierra methodology with NERA/Sierra inputs	-176,176	1,068,444
NERA/Sierra methodology with ARB Staff inputs	-50,916	388,634
CARBITS methodology with NERA/Sierra inputs	-309,243	905,371
CARBITS methodology with ARB Staff inputs	-72,472	64,244

2. Emissions Effects

Figure ES-2 shows the effects on emissions of two criteria pollutants as a result of the Staff Greenhouse Gas Proposal. Table ES-2 shows results for all four criteria pollutants over the period from 2009 to 2030. These results are based upon the NERA/Sierra inputs and NERA/Sierra methodology (Scenario 1). In 2020, the Staff Greenhouse Gas Proposal is projected to increase ozone precursor emissions (ROG plus NO_X) by about 30.4 tons per day in California.

Figure ES-2. Statewide ROG + NO_X Emissions Increases as a Result of the Staff Greenhouse Gas Proposal Using the NERA/Sierra Model with NERA/Sierra Input Assumptions (Scenario 1)

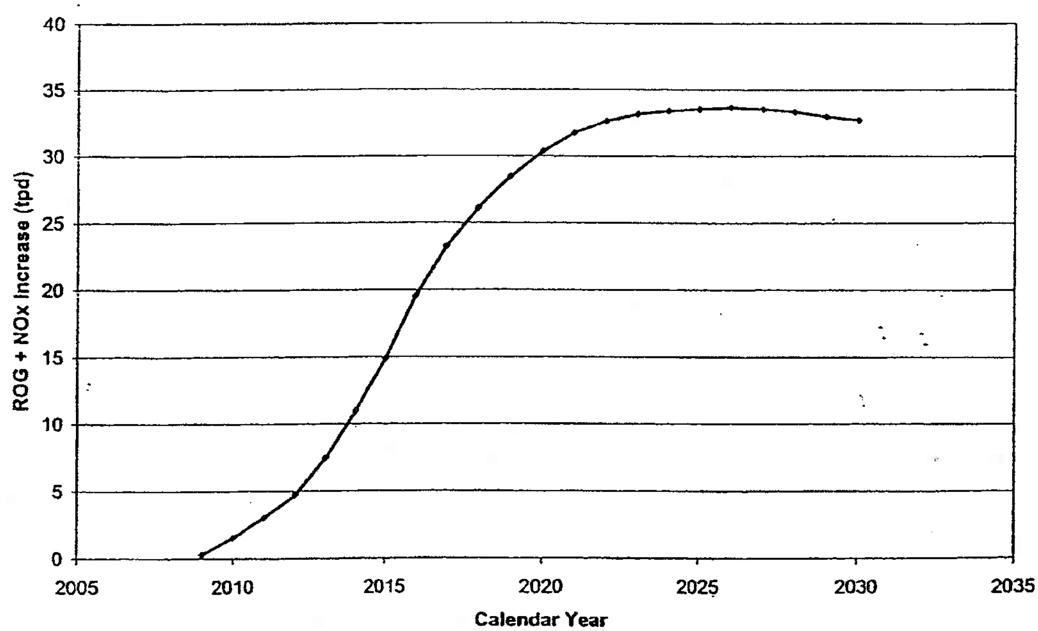


Table ES-2. Statewide Emissions Impacts of the Staff Greenhouse Gas Proposal Using the NERA/Sierra Model with NERA/Sierra Input Assumptions (Scenario 1)

Year	Criteria Pollutant Increases, Accounting for Turnover and Rebound (tons per day)			
	ROG	NOx	CO	PM_{10}
2009	0.18	0.16	1.67	0.01
2010	0.80	0.76	7.87	0.05
2011	1.58	1.49	15.68	0.10
2012	2.44	2.29	24.37	0.16
2013	3.88	3.60	38.69	0.26
2014	5.74	5.22	56.62	0.39
2015	7.89	7.01	76.52	0.56
2016	10.49	9.06	99.67	0.79
2017	12.64	10.62	117.38	1.00
2018	14.37	11.76	130.29	1.20
2019	15.87	12.61	139.99	1.40
2020	17.16	13.23	146.95	1.58
2021	18.18	13.59	150.98	1.77
2022	18.91	13.73	151.48	1.94
2023	19.44	13.73	150.38	2.09
2024	19.77	13.64	148.62	2.24
2025	20.04	13.50	146.77	2.38
2026	20.28	13.38	145.36	2.54
2027	20.37	13.16	142.64	2.67
2028	20.42	12.91	139.72	2.79
2029	20.37	12.59	136.02	2.90
2030	20.41	12.30	133.33	3.00

Table ES-3 summarizes the emissions effects in 2020 under all four scenarios. All four scenarios would lead to increases in criteria pollutants in 2020. For the ozone precursor emissions, the increases range from about 6.3 tons per day to about 44.7 tons per day.

Table ES-3. Summary of the Statewide 2020 Emissions Impacts of the Staff Greenhouse Gas Proposal

Scenarios	Criteria Pollutant Increases, Accounting for Turnover and Rebound (tons per day)			
	ROG	NO_X	CO	PM_{10}
NERA/Sierra methodology with NERA/Sierra inputs	17.16	13.23	146.95	1.58
NERA/Sierra methodology with ARB Staff inputs	5.56	4.36	46.55	0.50
CARBITS methodology with NERA/Sierra inputs	25.23	19.44	202.25	1.95
CARBITS methodology with ARB Staff inputs	3.56	2.77	29.45	0.41

Under the Staff Greenhouse Gas Proposal, the criteria pollutant increases reported above would be partially offset by a reduction of "upstream" emissions associated with the distribution and marketing of gasoline resulting from reduced gasoline consumption. Table ES-4 summarizes the emissions effects in 2020 under all four scenarios after taking into account the effects of reduced gasoline consumption. Reduced gasoline consumption has an insubstantial effect on all of the criteria pollutants except ROG. After taking into account the estimated change in gasoline consumption calculated using the same method employed by ARB, the estimates of the change in 2020 emissions in California of the ozone precursors ranges from about 2.3 tons per day to about 41.2 tons per day.

Table ES-4. Summary of the Statewide 2020 Emissions Impacts of the Staff Greenhouse Gas Proposal, Including the Effects of Reduced Gasoline Consumption

	Criteria Pollutant Increases, Accounting for Turnover, Rebound, and Reduced Gasoline Consumption (tons per day)			
Scenarios	**ROG**	**NO_x**	**CO**	**PM_{10}**
NERA/Sierra methodology with NERA/Sierra inputs	14.86	12.93	146.75	1.56
NERA/Sierra methodology with ARB Staff inputs	1.86	4.06	46.25	0.48
CARBITS methodology with NERA/Sierra inputs	22.03	19.14	202.05	1.93
CARBITS methodology with ARB Staff inputs	-.14	2.47	29.15	0.39

3. Consumer Welfare Effects

Table ES-5 summarizes the effects of the Staff Greenhouse Gas Proposal on consumer welfare in California, as measured by the change in consumer surplus of vehicle purchasers in the State. The values measure the reductions experienced by new motor vehicle purchasers as a result of increased vehicle prices and fuel efficiency. In 2016, California motor vehicle purchasers would experience a welfare loss of more than $4 billion dollars. (All values are in 2003 dollars.) The cumulative welfare loss over the period from 2009 to 2016 would be more than $12.8 billion.

Table ES-5. Effects of Staff Greenhouse Gas Proposal on Consumer Welfare

	Welfare Loss (Millions of $2003)	
Year	**Annual**	**Cumulative**
2009	-100	-100
2010	-469	-568
2011	-647	-1,215
2012	-830	-2,046
2013	-1,539	-3,585
2014	-2,251	-5,836
2015	-2,967	-8,803
2016	-4,013	-12,816

The results presented in the table take into account the effects on consumer welfare of increased prices, increased fuel efficiency, reduced sales, and changes to the mix of vehicles sold as a result of the Greenhouse Gas proposal. Because the New Vehicle Market Model is based on aggregated "trim level" information for each model, however, the consumer welfare calculation presented here omits one additional effect that is likely to reduce consumer welfare still further. The omitted loss is due to the possibility that some or all manufacturers may choose not to offer certain vehicles in California as a result of the regulation. Although the New Vehicle Market Model calculates the effects of reductions in sales for a given model aggregating over all trim levels, it does not account, for example, for the effects of *eliminating* certain trim levels from a manufacturer's offerings. Such a reduction in the variety of vehicles made available to consumers could contribute an additional loss in consumer welfare that is not included in the calculations presented here.

4. Economic Impacts

The economic impacts of the Staff Greenhouse Gas Proposal were estimated using a detailed economic model developed by Regional Economic Models, Inc. ("REMI"). As noted, the cost estimates are based upon the assumption that motor vehicle manufacturers adopt technology plans for their entire United States production and thus the values understate the per vehicle costs that would be incurred if these same technologies were developed for California sales volumes.

Table ES-6 summarizes the impacts of the Staff Greenhouse Gas Proposal on the California economy. The table shows both the annual changes in the economy and the cumulative effect over time in these impacts. By 2016, the Staff Greenhouse Gas Proposal would lead to almost 100,000 fewer jobs in California. The cumulative effects mean that over the period from 2009 to 2016, more than 300,000 person-years of employment would be lost. The California Gross Regional Product ("GRP") would be reduced by roughly $11.5 billion in 2016, with a cumulative loss from 2009 to 2016 of more than $36 billion. Disposable personal income losses are similar; in 2016, the annual loss is $8 billion with a cumulative total of almost $26 billion.

Table ES-6. Summary of Impacts of the Staff Greenhouse Gas Proposal on the California Economy

	Employment		Gross Regional Product (Millions of $2003)		Disposable Personal Income (Millions of $2003)	
Year	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
2009	-7,570	-7,570	-732	-732	-425	-425
2010	-25,450	-33,020	-2,552	-3,284	-1,535	-1,960
2011	-18,430	-51,450	-1,957	-5,241	-1,372	-3,332
2012	-13,340	-64,790	-1,540	-6,781	-1,308	-4,640
2013	-47,500	-112,290	-5,253	-12,033	-3,494	-8,133
2014	-56,570	-168,860	-6,453	-18,487	-4,542	-12,675
2015	-57,320	-226,180	-6,801	-25,287	-5,242	-17,917
2016	-95,700	-321,880	-11,468	-36,755	-7,985	-25,902

Figure ES-3 and Figure ES-4 show the estimated effects of the Staff Greenhouse Gas Proposal on the motor vehicle sector in California on an annual basis and on a cumulative basis, respectively. Annual employment in the automobile sector is about 1,800 lower in 2016, with a cumulative reduction of almost 6,000 person-years of employment by 2016.

Figure ES-3. Annual Employment Effects on the Automobile Sector in California

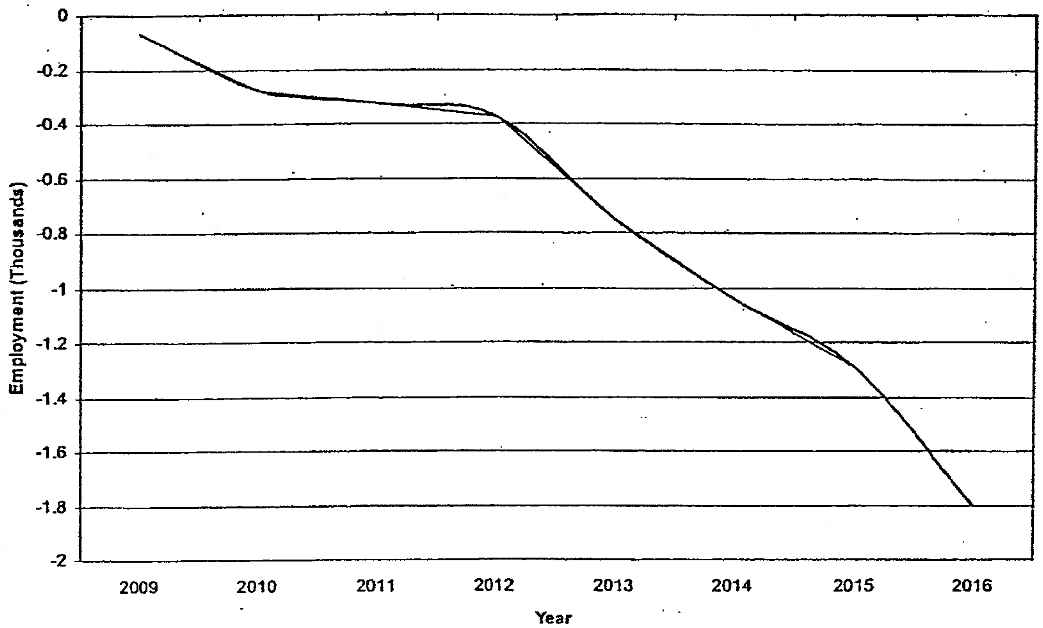
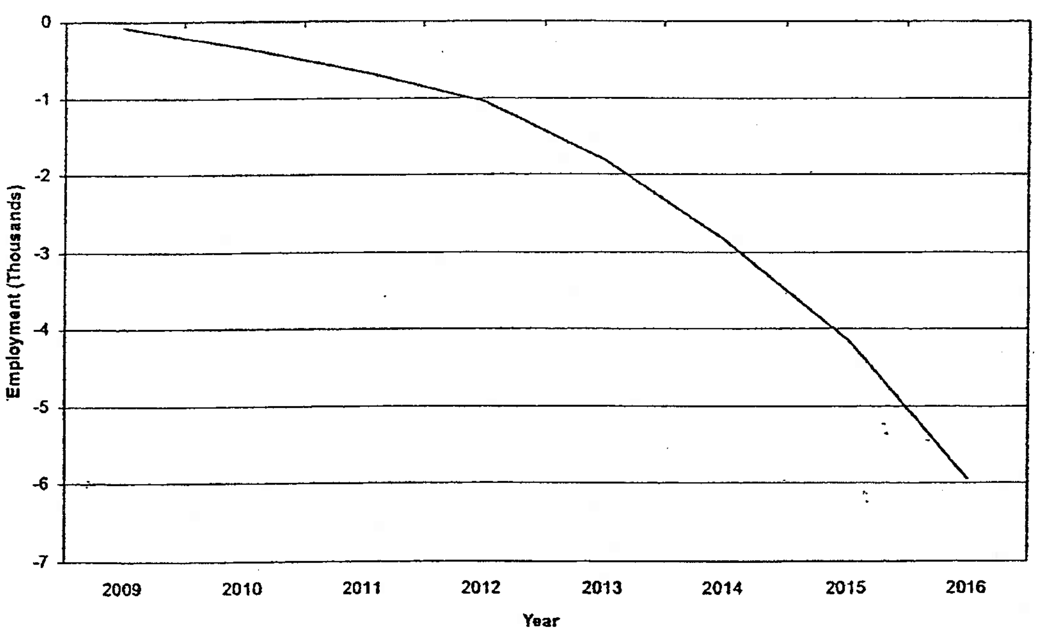


Figure ES-4. Cumulative Employment Effects on the Automobile Sector in California



5. State Revenue Impacts

Table ES-7 shows the effects of the Staff Greenhouse Gas Proposal on state tax revenues in California. Sales tax revenues would be about $600 million lower in 2016, with a cumulative reduction of almost $2 billion over the eight-year period from 2009 to 2016. Income tax revenues would be roughly $400 million lower, with a cumulative loss of nearly $1.3 billion. Overall state sales and income tax revenues in 2016 would be almost $1 billion less in California as a result of the Staff Greenhouse Gas Proposal, with a cumulative loss of more than $3.2 billion from 2009 to 2016.

Table ES-6. Tax Revenue Effects on the California State Government ($2003 Millions)

	Sales Tax (Millions of 2003$)		Income Tax (Millions of 2003$)		Total (Millions of 2003$)	
Year	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
2009	-30	-30	-22	-22	-53	-53
2010	-107	-137	-80	-102	-187	-239
2011	-105	-242	-69	-171	-174	-413
2012	-111	-353	-63	-234	-174	-587
2013	-261	-614	-177	-411	-437	-1,025
2014	-341	-954	-227	-638	-568	-1,593
2015	-400	-1,355	-258	-896	-658	-2,251
2016	-598	-1,952	-399	-1,296	-997	-3,248

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STUDY PARTICIPANTS

The NERA/Sierra study was directed by David Harrison, Jr., Ph.D., at NERA Economic Consulting, Inc., and by Thomas C. Austin at Sierra Research, Inc. The other NERA participants (in alphabetical order) are David A. Biegel, Per Klevnas, Hugh Li, Ph.D., Alex F. Lenkoski, James B. Patchett, Daniel B. Radov, Bernard J. Reddy, Ph.D., Paul M. Reschke, and Feng Y. Xu. The other Sierra participants (in alphabetical order) in this Appendix B study are Phillip L. Heirigs, James M. Lyons, and Mark P. Valdez.

I. INTRODUCTION

This report examines the effects of the August 6, 2004 proposal ("August Staff Report") by the staff of the California Air Resources Board ("ARB") to reduce greenhouse gas emissions from motor vehicles ("Staff Greenhouse Gas Proposal"). This study develops comprehensive estimates of the effects of the Staff Greenhouse Gas Proposal on the California vehicle fleet, on California fleet emissions, and on the California economy.

A. Background

California AB 1493, passed by the legislature and signed by the Governor in 2002, calls on the ARB to develop regulations for greenhouse gas emissions from motor vehicles. The legislation directs the ARB to adopt regulations that achieve the "maximum feasible and cost-effective reduction of greenhouse gas emissions from motor vehicles" (August Staff Report, p. 3) The criterion of "cost-effectiveness" is defined as being economically desirable from the standpoint of new vehicle purchasers. As noted above, on August 6, 2004, the ARB Staff released its proposal to implement AB 1493, the Initial Statement of Reasons ("August Staff Report"). On September 10, 2004, the ARB Staff issued an addendum to the Initial Statement of Reasons that presented revised cost analyses ("September Staff Addendum"). Subsequent to the September Staff Addendum, the ARB Staff released various economic and environmental analyses based upon the revised cost analyses. Although these subsequent materials change the ARB Staff's assessments of the environmental and economic effects, the Staff Greenhouse Gas Proposal is unchanged.

B. Objectives of the Report

The overall objective of this report is to provide estimates of the environmental and economic effects of the Staff Greenhouse Gas Proposal. We have developed a detailed and integrated set of models to estimate the various effects of the Proposal. In addition, we have obtained access to the model used by the ARB Staff to evaluate the effects of the Staff Greenhouse Gas Proposal on the motor vehicle fleet and thus are able to compare results using our set of models to those that would be obtained using an alternative vehicle population model. Our estimates begin with assessments of various CO_2-reducing technologies—and the costs of improvements in motor vehicle fuel economy—based upon information provided by manufacturers and expert judgment. We also consider effects based upon cost and mileage rating information reported in the September Staff Addendum.

The comprehensive environmental and economic estimates presented in this study include five types of effects.

1. *Motor vehicle market effects.* These effects include the effects of the Staff Greenhouse Gas Proposal on the characteristics of new vehicles sold in California as well as related changes in the stock of vehicles and vehicle miles traveled.

2. *Emissions effects.* These are changes in emissions of Reactive Organic Gases (ROG), Oxides of Nitrogen (NO_x), Carbon Monoxide (CO) and Particulate Matter (PM_{10}) in California.

3. *Consumer welfare effects.* These effects measure the effects of the Staff Greenhouse Gas Proposal on the welfare of California households as a result of the vehicle market effects.

4. *State economic effects.* These effects include effects on the California economy, including employment, Gross Regional Product ("GRP"), and disposable personal income.

5. *State revenue effects.* These effects include effects on California state revenues, including sales tax revenues and income tax revenues.

C. Outline of the Report

The remainder of the report is organized as follows. Chapter II provides an overview of the methodologies and data that are used in the study. Chapter III presents the results of the analyses. The attachments provide details on the methodologies and data.

II. METHODOLOGIES AND DATA

This chapter provides summary information on the methodologies and data used to estimate the comprehensive environmental and economic effects of the Staff Greenhouse Gas Proposal. As noted, the appendices to this report provide details on the data and methodologies.

A. Overview of Staff Greenhouse Gas Proposal and Implications for the Cost and Fuel Efficiency of New Vehicles

This section summarizes the Staff Greenhouse Gas Proposal and its implications for the per vehicle cost and fuel efficiency of new vehicles.

1. Staff Greenhouse Gas Proposal

The Staff Greenhouse Gas Proposal consists of a set of average emission standards for model years from 2009 to 2016, with a near-term standard phased in from 2009 to 2012 and a mid-term standard phased in from 2013 to 2016. Table 1 shows the Staff Greenhouse Gas Proposal for the two categories for which standards are developed, PC/LDT1 and LDT2.

Table 1. Staff Greenhouse Gas Proposal

Tier	Year	CO_2-Equivalent Emission Standard by Vehicle Category (g/mi)	
		PC/LDT1	LDT2
	2009	323	439
Near-term	2010	301	420
	2011	267	390
	2012	233	361
	2013	227	355
Mid-term	2014	222	350
	2015	213	341
	2016	205	332

Source: August Staff Report.

This study estimates the effects of the Staff Greenhouse Gas Proposal based upon a detailed analysis of the technology choices and their costs and effectiveness. The methodologies behind the cost and effectiveness estimates are provided in companion reports. Our estimates of the per vehicle costs of the Staff Greenhouse Gas Proposal are developed on the assumption that covered manufacturers as a whole minimize the combined costs of meeting the final 2016 mid-term standard, which assumes full averaging and trading among manufacturers. The costs for intervening years are based upon assessments of the mix of the final compliance technologies that would be employed for each of the vehicle types. A separate trajectory of per vehicle cost and related information is developed for four vehicle types: (1) passenger cars; (2) minivans; (3) pick-up trucks; and (4) sport-utility vehicles ("SUVs").

2. Scenarios Modeled

The ARB Staff developed a set of cost and fuel efficiency assumptions to accompany their Proposal. They input these assumptions into the CARBITS model to estimate the effects of the Proposal. Independently, NERA/Sierra developed a set of cost and fuel efficiency assumptions. The NERA/Sierra cost estimates differ from the ARB Staff assumptions. (Appendix C to the Comments of The Alliance of Automobile Manufacturers provides detailed estimates of these costs.)

For the purposes of the current analysis we have assumed that the technologies and vehicles required to comply with the Staff Greenhouse Gas Proposal are rolled out by manufacturers on a national basis. This is consistent with the assumptions used by CARB staff in the August Staff Report and September Addendum as well as with representations made by ARB Staff during the regulatory workshop on July 7 and with the interim NESCCAF report that forms the basis of ARB's cost estimates. Given the limited time available, we have not been able to consider alternative compliance strategies—for example, ones in which some manufacturers choose to offer modified vehicles for sale only in California and other states adopting the Proposal. Assuming that vehicles are rolled out nationwide yields per-vehicle cost estimates that are as low as possible, since lower production volumes would be associated with higher per-vehicle costs. Thus the impacts of the Staff GHG Proposal that result from the cost assumptions applied here are likely to underestimate the effects of the Proposal on the California economy and ozone precursor emissions.

This report examines the effects of the Staff Greenhouse Gas Proposal using two different models and two different sets of cost assumptions. As discussed above, the ARB Staff estimates of fuel efficiency and average cost of control differ from those developed for the present study. The ARB Staff used the CARBITS model to estimate the effects of their Greenhouse Gas Proposal, whereas we have developed our own models. So, in addition to the

NERA/Sierra model, we assess the impacts of the Staff Greenhouse Gas Proposal using the CARBITs model. With both models we use inputs developed by the ARB Staff and Sierra, so that we have the following four scenarios for the vehicle market and emissions effects:

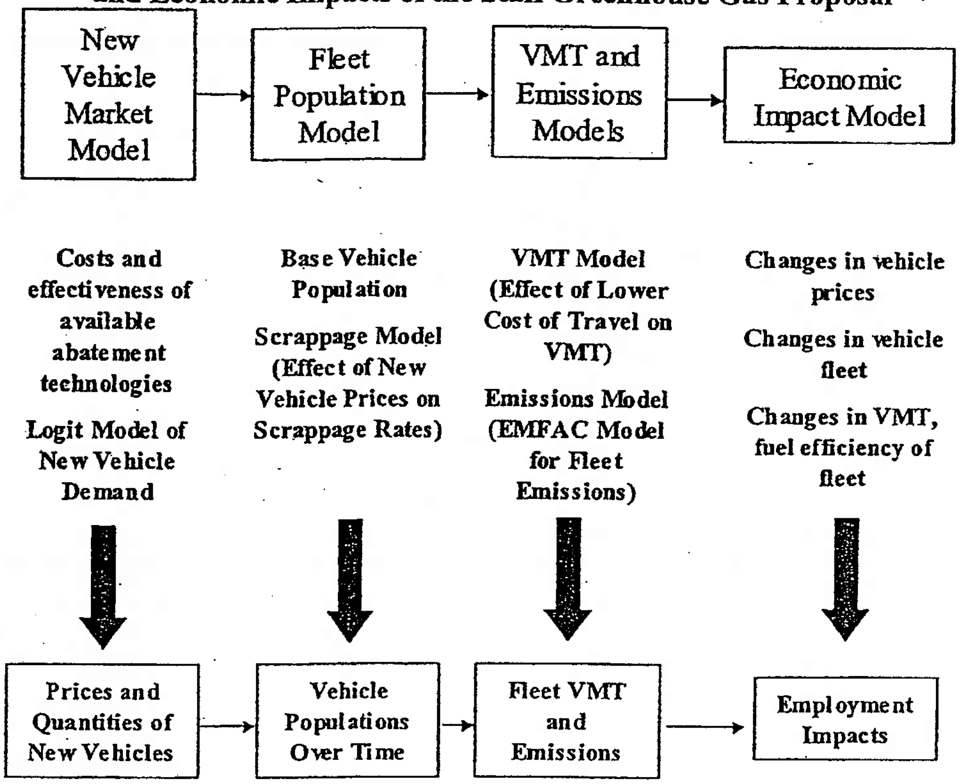
- Scenario 1: NERA/Sierra inputs and NERA/Sierra modeling.
- Scenario 2: ARB Staff inputs and NERA/Sierra modeling.
- Scenario 3: NERA/Sierra inputs and CARBITS modeling.
- Scenario 4: ARB Staff inputs and CARBITS modeling.

Results for consumer surplus, economic impacts and state revenue impacts are based on Scenario 1.

B. Overview of Methodology

The NERA/Sierra methodology represents a set of integrated models designed to evaluate the environmental and economic effects of the Staff Greenhouse Gas Proposal. Figure 1 shows the primary components of the NERA/Sierra modeling. These components include: (1) the New Vehicle Market Model, which is used to estimate the impacts of the Staff Greenhouse Gas Proposal on the prices and quantities of various new motor vehicle models, taking as inputs the costs and CO_2-abatement potential (and related fuel economy effects) of alternative technological changes and manufacturers' compliance plans; (2) the Fleet Population Model, which estimates the effects of changes in new vehicle prices and sales on the scrappage rates of existing vehicles and on the overall vehicle fleet populations over time; (3) the VMT and Emissions Models, which assess the effects on vehicle miles of travel and emissions; and (4) the Economic Impact Model, which assesses the effects on employment and other economic impacts.

Figure 1. Overview of the NERA/Sierra Methodology for Modeling the Environmental and Economic Impacts of the Staff Greenhouse Gas Proposal



The following sections provide summaries of the four major models, including the various subcomponents and the related data.

C. New Vehicle Market Model

This section summarizes the major data and methodologies used to develop the New Vehicle Market Model ("NVMM"). (A detailed description of the New Vehicle Market Model is provided in Attachment B-1.)

1. Effects Modeled

The Staff Greenhouse Gas Proposal will affect the market for new vehicles in California in several ways. Our modeling framework includes the following elements:

- Additional costs to manufacturers to modify motor vehicles to achieve the CO_2 emission reductions called for by the Staff Greenhouse Gas Proposal.

- Additional benefits to consumers, if any, of improvements to vehicle fuel economy.
- Shifts in the mix of new motor vehicles due to these additional costs, which differ by type of vehicle and model.[1]
- In the early years of the regulation, substitution towards vehicles produced by small manufacturers, who do not need to meet the 2012 standards until 2016.

2. Nested Logit Formulation

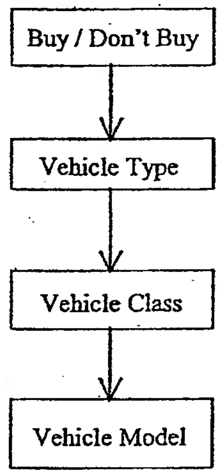
The NVMM is based upon a "nested logit" formulation. (Attachment B-1 provides details of the "nested logit" formulation and the data used to develop the model.) Economists and other analysts have used this type of formulation to evaluate factors affecting the demand for motor vehicles and other goods.[2] The technique also has been used in court proceedings to evaluate the effects of mergers and other changes in market conditions (see, e.g., Werden, Froeb and Tardiff 1996). The technique is also used to evaluate the potential market demand for new products and services (see, e.g., Tardiff 1998).

The "nests" in the nested logit formulation refer to the structure assumed for consumer choices in the new vehicle market. Our model assumes that consumers face decisions regarding the purchase of a new motor vehicle that can be described in four levels, as illustrated in Figure 2. (This nesting structure is described in more detail in Attachment B-1.) Consumers are assumed to decide whether to purchase a new vehicle or not. Assuming they choose to purchase a new vehicle, they select the type of vehicle from among three major vehicle types—cars, SUVs/minivans, and trucks. Assuming the choice of a vehicle type, they are assumed to select a specific vehicle class. Our model includes a total of 15 vehicle classes, including six passenger cars, six SUVs/minivans, and three trucks/vans (e.g., pick-ups and full vans). Finally, assuming the choice of a vehicle class, consumers choose from the vehicle models that are available in that class.

[1] The NVMM does not attempt to account for weight reductions that could result if manufacturers comply with the proposed regulations by intentionally reducing vehicle weight; such weight reductions are likely to be viewed negatively by consumers, assuming other attributes are held constant, and therefore would be expected to increase the overall welfare penalty due to the proposed the regulations.

[2] Dr. Daniel McFadden was awarded the 2000 Nobel Prize in Economics largely for his development of the logit methodology.

Figure 2. Overview of Nesting Structure



This structure provides for a rich pattern of own- and cross-price elasticities for different vehicle models. (The empirical estimates provide information on more than 200 separate vehicle models in each year.) The aggregate new vehicle price elasticity is assumed to be –1.0, a value consistent with the empirical literature.[3] New vehicle manufacturers are assumed to maximize the profits from selling their new vehicles. The empirical formulation of the logit model used in this study is based upon new vehicle sales, price, and characteristics information for the years from 2001 through 2003.

The NVMM develops estimates of the effects of the Staff Greenhouse Gas Proposal on new vehicle prices and sales. The model allows for substitution among vehicles that are covered differently under the regulation. Vehicles produced by manufacturers with lower sales volumes are subject to less stringent emissions standards in the early years of the regulation and thus have lower price increases and corresponding fuel efficiency changes during those years. The model allows for these differences to be reflected in changes in vehicle sales by model and manufacturer.

[3] See, e.g., Gruenspecht (2000) in Attachment B-1.

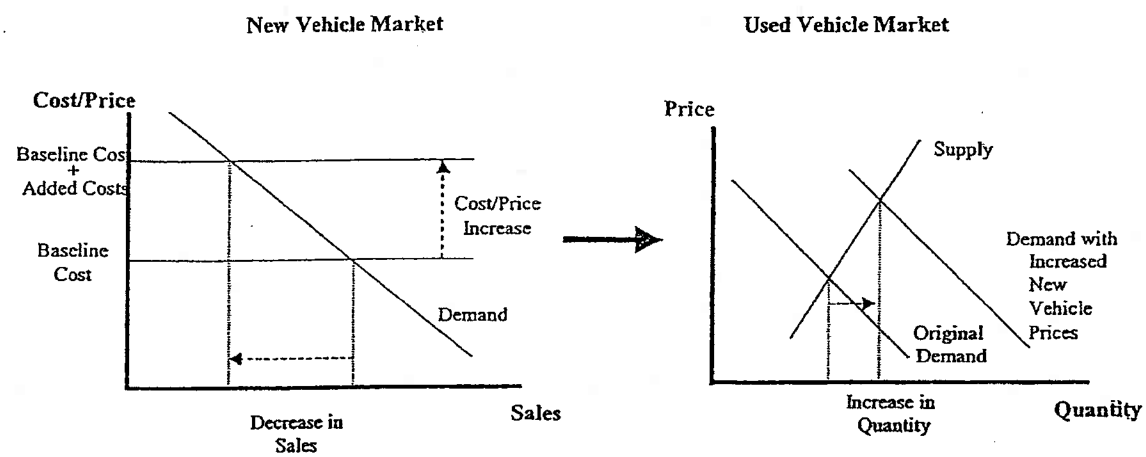
D. Fleet Population Model

The Fleet Population Model estimates the effect of changes in the new vehicle market—including prices and quantities of different types of vehicles sold—on the entire motor vehicle fleet. This model includes a statistically estimated scrappage model as well as models of the motor vehicle fleet.

1. Scrappage Rates

Previous research has established that new vehicle prices affect used vehicle scrappage rates. When the prices of new vehicles increase, the values of used vehicles also increase, and vehicle owners retain them for a longer period of time. Figure 3 illustrates how a change in new vehicle prices causes an increase in the number of used vehicles on the road. This increased quantity reflects a decrease in the scrappage rate of older vehicles.

Figure 3. Impact of Increased New Vehicle Prices on Used Vehicle Markets



The Fleet Population Model includes a detailed empirical model of the effect of changes in new vehicle prices on existing vehicle scrappage rates. (The scrappage model is described in detail in Attachment B-2.) Using a conceptual framework developed by previous researchers, we have developed an updated statistical model relating used vehicles' scrappage rates to new vehicle prices. The model includes statistically estimated relationships between scrappage rates for vehicles of different model year vintages at each age during their lifetimes to new vehicle prices and other factors (macroeconomic conditions, factors affecting total vehicle ownership and use, prices for scrap, and interest rates for new vehicle loans).

2. Fleet Populations

The empirical results from the scrappage model are used in combination with the new motor vehicle sales effects discussed above to assess the effects of the Staff Greenhouse Gas Proposal on the vehicle fleet. We developed a detailed spreadsheet model of the California vehicle fleet population based upon the vehicle populations in the ARB EMFAC model.

As described above, the NVMM estimates the effects of the proposed regulations on new vehicle sales over the course of the regulation, while the scrappage model estimates the effects on existing vehicle stocks. Applying the results of both of these models to the baselines in the Fleet Population Model allows us to simulate the effects of the Staff Proposal on the vehicle populations in California through the year 2030.

E. VMT and Emissions Models

The results of the Fleet Population Model provide an important component for estimating the overall effects of the proposed regulations on motor vehicle emissions. However, the emissions of the motor vehicle fleet also depend on the vehicle miles traveled ("VMT") of each vehicle. We developed a VMT model to provide estimates of VMT to complement the fleet population projections.

1. VMT Model

Increasing the fuel efficiency of a vehicle lowers the vehicle's emissions rate. However, it also lowers the cost per mile of driving, leading drivers to travel more miles. Thus, increasing fuel efficiency also raises VMT. Since the total emissions of a vehicle depend on both its emissions rate and its VMT, the effect of a decrease in the emissions rate is partially offset by an increase in VMT. This offset is known as the "rebound effect."

The VMT Model evaluates the effect on VMT of changes in the cost per mile of travel in California. (The VMT model is described in detail in Attachment B-3.) We use a set of California vehicle inspection data, which includes data on vehicle characteristics and VMT over a five-year period from June 1998 through November 2003. We estimate a statistical relationship between changes in VMT and changes in the cost of travel. Based on this relationship, we develop an estimate of the rebound effect for California. We then apply this estimated rebound effect to estimate the total change in VMT due to the Staff Proposal.

2. Emissions Model

The emissions model is based upon the ARB motor vehicle emissions model (EMFAC2002, version [2.02]), which is supplemented by estimates of indirect emissions for various vehicle technologies. (The Emissions Model is described in detail in Attachment B-4, supplemented by results in Attachment B-5 and Attachment B-6.)

a. EMFAC2002

The EMFAC2002 model represents the latest in a series of models developed by the ARB to generate comprehensive estimates of exhaust and evaporative emissions from on-road motor vehicles operated throughout California. These estimates are typically reported in terms of tons of emissions per day. The model takes into account vehicle emission rates, vehicle populations, vehicle speeds and usage patterns, gasoline properties, and ambient conditions, as well as other factors. Since estimates can be generated for past, current, and future years, the model is capable of accounting for changes in the vehicle fleet over time in terms of emission rates as well as vehicle populations.

b. Additional Emissions Calculations

As noted above, EMFAC2002 provides estimates of exhaust and evaporative emissions from on-road vehicles. However, when considering the emission benefits of the Staff Greenhouse Gas Proposal, ARB also considered so called "fuel cycle" emissions associated with gasoline-fueled vehicles. These are emissions associated with production/importation, marketing and distribution of gasoline. Our emissions modeling also accounts for these indirect effects. (Attachment B-6 contains details about these effects.)

Additionally, the August Staff Report implies that one benefit of the Staff Greenhouse Gas Proposal could be a reduction in tropospheric ozone concentrations. We have considered this issue in light of the effects the Staff Greenhouse Gas Proposal would have on global warming. (Attachment B-5 presents our discussion of this issue.)

c. Emissions Effects of the Staff Greenhouse Gas Proposal

For this analysis, the baseline emissions results for EMFAC2002 assume no changes due to the Staff Greenhouse Gas Proposal. Emissions estimates for each scenario are based on the two sets of emission inventory estimates for each scenario: (1) the baseline vehicle population distribution contained in the EMFAC2002; and (2) a second distribution ("NERA/Sierra" in the ensuing charts) using vehicle population estimates that account for the impact of increased prices on new vehicle purchases and the retirement of older vehicles. We compare the revised inventories to the baseline inventory to determine the comprehensive emissions impacts of each scenario.

F. Economic Impact Model

The economic impact estimates were developed for this study using a Regional Economic Models, Inc. ("REMI") model. The REMI model used for this study is described in Attachment B-7. The economic impact estimates developed here include the following effects:

- The increased costs of producing motor vehicles that achieve the relevant emissions standards will lead to higher prices for motor vehicles. This has multiple effects that we incorporate into the REMI model in various ways:
  - The higher prices will reduce the number of motor vehicles purchased by consumers, businesses, and governments. All else equal, this reduction in purchases of motor vehicles will lead to a shift of expenditures from motor vehicles to other goods and services. The motor vehicle sector loses from such a shift, while other sectors generally gain.
  - The higher prices will increase the amount spent per vehicle purchased by consumers, businesses, and governments. All else equal, this increase in prices will lead to a shift of expenditures from other goods and services and towards the inputs used to manufacture motor vehicles.
  - Above and beyond these shifts in expenditures, consumers, businesses, and governments are made worse off by these price increases. The cost of living is higher for consumers, the cost of business is higher for businesses, and the cost of providing services is higher for governments.
- The increased fuel efficiency for the motor vehicles that achieve the relevant emissions standards will lead to lower fuel consumption by those vehicles.
  - The lower fuel consumption will lead to a shift in expenditures away from the motor fuel sector and toward other goods and services. The motor fuel sector loses from such a shift, while other sectors generally gain.

- Beyond this shift in expenditures, consumers, businesses, and governments are made better off by the reduced fuel expenditures. The cost of living is lower for consumers, the cost of business is lower for businesses, and the cost of providing services is lower for governments.

- With higher prices for new cars, old cars are kept on the road longer; with higher efficiency for new cars, these cars are driven more miles. Both of these effects raise expenditures on vehicle repairs and reduce expenditures on other goods and services, by consumers, businesses, and governments.

- These effects in turn all have indirect and multiplier effects as they percolate through the economy.

III. Study Results

This chapter summarizes the study results for our analyses of the Staff Greenhouse Gas Proposal. The results are grouped into three categories:

1. Motor vehicle market effects.
2. Emissions effects.
3. Consumer welfare effects.
4. State economic effects.
5. State revenue effects.

The results presented here reflect the assumptions about costs and compliance strategies outlined in the previous chapter. In particular, as noted above, to be consistent with ARB Staff's own assumptions, we have assumed that manufacturers would implement the technologies required to comply with the Staff Greenhouse Gas Proposal on a nationwide basis. Assuming nationwide deployment of technologies allows economies of scale to reduce the per-vehicle costs and thus overall costs in California, and therefore substantially underestimates the effects of the GHG Proposal on the California economy and environment. In fact, some or even all manufacturers are likely to pursue another strategy, such as offering a different range of vehicles in California or restricting the sales of some vehicles in California. Such a strategy would result in substantially higher per-vehicle costs because of the lower production volumes. Moreover, such a strategy would affect the way that manufacturers were able to meet their Federal Corporate Average Fuel Economy (CAFE) standards. The more stringent requirements in California would mean that manufacturers would be able to offer larger vehicles in the rest of the country, and this would result in "leakage" of emissions from California to the rest of the U.S.

A. Motor Vehicle Fleet Effects

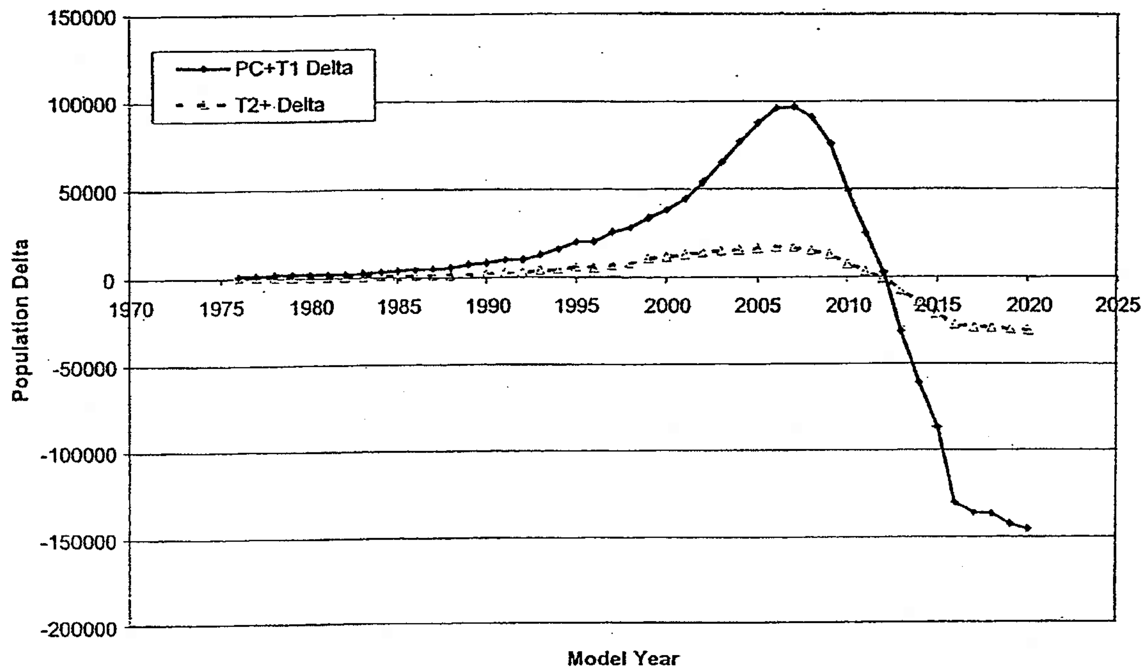
The Staff Greenhouse Gas Proposal will increase the cost to manufacturers of the various models they produce in California. The combined effects of these costs, the various manufacturer compliance plans, and the reactions of consumers to the changed new vehicle opportunities (including effects of changes in the fuel efficiency due to the reduced CO_2 emission technology added to vehicles) will lead to changes in the prices and sales of new vehicle models.

Figure 4 through Figure 7 summarize the effects of the Staff Greenhouse Gas Proposal on the fleet population in 2020. Figure 4 shows the effects based upon NERA/Sierra inputs and the NERA/Sierra modeling (Scenario 1). The figures show the changes to the fleet for both the PC/LDT1 and LDT2 vehicle categories, relative to the baseline conditions without implementation of the ARB Staff Proposal. The Staff Greenhouse Gas Proposal has the effect of changing the age distribution of the vehicle population in both categories. In 2020 the number of older vintage vehicles—including vehicles sold before 2009 and those sold between 2009 and 2012—is higher than in the base case because consumers opt to retain their existing vehicles for longer, rather than replacing them with more expensive newer vehicles. In 2020, sales of new PC/LDT1s and LDT2s combined are lower by about 176,000 vehicles in California as a result of the Staff Greenhouse Gas Proposal.[4] In contrast, the number of vehicles in the *fleet* with model years before the regulations would take effect (i.e., pre-2009 model year vehicles) is more than 1 million greater in 2020 as a result of the Staff Proposal.[5]

[4] The cumulative increase in purchase cost of new motor vehicles over the period from 2009 to 2016 due to the Staff Greenhouse Gas Proposal would be $14.6 billion (2003 dollars).

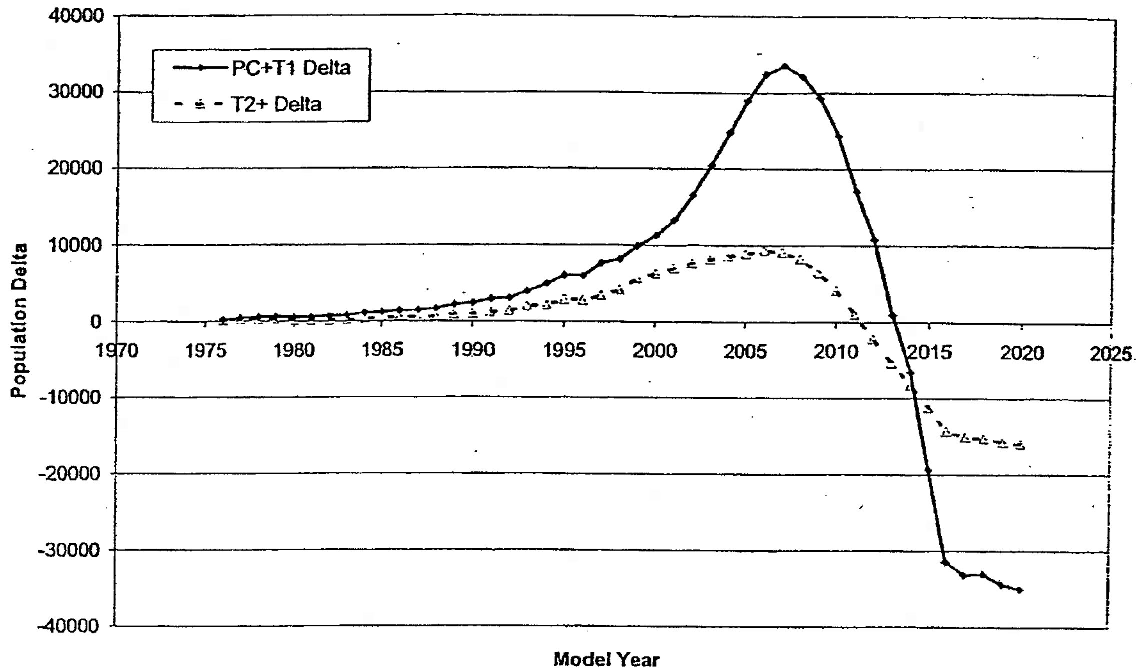
[5] Note that the fleet population results are derived using the EMFAC base population files, which do not reflect accurately the current proportions of vehicles in the PC, LDT1, and LDT2 categories. In fact, the proportion of LDT2s and larger vehicles in the California fleet is significantly higher than reflected by EMFAC. This affects the magnitude of the emissions results reported below.

Figure 4. Change in Statewide 2020 Vehicle Population Estimates as a Result of the Staff Greenhouse Gas Proposal Using the NERA/Sierra Population Model with NERA/Sierra Input Assumptions (Scenario 1)



A similar pattern of results emerges for the other three modeling cases. Figure 5 shows that based on the NERA/Sierra model, the lower cost assumptions used by the ARB Staff result in lower overall fleet impacts, but still show the same extended retention of older models and reduced purchases of new vehicles.

Figure 5. Change in Statewide 2020 Vehicle Population Estimates as a Result of the Staff Greenhouse Gas Proposal Using the NERA/Sierra Population Model with ARB Staff Input Assumptions (Scenario 2)



The CARBITS model used by the ARB Staff also generates similar results whether using ARB Staff cost assumptions or the NERA/Sierra cost assumptions. For both the PC/LDT1 category and the LDT2 category, CARBITS predicts substantial reductions in new vehicle sales under both cost alternatives as well as increases in the numbers of existing vehicles that remain on the road. Figure 6 and Figure 7 show these results.

Figure 6. Change in Statewide 2020 Vehicle Population Estimates as a Result of the Staff Greenhouse Gas Proposal Using the CARBITS Population Model with NERA/Sierra Input Assumptions (Scenario 3)

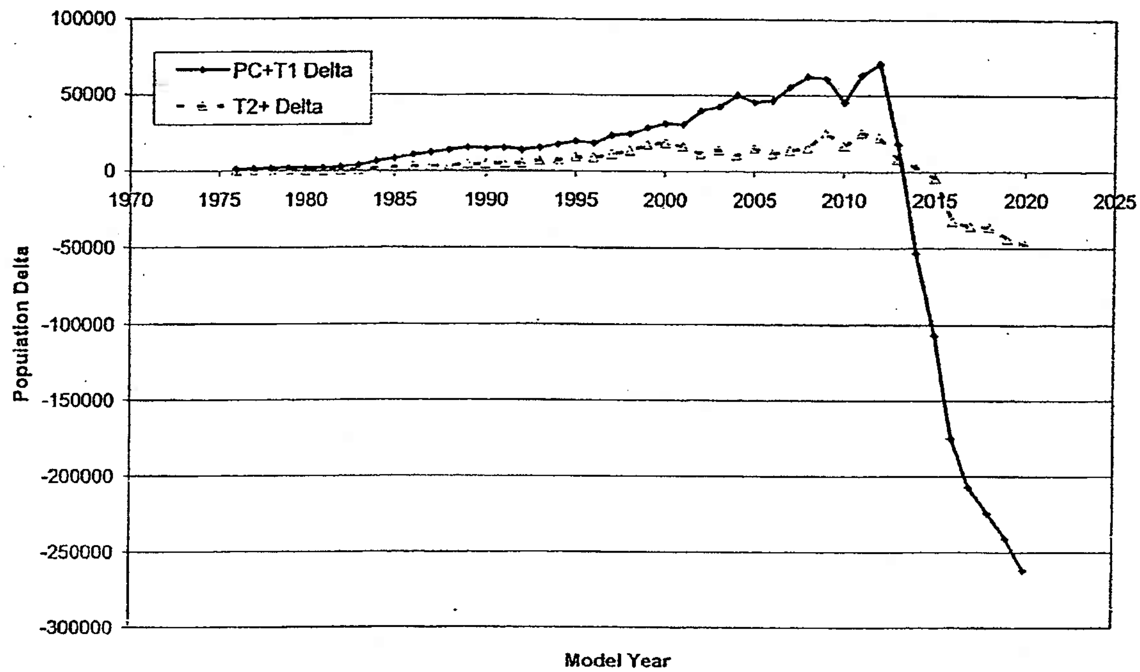
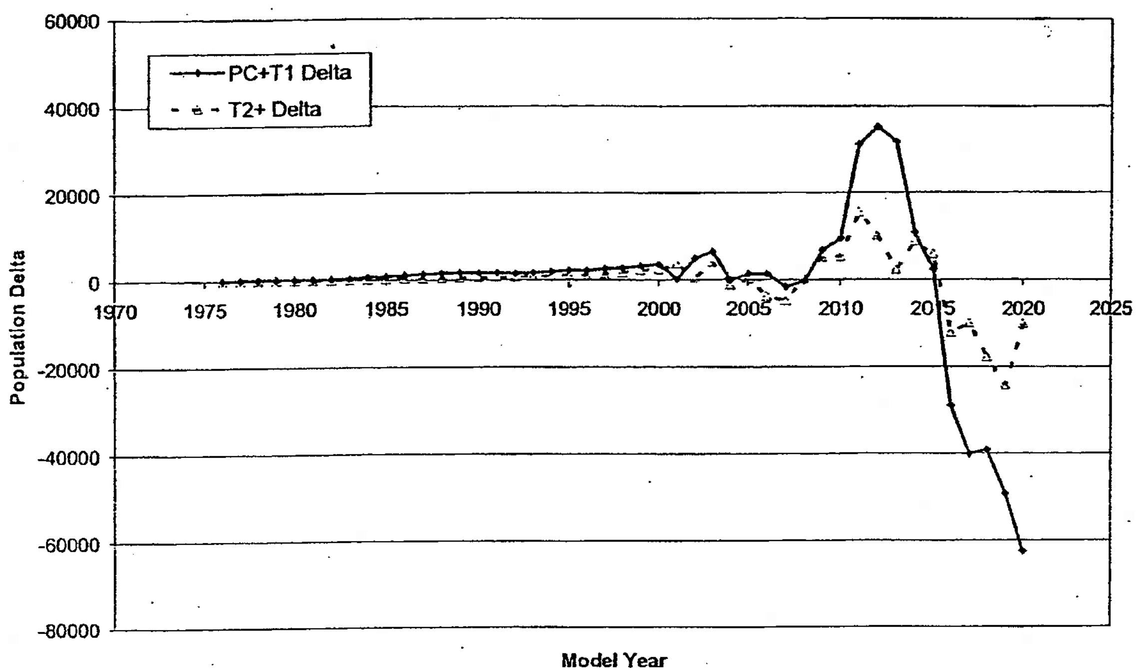


Figure 7. Change in Statewide 2020 Vehicle Population Estimates as a Result of the Staff Greenhouse Gas Proposal Using the CARBITS Population Model with ARB Staff Input Assumptions (Scenario 4)



In summary, all modeling approaches and alternative assumptions indicate that the age distribution of the fleet would change substantially if the Staff Greenhouse Gas Proposal were in place, with older vehicles remaining on the road longer and new vehicle sales reduced. These fleet impacts result in changes to fleet-wide criteria pollutant emissions, as detailed in the following section.

B. Emissions Effects

The effects on emissions of criteria pollutants as a result of the Staff Greenhouse Gas Proposal for the four scenarios described above are summarized in Figure 8 through Figure 11. Figure 8 shows results for the criteria pollutants over the period from 2009 to 2030 based upon NERA/Sierra inputs and the NERA/Sierra modeling (Scenario 1). In 2020, the Staff Greenhouse Gas Proposal is projected to increase ozone precursor emissions (ROG plus NO_X) by about 30.4 tons per day in California.

Figure 8. Statewide ROG+NO_x Emissions Increases as a Result of the Proposed Staff Greenhouse Gas Proposal Regulation Using the NERA/Sierra Population Model with NERA/Sierra Input Assumptions (Scenario 1)

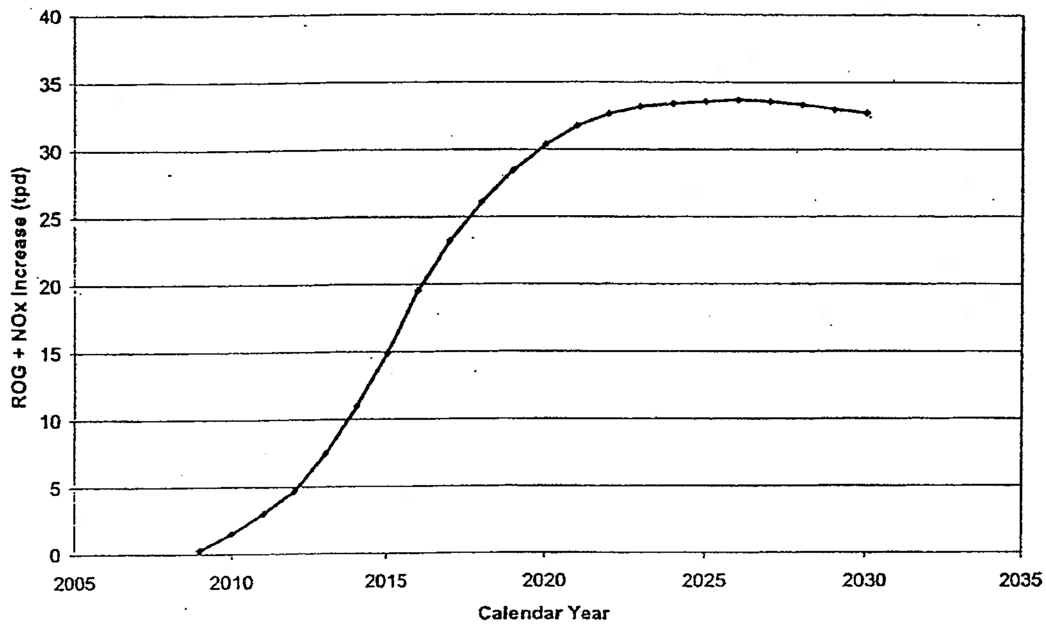
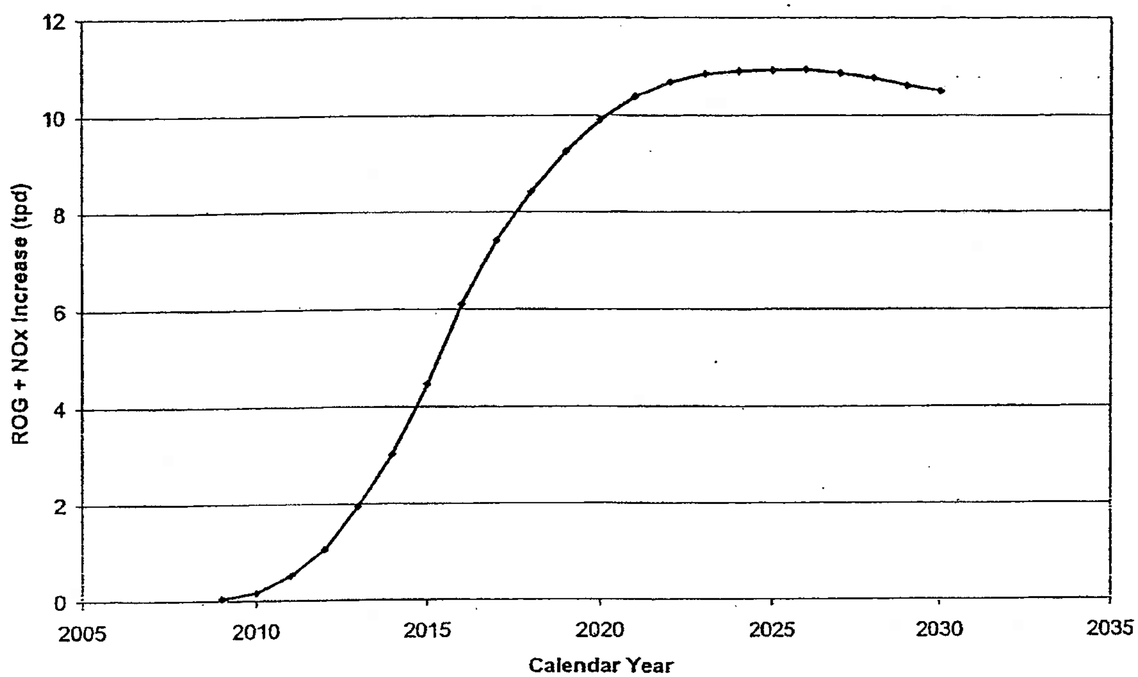


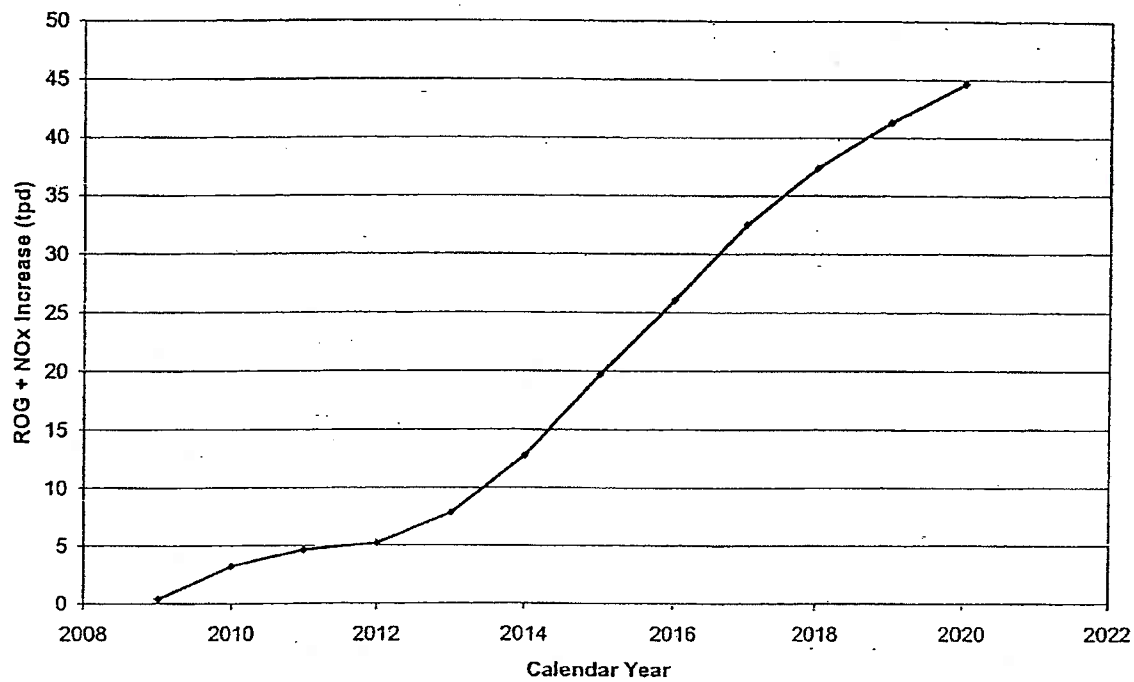
Figure 9 demonstrates the effects on emissions of the criteria pollutants as a result of the Staff Greenhouse Gas Proposal under the scenario using ARB Staff inputs and the NERA/Sierra methodology. Under this scenario, emissions of ROG plus NO_x are projected to increase by roughly 10 tons per day relative to the baseline by 2020 and remain more than 10 tons per day above the baseline through 2030.

Figure 9. Statewide ROG+NO_x Emissions Increases as a Result of the Staff Greenhouse Gas Proposal Using the NERA/Sierra Population Model with CARB Input Assumptions (Scenario 2)



Emissions are projected to rise substantially more under Scenario 3, as shown in Figure 10. As noted, Scenario 3 uses the CARBITS model and the NERA/Sierra Input assumptions. Using CARBITS and these modeling assumptions, daily emissions of ROG plus NO_X are estimated to grow steadily from the inception of the regulation in 2009 through 2020. (Note that CARBITS results are only available through 2020.) By 2020, this scenario shows an increase in emissions of nearly 45 tons per day of ROG plus NO_X.

Figure 10. Statewide ROG+NO_x Emissions Increases as a Result of the Staff Greenhouse Gas Proposal Using the CARBITS Population Model with NERA/Sierra Input Assumptions (Scenario 3)



Finally, Figure 11 shows the change in emissions over the period through 2020 using the CARBITS model and the ARB input assumptions (Scenario 4). As demonstrated in the figure, the results estimated in the CARBITS model indicate a decline in emissions of ROG plus NO_X in the early years of the regulation—2009 through 2015. However, between 2016 and 2020, the EMFAC model shows that emissions rise above baseline levels, reaching roughly six additional tons per day of ROG plus NO_X emissions at 2016.[6]

[6] Again, it is important to note here the discrepancy between EMFAC vehicle populations and current real-world proportions of vehicles in the three categories relevant here. Because costs for LDT2s are higher than for passenger cars in the early years of the proposed regulation, the unrealistically low LDT2 populations in EMFAC result in the model suggesting initial emissions benefits. If the EMFAC model more accurately reflected current populations, the emissions effects due to the LDT2 population changes would be more substantial and would probably result in higher emissions even in the early years of the regulation.

Figure 11. Statewide ROG+NO_x Emissions Increases as a Result of the Staff Greenhouse Gas Proposal Using the CARBITS Population Model with ARB Staff Input Assumptions (Scenario 4)

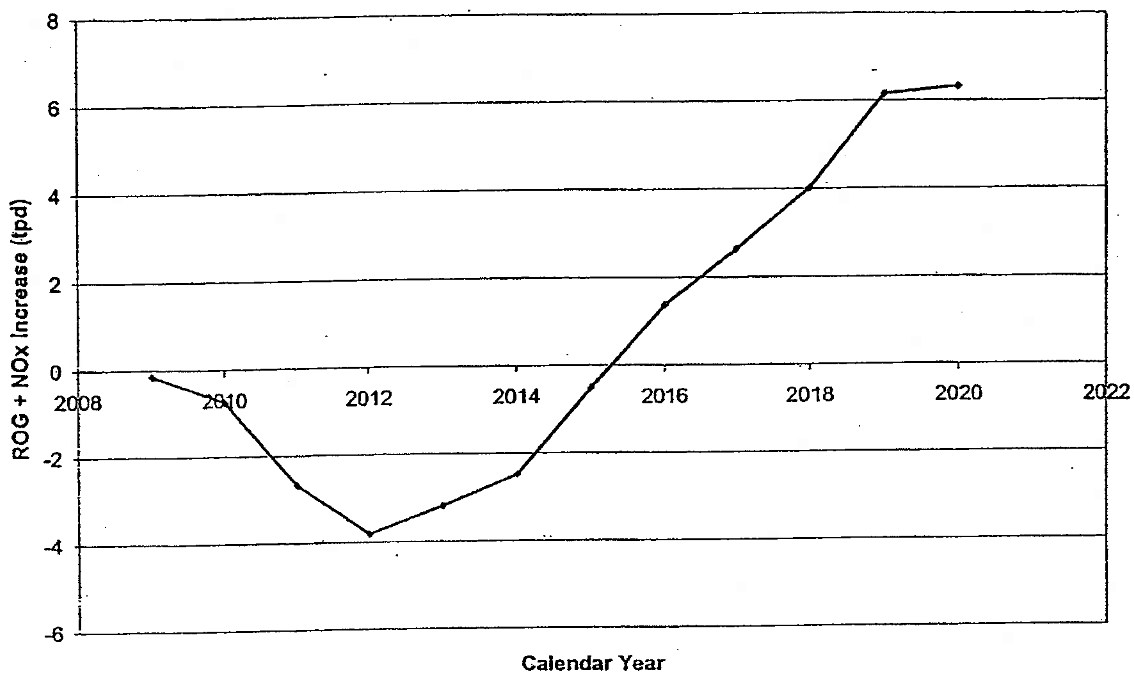


Table 2 through Table 5 summarize the emissions impacts of the Staff Greenhouse Gas Proposal under the four scenarios shown above. Table 2 shows the results of Scenario 1, using the NERA/Sierra Population Model and the NERA/Sierra input assumptions. The table demonstrates that emissions of all four criteria pollutants increase substantially over the period from 2009 through 2030.

Table 2. Statewide Emissions Impacts of the Staff Greenhouse Gas Proposal Using the NERA/Sierra Population Model with NERA/Sierra Input Assumptions (Scenario 1)

Year	Criteria Pollutant Increases, Accounting for Turnover and Rebound (tons per day)			
	ROG	NO_x	CO	PM_{10}
2009	0.18	0.16	1.67	0.01
2010	0.80	0.76	7.87	0.05
2011	1.58	1.49	15.68	0.10
2012	2.44	2.29	24.37	0.16
2013	3.88	3.60	38.69	0.26
2014	5.74	5.22	56.62	0.39
2015	7.89	7.01	76.52	0.56
2016	10.49	9.06	99.67	0.79
2017	12.64	10.62	117.38	1.00
2018	14.37	11.76	130.29	1.20
2019	15.87	12.61	139.99	1.40
2020	17.16	13.23	146.95	1.58
2021	18.18	13.59	150.98	1.77
2022	18.91	13.73	151.48	1.94
2023	19.44	13.73	150.38	2.09
2024	19.77	13.64	148.62	2.24
2025	20.04	13.50	146.77	2.38
2026	20.28	13.38	145.36	2.54
2027	20.37	13.16	142.64	2.67
2028	20.42	12.91	139.72	2.79
2029	20.37	12.59	136.02	2.90
2030	20.41	12.30	133.33	3.00

The emissions effects under Scenario 2—NERA/Sierra Population Model with ARB inputs—are illustrated in Table 3. The table shows that, even using the ARB inputs, emissions of all four criteria pollutants increase through 2030.

Table 3. Statewide Emissions Impacts of the Staff Greenhouse Gas Proposal Using the NERA/Sierra Population Model with ARB Staff Input Assumptions (Scenario 2)

Year	Criteria Pollutant Increases, Accounting for Turnover and Rebound (tons per day)			
	ROG	NO_x	CO	PM_{10}
2009	0.02	0.03	0.30	0.02
2010	0.07	0.10	0.91	0.03
2011	0.24	0.28	2.71	0.05
2012	0.50	0.56	5.46	0.08
2013	0.95	1.00	10.00	0.11
2014	1.51	1.51	15.38	0.16
2015	2.29	2.18	22.54	0.21
2016	3.20	2.90	30.53	0.28
2017	3.96	3.45	36.60	0.34
2018	4.58	3.85	40.99	0.40
2019	5.10	4.14	44.27	0.45
2020	5.56	4.36	46.55	0.50
2021	5.91	4.48	47.73	0.55
2022	6.16	4.51	47.61	0.60
2023	6.34	4.50	46.95	0.64
2024	6.45	4.46	46.09	0.67
2025	6.53	4.40	45.19	0.70
2026	6.60	4.34	44.44	0.74
2027	6.61	4.25	43.25	0.77
2028	6.62	4.14	42.02	0.79
2029	6.59	4.02	40.51	0.81
2030	6.60	3.90	39.34	0.83

Table 4 demonstrates the results of the third scenario, in which we apply the NERA/Sierra inputs to the CARBITS model. (Again, note that results from the CARBITS model are only available through 2020.) However, the model shows that there is a dramatic increase in the effects on criteria pollutants, particularly carbon monoxide, which increases by over 200 tons per day relative to the baseline.

Table 4. Statewide Emissions Impacts of the Staff Greenhouse Gas Proposal Using the CARBITS Population Model with NERA/Sierra Input Assumptions (Scenario 3)

Year	Criteria Pollutant Increases, Accounting for Turnover and Rebound (tons per day)			
	ROG	NO_x	CO	PM_{10}
2009	0.21	0.19	2.07	0.01
2010	1.74	1.51	16.07	0.07
2011	2.57	2.07	22.39	0.11
2012	2.94	2.29	24.75	0.14
2013	4.32	3.53	38.51	0.25
2014	6.95	5.86	61.79	0.42
2015	10.78	9.01	95.26	0.65
2016	14.21	11.89	125.16	0.93
2017	17.89	14.62	153.70	1.21
2018	20.71	16.65	174.73	1.47
2019	23.08	18.21	190.40	1.72
2020	25.23	19.44	202.25	1.95

Table 5 shows the final scenario, in which the ARB input assumptions are used in the CARBITS model. Using this methodology results in lower overall increases in criteria pollutants than using the NERA/Sierra inputs. Indeed, the results from the CARBITS model lead to EMFAC predictions that suggest reductions in many criteria pollutants in the early years of the regulation. As noted above, these early results would be reversed if EMFACs populations better reflected the actual vehicle population. By 2020, emissions of all four criteria pollutants are higher than in the base case even under this scenario.

Table 5. Statewide Emissions Impacts of the Staff Greenhouse Gas Proposal Using the CARBITS Population Model with ARB Staff Input Assumptions (Scenario 4)

	Criteria Pollutant Increases, Accounting for Turnover and Rebound (tons per day)			
Year	**ROG**	**NO_x**	**CO**	**PM_{10}**
2009	-0.07	-0.07	-0.57	0.01
2010	-0.46	-0.29	-3.61	0.02
2011	-1.39	-1.29	-12.90	0.00
2012	-1.99	-1.82	-18.79	0.00
2013	-1.66	-1.53	-15.41	0.02
2014	-1.33	-1.15	-12.10	0.06
2015	-0.27	-0.24	-1.92	0.11
2016	0.73	0.65	7.73	0.17
2017	1.42	1.22	13.64	0.24
2018	2.17	1.85	19.64	0.30
2019	3.41	2.75	28.72	0.37
2020	3.56	2.77	29.45	0.41

Under the Staff Greenhouse Gas Proposal, the criteria pollutant increases reported above would be partially offset by a reduction in "upstream" emissions associated with the distribution and marketing of gasoline resulting from reduced gasoline consumption. Table 6 summarizes the emissions effects in 2020 under all four scenarios after taking into account the effects of reduced gasoline consumption. Reduced gasoline consumption has an insubstantial effect on all of the criteria pollutants except ROG. After taking into account the change in gasoline consumption, the estimates of the increase in 2020 emissions in California of the ozone precursors ranges from about 2.3 tons per day to about 41.2 tons per day, depending upon the scenario.

Table 6. Summary of the Statewide 2020 Emissions Impacts of the Staff Greenhouse Gas Proposal, Including the Effects of Reduced Gasoline Consumption

	Criteria Pollutant Increases, Accounting for Turnover, Rebound, and Reduced Gasoline Consumption (tons per day)			
Scenarios	**ROG**	**NO_x**	**CO**	**PM_{10}**
NERA/Sierra methodology with NERA/Sierra inputs	14.86	12.93	146.75	1.56
NERA/Sierra methodology with ARB Staff inputs	1.86	4.06	46.25	0.48
CARBITS methodology with NERA/Sierra inputs	22.03	19.14	202.05	1.93
CARBITS methodology with ARB Staff inputs	-.14	2.47	29.15	0.39

Additionally, we found that the Staff Greenhouse Gas Proposal would have no more than a negligible effect on global warming and ozone concentrations.[7]

C. Consumer Welfare Effects

We determine the impacts of the Greenhouse Gas Proposal on consumer welfare using the New Vehicle Market Model. The model enables us to calculate the change in consumer welfare due to the proposed regulation and to value it in dollar terms. (Attachment B-8 describes the concept of consumers' surplus; Attachment B-1 describes the specific procedure used to estimate the change in consumer surplus due to the Staff Greenhouse Gas Proposal.) In 2016, California motor vehicle purchasers would experience a welfare loss of more than $4 billion dollars. (All values are in 2003 dollars.) The cumulative welfare loss over the period from 2009 to 2016 would be more than $12.8 billion.

[7] See Attachment B-5 for a discussion of this result.

Table 7. Effects of Staff Greenhouse Gas Proposal on Consumer Welfare

	Welfare Loss (Millions of $2003)	
Year	**Annual**	**Cumulative**
2009	-100	-100
2010	-469	-568
2011	-647	-1,215
2012	-830	-2,046
2013	-1,539	-3,585
2014	-2,251	-5,836
2015	-2,967	-8,803
2016	-4,013	-12,816

The results presented in the table take into account the effects on consumer welfare of increased prices, increased fuel efficiency, reduced sales, and changes to the mix of vehicles sold as a result of the Greenhouse Gas proposal. Because the New Vehicle Market Model is based on aggregated "trim level" information for each model, however, the consumer welfare calculation presented here omits one additional effect that is likely to reduce consumer welfare still further. The omitted loss is due to the possibility that some or all manufacturers may choose not to offer certain vehicles in California as a result of the regulation. Although the New Vehicle Market Model calculates the effects of reductions in sales for a given model aggregating over all trim levels, it does not account, for example, for the effects of *eliminating* certain trim levels from a manufacturer's offerings. Such a reduction in the variety of vehicles made available to consumers could contribute an additional loss in consumer welfare that is not included in the calculations presented here.

D. Economic Impact Results

The economic impacts of the Staff Greenhouse Gas Proposal were estimated using a detailed economic model developed by Regional Economic Models, Inc. ("REMI"). As noted, the cost estimates are based upon the assumption that motor vehicle manufacturers adopt technology plans for their entire United States production and thus the values understate the per vehicle costs that would be incurred if these same technologies were developed for California sales volumes.

Table 8 summarizes the impacts of the Staff Greenhouse Gas Proposal on the California economy. The table shows both the annual changes in the economy and the cumulative effect over time in these impacts. In 2016, the Staff Greenhouse Gas Proposal would lead to almost 100,000 fewer jobs. The cumulative effects mean that by 2016 more than 300,000 person-years of employment would be lost over the eight-year period. The California Gross Regional Product ("GRP") would be reduced by roughly $11.5 billion in 2016, with a cumulative loss from 2009 to 2016 of more than $36 billion. Disposable personal income losses are similar, reaching $8 billion in 2016 with a cumulative total of more than $25 billion.

Table 8. Summary of Impacts on the California Economy

Year	Employment		Gross Regional Product (Millions of $2003)		Disposable Personal Income (Millions of $2003)	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
2009	-7,570	-7,570	-732	-732	-425	-425
2010	-25,450	-33,020	-2,552	-3,284	-1,535	-1,960
2011	-18,430	-51,450	-1,957	-5,241	-1,372	-3,332
2012	-13,340	-64,790	-1,540	-6,781	-1,308	-4,640
2013	-47,500	-112,290	-5,253	-12,033	-3,494	-8,133
2014	-56,570	-168,860	-6,453	-18,487	-4,542	-12,675
2015	-57,320	-226,180	-6,801	-25,287	-5,242	-17,917
2016	-95,700	-321,880	-11,468	-36,755	-7,985	-25,902

The employment impacts in California by major sector are summarized in the first table below, and the effects on Gross State Product ("GSP") by sector are shown in the second table. The largest employment impacts are in the non-manufacturing sector. The effects on GSP are widely dispersed among many of the sectors, with the service sector the most affected.

Table 9. Summary of Employment Impacts by Sector

	2009	2012	2016
Manufacturing			
Durables	-939	-1,925	-12,940
Motor Vehicles	-68	-375	-1,803
Non-Durables	-320	-445	-3,672
Non-Manufacturing	-6,313	-11,040	-79,440
Government–State and Local	2	71	353
Total	-7,570	-13,340	-95,700

Table 10. Summary of Gross State Product Impacts by Sector (Millions of $2003)

	2009	2012	2016
Durables Manufacturing	-231	-510	-3,895
Non-Durables Manufacturing	-42	-87	-645
Mining	-6	-27	-139
Construction	-39	-88	-569
Transportation & Public Utilities	-49	-96	-734
Finance, Insurance, Real Estate	-82	-110	-1,002
Retail Trade	-52	-124	-833
Wholesale Trade	-68	-222	-1,352
Services	-159	-276	-2,279
Agriculture, Forestry & Fishing Services	-3	-5	-41
Total	-732	-1,544	-11,488

The effects on employment over time in California are shown in Figure 12 and Figure 13. Figure 12 shows annual effects and Figure 13 shows cumulative effects. Figures Figure 14 and Figure 15 provide similar results for the motor vehicle sector in California. Annual employment losses in the automobile sector reach about 1,800 jobs lost in 2016, with a cumulative reduction of almost 6,000 person-years of employment by 2016.

Figure 12. Annual Employment Effects in California

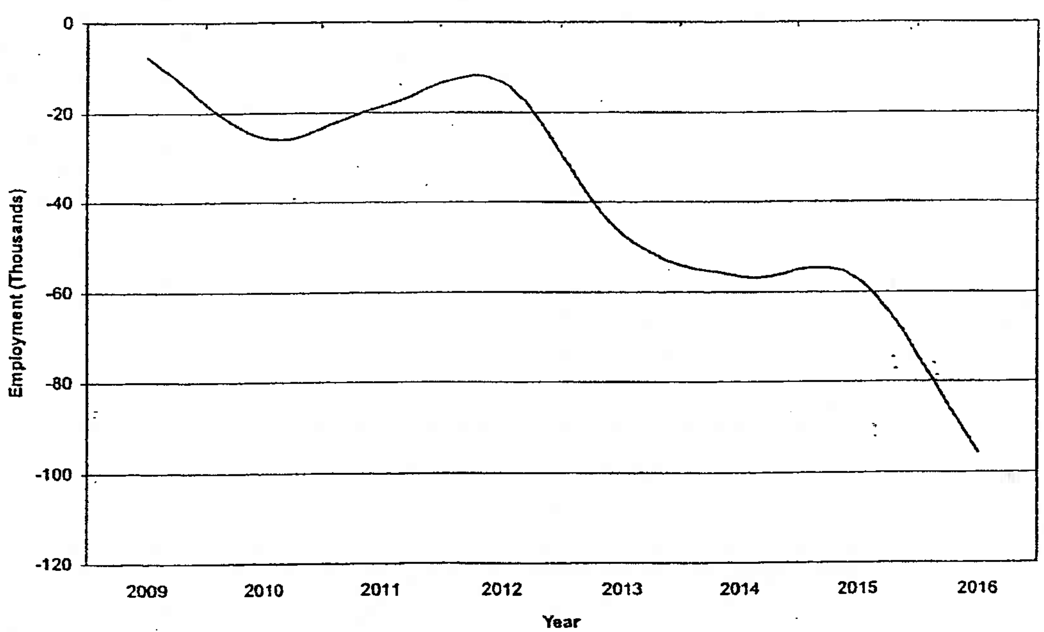


Figure 13. Cumulative Employment Effects in California

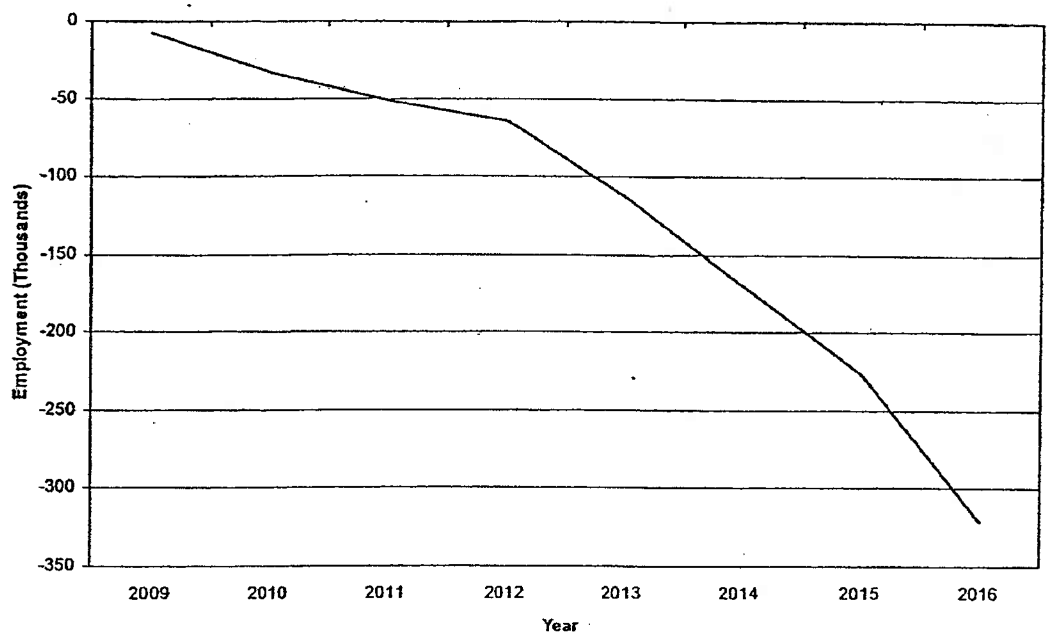


Figure 14. Annual Employment Effects on the Automobile Sector in California

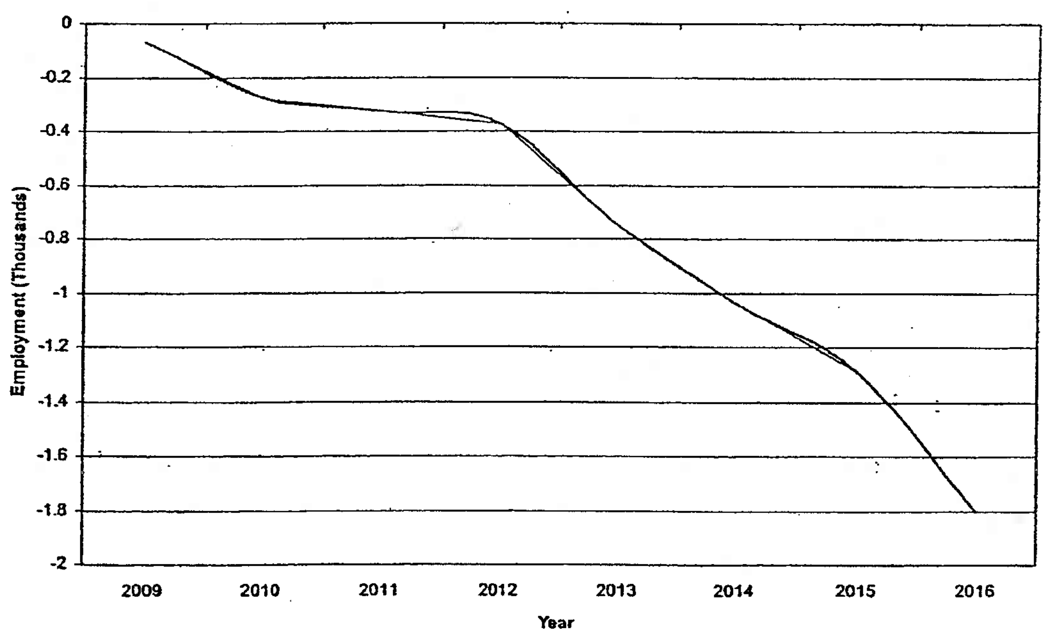
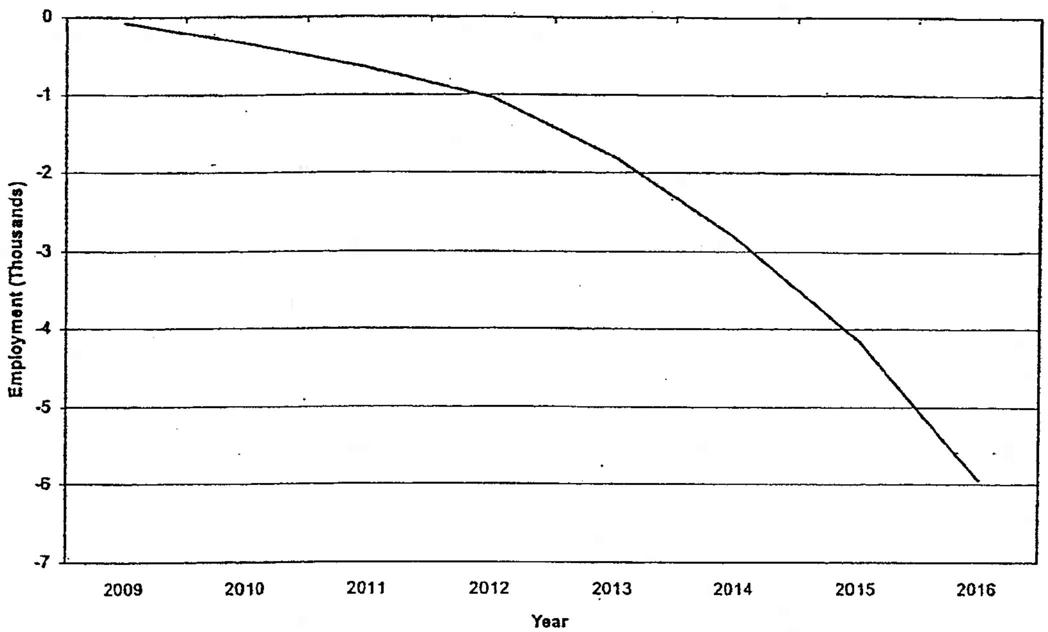


Figure 15. Cumulative Employment Effects on the Automobile Sector in California



E. State Revenue Impacts

Table 11 shows the effects of the Staff Greenhouse Gas Proposal on state tax revenues in California. Sales tax revenues would be about $600 million lower in 2016, with a cumulative reduction of almost $2 billion over the eight-year period from 2009 to 2016. Income tax revenues would be roughly $400 million lower, with a cumulative loss of nearly $1.3 billion. Overall state sales and income tax revenues in 2016 would be almost $1 billion less in California as a result of the Staff Greenhouse Gas Proposal, with a cumulative loss of more than $3.2 billion from 2009 to 2016.

Table 11. Tax Revenue Impacts on California State Government (Million 2003 Dollars)

	Sales Tax (Millions of 2003$)		Income Tax (Millions of 2003$)		Total (Millions of 2003$)	
Year	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
2009	-30	-30	-22	-22	-53	-53
2010	-107	-137	-80	-102	-187	-239
2011	-105	-242	-69	-171	-174	-413
2012	-111	-353	-63	-234	-174	-587
2013	-261	-614	-177	-411	-437	-1,025
2014	-341	-954	-227	-638	-568	-1,593
2015	-400	-1,355	-258	-896	-658	-2,251
2016	-598	-1,952	-399	-1,296	-997	-3,248

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ATTACHMENT B-1: NEW VEHICLE MARKET MODEL

NERA has developed a New Vehicle Market Model to determine the effects of the Staff Greenhouse Gas Proposal on the vehicle market in California and the rest of the United States. The model uses a nested logit demand framework based on historical transaction prices, sales data, and vehicle characteristics for both regions. The framework provides a way to use the volumes and prices of vehicles sold in California and the rest of the United States to assess demand for each vehicle, as well as the valuation of different vehicle attributes by consumers.

The sections below detail the methods used to develop the New Vehicle Market Model and apply it to the Staff Greenhouse Gas Proposal. Following a general description of the conceptual approach, we outline the data and parameters used to implement the New Vehicle Market Model.

B-1.1 Conceptual Approach: Nested Logit Model

Logit discrete choice analysis provides a method for predicting consumer choices, and therefore demand, based on previously observed consumer behavior and other assumptions about demand (see e.g., Ben-Akiva and Lerman 1985). The most basic logit framework, also referred to as the "simple" logit framework, groups all product alternatives together and therefore allows only very limited patterns of own-price and cross-price elasticity between different alternatives. This limitation is often referred to as the "Independence of Irrelevant Alternatives" ("IIA") problem. The nested logit framework builds on this simple framework, but provides for a much richer pattern of cross-elasticity between different alternatives through the nesting structure.

B-1.1.1 Basic Framework

We assume that consumers choose among a set of vehicle models, and may also choose not to purchase a vehicle at all. For alternative i, the utility that a given consumer obtains from choosing that alternative can be written as a function of an alternative-specific parameter and the price for the alternative:

$$U_i = \alpha_i - \beta P_i + \varepsilon_i \tag{1}$$

We define alternative "0" as the no-purchase alternative, and the remaining alternatives represent individual vehicle models. The parameter α_i measures the attractiveness of good i to consumers. We assume that the price for the outside good is zero. P_i is the price of alternative i, and β is a positive parameter. The random error terms ε_i are assumed to be distributed as a multivariate generalization of the standard extreme value distribution.

The potential purchaser is assumed to choose the alternative that yields the highest utility, taking into account both the deterministic and random components of utility. Given the logit demand assumptions, we determine the expected market share for each vehicle alternative. Conditional upon the consumer's decision to purchase a vehicle within vehicle group (or "nest") A (as described below), the expected share for vehicle alternative i can be written as:

$$s_{i|A} = \frac{\exp((\alpha_i - \beta P_i)/\lambda_A)}{\sum_{j \in A} \exp((\alpha_j - \beta P_j)/\lambda_A)}, \tag{2}$$

where λ_A is the "nesting parameter" for the appropriate vehicle group, or "nest" (as described below).[8]

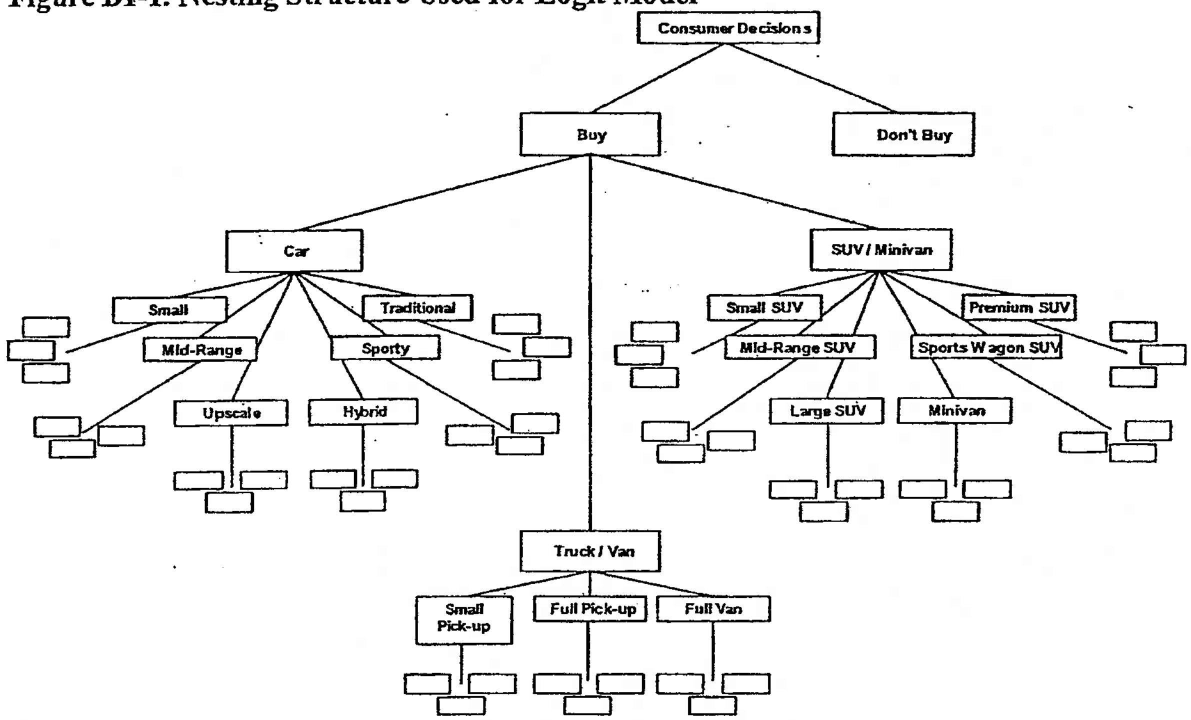
B-1.1.2 Nesting Assumptions

Our logit model assumes the nesting structure shown in Figure B1-1. As the figure shows, we divide the choice problem first into the decision to buy or not buy a vehicle. Conditional upon the choice to purchase a vehicle, consumers choose the vehicle type—in this case, passenger cars, pickup trucks or full-size vans, and SUVs or minivans. Conditional on the

[8] Because terms that are constant across all alternatives do not affect the choice of alternatives, it is common to normalize the alternative-specific term α_i . As a normalization rule, we set α_i equal to zero for one vehicle model. Adding or subtracting a common amount to all the α_i terms leaves the choice of alternatives unchanged, so any other normalization rule would yield identical results.

choice of vehicle type, consumers choose the vehicle class—for example, small cars or mid-range cars (among others) in the passenger car group.

Figure B1-1. Nesting Structure Used for Logit Model



Conditional on the bottom-level group, consumers choose one of the individual vehicle models available. The bottom level of the nesting structure includes over 200 vehicle models from which consumers may choose.

The model allows the utility that consumers derive from the purchase of different models to depend on the vehicle category and class via the nesting parameters (λ), which take values between zero and one.[9] One nesting parameter applies to the purchase decision; another set of nesting parameters apply to the choice of vehicle types; and a third set apply to the choice of vehicle classes. The nesting parameter for the purchase decision must be at least as large as

[9] The nesting parameters are sometimes known as "inclusive value coefficients."

the nesting parameters for vehicle type. For each vehicle type, the nesting parameter for the nest must be at least as large as the parameters for all vehicle classes contained within the top-level group. The nesting structure implies that vehicles within one group are closer substitutes for each other than they are for vehicles in different groups. The cross-price elasticities between vehicles within the same group are therefore higher than the cross-price elasticities for vehicles in different groups.

As noted above, one advantage of the nested logit model over the simple logit model is that it provides for a richer pattern of own- and cross-price elasticities. In the nested logit model, the IIA property need not hold across groups. That is, the ratio of the share for a particular car model in one bottom-level nest to the share of a vehicle in a different bottom-level nest, for example, depends not only on the characteristics of those two vehicle models, but also on the substitution patterns implied by the nesting structure and nesting parameters. The nesting parameters therefore enrich the simple logit model. If all nesting parameters equal one, then the nested logit model becomes a simple logit model.

For ease of notation, we define the inclusive value term for bottom-level group A (the vehicle class) as

$$I_A = \ln\left[\sum_{j\in A} \exp((\alpha_j - \beta P_j)/\lambda_A)\right]. \tag{3}$$

We also define an inclusive value term for top-level group X (the vehicle type) as:

$$I_X = \ln\left[\sum_{A\in X} \exp(I_A \lambda_A / \lambda_X)\right]. \tag{4}$$

Finally, we define an inclusive value term for the purchase alternative:

$$I_{buy} = \ln\left[\sum_{X} \exp(I_X \lambda_X / \lambda_{buy})\right] \tag{5}$$

The share of top-level group X in total purchase can then be written as:

$$s_{X|buy} = \frac{\exp(I_X \lambda_X / \lambda_{buy})}{\sum_Y \exp(I_Y \lambda_Y / \lambda_{buy})} \qquad (6)$$

Finally, the logit framework gives an expression for the proportion of potential buyers who choose to purchase a vehicle:

$$s_{buy} = \frac{\exp(I_{buy} \lambda_{buy})}{\exp(I_{buy} \lambda_{buy}) + \exp(\alpha_0)}, \qquad (7)$$

where α_0 is the value derived by the consumer from a no-purchase decision.

B-1.1.3 Market Simulation

The own-price elasticity of demand for alternative *i* can be written as:

$$\eta_i = -\beta P_i (1 - s_i), \qquad (8)$$

where s_i is the unconditional share of alternative *i* (i.e., its share over all potential consumers, not only those who choose to purchase a vehicle).

The aggregate price elasticity of demand can be calculated by increasing the prices of all goods by a common percentage, finding the percentage change in total demand, and taking the limit of this percentage change in demand as the percentage change in price goes to zero. The aggregate price elasticity of demand can be written as

$$E = -\beta \overline{P} (1 - s_{buy}) \qquad (9)$$

where s_{buy} is the fraction of potential purchasers who actually purchase a new vehicle and $\overline{P}$ is the sales-weighted average price of vehicles.

We assume that the motor vehicle market is characterized by a Bertrand competition where each manufacturer sets prices to maximize its overall profits, taking account the fact that it is a multi-product firm. In a Nash equilibrium for this Bertrand competition, the profit-maximizing price for a single-product firm can be written as follows (where MC_i is the marginal cost for alternative *i*, assumed constant):[10]

$$\frac{P_i - MC_i}{P_i} = \frac{1}{\eta_i}\ , \qquad \text{or}$$

$$P_i = MC_i + \frac{P_i}{\eta_i}\ . \tag{10}$$

If one observes P_i, then knowing either the marginal cost or the elasticity provides enough information to calculate the other.

For a multi-product firm (as is the case for all major auto firms in the United States), the pricing equations include additional terms that reflect the unit profits on other products made by the firm and the cross-elasticities of demand between good *i* and these other products. The basic logic is that as the price of good *i* increases, some of the lost sales of that good will be replaced by increased sales of other goods sold by the same firm.[11] Our model takes these effects into account.

B-1.1.4 Solving for Alternative-Specific Parameters

As described above, the nested logit choice framework offers a method to estimate consumer demand for differentiated products, using as data the prices and parameters that measure the relative attractiveness of each product. Using the logit framework, we solve simultaneously for the β parameter and "alternative-specific" parameters that are consistent with the observed market shares and prices. If two products in the same group have the same *price* but different market shares, then the one with the higher share must be more attractive to consumers. Similarly, if two products in the same group have the same *market share* but different prices, then the one with the higher price must be more attractive to consumers, since consumers are observed to pay a premium for it.

[10] See, e.g., Carlton and Perloff (1999) for a discussion of the Bertrand-Nash assumptions.

We use the logit framework to estimate alternative-specific parameters for each vehicle model. We make assumptions concerning the nesting parameters, the aggregate price elasticity of demand, and the price elasticity of demand for one specific alternative. Given the structure of our nested logit model, these assumptions, the observed prices, and the observed market shares are sufficient for us to derive estimates of the alternative-specific parameters (including those for the outside good).

B-1.1.5 Estimating Consumer Valuations of Vehicle Attributes

Once we calculate the alternative-specific parameters implied by the observed vehicle shares and prices, we are able to estimate the extent to which consumers value each vehicle attribute through a "second-stage" regression for the alternative specific parameters. For each vehicle in the sample, we regress the alternative specific parameters on vehicle characteristics such as horsepower, weight, and fuel economy.

We assume each vehicle's alternative-specific parameter depends upon the vehicle's type and attributes according to the following model:

$$\alpha = X\beta + D_{nest}\gamma_{nest} + \delta_{year}D_{year} + \phi_{make}D_{make} + \varepsilon \, , \qquad (11)$$

where

α is the alternative-specific coefficient,

X are vehicle characteristics,

D_{nest} are dummy variables corresponding to vehicle nests,

D_{year} are dummy variables corresponding to vehicle model years ,

D_{make} are dummy variables corresponding to the vehicle make (manufacturer),

ε is an error term capturing unobserved characteristics, and

(...continued)

11 See Berry, Levinsohn, Pakes (1995) or Goldberg (1995) for a discussion of these issues, among others.

β, γ_{nest}, δ_{year}, and ϕ_{make} are estimated parameters.

B-1.1.6 Effects of the Staff Greenhouse Gas Proposal

The additional costs of the Staff Greenhouse Gas Proposal will be reflected in higher vehicle costs. The new vehicle market model calculates each manufacturer's response to the additional costs in each year. The marginal cost of covered vehicles for each manufacturer is adjusted to reflect the technologies required to comply with the Staff Greenhouse Gas Proposal by 2016, including added costs and increased fuel efficiency.

B-1.2 Specific Implementation Parameters and Data

B-1.2.1 Vehicle Sales

Table B1-1 shows the manufacturers included in the analysis and their classification as either large or intermediate, which is relevant to the estimation of when and what regulation requirements apply. Each manufacturer produces a number of vehicle models, and many manufacturers produce more than one make of vehicle.

Table B1-1. Manufacturers Included in New Vehicle Market Model

Large Manufacturers	Intermediate and Small Manufacturers
DaimlerChrysler	BMW
Ford	Isuzu
GM	Mitsubishi
Honda	Porsche
Nissan	Subaru
Toyota	Volkswagen
Hyundai	

We use national and California-specific vehicle sales data from JD Power and Associates to determine the market share for each vehicle model, aggregated across trim levels, for the years 2001-2003. For each model year, we use sales over the period October – September to reflect as accurately as possible the timing of new model availability. We subtract California sales from nationwide sales to estimate the number of vehicles of each model sold outside California. If a vehicle sold less than 1,000 units nationally, the vehicle model was eliminated from the dataset. To avoid under-valuation of models that were either discontinued or that were first introduced during the middle of a model year because the actual sales would not be good estimates of their annual sales, we eliminated observations where the number of vehicles sold was dramatically smaller than in the previous or subsequent year for the same model.

B-1.2.2 Vehicle Prices

We use data on transaction prices for each model from JD Power and Associates for both California and the rest of the United States. The transaction prices are sales weighted and reflect the different prices charged for different trim levels. For a few models where data were missing, we supplemented the JD Power data with price data taken from the Automotive News Market Data Book.

B-1.2.3 Vehicle Fuel Economy Data

We use data derived from EPA's Fuel Economy statistics to reflect the fuel efficiency of each vehicle model. Specifically, we use the EPA adjusted average fuel economy for combined city and highway driving as the measure of fuel efficiency.

B-1.2.4 Other Vehicle Characteristics

We rely on data from Ward's for information about other vehicle attributes, including engine size, number of cylinders, curb or test weight, horsepower, length, and height. Missing data on average curb weight and width were supplemented using the Automotive News Market Data Book for the corresponding year.

B-1.2.5 Additional Information

We use vehicle categories from Automotive News Market Data Book to define the vehicle nesting structure depicted in Figure A-1.

B-1.2.6 Aggregate Market Elasticity and Vehicle Elasticities

Consistent with various literature sources, we assume an aggregate elasticity for the new vehicle market of –1.0.[12] We set the own-price elasticity of the "normalized" vehicle model (whose alternative-specific parameter is normalized to zero) to be –4.0, which is consistent with various other literature estimates of individual model own-price elastiticies.[13]

B-1.2.7 Nesting Parameters

The nesting parameters for nested logit models represent the similarity between choices for vehicles falling within the same "nest." The nesting parameters influence the relative substitutability within each nest, and also between different nests. Nesting parameters may take any value between zero and one, with lower values indicating greater similarity between the alternatives within the respective nest. We use nesting parameters that yield appropriate elasticities for the various vehicle models and classes. For the "Buy" nest we use a nesting parameter equal to 0.9, for vehicle types we use a nesting parameter equal to 0.6 and for vehicle classes we use nesting parameters equal to 0.3.

B-1.2.8 New Vehicle Marginal Cost

The model estimates marginal costs for each model based on the profit-maximization condition applied to each manufacturer as shown in Equation 10. This condition assumes that each manufacturer chooses prices for its vehicle offerings that will maximize its profits, taking into account the new vehicle marginal costs, the sensitivity of consumer demand to changes in vehicle prices, and the availability to consumers of substitute vehicles offered by that manufacturer and its competitors. In general, the model uses vehicle prices and assumptions about consumer responses to changes in those prices to calculate marginal costs that are consistent with both profit-maximizing behavior and the observed market shares. Marginal costs for each vehicle are calculated based on each vehicle's calculated elasticity.

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12 See, e.g., Gruenspecht (2000).

13 See for example Berry, Levinsohn, and Pakes (1995).

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ATTACHMENT B-2: SCRAPPAGE MODEL

This Attachment provides information on the scrappage model developed for this study.

B-2.1 Vehicle Prices and Scrappage Behavior

The idea that *economic* as well as technical considerations can influence the life spans of durable capital goods such as motor vehicles has long been recognized. Specifically, the logic underlying the linkage between a vehicle's market value and its service lifetime was first explicitly recognized more than three decades ago. This logic is straightforward: a vehicle is retired from service (or scrapped) when the difference between its resale price in working condition and its scrap value—a measure of the *increase* in its value from maintaining the vehicle in working condition—exceeds the maintenance or repair outlay necessary to do so.

Building on this basic insight, early research by Walker (1968) and Parks (1977) investigated the influence of a vehicle's market value, as well as characteristics such as its age, on the vehicle owner's decision to retire the vehicle from service rather than maintain it in working condition. Both authors present statistical evidence of the influence of vehicle prices on the scrappage rates of used vehicles of different model year vintages and ages, demonstrating that variation in automobile prices exerts a detectable influence on scrappage rates of used cars. Applying a model based on the same underlying logic recognized by Parks to international data, Manski and Goldin (1982) subsequently demonstrated that increasing prices for used automobiles can extend their service lifetimes significantly. Berkovec (1985) later incorporated the framework developed in this earlier research in a model encompassing new automobile production and sales activity, vehicle pricing behavior, and scrappage of used autos.

Drawing on previous results, Gruenspecht (1982) recognized that the connection between new and used vehicle prices—whereby rising prices for new models exert an upward "pull" on resale prices for used vehicles—meant that changes in prices for new automobiles could influence scrappage decisions by older cars' owners. As a result, he hypothesized, emissions regulations that raised production costs and sales prices of *new* vehicles might retard the scrappage and replacement of older models sufficiently to offset the reduction in conventional emissions from introducing cleaner new models into the vehicle fleet.

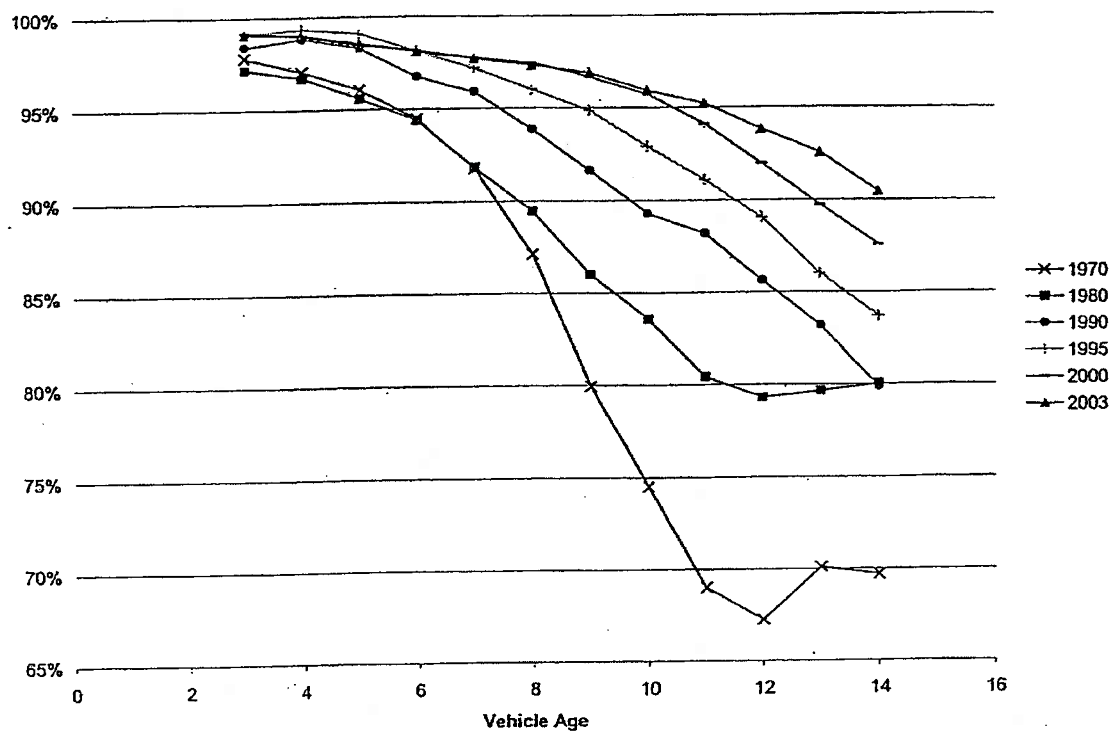
Gruenspecht's research produced compelling evidence that the increase in new car prices resulting from manufacturers' compliance with the 1980-81 federal emissions standards could be sufficient to have this effect. This present study can be considered as an updated version of Gruenspecht's statistical model relating used vehicles' scrappage rates to new vehicle prices. This model is used to examine whether or not—recognizing these plausible but typically overlooked responses—the Staff Greenhouse Gas Proposal could raise sale prices for new passenger vehicles sufficiently to have the unintended effect of increasing *fleet-wide* total emissions of conventional pollutants.

B-2.2 Model Developed in this Study

The vehicle scrappage model developed here is based on well-established economic theory and empirical evidence on the response of owners' decisions about retiring (or "scrapping") used vehicles to changes in economic factors. The model estimated a relationship between scrappage or retirement rates for vehicles of different model year vintages at each age during their lifetimes to macroeconomic conditions (such as the unemployment rate), factors affecting total motor vehicle ownership and use, and prices for repairing or replacing used vehicles. This relationship was developed using various data and statistical procedures appropriate for these data.

Our study estimates a "reduced-form" scrappage model using aggregate scrappage rates for the individual vehicle model years comprising the U.S. passenger vehicle fleet over the 1970-2002 period (rather than the scrappage rates for individual vehicle models originally employed by Gruenspecht). Updating results from Gruenspecht's earlier model is necessitated by dramatic increases in the expected lifetimes and average ages of passenger vehicles that have occurred since that time. Figure B2-1, which displays yearly survival rates of vehicles manufactured during different model years, illustrates these changes.

Figure B2-1. Vehicle Survival Rates by Age and Calendar Year



Source: NERA/Sierra calculations based on data from R.L. Polk & Company
Note: Each series presented in the figure show survival rates of vehicles of different ages in a given calendar year.

B-2.3 Basic Theory of the Model

A vehicle's owner will retire the vehicle from service and sell it for its scrap value if its value in working condition exceeds its scrap value by less than the cost of any repairs necessary to maintain it in working condition. Since the expected cost of these repairs depends on how long a vehicle has been in service as well as on the materials and manufacturing technology employed when it was produced, the probability that it will be scrapped is likely to depend on *both* its original model year and its age. To some extent, a vehicle's age may simply be a surrogate measure of its accumulated usage, although its age *per se* may also affect its sale value in working condition and thus the likelihood that it will be retired.

At the aggregate or fleet-wide level, the scrappage rate among a "cohort" of vehicles in service (measured by the proportion of those in service at the beginning of a year that are retired or scrapped before it ends) will thus depend on both their model year and their age during that year. Owners' decisions to retire vehicles from service also depend on the costs of repairs necessary to keep them in service. Because prices for *new* vehicles are in turn an important influence on those for used vehicles of different ages, scrappage rates for vehicles of each model year comprising the fleet during a calendar year are likely to be affected significantly by changes in new vehicle prices and the myriad factors that determine them (including manufacturers' costs for complying with government regulations).

Finally, scrappage rates for all model years in service are also likely to be affected—although not necessarily uniformly—by changes in other economic variables such as employment or personal incomes, and costs for financing vehicle purchases. This occurs because keeping used vehicles in service longer provides a temporary mechanism for accommodating increases in total demand for motor vehicle travel that result from sudden or unforeseen changes in economy-wide conditions. Extending the service lifetime of a used vehicle in order to accommodate increased travel demand is accomplished by deferring its retirement beyond the age at which it would otherwise have occurred, a response that reduces the aggregate scrappage rate for vehicles of various ages.

B-2.4 Model Variables and Data Sources

The data used to develop our model of these empirical relationships include scrappage rates calculated from U.S. annual vehicle registration data for the years 1970 through 2003. During each calendar year of this period, we use registration data for passenger vehicles reported by R.L. Polk & Company to calculate scrappage rates for vehicles of ages 3 through 18 years. While the specific types of vehicles included in these registration data—and thus in the scrappage rates used to develop our model—vary slightly over the extended period covered by our study, for most of those periods they closely match those encompassed by Staff Greenhouse Gas Proposal and the federal government's Corporate Average Fuel Economy (CAFE) standards. Recognizing the "panel" nature of the data used to develop it, the scrappage model also includes categorical, age specific variables (termed "fixed effects" in statistical analysis).

Each of the scrappage model variables is summarized below, along with the specific rationale for including it and a brief description of the specific data source used to measure it.

1. *Equivalent Vehicle Stock.* This variable represents the number of new vehicles that would have been required to provide the total amount of VMT driven during the *previous year* by vehicles of all ages. It is intended to measure the effect of previously postponed scrappage and replacement of older vehicles due to macroeconomic conditions on scrappage in subsequent periods; higher values of the variable are expected to reduce scrappage of older vehicles. The measure is calculated from total annual miles driven by automobiles plus two-axle, four tire trucks, as reported by the U.S. Federal Highway Administration in its annual *Highway Statistics*, divided by average annual miles driven in new light-duty vehicles, tabulated from the Federal Highway Administration's Nationwide Personal Transportation Surveys conducted during various years.

2. *Unemployment Rate.* This variable measures the effect of macroeconomic conditions on vehicle scrappage; higher unemployment during periods of slow economic growth or recession may cause vehicle owners to delay scrappage and replacement of older vehicles. It is measured by the annual unemployment rate among males aged 19-65 years of age, as reported by the U.S. Bureau of Labor Statistics.

3. *Interest Rates.* Interest rates for new car loans are a component of the cost of owning motor vehicles, and thus of the cost of motor vehicle travel. As interest rates rise, new vehicle ownership becomes more expensive relative to owning used vehicles, which should delay used vehicle owners' decisions to scrap and replace them with new vehicles. The measure employed is the average financing rate on new automobile loans, compiled by the Federal Reserve Board along with other historical terms of credit figures. Historical rates are adjusted to remove the component of the interest rate representing expected price inflation using the CPI deflator (reported by the Bureau of Labor Statistics).

B-2.5 Model Form and Estimation

The specific mathematical form of the scrappage model employs the measure

$$\ln[s/(1-s)]$$

as its dependent variable, where s is the aggregate scrappage rate for vehicles of an individual model year at a specific age, and ln(.) denotes the natural logarithm of the quantity in brackets. This transformation of the scrappage rate, sometimes called the "logit" of the scrappage rate, converts a measure bounded by the values zero and one—and in practice varying over a much narrower range—to one spanning a wider range of values. Using the transformed value of the scrappage rate as the model's dependent variable allows the estimated coefficients to exhibit desirable statistical properties.

B-2.6 Statistical Results

The resulting model performs well in explaining variation among scrappage rates across the wide range of model years and extended historical period spanned by the underlying data. Table B2-2 presents the statistical coefficient estimates and other results of the estimated model in detail. The arithmetic signs and general magnitudes of the estimated coefficients for nearly all of the model's variables reflect the directions and magnitudes of the effects on scrappage rates anticipated in the preceding discussion, while the patterns of variation among the estimated coefficients that differ by vehicle age also accord largely with expectations. The exception is the coefficient on the age-3 vehicle variable which is positive (though statistically insignificant). Most of the coefficient estimates for vehicle age and new car price-age interactions are statistically significant. In addition to the age coefficients, the unemployment rate and equivalent vehicle stock variables also indicate statistically significant impacts on scrappage rates.

Table B2-2. Coefficient Estimates for Model of Age-Specific Vehicle Scrappage Rates

Dependent Variable	ln[(s/(1-s)]	**Sample Period**	1970-2002
New Car Price Series	Real New Car Price	**# Observations**	433
Scrappage Rate Measure	Polk Registration	**R-square**	0.937
Fixed Effects	Model Years (decades)	**Standard Error of Estimate**	0.310
		F(32, 400)	185.503

Variable	Coefficient	Std. Error	t-statistic
Constant	-4.064835	0.605654	-6.711486
Age dummy - 4 yrs	2.043355	0.719472	2.840074
Age dummy - 5 yrs	3.122724	0.721724	4.326758
Age dummy - 6 yrs	3.406926	0.724980	4.699338
Age dummy - 7 yrs	4.835749	0.729167	6.631883
Age dummy - 8 yrs	5.730339	0.734846	7.798015
Age dummy - 9 yrs	6.664502	0.742118	8.980378
Age dummy - 10 yrs	7.071725	0.751474	9.410470
Age dummy - 11 yrs	7.139856	0.765071	9.332283
Age dummy - 12 yrs	6.809210	0.778405	8.747640
Age dummy - 13 yrs	6.205812	0.792765	7.828062
Age dummy - 14 yrs	5.579172	0.803655	6.942248
Age dummy - 15 yr and up	4.919242	0.807552	6.091546
New car price x Age dummy 3 yrs	0.064313	0.035801	1.796392
New car price x Age dummy 4 yrs	-0.042297	0.035948	-1.176613
New car price x Age dummy 5 yrs	-0.082146	0.036179	-2.270548
New car price x Age dummy 6 yrs	-0.071240	0.036448	-1.954563
New car price x Age dummy 7 yrs	-0.131457	0.036715	-3.580479
New car price x Age dummy 8 yrs	-0.158635	0.037051	-4.281531
New car price x Age dummy 9 yrs	-0.190126	0.037484	-5.072249
New car price x Age dummy 10 yrs	-0.194360	0.038067	-5.105778
New car price x Age dummy 11 yrs	-0.184288	0.038752	-4.755619
New car price x Age dummy 12 yrs	-0.155272	0.039415	-3.939462
New car price x Age dummy 13 yrs	-0.116102	0.040101	-2.895217
New car price x Age dummy 14 yrs	-0.077483	0.040495	-1.913378
New car price x Age dummy 15 yrs and up	-0.039098	0.041205	-0.948874
Real scrap steel price	-0.000081	0.000513	-0.157391
Equivalent vehicle stock	-0.000010	0.000002	-5.873363
Unemployment rate	-7.913386	1.376384	-5.749402
Real interest rate on new car loans	-0.447412	1.202340	-0.372117
Model year dummy – 1970's	-0.049568	0.079984	-0.619716
Model year dummy – 1980's	0.220696	0.081735	2.700128
Model year dummy – 1990's	0.300491	0.062707	4.791979

The model highlights the sensitivity of scrappage rates to changes in new vehicle prices. As expected, rising prices for new models significantly reduce scrappage rates for vehicles of ages from four to fifteen plus years. Our model allows new vehicle prices to have different effects on scrappage of used vehicles of different ages. The effect gradually increases with age until age-10, and then slightly decreases. Table B2-3 shows the calculated price elasticity of scrappage that the model implies for each age group.

Table B2-3. Price Elasticities of Scrappage for Calendar Year 2003

Model Year	Current age	Scrappage rate	Percent of fleet	Price elasticity
2000	3	0.912	6.80%	1.27
1999	4	0.963	6.20%	-0.835
1998	5	1.424	5.80%	-1.614
1997	6	1.895	6.00%	-1.393
1996	7	2.299	5.60%	-2.56
1995	8	2.687	6.50%	-3.077
1994	9	3.097	5.60%	-3.672
1993	10	4.055	5.50%	-3.717
1992	11	4.787	5.00%	-3.497
1991	12	6.169	5.00%	-2.904
1990	13	7.44	4.80%	-2.142
1989	14	9.545	4.70%	-1.397
1988	15	11.434	4.20%	-0.69
1987	16	12.991	3.60%	-0.678
1986	17	13.866	3.00%	-0.671
1985	18	15.515	2.30%	-0.658
Total	All	5.082	80.6%	-1.828

B-2.7 Using the Scrappage Model

We used our estimates of the effects of changes in prices predicted under Staff Greenhouse Gas Proposal in conjunction with the age-specific effects of new vehicle prices on scrappage rates produced by our model to simulate future changes in the age distribution of these vehicles in the United States. Specifically, we estimated the *changes* in scrappage rates for vehicles of each age from three to eighteen years predicted by the model's coefficients to result from a specified increase in the average sales price of new vehicles.

These age-specific changes in scrappage rates were then applied to scrappage rates for vehicles of each corresponding age reflected in the "Base Case" vehicle population forecast generated with the ARB Staff's EMFAC2002 model vehicle base case populations. We assumed that scrappage rates for vehicles less than three years old would not change in response to higher prices for new vehicles. At the same time, we assumed that scrappage rates for vehicles older than fifteen years would change from their Base Case values so that they always accounted for the same proportion of scrappage within this age. This latter assumption causes our simulated changes in the age distribution of the California fleet and in its emissions to be conservative relative to those resulting from different but equally reasonable assumptions about scrappage of older vehicles.

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ATTACHMENT B-3: VMT MODEL

NERA has developed a model to project changes in the vehicle miles of travel ("VMT") due to the Staff Greenhouse Gas Proposal. One of the effects of the Staff Greenhouse Gas Proposal would be to increase motor vehicle fuel efficiency, which implies a decrease in the cost of travel. The VMT model examines how this side effect will influence VMT, using data on VMT and gas prices in California. The sections below discuss the relationship of VMT to the cost of travel (the "rebound effect"), outline the conceptual approach for the VMT model, and describe the data and parameters used in the model. The final section provides the results of the VMT model.

B-3.1 The Rebound Effect

Basic economic theory indicates that, other things equal, decreasing the price of a good will raise the amount of the good demanded. Specifically, decreasing the cost-per-mile of travel will increase the number of miles traveled. Thus, a regulation that decreases the cost of travel (as would the Staff Greenhouse Gas Proposal) will increase VMT. Since an increase in VMT implies an increase in emissions, whatever gains are associated with the regulation will be mitigated by the increase in VMT. This effect is an example of a "rebound effect"—a case in which the desired results of some policy are reduced by an opposing effect. For the present case, the rebound effect is measured by the elasticity of VMT with respect to cost-per-mile of travel.

Several empirical studies have explored the rebound effect associated with VMT and cost-per-mile for the entire U.S. Green, Kahn, and Gibson (1999) estimate an overall rebound effect of 23 percent, Schimek (1996) estimates rebound effects of 7 percent for the short term and 29 percent for the long term, and Houghton and Sarkar (1996) estimate rebound effects of 16 percent for the short term and 22 to 23 percent for the long term. Recently, the Congressional Budget Office ("CBO") (2003) reported a 20 percent rebound effect for the U.S. based upon their review of studies. However, none of these studies estimates a rebound effect specifically for California.

Many components contribute to the cost of travel, including maintenance and time costs, but the major out-of-pocket cost is the cost of gasoline. Fuel efficiency and the price of gasoline together provide a direct measure of the fuel-related cost-per-mile of travel. For a given motor vehicle, cost-per-mile can be approximated as the price of gasoline divided by fuel efficiency (price per gallon/miles per gallon = price per mile).

The VMT model estimates the rebound effect by relating changes in VMT to changes in the price of gasoline. The result applies equally well to the effects of the Staff Greenhouse Gas Proposal, since a decrease in MPG has the same impact on the price per mile as does an increase in the price of per gallon.

B-3.2 Conceptual Model

The VMT model is based on observations that track the behavior of individual vehicles over time. Each observation incorporates two data measurements for a single vehicle, separated by several months. The model estimates the following equation:

$$VMT_d = \alpha + \beta P + \gamma X + \varepsilon, \qquad (1)$$

where VMT_d is the average VMT per day between two measurements; P is the average price of gasoline between two measurements; X includes population density, month indicators, county indicators, and vehicle make, model, and model year indicators; and ε is the unobserved error term. Population density is included as a measure of urbanization, which we expect to influence VMT. The rest of the variables included in X are dummy variables that capture fixed effects for seasons, locations, and vehicle types.

Other things equal, a percentage change in the price of gas implies the same percentage change in the fuel cost-per-mile of travel. Thus, the elasticity of VMT with respect to fuel cost-per-mile is the percent change in VMT divided by the percent change in the price of gas (that is, $\Delta VMT/VMT$ divided by $\Delta P/P$).[14] Since the estimated coefficient β in our model describes the behavior of $\Delta VMT/\Delta P$, we can estimate the elasticity of VMT with respect to fuel cost-per-mile as follows:

[14] Since VMT is determined by fuel price per mile plus other costs—and thus fuel costs are only one component of the "total" cost per mile of driving, the elasticity of VMT with respect to fuel cost will be only a fraction of the elasticity with respect to total cost per mile. Nevertheless, the elasticity of VMT with respect to fuel price is the same value as the elasticity with respect to fuel efficiency (miles per gallon).

$$E = (\text{Mean } P \div \text{Mean } VMT_d) \times \beta, \quad (2)$$

where the mean values are taken over all observations.

B-3.3 Data and Parameters

The primary data for the VMT model came from the California Smog Check system, which catalogues vehicle inspections by their vehicle identification number ("VIN").[15] The sample covered inspections from June 1998 through November 2003, and provided data on vehicle inspection dates, VINs, odometer readings, and inspection station identification numbers. For each vehicle inspected, the VIN indicates the make, model, and model year of the vehicle. Additionally, VINs make it possible to track the information on a single vehicle through two successive inspections.

The full data set contained over 26 million observations (sets of two successive inspections of a single vehicle). To make the dataset uniform and reliable, we removed observations based on three criteria:

- We removed all observations of vehicles with invalid VINs. Because we were only able to verify VIN numbers for vehicles made in or after 1981, we removed all observations of vehicles with pre-1981 model years.
- We removed all observations whose inspections were separated by less than 23 months or more than 25 months, to produce a more uniform dataset than the original. Since the California Smog Check system requires that a vehicle be inspected once every two years, we considered observations that met this requirement to be the most reliable. (Observations that did not meet this requirement likely resulted from a change in ownership of the vehicle.)
- We removed all observations whose odometer readings were negative or zero in either inspection or whose odometer readings decreased between the first and second inspections. Such odometer readings clearly represent errors in the inspections, and hence unreliable data.

The inspection station identification number from each inspection can be mapped to the zip code in which the inspection took place. This information allowed us to match each observation to a specific county. Additionally, we obtained county-specific population density

[15] These data were provided by Sierra Research Inc., which maintains a detailed file on Smog Check data.

data from the US Census Bureau's 1990 Census and zip-code-specific gasoline price data from the Oil Price Information Service ("OPIS"). We calculated the average price of gasoline between inspections as the average weekly price of gasoline for all weeks between the inspections, weighted by the number of days in that week between the inspections (including the inspection days). So, if, for some observation, the first inspection had occurred on a Wednesday, the price of gasoline during that week was weighted by four days. We calculated VMT_d as the difference in odometer readings from the second and first inspections, divided by the number of days between the inspections (including inspection days). To determine the values of the month indicators, we matched each observation to the month of its second inspection. Because all of our observations had relatively uniform time intervals between inspections, this method for assigning month intervals was also uniform.

The final data set contained 5,971,029 observations. Note that this number is based on twice as many inspections in the original data.

B-3.4 Results

As discussed in the previous section, the inspection station identification numbers from each inspection allowed us to identify each observation with a single county. However, there were many observations for which the first inspection occurred in a different county from the second. So we estimated the VMT model twice—first letting the second inspection's location determine the location of the observation, and then letting the first inspection's location determine the location of the observation.

Table B3-1 shows the results of ordinary least squares estimations on our model. The first line of results comes from an estimation that included all 5,971,029 observations. The line contains all of the results that go into the calculation of the elasticity of VMT with respect to cost-per-mile, and the estimated elasticity. Of all the observations in the original estimation, 19,588 (.33 percent) had values of VMT_d above 200, and 2,477 (0.04 percent) had values of VMT_d above 1000. To ensure accurate results, we checked to see whether these outliers had influenced the estimation substantially. We re-estimated the model seven times, successively excluding the observations with values of VMT_d larger than 1,000, 800, 600, 500, 400, 300, and 200 miles per day. The table shows these results below the results of the original estimation.

Table B3-1. Results with Location Determined by Second Inspection Station

VMT_d Range Allowed	Observations	Mean Values: VMT_d (Miles)	Mean Values: P (Gal./$)	Estimated Coefficient (ß)	Standard Error of ß	Elasticity E = (P/VMT)*ß
All	5,971,029	30.37	1.70	-2.81	0.222	-0.16
[0,1000]	5,968,552	29.91	1.70	-2.98	0.178	-0.17
[0,800]	5,966,814	29.66	1.70	-3.05	0.155	-0.18
[0,600]	5,965,339	29.49	1.70	-3.03	0.142	-0.18
[0,500]	5,964,577	29.43	1.70	-3.05	0.138	-0.18
[0,400]	5,963,170	29.33	1.70	-3.03	0.133	-0.18
[0,300]	5,960,485	29.19	1.70	-3.08	0.127	-0.18
[0,200]	5,951,441	28.87	1.70	-3.07	0.117	-0.18

Table B3-2 shows more results of OLS estimations on our model, under the interpretation that the location of an observation is the location of its first inspection station. Again, we checked to see whether observations with outlying values of VMT_d had influenced the estimation substantially.

Table B3-2. Results with Location Determined by First Inspection Station

VMT_d Range Allowed	Observations	Mean Values: VMT_d (Miles)	Mean Values: P (Gal./$)	Estimated Coefficient (ß)	Standard Error of ß	Elasticity E = (P/VMT)*ß
All	5,971,029	30.37	1.70	-3.22	0.222	-0.18
[0,1000]	5,968,552	29.91	1.70	-3.35	0.178	-0.19
[0,800]	5,966,814	29.66	1.70	-3.38	0.155	-0.19
[0,600]	5,965,339	29.49	1.70	-3.35	0.142	-0.19
[0,500]	5,964,577	29.43	1.70	-3.38	0.138	-0.20
[0,400]	5,963,170	29.33	1.70	-3.33	0.133	-0.19
[0,300]	5,960,485	29.19	1.70	-3.40	0.127	-0.20
[0,200]	5,951,441	28.87	1.70	-3.43	0.117	-0.20

In both cases, outlying values of VMT_d had only small effects on our results. To be conservative, we take the results that reflect all values of VMT_d to be our best estimates. Since there is no clear reason to treat the first inspection as a better indicator of location than the second inspection station, or vice versa, we use –0.17 as our estimate of the elasticity of VMT with respect to cost-per-mile. That means that if the cost-per-mile of travel in California decreases by 10 percent, then the VMT in California will increase by 1.7 percent. Our estimated rebound effect for California, then, is 17 percent.

B-3.5 Using the VMT Model

We have estimated a 17 percent rebound effect for California between 1998 and 2003. However, rather than assume that this rebound effect will remain constant through 2020, we have assumed that the relationship between VMT and cost-per-mile is described by a linear demand curve, so that the elasticity of VMT with respect to cost-per-mile will vary with cost-per-mile. We used the results of the VMT model to determine initial parameters (the constant and the coefficient of cost-per-mile) for the linear demand curve. Then, using forecasted cost-per-mile data from the EIA 2004 Annual Energy Outlook, we adjusted the parameters for each year so that the EMFAC2002 base-case VMT and the cost-per-mile fit the demand curve described by the two parameters. The parameters and the cost-per-mile determine the elasticity of VMT with respect to cost-per-mile. By this procedure, our estimated rebound effect for California in 2020 is 16 percent.

The Fleet Population Model uses the estimated rebound effect for each calendar year to calculate the change in VMT due to the Staff Greenhouse Gas Proposal. Before implementing the rebound effect, we normalize the adjusted VMT so that it totals to the total base case VMT. Thus, the changes in VMT that we report reflect only the rebound effect.

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ATTACHMENT B-4: POLLUTANT EMISSIONS MODEL

This Attachment describes the development and use in this study of the EMFAC2002 Fleet Emissions Model (an Excel spreadsheet model). Consistent with the August Staff Report, this study uses the April 23, 2003, version of EMFAC2002 to generate estimates of the impacts of the Staff Greenhouse Gas Proposal on criteria pollutants in California.[16] The model accounts for "fleet-turnover" effects and "rebound" effects on emissions of ROG, NO_x, CO, and PM_{10}. The discussion below summarizes the methodology used to develop model-year specific gram-per-mile ("g/mi") emission factors, vehicle populations, and VMT and how those parameters were altered to account for the emissions impacts for the various scenarios investigated in this study.

B-4.1 Baseline Model-Year Specific Emissions, Population, and VMT

The baseline model-year specific emission rates, vehicle populations, and VMT were generated by running EMFAC2002 for each individual model year present in the calendar year being evaluated. For example, a calendar year 2020 EMFAC2002 run includes vehicles from the 1976 model year through the 2020 model year (45 model years total). The model output consists of ton-per-day emissions results, which were divided by the estimated daily VMT by vehicles of that model year to arrive at g/mi emission rates for each model year. The model runs were configured to output statewide annual-average emissions, and estimates were prepared separately for the passenger car (PC), light-duty truck 1 (LDT1), light-duty truck 2 (LDT2), and medium-duty vehicle (MDV) classes (which cover all light-duty vehicles through 8,500 lbs. gross vehicle weight rating).

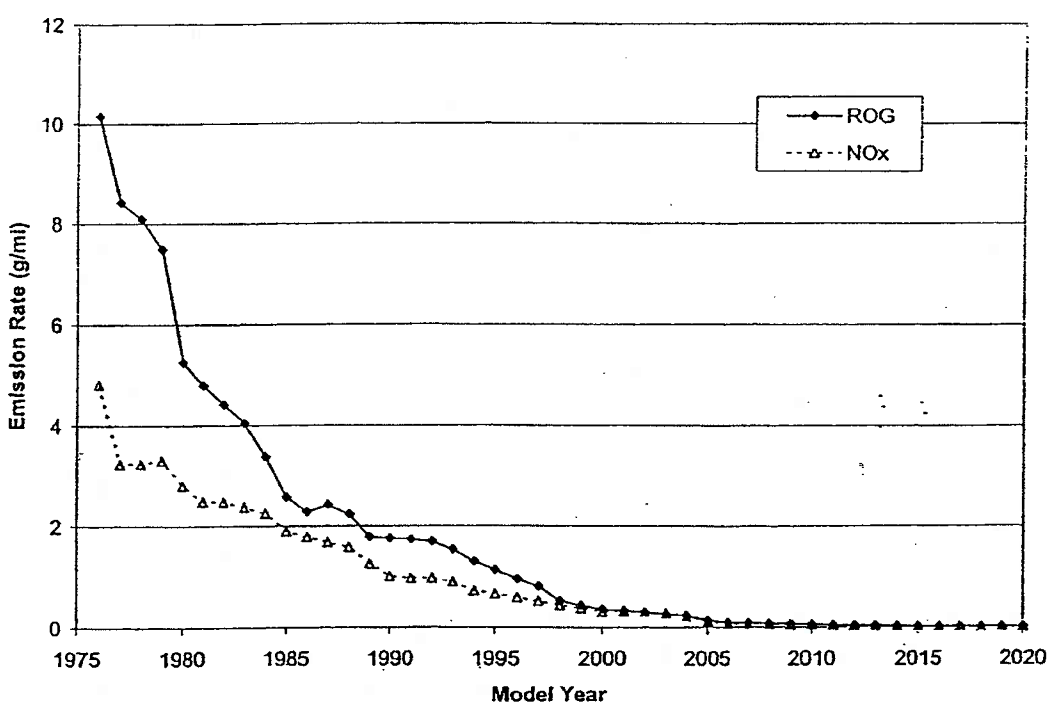
The ROG (exhaust and evaporative emissions combined) and NO_x emission rates developed in this manner are illustrated in Figure B4-1 for passenger cars. Of particular interest in this figure is the very large increase in g/mi emissions for the older model year

[16] The EMFAC2002 model can be downloaded from CARB's internet website at http://www.arb.ca.gov/msei/on-road/latest_version.htm. Note that the executable version of the model used by Sierra was recompiled from the Fortran code to allow reporting of the ton-per-day emissions estimates to four digits past the decimal point rather than two. This is necessary when calculating gram-per-mile emission rates for some vehicle classes and model years that have a relatively small population.

vehicles relative to the newer vehicles, which holds true for both pollutants. It is for this reason that relatively small shifts in the age distribution of vehicles in the fleet can have a significant negative impact on the emission inventory (i.e., this is the "fleet-turnover" effect).

The model year specific g/mi emission rates developed as described above were used in conjunction with vehicle populations and daily VMT by vehicle age to generate ton-per-day ("tpd") emissions estimates. Emission inventory estimates for the state were generated by multiplying the vehicle population (by model year) by the per-vehicle average daily VMT (by model year) and the g/mi emission rate (by model year). These products were then summed over all model year vehicles in the fleet (e.g., 1976 through 2020 for a calendar year 2020 analysis) to obtain the inventory for the scenario being analyzed. A sample of the calculation for baseline exhaust ROG emissions from passenger cars is shown in Table B4-1, and a comparison of the results directly from EMFAC2002 versus those obtained with the emissions model developed for this effort is shown below.

Figure B4-1. EMFAC2002 Passenger Car ROG and NO_x Emission Rates



As observed above, the Fleet Emissions Model overpredicts PC exhaust ROG emissions by 0.02 tpd relative to a standard EMFAC2002 run (likely a result of rounding differences), while the NO_x estimates from the two models are identical.

As described in the next section of this Attachment, the fleet-turnover effects are estimated by modifying the baseline vehicle population, and the rebound effects are calculated by modifying the baseline VMT per vehicle estimates from EMFAC2002.

Table B4-1. Summary of 2020 Statewide Passenger Car Exhaust ROG Inventory Calculation

Model Year	Total Passenger Cars	Daily VMT (mi/day)	Exhaust ROG (g/mi)	Exhaust ROG (tpd)
2020	1,124,930	46.7	0.006	0.36
2019	1,106,550	45.0	0.007	0.39
2018	1,058,340	43.5	0.008	0.39
2017	1,023,900	42.0	0.009	0.41
2016	993,193	40.5	0.010	0.45
2015	980,507	39.2	0.011	0.47
2014	951,225	37.8	0.014	0.55
2013	918,807	36.5	0.015	0.57
2012	886,918	35.3	0.017	0.57
2011	854,996	34.1	0.019	0.60
2010	832,437	32.9	0.024	0.71
2009	779,230	31.7	0.026	0.72
2008	721,409	30.7	0.029	0.70
2007	660,796	29.7	0.033	0.70
2006	597,716	28.7	0.036	0.67
2005	545,798	27.7	0.055	0.91
2004	471,116	26.8	0.090	1.26
2003	393,009	25.9	0.097	1.09
2002	324,022	25.1	0.111	0.99
2001	270,482	24.2	0.117	0.84
2000	237,767	23.5	0.122	0.75
1999	217,839	22.7	0.183	1.00
1998	181,150	21.9	0.249	1.09
1997	166,353	21.1	0.331	1.28
1996	134,564	20.4	0.362	1.09
1995	145,889	19.8	0.420	1.33
1994	119,836	19.1	0.494	1.25
1993	109,915	18.5	0.681	1.52
1992	98,200	17.8	0.803	1.55
1991	111,252	17.2	0.804	1.70
1990	108,523	16.8	0.830	1.67
1989	110,213	16.3	0.826	1.63
1988	97,077	15.7	0.810	1.36
1987	85,778	15.2	0.833	1.20
1986	67,892	14.7	0.870	0.96
1985	55,493	14.2	0.968	0.84
1984	42,413	13.8	1.594	1.03
1983	25,138	13.3	1.923	0.71
1982	18,528	13.0	2.150	0.57
1981	14,208	12.5	2.310	0.45
1980	11,637	12.1	2.348	0.36
1979	13,758	11.7	3.668	0.65
1978	11,280	11.2	3.910	0.55
1977	7,978	10.9	4.011	0.38
1976	5,114	10.5	3.847	0.23
			Total Exhaust ROG (tpd):	**38.53**

B-4.2 Impacts of the Proposed Regulation

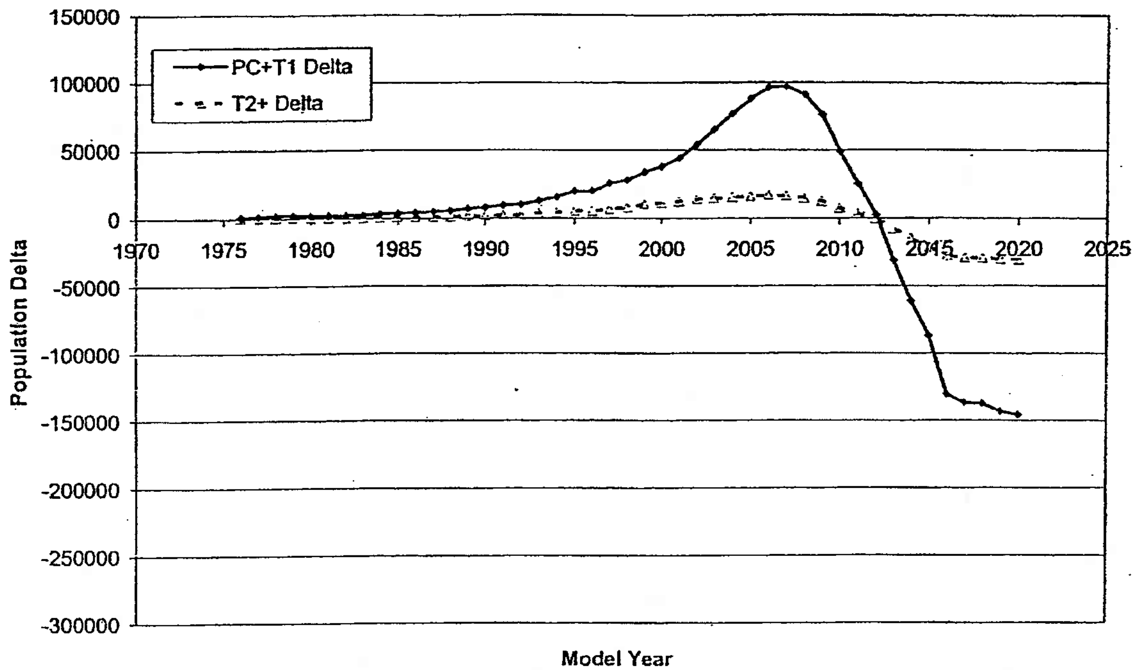
There are two primary effects from implementing the proposed regulation that will impact criteria pollutant emissions: fleet-turnover effects and rebound effects. These are discussed below.

B-4.2.1 Fleet-Turnover Effects

As noted elsewhere in this report, the new vehicle price increases that result from the Staff Greenhouse Gas Proposal regulations will have a significant impact on fleet turnover, causing reduced new vehicle sales and the retention of older, higher-emitting vehicles. This can have a substantial impact on the criteria pollutant emissions inventory, as older vehicles in the fleet can have emission rates that are a hundred times higher than those of new vehicles (see Figure D-1). Obviously, any increase in travel from these vehicles has a negative impact on the emissions inventory and air quality.

An example of the change in the distribution of vehicles in the fleet as a result of the proposed regulations is shown in Figure B4-2. This figure illustrates the change in the statewide vehicle population in 2020, where a positive number reflects more vehicles than in the baseline case and a negative number reflects fewer vehicles than in the baseline case. As observed in the figure, the population of pre-2012 model year vehicles is increased and the population of 2012 and newer model year vehicles is decreased relative to the base case. This change in vehicle population, which results in an older vehicle fleet, also results in increased ROG, CO, NO_x, and PM_{10} emissions compared to the baseline fleet.

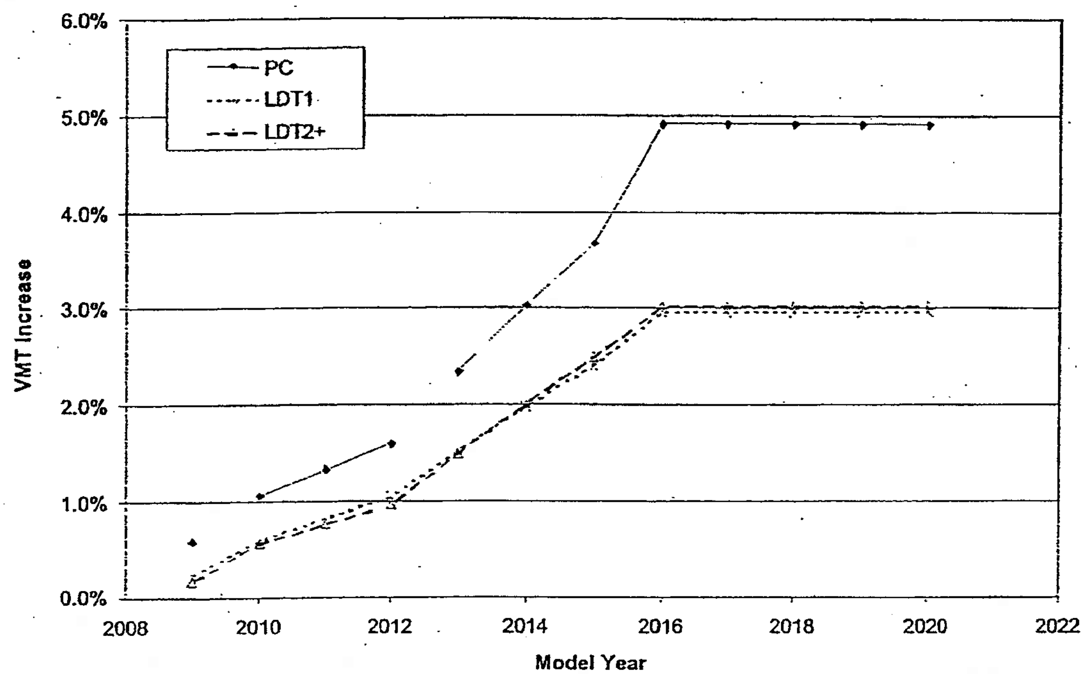
Figure B4-2. Example of the Change in Statewide 2020 Vehicle Population Estimates as a Result of the Staff Greenhouse Gas Proposal



B-4.2.2 Rebound Effects

Also as noted elsewhere in this report, a secondary outcome of the improved fuel economy required by the Staff Greenhouse Gas Proposal regulations is additional VMT being accumulated by those vehicles subject to the regulations (i.e., the "rebound" effect). As the cost of travel decreases, total VMT increases. An example of this effect is illustrated in Figure B4-3, which shows that VMT accrual is estimated to increase from the 2009 model year (the first year of the regulation) to the 2016 model year (when the regulation is fully phased in).

Figure B4-3. NERA/Sierra Estimates of the Per-Vehicle Increase in VMT from the Rebound Effect



B-4.2.3 Emissions Impacts of Fleet-Turnover and Rebound Effects

The emissions impacts of the fleet-turnover and rebound effects were calculated by simply modifying the baseline vehicle population estimates and the baseline per-vehicle VMT estimates in the spreadsheet model developed for this effort. Fleet turnover impacts all model year vehicles, while the rebound effect is only applied to vehicles subject to the regulation (i.e., 2009 and newer model years). For this analysis, the following four scenarios were evaluated:

- Scenario 1: NERA population model with NERA/Sierra inputs.
- Scenario 2: NERA population model with ARB Staff inputs.
- Scenario 3: CARBITS population model with NERA/Sierra inputs.
- Scenario 4: CARBITS population model with ARB Staff inputs.

The revised population files for each of the scenarios outlined above were input into the EMFAC2002 Fleet Emissions Model developed for this study. For each scenario, the total VMT (absent rebound effects) was held constant. This was accomplished by making slight modifications to the baseline daily VMT per vehicle for all vehicles. This was necessary because the total vehicle population (and the age distribution) changed under each scenario; thus, if the baseline VMT per vehicle was applied to each model year, the total VMT under the control cases would not be equal to the total VMT under the baseline case. Once this initial VMT adjustment was made, the VMT from 2009 and newer vehicles was increased to account for the rebound effect.

For each scenario, the following results are presented:

- A line graph depicting the change in the 2020 vehicle population estimates (similar to Figure D-2);
- A line graph showing the increase in ROG+NO_x emissions from 2009 through 2030 (2020 for the scenarios based on the CARBITS model, which is only configured through 2020); and
- Tabulated results for ROG, CO, NO_x, and PM_{10}.

These results, which appeared in Chapter III, follow. They are organized according to Table B4-2.

Table B4-2. Outline for Presentation of Results

Scenario	Population Model	Source of Inputs	2020 Vehicle Populations	ROG+NO_x Results	Tabulated Results
1	NERA/Sierra	NERA/Sierra	Figure B4-4	Figure B4-5	Table B4-3
2	NERA/Sierra	ARB Staff	Figure B4-6	Figure B4-7	Table B4-4
3	CARBITS	NERA/Sierra	Figure B4-8	Figure B4-9	Table B4-5
4	CARBITS	ARB Staff	Figure B4-10	Figure B4-11	Table B4-6

Note that under Scenarios 2 and 4, the rebound effect was calculated to be consistent with ARB Staff estimates presented in the August 6, 2004 staff report—0.77 percent for all

2009 and newer model year vehicles (i.e., 25 percent of 3.08 percent). Under scenarios 1 and 3, the rebound effect was based on NERA/Sierra estimates.

Figure B4-4. Change in Statewide 2020 Vehicle Population Estimates as a Result of the Staff Greenhouse Gas Proposal Using the NERA/Sierra Population Model with NERA/Sierra Input Assumptions (Scenario 1)

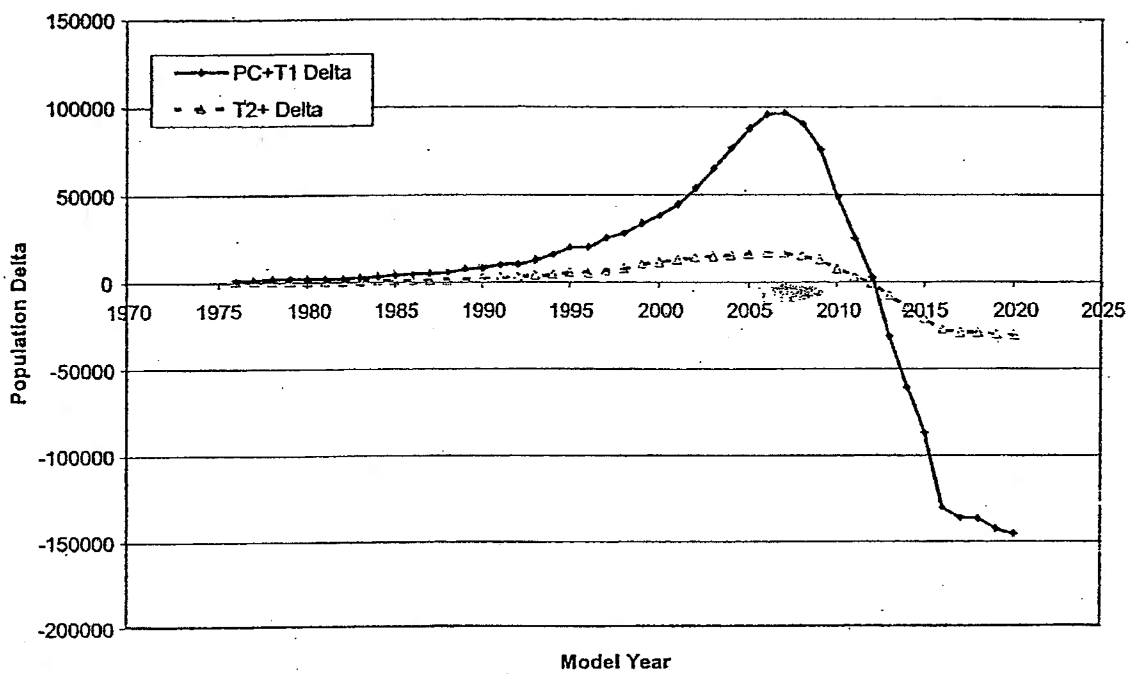


Figure B4-5. Statewide ROG+NO_x Emissions Increases as a Result of the Staff Greenhouse Gas Proposal Using the NERA/Sierra Population Model with NERA/Sierra Input Assumptions (Scenario 1)

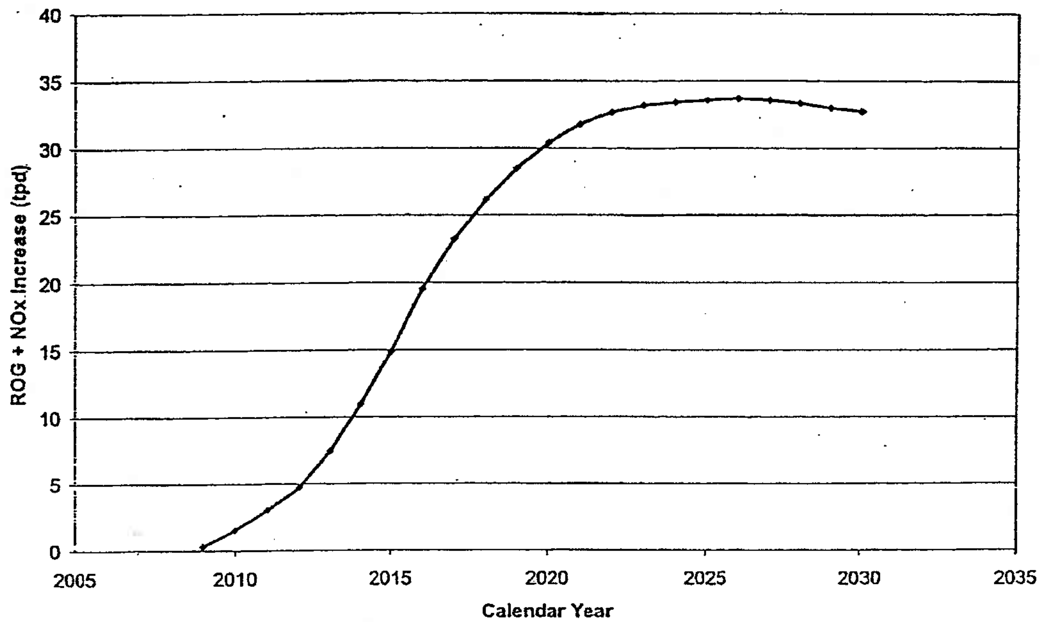


Table B4-3. Statewide Emissions Impacts of the Staff Greenhouse Gas Proposal Using the NERA/Sierra Population Model with NERA/Sierra Input Assumptions (Scenario 1)

	Criteria Pollutant Increases Accounting for Turnover and Rebound (tons per day)			
Year	**ROG**	**NO_x**	**CO**	**PM_{10}**
2009	0.18	0.16	1.67	0.01
2010	0.80	0.76	7.87	0.05
2011	1.58	1.49	15.68	0.10
2012	2.44	2.29	24.37	0.16
2013	3.88	3.60	38.69	0.26
2014	5.74	5.22	56.62	0.39
2015	7.89	7.01	76.52	0.56
2016	10.49	9.06	99.67	0.79
2017	12.64	10.62	117.38	1.00
2018	14.37	11.76	130.29	1.20
2019	15.87	12.61	139.99	1.40
2020	17.16	13.23	146.95	1.58
2021	18.18	13.59	150.98	1.77
2022	18.91	13.73	151.48	1.94
2023	19.44	13.73	150.38	2.09
2024	19.77	13.64	148.62	2.24
2025	20.04	13.50	146.77	2.38
2026	20.28	13.38	145.36	2.54
2027	20.37	13.16	142.64	2.67
2028	20.42	12.91	139.72	2.79
2029	20.37	12.59	136.02	2.90
2030	20.41	12.30	133.33	3.00

Figure B4-6. Change in Statewide 2020 Vehicle Population Estimates as a Result of the Staff Greenhouse Gas Proposal Using the NERA/Sierra Population Model with ARB Staff Input Assumptions (Scenario 2)

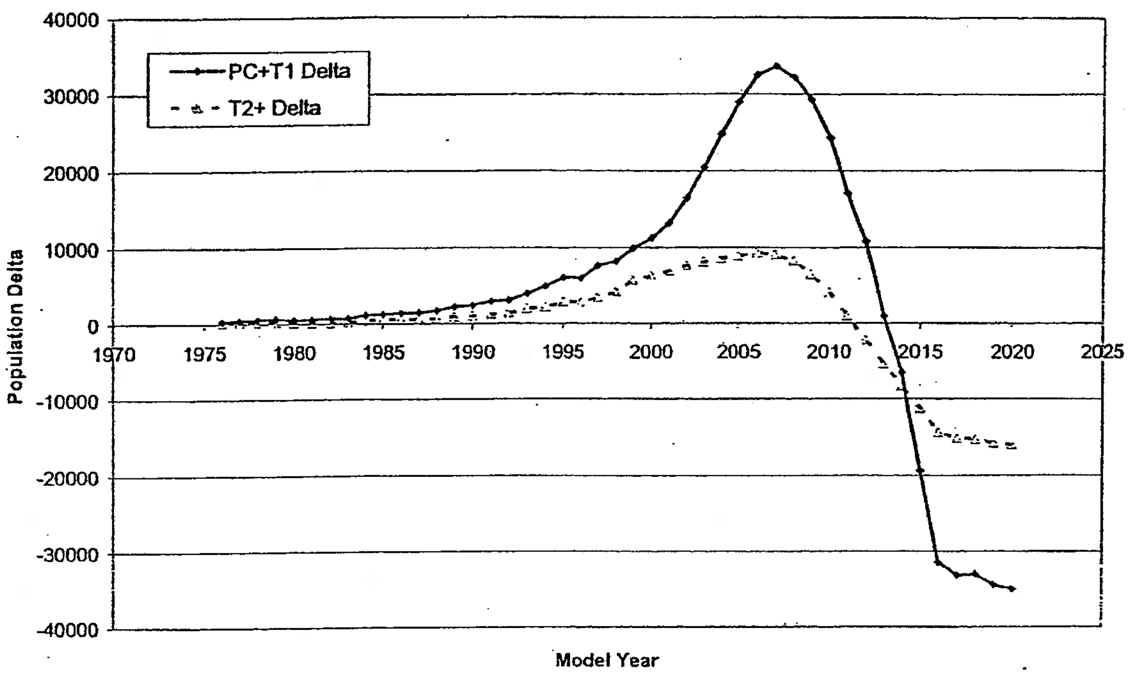


Figure B4-7. Statewide ROG+NO_x Emissions Increases as a Result of the Staff Greenhouse Gas Proposal Using the NERA/Sierra Population Model with ARB Staff Input Assumptions (Scenario 2)

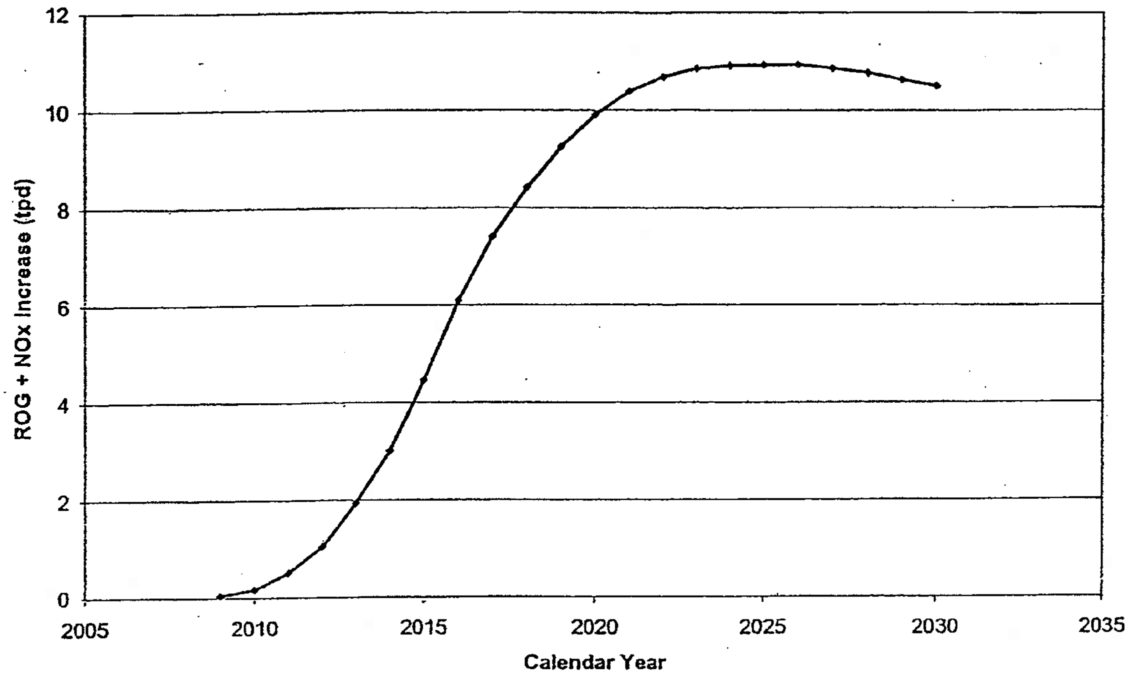


Table B4-4. Statewide Emissions Impacts of the Staff Greenhouse Gas Proposal Using the NERA/Sierra Population Model with ARB Staff Input Assumptions (Scenario 2)

Year	Criteria Pollutant Increases Accounting for Turnover and Rebound (tons per day)			
	ROG	NO_x	CO	PM_{10}
2009	0.02	0.03	0.30	0.02
2010	0.07	0.10	0.91	0.03
2011	0.24	0.28	2.71	0.05
2012	0.50	0.56	5.46	0.08
2013	0.95	1.00	10.00	0.11
2014	1.51	1.51	15.38	0.16
2015	2.29	2.18	22.54	0.21
2016	3.20	2.90	30.53	0.28
2017	3.96	3.45	36.60	0.34
2018	4.58	3.85	40.99	0.40
2019	5.10	4.14	44.27	0.45
2020	5.56	4.36	46.55	0.50
2021	5.91	4.48	47.73	0.55
2022	6.16	4.51	47.61	0.60
2023	6.34	4.50	46.95	0.64
2024	6.45	4.46	46.09	0.67
2025	6.53	4.40	45.19	0.70
2026	6.60	4.34	44.44	0.74
2027	6.61	4.25	43.25	0.77
2028	6.62	4.14	42.02	0.79
2029	6.59	4.02	40.51	0.81
2030	6.60	3.90	39.34	0.83

Figure B4-8. Change in Statewide 2020 Vehicle Population Estimates as a Staff Greenhouse Gas Proposal Using the CARBITS Population Model with NERA/Sierra Input Assumptions (Scenario 3)

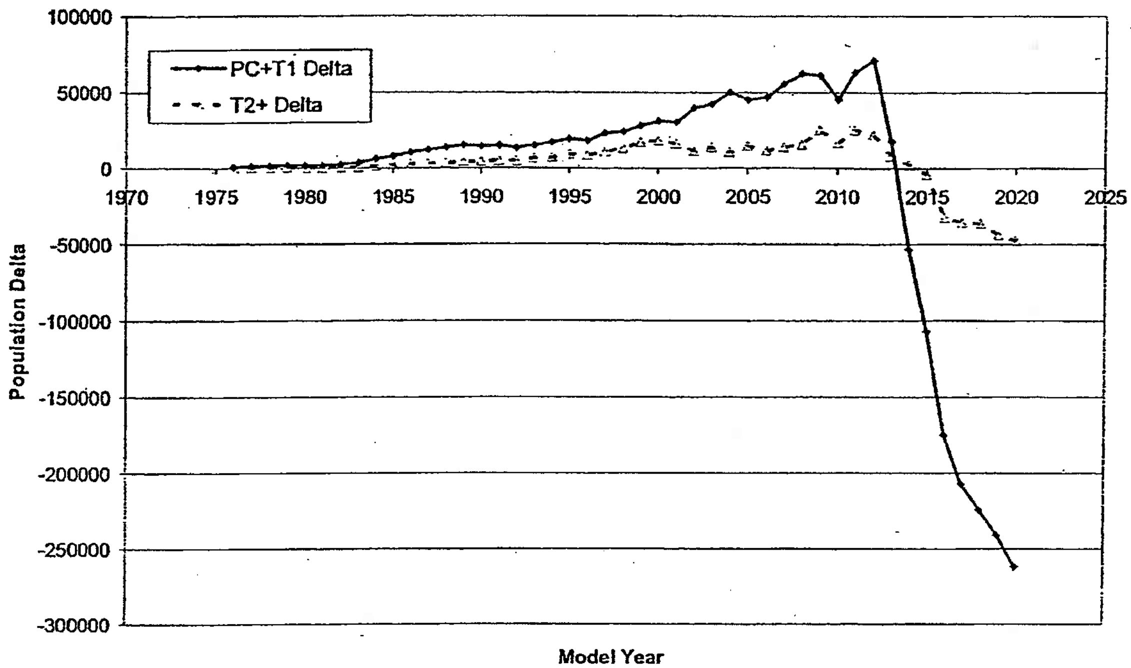


Figure B4-9. Statewide ROG+NO_x Emissions Increases as a Result of the Staff Greenhouse Gas Proposal Using the CARBITS Population Model with NERA/Sierra Input Assumptions (Scenario 3)

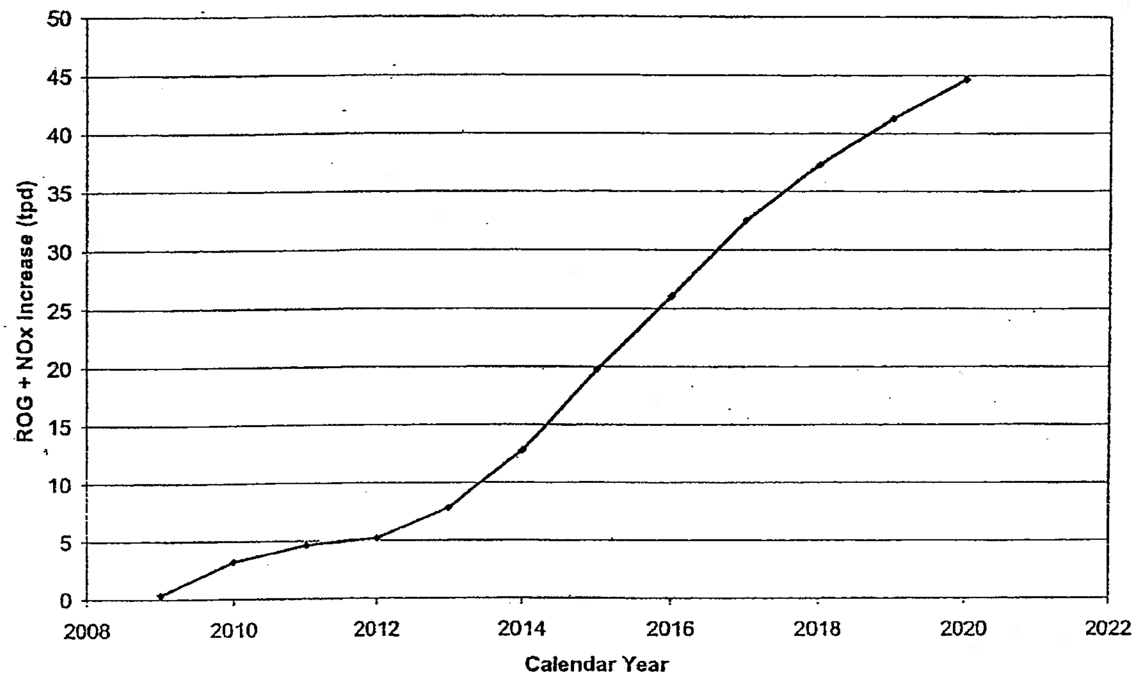


Table B4-5. Statewide Emissions Impacts of the Staff Greenhouse Gas Proposal Using the CARBITS Population Model with NERA/Sierra Input Assumptions (Scenario 3)

Year	Criteria Pollutant Increases Accounting for Turnover and Rebound (tons per day)			
	ROG	NO_x	CO	PM_{10}
2009	0.21	0.19	2.07	0.01
2010	1.74	1.51	16.07	0.07
2011	2.57	2.07	22.39	0.11
2012	2.94	2.29	24.75	0.14
2013	4.32	3.53	38.51	0.25
2014	6.95	5.86	61.79	0.42
2015	10.78	9.01	95.26	0.65
2016	14.21	11.89	125.16	0.93
2017	17.89	14.62	153.70	1.21
2018	20.71	16.65	174.73	1.47
2019	23.08	18.21	190.40	1.72
2020	25.23	19.44	202.25	1.95

Figure B4-10. Change in Statewide 2020 Vehicle Population Estimates as a Result of the Staff Greenhouse Gas Proposal Using the CARBITS Population Model with ARB Staff Input Assumptions (Scenario 4)

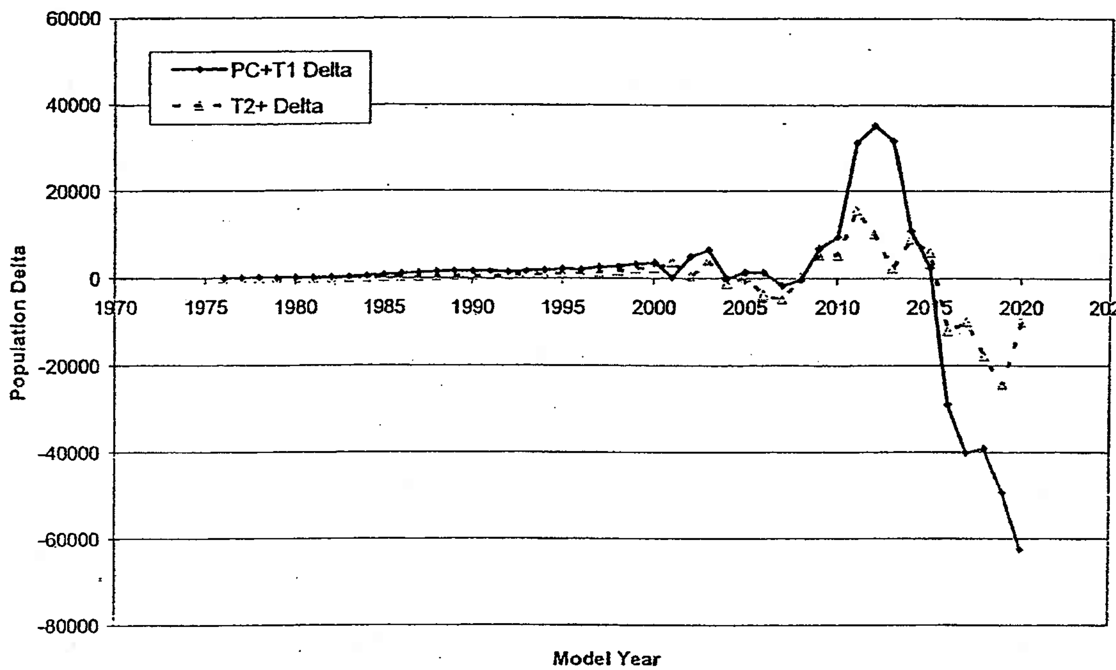


Figure B4-11. Statewide ROG+NO_x Emissions Increases as a Result of the Staff Greenhouse Gas Proposal Using the CARBITS Population Model with ARB Staff Input Assumptions (Scenario 4)

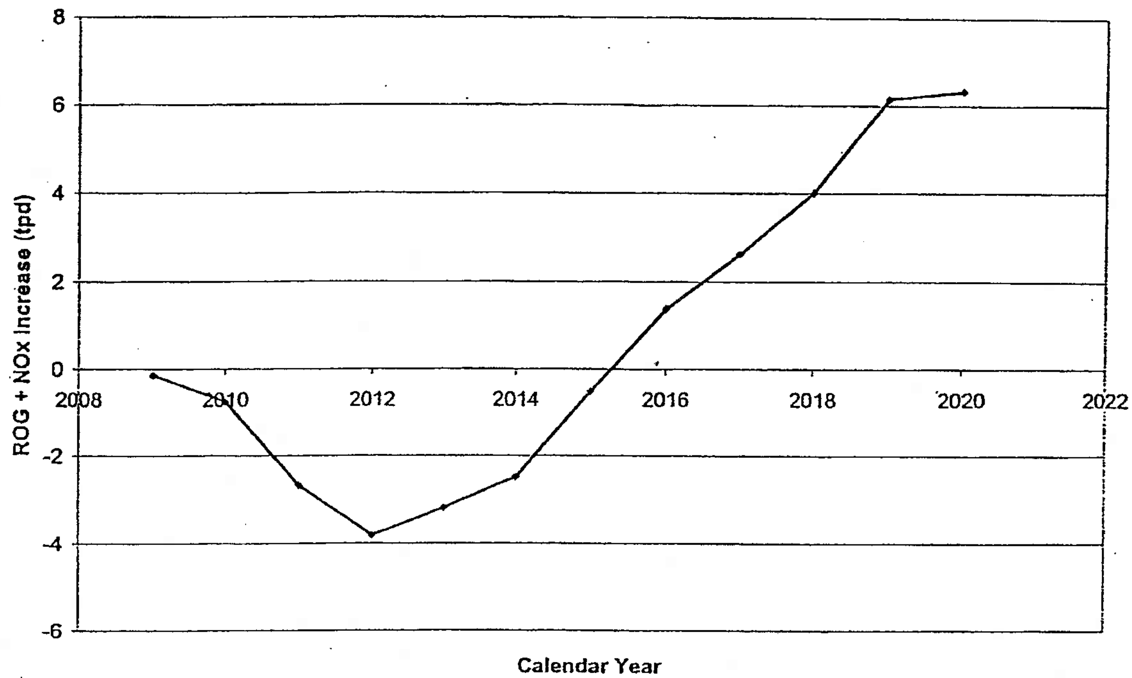


Table B4-6. Statewide Emissions Impacts of the Staff Greenhouse Gas Proposal Using the CARBITS Population Model with ARB Staff Input Assumptions (Scenario 4)

	Criteria Pollutant Increases Accounting for Turnover and Rebound (tons per day)			
Year	ROG	NO_x	CO	PM_{10}
2009	-0.07	-0.07	-0.57	0.01
2010	-0.46	-0.29	-3.61	0.02
2011	-1.39	-1.29	-12.90	0.00
2012	-1.99	-1.82	-18.79	0.00
2013	-1.66	-1.53	-15.41	0.02
2014	-1.33	-1.15	-12.10	0.06
2015	-0.27	-0.24	-1.92	0.11
2016	0.73	0.65	7.73	0.17
2017	1.42	1.22	13.64	0.24
2018	2.17	1.85	19.64	0.30
2019	3.41	2.75	28.72	0.37
2020	3.56	2.77	29.45	0.41

B-4.3 Review of ARB Staff Estimates of Fleet-Turnover and Rebound Effects

In the August Staff Report and the September Staff Addendum, the ARB Staff presented its estimates of the impact of fleet-turnover and rebound effects on criteria pollutant inventories. These estimates are reviewed below.

B-4.3.1 Fleet-Turnover Effects

The emissions impacts of changes to the vehicle fleet population as a result of the proposed regulations were modeled by the ARB Staff by inputting alternative vehicle population by age and vehicle type into the EMFAC2002 model. In general, this is a valid approach to estimating the emissions impacts of fleet-turnover effects as long as the total fleet VMT remains relatively constant between the base case and the fleet-turnover scenario. However, in the analysis performed by the ARB Staff for calendar year 2020, the overall fleet VMT decreased by 5.47 million miles per day statewide. Assuming that VMT should be held constant across the baseline and fleet-turnover scenarios, the emissions inventory estimates under the fleet-turnover scenario must be increased to account for the VMT "lost." By multiplying the revised inventory by the ratio of VMT under the baseline and control cases, the inventory is increased such that the lost VMT is assumed to be made up by a fleet-average vehicle.

As an example of this correction, the NO_x inventory estimates under the baseline and control cases were calculated by the ARB Staff to be 190.20 and 191.15 tpd, respectively, for a 0.95 tpd NO_x increase as a result of the fleet-turnover effects. However, as noted above, the control case has a lower total VMT. Thus, the inventory should be increased as follows to allow VMT to be conserved between the two cases:

191.15 tpd × (1,020,479 million miles/1,015,011 million miles) = 192.18 tpd,

where 1,020,479 million miles reflects the VMT under the baseline case and 1,015,011 million miles reflects the VMT under the regulatory (or control) case. Thus, instead of an increase of 0.95 tpd NO_x as calculated by the ARB Staff, the full impact of the fleet turnover effect (assuming VMT is conserved) is 1.98 tpd.

The same calculations were applied to ROG, NO_x, and PM_{10} emissions estimates, and the results are summarized in Table B4-7. As observed, properly accounting for VMT differences between the baseline and control model runs results in substantial increases in the emissions impacts of the fleet-turnover effect.

Table B4-7. Summary of ROG, NO_x, and PM_{10} Emissions Estimates, from Fleet Turnover

Scenario	ROG	NO_x	PM_{10}
Original ARB Staff Estimate (tpd)	+1.52	+0.95	-0.04
Corrected ARB Staff Estimate (tpd)	+2.77	+1.98	+0.19

Source: August Staff Report and NERA/Sierra calculations.

B-4.3.2 Rebound Effects

The ARB Staff estimated the rebound effects by modifying the mileage accrual rates in EMFAC2002 to reflect the additional annual VMT traveled by vehicles with improved fuel economy relative to the baseline case. The ARB Staff analysis was performed for calendar year 2020, and therefore the mileage accrual rates were modified for 2009 through 2020 model years. As discussed in the August Staff Report (p. 185), a dynamic rebound effect of 3.08 percent was estimated by Kenneth Small of U.C. Irvine, and ARB Staff used this estimate with the percent change in operating cost by model year (assumed to be 25 percent for all 2009 to 2020 model year vehicles) to account for the change in travel as a result of the rebound effect. Thus, the annual mileage accrual was assumed to be increased by 0.77 percent (i.e., 25 percent of 3.08 percent) for all 2009 and newer model year vehicles subject to the regulations.

The rebound effect estimated by the ARB Staff is much lower than that estimated by NERA/Sierra. The reasons for those differences are discussed elsewhere in this report; this Attachment reviews the methodology used by the ARB Staff to estimate the impacts on the criteria pollutant inventory.

Using the percent increase in VMT cited above for 2009 to 2020 model year vehicles (i.e., 0.77 percent), the ARB Staff modified the baseline annual mileage accrual rates in EMFAC2002 for the first 12 model years considered by the model. This approach has the intended effect of increasing the VMT from the 2009 to 2020 model years. However, a secondary effect of this methodology is to increase emissions deterioration for all model year vehicles. This occurs because the average mileage at a given age is calculated in the model by summing the annual mileage accrual rates. Thus, although a 2008 model year vehicle is not subject to the Staff Greenhouse Gas Proposal regulations (and therefore would not be expected to have increased VMT relative to the baseline case) the average mileage of a passenger car of this vintage (in 2020) increases from 171,828 to 173,070 miles. Because of this increase in accumulated mileage, the model predicts that a 2008 model year vehicle under the rebound case will have a slightly higher emission rate than in the baseline case. As a result, about half of the exhaust ROG, CO, and NO_x emissions increase associated with the rebound effect calculated by ARB Staff is from vehicles older than 2009 model year and not subject to the regulation.

The methodology used by ARB Staff to estimate the rebound effect has a curious impact on evaporative ROG emissions. The model predicts an overall decrease in evaporative ROG emissions from an increase in mileage accrual rates for 2009 and newer vehicles. (In fact, the decrease in evaporative ROG is greater than the increase in exhaust ROG, resulting in a net decrease in total ROG emissions.) Further, this decrease in evaporative emissions only occurs for 1997 and older model years, while there is no change to evaporative emissions from vehicles that are covered by the regulation (where one would expect an increase, at least for running loss emissions). It is unclear why this occurs, but it is likely a result of how the Smog Check program is modeled by EMFAC2002. When the model is configured to turn off the Smog Check program, there is no change in evaporative ROG emissions as a result of modifications to the mileage accrual rates.

Based on the above assessment, it appears that the methodology used by the ARB Staff to estimate the emissions impacts of the rebound effect is seriously flawed, particularly with respect to the ROG emissions estimates. For example, if only 2009 through 2020 vehicles are considered in the analysis, and if evaporative running loss and hot soak emissions are included in the rebound analysis,[17] the differences between ARB Staff estimates and the corrected estimates (in tons per day) are shown in Table B4-8. Note that a positive value indicates an increase in emissions, while a negative value reflects a decrease in emissions.

[17] For the corrected analysis, Sierra assumed that increased VMT from the rebound effect would have no impact on diurnal and resting loss emissions, but that it would impact both evaporative running loss and hot soak emissions in the same proportion as the VMT increase.

Table B4-8. Summary of ROG, NO_x, and PM_{10} Emissions Estimates, from Rebound

Scenario	ROG	CO	NO_x	PM_{10}
Original ARB Staff Estimate	-0.25	+7.85	+0.58	+0.27
Corrected ARB Staff Estimate	+0.24	+3.71	+0.25	+0.20

Source: August Staff Report and NERA/Sierra calculations.

The values above show that the ARB Staff methodology substantially underestimates the impact of the rebound effect on ROG emissions, while it overestimates the impact on CO, NO_x, and PM_{10} emissions.

B-4.3.3 Combined Effects

Both the August Staff Report and the September Staff Addendum present the combined impacts of the fleet-turnover and rebound effects. As noted above, the methodology used to evaluate the fleet-turnover effects likely underestimates the emissions impacts because there is a net loss in VMT in the fleet. In addition, the methodology used to account for the rebound effect is seriously flawed. As a result, the combined turnover and rebound effects presented in the August Staff Report and the September Staff Addendum are flawed.

Using the spreadsheet model developed by Sierra, ARB Staff estimates of the fleet-turnover effects on vehicle populations and the rebound effects on VMT per vehicle for 2009 and newer model years were evaluated. The combined effects reported by the ARB Staff in the September Staff Addendum are compared to the estimates that have been corrected to conserve VMT for pre-2009 model year vehicles and to only include rebound effects for 2009 and newer vehicles. These results are shown in Table B4-9.

Table B4-9. Summary of ROG, NO_x, and PM_{10} Emissions Estimates, from Fleet Turnover and Rebound

Scenario	ROG	NOx	PM_{10}
Original ARB Staff Estimate	+1.61	+1.17	+0.20
Corrected ARB Staff Estimate	+3.09	+2.32	+0.40

Source: August Staff Report and NERA/Sierra calculations.

B-4.4 Review of EMFAC2002 Baseline Vehicle Population Estimates

The EMFAC2002 model contains baseline vehicle population estimates for California based on registration data from 1999. These baseline population estimates are stored in the model by vehicle type and vehicle age (estimates are included for each of 45 model years). The model forecasts the vehicle population estimates to future calendar years with the following steps:

1. The total calendar year 1999 population (by vehicle class) is forecasted to calendar year 2000 based on growth factors contained in the model.

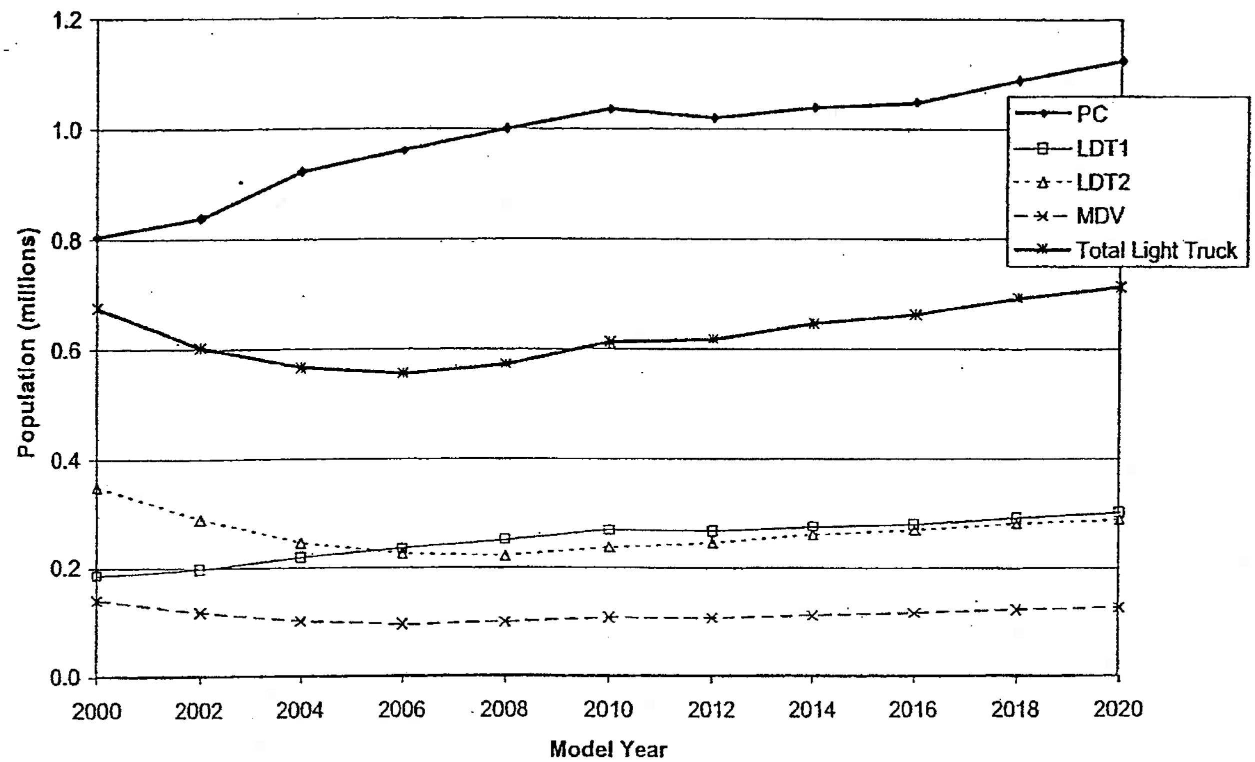
2. Vehicle survival rates (which are a function of vehicle age) are applied to each model year in the 1999 calendar year fleet, such that the population of each model year in calendar year 2000 has been reduced because of attrition.

3. The population of the 2000 model year vehicles (by vehicle class) in calendar year 2000 is determined by subtracting the total calendar year 2000 population (from step 1) from the total vehicles remaining after attrition is accounted for (from step 2)

4. Calendar year 2001 and subsequent populations are estimated by repeating steps 1 to 3 until the analysis year is reached.

Using the above approach, the total fleet population (by vehicle class) increases over time. However, because the new vehicle populations in each calendar year are determined through subtraction (in step 3 above), there can be apparent inconsistencies in some of those estimates. This is observed in Figure B4-12, which shows the statewide new vehicle populations calculated by EMFAC2002 for model years 2000 through 2020.. As observed in that figure, total light-duty truck sales (i.e., the sum of LDT1, LDT2, and MDV vehicle classes) are estimated by EMFAC2002 to decrease between the 2000 and 2006 model years. This is counter-intuitive, and it is unlikely to track reality. In addition, the EMFAC2002 estimates are inconsistent with the car/truck split that the ARB Staff has used for a number of its economic analyses. For example, Table 6.1-4 of the August 6, 2004, Staff Report lists the PC/LDT1 versus LDT2 (which includes the EMFAC2002 LDT2 and MDV classes) split as 53 percent versus 47 percent for the six major auto manufacturers in 2002. However, the EMFAC2002 model estimates the split to be 72 percent versus 28 percent in 2002, and the discrepancy grows to 78 percent PC/LDT1 versus 22 percent LDT2 in 2010. Despite these inconsistencies, Sierra/NERA used EMFAC2002 in its emissions estimates because it is the official inventory model for California used for SIP development purposes.

Figure B4-12. Statewide New Vehicle Population Estimates Calculated with EMFAC2002



ATTACHMENT B-5: THE POTENTIAL EFFECT OF THE PROPOSED REGULATIONS ON AMBIENT TEMPERATURE AND OZONE CONCENTRATIONS

In Sections 2.6 and 8.3 of the August Staff Report, the ARB Staff infers that one of the benefits of the proposed regulations would be a reduction in tropospheric ozone concentrations. The ARB Staff notes that there is a positive correlation between tropospheric ozone concentrations and higher temperatures, and suggests that because the proposed regulations will mitigate the temperature rise associated with global warming, they will also lead to lower ozone levels. In section 8.3, the ARB Staff also justifies California's adoption of the regulation by noting that it could be a catalyst for the adoption of similar regulations in other states and perhaps nationwide, which would lead to even greater reductions in climate change gas emissions. However, the ARB staff has made no effort to demonstrate that ozone levels would in fact be affected, nor has the agency quantified the degree to which the proposed regulations adopted either in California alone or in additional states could affect either temperature or ozone.

As outlined below, we have performed an analysis of this issue with the very optimistic assumption that the proposed regulations are adopted nationwide. Even with this optimistic assumption, our analysis indicates that the potential reduction in temperature in California will be on the order of 0.01°C and that the impact on peak ambient ozone levels in California would be on the order of 0.02 percent. The effect of adoption of the proposed regulations only in California on temperature and temperature driven changes in ozone levels would be substantially less. Our results demonstrate that the proposed regulations will have no discernable impact on temperature and that the very small increase in ambient temperature that would occur without their adoption will have no measurable impacts on peak ozone concentrations. Therefore, the ARB Staff cannot claim either reductions in ambient temperatures or temperature driven ozone levels as a benefit of the proposed regulations. However, as documented extensively elsewhere in this report, the proposed regulations will lead to significantly higher ozone levels as the direct result of an increase in emissions of ozone precursors.

According to the U.S. Environmental Protection Agency, the heat-trapping properties of greenhouse gases cause the average surface temperature of the Earth to be about 33°C higher than it would be otherwise.[18] Over 90 percent of the greenhouse effect is associated with water vapor, whose quantity is not significantly affected by human activity. Approximately 3°C is attributable to all other greenhouse gases, the most significant of which is carbon dioxide. It is therefore not surprising that, several researchers have estimated that a doubling of carbon dioxide would increase temperatures by another 3°C. It should be noted, however, that a doubling of anthropogenic carbon dioxide emissions will not cause a doubling of ambient carbon dioxide concentrations because of the influence of natural sources of carbon dioxide and uncertainty regarding the rate at which higher concentrations of carbon dioxide will be removed by natural "sinks."

The United Nations Intergovernmental Panel on Climate Change ("IPCC") estimates that global temperatures have risen only 0.6°C over the entire 20th century. Most of the increase occurring over the last 50 years is attributed to human influence. The pre-industrial atmospheric concentration of carbon dioxide has been estimated at 278 ppm. It had increased to 365 ppm by 1998.

According to Oak Ridge National Laboratory,[19] global carbon dioxide emissions from fossil fuel combustion (including gas flaring) were 6,611 million metric tons carbon in calendar year 2000. Data on highway gasoline use for 2001 reported by the Federal Highway Administration indicates annual consumption of 129.7 billion gallons, which is equivalent to 314 million metric tons of carbon (almost all of which is emitted in the form of carbon dioxide). Absent changes in CAFE standards, the National Research Council[20] estimates that gasoline consumption will increase to 195 billion gallons per year by 2030, which is equivalent to 473 million metric tons of carbon.

Ignoring the fact that not all gasoline is consumed in vehicles subject to CAFE standards, and assuming a 17 percent rebound effect, reducing the fuel consumption of all

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[18] See U.S. Greenhouse Gas Inventory Program (2002).

[19] See http://cdiac.esd.ornl.gov/ftp/ndp030/global00.ems.

[20] See Committee on the Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards (2002).

gasoline-fueled vehicles by 25 percent (the reduction associated with the proposed standards) would reduce carbon emissions from gasoline-fueled vehicles by 103 million metric tons per year.[21] This is 1.56 percent of the current estimate of total anthropogenic carbon dioxide emissions and 1.7 percent of the 6,059 million metric tons of carbon per year increase in anthropogenic carbon dioxide emissions during the last 100 years. If all anthropogenic emissions caused an increase in temperatures of 0.6°C, then a change in carbon dioxide emissions of 103 million metric tons carbon per year would be expected to change temperatures by 0.01°C (0.017*0.6°C).

Not only is this calculated temperature change exaggerated by assuming that all temperature change occurring during the last century was caused by anthropogenic carbon dioxide, it also assumes that measures taken to improve motor vehicle fuel economy in the U.S. would not affect carbon dioxide emissions elsewhere. In fact, reduced demand for petroleum in the U.S. would suppress petroleum prices worldwide. This would be expected to lead to higher consumption and increased carbon dioxide emissions in other parts of the world.

To estimate the effect of a 0.01°C temperature increase on ozone concentrations, the U.S. EPA's Empirical Kinetic Modeling Approach ("EKMA") model was used. The OZIPM-4 version of the EKMA model was run using a default example case provided by EPA incorporating a morning temperature of 294°K (69.5°F) rising to 308°K (94.7°F) in the late afternoon. The temperature profile was then uniformly increased by 0.6°C (1.08°F) and the model was re-run. The peak ozone levels for the second run increased by 1.73 ppb, from 0.16969 ppm to 0.17142 ppm. Using the temperature decrease predicted for a nationwide reduction in motor vehicle fuel consumption of 25 percent (0.01°C), the proportional change in peak ozone concentration would be 0.03 ppb, which is 0.00003 ppm. This amounts to an increase of 0.02 percent in the peak ozone level ((0.00003/0.16969)*100).

For the reasons summarized above, the suggestion in the August Staff Report that the proposed regulations will yield meaningful reductions in temperature and ozone concentrations

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[21] A 25 percent reduction in carbon emissions would reduce carbon emissions from gasoline combustion to 355 million metric tons/year. A 17 percent rebound effect would increase this to 370 million metric tons/year (((0.17*0.25)+1)*355). 370 million metric tons is 103 tons less than the projected 2030 baseline (473-130=103).

as the result of reduced global warming is baseless. No measurable change in temperatures or ozone concentrations would be expected even using pessimistic projections of the relationship between carbon dioxide emissions and ambient temperature.

References

Committee on the Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards, National Research Council, 2002. "Effectiveness and Impact of Corporate Average Fuel Economy (CAFE)."

U.S. Greenhouse Gas Inventory Program, Office of Atmospheric Programs, Environmental Protection Agency, 2002. "Greenhouse Gases and Global Warming Potential Values, Excerpt from the Inventory of U.S. Greenhouse Emissions and Sinks: 1990-2000." April 2002.

ATTACHMENT B-6: EMISSIONS IMPACTS ASSOCIATED WITH REDUCED GASOLINE CONSUMPTION

Section 8.4 of the August Staff Report addresses the impacts that a reduction in California gasoline consumption as a result of the proposed regulations would have on emissions related to the distribution and marketing of gasoline in California. The ARB Staff presents estimates of this impact for emissions of climate change gases in Table 8.4-1, and emissions of ROG, NO_x, and CO in Table 8.4-2 and emissions of ROG, NO_x, CO, and PM_{10} in Table 12.4-1. The values presented in Tables 8.4-2 and 12.4-1 were revised as part of the September Staff Addendum to correct an error in unit usage and to "account for updated emission factors". Nowhere in either the Report or the Addendum are the emission factors or the data and methodology used to compute these emission impacts documented or referenced. In response to our requests for detailed information regarding the emission factors, methodology and data used to arrive at these estimates, the ARB Staff has released[22] the emission factors for ROG, NO_x, PM_{10}, and CO and provided two references[23] for the methodology used.

The primary reference cited by the ARB Staff is a report prepared in May 2003 by Tiax under contract to the ARB. This report was used by the ARB and the California Energy Commission to estimate the emission benefits associated with reduced petroleum usage in California pursuant to AB 2076. Problems with the ROG emission factor in the Tiax report have been documented previously and the corrections made to properly account for ARB EVR regulations described previously are used here.[24] In addition, the ARB has noted[25] that emission factors used by Tiax had been modified to account for longer travel distances by marine vessels bringing gasoline (100 miles compared to the 26 miles assumed in the references) into California and to more accurately account for tanker truck emissions. No

[22] Email from Eileen Tutt of ARB to James Lyons of Sierra, September 15, 2004.

[23] See Jackson et al (2003) and Unnasch et al., (2001).

[24] See, e.g, Austin, et al. (2003).

[25] Email from Eileen Tutt of ARB to James Lyons of Sierra, September 17, 2004.

additional details explaining or justifying those changes has been provided. The undocumented emission factors used in the September Staff Addendum and those used here are presented in Table B6-1.

As shown in Table F-1, the emission factors used by the ARB staff for NO_x and PM_{10} are far higher than those published previously. The ROG emission factor is lower than either ARB staff factor as explained above.

Table B6-1. Emissions Factors for Gasoline Distribution (grams/gallon)

Pollutant	ISOR Addendum	This Study
NO_x	0.141	0.037
ROG	0.472	0.388
PM	0.082	0.002
CO	0.022	0.029

Given our inability to review the methodology and data used by the ARB staff to develop the emission factors in the addendum, we have elected to use the Tiax factors for NO_x, CO and PM_{10} and the corrected emission factor for ROG to estimate the emission impacts associated with reduced gasoline consumption under each of the four scenarios analyzed in this report. Again, these scenarios are:

- Scenario 1: NERA population model with NERA/Sierra inputs.
- Scenario 2: NERA population model with ARB Staff inputs.
- Scenario 3: CARBITS population model with NERA/Sierra inputs.
- Scenario 4: CARBITS population model with ARB Staff inputs.

Changes in gasoline consumption were estimated using the EMFAC2002 Fleet Emissions model that was used to estimate the criteria pollutant impacts for this study. The basic approach to estimating fuel consumption in the EMFAC2002 Fleet Emissions model was the same as that used in the standard version of EMFAC2002. Based on a review of the source code for that model, fuel usage is calculated with the following equation:

$$\text{Fuel Use} = (\text{Tons } CO_2 \times 0.273 + \text{Tons CO} \times 0.429 + \text{Tons HC} \times 0.866) \times 375$$

Note that the CO_2 reductions (by model year and vehicle type) used for this analysis were based on those developed by the ARB staff for the September Staff Addendum. These estimates likely overstate the reduction in gasoline consumption estimated for the Staff Greenhouse Gas Proposal. However, they were used here to be consistent with ARB staff estimates.

As an example, the reduction in fuel usage associated with Scenario 1 (i.e., the NERA/Sierra population model configured with NERA/Sierra inputs, which includes turnover and rebound effects) for calendar year 2020 is given in Table B6-2.

Table B6-2. Reduction in Fuel Usage with the NERA/Sierra Population Model and NERA/Sierra Inputs (Scenario 1)

Scenario	CO_2 (tpd)	CO (tpd)	ROG (tpd)	Fuel Use (gal/day)
Base Case	485,150	2,097	84	50,032,000
Scenario 1	409,940	2,244	90	42,358,000

Based on the above, gasoline usage under Scenario 1 would be reduced by 7.7 million gallons a day in calendar year 2020 (i.e., 50,032,000 - 42,358,000). This same calculation was performed for all calendar years for each scenario modeled. The reductions in gasoline consumption under each scenario as well as that assumed by the ARB staff in preparing its emission impacts is shown in 2020 and 2030 (where available) are shown in Table B6-3.

Table B6-3. Reductions in Gasoline Consumption (1000s of Gallons per Day)

Scenario	2020	2030
1	7681	13956
2	8617	15486
3	7454	-
4	8671	-
Addendum	8793	15309

Source: September Staff Addendum and NERA/Sierra calculations.

The emission reductions associated with the reductions in gasoline consumption shown in Table B6-3 were estimated by multiplying those consumption values by the Tiax emission factors presented in Table B6-1 and in the case of ROG by the corrected emission factor. The results are shown in Table B6-4. Also provided for purposes of comparison are the emission reduction estimates published in the September Staff Addendum. As shown, the estimated emission reductions for NO_x, PM_{10} and ROG are lower in all scenarios than those reported by the ARB staff.

Table B6-4. Emission Reductions Due to Reduced Gasoline Consumption (Statewide Tons per Day)

Scenario	Year	NO_x	PM_{10}	ROG	CO
Addendum – ARB	2020	1.4	0.8	4.6	0.2
Addendum - ARB	2030	2.3	1.4	7.9	0.4
Addendum – Sierra	2020	0.4	0.02	3.8	0.3
Addendum - Sierra	2030	0.6	0.04	6.6	0.5
1	2020	0.3	0.02	3.3	0.2
1	2030	0.6	0.03	6.0	0.4
2	2020	0.3	0.02	3.7	0.3
2	2030	0.6	0.04	6.6	0.5
3	2020	0.3	0.02	3.2	0.2
4	2020	0.3	0.02	3.7	0.3

Source: September Staff Addendum and NERA/Sierra calculations.

References

Austin, T.C., R.G. Dulla, and J.M. Lyons, 2003. "Reducing California's Petroleum Dependence, A Critical Review," *Sierra Research Report Number SR2003-11-03*, November 25, 2003.

Jackson, M., S. Fable, S. Unnasch, et al., 2003. "Benefits of Reducing Demand for Gasoline and Diesel (Task 1)," *Well-to-Wheel Emissions*, Appendix C of A Consultant report for California Energy Commission and California Air Resources Board, CEC Report P600-03-005A1, May 2003.

Unnasch, S., R. Wiesenberg, and E. Kassoy, 2001. "Refinement of Selected Fuel-Cycle Emissions Analyses- Final Report," *ARB Contract 98-338*. April 2001.

ATTACHMENT B-7: REMI MODEL

This Attachment summarizes the methodology used to estimate the effects of the Staff Greenhouse Gas Proposal on the California economy.

B-7.1 Introduction and Overview of Economic Impacts Modeled

The estimates of the economic impacts of the Staff Greenhouse Gas Proposal are developed using a model based upon the Regional Economic Models, Inc. ("REMI") approach. Economic impacts modeled include the following effects of the Staff Greenhouse Gas Proposal:

- The increased costs of producing motor vehicles that achieve the relevant emissions standards will lead to higher prices for motor vehicles. This has multiple effects that we incorporate into the REMI model in various ways:
  - The higher prices will reduce the number of motor vehicles purchased by consumers, businesses, and governments. All else equal, this reduction in purchases of motor vehicles will lead to a shift of expenditures from motor vehicles to other goods and services. The motor vehicle sector loses from such a shift, while other sectors generally gain.
  - The higher prices will increase the amount spent per vehicle purchased by consumers, businesses, and governments. All else equal, this increase in prices will lead to a shift of expenditures from other goods and services and towards the inputs used to manufacture motor vehicles.
  - Above and beyond these shifts in expenditures, consumers, businesses, and governments are made worse off by these price increases. The cost of living is higher for consumers, the cost of business is higher for businesses, and the cost of providing services is higher for governments.
- The increased fuel efficiency for the motor vehicles that achieve the relevant emissions standards will lead to lower fuel consumption by those vehicles.
  - The lower fuel consumption will lead to a shift in expenditures away from the motor fuel sector and toward other goods and services. The motor fuel sector loses from such a shift, while other sectors generally gain.
  - Beyond this shift in expenditures, consumers, businesses, and governments are made better off by the reduced fuel expenditures. The cost of living is lower for consumers,

the cost of business is lower for businesses, and the cost of providing services is lower for governments.

- With higher prices for new cars, old cars are kept on the road longer; with higher efficiency for new cars, these cars are driven more miles. Both of these effects raise expenditures on vehicle repairs and reduce expenditures on other goods and services, by consumers, businesses, and governments.

- These effects in turn all have indirect effects as they percolate through the economy.

B-7.2 Methodology

This section summarizes the methodology used to estimate the effects of the Staff Greenhouse Gas Proposal on the California economy.

B-7.2.1 Overall Methodology

The starting point for our analysis is the set of results from the NERA New Vehicle Market Model and Fleet Population Model, which predict the effects over time of the Staff Greenhouse Gas Proposal on new vehicle prices and fuel efficiency and the resulting effects on the entire vehicle fleet population. The next step is to estimate direct impacts of the increase in new vehicle prices and improvements in fuel efficiency due to the Staff Greenhouse Gas Proposal, including effects on households, businesses and governments, as well as production expenditures and changes in consumption of new vehicles. The third step is to assess the indirect effects on related markets for gasoline and used vehicle repair services. These direct and indirect effects are inputs to the REMI model, which develops estimates of the full effects including the "multiplier" effects of successive rounds of spending. Note that REMI is a dynamic model, and thus the effects reflect the adjustment process as the various direct and indirect effects work through the economy.

The following sections provide an overview of the REMI model and describe the methods used to develop the inputs to the REMI model.

B-7.2.2 REMI Model

B-7.2.2.a Overview

The REMI model is a state-of-the-art regional economic model that has been used extensively for forecasting and policy analyses. In contrast to simpler methods that rely almost exclusively on the input-output structure, REMI models the behavior of markets within the region and the dynamics of market changes. The REMI model provides estimates of the impacts on the regional economy over a planning horizon when all the feedback mechanisms in the economy are taken into account. These effects are estimated in a dynamic framework that projects effects through 2035. The REMI model is calibrated using a data set that includes a history of employment by sector from 1969 to the present. The model also uses national forecasts of future growth or decline by industry sector, produced by the U.S. Bureau of Labor Statistics. The historical data are used to track how the industrial mix and employment in the region differ from those in the rest of the country, and how, for each industry sector, the economic growth trends in the region differ from national trends.

The REMI model predicts the effects of policy options, such as changes in electric rates or coal demand, on the level and distribution of employment in the region for 53 industry categories and 94 occupational groups. The model predicts many other variables, including population, personal income, wage rates, output, and value added at a detailed level.

B-7.2.2.b Experience With REMI

The REMI model has been used for numerous applications to predict the effects on the regional, state and national economy of policies in transportation and many other areas. The REMI model was chosen by the South Coast Air Quality Management District ("SCAQMD") from all relevant models to evaluate the economic impacts of its regulations. The SCAQMD's use of the REMI model for the evaluation of economic impacts was validated by a 1997 California Court of Appeals decision (60 Cal.App.4th 55, 70 Cal. Reptr.2d 54).

B-7.2.3 Direct Welfare Impacts of Increased Vehicle Prices on Vehicle Purchasers

As described, the Staff Greenhouse Gas Proposal would lead to increased prices for vehicles in California and the RUS. The increase in new vehicle prices is derived in the New Vehicle Market Model, which calculates the increase in prices for various vehicle types based on demand elasticities and other information on vehicle markets. (The New Vehicle Market Model is described in Attachment B-1.) Increased vehicle prices lead to increased costs for three distinct groups of vehicle purchasers—individual households, businesses and governments. The REMI inputs for these three groups are developed separately and described below.

B-7.2.3.a Consumer, Business, and Government Shares of Passenger Car Sales

To estimate the impact of the vehicle price increases borne by consumers, businesses, and governments, we calculate the percentage of total passenger car sales accounted for by each category. We make this calculation using Bureau of Economic Analysis ("BEA") data which show that households account for roughly 57 percent, businesses for 40 percent, and government for 3 percent of national passenger car sales (BEA 2004). Passenger car sales are used instead of passenger car and LDT1 sales because the BEA does not disaggregate their sales data by light duty truck class. These numbers are then adjusted for the fact that BEA includes all leases to households, businesses and government in their estimation of purchases by the business sector.

In order to calculate the number of leases in each consumer category, we use data from Ward's Communications, which state that, in 2003, 24.7 percent of all vehicle sales (passenger cars and light duty trucks) were leases (Ward's 2003).

Using the vehicle lease data, we calculate the total number of vehicles leased by multiplying the percentage leased by the total number of vehicles sold. Total leases are then subtracted from the BEA new passenger car business sales amount and apportioned to consumers, businesses, and government based on the assumption that 24.7 percent of all sales in each category are leases. We thus calculate that 63 percent of all passenger car purchases are made by households, 34 percent are made by businesses, and 3 percent are made by government.

B-7.2.3.b Impact on Households

The consumer welfare effect of increased vehicle prices in each year is equivalent to the change in consumer surplus due to the increased prices. The effect on consumer surplus due to the price increase is estimated in the NVMM by calculating the difference between consumers' indirect utility (as embodied in the NVMM) under the baseline prices and under the prices in the regulation case (holding fuel efficiency constant) and then dividing by the price coefficient to convert the difference into a dollar value. This dollar value is then multiplied by the number of potential consumers (i.e., the number of motor vehicles divided by a consumer's probability of buying a new vehicle).

Because households experience only a portion (roughly 63 percent) of this negative economic impact, the overall impact on households is calculated by multiplying this total consumer welfare effect by the fraction of new passenger car purchases made by households.

The impact of increased prices on households is modeled in REMI as a general price increase. It is put into variable number 960 (Consumer Expenditure Price Index). This welfare effect is modeled as a general price increase to avoid overestimating the substitution effect, which is modeled separately (see below). The substitution away from new vehicles and towards other products is modeled separately because the New Vehicle Market Model and Fleet Population Model provide a more detailed representation of new vehicle demand than is available in the REMI model. The price increase is thus modeled solely as a loss of income to households who purchase vehicles covered under the Staff Greenhouse Gas Proposal.

B-7.2.3.c Impact on Businesses

The impact of the Staff Greenhouse Gas Proposal on businesses is modeled as an increase in production cost for producers who use vehicles as inputs. The overall impact on businesses is estimated by multiplying the total welfare effect (as described above) by the proportion of motor vehicle purchases by businesses.

Because REMI does not have a policy variable for the increase of production cost due to the increased price of a good, the regional input-output ("I/O") table is used to determine how this welfare effect will be shared across industries. The proportion of the welfare loss borne by each industry is estimated by first determining the percentage of production accounted for by motor vehicles for each industry (from the I/O table). This number is then multiplied by total annual output to estimate the number of dollars spent on motor vehicles annually by each industry. For each industry, this value can be used to determine the proportion of annual motor vehicle demand that each industry is responsible for. This proportion is used to approximate each industry's share of the total welfare impact on businesses.

Production cost increases are modeled using REMI policy variables 1451-1499 (Production Cost [of individual industries]).

B-7.2.3.d Impact on Government

Government purchases constitute roughly three percent of passenger car sales (see above). Because we assume that the government has a balanced budget constraint, the increased expenditure on new covered vehicles must be offset by either an increase in taxes or a decrease in other expenditures. For this analysis, we assume that the government pays for its share of increased vehicle prices by increasing taxes to households. The amount of this increase is equal to the total consumer welfare effect multiplied by the proportion of total vehicle purchases by the government (0.03).

This effect is placed into REMI policy variable number 954 (Personal Taxes: Applicable Personal Income).

B-7.2.4 Direct Impacts of Increased Fuel Efficiency on Vehicle Users

As for the effects of increased vehicle prices described above, the welfare effects due to increased fuel efficiency accrue to three distinct groups—households, business, and governments. However, unlike the price effects of new vehicle purchases, which occur in the year in which a vehicle is bought, these effects occur over the lifetime of a vehicle. That is, the fuel efficiency effects occur as the vehicle is actually driven.

The effects of fuel efficiency are estimated by taking the average of total VMT under the regulation case and under the baseline case for each model year. This average VMT is then multiplied by the difference in the cost of travel between the regulation and baseline case for each model year to estimate overall fuel efficiency savings. The cost of travel for a particular model year and calendar year is equivalent to the fuel efficiency for each vintage multiplied by the price of gasoline in that year. Forecasts of gasoline prices were taken from the Energy Information Administration (net of taxes, which are transfers).

These consumer welfare gains due to fuel efficiency are divided among households, businesses and governments using the same approach as described above for the price increases. For households, these effects increase consumer surplus and thus have the opposite sign of the price effects described in the previous section.

Like the price effects described in the previous section, these effects are divided among households, businesses, and government. For households, these effects are placed into variable number 960 (Consumer Expenditure Price Index). For businesses, these effects are placed into REMI policy variables 1451-1499 (Production Cost [of individual industries]). For governments, these effects are placed into REMI policy variable number 954 (Personal Taxes: Applicable Personal Income).

B-7.2.5 Increased Expenditures by Vehicle Manufacturers

As explained above, the price increases experienced by vehicle purchasers reflect the added costs arising from the Staff Greenhouse Gas Proposal, i.e., the added cost to produce vehicles that meet the standards. In this context, we can think of the revenues from the price increase as incremental expenditures spent by the vehicle manufacturers to produce the lower emissions vehicles. These increased expenditures would create positive economic impacts in the areas in which they would be spent—i.e., where the new vehicle parts would be manufactured and the subsequent rounds occur.

We first estimate the total increase in manufacturer costs. Increased manufacturer expenditures per vehicle are equivalent to the increase in per vehicle manufacturer costs, which are estimated in the NVMM. This effect is then multiplied by the number of new vehicles sold to estimate the overall increase in manufacturer expenditures.

Because there is no specific evidence regarding the location and precise nature of the increased expenditures, we assume that only the proportion reflected by the regional purchase coefficient ("RPC") for the motor vehicle sector would be spent locally. In conjunction with the RPC, the I/O table can be used to estimate the amount of additional expenditures for intermediate goods in different sectors resulting from the added equipment expenditures. Thus, we first determine the proportion of expenditures that motor vehicle manufacturers spend in California (using the RPC) and multiply this proportion by the total manufacturer cost increase. We then assume that manufacturers make these expenditures in proportion to the industries shown in the REMI I/O table.

These expenditures are placed into REMI policy variables numbers 651-699 (Exogenous Final Demand: [Specific industries]).

As described above, these increases in expenditures also would lead to a shift of consumer purchases away from other sectors. (The dollars spent due to the increased vehicle prices mean consumers would have fewer dollars to spend on other goods.) This effect would have a negative impact on the California economy, although the precise impact is difficult to determine because of uncertainty over the location and nature of the added expenditures. We use the local RPC to estimate the percent of expenditures that will be made locally. Because of the uncertainty of this approach, we have excluded the negative effect on the local economy of shifts in consumers' expenditures away from other goods. This combined set of assumptions is likely to understate negative effects on the California economy.

B-7.2.6 Vehicle Substitution

As a result of changes in vehicle price and fuel efficiency, consumers purchase fewer of these new vehicles. These substitution effects are estimated in the New Vehicle Market Model and Fleet Population Model, as described in Attachment B-1. The outputs of the Fleet Population Model include estimates of the changes in new vehicle sales by year and vehicle type. These values are multiplied by the baseline vehicle prices to develop estimates of the shifts in purchases due to the price effects.

The net change in the number of vehicles purchased under the Staff Greenhouse Gas Proposal relative to the baseline is negative because of the increased prices. This result is primarily caused by the fact that some consumers get "priced out" of the new vehicle market and decide not to buy a new vehicle. Because consumers are buying fewer new vehicles, they can purchase more of other goods.

The change in new vehicle expenditures is placed into REMI policy variable number 54 (Consumer Spending by Residents: Vehicles and Parts). An equal and opposite amount is placed in policy variable number 180 (Consumption Reallocation by Residents: All Consumption Sectors) to account for the expenditure shift made by some consumers to other, non-vehicle goods.

B-7.2.7 Effects on Related Markets

This section outlines the methodology for modeling the changes in gasoline and used vehicle repair expenditures. Because this primarily amounts to a rebalancing of expenditures, all changes in expenditure on these goods are balanced with equal and opposite changes in consumption on all other goods.

B-7.2.7.a Gasoline Consumption

The Staff Greenhouse Gas Proposal leads to two offsetting effects in the gasoline markets:

- Because the new vehicles purchased under the Staff Greenhouse Gas Proposal have increased fuel efficiency, the average gasoline consumption per mile is lower.
- Due to the rebound effect, vehicle owners travel more miles annually and thus spend more on gasoline. (See Attachment B-4.)

These two effects act in opposite directions on gasoline consumption. However, the net effect is an overall reduction in gasoline consumption. The overall effect on gasoline expenditures is calculated by multiplying this *net* change in gasoline consumption by the average fuel price.

For this calculation, we relied on data from the Energy Information Administration ("EIA"), which provides forecasts of motor fuel prices through 2025. For California, these prices were adjusted to reflect the standard "mark-up" (i.e., the historical difference between California and U.S. fuel prices).

The change in gasoline expenditures is entered into policy variable number 59 (Consumer Spending by Residents: Gasoline and Oil). As with the change in new covered vehicle expenditure, an equal and opposite amount is put into policy variable number 180 (Consumption Reallocation by Residents: All Consumption Sectors).

B-7.2.7.b Used Car Repair Consumption

The increases in new vehicle prices will lead to reduced scrappage of existing vehicles. This scrappage effect translates into an increase in used car repair. Increases in overall VMT will also lead to increased spending on used car repair.

The effect on repair cost expenditures is equal to the difference in repair costs in the baseline and the regulation cases. We estimate these effects by first obtaining an estimate of average repair expenditures per VMT from Ward's. These estimates are then projected forward assuming a linear trend in the real cost of repair. Baseline repair cost expenditures are estimated by multiplying baseline VMT by the baseline cost per mile. This amount is then subtracted from the repair costs under the Staff Proposal.

Because repair costs are correlated with both VMT and the age of the fleet, we estimate repair costs under the Staff Greenhouse Gas Proposal as one plus the percentage increase in the fleet composed of used vehicles multiplied by VMT under the regulation multiplied by the baseline cost per mile.

Increased expenditure on used vehicle repair is placed into REMI policy variable number 54 (Consumer Spending by Residents: Vehicles and Parts). An equal amount is taken out of policy variable number 180 (Consumption Reallocation by Residents: All Consumption Sectors) to account for the decrease in the consumption of other goods.

References

U.S. Bureau of Economic Analysis ("BEA"), 2004. "Table 7.2.5S. Auto and Truck Unit Sales, Production, Inventories, Expenditures, and Price." URL: http://www.bea.gov/bea/dn/nipaweb/nipa_underlying/TableView.asp?SelectedTable=59&FirstYear=1967&LastYear=2004&Freq=Month. Accessed September 2, 2004.

Ward's Communications ("Ward's"), 2003. "Lease Penetration Rates By Vehicle Segment." URL: http://subscribers.wardsauto.com/files/1004/yearly/03usaS12.xls. Accessed September 2, 2004.

Attachment B-8: Use of Consumers' Surplus to Measure Welfare Changes from Regulation-Induced Changes in Price and Product Characteristics

Consumers' surplus is a concept commonly used to measure how much consumers are made better (or worse) off with changes in market conditions. The concept of consumer surplus can be used to measure the loss to purchasers of motor vehicles due to regulations that increase vehicle prices while simultaneously changing motor vehicle characteristics. As many commentators have pointed out, it is unlikely that such regulatory requirements would increase consumers' surplus in markets in which vendors compete strongly to sell products that customers want.[26] It is important, however, to consider the full welfare effects of regulatory-induced changes, including changes in vehicle prices and characteristics.

B-8.1 Definition of Consumers' Surplus

Consumers' surplus for a product is defined as the amount (in aggregate) that consumers would have been willing to pay, above and beyond the amount actually paid, for the units purchased of the product. A demand curve traces out the marginal values to consumers from different quantities of a product. As a result, consumers' surplus is usually calculated from areas under demand curves. When price but not quality changes for a product, only a single demand curve needs to be considered in the analysis. When quality changes, the demand curve shifts; a quality improvement makes the demand curve shift outward. As a result, analyses of changes in consumers' surplus that depend at least in part on quality changes must consider two demand curves, with and without the quality change.

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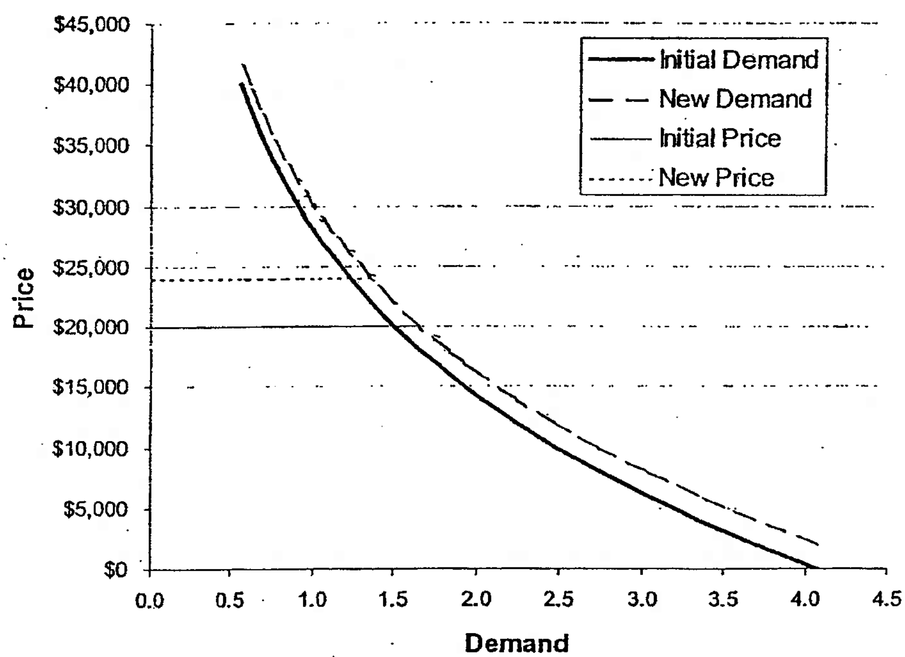
[26] For further discussion of this issue in the context of CAFE standards, see: Paul R. Portney, Ian W.H. Parry, Howard K. Gruenspecht, and Winston Harrington, "Policy Watch: The Economics of Fuel Economy Standards," *Journal of Economic Perspectives*, Vol. 17, No. 4, Fall 2003, pp. 203-217 ("RFF study"); and Congressional Budget Office, "The Economic Costs of Fuel Economy Standards Versus a Gasoline Tax," December 2003 ("CBO study").

B-8.2 An Illustrative Example

The basic concepts are depicted in Figure B8-1, with parameters chosen for illustrative purposes.[27] Consider the initial situation with an initial demand curve and an initial price. Total consumers' surplus for that demand at the initial price (here $20,000) is the area above that price but below (or, equivalently, to the left of) that demand curve. For the parameters used in this illustrative example, the total consumers' surplus is $30,000.

Figure B8-1. Illustration of Consumers' Surplus Changes Due to a Regulation-Induced Change in Price and a Desirable Vehicle Characteristic



Consider the case of a regulatory requirement that would lead to an increase in the price of the product from $20,000 to $24,000 and an increase in the level of some feature that

[27] This figure is based on demand with a semi-logarithmic functional form: $\ln(D) = a - bP$. This specific figure is based on an initial price of $20,000, an initial quantity of 1.5 million, and an initial elasticity of -1. The "new" price is $24,000, and the upward shift from the initial demand to the "new" demand is $2,000. Since the quantity in this illustrative example is measured in millions of units, the consumers' surplus calculations presented here are in millions of dollars.

consumers value positively.[28] The loss in consumers' surplus due to this change can be measured by the difference in consumer surplus between the initial condition and the regulatory condition. The new total consumers' surplus is calculated as the area under the new demand curve but above the new price of $24,000: $27,145. Compared with the initial consumers' surplus of $30,000, the loss in consumers' surplus is $2,855. This change can be decomposed into an effect due to the price increase and an effect due to the shift in demand for the product.

In this simple example, the loss in consumers' surplus due to the price increase is $5,438. This loss has two components: (1) the units that continue to be purchased now cost more, and thus consumers are worse off due to the price increase; and (2) some units that initially were worth purchasing at the low price are no longer worth purchasing at the high price.

The effects on welfare of the improved product characteristic—ignoring the effects of the higher price in order to focus on the ability of the consumer surplus calculation to account for the value placed on the improved characteristic—can be measured by the area between the two demand curves but above the initial price. In this illustrative example, this "gain" in consumers' surplus is $3,155.

In summary, although in this illustrative example, consumers place a positive value on the improved product characteristic, the net effect of the regulation-induced change in the market is to reduce consumer welfare by $2,855. [29]

B-8.3 Implication

The important point of this example is that consumer surplus can be used to measure the welfare effects of regulation-induced changes in product prices and product characteristics. The

[28] This example does not include other potential effects on product characteristics that would be considered negative by consumers. Such changes would lead to a shift inward in the demand curve.

[29] The main document provides empirical estimates of the net effects of the Staff Greenhouse Gas Proposal on consumer welfare. Attachment B-1 describes the methods used to calculate changes in consumer surplus.

value reflects the loss due to the price increase as well as the value that consumers place on any changes in product characteristics.

References

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