Saving Fuel, Saving Money, Saving Our Climate

BENEFITS FOR THE THIRTEEN STATES THAT HAVE ADOPTED CALIFORNIA'S CLEAN CAR STANDARDS

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Executive Summary

This report analyzes automobile fleet data of 13 states[1] using the VISION model developed by Argonne National Laboratory to forecast emissions and fuel use through 2030 under two scenarios.[2] We developed a business-as-usual reference case and compared it to a scenario representing adoption of Clean Car standards[3] similar to California's greenhouse gas emissions performance standards. The analysis indicates that implementing the Clean Car standards will result in significant economic and environmental benefits in these 13 states.

The Clean Car standards will contribute significantly to fighting global warming. The Clean Car standards can be achieved through the use of many technologies including alternative fuels, advanced tires, engine adjustments, and improved air conditioning systems. We estimate the Clean Car standards can avoid over 100 million metric tons of annual greenhouse gas emissions (i.e., GHG, carbon dioxide equivalent) in 2030, will cumulatively avoid nearly one billion tons of GHG emissions from 2010 through 2030, and will continue to yield benefits thereafter.

Drivers will save fuel and realize substantial cost savings with implementation of the Clean Car standards. We estimate that in the year 2030, Clean Car standards will avoid consumption of 16 billion gallons in the 13 analyzed states, thereby saving drivers $40 billion dollars in transportation fuel costs[4].

Drivers of 2030 model cars will save $190 to $720 annually through avoided fuel costs, and the average new light truck driver will save $385 to $1,430 annually in fuel costs.[5] The California Air Resources Board estimates that annualized costs of vehicle modifications to meet the Clean Car standards will average $158 per car or $43 per truck.[6] We can gauge the net benefits to consumers by subtracting the California Air Resources Board's cost estimate from our estimate of avoided fuel costs. This calculation yields a net benefit to drivers of 2030 model cars of between $33 and $560 annually and to drivers of average light duty trucks of between $340 and $1,390 annually.

Low-income drivers in particular will benefit from the Clean Car standards through avoided fuel costs. In 10 of 13 states studied, more than 20% of residences are low-income households that would be hit hardest by rising fuel prices. Low-income families benefit more significantly from Clean Car standards than the average family because they spend proportionately twice as much of their household budget on transportation[7]. Our analysis evaluated the benefits to an average low income driver in 2030 by estimating the costs of driving a 2020 model year, Clean Car compliant vehicle to depict the 10 year average age of vehicles in low income households[8].

People driving 10-year-old cars in 2030 will save from $210 to $816 in fuel costs depending on their extent of driving and fuel prices.[9] The California Air Resources Board estimates that costs associated with modifications to meet the Clean Car standards will average $46 per used car per year.[10] Subtracting the California Air Resources Board's cost from avoided fuel costs suggests low-income drivers would gain a net benefit of $164 to $770 per year.[11]

Each of the 13 states will enjoy benefits from avoided fuel costs and reduced greenhouse gas emissions. Although we modeled the 13 states in aggregate as a single fleet, we estimated state-specific benefits based on the proportion of the total 13 state fleet that can be attributed to each state's current fleet. States with larger fleets will benefit most, but all states benefit. With one-quarter of the 13-state fleet, the State of New York will save drivers nearly $8 billion in fuel costs in 2030, and will avoid 184 million metric tons of GHG emissions from 2010 through 2030.

Results

We analyzed vehicle fleet data for the thirteen states[12] that have adopted Clean Car standards under two scenarios through 2030: (1) Business-as-usual vehicle fleet characteristics, incorporating currently mandated and projected federal standards, and (2) Clean Car standards with implementation beginning with model year 2010.

The Clean Cars scenario reflected the increased application of technologies that reduce vehicular greenhouse gas emissions, including reducing tailpipe emissions of N_20 and CH_4, CO_2 emissions resulting from operating the air conditioning system, HFC refrigerant emissions released from the air conditioning system due to leakage or release from vehicle scrappage, and exhaust CO_2 emissions[13].

As listed in Table 1, the 13 states in this study represent about one quarter of the 2006 U.S. vehicle fleet and vehicle miles of travel (VMT).

TABLE 1

Cars, Trucks and VMTs in 2006 for States Adopting California's Clean Car Standards[14]

	Cars (thousands)	Proportion of 13 State Car Fleet	Light Trucks (thousands)	Proportion of 13 State Truck Fleet	Cars + Light Trucks (thousands)	VMT (millions)
Arizona	2,100	6.2%	1,950	9.3%	4,050	62,000
Connecticut	2,000	5.9%	1,000	4.8%	3,000	32,000
Maine	575	1.7%	475	2.3%	1,050	15,000
Maryland	2,600	7.6%	1,800	8.6%	4,400	56,000
Massachusetts	3,300	9.7%	2,000	9.5%	5,300	55,000
New Jersey	3,600	10.6%	2,100	10.0%	5,700	75,000
New Mexico	685	2.0%	855	4.1%	1,540	26,000
New York	8,450	24.9%	2,500	11.9%	10,950	141,000
Oregon	1,400	4.1%	1,500	7.1%	2,900	35,000
Pennsylvania	5,800	17.1%	3,900	18.6%	9,700	108,000
Rhode Island	500	1.5%	290	1.4%	790	8,000
Vermont	310	0.9%	270	1.3%	580	8,000
Washington	3,000	8.8%	2,500	11.9%	5,500	57,000
Total – 13 States	34,000		21,000		55,000	680,000
Total – 48 States (Continental U.S.)	135,000		105,000		240,000	3,000,000
13 States Proportion of 48 States	25%		20%		23%	24%

I. Implementation of the Clean Car Standards Will Significantly Reduce Vehicle Global Warming Pollution

Implementing Clean Car standards in the 13 states will significantly reduce vehicular GHG emissions. The program's flexible, fleetwide average standard will spur the application of a broad array of opportunities to reduce vehicle GHG emissions, including use of alternative fuels, advanced tire technology, engine adjustments, and low GHG emissions air conditioning systems.

Through greater application of these low GHG emitting technologies, the Clean Car standards will significantly reduce vehicular global warming pollution. Figure 1 shows total annual GHG emissions in the reference case compared to annual GHG emissions in the Clean Car standards case from 2010 through 2030. Figure 2 provides a chronological representation of the annual avoided GHG emissions starting in 2010 and ending in 2030. Table 2 summarizes the results of these two figures, showing that annual GHG emission reductions from implementing the Clean Car standards will exceed 100 million metric tons in 2030 and that cumulative reductions between 2010 and 2030 total nearly one billion tons of avoided GHG emissions.

FIGURE 1

Clean Car Standards Significantly Reduce GHG Emissions between 2010 and 2030

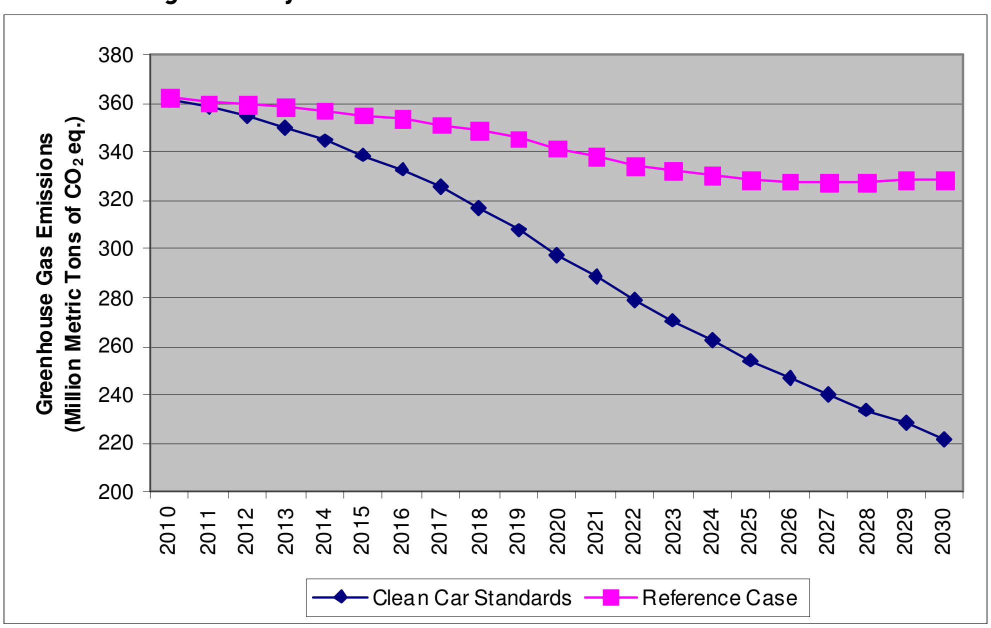


Figure 1 shows carbon dioxide emissions from 2010 through 2030 for reference case and Clean Car standards. The total area between the two lines is the benefit from Clean Car standards, equaling nearly one billion tons of avoided emissions during the study period.

FIGURE 2

By 2030 Clean Car Standards Can Reduce GHG by 110 Million Metric Tons Per Year

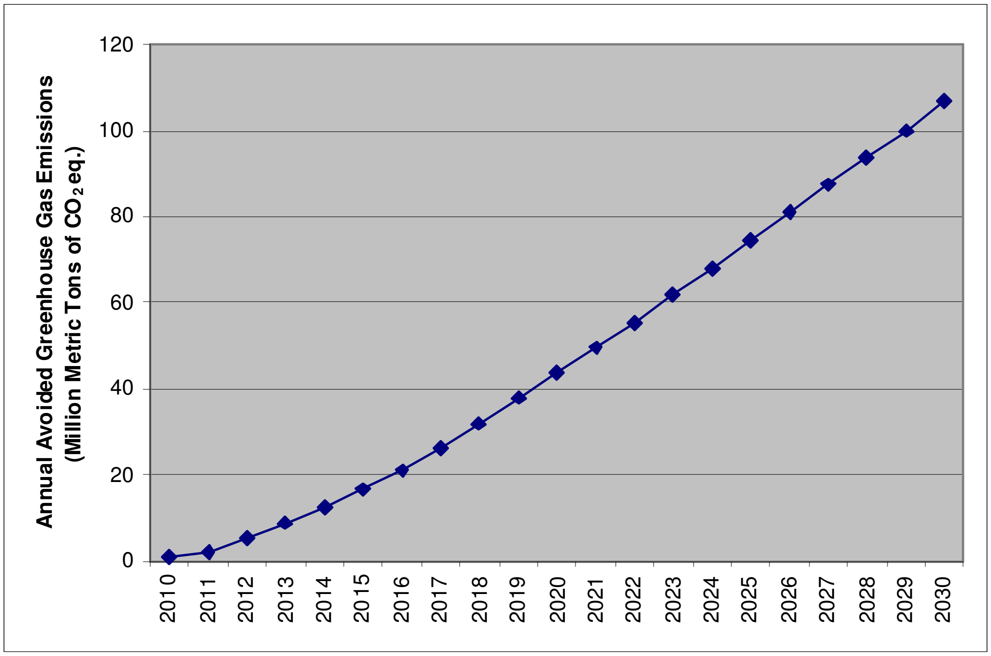


Figure 2 shows annual avoided emissions from Clean Car standards reaching about 110 metric tons per year by 2030.

TABLE 2

Summary of Avoided Greenhouse Gas Emissions in 2030 with Clean Car Standards

	Cars	**Light Trucks**	**Cars + Light Trucks**
Annual Avoided GHG Emissions (MMTCO2 Eq, 2030)	55	50	105
Cumulative Avoided GHG Emissions (MMTCO2 Eq, 2010-2030)	515	470	985

II. Implementation of the Clean Car Standards Will Save Consumers Money

Implementation of the Clean Car Standards will spur the application of a wide variety of opportunities to reduce vehicular GHG emissions. This analysis examines the benefits due to more fuel-efficient engines and onboard air conditioning, just two of the suite of measures available to reduce greenhouse gas emissions. More efficient engines will reduce greenhouse gas emissions, save consumers money in fuel costs, and strengthen national security by reducing the nation's reliance on imported oil.

Our model of the wide range of changed vehicle fleet characteristics under the Clean Car standards included estimates of vehicle fuel efficiency, based on estimates developed by the California Air Resources Board[15]. We used these estimates to gauge the benefits of reduced fuel costs and avoided fuel use from implementation of the Clean Car standards.

Table 3 shows that by 2030 Clean Car standards cut 16 billion gallons of annual fuel consumption from the forecasted vehicles fleets of the 13 states studied.[16] Figure 4 demonstrates the range of potential consumer fuel cost savings that implementation of the Clean Car standards will provide. Drivers of 2030 model cars will save $190 to $720 annually through avoided fuel costs and new truck drivers will save $385 to $1,430.[17]

The California Air Resources Board estimates that the annualized costs of vehicle modifications to meet the Clean Car standards will average $158 per car or $43 per truck.[18] We can gauge the net benefits to consumers by subtracting the California Air Resources Board's cost estimate from our estimate of avoided fuel costs. This calculation yields an annual net benefit to drivers of 2030 model cars of between $33 and $560 and to drivers of average light duty trucks of between $340 and $1,390.[19]

TABLE 3
Summary of Fuel Saving Benefits of Clean Car Standards

	Cars	Light Trucks	Cars + Light Trucks
Avoided Fuel Use in 2030 (Gallons/Year)	10,000,000,000	6,500,000,000	16,000,000,000
Avoided Fuel Costs ($/Year)	$24,000,000,000	$16,000,000,000	$40,000,000,000
Avoided Fuel Costs for New 2030 Car ($/Year)[20]	$190 - $720	$385 - $1,430	-

FIGURE 3

Clean Car Standards Will Save Billions of Gallons of Fuel from 2010 to 2030

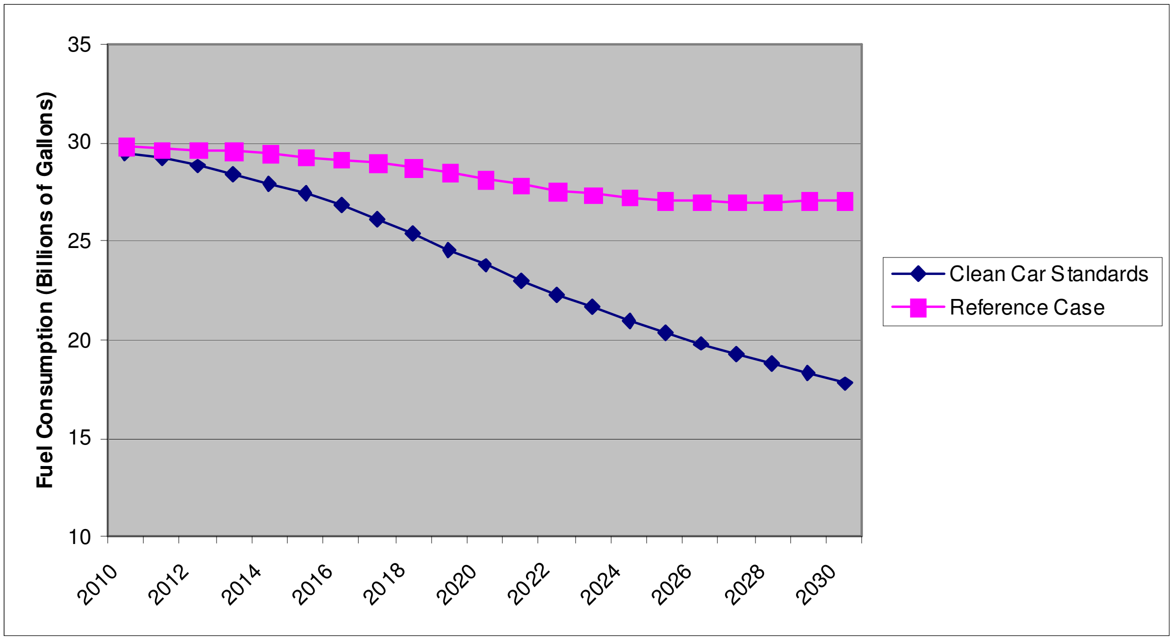


Figure 3 displays the fuel consumption from 2010 thru 2030 in the reference case and the Clean Car standards case. The total area between the two lines is the fuel savings benefit from Clean Car standards, equaling nearly 100 billion gallons of avoided fuel use during the study period.

FIGURE 4

Fuel Cost Savings from Clean Car Standards by Fuel Price (per Gallon) and VMT

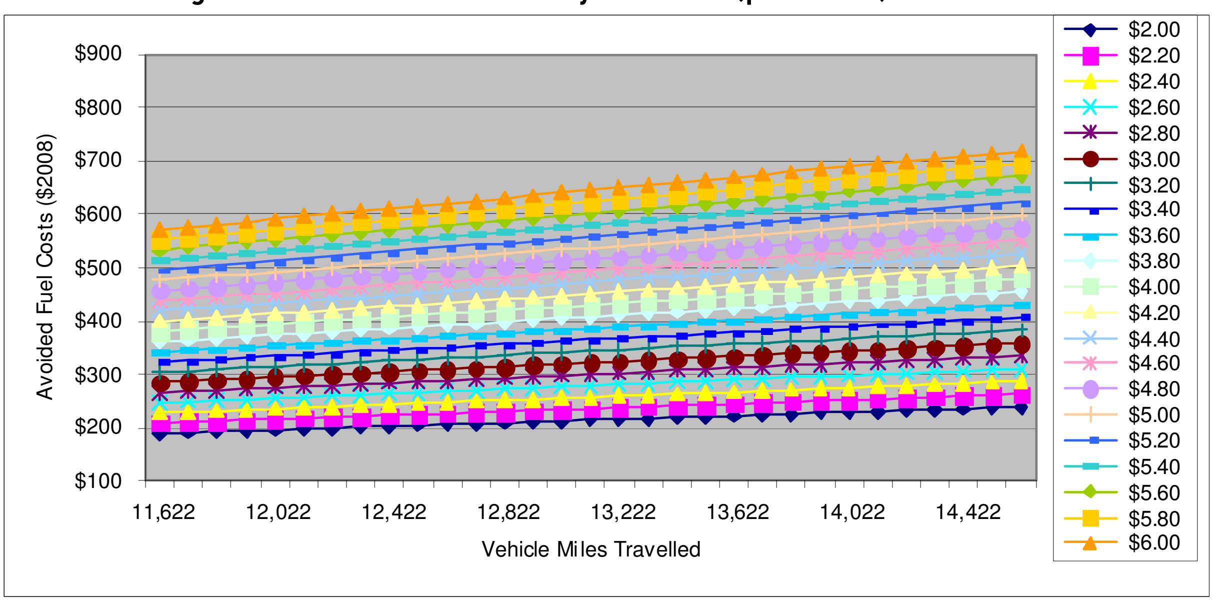


Figure 4 represents the savings based on a range of fuel prices and VMT for new cars that meet Clean Car standards in 2030. The figure demonstrates that estimated savings varies widely based on the assumptions of fuel price and vehicle miles traveled, from less than $200 to over $700.

III. Implementation of Clean Car Standards Will Benefit Low Income Households

Ten of the thirteen states in our study have at least 20% of all households considered low income (see Figure 5). Low-income families benefit more significantly from Clean Car standards because they spend proportionately twice as much of their household budget on transportation than the average family[21]. Americans, on average, spend as much as $0.20 of every dollar they earn to put gas in their vehicle,[22] but most low-income households spend substantially more. Economic constraints also mean low income drivers will tend to drive older cars, are prone to shorter average trip distances, and will drive fewer miles annually.

While drivers from low-income households will tend to drive less, and will tend to drive older cars, their proportionally higher spending on transportation means that they will particularly gain from implementation of the Clean Car standards. Our estimates evaluated the benefits to an average low income driver in 2030 by estimating the benefits of driving a 2020 model year, Clean Car compliant vehicle (representing the 10 year average age of vehicles in low income households[23]).

Figure 6 shows that drivers of 2020 cars in 2030 will save from $210 to $815 in fuel costs depending on their extent of driving and actual fuel prices[24]. The California Air Resources Board estimates that annualized costs associated with modifications to meet the Clean Car standards will average $46 per used car and $51 per used truck.[25] An estimate of net benefits to low income consumers is the difference between fuel cost savings and the cost of modification to meet Clean Car standards. Subtracting the California Air Resources Board's cost estimate from our estimate of avoided fuel costs, we find that drivers of year 2020 cars in 2030 would gain a net benefit of $164 to $770 per year.[26]

FIGURE 5

Percent of Low Income Households in each of the 13 States

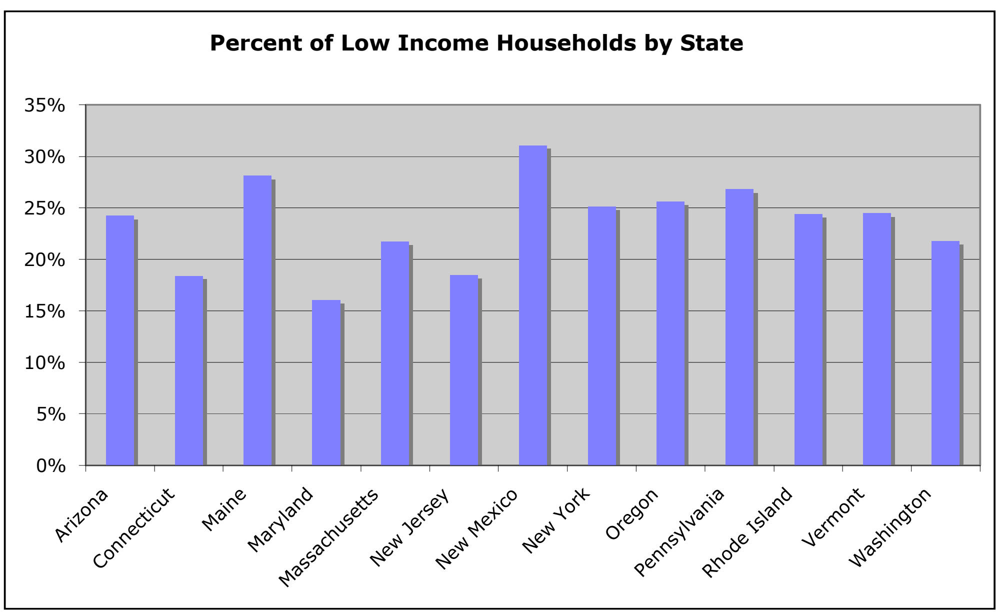


Figure 5 shows the percentage of low income households in each state of this study. A low income household is a household with an annual income of $25,000 or less comprising two parents, or one single parent, and at least one child under 18. New York had the overall largest number of low income households, and New Mexico has the highest percentage of low income households.

FIGURE 6

Savings as Function of Fuel Price (per Gallon) and VMT for 10-year old Vehicles in 2030

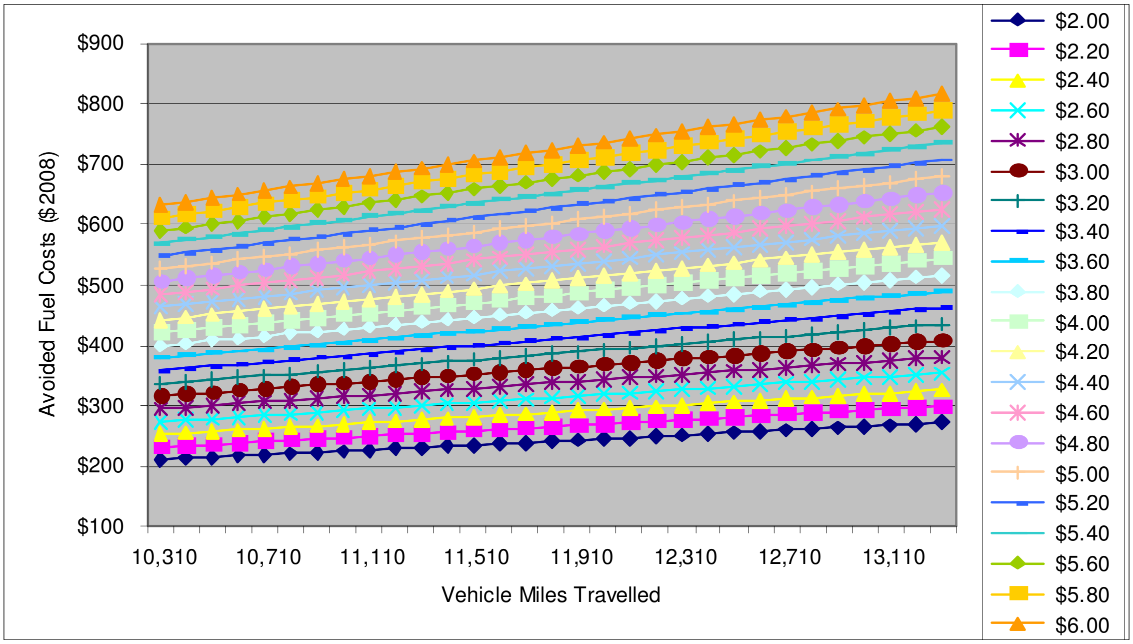


Figure 6 represent driver savings as a function of fuel price and VMT for 10-year old vehicles in 2030 that meet Clean Car standards when compared with CAFE standards. Vehicles that are 10 years older in 2030 will have a fuel efficiency based on the Clean Car standards model year 2020 requirements. This figure indicates low-income driver annual fuel cost savings in 2030.

IV. Implementation of Clean Car Standards Will Benefit Each of the 13 States

We modeled the vehicles in 13 states as one fleet, but we can estimate the benefits for individual states using the proportion each states' fleet represented in the aggregate 13-state fleet. Table 5 translates the findings presented in Tables 3 and 4 using the proportional representation of individual states' fleets shown in Table 1. The states with the largest fleets, notably New York and Pennsylvania, will enjoy the most benefits.

TABLE 5

States' Avoided Greenhouse Gas Emissions and Avoided Fuel Costs with Clean Car Standards

	Cars		Trucks		Cars + Trucks	
	Avoided Fuel Costs in 2030 ($million/Year)	Avoided GHG Emissions 2010-2030 (MMTCO2 E)	Avoided Fuel Costs in 2030 ($million/Year)	Avoided GHG Emissions 2010-2030 (MMTCO2 E)	**Avoided Fuel Costs in 2030 ($million/Year)**	**Avoided GHG Emissions 2010-2030 (MMTCO2 E)**
Arizona	$1,500	31.8	$1,500	43.6	**$3,000**	**75.5**
Connecticut	$1,400	30.3	$800	22.4	**$2,200**	**52.7**
Maine	$400	8.7	$400	10.6	**$800**	**19.3**
Maryland	$1,800	39.4	$1,400	40.3	**$3,200**	**79.7**
Massachusetts	$2,300	50.0	$1,500	44.8	**$3,800**	**94.7**
New Jersey	$2,500	54.5	$1,600	47.0	**$4,100**	**101.5**
New Mexico	$500	10.4	$700	19.1	**$1,200**	**29.5**
New York	$6,000	128.0	$1,900	56.0	**$7,900**	**183.9**
Oregon	$1,000	21.2	$1,100	33.6	**$2,100**	**54.8**
Pennsylvania	$4,100	87.9	$3,000	87.3	**$7,100**	**175.1**
Rhode Island	$400	7.6	$200	6.5	**$600**	**14.1**
Vermont	$200	4.7	$200	6.0	**$400**	**10.7**
Washington	$2,100	45.4	$1,900	56.0	**$4,000**	**101.4**
13 State Total	$0	515.0	$0	470.0	**$0**	**985.0**

Appendix: Methods

The findings presented in this report are based on a computer model developed to simulate the 22-year evolution of passenger car and light truck fleets in the 13 states adopting California's Clean Car standards from 2008 through 2030. We used the *VISION AEO 2008 Expanded Model* to quantify complex economic, socio-demographic and environmental interactions using several metrics and inputs:

- Initial Condition Inputs from 1970
  - Number of existing passenger cars (PC) and light trucks (LT) by age
  - Fuel efficiency by vehicle type
  - Vehicle usage (i.e., miles of travel) by vehicle type and age
  - Fuel prices
  - Carbon content by fuel type
- Forecast Inputs through 2030
  - PC and LT fleet by type and age
  - Vehicle usage by vehicle and fuel type (e.g., gasoline, diesel, electric)
  - Fuel efficiency by vehicle class
  - Prices by fuel type
  - Price-demand response functions
- Outputs for each year through 2030
  - Vehicle miles of travel by vehicle type
  - Fuel consumption by fuel type
  - Carbon dioxide and carbon dioxide equivalent emissions by vehicle type

VISION was developed by researchers at Argonne National Laboratory and has been used to study the fuel and emissions effects of various transportation policies.[27] Nevertheless, like any vehicle fleet model, VISION provides an analog of a complex socio-technical system that has decreasing reliability as we look further into the future[28]. In this section we discuss our modeling approach and associated biases that may be introduced by our methods. It is appropriate to consider the ways in which VISION is a reliable forecasting tool and how the model affects the reliability of findings presented in this report. While myriad commentaries have categorized modeling uncertainties[29], it is useful to consider four important sources of uncertainty when using models to evaluate policy:

1. *Model formulation uncertainty* – Are the algorithms in the model complete and accurate representations of the processes of interest? Does the modeling construct allow for representation of the changes engendered by the policy being studied? Does the model formulation contribute to output biases?
2. *Forecast uncertainty* – How far in the future does the model forecast? What is the historical basis and how robust is the observational database that provides input values? Is the empirical evidence from historical observations a reliable basis for predicting the future?
3. *Problem definition uncertainty* – Is the model representing the relevant processes? Is the set of solutions represented accurately and completely?
4. *Model input data uncertainty* – Do the input values accurately and completely describe the range of likely values? In what ways might the input data bias model results? Is there

potential for compensating error? Are input parameter assumptions and values based on theoretical values or direct observation? Are the observations that provide the basis for input values statistically significant and representative samples?

Each of these sources of uncertainty is discussed below with respect to modeling thirteen states' vehicle fleets using VISION. Most attention is devoted to the fourth source of uncertainty, input data, because the unique contribution of our study is to modify input assumptions to represent a 13-state fleet and to input changes to represent the Clean Car standards.

Model Formulation and Forecast Uncertainty

VISION is a state-of-the-science, open source, publicly available model. It is used for research that is frequently published in peer-reviewed journals. Though not perfect, the model is well vetted and has an excellent pedigree.

VISION is necessarily a simplification of very complex and dynamic socioeconomic and technical processes. VISION links fuel efficiency and fuel costs with vehicle use, but doing so necessarily introduces uncertainty and the relationship is not fully dynamic. Changing fuel cost assumptions does change VMT at a constant rate based on a "VMT elasticity" of -0.1. In words, VMT will decline by 10% if fuel prices grow by 100%. Real driving behavior is influenced by changes in fuel costs, but the appropriate elasticity value is debatable, influenced by a variety of factors (notably the availability of transportation alternatives) and is thus likely not constant across time, fuel prices or the 13 states.[30]

Our ability to forecast differences in fleet characteristics is increasingly uncertain as we look farther into the future.[31] To address this unavoidable limitation, we present findings through only 2030 even though VISION is constructed to forecast to 2100.

The historical database used to represent the existing vehicle fleet is robust because VISION defaults are based on observational data reported in the Energy Data Book for 1990 dating back to 1970, and then "evolved" with a stock that is calibrated to observed new vehicle sales data. While the preferred approach for representing the fleets of the 13 states would be to acquire actual data for each state describing registered vehicles by class and age, those data are not readily available. Below we discuss the potential for output biases introduced by using a sampling of the national fleet to represent the fleets of 13 States.

Our study compares scenarios that depict differences by policy actions and not other types of systemic responses such as fuel taxes or driving restrictions. We also do not attempt to represent compliance with the Clean Car standards through increased use of alternative fuels or alternative-fueled vehicles. To the extent that formulation errors manifest in outputs for both scenarios, the calculation of scenario *differences* will minimize the importance of output biases shared by both scenarios. For this reason, we report outputs in terms of differences between scenarios.

Input Data Uncertainty

VISION has default national fleet data that we adjusted to represent vehicle fleets of the 13 states that have adopted California's Clean Car standards. We also adjusted parameters to more accurately represent these fleets, such as the proportion of forecasted light-duty truck and passenger car sales.

To represent 13 states in VISION, we examined U.S. Bureau of Transportation Statistics database to determine the portion of the 2008 U.S. fleet that is represented by the 13 States' fleets. We then adjusted the default national fleet in VISION to represent only the 13 Clean Car States' fleets. The VISION model builds its forecast by observing trends from 1970, including retiring vehicles at previously observed rates, so we disaggregated all vehicles into age classes based on profiles developed from the actual vehicle fleets in California and Texas. We did not adjust fleet age to represent shorter lifetimes in the northeastern states due to harsher wintertime conditions, but the error introduced in representing old vehicles is minimized by studying fleets through 2030. To the extent that the fleets of the 13 states are retired at rates faster than assumed in VISION, the findings about benefits of lower GHG emitting cars are conservative. If vehicles are retired faster – older, higher GHG emitting vehicles spend less time on the road – the benefits from lower GHG emitting cars will be enjoyed sooner and more extensively.

We used default values for the market penetration of new technologies, such as electric vehicles and plug-in electric vehicles. There are several ways to forecast strategies used to comply with the Clean Car standards:

- Fuel switching
- Vehicle switching
- Vehicle technologies that improve air conditioning efficiencies and reduce leakage, and that reduce emissions of non-CO2 greenhouse gases, notably nitrous oxide and methane.
- Vehicle fuel efficiency
- Advanced tire technology
- Combinations of the above

The forecasted fleet characteristics provided from CARB include credits for air conditioning, nitrous oxide and methane compliance strategies, and fuel efficiency.[32] Our analysis of fuel savings focused on CARB's break-out of modeled fleet fuel efficiency.

We study a range of values for fuel costs. Our midrange values for gasoline are $2.47 per gallon in 2030, which VISION provides as a default value based on forecasts by the U.S. Department of Energy's Energy Information Administration. The gasoline and other fuel price assumptions are conservative, as discussed in more detail below. To the extent that future fuel prices are higher, so too will be the benefits of fuel savings.

Adapting VISION Default Fleet to Represent 13 States' Fleets

Several steps were taken to adapt VISION to represent the existing and future vehicle fleets of 13 states. The default fleet in VISION describes the entire United States.

Passenger Car (PC) Fleet Adjustment

1) We developed an estimate of the existing fleet of passenger cars (PC) for model years 1970 through 2030. As summarized in Table 1, we examined 2006 data from the Bureau of Transportation Statistics to determine the proportion of all vehicles in the U.S. in the 13 states for both PC and LT. The 13 states account for 23% of the national fleet. We estimate sales of PC for each year in the 13 states back to 1970 and forecasted to 2030. To do so, we calculated the proportion of total light duty vehicle sales that were PC and LT, and then split 23% of national forecasted sales amongst PC and LT. This method represents the dramatic growth in LT. Sales of LT were a smaller portion (about 14%) of total light duty vehicles in 1970, but 40% of sales in 2006, and are expected to be 52% by 2030 according to the defaults in VISION.
2) Although we calculate PC sales from 1970 to 2030, VISION only uses sales after 1990. Prior to 1990, fleet values are static in the model. Therefore, to better represent PC between 1970 and 1990 we examined VISION default data to estimate an annual retirement rate and then applied these factors to estimate fleets from 1990 back to 1970.
3) To calibrate VISION fleet data for PC, we compared the 2006 BTS data with the fleet in VISION. We found that PC fleets in BTS data were about 11% larger than in VISION, so we used this difference as a stock correction factor. We corroborated our results with the BTS data. The BTS data indicates 34,522,000 passenger autos in 2006, whereas VISION calculates 34,710,000, a difference of 188,000 vehicles or less than 1%.

Light Duty Truck Fleet Adjustment

1) Like passenger vehicle fleets, we developed an estimate of the existing fleet of light duty trucks (LT) for years 1970 through 2030. We used the same method as the PC fleet, starting with examination of 2006 data from the Bureau of Transportation Statistics as listed in Table 1 to determine the proportions of PC and LT.
2) VISION uses sales of LT to calculate fleet totals after 2000 whereas for PC sales determine the fleet for 1991 onward. Before 2000, VISION has static LT fleet values. Therefore, to better represent LT between 1970 and 2000, we examined VISION default data to estimate an annual retirement rate and then applied that rate to estimate fleets from 2000 back to 1970.
3) To calibrate VISION fleet data for LT, we compared the 2006 BTS data with the fleet generation in VISION and found that LT fleets in BTS data were very similar to the generated fleet numbers for LT in 2006. We did not need to adjust the stock correction factor in the model for the entire LT fleet.
4) We corroborated our fleet estimate with the BTS data. The VISION LT fleet in 2006 using BTS data was quite similar to VISION values, so we did not alter the stock correction factor. VISION calculates 21,393,000 LT for 2006, whereas BTS data indicate 21,386,000, a difference of 25,000 cars or less than 1%.

Fleet Assumptions for Calculating Fuel Savings

Our analysis estimated the magnitude of two major co-benefits of the Clean Car standards: reduced fuel consumption and reduced fuel costs. In order to assess these co-benefits, we focused on the break-out of estimated fuel efficiency, one of a range of strategies to meet the Clean Car standards.

VISION calculates the fleet average fuel efficiencies, whereas we input assumptions for new cars from 2009 through 2030. Fuel efficiencies for the on-road fleet and new cars differ as shown in Table M-1 for years 2020 and 2030 for cars and light trucks.

Our assumptions about new car fuel efficiency in the 13 state fleets are shown in Figure M-1 and Table M-2. We developed these assumptions from several sources:

- VISION defaults that represent the effects of Federal CAFE standards
- CARB forecasts for the Clean Car standards in the California fleet
- Estimates by UC Davis researchers who adapted VISION to reflect the California.

Forecasts from CARB provide the basis for fuel efficiency associated with implementing Clean Car standards, but CARB's forecast is to 2020, so we use the trend established from 2010 through 2020 to forecast 2021 through 2030.

TABLE M-1

Differences between New Car Fuel Efficiencies and Fleet Average Fuel Efficiencies

Year	New Car CAFE Reference	New Car Clean Car Standards	VMT weighted 13 State Car Fleet CAFE Reference	VMT weighted 13 State Car Fleet Clean Car Standards
2020	32.70	49.10	24.49	29.05
2030	42.73	65.76	25.77	40.80
	New Light Truck – CAFE Reference	**New Light Truck Clean Car Standards**	**VMT weighted 13 State Light Truck Fleet CAFE Reference**	**VMT weighted 13 State Light Truck Fleet Clean Car Standards**
2020	21.88	31.97	17.27	19.81
2030	21.98	33.01	17.48	26.55

FIGURE M-1

Fuel Efficiency Assumptions for 13 State Fleets

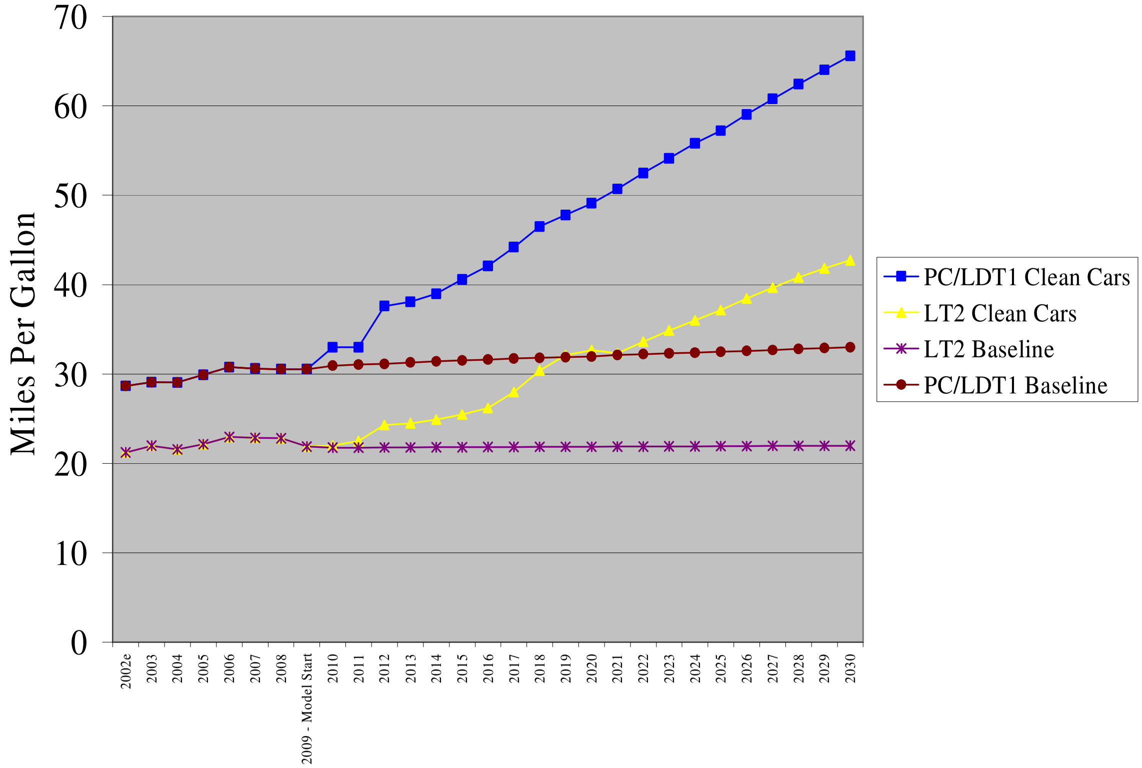


TABLE M-2

Fuel Efficiency Assumptions

Model Year	Clean Car Standards PC/LDT1	Clean Car Standards LT2	CAFE Standards PC/LDT1	CAFE Standards LT2
2002	28.68	21.24	28.68	21.24
2003	29.08	21.99	29.08	21.99
2004	29.07	21.59	29.07	21.59
2005	29.91	22.17	29.91	22.17
2006	30.77	22.96	30.77	22.96
2007	30.62	22.87	30.62	22.87
2008	30.54	22.82	30.54	22.82
2009 - Model	30.50	21.90	30.54	21.90
2010	33.00	22.00	30.93	21.77
2011	33.00	22.50	31.07	21.78
2012	37.60	24.30	31.13	21.79
2013	38.10	24.50	31.29	21.80
2014	39.00	24.90	31.42	21.81
2015	40.60	25.50	31.52	21.82
2016	42.10	26.20	31.63	21.83
2017	44.20	28.00	31.73	21.84
2018	46.50	30.40	31.81	21.85
2019	47.80	32.10	31.88	21.86
2020	49.10	32.70	31.97	21.88
2021	50.81	32.32	32.12	21.89
2022	52.62	33.61	32.22	21.90
2023	54.21	34.87	32.32	21.91
2024	55.91	36.02	32.41	21.92
2025	57.31	37.17	32.50	21.93
2026	59.16	38.45	32.60	21.94
2027	60.91	39.67	32.70	21.95
2028	62.56	40.81	32.80	21.96
2029	64.19	41.84	32.90	21.97
2030	65.76	42.73	33.01	21.98

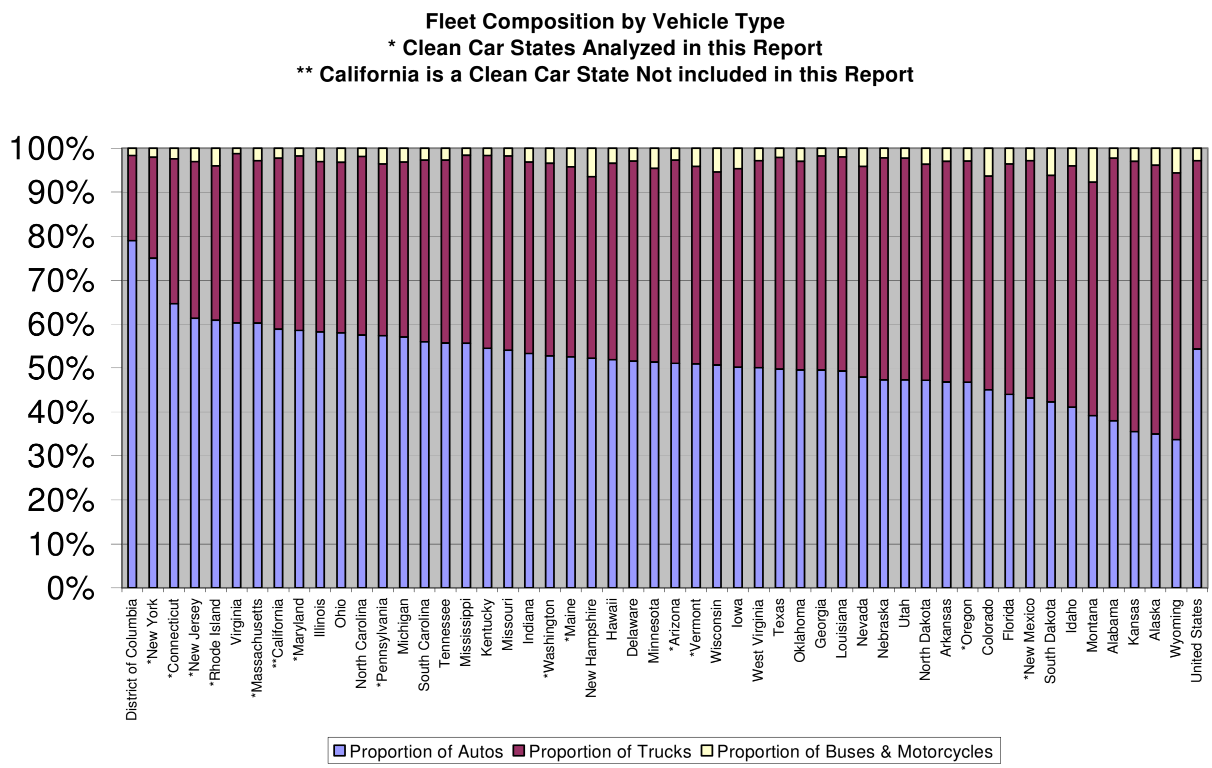
Yellow	VISION AEO Base Case Auto-LT Data Tab
Olive	Based on VISION-CA Auto-LT Data tab; derived from Margaret Singh
Magenta	Model start year
Blue	CARB, Canada vs US Pavley and CAFE adoption reports
Dark green	Forecasted from the previous years
Lavender	Taken from VISION Base Case Auto-LT Data Tab.
Bright green	EDF Forecast

Comparing the 13 States with the U.S. Fleet

Our method for representing the fleets of 13 states relies on using a portion of the full U.S. fleet. This may introduce misrepresentations if the 13 states' fleets are very different than the national fleet in terms of vehicle age, proportion of light trucks and cars, and vehicle miles of travel. There are good reasons to believe that states may differ dramatically. For example, approximately 65% of all vehicles in Connecticut are passenger autos, whereas the New Mexico fleet has only 45% passenger autos. The fleet composition of states is shown in Figure M-2 with the 13 states noted by an asterisk (*). We adjusted fleet growth (i.e., proportion of new cars and light trucks sold) to represent the higher proportion of LT sales in the 13 states, but we did not adjust for VMT or fuel prices; below we discuss the potential output errors introduced as a result.

FIGURE M-2

Fleet Composition by Vehicle Type for 13 States' Fleets



Small urbanized states such as Connecticut are likely to have lower VMT per capita than bigger less urbanized states such as Arizona. We examined BTS data to compare the 13 states' fleets with the rest of the U.S., finding that drivers in the 13 states generally cover fewer miles each year than the national average, as shown in Figures M-3 and M-4.

FIGURE M-3

Distribution of Annual Per Capita VMT

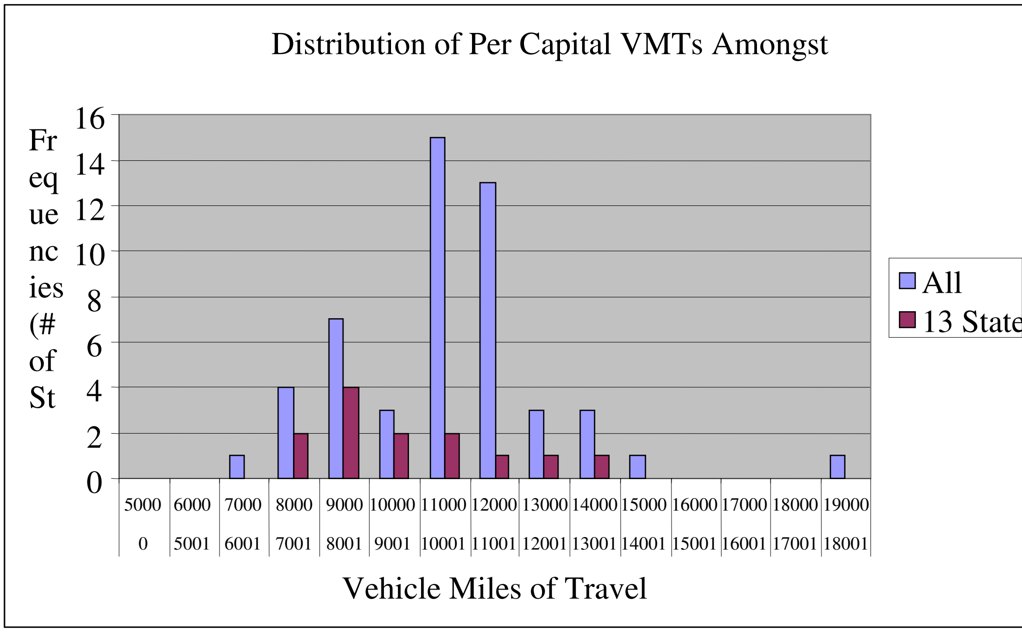
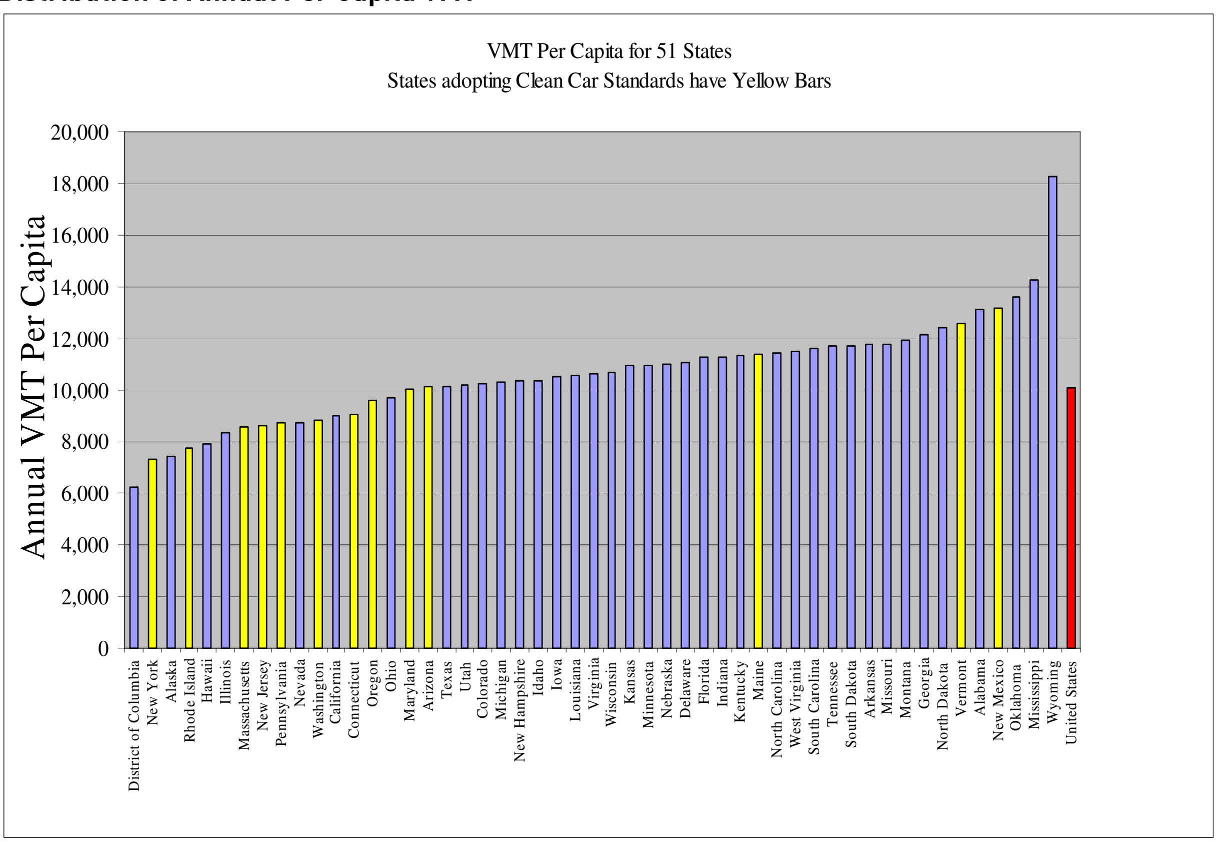


FIGURE M-4

Distribution of Annual Per Capita VMT



The economic benefits of Clean Car standards are also a function of fuel prices. To the extent that national average fuel prices are lower than in the 13 states, then the benefits of fuel savings will be underestimated by using national averages. Figures M-5 and M-6 show that average prices at the pumps, which include both fuel price and taxes, tend to be higher in the 13 states than the national average.

FIGURE M-5
Fuel Prices by State

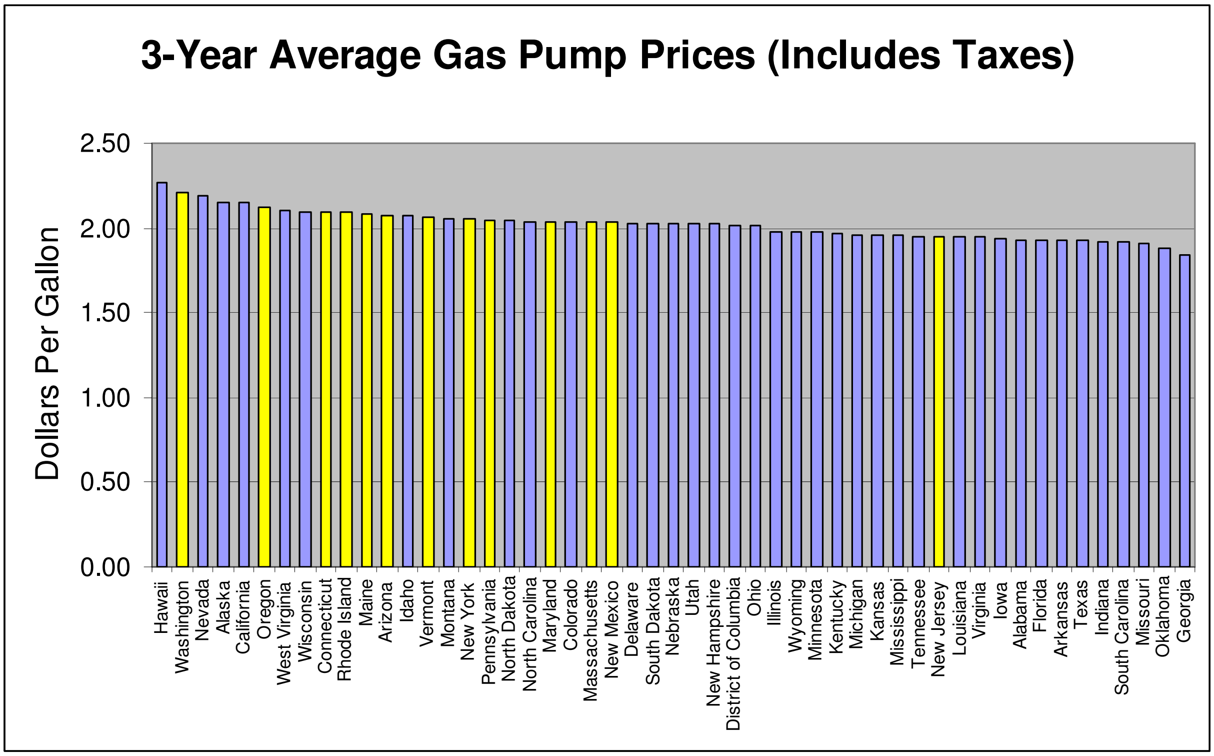
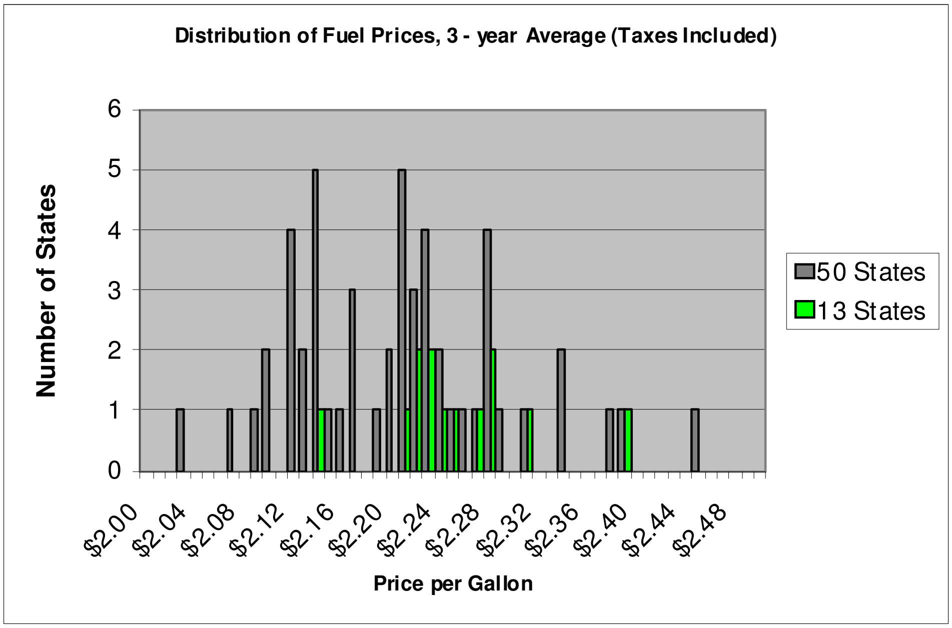


FIGURE M-6

Distribution of Fuel Prices by State



As shown in Figures M-5 and M-6, the 13 Clean Car states have higher fuel prices than the U.S average. Using national fuel price forecasts in VISION rather than state-specific forecasts biases findings downward. To more accurately represent the 13 Clean Car states, it would be appropriate to inflate fuel price forecasts slightly, but the results presented here use default VISION fuel price forecasts.

Table M-3 shows VISION default prices for selected years and various fuel types. Figure M-7 depicts the range of fuel price forecasts, and depicts visually the large uncertainty about fuel prices in 2030. Clearly, the uncertainties associated with future fuel prices are significantly greater than small biases introduced by the relatively small fuel price differences between the 13 states and the national average.

TABLE M-3

VISION Default of Fuel Prices

Fuel Prices	2000	2010	2020	2030
Gasoline	1.70	2.57	2.38	2.47
Diesel	1.52	2.38	2.21	2.37
Natural Gas	1.16	1.65	1.47	1.56
Ethanol (E85)	2.23	2.86	2.20	2.38
Hydrogen	14.53	10.90	5.81	4.36
F-T Diesel	2.18	2.36	2.02	2.12
Bio-Diesel	2.24	2.47	2.19	2.18
Methanol	1.94	2.88	2.43	2.57
Electricity	2.04	2.29	2.20	2.23

FIGURE M-7

EIA World Oil Price Forecasts and Actual Price, 1997 - 2007

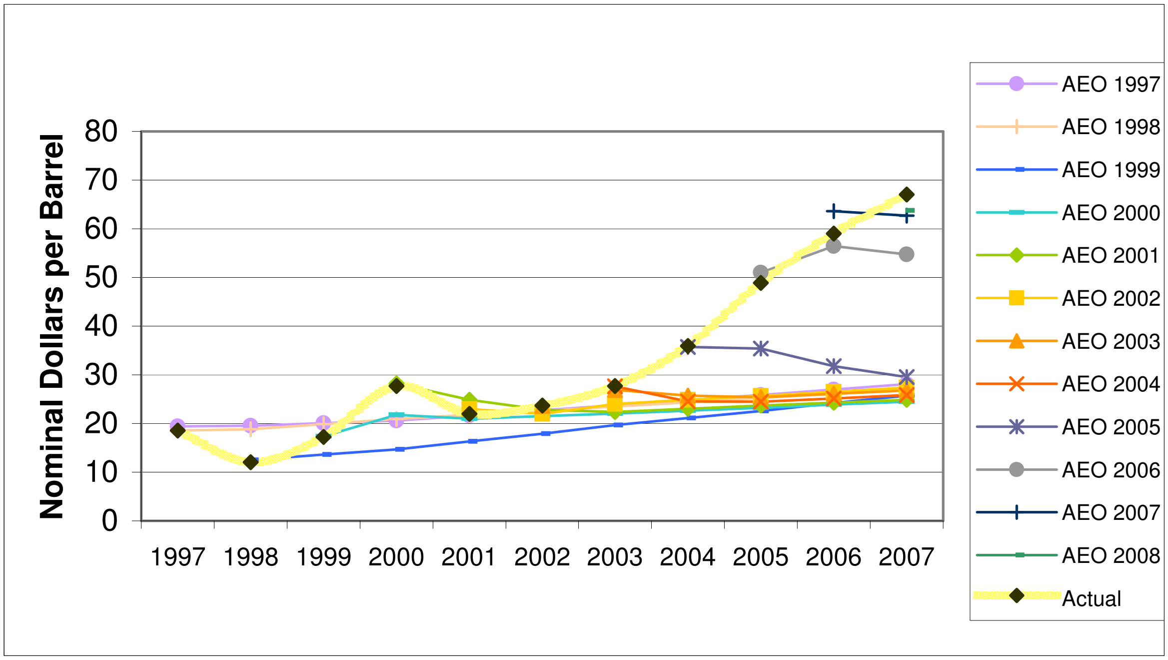


Figure M-7 shows that forecasts developed by the U.S. Energy Information Administration – the Annual Energy Outlook (AEO) - have tended to underestimate fuel prices since the turn of the 21st Century. The average underestimate for years 2000 thru 2007, from all AEO reports, is +32%. This means that oil price forecasts tend to be underestimates by about one third, which is significant and dominating uncertainty, in the context of forecasting 2030 fuel prices.

Conclusion about Uncertainties Introduced by Methods

Carving a representation of the 13 Clean Car state fleets from the national fleet introduces at least two sources of bias pertaining to vehicle miles of travel and fuel prices. VMTs are overestimated, but fuel prices are undervalued. The relative magnitude of these biases is small and minimized in outputs because they counterbalance (i.e., compensating errors). Other sources of uncertainty are far more significant, however, and are unavoidably due to the necessary simplification of representations of very complex and variable socioeconomic dynamics, notably the relationship between driving cost and vehicle miles of travel, and future fuel prices. The importance of these uncertainties is minimized, however, by comparing differences amongst scenarios rather than focusing on absolute values, and by forecasting only to 2030.

The 50 state mean per capita vehicle miles of travel is 10,627 miles per year, or approximately 9% higher than the 13 state mean of 9,675 miles annually. However, the 50 state mean fuel price is 2% lower, $2.20 per gallon instead of $2.25. Overall, these biases are minor compared with more significant uncertainties pertaining to future fuel characteristics, including carbon content and price and vehicles stocks as well as uncertainties about the relationships between marginal driving costs and changes in vehicle miles of travel.

In VISION, vehicle miles of travel is a dependent variable that is influenced by vehicle fuel efficiency. While the basic tenants of economics suggest that higher fuel efficiency will result in increased vehicle usage due to lower marginal costs, the algorithm to represent this relationship remains uncertain due to lack of complete knowledge and natural variability. We do know enough, however, to be confident that the dynamic relationships of the real world are represented in VISION, though not completely.

Similar to the treatment of driving demand (VMTs), VISION calculates fuel expenditures based on fuel price forecasts and vehicle miles of travel (by vehicle type and age). However, VISION does not allow for a dynamic relationship between driving demand and changes in fuel prices. Consequently, it is not possible to analyze the sensitivity of outputs to VMT and fuel prices. Therefore, no assessment of the relative significance (and net effects) of compensating errors is possible.

Representing the 13 state vehicle fleets using one-quarter of the U.S. fleet is a valid analog for examining the economic and emissions consequences of vehicle emissions standards. While it would not be appropriate to claim that the numbers presented in this analysis are irrefutably correct, we are confident that the modeling results provide an acceptable analog of a real, very complex socio-technical system, and that the modeling comparison is an adequate guide for use in policy making.

While the 13 states differ from the U.S. fleet averages in several important ways – people in the 13 states drive less and pay more for gasoline – the errors are small relative to the large differences between the two scenarios compared in this analysis. Even if the biases were additive rather than compensating, the error introduced is on the order of +/- 15%, suggesting a range that still has very large positive results.

e

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Endnotes

[1] States adopting the California GHG emissions standards that are included in this analysis are: Arizona, Connecticut, Maine, Maryland, Massachusetts, New Jersey, New Mexico, New York, Oregon, Pennsylvania, Rhode Island, Vermont and Washington. Several additional states are considering action but were not included in this analysis: for example, Florida, Utah and Montana are committed by Executive Order to the Clean Car standards.
[2] The original VISION model and user information can be found at www.transportation.anl.gov/modeling_simulation/VISION/index.htm.
[3] These standards are promulgated by the California Air Resources Board in accordance with California's 2005 Assembly Bill 1493; though often called Pavley GHG auto standards, we refer to them as "Clean Car standards". AB1493 establishes declining GHG emissions performance standards through model year 2016 for passenger autos, light duty and medium duty trucks. By Executive Order, California has to achieve a 45% reduction in greenhouse gas emission rates from vehicles by 2020 using a 2002 baseline.
[4] Based on fuel costs of $2.47 per gallon in 2030 per forecasts by the Energy Information Administration. This is a very conservative assumption since fuel prices approached $4.00 per gallon in some parts of the U.S. in 2008. For example, General Motors, in its 2009-2014 Restructuring Plan submitted Feb. 17, 2009 to the U.S. Department of the Treasury, assumed that average U.S. gasoline prices would reach $4.00 per gallon by 2014. See General Motors Corporation, 2009-2014 Restructuring Plan, Presented to the U.S. Department of the Treasury As Required Under Section 7.20 of the Loan and Security Agreement Between General Motors and the U.S. Department of the Treasury Dated December 31st, 2008 (Feb. 17, 2009), available at http://media.gm.com/us/gm/en/news/govt/docs/plan.pdf.
[5] The range depends on fuel costs and actual vehicles of travel. We use a 2030 fuel cost range from $2.00/gallon to $6.00/gallon in 2030 to represent the range of views on future fuel prices, and per capita VMT range from 11,680 to 14,680 miles per year, which is plus/minus 20% of the median VMT forecasted in the VISION modeling results. See Figures 5 and 6 for more details.
[6] The scope of our analysis did not include developing our own assessment of the cost of vehicle modifications necessary to meet the Clean Car standards. The California Air Resources Board has developed estimates. See Tables 10.2-1 and 11.4-1 of California Environmental Protection Agency, California Air Resources Board, Addendum Presenting And Describing Revisions To: Initial Statement Of Reasons For Proposed Rulemaking, Public Hearing To Consider Adoption Of Regulations To Control Greenhouse Gas Emissions From Motor Vehicles, September 10, 2004. Table 10.2-1 presents annualized costs by vehicle type for 2009 through 2030, whereas Table 11.4-1 presents the annualized used vehicle estimate of $46 for cars and $51 for trucks. These point estimates do not take into account the range of costs that different types of vehicles may encounter but does give a picture of the estimated average cost per vehicle.
[7] Source: U.S. Census Bureau Data from the Survey of Income and Program Participation. Median percentage spent on commuting by income level. In 1999, persons making annual income below $8,000 spent 9.5% on commuting compared to all persons that spent 3.9% on commuting.
8 See Murakami, E, and J. Young, Daily Travel by Persons with Low Income, Federal Highway Administration and University of Tennessee, NPTS Symposium, Betheda, MD, October 29-31, 1997, Page 6, Table 4 at http://ntl.bts.gov/lib/5000/5100/5141/LowInc.pdf. For more recent information about low-income household travel characteristics, see Hu, P. and T. Reuscher, 2004, Summary of Travel Trends, 2001 National Household Travel Survey, US Department of Transportation Federal Highway Administration at http://nhts.ornl.gov/2001/pub/STT.pdf.
[9] The range presented here is based on two ranges: vehicle miles of travel ranging from 11,680 to 14,680 and fuel prices ranging from $2 to $6 per gallon. For a visual depiction of individual 2030 fuel cost savings for people driving new and 10-year old cars, refer to Figures 5 and 6.
[10] See note 7.
[11] See note 7.
[12] See Table 1 for a list of states included in this study.
[13] California Air Resources Board, Comparison of GHG Regulations for the U.S. and Canada Under U.S.CAFE Standards and ARB GHG Regulations (Feb. 25, 2008), available at http://www.arb.ca.gov/cc/ccms/reports/pavleycafe_reportfeb25_08.pdf. For an exhaustive list of technologies and their emissions benefits, refer to California Environmental Protection Agency, California Air Resources Board, Addendum Presenting And Describing Revisions To: Initial Statement Of Reasons For Proposed Rulemaking, Public Hearing To Consider Adoption Of Regulations To Control Greenhouse Gas Emissions From Motor Vehicles, September 10, 2004.
[14] These data are from the U.S. Department of Transportation, Federal Highway Administration, Highway Statistics, Table VM-2, Washington, DC: Annual editions; U.S. Dept of Commerce, U.S. Census Bureau, Statistical http://www.bts.gov/publications/state_transportation_statistics/state_transportation_statistics_2007/html/table_05_03.html
[15] See California Air Resources Board, Addendum Presenting And Describing Revisions To: Initial Statement Of Reasons For Proposed Rulemaking, Public Hearing To Consider Adoption Of Regulations To Control Greenhouse Gas Emissions From Motor Vehicles, September 10, 2004 and California Air Resources Board, Comparison of GHG Regulations for the U.S. and Canada Under U.S.CAFE Standards and ARB GHG Regulations (Feb. 25, 2008), available at http://www.arb.ca.gov/cc/ccms/reports/pavleycafe_reportfeb25_08.pdf.

[16] Savings is a function of fuel price, VMTs, and costs for cars that meet the Clean Car standards. Table 3 results are based on fuel costs of $2.47 per gallon, drawn from the default values in the VISION 2008 model that are based on the Energy Information Administration. Further analysis found below in this report evaluates a range of savings based on a set of VMTs and fuel prices from $2.00 to $6.00 per gallon.
[17] The range depends on fuel costs and actual vehicles of travel. We use a 2030 fuel cost range from $2.00/gallon to $6.00/gallon in 2030 to represent the range of views on future fuel prices, and per capita VMT range from 11,680 to 14,680 miles per year, which is plus/minus 20% of the median VMT forecasted in the VISION modeling results.
[18] See note 7.
[19] See note 7.
[20] Costs associated with onboard technologies needed to meet the Clean Car standards are not included in these ranges. For a discussion of costs associated with onboard technologies, refer to note 7.
[21] Source: U.S. Census Bureau Data from the Survey of Income and Program Participation. Median percentage spent on commuting by income level. In 1999, persons making annual income below $8,000 spent 9.5% on commuting compared to all persons that spent 3.9% on commuting.
[22] BTS. Bureau of Transportation Statistics. "Commuting Expenses: Disparity for the Working Poor." March 2003.
23 See note 9.
[24] The range presented here is based on two ranges: vehicle miles of travel ranging from 11,680 to 14,680 and fuel prices ranging from $2 to $6 per gallon. For a visual depiction of individual 2030 fuel cost savings for people driving new and 10-year old cars, refer to Figures 5 and 6.
[25] See note 7.
[26] See note 7.
[27] For examples, see ongoing research at U.C. Davis at http://steps.ucdavis.edu/research/Thread_6, and Greene et al, 2005, Energy Policy, at http://www-cta.ornl.gov/cta/Publications/Reports/FeebateEnergyPolicy_FINAL.pdf.
[28] Ascher, W. 1976. Forecasting : An Appraisal for Policy-makers and Planners. Brewer, G. 1975. An Analyst's View of the Uses and Abuses of Modeling for Decisionmaking.
[29] For a few examples, see Dutton, W. and Kraemer, K. 1985. Modeling as Negotiating: The Political Dynamics of Computer Models in the Policy Process. Ablex Publishing Corp. Norwood, N.J. and Finkel, A. 1990. Confronting Uncertainty in Risk Management: A Guide to Decision-Makers. Center for Risk Management, Resources For The Future. Washington, D.C., and J. Rotmans and de Vries, B. 1997. Chapter 10: Uncertainties in Perspective. Perspectives on Global Change: The TARGETS Approach. Cambridge University Press.
[30] For a useful summary of demand "elasticities" see Litman, T. *Transportation Elasticities: How Prices and Other Factors Affect Travel Behavior,* Victoria Transport Policy Institute, June 12, 2008 For a summary of modeling studies to evaluate policies that reduce driving-related greenhouse gas emissions, refer to Johnston, R. *Review of U.S. and European Regional Modeling Studies of Policies Intended to Reduce Transportation Greenhouse Gas Emissions*. Department of Environmental Science & Policy, University of California at Davis, July 30, 2007.
[31] Ibid. footnote 2.
[32] California Air Resources Board, Comparison of GHG Regulations for the U.S. and Canada Under U.S.CAFE Standards and ARB GHG Regulations (Feb. 25, 2008), available at http://www.arb.ca.gov/cc/ccms/reports/pavleycafe_reportfeb25_08.pdf.