OPTION 1A
IMPROVED VEHICLE FUEL ECONOMY

Description

This option is increasing light-duty gasoline vehicle efficiency by using advanced vehicle technologies. In previous work on reducing petroleum fuel consumption,[1] the staff included a wider variety of technologies and technology "packages" or groups of technologies that could be used to increase new vehicle fuel efficiency than in the current analysis. Since the previous petroleum dependence report, the California Air Resources Board (CARB) adopted a standard to reduce greenhouse gas (GHG) emissions from light-duty vehicles.[2] These standards were based in part on the potential for vehicle manufacturers to use several technologies that were included in the previous study. Thus, some of these technologies will already be used in new vehicles and become part of our base case comparison.

The current analysis focuses on the "mild hybrid" and "full hybrid" technology packages from the earlier work and the effects of the CARB GHG emissions standard. Increasing fuel efficiency levels provide the opportunity to meet transportation demand using less fuel. As a result, increasing vehicle efficiency, particularly in mass-production vehicles that constitute the majority of transportation energy demand, can result in significant reductions in petroleum use.

Background

Fuel efficiency improvements for commercially viable, production-volume vehicles have had significant attention and study. Because of the significant capital investments in vehicle manufacturing, as well as the product cycles of automobiles, most work examining changes in automotive product offerings considers scenarios for several years in the future. In the previous Energy Commission and CARB study[3] on petroleum dependence, we evaluated eight different approaches to improve light-duty vehicle fuel use efficiency.

Since many of the technologies used in the earlier study are expected to be included in future light-duty vehicle offerings in response to the CARB GHG standard, this analysis focuses on the more aggressive efficiency improvements, namely the "mild hybrid" and the "full hybrid" approaches. These two fuel efficiency improvement approaches are documented in an analyses performed by the American Council for an Energy-Efficient Economy[4] (ACEEE). The staff supplemented the ACEEE mild hybrid and full hybrid vehicle costs with cost estimates prepared by the CARB staff.[5]

ACEEE Technology Study

The ACEEE documented several technology levels or “packages” that could be used to achieve improved vehicle fuel efficiency. These packages include various technologies and are not limited to a particular device or implement. Rather, these technology options are assembled into systems that would collectively deliver improved fuel efficiency. Even though the current analysis uses only the mild hybrid and full hybrid vehicle efficiency improvement approaches, all of the options are discussed below in summary fashion because the hybrid approaches also employ the moderate and advanced technology packages.

The purpose of the ACEEE study was to provide an assessment of “technically optimum” applications of affordable vehicle efficiency improvements to allow policy makers to make more informed decisions. The authors defined four vehicle fuel efficiency improvement treatments as follows:

Moderate (29.9 miles per gallon [mpg] weighted average fuel economy)

This treatment uses current trends in the automotive industry to apply improvements that increase fuel efficiency, including some improvements now intended primarily to enhance performance rather than fuel efficiency.[6] These include:

- Mass reduction (0 percent for small cars, 10 percent for mid-sized cars, and 20 percent for minivans, pickups, and sport-utility vehicles [SUVs]).
- Aerodynamic streamlining to reduce drag 10 percent.
- More use of low rolling resistance tires (for 20 percent less rolling resistance).
- More efficient accessories.
- An advanced, high-efficiency gasoline engine (50 kilowatts per liter in place of the current 43 kilowatts per liter, without direct injection).
- Integrated starter-generator with 42-volt system.
- Improved electronically-controlled transmissions (continuously variable transmissions for cars and 5-speed automatics for trucks).

No size reductions are needed. However, small cars become slightly larger. Some of these options have already entered the market in limited applications.

Advanced (34.4 mpg)

This treatment extends the moderate treatment by using:

- More mass reduction (10 percent for small cars, 20 percent for mid-sized cars, and 33 percent for minivans, pickups, and SUVs).

- The same streamlining, low rolling resistance tires, and accessory improvements as the moderate treatment.
- An advanced, direct-injection gasoline engine (55 kilowatts per liter).
- The same integrated starter-generator with 42-volt system as the moderate case.
- Advanced electronically controlled transmissions (continuously variable transmissions for cars and 6-speed transmissions for other vehicles, all fully optimized for low emissions, low fuel consumption, and low road-load operation).

Advanced, compact, and integrated engine-transmission power trains contribute to weight reductions, but SUV mass reductions also require new materials.

Mild Hybrid (39.9 mpg)

This treatment assumes that mild hybrids will extend the advanced treatment by adding a hybrid-electric power train and electric power for 15 percent of peak power to achieve 15 to 18 percent further fuel efficiency improvements.[7] The Honda Insight mild hybrid vehicle, with an aluminum body, is identified in the ACEEE study as "an Advanced Package platform." Two categories of incremental vehicle costs are used for each of six vehicle classes. One price category is directly from the ACEEE study and represents an evolutionary process of future cost reductions as the market matures. The other price category is labeled "CARB" and represents a more aggressive cost reduction pathway, especially requiring major cost reductions for motor-controller hardware and batteries by the 2016 model year. There are consistent with the previous petroleum displacement study, updated to 2005 dollars.

Full Hybrid (45.0 mpg)

This treatment extends the mild hybrid treatment by using electric power for 40 percent of peak power to achieve 29 to 33 percent fuel efficiency improvement over the advanced treatment. Two price categories are used, as discussed above for mild hybrid vehicles and updated to 2005 dollars.

Status

In 1975 Congress passed legislation calling for Corporate Average Fuel Economy (CAFE) standards and adopted standards for light-duty passenger cars as a direct result of shortages of crude oil and petroleum products in the early 1970s. Congress directed the National Highway Transportation Safety Administration (NHTSA) to study fuel efficiency of light trucks and set their standards. When implementing CAFE requirements, Congress called on the automobile industry to double fuel efficiency of their U. S. passenger car vehicle offerings by 1985.

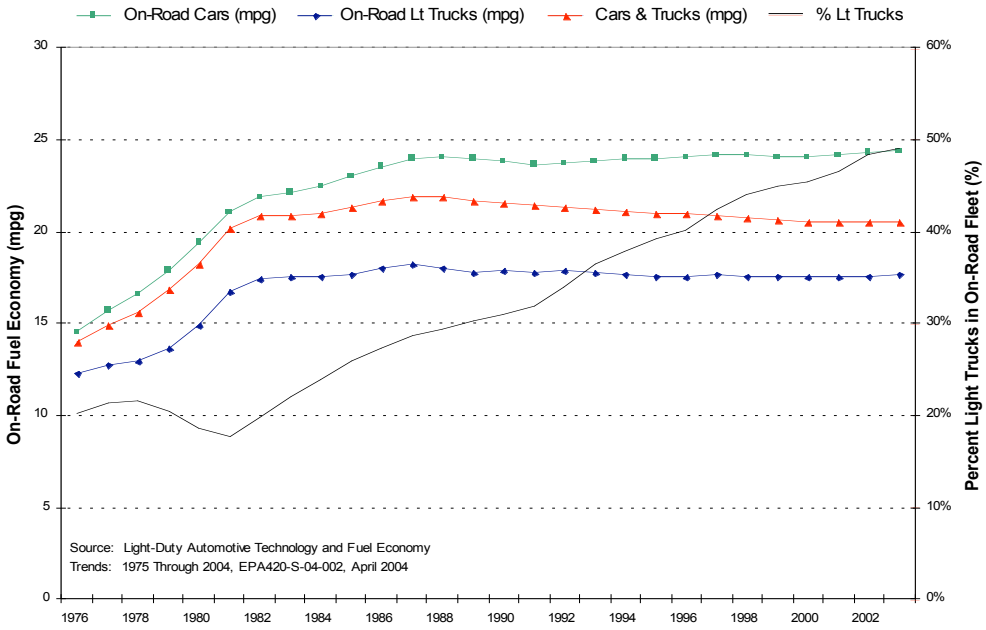
As a direct result of CAFE requirements, passenger vehicle fuel efficiency improved steadily until it reached an average of 27.5 mpg, applicable to vehicles built for Model Year (MY) 1985. This value was lowered in MYs 1986 to 1989, but was returned to 27.5 mpg in MY 1990 and has remained at that level since then.

The first year NHTSA required improved CAFE fuel efficiency in light trucks was MY 1979, at 17.2 mpg for 2-wheel drive vehicles and 15.8 mpg for 4-wheel drive vehicles. The light truck CAFE standard was gradually increased until both 2-wheel and 4-wheel drive vehicles were required to meet a standard of 20.2 mpg in MY 1992. This gradually increased to 20.7 in MY 1996. On March 31, 2003 NHTSA raised the requirement to 21.0 mpg for MY 2005, 21.6 mpg for MY 2001 and 22.2 mpg for MY 2007.

With the growing popularity of SUVs, which are classified as “light trucks” for CAFE purposes, the overall fuel efficiency of light-duty vehicles on the road has declined steadily after peaking in 1987. In 1978, light trucks comprised about 22 percent of light-duty vehicle sales. This percentage grew to approach 50 percent of all new light-duty vehicle sales in 2003.

Figure 1 shows a three-year “rolling average” of fuel economy trends of light-duty vehicles. This averaging technique is used to smooth out year-by-year effects. The curves illustrate the fuel economy progress created by federal standards and explains the impact of increased light truck sales on overall light-duty fuel economy. The top line (plotted using squares) represents the fuel consumption of fleet-average passenger cars, beginning at less than 15 mpg in 1976, increasing to about 24 mpg in 1988 and remaining fairly constant after that.[8] The third line down (plotted using diamonds) represents the fuel economy for light trucks, beginning at about 12.5 mpg in 1976, increasing to about 18 mpg in 1987 and remaining relatively unchanged thereafter. The solid line (plotted as a thick black line) represents the percent of sales of light trucks, and uses the axis values on the right of the figure. The overall fuel efficiency of all light-duty vehicle sales is displayed by the second line from the top (plotted using triangles). The overall fuel efficiency of new light-duty vehicle sales peaked in 1987 at 21.9 mpg and has decreased slowly but steadily since then, retreating to 20.6 mpg in 2003. The decline is caused by the sale of an increasing percentage of light trucks compared to passenger cars.

Figure 1. Three-Year Rolling Average Light-Duty Vehicle Fuel Economy Trends

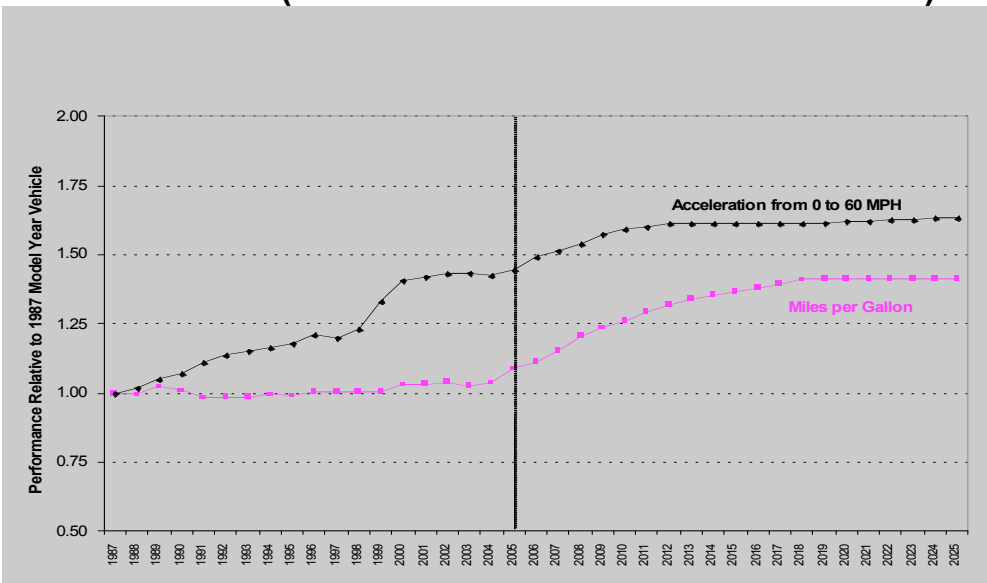


Failure to meet these standards means that an automobile manufacturer must pay $55 per vehicle for each vehicle sold multiplied by the number of mpg under the standard. While some European manufacturers have paid this fine rather than meet the CAFE standard, no Asian or domestic auto manufacturers have yet been required to pay it.

Automobile manufacturers have improved vehicle performance while generally meeting federal CAFE requirements. For example, since about 1981, manufacturers have improved the horsepower-to-weight ratio about 50 percent and reduced the 0-to-60 miles per hour acceleration by 26 percent. Furthermore, customers have been willing to pay for the cost of these improvements. In 1980, a new car cost about $15,900, while by the year 2000 a new car cost about $22,300, all in year 2001 dollars.[9] Correspondingly, fuel efficiency remained relatively constant while horsepower, weight, horsepower/weight ratio, and top speed all increased.[10]

In general, automobile manufacturers have improved the attributes of passenger cars since 1987. For example, during the 1987 to 2004 period midsize vehicle fuel efficiency held steady or improved slightly while acceleration steadily increased. In 2004 fuel efficiency was about 4 percent better than 1987 while acceleration was 40 percent better. Figure 2 shows the historical and projected trends in both fuel efficiency and acceleration for midsize cars. The projected data show the expected gain in fuel efficiency caused by the CARB GHG standards and the expected continued improvement in acceleration capability. Trends for other sizes of passenger cars are similar.

Figure 2. Midsize Car Fuel Efficiency and Acceleration from 0-to-60 MPH (with CARB GHG Standards in Place)



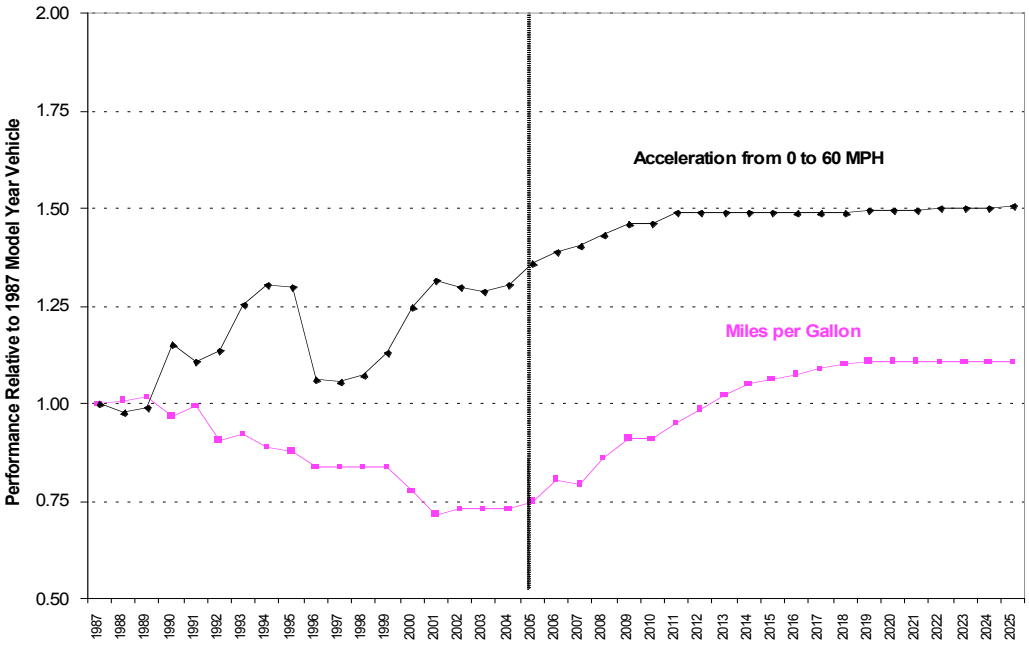
The trends for various classes of light-duty trucks are different from that of passenger cars. For example, small cross-utility light truck fuel efficiency improves slightly between 1987 and 1989 and then degrades steadily until it is only about 75 percent of the 1987 value in 2001. At that time, it holds fairly steady but is expected to increase after 2005. It does not return to 1987 levels until about 2012. Acceleration for small cross-utility light trucks degrades slightly from 1987 to 1989 and then increases from there in an oscillating fashion. By 2005 acceleration of small cross-utility trucks was 36 percent better than 1987. Future trends for both fuel efficiency and acceleration are expected to continue to improve with the CARB GHG standards in place. These trends are shown in Figure 3.

In 2001, Congress asked the National Academy of Sciences to study CAFE requirements, including potential fuel efficiency improvements and their impact on motor vehicle safety, employment, the automotive business sector, the consumer, and the impact of different CAFE requirements for both domestic and non-domestic vehicle sales. The results of this study were published in a report entitled *Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards*.[11]

Assumptions

Energy Commission staff used a consumer preference model called “CalCars” to forecast base gasoline (and diesel demand) from light-duty vehicles. Staff then used a spreadsheet model called FUTURES to extend the CalCars results to consider further enhanced fuel efficiency. This enables staff to study future vehicle configurations but does not allow use of consumer preference to determine which model of vehicles consumers would choose.

Figure 3. Small Cross-Utility Truck Fuel Efficiency and Acceleration from 0-to-60 MPH (with CARB GHG Standard in Place)



Staff used FUTURES to estimate the cost tradeoff between incremental capital cost of the advanced efficiency technologies and fuel savings over a vehicle's life, using the mild hybrid and full hybrid technologies described above to represent the advanced efficiency measures.[12]

The CARB GHG standards are expected to lead to more fuel efficient vehicles beginning in 2009. Each class of vehicle will become more fuel efficient over time due to the CARB standards. We include a scenario where the CARB standards are not in effect to see the benefits of the CARB standards. Under this alternative scenario, rising fuel prices will cause the market to demand slightly more fuel efficient light-duty vehicles as shown in Figure 4. In either case, the fuel efficiency of vehicles will improve gradually over time, and the effect is shown in the tables below.

Hybrid-electric light-duty vehicles are a small but growing segment of new vehicle sales. The CalCars Base Case forecast assumes that this segment will grow until it represents approximately 10 percent of new vehicle sales by 2020. The Base Case also assumes that the CARB GHG standards begin to require more fuel efficient vehicles beginning in 2009 and that the CARB standards would be fully implemented by 2016. The current analysis assumes that more fuel efficient vehicles and hybrid vehicles will continue to enter the market. The analysis also examines a scenario where the CARB standards do not take effect. In either case, the analysis focuses upon improving fuel efficiency only in the non-hybrid portion of the market, about 90 percent of new vehicle sales. These are the fleet of vehicles that are assumed to be converted to either a mild hybrid or a full hybrid configuration.

Fuel Efficiency Levels

Table 1 shows the level of fuel efficiency improvement expected for 15 vehicle classes, both with and without the CARB GHG standards. Values are shown for conventional and hybrid vehicles for each vehicle class and technology modeled. The number of vehicle classes of conventional gasoline vehicles has been expanded from 13 classes in the previous study[13] to 15 classes in the current CalCars model. Many of these 15 classes also have a hybrid vehicle option, and these are also shown in the table. A blank row indicates where the base case did not include a hybrid option for at least a portion of the forecast period.

To match the ACEEE classes to the 15 classes in the current base case, it was necessary to associate the 5 vehicle classes used in the ACEEE study with the 15 vehicle classes used in the FUTURES spreadsheet. This was accomplished by matching vehicle classes where appropriate. For example, the ACEEE small car results were assumed to apply for both the subcompact and compact vehicle classes for purposes of determining fuel efficiency improvement and incremental price.

For the FUTURES simulations, fuel efficiency improvements relative to the base case forecast were determined by factoring up the CALCARS baseline estimates using the percent improvements determined in the ACEEE study.[14] Because of the complexity of designing and manufacturing automobiles, it was assumed that five years would be needed before new technologies could enter the California market place and that a complete changeover could occur in seven years. In these simulations, during the seven-year implementation period one-seventh of new vehicles in each class were assumed to move from their business-as-usual fuel use rate to the mild hybrid or full hybrid fuel use rate shown in Table 1, depending on the case studied. Deployment was assumed to begin in model year 2010 and proceed uniformly for seven years, with 100 percent of new vehicle sales occurring by 2017. This allows for a relatively typical market penetration rate of a new vehicle technology. This is not meant to suggest, however, that these market penetrations are going to occur. Rather, the assumptions assist in constructing a reasonable bound for what is possible in terms of petroleum reduction, fuel savings, and associated economic effects.

Table 2 shows the incremental vehicle capital costs for each vehicle class and technology improvement case considered. These costs represent analysts' best estimates of the incremental cost of incorporating each technology in national new car sales. They are the same values used in the previous petroleum displacement analysis, updated to 2005 dollars and mapped to the 15 vehicle classes rather than the 13 classes used in the previous assessment. The estimates of incremental costs for state-only implementation would be higher, but have not been estimated (see key drivers and uncertainties below).[15]

Results

Light-duty vehicle gasoline demand reductions for each case are given in Tables 3 through 10 with results expressed in 2005 dollars. Negative values are shown with a curved bracket. Each table is for a different fuel price both with and without the CARB GHG standards. Each table includes results for millions of gallons of gasoline saved and percent saved relative to the base case forecast for gasoline demand from light-duty vehicles. Next, each table shows economic impact to consumers (Column A), change in government revenue associated with loss of state and federal excise taxes and any increased vehicular traffic associated with incremental increases in travel associated with lower cost driving achieved by the increase in fuel use efficiency (Column B), environmental benefits of reduced fuel use (Column C), the economic value of reduced petroleum dependency (Column D) and the net effect of Columns A, B, C and D.

Results are shown for discount rates ranging from 5 percent to 12 percent, with the 5 percent value representative of a societal perspective and the 12 percent representative of a private investment perspective. Tables 3, 5, 7 and 9 show results for the 5 percent discount rate and Tables 4, 6, 8 and 10 show results for the 12 percent discount rate.

Tables 3 and 4 show results for the low price forecast, which begins at $2.13 per gallon in 2004, decreases to $1.75 per gallon in 2010 and then grows slowly to $1.89 per gallon in 2025. It applies to the Energy Commission's Base Case forecast, which assumes that the CARB GHG standards are in place.

Table 1. On-Road Fuel Efficiency Levels For Each Vehicle Class in 2025 (mpg)

Vehicle Class	Baseline Forecast	Without CARB GHG Standards	Conventional Vehicle Converted to:	
			Mild Hybrid	Full Hybrid
Conventional Vehicles				
- Subcompact Car	31.8 to 37.8	27.3 to 29.9	53.3	60.0
- Compact Car	29.0 to 34.2	24.9 to 27.1	46.8	52.7
- Midsize Car	27.5 to 30.9	23.5 to 25.4	44.2	49.7
- Large Car	23.2 to 26.7	21.0 to 23.1	40.6	45.7
- Sports Car	24.5 to 26.4	22.2 to 23.3	45.5	51.2
- Small Cross-utility Car	29.5 to 35.6	25.4 to 27.7	35.8	40.4
- Small Cross-utility Truck	25.1 to 30.6	21.6 to 23.7	35.8	40.4
- Midsize Cross-utility Vehicle	23.8 to 28.1	20.7 to 23.3	26.3	29.7
- Compact Sport Utility Vehicle	21.0 to 24.5	17.8 to 20.6	35.1	39.5
- Midsize Sport Utility Vehicle	19.0 to 22.0	16.0 to 18.3	28.8	32.4
- Large Sport Utility Vehicle	16.8 to 18.8	14.9 to 16.8	28.8	32.4
- Compact Van	24.0 to 28.4	21.0 to 23.6	47.9	54.1
- Standard Van	17.8 to 20.7	15.5 to 17.8	32.8	37.1
- Compact Pickup	22.1 to 26.4	18.3 to 21.3	35.8	40.4
- Standard Pickup	18.0 to 20.3	15.7 to 17.9	26.3	29.7
Business-As-Usual Hybrids				
- Subcompact Car	41.0 to 48.7	35.3 to 38.4		
- Compact Car	39.3 to 46.7	33.8 to 36.8		
- Midsize Car	34.7 to 39.2	29.8 to 32.3		
- Large Car	34.3 to 41.0	30.7 to 33.9		
- Sports Car				
- Small Cross-utility Car	36.3 to 42.7	31.2 to 33.8		
- Small Cross-utility Truck	32.5 to 39.6	28.0 to 30.7		
- Midsize Cross-utility Vehicle	30.5 to 36.1	26.6 to 29.9		
- Compact Sport Utility Vehicle				
- Midsize Sport Utility Vehicle				
- Large Sport Utility Vehicle	22.9 to 25.6	20.3 to 22.9		
- Compact Van				
- Standard Van				
- Compact Pickup				
- Standard Pickup				

Table 2. Incremental Capital Cost Assumptions for Each Case in 2005 Dollars (Nationwide Deployment)

Vehicle Class	ACEEE Mild Hybrid	CARB Mild Hybrid	ACEEE Full Hybrid	CARB Full Hybrid
Subcompact Car	$3429	$1125	$4741	$2491
Compact Car	$3429	$1125	$4741	$2491
Midsize Car	$3857	$1339	$5572	$2813
Large Car	$3857	$1554	$5572	$3375
Sports Car	$3857	$1339	$5572	$2813
Small Cross-utility Car	$4982	$1821	$7125	$4072
Small Cross-utility Truck	$4982	$1821	$7125	$4072
Midsize Cross-utility Vehicle	$4982	$1821	$7125	$3241
Compact Sport Utility Vehicle	$4393	$1500	$6000	$3241
Midsize Sport Utility Vehicle	$4393	$1500	$6000	$3241
Large Sports Utility Vehicle	$4393	$1500	$6000	$3241
Compact Van	$4554	$1607	$6375	$3536
Standard Van	$4554	$1821	$6375	$4072
Compact Pickup	$4982	$1821	$7152	$4072
Standard Pickup	$4982	$1821	$7152	$4072

Table 3. Gasoline Reduction Relative to the Base Case Forecast from Improved Light-Duty Vehicle Fuel Efficiency (Low Price Forecast and 5 Percent Discount Rate)

Alternative Fuel Option or Scenario	+Displacement in 2025, Billion gal/yr gasoline equivalent	Reduction from Base Case Demand, percent	Present Value of Cumulative Costs and Benefits from 2005 to 2025 Billion $2005				
			A	B	C	D	A+B+C+D
			Direct Non-Environmental Benefits	Change in Government Revenue	Direct Environmental Net Benefit	External Cost of Petroleum Dependency	Direct Net Benefits
ACEEE Mild Hybrid	2.4	15.6	(23.4)	(3.5)	2.1	1.2	(23.6)
CARB Mild Hybrid	2.4	15.6	3.7	(3.5)	2.1	1.2	3.5
ACEEE Full Hybrid	3.2	20.6	(35.1)	(4.5)	2.7	1.5	(35.4)
CARB Full Hybrid	3.2	20.6	(8.6)	(4.5)	2.7	1.5	(8.9)

Table 4. Gasoline Reduction Relative to the Base Case Forecast from Improved Light-Duty Vehicle Fuel Efficiency (Low Price Forecast and 12 Percent Discount Rate)

Alternative Fuel Option or Scenario	+Displacement in 2025, Billion gal/yr gasoline equivalent	Reduction from Base Case Demand, percent	Present Value of Cumulative Costs and Benefits from 2005 to 2025 Billion $2005				
			A	B	C	D	A+B+C+D
			Direct Non-Environmental Benefits	Change in Government Revenue	Direct Environmental Net Benefit	External Cost of Petroleum Dependency	Direct Net Benefits
ACEEE Mild Hybrid	2.4	15.6	(9.3)	(1.4)	0.8	0.5	(9.4)
CARB Mild Hybrid	2.4	15.6	1.5	(1.4)	0.8	0.5	1.4
ACEEE Full Hybrid	3.2	20.6	(13.9)	(1.8)	1.1	0.6	(14)
CARB Full Hybrid	3.2	20.6	(3.4)	(1.8)	1.1	0.6	(3.5)

Table 5. Gasoline Reduction Relative to the Base Case Forecast from Improved Light-Duty Vehicle Fuel Efficiency (Very High Price Forecast and 5 Percent Discount Rate)

Alternative Fuel Option or Scenario	+Displacement in 2025, Billion gal/yr gasoline equivalent	Reduction from Base Case Demand, percent	Present Value of Cumulative Costs and Benefits from 2005 to 2025 Billion $2005				
			A	B	C	D	A+B+C+D
			Direct Non-Environmental Benefits	Change in Government Revenue	Direct Environmental Net Benefit	External Cost of Petroleum Dependency	Direct Net Benefits
ACEEE Mild Hybrid	2.3	15.4	(19.1)	(3.4)	2.0	1.1	(19.4)
CARB Mild Hybrid	2.3	15.4	8.0	(3.4)	2.0	1.1	7.7
ACEEE Full Hybrid	3.0	20.5	(27.8)	(4.4)	2.6	1.5	(28.1)
CARB Full Hybrid	3.0	20.5	(3.1)	(4.4)	2.6	1.5	(3.4)

Table 6. Gasoline Reduction Relative to the Base Case Forecast from Improved Light-Duty Vehicle Fuel Efficiency (Very High Price Forecast and 12 Percent Discount Rate)

Alternative Fuel Option or Scenario	+Displacement in 2025, Billion gal/yr gasoline equivalent	Reduction from Base Case Demand, percent	Present Value of Cumulative Costs and Benefits from 2005 to 2025 Billion $2005				
			A	B	C	D	A+B+C+D
			Direct Non-Environmental Benefits	Change in Government Revenue	Direct Environmental Net Benefit	External Cost of Petroleum Dependency	Direct Net Benefits
ACEEE Mild Hybrid	2.3	15.4	(7.6)	(1.4)	0.8	0.5	(7.7)
CARB Mild Hybrid	2.3	15.4	3.2	(1.4)	0.8	0.5	3.1
ACEEE Full Hybrid	3.0	20.5	(11.0)	(1.7)	1.0	0.6	(11.1)
CARB Full Hybrid	3.0	20.5	(1.2)	(1.7)	1.0	0.6	(1.3)

Table 7. Gasoline Reduction from Improved Light-Duty Vehicle Fuel Efficiency Relative to the Fuel Demand without the CARB GHG Standards (Low Price Forecast and 5 Percent Discount Rate)

Alternative Fuel Option or Scenario	+Displacement in 2025, Billion gal/yr gasoline equivalent	Reduction from Base Case Demand, percent	Present Value of Cumulative Costs and Benefits from 2005 to 2025 Billion $2005				
			A	B	C	D	A+B+C+D
			Direct Non-Environmental Benefits	Change in Government Revenue	Direct Environmental Net Benefit	External Cost of Petroleum Dependency	Direct Net Benefits
ACEEE Mild Hybrid	4.9	26.3	(6.8)	(6.6)	4.0	2.3	(7.1)
CARB Mild Hybrid	4.9	26.3	20.4	(6.6)	4.0	2.3	20.1
ACEEE Full Hybrid	5.7	30.6	(18.1)	(7.6)	4.6	2.6	(18.5)
CARB Full Hybrid	5.7	30.6	8.2	(7.6)	4.6	2.6	7.8

Table 8. Gasoline Reduction from Improved Light-Duty Vehicle Fuel Efficiency Relative to the Fuel Demand without the CARB GHG Standards (Low Price Forecast and 12 Percent Discount Rate)

Alternative Fuel Option or Scenario	+Displacement in 2025, Billion gal/yr gasoline equivalent	Reduction from Base Case Demand, percent	Present Value of Cumulative Costs and Benefits from 2005 to 2025 Billion $2005				
			A	B	C	D	A+B+C+D
			Direct Non-Environmental Benefits	Change in Government Revenue	Direct Environmental Net Benefit	External Cost of Petroleum Dependency	Direct Net Benefits
ACEEE Mild Hybrid	4.9	26.3	(2.8)	(2.6)	1.6	0.9	(2.9)
CARB Mild Hybrid	4.9	26.3	8.0	(2.6)	1.6	0.9	7.9
ACEEE Full Hybrid	5.7	30.6	(7.4)	(3.0)	1.8	1.0	(7.6)
CARB Full Hybrid	5.7	30.6	3.1	(3.0)	1.8	1.0	2.9

Table 9. Gasoline Reduction from Improved Light-Duty Vehicle Fuel Efficiency Relative to the Fuel Demand without the CARB GHG Standards (Very High Price Forecast and 5 Percent Discount Rate)

Alternative Fuel Option or Scenario	+Displacement in 2025, Billion gal/yr gasoline equivalent	Reduction from Base Case Demand, percent	Present Value of Cumulative Costs and Benefits from 2005 to 2025 Billion $2005				
			A	B	C	D	A+B+C+D
			Direct Non-Environmental Benefits	Change in Government Revenue	Direct Environmental Net Benefit	External Cost of Petroleum Dependency	Direct Net Benefits
ACEEE Mild Hybrid	4.1	24.0	(3.0)	(5.7)	3.9	2.3	(2.5)
CARB Mild Hybrid	4.1	24.0	24.2	(5.7)	3.9	2.3	24.7
ACEEE Full Hybrid	4.9	28.4	(10.4)	(6.7)	4.6	2.7	(9.8)
CARB Full Hybrid	4.9	28.4	30.7	(6.7)	4.6	2.7	31.3

Table 10. Gasoline Reduction from Improved Light-Duty Vehicle Fuel Efficiency Relative to the Fuel Demand without the CARB GHG Standards (Very High Price Forecast and 12 Percent Discount Rate)

Alternative Fuel Option or Scenario	+Displacement in 2025, Billion gal/yr gasoline equivalent	Reduction from Base Case Demand, percent	Present Value of Cumulative Costs and Benefits from 2005 to 2025 Billion $2005				
			A	B	C	D	A+B+C+D
			Direct Non-Environmental Benefits	Change in Government Revenue	Direct Environmental Net Benefit	External Cost of Petroleum Dependency	Direct Net Benefits
ACEEE Mild Hybrid	4.1	24.0	(1.3)	(2.3)	1.6	0.9	(1.1)
CARB Mild Hybrid	4.1	24.0	9.4	(2.3)	1.6	0.9	9.6
ACEEE Full Hybrid	4.9	28.4	(4.3)	(2.7)	1.8	1.0	(4.2)
CARB Full Hybrid	4.9	28.4	12.0	(2.7)	1.8	1.0	12.1

Tables 5 and 6 show corresponding results for our very high gasoline price forecast. This price forecast also begins at $2.13 per gallon in 2004 but grows to $2.34 per gallon in 2005. It then declines to $2.17 per gallon in 2010 before steadily growing to $2.45 per gallon in 2025. It also applies to the Energy Commission's Base Case forecast which includes the effect of the CARB GHG standard.

Potential fuel savings range from 2.3 to 3.2 billion gallons per year by 2025. This reduces gasoline consumption from light-duty vehicles by 15.4 to 20.6 percent. Gasoline savings would be only slightly higher if the analysis had been expanded to include the small portion of hybrid vehicles that are already in the base case. This is because they constitute only a small fraction of new vehicle sales and because they are already fairly fuel efficient as shown in the bottom portion of Table 1.

CARB sent their GHG standard to the California Legislature and Governor in December 2004. The enabling legislation required that the CARB standard not go into effect prior to January 1, 2006, to allow the Legislature time to review them and determine if further legislation is needed. Also in December 2004, the Alliance of Automobile Manufacturers and a group of automobile dealers in the San Joaquin Valley filed suit in a U.S. District Court located in Fresno to block the CARB GHG standard.

Due to the unsettled nature of the CARB GHG standard, it is prudent to evaluate demand for gasoline in the event that the standard does not go into effect. Tables 7 and 8 (for the low price series) and Tables 9 and 10 (for the very high price series) show the results of the analysis with gasoline reduction and cumulative benefits if the CARB GHG standard does not go into effect. Table 7 should be compared to Table 3, Table 8 should be compared to Table 4, Table 9 should be compared to Table 5, and Table 10 should be compared to Table 6.

The results of the analysis under this alternative scenario where the CARB GHG standard does not go into effect are greater than the Base Case results because there is greater gasoline consumption without the CARB GHG standard and therefore comparatively greater benefits are available.

Figure 4 shows projected fuel demand for each case. Both the mild hybrid and full hybrid cases lower gasoline demand nearly to 2003 levels by 2015 and in both cases gasoline consumption continues to decline after 2015. In the mild hybrid case, by 2025 gasoline demand reaches a level about 13 percent below 2003 demand levels. In the full hybrid case, by 2025 gasoline demand reaches a level about 18 percent below 2003 demand levels.

If the CARB GHG standard is not implemented, light-duty vehicle gasoline demand would be about 19 percent <u>above</u> projected demand levels.

Economic Benefits of Gasoline Demand Reductions (Columns A and B)

The increased fuel savings associated with higher fuel efficiency levels come with higher vehicle costs due to the associated technologies. In all cases where the results in column A are negative, consumers would experience greater out-of-pocket expenses if they employ the technology. Simply put, the fuel savings would not be sufficient to overcome the incremental capital cost of the technologies. This result is consistent with the current market for many forms of hybrid-electric vehicles which are being sold at prices higher than the economic value of the fuel savings at 2004-2005 fuel prices. In every case, state and federal governments lose revenue in the form of reduced tax collections and increased roadway maintenance.

Tables 3 through 10 also show the cumulative benefits to society, the environmental benefits, and an estimate of the cost of petroleum dependency summed over the 2005 to 2025 period.

Key Drivers and Uncertainties

Several variables interact to impact the results for each case. Changes in these variables, such as fuel price or technology cost, can dramatically alter the relative rankings of each case.

- **Incremental Capital Costs.** Each of the cases is based upon incremental capital costs associated with nationwide implementation of the associated technologies. Although we do not have estimates of their magnitude, a California-only implementation could result in somewhat higher vehicle costs.

- **GHG Emission Standard.** In December 2004, the Alliance of Automobile Manufacturers and a group of automobile dealers in the San Joaquin Valley filed suit in a U.S. District Court located in Fresno to block the CARB GHG standard. If this suit prevails, gasoline demand will be higher, as shown in Figure 4. Under this scenario, greater gasoline reductions would occur with the options evaluated in this option, and they would be more cost effective due to the larger volumes of gasoline displaced.

- **Gasoline Fuel Price.** Future gasoline prices have a greater effect on the results than any other variable in this study. If the lower fuel prices prevail, the advanced technologies are not worth pursuing from a societal perspective unless there are greater external benefits that were not reflected in the analysis. Also, in the analysis we did not include a market feedback. If gasoline demand were to drop to the degree shown in Figure 4, oil companies would likely respond by lowering retail fuel prices. This would tend to make

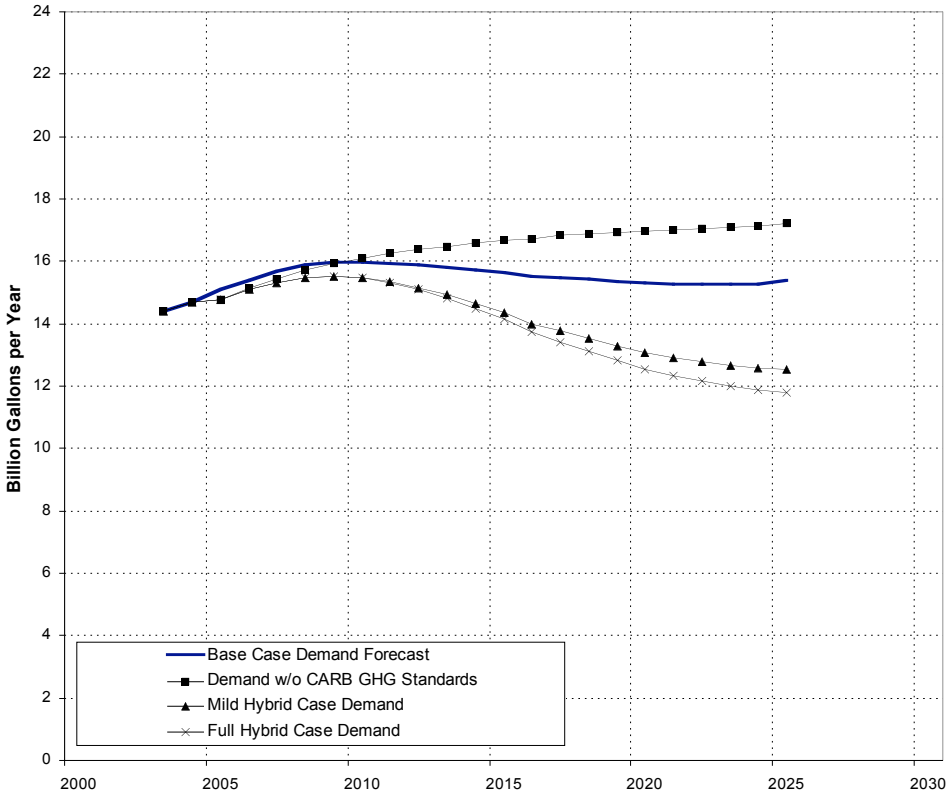
the more efficient technologies less cost-effective (simply because the fuel being displaced would cost consumers less).

- **Technology Cost Estimates.** The technology costs in this work are based on estimates derived by the ACEEE and CARB. Each of these estimates represents careful, thoughtful analysis. However, the long-term nature of these forecasts results in a significant degree of uncertainty in the technology costs used in this examination. The economic impacts calculated in this effort are, not surprisingly, highly dependent upon the assumed cost of improved fuel efficiency.

The studies were consulted to minimize this uncertainty by examining a range of incremental vehicle costs. This effort presents this range in an attempt to bracket potential costs and benefits. It is likely that the actual range of technology costs is narrower than those presented here, as industry innovation is difficult to predict. This is especially true for the most advanced fuel efficiency technologies like full hybrids since cost estimates for this technology are “best guesses” today. The implications of these shifts in technology cost, however, are obvious. Lower technology costs not only mean higher “net” benefits, but they also lead to broader technology use and introduction.

In order to translate technology improvements into real world fuel efficiency improvements, consumers will have to decide that vehicles have attained sufficiently improved performance, and that further technology improvements are worth the extra price they will require.

Figure 4. Fuel Consumption for Each Case from 2002 to 2025



Endnotes

[1] *Reducing California's Petroleum Dependence.* Joint Agency Report of the Energy Commission and CARB, August 2003.

[3] Ibid.

[4] *Technical Options for Improving the Fuel Efficiency of U.S. Cars and Light Trucks by 2010-2105*, ACEEE, April 2001.

[5] Personal communication, M Childers, CARB Staff, October 27, 2002.

[6] Numerical values in brackets are computed by FUTURES. They should be compared to "business as usual" at 20.4 mpg.

[7] Near-term hybrids now being introduced by automobile manufacturers are more likely to use technologies from the moderate treatment (see text for an exception for the Honda Insight).

[8] These values are lower than CAFE standards by about 15 percent because the graph shows on-road values rather than laboratory test conditions. These values are consistent with CAFE requirements.

[9] NRC, Figure 2-8, adjusted to $2001 dollars.

[10] NRC, Figure 2-7.

[11] www.nhtsa.dot.gov/cars/rules/CAFE/docs/162944_web.pdf

[12] Data from the ACEEE and CARB studies were used for incremental vehicle cost and associated fuel savings. The corresponding per vehicle class data on projected vehicle sales, sales percentages, and vehicle miles traveled were obtained from CALCARS. In addition to fuel use, FUTURES provides direct costs and fuel savings benefits to vehicle consumers, but does not account for consumer value of other vehicle attributes such as performance.

[13] *Reducing California's Petroleum Dependence.* Joint Agency Report of the Energy Commission and CARB, August 2003.

[14] CALCARS is a behaviorally-based vehicle choice, usage, and demand model estimated specifically for California. The model predicts at the household level, using 57 types of households that vary by annual income, number of members, and number of employed members.

[15] In general, capital costs were obtained directly from the two references, adjusting to year 2001 dollars, rounding to the nearest $25 and then adjusting to year 2004 dollars. These values were applied to the vehicle classes in the same manner as the fuel efficiency values. One variation is that the ACEEE Mild Hybrid and ACEEE Full Hybrid cases were supplemented with lower cost data based upon CARB staff estimates for price reductions that could occur by 2015 due to market growth that reduces battery costs and technology evolution that significantly reduces electric motor and controller costs. More moderate cost reductions are assumed for the 2010 to 2015 time period. These CARB values were not rounded to the nearest $25. These cases are called "CARB Mild Hybrid" and "CARB Full Hybrid" cases. The fuel efficiency was the same as corresponding ACEEE cases