CALIFORNIA
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COMMISSION

ADDENDUM TO: OPTIONS TO REDUCE PETROLEUM FUEL USE

IN SUPPORT OF THE
2005 INTEGRATED ENERGY POLICY REPORT

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STAFF REPORT

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Table of Contents

Efficiency Options

Alternative Fuel Options

Other Fuel Demand Reduction Option

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 California Energy Commission (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.

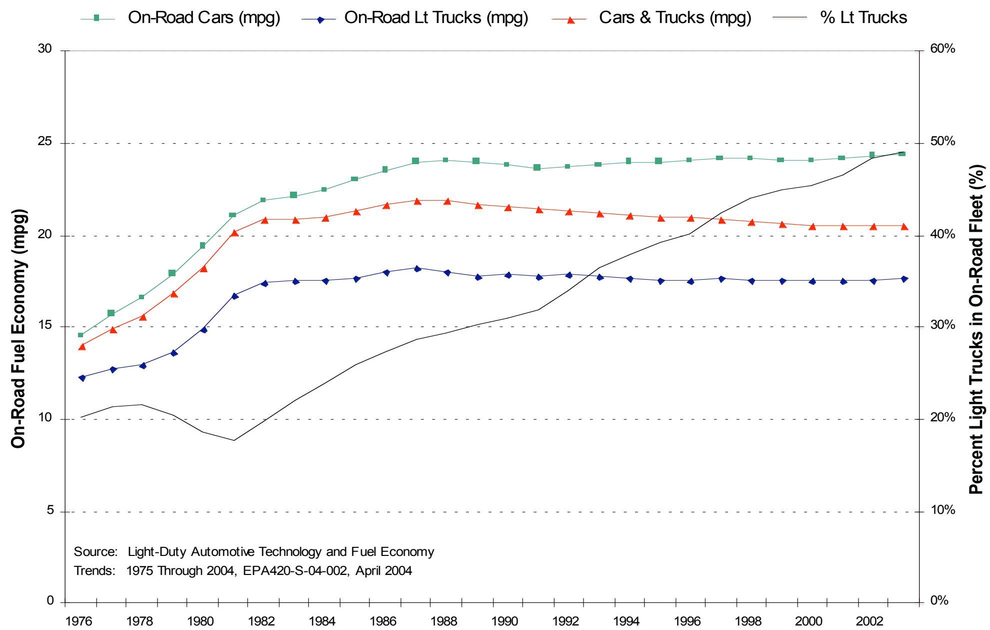
As a direct result of CAFE requirements, passenger vehicle fuel efficiency improved steadily until it reached an average of 27.5 mpg, applicable to vehicles built for Model Year (MY) 1985. This value was lowered in MYs 1986 to 1989, but was returned to 27.5 mpg in MY 1990 and has remained at that level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

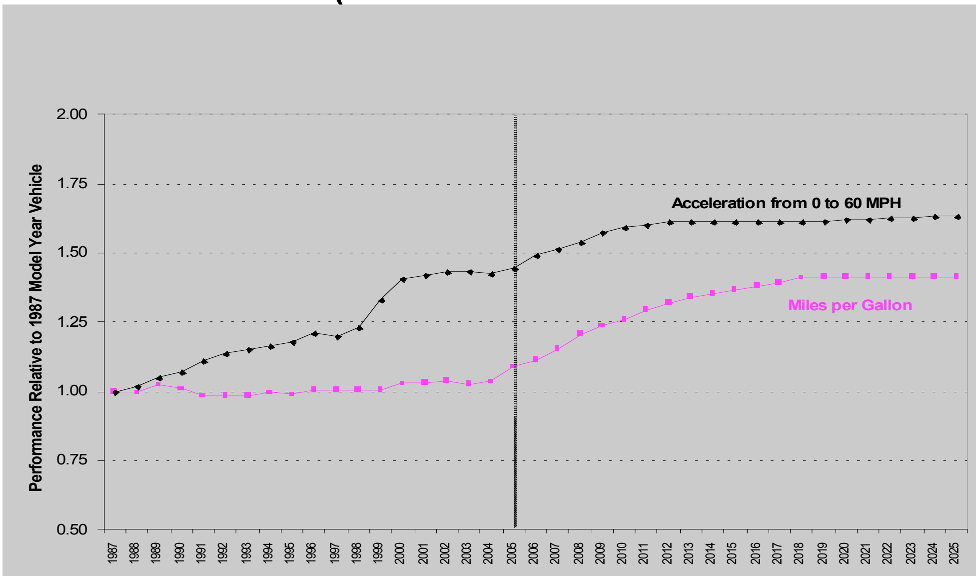


Failure to meet these standards means that an automobile manufacturer must pay $55 per vehicle for each vehicle sold multiplied by the number of mpg under the standard. While some European manufacturers have paid this fine rather than meet the CAFE standard, no Asian or domestic auto manufacturers have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



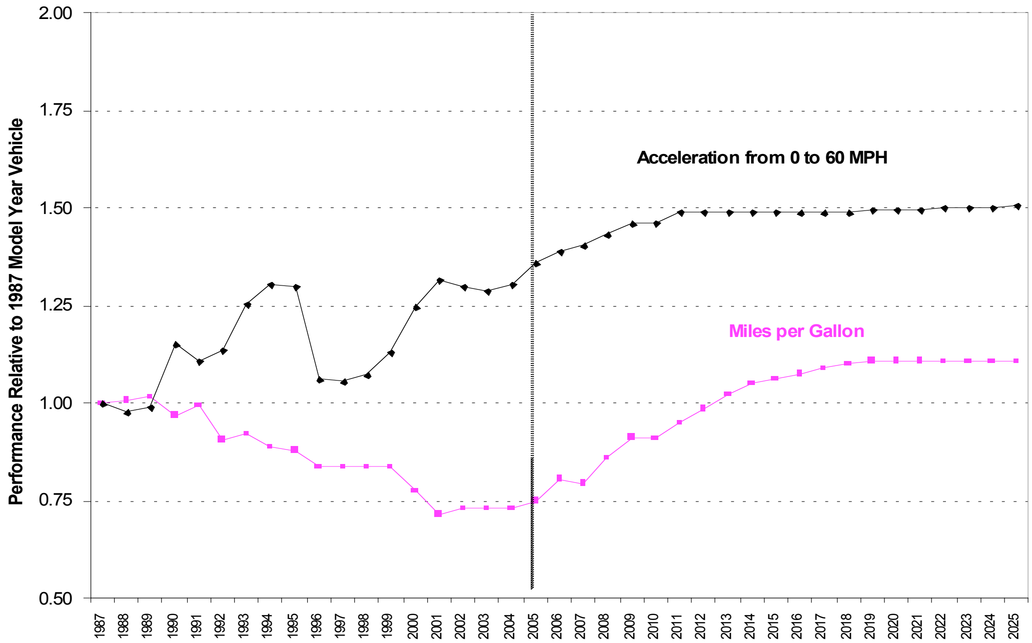
The trends for various classes of light-duty trucks are different from that of passenger cars. For example, small cross-utility light truck fuel efficiency improves slightly between 1987 and 1989 and then degrades steadily until it is only about 75 percent of the 1987 value in 2001. At that time, it 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 Gallon/year 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 Gallon/year 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 Gallon/Year 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 Gallon/Year 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 Gallon/Year 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 Gallon/Year 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 Gallon/Year 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 Gallon/Year 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 above 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.

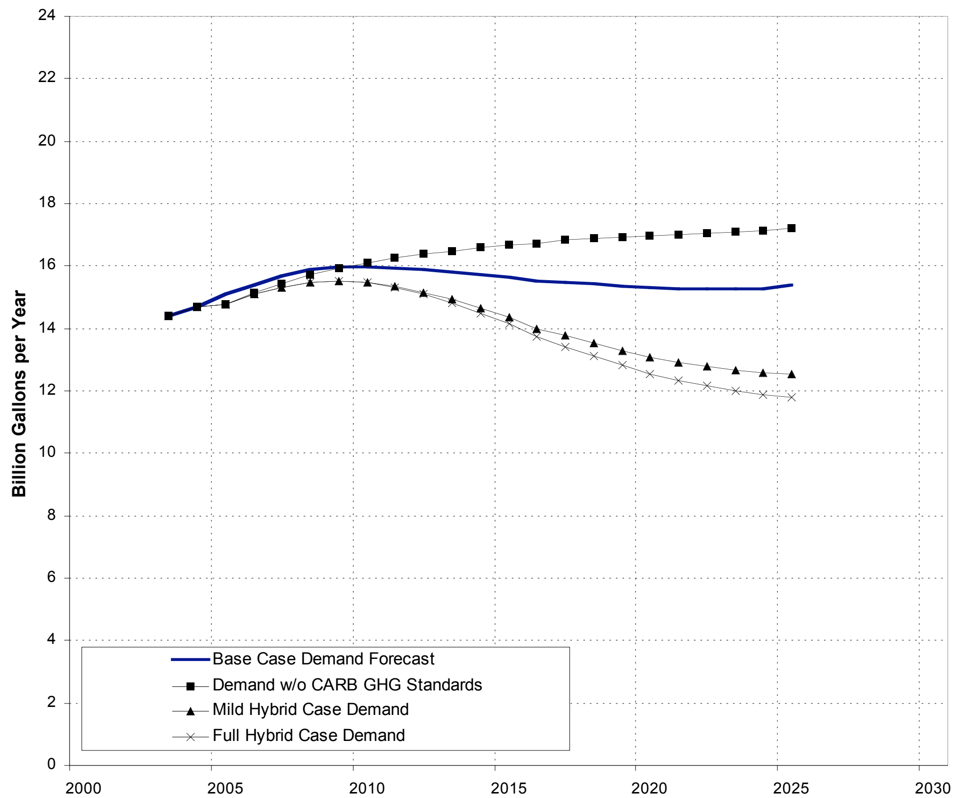
- **Gasoline Fuel Price.** Future gasoline prices have a greater effect on the results than any other variable in this study. If the lower fuel prices prevail, the advanced technologies are not worth pursuing from a societal perspective unless there are greater external benefits that were not reflected 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.

OPTION 1B - FUEL EFFICIENT REPLACEMENT TIRES

Background

This option evaluates possible reductions in fuel consumption through greater use of low-rolling resistance (LRR) replacement tires. Consumers are not aware that tires vary in fuel efficiency based on their rolling resistance characteristic and that the tires sold on new cars are usually more fuel efficient than replacement tires normally purchased. Optimization of fuel efficiency for replacement tire selection might be achieved through an education program regarding the energy efficiency performance of tires.

However, no definitive data exists regarding the quantitative potential for fuel savings using fuel efficient tires. At the same time, no definitive evidence exists that fuel economy of tires can be improved without significantly affecting a tire's safety. In March 2005, the California Energy Commission (Energy Commission) initiated a Fuel Efficient Tire Study (Tire Study) to generate verifiable tire test data that will demonstrate the potential of low rolling resistance tires to save fuel in real world conditions.

Status

Senate Bill 1170 (Sher), [Chapter 912, Statutes of 2001] directed the Energy Commission to make recommendations on a California State Fuel-Efficient Tire Program. The final report on this subject, *Recommendation for a California State Fuel-Efficient Tire Program,* found "Potential fuel savings from fuel-efficient tires is substantial" ….however…."Sufficient data is not available to draw conclusions regarding the performance and characteristics of fuel efficient tires."[1]

There is substantial reason for uncertainty regarding the practicality of achieving significant fuel savings from low-rolling resistance tires. Tire manufacturers (represented through the Rubber Manufacturers Association) have long asserted that any improvement in fuel economy will come at a cost of either tire longevity, performance, a safety characteristic, or significantly greater initial expense. Tire manufacturers routinely use rolling resistance in the engineering and the design process for developing new tires. Because of this assertion and because the tire manufacturers have the only significant and extensive existing data regarding rolling resistance (and hence fuel economy), the Energy Commission can not presently predict with any accuracy what fuel savings, if any, the use of low-rolling resistance tires could practically achieve.

It is anticipated that the Tire Study will produce hard data that can be used to accurately predict in scenario form, the potential statewide fuel savings that a fuel efficient tire program could achieve. The Tire Study goals are to:

1. Select the most effective, Society of Automotive Engineers (SAE) recognized rolling resistance test for determining the relative fuel economy of light-duty vehicle tires (SAE J2452 or SAE J1269).

2. Identify the range of rolling resistance for replacement tires in light-duty vehicles.

3. Explore the relationship (if any) of low rolling resistance tires with tire performance, sidewall rating characteristics, tire life, cost, and safety aspects such as wet traction and stopping distance.

4. Determine the feasibility of imposing a minimum fuel economy standard for light-duty vehicle replacement tires

It is expected that significant data from the Tire Study will become available late in 2005 with the final report due in September 2006. The results of this study will also be used for the basis of rulemaking activities as mandated by Assembly Bill 844 (Nation), Chapter 645, Statutes of 2003.

Assembly Bill 844, commonly referred to as the Tire Bill, requires tire manufacturers to report to the Energy Commission the rolling resistance and relative fuel economy of replacement tires sold in California. With this information composed in a reportable format, consumers will for the first time, be able to select tires regarding fuel economy in addition to the existing parameters of use, cost, and longevity. The Energy Commission will also be required to adopt (if feasible) minimum fuel efficiency standards for replacement tires resulting in a fuel economy equal to or better than for tires on new vehicles.

Even if what the tire manufacturers claim to be true is confirmed in the Tire Study, there still may be the potential for significant fuel savings in the Energy Commission’s Fuel Efficient Tire Program. Consumers often purchase tires with excess performance capacities such as speed ratings over 130 miles per hour or wet traction ratings where it seldom rains (such as Southern California deserts) or all season capacity where it seldom snows (Southern California). The knowledge that these extra and often unneeded performance characteristics may have a fuel penalty in addition to extra cost may sway the rationale of consumers to purchase tires with performance characteristics that are not necessary for the safe operation of their vehicles. The Energy Commission’s database of rolling resistance and relative fuel economy for replacement tires can be used to guide consumers in making a more informed decision in purchasing replacement tires that can perform safely while still offering fuel savings.

Endnotes

[1] Energy Commission, *California State Fuel-Efficient Tire Program: Volume* 1 – *Summary of Findings and Recommendations,* January 31, 2003, CEC 600-03-001F-VOL1.

OPTION 1C – FUEL EFFICIENT FLEETS

An opportunity may exist to reduce gasoline fuel demand by examining the vehicle purchasing policy of public and private fleets. Fleets of light-duty vehicles may annually purchase a large fraction of the new vehicles sold each year. If vehicle operators were to emphasize the purchase of best-in-class fuel economy vehicles, the state could reduce petroleum demand without compromising any of the transportation service attributes of these fleets.

To estimate the range of fuel savings from a best-in-class purchasing policy, the existing fleets must be characterized by their current purchasing policy, annual fuel consumption, vehicle classes in each fleet, vehicle population and trends and on-road fuel economy for their vehicles. However, there is no centralized data base for fleets where this information is readily available. Acquiring such information would require an extensive fleet survey and subsequent analysis. Although scenarios might be evaluated to bound the amount of fuel reduction that may be possible, the lack of usable information on fleet vehicle populations and annual fuel consumption by fleets makes any estimate of possible fuel reduction highly uncertain.

The discussion that follows provides background information on public and private fleets and describes some recent actions being taken to elevate fuel consumption as a fleet performance criterion.

Public-Fleet Fuel Efficiency

The State of California's fleet, like many other large state and federal fleets, has worked consistently to improve the fuel-efficiency and environmental profile of its fleet over the past five years. The fleet has;

- ordered the sale of inefficient and under utilized vehicles,
- established non-petroleum alternative fueling facilities,
- utilized recycled oil,
- improved the environmental standards of the various fleet maintenance shops,
- is investigating potential fuel efficiency improvements from low-rolling resistance tires, and
- incorporated a fleet lifecycle evaluation (including fuel economy, emission, and capital) for the selection of fleet vehicles for purchase under the state bid vehicle contract.

Several of these actions are considered to be part of the “new frontier” of fleet fuel efficiency, and could well have wide-ranging effects for other public fleets, private fleets and the general public. Public fleets are interested in providing the types of vehicles that are essentially least-cost for the particular service for which they are needed. For example, the California fleet now evaluates each and every agency and Legislature request for a Sports Utility Vehicle (SUV), to determine whether the SUV is essential, or whether a van or two-wheel drive or smaller (better fuel economy) vehicle adequately fulfills the specific vehicle needs.

The recently enacted vehicle procurement method was unveiled in September 2004, and will have an effect far beyond the state fleet. The new method requests that vehicle manufacturers provide all specification information as before (including fuel economy, tailpipe emissions rating, and capital cost) but this past year the automakers were informed that their bids would be judged using evaluative criteria; fuel economy, tailpipe emissions, and capital cost. This is the first attempt at a modified “life-cycle cost” evaluation for the vehicles, leading to “best-in-class” selections in the vehicle size categories. Important information considered in the fleet vehicle contract bid includes;

- expected years or mileage life in the fleet,
- maintenance costs,
- expected fuel usage and cost,
- cumulative emissions over the fleet life of the vehicle and,
- potential resale value for the vehicle when surveyed out for auction after its useful fleet life.

The new procurement method will undoubtedly save a significant amount of fuel for the state fleet now and into the future. The impact this new method can have on other public fleets is potentially larger because these other public fleets often use the state vehicle contract bid to procure their fleet vehicles. This sound public policy of reasoned, informed, cost-effective, and environmentally sound vehicle procurement will influence vehicle purchases, transportation fuel use and vehicle manufacturer’s offerings, each and every year, into the future.

Private Fleet Fuel Efficiency

Private fleet fuel efficiency has not kept pace with that of the public sector largely due to the diverse types, needs, geographic requirements, and management of those fleets. Many of the private fleets participate in regional or national fleet associations and therefore stay well informed regarding advanced fleet management techniques, developments in fuel-efficiency, and vehicle maintenance practices. Due to their commerce-driven mission, private fleets are not typically on the cutting edge for fuel-efficiency improvements; though this could soon change with the higher plateau of petroleum transportation fuel pricing we are now experiencing reshapes the fuel-efficiency needs of these fleets in the future.

Private fleet management has made great strides with regard to overall fleet maintenance and lowering operational costs on the whole, but measurable gains in fuel efficiency of the private fleet vehicle is now, and in the future will be, influenced primarily by national policy for corporate average fuel economy (CAFE) standards and the vehicle offerings resulting from it.

OPTION 1D – VEHICLE MAINTENANCE PRACTICES

Description

This option examines the potential impact of increasing the fraction of consumers who properly maintain their light-duty vehicles and improve the fuel efficiency of existing vehicles. A consumer outreach and education campaign on vehicle maintenance practices would be conducted annually. Although the fuel savings per vehicle may be relatively small, the overall petroleum fuel reduction can be large if enough consumers are motivated to act. Improving the efficiency performance of California's vehicle population can achieve near-term savings. If the campaign can effect a change in behavior, the savings can multiply over the long term.

Background

During the 1970s when oil shocks caused consumers to more seriously consider fuel economy when acquiring a new vehicle, the federal government established the Fuel Economy Information Program. Since then, the level of interest and investment in public information campaigns have followed fuel price trends, increasing when prices spike only to wane when prices drop below some "public pain" threshold.[1] In a final report on the *Green Vehicle Market Alliance Project* contracted by Oak Ridge National Laboratory, John DeCicco of Environmental Defense pointed to the increasing government interest away from consensus-building and near-term strategies and toward long-term high technology approaches.[2]

Between 1999 and 2003, a series of workshops, *Green Vehicle Market Alliance Project*, were held nationwide, attended by state government representatives (including the California Energy Commission [Energy Commission]), the automotive manufacturers, federal agencies, federal research laboratories, environmental groups, and universities.[3] One meeting in the sequence was hosted by the Institute of Transportation Studies, University of California at Davis. This meeting focused on market research issues with the inclusion of social marketing. Social marketing is defined as the use of marketing and social-science strategies to change individual behavior for the good of society.[4] Social marketing's premise is that the audience may not share the same social objectives when prioritizing their buying decisions. However, social marketing uses the same advertising and public relations strategies used for general product marketing. The automakers' view from the same series of workshops suggested that education related to the importance of fuel economy for the reasons of national security (rather than environmental ideologies) might be acceptable to them.

In response to escalating fuel prices in California, a 44 percent increase between December 2003 and May 2004, Governor Schwarzenegger enacted a Call-to-Action and a *Flex Your Power at the Pump* campaign.[5] Leaders from both political parties reached consensus over the need to increase the state's use of alternative power, along with a large dose of conservation.[6]

Status

The Car Care Council surveyed drivers on routine maintenance. Table 1 summarizes the survey results.[7] This is a decrease in good maintenance practices from their 2000 survey that found 10 percent of the vehicle population needed air filter replacement and 20 percent had exceeded their oil and filter change interval.[8]

Table 1. Percentages of Vehicles Not Following Suggested Maintenance Schedules

Driving on under-inflated tires.	54 percent[9]
Not following recommended oil maintenance.	38 percent[10]
Not replacing dirty air filters.	16 percent[11]

For this analysis, the staff assumed that vehicles that could improve fuel economy performance through a tune-up are accounted for in the base case demand forecast.[12]

Several conditions and trends regarding fuel economy make any action for vehicle fuel conservation more important now than in the past.

- Although they can perform the same function as cars, light-trucks – including sport utility vehicles (SUVs) – are not subject to the same penalties for poor fuel economy as are cars. Cars with combined fuel economy ratings of less than 22.5 miles per gallon (mpg) are penalized with a tax of $1,000 to $7,700.[13] No such tax is applied to light-trucks. The fuel economy standard for light-trucks is also less than for cars. As the proportion of new vehicle sales has increased for light-trucks compared to cars, the overall fuel economy of light-duty vehicles has dropped.

- The average fuel economy of new cars and trucks has declined from about 26 mpg in 1988 to 24 mpg in 2000.[14] Staff's transportation energy demand model, CALCARS, reflects this same downward fuel economy trend in the estimates of California light-duty vehicle gasoline consumption. Contrary to this actual result, a Roper poll[15] found that 62 percent of United States adults believed that auto fuel economy was improving each year, 12 percent believed the fuel economy remained stable, and only 17 percent realized that average fuel economy had declined. In addition, two-thirds of Americans did not realize transportation was the largest user of petroleum.

- Gasoline consumption estimates made by the U.S. Environmental Protection Agency (EPA) are based on data collected from vehicles being driven over a specific driving cycle. The driving cycle has not been updated to reflect increased traffic congestion, increased highway speeds, and more powerful vehicles.[16,17] Thus, vehicle fuel economy may be overestimated by as much as 34 percent.[18]

Although the resulting fuel economy improvement from the maintenance practices in this scenario can be small, their fuel consumption impact is magnified by California's existing population of vehicles and the relatively long life of these vehicles. Because vehicle fuel consumption is inversely related to fuel economy, a percentage change in fuel economy in a vehicle with low fuel economy will have a greater fuel consumption impact than the same percentage change in a more efficient vehicle. For example, a 1 percent change in the fuel economy of a vehicle that gets 16 mpg will save 25 percent more gasoline per mile than the same 1 percent change in a vehicle that gets 20 mpg. Thus, at a time when our vehicle population has a declining fuel economy and these vehicles will be operating for a decade or more, promoting fuel conservation measures for these vehicles is an important contributor to reduced petroleum fuel use.

Assumptions

Improving the efficiency performance of California's vehicle population can be achieved by focusing on fuel conservation-related measures that do not require technology advancements and can be initiated by individual actions with state or federal promotion. In general, these actions may include periodic engine tune-ups, engine lubrication, air and oil filter replacements, and proper tire inflation. However, the California Smog Check program is assumed to find engine operating problems that would be corrected by major engine tune-ups. Thus, tune-ups are not included in this evaluation because the Energy Commission staff's base case fuel demand forecast includes these tune-ups as normal practice.

This option would involve a state campaign to educate motorists on the benefits of improved maintenance practices. The options would include following manufacturers guidelines for oil and oil filter changes, air filter cleaning and replacement, and maintaining recommended tire inflation pressure. From California media campaign programs to encourage more efficient electricity use, the value of savings has been about double the cost to produce the savings.[19]

The U.S. Department of Energy (DOE) estimates that replacing air filters can increase vehicle fuel economy by up to 10 percent, replacing dirty oil by up 1 to

2 percent, and maintaining proper tire inflation by up to 3 percent.[20] Increased participation by vehicle owners and sustained gasoline savings over the life of the vehicle will only be achieved through a sustained media campaigns. It is assumed that each $1 million spent on advertising will increase participation by 3 percent.[21]

Without a campaign, staff assumed a maximum of 2 percent of the owners of the state's vehicles will change their behavior and increase the frequency of air filter changes with the current level of website information, publications, limited media coverage, and rising fuel prices. A major campaign effort, similar to recycling and electricity conservation campaigns, is assumed to change the behavior of up to 30 percent of the vehicle owners who are not performing maintenance practices.

Air Filters

Dirty air filters reduce the flow of air required for efficient combustion of fuel. It takes air to completely oxidize the fuel in the combustion process. If an engine is starved for air, fuel is not fully combusted and is wasted.

Based on the most recent surveys, 16 percent of the vehicle population was not getting air filters changed regularly (every 10,000 miles if the vehicle is not being driven regularly in dirty conditions). Replacing a dirty air filter will increase the individual vehicle efficiency by 10 percent.[22]

Tables 2 and 3 summarize average petroleum displacement and direct benefits for air filter maintenance at 2 percent and 30 percent participation, respectively.

Table 2: Air Filters, 2 Percent Participation, Average Petroleum Displacement and Direct Benefit

	Average Conventional Fuel Displaced (Billions Gallons)	Average Consumer Savings (Million $)		Average Change in Government Revenue (Million $)	
		Discount Rate		Discount Rate	
		12%	5%	12%	5%
2005 to 2010					
With GHG Standards					
• Low Fuel Price	0.0099	$46.56	$75.86	($6.94)	($11.30)
• Very High Fuel Price	0.0097	$45.73	$78.80	($6.81)	($11.09)
Without GHG Standards					
• Low Fuel Price					
• Very High Fuel Price	0.01	$46.94	$74.44	($6.99)	($11.17)
	0.0097	$46.04	$75.00	($6.86)	($18.75)
2005 to 2020					
With GHG Standards					
• Low Fuel Price	0.0094	$27.04	$106.29	($4.03)	($15.84)
• Very High Fuel Price	0.0091	$26.42	$103.68	($3.94)	($15.45)
Without GHG Standards					
• Low Fuel Price					
• Very High Fuel Price	0.01	$28.26	$112.61	($4.21)	($16.78)
	0.0090	$27.38	$108.65	($4.08)	($16.19)
2005 to 2025					
With GHG Standards					
• Low Fuel Price	0.0093	$16.70	$98.92	($2.49)	($14.74)
• Very High Fuel Price	0.0092	$16.31	$96.36	($2.43)	($14.36)
Without GHG Standards					
• Low Fuel Price					
• Very High Fuel Price	0.0102	$17.65	$106.85	($2.63)	($15.92)
	0.0097	$17.05	$102.54	($2.54)	($15.28)

Table 3: Air Filters, 30 Percent Participation, Average Petroleum Displacement and Direct Benefit

	Average Conventional Fuel Displaced (Billions Gallons)	Average Consumer Savings (Million $)		Average Change in Government Revenue (Million $)	
		Discount Rate		Discount Rate	
		12%	5%	12%	5%
2005 to 2010					
With GHG Standards					
• Low Fuel Price	0.148	$697.15	$1135.83	($103.86)	($169.21)
• Very High Fuel Price	0.148	$684.68	$1114.61	($102.00)	($166.05)
Without GHG Standards					
• Low Fuel Price	0.149	$702.88	$1146.18	($104.71)	($170.75)
• Very High Fuel Price	0.145	$684.68	$1114.61	($102.00)	($166.05)
2005 to 2020					
With GHG Standards					
• Low Fuel Price	0.140	$404.78	$1591.28	($60.31)	($237.06)
• Very High Fuel Price	0.137	$395.56	$1552.21	($58.93)	($231.25)
Without GHG Standards					
• Low Fuel Price	0.150	$423.07	$1685.85	($63.03)	($251.15)
• Very High Fuel Price	0.137	$395.56	$1552.21	($58.93)	($231.25)
2005 to 2025					
With GHG Standards					
• Low Fuel Price	0.139	$250.04	$1480.87	($37.25)	($220.62)
• Very High Fuel Price	0.135	$244.14	$1442.62	($36.37)	($214.92)
Without GHG Standards					
• Low Fuel Price	0.152	$264.29	$1599.69	($39.38)	($238.32)
• Very High Fuel Price	0.135	$244.14	$1442.62	($36.37)	($214.92)

Tires

Low tire pressure increases rolling resistance, or friction with the road, as the vehicle moves. This increases heat generated in the tires – energy from the engine that is not going towards moving the vehicle.[23] The more time spent driving at higher speeds, such as freeway driving, the more fuel is wasted from low tire pressure. Tire pressure will also fluctuate with changes in weather and air temperature.

An average of 54 percent of the population is assumed to be driving on four tires not maintained at the correct pressure. Maintaining proper tire pressure is assumed to decrease fuel consumption by 3 percent per vehicle (each tire is about five pounds per square inch or more below recommended pressure) from the baseline gasoline consumption.

Tables 4 and 5 summarize average petroleum displacement and direct benefits for tire maintenance at 2 percent and 30 percent participation, respectively.

Table 4: Tires, 2 Percent Participation, Average Petroleum Reduction and Direct Benefit

	Average Conventional Fuel Displaced (Billions Gallons)	Average Consumer Savings (Million $)		Average Change in Government Revenue (Million $)	
		Discount Rate		Discount Rate	
		12%	5%	12%	5%
2005 to 2010					
With GHG Standards					
• Low Fuel Price	0.0107	$50.35	$82.03	($7.50)	($12.22)
• Very High Fuel Price	0.0105	$49.45	$80.50	($7.37)	($11.99)
Without GHG Standards					
• Low Fuel Price					
• Very High Fuel Price	0.0108	$50.76	$87.74	($7.56)	($12.33)
	0.0105	$49.78	$81.10	($7.42)	($12.08)
2005 to 2020					
With GHG Standards					
• Low Fuel Price	0.0101	$29.24	$114.95	($4.36)	($17.12)
• Very High Fuel Price	0.0099	$28.57	$112.12	($4.26)	($16.70)
Without GHG Standards					
• Low Fuel Price					
• Very High Fuel Price	0.0109	$30.56	$123.78	($4.55)	($18.14)
	0.0099	$29.61	$117.49	($4.41)	($17.50)
2005 to 2025					
With GHG Standards					
• Low Fuel Price	0.0100	$18.06	$106.97	($2.69)	($15.93)
• Very High Fuel Price	0.0010	$17.64	$104.21	($2.63)	($15.52)
Without GHG Standards					
• Low Fuel Price					
• Very High Fuel Price	0.0110	$19.09	$115.56	($2.84)	($17.21)
	0.0100	$18.44	$110.89	($2.75)	($16.52)

Table 5: Tires, 30 Percent Participation, Average Petroleum Reduction and Direct Benefit

	Average Conventional Fuel Displaced (Billions Gallons)	Average Consumer Savings (Million $)		Average Change in Government Revenue (Million $)	
		Discount Rate		Discount Rate	
		12%	5%	12%	5%
2005 to 2010					
With GHG Standards					
• Low Fuel Price	0.160	$753.79	$1228.09	($112.29)	($182.94)
• Very High Fuel Price	0.157	$740.31	$1205.15	($110.28)	($179.52)
Without GHG Standards					
• Low Fuel Price					
• Very High Fuel Price	0.161	$759.98	$1239.28	($113.21)	($184.60)
	0.157	$740.31	$1205.15	($110.28)	($179.52)
2005 to 2020					
With GHG Standards					
• Low Fuel Price	0.152	$437.69	$1720.56	($112.29)	($182.94)
• Very High Fuel Price	0.148	$427.72	$1678.33	($63.71)	($250.01)
Without GHG Standards					
• Low Fuel Price					
• Very High Fuel Price	0.163	$457.47	$1822.81	($68.15)	($271.53)
	0.148	$427.72	$1678.33	($63.71)	($250.01)
2005 to 2025					
With GHG Standards					
• Low Fuel Price	0.150	$270.38	$1601.21	($40.28)	($238.52)
• Very High Fuel Price	0.146	$264.00	$1559.85	($39.33)	($232.36)
Without GHG Standards					
• Low Fuel Price					
• Very High Fuel Price	0.165	$285.78	$1729.66	($42.57)	($257.65)
	0.146	$264.00	$1559.85	($39.33)	($232.36)

Oil

As oil becomes dirty, its critical properties of lubrication and heat transfer deteriorate. This causes the engine to work harder and generate more heat – energy that is not being used to move the vehicle.

It was assumed 38 percent of the vehicle population was not changing oil according to vehicle manufacturer recommendations. Changing oil regularly is assumed to increase the individual vehicle efficiency by 2 percent.

Tables 6 and 7 summarize average petroleum displacement and direct benefits for oil maintenance at 2 percent and 30 percent participation, respectively.

Table 6: Oil, 2 Percent Participation, Average Petroleum Reduction and Direct Benefit

	Average Conventional Fuel Displaced (Billions Gallons)	Average Consumer Savings (Million $)		Average Change in Government Revenue (Million $)	
		Discount Rate		Discount Rate	
		12%	5%	12%	5%
2005 to 2010					
With GHG Standards					
• Low Fuel Price	0.0051	$23.83	$38.84	$3.55)	($5.79)
• Very High Fuel Price	0.0050	$23.41	$38.11	($3.49)	($5.68)
Without GHG Standards					
• Low Fuel Price	0.0051	$24.03	$39.19	($3.58)	($5.84)
• Very High Fuel Price	0.0050	$23.57	$38.40	($3.51)	($5.72)
2005 to 2020					
With GHG Standards					
• Low Fuel Price	0.0048	$13.83	$54.41	($2.06)	($8.11)
• Very High Fuel Price	0.0047	$13.52	$53.07	($2.02)	($7.91)
Without GHG Standards					
• Low Fuel Price	0.0052	$14.46	$57.65	($2.16)	($8.59)
• Very High Fuel Price	0.0050	$14.01	$55.62	($2.09)	($8.29)
2005 to 2025					
With GHG Standards					
• Low Fuel Price	0.0047	$8.54	$50.63	($1.27)	($7.55)
• Very High Fuel Price	0.0046	$8.34	$49.32	($1.24)	($7.35)
Without GHG Standards					
• Low Fuel Price	0.0052	$9.03	$54.70	($1.35)	($8.16)
• Very High Fuel Price	0.0050	$8.72	$52.49	($1.30)	($7.83)

Table 7: Oil, 30 Percent Participation, Average Petroleum Reduction and Direct Benefit

	Average Conventional Fuel Displaced (Billions Gallons)	Average Consumer Savings (Million $)		Average Change in Government Revenue (Million $)	
		Discount Rate		Discount Rate	
		12%	5%	12%	5%
2005 to 2010					
With GHG Standards					
• Low Fuel Price	0.076	$357.18	$582.01	($53.25)	($86.76)
• Very High Fuel Price	0.074	$350.79	$571.14	($52.30)	($85.14)
Without GHG Standards					
• Low Fuel Price					
• Very High Fuel Price	0.076	$360.12	$587.32	($53.69)	($87.55)
	0.074	$350.79	$571.14	($52.30)	($85.14)
2005 to 2020					
With GHG Standards					
• Low Fuel Price	0.072	$207.32	$815.34	($30.92)	($121.56)
• Very High Fuel Price	0.070	$202.59	$795.31	($30.22)	($118.58)
Without GHG Standards					
• Low Fuel Price					
• Very High Fuel Price	0.077	$216.70	$863.84	($32.32)	($128.78)
	0.070	$202.59	$795.31	($30.22)	($118.58)
2005 to 2025					
With GHG Standards					
• Low Fuel Price	0.071	$128.03	$758.72	($19.10)	($113.13)
• Very High Fuel Price	0.069	$125.01	$739.10	($18.65)	($110.21)
Without GHG Standards					
• Low Fuel Price					
• Very High Fuel Price	0.078	$135.34	$819.64	($20.19)	($122.20)
	0.069	$125.01	$739.10	($18.65)	($110.21)

Combination of Air Filter, Oil, and Tire Maintenance

Fuel savings from more diligent maintenance practices accrue by reducing the deterioration rate of the vehicle's fuel economy due to deteriorating vehicle performance. Thus, the savings from combined maintenance practices are not the additive of the individual savings, i.e., under "perfect" conditions, each vehicle has a maximum fuel economy it can obtain.

For the combination of maintenance practices, 14 percent fuel saving was calculated. It was estimated that 54 percent of the population had low tires, and dirty air filters and oil. This was based on the data regarding the population of low tires (54 percent) and the combination of the population for dirty air filters and oil (54 percent).

For the combined maintenance practices option, the table shows only the potential fuel savings with an ad campaign effecting a 30 percent participation. Energy Commission staff assumed the behavior of each participant changed for one cycle of maintenance or approximately two years.

Table 8 summarizes average petroleum displacement and direct benefits for air filter, oil, and tire maintenance at 30 percent participation.

Table 9 summarizes the cumulative petroleum displacement and benefits for air filter, oil, and tire maintenance at 30 percent participation.

Table 8: Combined Maintenance Practices, 30 Percent Participation, Average Petroleum Displaced and Direct Benefits

	Average Conventional Fuel Displaced (Billions Gallons)	Average Consumer Savings (Million $)		Average Change in Government Revenue (Million $)	
		Discount Rate		Discount Rate	
		12%	5%	12%	5%
2005 to 2010 With GHG Standards • Low Fuel Price • Very High Fuel Price	 0.687 0.673	 $3208.71 $3150.67	 $5235.73 $5137.00	 ($483.26) ($474.62)	 ($787.22) ($772.51)
2005 to 2020 With GHG Standards • Low Fuel Price • Very High Fuel Price	 0.652 0.636	 $1852.19 $1809.29	 $5235.73 $7137.82	 ($483.26) ($274.09)	 ($787.22) ($1075.31)
2005 to 2025 With GHG Standards • Low Fuel Price • Very High Fuel Price	 0.644 0.626	 $1140.17 $1112.74	 $6803.33 $6625.45	 ($173.26) ($169.17)	 ($1025.84) ($999.34)

Table 9: Petroleum Reduction and Benefits for Improved Maintenance Practices

Alternative Fuel Option or Scenario	+Displacement in 2025, Billion Gallon/Year Gasoline Equivalent	Reduction from Base Case Demand, Percent	Highest Cumulative Benefit or Change, Present Value, 2005-2025, 5% Discount Rate, 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
30% Participation With GHG • Highest Fuel Price	0.89	4.26	7.18	(1.00)	1.46	0.78	8.51

Uncertainties

- There is an uncertainty regarding the number of California consumers who do not perform regular maintenance since statistical data was drawn from nationwide surveys. The surveys also did not determine if maintenance practices were delayed versus not performed.

- The statistical data does not indicate what percentage of consumers continues with regular maintenance once they are induced to change behavior. This added knowledge would assist in establishing a baseline condition from which we could measure the effect of consumer change on gasoline consumption and savings.

- Consumer benefits and gasoline savings also depends on things beyond their control such as weather and the cost of gasoline.

- There is a pervasive view in the transportation sector that consumer information campaigns for fuel conservation measures will not produce large or long-term impacts on energy use. The electricity sector held an analogous view prior to campaigns for electricity conservation – individual conservation actions could not sufficiently impact California demand for energy.

Endnotes

[1] Energy Commission staff experience with providing information to media and websites during gasoline price spikes, and electricity shortages.

[2] DeCicco, John M., *Final Report on the Green Vehicle Market Alliance Project*, prepared for Oak Ridge National Laboratory, March 2004.

[3] March 1999, June 2000, December 2000, March 2001, December 2001, and January 2003.

[4] Ogilvy Public Relations Worldwide *Applying social Marketing Principles to Selling* '*Green' Cars* presentation by C. Black to the workshop on *Marketing Clean and Efficient Vehicles* University of California – Davis, March 22-23, 2001.

[5] www.fypower.org/save_gasoline/.

[6] *State makes progress in kicking oil habit* San Francisco Chronicle, October 24, 2004.

[7] www.carcarecouncil.org/service_schedule.shtml March 2005. The percentages are not mutually exclusive, i.e. some of the cars that had dirty engine oil also had low tire pressure.

[8] Ibid.

[9] National Care Council www.carcarecouncil.org March 21, 2005.

[10] Ibid.

[11] Ibid.

[12] CALCARS modeling run conducted by the Energy Commission in February/March 2005.

[13] Form 6197, *Gas Guzzler Tax*, Department of the Treasury, Internal Revenue Service, January 2004.

[14] Department of Transportation's annual report to Congress for 2001 model year vehicles stated an average fuel economy of 24.4 mpg. EPA's annual report to Congress stated 23.9 to 20.4 mpg for the 2001 model year.

[15] *American's Low Energy IQ: A Risk to Our Energy Future: Why America Needs a Refresher Course on Energy, Tenth Annual National Report Card: Energy Knowledge, Attitudes, and Behavior*, National Environmental Education & Training Foundation and Roper ASW, August 2003.

[16] www.fueleconomy.gov/feg/info.shtml *How are fuel economy estimates obtained?*

[17] Davis, Stacy and Susan Diegel, Oak Ridge National Laboratory, Center for Transportation Analysis, *Transportation Energy Data Book: Edition 24*, ORNL-6973, December 2004.

[18] Bluewater Network, *Fuel Economy Falsehoods: How government misrepresentation of fuel economy hinders efforts to reduce global warming and US dependence on foreign oil*, October 2002 revision and re-issue.

[19] Steve Nadel and Marty Kushler, *Public Benefit Funds: A Key Strategy for Advancing Energy Efficiency,* The Electricity Journal, October 2000. Pp. 74-84.

[20] www.fueleconomy.gov.

[21] Cost assumes an initial expenditure to develop the media campaign and the cost of television air time. Estimate based on the *Electric Vehicle Consumer Awareness Program* prepared by Edson + Modisette for DOE and the Energy Commission, and *Summary of Dealer Fuel Efficiency Incentive Program Proposal* by Ecos Consulting for the Energy Commission.

[22] DOE and EPA, *Gas Mileage Tips* www.fueleconomy.gov/feg/maintain.html
March 21, 2005.

[23] Cummins, *Secrets of Better Fuel Economy: The Physics of MPG*,
December 2003.

OPTION 1E - MORE EFFICIENT ON-ROAD DIESEL MEDIUM- AND HEAVY-DUTY TRUCKS

Description

This paper updates prior analysis[1] performed under legislative direction in 2001 and subsequently incorporated in the proceedings for the California Energy Commission (Energy Commission's) *2003 Integrated Energy Policy Report*. The option assumes implementation of a regulatory strategy intended to achieve fuel use efficiency improvements in medium- and heavy-duty vehicles, defined as vehicles weighing greater than 14,000 pounds gross vehicle weight. Based on the staff's monitoring of research and development activity by government and industry, we find negligible change in the status, implementation, implementation rate and cost to implement efficient technologies onto heavy-duty vehicle platforms since 2003.

The aggressive scenario under this option assumes implementation of a national fuel economy standard for the heavy-duty vehicle fleet based on the U.S. Department of Energy's (DOE's) 21st Century Truck Program (21st Century Truck Program) targets.[2] The Business-As-Usual (BAU) scenario assumes fuel economy targets that are less aggressive than the 21st Century Truck Program targets. The less aggressive fuel economy improvement scenario is based on previous studies[3,4,5] that suggest modest efficiency gain potential for medium- and heavy-duty vehicles. These two scenarios of improved fuel economy are used to project upper and lower bound impacts on future diesel fuel demand in California.

For the BAU Scenario, on-road diesel demand is reduced by 2 percent or 0.6 percent of combined gasoline and diesel fuel demand in 2025 with no net direct benefits over the range of fuel prices and discount rates used in the analysis. The net benefit is expressed as a present value result over the period 2005 to 2025. For the Aggressive Scenario, on-road diesel demand is reduced by 42 percent or 11 percent of combined gasoline and diesel fuel demand in 2025 and with positive net direct benefits. The key components in the net direct benefit result are displayed in Tables 1-4 along with their monetary present values.

Table 1: Summary of Results for Low Fuel Price and 5 Percent Discount Rate

Alternative Fuel Option or Scenario	Displacement in 2025, Billion Gallon Gasoline Equivalent	Reduction from Base Case Demand, Percent	Highest Cumulative Benefit or Change, Present Value, 2005-2025, 5% Discount Rate, Billion $2005				
			A	B	C	D	A+B+C+D
			Direct Non-Environmental Benefit	Change in Government Revenue	Direct Environmental Net Benefit	External Cost of Petroleum Dependency	Direct Net Benefit
Business As Usual	0.12	0.57	(0.77)	(0.06)	0.12	0.06	(0.65)
Aggressive	2.3	11	7.5	(1.43)	1.93	1.04	9.04

Table 2: Summary of Results for Low Fuel Price and 12 Percent Discount Rate

Alternative Fuel Option or Scenario	Displacement in 2025, Billion Gallon Gasoline Equivalent	Reduction from Base Case Demand, Percent	Highest Cumulative Benefit or Change, Present Value, 2005-2025, 5% Discount Rate, Billion $2005				
			A	B	C	D	A+B+C+D
			Direct Non-Environmental Benefit	Change in Government Revenue	Direct Environmental Net Benefit	External Cost of Petroleum Dependency	Direct Net Benefit
Business As Usual	0.12	0.57	(0.53)	(0.02)	0.12	0.06	(0.37)
Aggressive	2.3	11	2.3	(0.56)	1.93	1.04	4.71

Table 3: Summary of Results for High Fuel Price and 5 Percent Discount Rate

Alternative Fuel Option or Scenario	Displacement in 2025, Billion Gallon Gasoline Equivalent	Reduction from Base Case Demand, Percent	Highest Cumulative Benefit or Change, Present Value, 2005-2025, 5% Discount Rate, Billion $2005				
			A	B	C	D	A+B+C+D
			Direct Non-Environmental Benefit	Change in Government Revenue	Direct Environmental Net Benefit	External Cost of Petroleum Dependency	Direct Net Benefit
Business As Usual	0.12	0.57	(0.69)	(0.06)	0.12	0.06	(0.49)
Aggressive	2.3	11	9.5	(1.43)	1.93	1.04	11.04

Table 4: Summary of Results for High Fuel Price and 12 Percent Discount Rate

Alternative Fuel Option or Scenario	Displacement in 2025, Billion Gallon Gasoline Equivalent	Reduction from Base Case Demand, Percent	Highest Cumulative Benefit or Change, Present Value, 2005-2025, 5% Discount Rate, Billion $2005				
			A	B	C	D	A+B+C+D
			Direct Non-Environmental Benefit	Change in Government Revenue	Direct Environmental Net Benefit	External Cost of Petroleum Dependency	Direct Net Benefit
Business As Usual	0.12	0.57	(0.50)	(0.02)	0.12	0.06	(0.34)
Aggressive	2.3	11	3.1	(0.56)	1.93	1.04	5.51

Previous Studies

Assessments to determine potential vehicle and truck fuel economy improvement have been conducted since the early seventies. We rely on three of those studies to determine the potential for reducing petroleum use from heavy-duty vehicles in this option.

The DOE's Energy Information Administration (EIA) National Energy Modeling System (NEMS) projects fuel economy improvements based on truck efficiency gains of 0.4 percent per year from a 1982 baseline of 5.2 miles per hour (mph).[6] If this 0.4 percent annual efficiency gain is maintained and applied to the 2000 fleet average fuel economy of 6.5 miles per gallon (mpg), then the fuel economy of heavy trucks (Class 7 and 8) will have improved to 6.76 mpg, 7.04 mpg, and 7.33 mpg by 2010, 2020, and 2025, respectively. Applying the same improvement rate to the fleet average fuel economy of 12.5 mpg for medium-duty vehicles, (Class 3-6) could result in fuel economy levels of 13 mpg, 13.5 mpg, and 14.1 mpg by 2010, 2020, and 2025, respectively.

In another technology assessment, DeCicco cites KG Duleep's estimate for new heavy-duty truck fuel economy improvements of 1.2 percent per year[7]. Applying this fuel economy improvement rate to the 2000 fleet average fuel economy of 6.5 mpg, would result in fuel economy values for Class 7 and 8 trucks of 7.3 mpg, 8.3 mpg, and 8.7 mpg by 2010, 2020, and 2025, respectively. The corresponding numbers for medium-duty vehicles are 14.1 mpg, 15.9 mpg, and 16.8 mpg by 2010, 2020, and 2025, respectively.

The American Council for an Energy-Efficient Economy's (ACEEE's) *Transportation Energy Trends in 2030* report[8] assesses long-term potential for heavy-truck fuel economy improvement as 65 percent by 2030 over 1990 levels. This is equivalent to a 1.65 percent annual improvement rate over the 40 year period. The ACEEE projects heavy-truck fuel economy to improve 65 percent by 2030 compared to 1990 levels.[9] This improvement is equivalent to an average annual improvement rate of 1.65 percent over a 40-year period.

We took a simple average of these three previous estimates and the observed annual fuel economy improvement rate of 1.25 percent in the last two decades to establish a lower bound fuel economy improvement rate of 1.125 percent for this analysis. The fuel economy values generated from the 1.125 percent annual fuel economy improvement rate are used in our Scenario 1 (BAU) analysis later. The fuel economy estimates based on this approach are lower than the 21st Century Truck Program goals.

21st Century Truck Program Goals

DOE's 21st Century Truck Program is a government-industry initiative to double the 2000 fuel economy of a prototype Class 8 truck on a ton-mile/gallon basis by 2010. The 21st Century Truck Program will also triple the fuel economy of a prototype representative Class 2b-6 vehicle, as well as transit buses, on a mpg basis by 2010, while meeting prevailing emission standards.[10]

Applying the 21st Century Truck Program targets to the year 2000 fuel economies on a mpg basis will produce 13 mpg for Class 7-8 trucks and 38.1 mpg for Class 3-6 trucks. However, due to the uncertainty in implementing the breakthrough technologies to triple the fuel economy for Class 3-6 vehicles, the analytical team lowered the fuel economy improvement target for Class 3-6 vehicles, to match the 2x multiplier for the Class 7 and 8 vehicles. Therefore, this analysis uses a fuel economy target of 25.4 mpg for Class 3-6 vehicles.

Anticipated improvements in diesel vehicle technologies are the bases for the projected efficiency gains. Technology development and commercialization prospects were determined feasible from a comprehensive assessment of potential technologies in the 21st Century Truck Program Roadmap. According to the roadmap, fuel economy improvements are possible from a suite of technologies that include combustion improvements, vehicle weight reduction, use of hybrid and auxiliary power technologies, aerodynamic improvements, and rolling and inertia resistance improvements.

Assumptions and Methodology

The following assumptions and methodology are common to the two scenarios considered:

- The assumed fuel economy targets are achieved
- The 21st Century Truck Program Goals are established as federal fuel economy standards for 2010 and beyond
- All new vehicles sold comply with the assumed federal fuel economy standards
- All new vehicles sold comply with the prevailing emission standards
- Variable penetration rates in all vehicle classes with higher rates in some time periods[11]
- Certain costs for achieving the fuel economy targets and the estimated petroleum displacements include the added capital costs for hybrid propulsion systems in certain vehicle classes, new electrical systems, and new materials. The costs are distributed across the vehicle classes.

Fuel Economy and Vehicles Miles Traveled

The 2005 base case year fuel economies used for the vehicle classes were determined by reviewing and taking the weighted average of miles traveled and fuel consumed data from several sources.[12,13,14,15] We estimated 12.5 mpg for vehicle Class 3, 4, 5, 6, and 6.5 mpg for vehicle Class 7 and 8. (Our analyses cover Class 3, 4, 5, 6, 7, and 8. This is a subset of the DOE's program that focuses on Class 2b-8.) From the same sources we also determined a fleet average vehicle miles traveled of 36,000 miles for Class 3-6 vehicles and 87,000 miles for Class 7-8 vehicles. We used 16 years as the useful life for the analysis. This is the observed useful life reported in the Gas Research Institute Study for medium- and heavy-duty vehicles.[16]

Since the initial analysis, new information has emerged that suggest the fleet average fuel economy has declined. Several industry reports[17] confirmed the projected fuel economy losses of 3.5 to 5 percent by new diesel vehicles that accompanied the introduction of emission control technologies in October 2002 and 2004. An additional fuel economy drop of 3.5 to 5 percent is anticipated as the 2007 emission standards take effect.[18] Fuel economy decreases of 1 percent to 3 percent are anticipated as new ultra-low sulfur diesel fuel is introduced in 2006.[19]

For this analysis, we adjusted the model year 2000 base fleet average fuel economy for the relevant vehicle classes on a weighted average basis by 8 percent to account for these declines. We then projected future fuel economies from the adjusted base.

For future fuel economies used to assess petroleum reduction potential based on efficient technologies, we used the lower and upper bound numbers discussed previously and summarized in Table 5.

Table 5: Summary of Fuel Economies

	2010		2020		2025	
Scenario	Class 3-6	Class 7-8	Class 3-6	Class 7-8	Class 3-6	Class 7-8
Lower Bound/Nominal Fuel Economy (mpg)	N/A	N/A	14.2	7.1	15	7.5
Upper Bound/ Aggressive Fuel Economy (mpg)	N/A	N/A	24.5	13.5	24.5	13.0

Costs

The incremental capital cost (price) of Class 7 and 8 heavy-duty vehicles with technologies to meet the assumed fuel economy target is estimated to be $7,500 by 2020. This incremental cost declines to $3,600 by 2025-2030. The decline in cost is expected to occur from scale-up in manufacturing volume and learning curve effects. Medium-duty vehicle incremental capital cost is projected to be $5,000 by 2010, rise to $7,000 by 2020, but decline to $3,000 by 2025-2030. The anticipated rising trend for medium-duty vehicle incremental cost through 2020 is due to greater deployment of more expensive hybrid technologies that include fuel cell hybrids and advanced batteries. By 2025, we estimate that the incremental cost drops by more than half due to scale manufacturing, learning curve effects, and a more responsive market. We generated these estimates from previous studies[20,21,22] that estimated the cost associated with fuel economy improvements in heavy-duty vehicles.

In one such study, Sachs et al identified eight efficiency improvement technology areas, potential improvement and associated costs.[23,24] An additional improvement area discussed by Sachs is related to changes in driver behavior. However, this potential improvement is not used in this analysis because fuel economy benefits based on driver behavior is not a reliable predictor of fuel demand changes. The technology areas are listed in Tables 1-4. It is anticipated that these technologies will be implemented by 2010, if the requisite investments are made for efficiency improvements. The 21st Century Truck Program relies on many of these same broad technology improvement areas.

Our cost estimates assume that some of the identified technologies, such as turbo charging have already been fully implemented, while others have been implemented partially (as an example aerodynamic improvements), and others requiring breakthroughs (such as improvements in the basic thermodynamic cycle) not yet implemented. We used a technology implementation schedule to characterize the technology implementation rate and cost. Under this schedule, technologies not yet implemented have 100 percent or full potential to improve the vehicle fuel economy. Technologies partially implemented at the 25 percent, 50 percent, or 75 percent levels have a corresponding residual potential to improve vehicle fuel economy. Based on the assumption that some technologies are already partially implemented, we employed a simplified approach to reduce DeCicco's estimated cost by the percent by which a fuel economy improvement technology has been implemented since 1992. For example, where DeCicco estimated a $100 cost for a fuel economy improvement measure that has since been implemented 50 percent onto a vehicle platform, we estimated the cost of capturing the residual improvement benefit to be $50, or half the initial cost. This adjusted cost was then expressed in 2001 dollars. Similarly, we used the full DeCicco cost, adjusted for 2001 dollars, for a technology that the 21st Century Truck Program Roadmap indicates still offers significant (> 75 percent to full) fuel economy improvement potential.

We converted 1992$ to year 2001$ using the Energy Commission's price inflator-deflator series of 3.0 percent for the period.[25] For the 2005 base numbers, we assumed negligible change in the cost for this analysis. We reduced the resulting numbers by 60 percent to account for economy of scale manufacturing (reduced component costs due to increased production volume)[26]. Table 6 summarizes these estimated fuel economy improvement measure costs for Class 7 and 8 trucks.

Table 6: Fuel Economy Improvement Potential and Estimated Cost (Price Increment)

		DeCicco et. al [2]	DeCicco et. al Updated Costs	Residual Technology Implementation Factor		Adjusted Costs Lower Bound (LB) Fuel Economy	Adjusted Costs Upper Bound (UB) Fuel Economy
Fuel Economy Improvement Area	Delta Benefit %	Cost 2001$	Updated (2004$)	LB	UB	Cost 2004$	Cost 2004$
Aerodynamics - Tractor	14	$3914	$4150	0.25	0.50	$625	$1240
Aerodynamics - Trailer	5	$2610	$2768	0.25	0.75	$414	$1240
Engine control technology	16	$5220	$5535	0.25	0.50	$827	$1665
Other available engine technology	15	$2088	$2214	0.50	0.25	$657	$329
Advanced engines	10	$13048	$13836	0.25	0.50	$2078	$4135
Drive train	7	($1500)	($1500) [a]	N/A	N/A	($1500)	($1500)
Tires	8	$913	$968	0.25	0.50	$148	$290
Weight reduction	1	$3914	$4150	0.25	0.25	$625	$625

a. Not updated. Assumed reduction in drive train cost constant, and extended due to component simplification and modularization.

We assumed four fuel economies for the class of vehicles examined. For Class 3-6 vehicles we used a nominal fuel economy of 17.5 mpg in the year 2020 for the lower bound case. We used 25.4 mpg by 2020 to represent an upper bound based on the aggressive targets of the 21st Century Truck Program. We used a nominal fuel economy of 8.5 mpg by 2020 for Class 8 trucks for our lower bound case. We used 13 mpg by 2020 to represent an upper bound based on the aggressive targets of the 21st Century Truck Program.

Costs corresponding to the fuel economy gains are estimated by projecting the technology sets most likely to be implemented in the target years as done in previous studies[27,28] and summing the associated costs. Based on our assumptions and adjustments to the cost ranges inferred from the ACEEE[29] and Oak Ridge National Laboratory[30] studies, the incremental cost to achieve the lower (7.5 mpg) and higher bound (13.0 mpg) fuel economy for a Class 8 truck, by 2020, ranges from $3,600 to $7,500. The incremental cost to achieve these mpg figures ranges from $3,500 to $3,600 for lower bound and higher bound fuel economies by 2025 to 2030.

We have not reported cost estimates for year 2010 fuel economy improvements because that date is too short a time to achieve the technology penetration levels to realize meaningful petroleum fuel use reduction impacts. We used a similar approach to estimate the incremental cost for medium-duty vehicles. These incremental costs range from $4,700 to $7,000 by 2020 and $3,000 to $6,700 by 2025 to 2030 for lower bound (14.2 mpg) and higher bound (25.4 mpg) fuel economy levels. Hybridization accounts for the higher incremental cost for the medium-duty vehicle classes for the upper bound fuel economy. These results are summarized in Table 7.

Table 7. Summary of Incremental Cost (Price) Values and Fuel Economy Estimates

Vehicle Scenario		2010		2020		2025	
		Class 3-6	Class 7-8	Class 3-6	Class 7-8	Class 3-6	Class 7-8
Lower Bound-Nominal Fuel Economy	mpg	N/A	N/A	14.2	7.1	15	7.5
	cost	N/A	N/A	$4,700	$3,600	$3,000	$3,500
Upper Bound-Aggressive Fuel Economy	mpg	N/A	N/A	25.4	13.0	25.4	13.0
	cost	N/A	N/A	$7,000	$7,500	$6,700	$3,600

A present value of costs and benefits is calculated and presented in the result section for the milestone years of 2010, 2020, and 2025 by applying a 5 and 12 percent discount factor.

Penetration Rates and Scenarios

Developing a future vehicle penetration scenario for advanced, more efficient diesel technologies is complex and challenging due to the number of factors that influence the penetrations and the overall scenario period. The process is simplified by limiting the maximum new vehicle penetration rate in any year to 7 percent, which is the historical maximum[31] of the existing vehicle population or 100 percent of the new vehicle sales, whichever is less. Additionally, the penetration period is divided into segments based on a number of clearly defined factors. A minimum penetration rate equivalent to 1 percent of the vehicle population is also assumed. This minimum rate is taken as half of the 2 percent nominal historical vehicle population growth rate reported in the 1996 World Vehicle Forecast and Strategies.[32] This rate corresponds to 14.3 percent of the new vehicle sales.

Three penetration periods between 2005 to 2025 are defined to develop an accurate penetration scenario. The three penetration periods are 2008-2010; 2011-2020; and 2021-2025. The 2005-2007 period penetrations are negligible as they are limited to prototype demonstrations and field trials. The penetration periods are defined based on regulatory milestone events, technology phase-in, maturation and availability, and alternative fuel infrastructure deployment. A more detailed description of the rationale used to formulate these penetration periods is provided below.

Superimposed onto the penetration period determinants are two key factors that interact to define the likely penetration scenarios for the analysis: Cost to meet the emission standards and consumer hesitation due to uncertainty about reliability, durability, and expected performance in the early years.

Cost to Meet Emission Standards

Based on published industry information and analysis of costs (see notes to Table 2) to comply with emission standards by the U.S. Environmental Protection Agency (EPA)[33], the supporting analysis finds that advanced diesel vehicles are likely to cost $15,000 to $30,000 more than diesel vehicles manufactured before October 2002. These costs presented in Table 2 include emission control components and systems, as well as related vehicle engineering costs to accommodate the new emission control components. The emission control cost is an additional incremental above the vehicle cost of $3,600 to $7,000 to achieve improved fuel economy. These higher incremental costs are assumed to influence consumer purchase decisions and therefore modulate advanced vehicle penetrations.

Consumer Hesitation

Historically, consumers hesitate to embrace a new technology until its reliability, durability, and performance expectations are proven. This is even more so for heavy-duty diesel vehicles that are employed in mission-driven applications. This market reality is expected to constrain the penetration of the advanced technology diesel vehicles for up to three years after their initial introduction.

The following penetration scenarios are likely to emerge as a result of the factors discussed above.

1. For the 2005-2007 period, sales of advanced new diesels are negligible, limited to prototypes, field trials and demonstrations. This penetration period is negligible for purposes of this analysis.

2. In the 2008-2010 period, we assumed the minimum penetration rate of 1 percent of the vehicle population in each year of the analysis period or 14.3 percent of the new vehicle sales. During this period, consumers are likely to prefer buying 2.0 gm oxides of nitrogen (NOx) per brake-horsepower-hour natural gas (NG) and diesel products, now in the market for five years, versus the higher priced and less proven 0.2 gm NOx

engines entering the market. As a consequence, sales of 0.2 gm NOx NG and diesel vehicles decline sharply due to product performance uncertainties and customer purchase hesitations.

3. In the 2011-2020 period, we assumed a penetration rate equal to the average of the maximum and minimum penetration rates or 57.1 percent of new vehicle sales. During this period, vehicle sales are driven by fleets replacing aging 4.0gm and 2.5gm NOx engines.

4. In the 2021-2025 period, we assume that penetration rates peak to about 100 percent of the new vehicle sales as more fleets purchase newer vehicles to replace aging vehicles and to take advantage of the potential fuel savings from the more efficient advanced vehicles.

The vehicle penetrations in the three penetration periods account for the composite populations in the milestone years for the analysis. Table 8 presents the penetration rates used in the analysis.

Table 8: Interactive Penetration Rates for Advanced Heavy-Duty Diesel as a Fraction of New Vehicle Sales

Period	Class 3-6	Class 7 & 8
2005-2007	Negligible	Negligible
2008-2010	14.3%	14.3%
2011-2020	57%	57%
2021-2025	100%	100%

Scenario 1 (BAU/Nominal Fuel Economy Improvement)

The first scenario is a lower bound scenario. The penetration rates for Scenario 1 are varied according to the schedule in Table 8 as a fraction of new vehicle sales. Moderate fuel economy improvements compared to 2000 levels are also derived (5 percent for Class 3 through 6, and 20 percent for Class 7 and 8 by 2025 over year 2000 levels) As previously described, the composite fuel economy improvement is based on the average between the observed historical fuel economy improvement rate for heavy-duty vehicles and model projections from studies performed by the ACEEE and the EIA's NEMS model.

Based on the penetration rate assumptions, we estimate the number of new vehicles using more efficient diesel technologies, and entering service, over the scenario period. The corresponding annual number of new vehicles using the more efficient diesel technologies in California are 1,000 per year in 2005-2010, 6,300 per year in 2011-2020, and 11,000 per year in 2021-2025.

Scenario 2 (Aggressive Fuel Economy Improvement)

The second scenario is an upper bound scenario. The penetration rates for Scenario 2 are displayed in Table 8 as a percent of annual new vehicle sales. Aggressive fuel economy improvements compared to the 2000 levels are also derived (100 percent for Class 3 through 6, and 100 percent for Class 7 and 8 by 2025).

Under the assumptions made in this analysis, we expect the population of more fuel efficient heavy-duty vehicles in California to comprise 5.9 percent and up to 15.3 percent of the heavy-duty vehicle population 2010, 13.2 percent and up to 30 percent of the heavy-duty vehicle population in 2020, and 15.3 and up to 49.4 percent of the heavy-duty vehicle population in 2025 under the BAU and Aggressive scenarios, respectively.

Results

The impact on California's diesel and gasoline demand from using more efficient technologies in medium- and heavy-duty vehicles is discussed below and summarized in Tables 9 and 10. Net-Direct benefits to the state are characterized by *Direct-Non-Environmental Benefits*, *Change in Government Revenue Due to Reduced Fuel Taxes*, *Direct Environmental Net Benefits, and the External Cost of Petroleum Dependency.*

BAU Scenario

For the BAU Scenario, more efficient diesel technologies for heavy trucks reduce California's on-road diesel demand by 0.1 billion gallons or about less than 1 percent of the state's on-road gasoline and diesel demand in 2025.

Under this scenario, a 5 percent discount rate and low diesel fuel price of $1.82 per gallon, consumers are estimated to lose $0.77 billion in 2025. There is a loss in government revenue of $0.062 billion. The corresponding outcomes under this scenario, a 5 percent discount rate and high diesel fuel price of $2.18 per gallon, are estimated to be $0.7 billion in 2025. There is a loss in government revenue of $0.02 billion.

Under this scenario, a 12 percent discount rate and low diesel fuel price of $1.82 per gallon, consumers are estimated to lose $0.53 billion in 2025. The corresponding outcomes under this scenario, a 12 percent discount rate and high diesel fuel price of $2.18 per gallon is estimated to be a loss to consumers of $0.7 billion. There is a $0.02 billion loss in government revenue.

Aggressive Scenario

For the Aggressive Scenario, more efficient diesel technologies for heavy trucks reduce California's on-road diesel demand by 2.3 billion gallons or about 11 percent of the state's on-road gasoline and diesel demand in 2025.

Under this scenario, a 5 percent discount rate and low diesel fuel price of $1.82 per gallon, consumers are estimated to save $7.5 billion in 2025. The corresponding outcomes under this scenario, a 5 percent discount rate and high diesel fuel price of $2.18 per gallon are estimated to be $9.5 billion in 2025. There is a loss in government revenue of $1.4 billion for both.

Under this scenario, a 12 percent discount rate and high diesel fuel price of $1.82 per gallon, consumers are estimated to save $2.3 billion in 2025. The corresponding outcomes under this scenario, a 12 percent discount rate and high diesel fuel price of $2.18 per gallon are estimated to be $3.1 billion in 2025. There is a $0.56 billion loss in government revenue.

Table 9. Petroleum Reduction and Benefits for Medium and Heavy-Duty Diesel Vehicles

Alternative Fuel Option or Scenario	Displacement in 2025, Billion Gallon Gasoline Equivalent	Reduction from Base Case Demand, Percent	Cost and Benefits, Present Value, 2005-2025, 5% Discount Rate, Billions $2005				
			A	B	C	D	A+B+C+D
			Direct Non-Environmental Benefit	Change in Government Revenue	Direct Environmental Net Benefit	External Cost of Petroleum Dependency	Direct Net Benefit
Business As Usual, Low Petroleum Fuel Price ($1.82 per gallon diesel)	0.1	0.57	(0.77)	(0.06)	0.12	0.06	(0.37)
Aggressive, Highest Petroleum Fuel Price ($2.18 per gallon diesel)	2.3	11	9.5	(1.43)	1.93	1.04	8.96

Table 10. Petroleum Reduction and Benefits for Medium and Heavy-Duty Vehicles

Alternative Fuel Option or Scenario	Displacement in 2025, Billion Gallon Gasoline Equivalent	Reduction from Base Case Demand, Percent	Costs and Benefits Present Value, 2005-2025, 12% Discount Rate, Billions $2005				
			A	B	C	D	A+B+C+D
			Direct Non-Environmental Benefit	Change in Government Revenue	Direct Environmental Net Benefit	External Cost of Petroleum Dependency	Direct Net Benefit
Business As Usual, Low Petroleum Fuel Price ($1.82 per gallon diesel)	0.1	0.57	(0.53)	(0.02)	0.12	0.06	(0.37)
Aggressive, Highest Petroleum Fuel Price ($2.18 per gallon diesel)	2.3	11	3.1	(0.56)	1.93	1.04	5.51

Key Drivers and Uncertainties

- Assuming that a fuel economy standard will be established to accelerate the market penetration of more fuel efficient heavy-duty vehicles and spur industry to achieve the assumed fuel economies.
- Vehicle class distribution does not change
- Changing material and manufacturing costs associated with achieving higher fuel economy
- No change in vehicle miles traveled (affects demand reduction and incremental operating costs)
- Fleet turnover rate in the years 2015-2025 as vehicle fleet ages and replacement justified by lower operating cost from more fuel-efficient vehicles.
- Diesel fuel price volatility
- Manufacturers' capacity to produce 0.2 gm NOx engines.

Endnotes

[1] Energy Commission, *Reducing California's Petroleum Dependence,* August 2003*, 600-03-005F.*

[2] *Technology Roadmap for the 21st Century Truck Program* DOE, December 2000.

[3] DeCicco, John M., Ledbetter, Marc, Mengelber, Ulrike, Sachs, Harvey M. *Heavy Truck Fuel Economy: A Review of Technologies and the Potential for Improvement* American Council for an Energy Efficient Economy, January 1992.

[4] *Scenarios for U.S. Carbon Reductions: Potential Impacts of Energy Efficient and Low Carbon Technologies by 2010 and Beyond* Oak Ridge National Laboratory, May 2000.

[5] DeCicco, John M. *Transportation Energy Issues through 2030* American Council for an Energy Efficient Economy, December 1997.

[6] Ibid.

[7] Ibid.

[8] Ibid.

[9] Ibid.

[10] *Technology Roadmap for the 21st Century Truck Program* DOE, December 2000.

[11] As used in this analysis, vehicle penetration rate means a percentage of new vehicles entering the existing fleet population. For this scenario, 100 percent of new vehicles sold meet the fuel economy standards. It is estimated that new vehicle sales are fewer than 10 percent of the existing population in any given year. The penetration rate is varied during the analysis period. It is lower (1 to 2 percent) in some years, due to smaller production runs and slower adoption of the technology in certain vehicle classes, and market maturation or saturation. It is higher (5-7 percent) in some years, due to the rapid turnover of the vehicle population assumed to occur in the years 2015-2025 from aging and the availability of more efficient vehicles. The penetration rate is moderate (3-4 percent) in other years as the market matures and demand stabilizes. A composite vehicle class distribution is used in estimating the vehicle penetrations.

[12] *Lower Your Cost of Ownership* Arrow Truck Sales, Inc., March 2002.

[13] *1997 Truck Inventory Use Survey* U.S. Census Bureau, U.S. Department of Commerce.

[14] *Profile and Segmentation of Medium and Heavy Vehicle Purchase Patterns and Current and Projected Populations* MacKay & Company, February 1995.

[15] *California Motor Vehicle Stock, Travel and Fuel Forecast* California Department of Transportation, November 2001.

[16] *Profile and Segmentation of Medium and Heavy Vehicle Purchase Patterns and Current and Projected Populations* MacKay & Company, February 1995.

[17] Ibid.

[18] p12, *Light & Medium Truck*, April 2005.

[19] p42, *Light and Medium Truck*, April 2005.

[20] DeCicco, John M., Ledbetter, Marc, Mengelber, Ulrike, Sachs, Harvey M. *Heavy Truck Fuel Economy: A Review of Technologies and the Potential for Improvement* American Council for an Energy Efficient Economy, January 1992.

[21] *Scenarios for U.S. Carbon Reductions: Potential Impacts of Energy Efficient and Low Carbon Technologies by 2010 and Beyond* Oak Ridge National Laboratory, May 2000.

[22] DeCicco, John M. *Transportation Energy Issues through 2030* American Council for an Energy Efficient Economy, December 1997.

[23] Ibid.

[24] DeCicco, John M., Ledbetter, Marc, Mengelber, Ulrike, Sachs, Harvey M. *Heavy Truck Fuel Economy: A Review of Technologies and the Potential for Improvement* American Council for an Energy Efficient Economy, January 1992.

[25].Energy Commission *Reducing California's Petroleum Dependence*, August 2003, Pub. No. 600-03-005F.

http://www.energy.ca.gov/fuels/petroleum_dependence/documents/index.html.

[26] An, Feng, Stodolsky, Frank, Vyas, Anant, and Cuenca, Roy, Eberhardt, James J. *Scenario Analysis of Hybrid Class 3-7 Heavy Vehicles* Society of Automotive Engineers (SAE) Paper 2000-01-0989.

[27] DeCicco, John M., Ledbetter, Marc, Mengelber, Ulrike, Sachs, Harvey M. *Heavy Truck Fuel Economy: A Review of Technologies and the Potential for Improvement* American Council for an Energy Efficient Economy, January 1992.

[28] DeCicco, John M., Greene, David L. *Engineering-Economic Analysis of Automotive Fuel Potential in the United States* Oak Ridge National Laboratory, February 2000.

[29] Ibid.

[30] DeCicco, John M., Ledbetter, Marc, Mengelber, Ulrike, Sachs, Harvey M. *Heavy Truck Fuel Economy: A Review of Technologies and the Potential for Improvement* American Council for an Energy Efficient Economy, January 1992.

[31] DeCicco, John M. *Transportation Energy Issues through 2030* American Council for an Energy Efficient Economy, December 1997.

[32] Pemberton, Max. *1996 World Vehicle Forecasts and Strategies: The Next 20 years: A Special Report Covering the Period from 1960-2015* Ward's Communications. Pemberton Associates, Warwickshire, UK, 1996.

[33] *Regulatory Impact Analysis: Control of Emissions of Air Pollution from Highway Heavy-Duty Engines* U.S. Environmental Protection Agency, document EPA 420-R-00-10, July 2000.

OPTION 1F – LIGHT-DUTY DIESEL VEHICLES

Description

This option examines greater use of light-duty diesel (LDD) vehicles (less than 8,500 pounds gross vehicle weight) to address California's growing transportation energy demand. LDD's market penetration, impacts on refinery balance, and overall impacts on fuel prices are evaluated through 2025. This option considers an "Aggressive Case" scenario, which assumes 12 percent LDD penetration for cars and 21 percent penetration for trucks.

The California Energy Commission (Energy Commission) forecasts that by 2025, 60 percent of growth in on-road transportation fuels will be for gasoline.[1] In the *Aggressive Case Scenario*, all growth in on-road transportation fuel demand is met with increased diesel fuel use via light-duty dieselization.

Background

Engine Technology and Market Response

Turbo-charged, direct-injection, LDD engines are a well-established technology that captured 48 percent of the European passenger car market in the 2004 model year.[2] While higher fuel prices in Europe are part of the explanation for this, it appears that European car buyers consider the modern diesel an acceptable alternative to the gasoline engine vehicle, despite their higher price. Diesels offer attributes beyond fuel economy and cost that will affect their use in California's market. Greater driving range and durability, and higher torque (better response) compared to gasoline counterparts may allow the diesel to capture a larger share of the California market.[3]

Fuel Supply

California refiners maximize production of gasoline from crude oil relative to diesel and jet fuel. In 2000, gasoline represented 64 percent of each barrel of crude oil produced with jet fuel at 18 percent, and diesel at 12 percent.[4] Although greatly influenced by the refineries' complexity and crude oil composition; the maximum yield of refined products, at the lowest cost, is with less gasoline and more diesel production. Staff assumes that applying an Department of Energy's (DOE's) Energy Information Administration (EIA) analysis finding to California's market, moving towards a lower-gasoline and higher-diesel production, would greatly improve California's market resilience and lower prices.[5] Increasing LDD vehicle penetration as a means to help balance demand is crucial to achieving this result.

Air Quality Concerns

Historically, diesel engines emitted significantly more exhaust emissions of oxides of nitrogen (NO_x) and particulate matter (PM) than their gasoline counterparts. Conversely, diesel engines emitted lower hydrocarbons, carbon monoxide, CO_2, and essentially no evaporative emissions. In 1998, California Health and Regulatory Agencies concluded that diesel exhaust is a toxic air contaminant. In 2004-2010 federal and state exhaust emission or air quality regulations standards compel both gasoline and diesel exhaust emissions to be reduced to near-zero levels for all regulated exhaust emissions including PM.

All LDDs offered in California beginning in 2008 will use PM after-treatment devices which reduce PM by at least 95 percent.

Particulate emissions emitted by on-road diesel-fueled vehicles are expected to decline by 60 percent from 1995 to 2010 as a result of mobile source air quality regulations already adopted by the California Air Resources Board (CARB).[6]

The U.S. Environmental Protection Agency (EPA) has noted the positive progress of the emissions performance made with diesel engines and diesel emission controls.[7] EPA claims that once diesel engines attain the adopted standards, they will be as clean as gasoline engines for heavy- and light-duty applications. Furthermore, the potential health risks associated with diesel exhaust are reduced to the equivalent gasoline level by the federal Tier II Emissions Standards.[8,9]

Status

Until September 1, 2006, when 15 parts per million (ppm) sulfur diesel fuel is available nationwide, vehicle manufacturers are precluded from selling federal Tier II Bin-5 or California equivalent low-emission vehicle (LEV) II compliant diesel vehicles. (For brevity sake, this paper will use the federal Bin-5 exhaust emission standards to also include the CARB LEV II standard, even though there are compliance differences between the two standards.)

Although, no LDD vehicle has been certified to the federal Bin-5 exhaust emission standards, EPA has tested five vehicles that meet these standards at low mileages.[10,11] In 2004, Cummins demonstrated under more difficult conditions than specified for the federal Bin-5 standard, a diesel engine meeting federal Bin-5's useful life emission levels. As of early 2005, compliance with EPA's and CARB's NO_x emission standards is still viewed by the automotive industry as the greatest impediment and risk to the widespread market penetration of LDDs in the United States and California markets.

Meeting the exhaust emission standard for NO_x remains a critical challenge, both technically and economically, for diesel technology. One manufacturer has demonstrated a federal Bin-5 compliant diesel engine; however, the emission compliant power train costs more than the industry believes they can recover in the market. Further refinement is necessary to develop a lower-cost emission compliant diesel engine. Yet, even with significantly greater success, the final LDD vehicle at the Bin-5 (and lower) levels may still prove too great a risk and challenge for industry to take.

LDD vehicles make up less than 2 percent of California's LDD population. Sales of LDD vehicles ceased in the 2004 model-year because California's gasoline-based exhaust emission standards cannot be met with California's high sulfur diesel fuel. Meanwhile, diesel-fueled pick-up trucks certified to diesel-based emission standards (gross vehicle weight of 8,501–10,000 pounds) have reached over 52 percent of 2003 model-year registered vehicles.[12] Diesel-powered, heavy-duty suspension, sport utility vehicles (SUVs) of this size, first offered in 2000 in California, represented 27 percent of their vehicle class in 2003. Excluding heavy-duty vehicles (over 10,001 pounds), California's gasoline vehicle population is near 24.5 million, and about 350,000 vehicles are registered as diesel-fueled.

Assumptions

The information presented below was adapted from an assessment performed by K.G. Duleep[13] and Energy Commission staff. The assumed projected incremental retail price for 2008 and beyond 2012 LDD vehicle sizes is presented in Table 1. The LDD vehicles referenced in Table 1 are targeted to meet federal Bin-5 emission standards. Staff determined fuel economy improvement values as shown below.

Table 1. Diesel Vehicles Incremental Prices and Fuel Economy Used

Vehicle Size	Diesel Vehicles Incremental Retail Price, $	Volumetric Fuel Economy Multiplier Compared to Gasoline[a]
Small Car	2,350	1.35
Large Car[b]	3,150	1.35
SUV	3,150	1.40
Minivan	3,150	1.40
Pickup Trucks, Large Vans	3,400	1.45

[a] The fuel economy improvement of the diesel vehicle includes the impact of complying with California's LEV II (federal Bin-5) emission standards.
[b] The large car size includes intermediate-sized cars

From the data gathered on production vehicles in North America and Europe, the range of fuel economy improvement for an LDD, expressed as a fuel economy multiplier, is 1.20 to 1.65 with a mean of 1.40 to 1.45 city-to-highway, respectively. Staff assumed that the average LDD vehicle will have a fuel economy improvement range within these values. Staff used a 1.45 fuel economy improvement multiplier for full-sized SUVs, vans, and pickup trucks; 1.40 for mini-vans, smaller SUVs, and compact pickup trucks; and 1.35 for large and small cars.

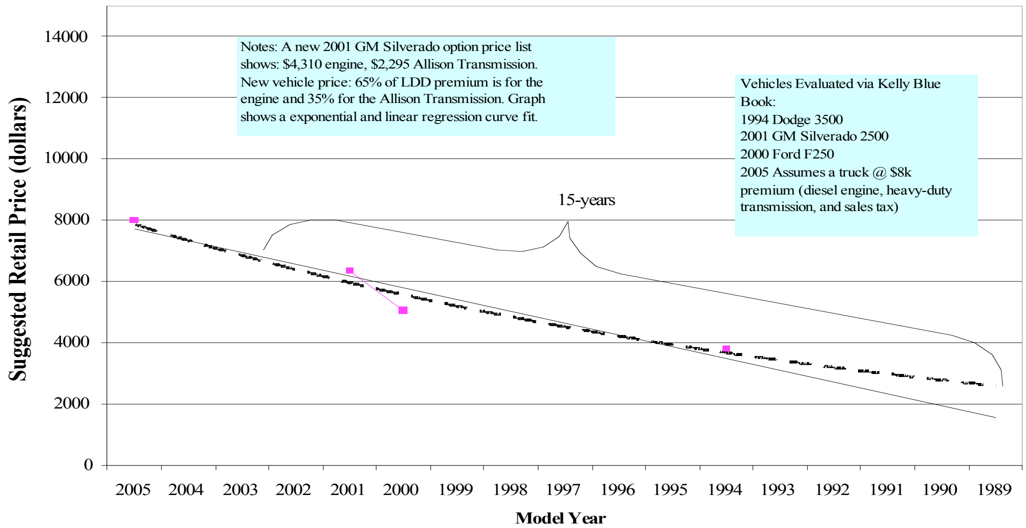
The base case for LDD market penetration was determined by employing the CALCARS model, using the vehicle classes with the attributes shown in Table 1. The CALCARS model was run assuming the concurrent availability of gasoline-hybrid vehicles competing in the same market. The incremental vehicle price used in this analysis assumed additional cost for federal Bin-5 emissions compliance. The base case is adopted as part of the Energy Commission's base demand forecast and is discussed in the *Forecasts of California Transportation Energy Demand 2005-2025.*[14]

Staff assumed that manufacturers introduce LDDs complying with California's LEV II emission standards into California's market in 2008. This assumes that NOx and PM after-treatment will be available and used on LDD vehicles in 2007 and subsequent model years, allowing sales to occur. LDD vehicles are assumed to emit at the same particulate levels as gasoline vehicles. Staff also assumed that ultra-low sulfur diesel fuel (15-ppm sulfur) will be available in mid-2006, as required by EPA and CARB regulations.

Staff also assumed diesel retail station availability to be 33 percent for the initial years, growing to 50 percent by 2020. This was based in part on the Oak Ridge National Laboratory's (ORNL) analysis[15] and a 1998-1999 survey of approximately 7,500 retail service stations in California.[16] The existing retail infrastructure for dispensing diesel is assumed adequate for the projected growth in diesel vehicle population during the initial years for the scenario evaluated. For additional infrastructure beyond this level, staff assumed that the cost of expanding retail fuel stations to dispense diesel will be absorbed by private industry as a normal investment option, controlled by the economic opportunity of supplying diesel fuel to meet demand. The diesel fuel price used in the analysis includes a retail margin that would normally pay for infrastructure expenses.

The operating cost of LDD vehicles is assumed to be the same as their gasoline counterpart, excluding fuel, and depreciation cost. This assumes that the net cost of oil changes, tune-ups, maintenance, insurance, and smog inspections are roughly equivalent. According to *Kelly Blue Book* values, diesel vehicles depreciate at a slower rate than their gasoline counterparts. Figure 3 shows suggested sales price differentials for some used diesel pickup trucks compared to gasoline vehicles. Staff conservatively determined LDDs retain 25 percent of the incremental purchase price of the diesel option after 15-years of service. Consequently, a $2,350 incremental price for a new diesel engine, after 15-years, would have a present value of $95 and $250 respectively assuming a 12 and 5 percent discount.

Fig. 3 Kelly Blue Book Differential Retail Prices of Used Pickup Trucks



Aggressive Case

Theoretically, among various options, California's future transportation fuel demand can be met by significantly expanding either gasoline or diesel production. The *Aggressive Case Scenario* considers the impacts of meeting California's future transportation energy demand with diesel and evaluates its impacts and economics.

Currently, 64 percent of crude oil is refined into gasoline, 12 percent into diesel, and 18 percent into jet fuel in California. These proportions result from market demands and are assumed to reflect the lowest production cost for these fuels and related volumes. However, future demand could be influenced to produce a refinery product distribution that uses crude oil more efficiently and with greater product volume per unit crude oil processed. We expect that a more efficient refinery would produce less gasoline, more diesel and jet fuel if market conditions were suitable for this output distribution.[17] Staff designed the *Aggressive Case* with the objective to cap gasoline demand at current levels, and to use LDDs to meet future demand growth. Staff relied upon a 1998 analysis performed by the EIA to quantify the affects and benefits.[18]

Staff applied the EIA analysis for a 30 percent light-duty diesel penetration (modeled nationally, but applied to the California market) to further evaluate this scenario. Accordingly, a 30 percent LDDs penetration would result in a 22 percent reduction in gasoline demand and a 52 percent increase in diesel use for 2025. This would result in lower gasoline prices (10 cents per gallon) and diesel prices (1 cent per gallon) and higher refinery margins in 2025 than in the *Base Case*.[19] In the cost-benefit analysis, staff applied a 1 cent lower gasoline price, growing by 1 cent annually, to 5 cents per gallon from 2021-2025 attributed to LDD's gasoline displacement. This resulted in $822–$80 million savings assuming a 5 and 12 percent discount rate, respectively. These results were combined with the Consumer's Direct Non-Environmental Benefits.

An additional benefit, not valued in the analysis, is that expanded use of LDDs opens the diesel market to using significantly greater amounts of gas-to-liquids and renewable diesel fuels. Without this balancing effect, significant use of these alternative diesel fuels and renewable fuels would be counterproductive to market demand and would be significantly market-limited.

Results

Tables 2 and 3 display the results for reduced gasoline and increased diesel fuel use from LDD vehicles, using the "FUTURES Model," an Energy Commission model employed to determine the change in gasoline and diesel volumes and Cost-Benefits of the various options. The results are expressed assuming a 5-12 percent discount.

Table 2. Petroleum Reduction and Benefits for Light-Duty Diesel Vehicles

Efficiency Option or Scenario	Displacement in 2025, Billion Gallon Gasoline Equivalent	Reduction from Base Case Demand, Percent	Highest Cumulative Benefit or Change, Present Value, 2005-2025, 5% Discount Rate, Billion $2005				
			A	B	C	D	A+B+C+D
			Direct Non-Environmental Benefit	Change in Government Revenue	Direct Environmental Net Benefit	External Cost of Petroleum Dependency	Direct Net Benefit
Low Fuel Price ($1.88/gallon diesel)	3.4 (1.9)	15 (8)	1.0	(3.5)	2.4	1.5	1.4
High Fuel Price ($2.20/gallon diesel)	2.7 (1.5)	12 (7)	1.3	(2.3)	1.7	1.0	1.7
Highest Fuel Price ($2.43/gallon diesel)	2.5 (1.3)	11 (6)	1.3	(1.7)	1.4	0.9	1.9
Includes the EIA-determined reduced gasoline retail prices effect.							

Table 3. Petroleum Reduction and Benefits for Light-Duty Vehicles

Efficiency Option or Scenario	Displacement in 2025, Billion Gallon Gasoline Equivalent	Reduction from Base Case Demand, Percent	Highest Cumulative Benefit or Change, Present Value, 2005-2025, 12% Discount Rate, Billion $2005				
			A	B	C	D	A+B+C+D
			Direct Non-Environmental Benefit	Change in Government Revenue	Direct Environmental Net Benefit	External Cost of Petroleum Dependency	Direct Net Benefit
Low Fuel Price ($1.88/gallon diesel)	3.4 (1.9)	15 (8)	0.2	(1.7)	1.1	0.8	0.4
High Fuel Price ($2.20/gallon diesel)	2.7 (1.5)	12 (7)	0.4	(1.0)	0.8	0.5	0.7
Highest Fuel Price ($2.43/gallon diesel)	2.5 (1.3)	11 (6)	0.4	(0.7)	0.6	0.4	0.7
Includes the EIA-determined reduced gasoline retail prices effect.							

Key Uncertainties

The key uncertainties in this analysis include:

- California consumer response to LDD vehicles under 8,500 pounds (gross vehicle weight). Will LDD vehicle attributes be sufficient to persuade consumers to pay significantly more for them?

- Future higher-efficiency gasoline vehicles significantly offset diesel’s operating cost advantage and reduce its attractiveness.

- Will the NO_x-stringent, gasoline-based emission regulations make compliant LDD vehicles unattractive to the consumer? Will NO_x standards preclude vehicle manufacturers from offering LDDs in California? Or restrict LDD availability to only the largest of vehicles, where economics and other attributes justify the higher cost?

- Will Corporate Average Fuel Economy (CAFE) regulations be raised to a level that makes diesel engines a more attractive technology for vehicle manufacturers to more significantly deploy in their product offerings?

- Will amendments be necessary, and allowed, by regulators for higher diesel NO_x standards if industry determines the federal Bin 5 levels is market prohibitive? Can modified performance standards for LDDs be developed to maintain equivalent environmental performance as a gasoline equivalent vehicle?

- Will aggressive NO_x reduction regulations be maintained due to evidence that NO_x emission reductions increase ozone formation in volatile organic compound (VOC) limited Air Basins? (Weekend/Weekday Research) [20]

Endnotes

[1] *Forecast of California Transportation Energy Demand 2005-2025*. Energy Commission CEC 600-2005-008.

[2] Bradford Werner & Alex Ricciuti *Filter Shortage cuts Peugeot-Citroen output,* cited value referenced to ACEA, The European Car Manufacturers Association, Automotive News, 2005.

[3] *Future Potential of Hybrid and Diesel Powertrains in the U.S. Light-Duty Vehicle Market* David L. Green, August 20, 2004.

[4] 2003 Integrated Energy Policy Report Subsidiary Volume, *Transportation Fuels, Technologies, and Infrastructure Assessment Report*, Pg. 9. http://www.energy.ca.gov/reports/100-03-013F.PDF.

[5] 2002 and 2004 conversations with refinery industry knowledgeable people and Energy Commission staff (Mr. Ramish Ganeriwal, Energy Commission staff, Mr. Anthony Finizza, AJF Consulting).

[6] CARB Resolution on Diesel Toxicity 1998.

[7] Margo Oge, Director of the EPA's Office of Air & Radiation, as quoted in InsideFuelsAndVehicles.com (October 1, 2002).

[8] Jeff Holmstead, EPA Assistant Administrator's comments made at a Blue Ribbon panel discussion at the Society of Automotive Engineers (SAE) Annual World Congress, March 2003. Source: Diesel Fuel News, *Top EPA Deputy Nixes any Plan to Trade 'CAFE' for TIER 2 Emissions*, pg.10.

[9] Margo Oge, Director of the EPA's Office of Air & Radiation, as quoted in InsideFuelsAndVehicles.com (October 1, 2002).

[10] EPA Tier 2 Light-Duty Diesel Progress Report, SAE 2004-01-1791.

[11] In 2002, Ford demonstrated ULEV emission levels using a selective catalytic reduction (SCR) after-treatment on a diesel vehicle. By the end of 2004, Ford announced the development of their Diesel Hybrid Concept Vehicle, the world's first diesel-powered partial zero-emission vehicle. The Concept Vehicle was a research exercise to test how far emissions could be reduced without regard to production viability and costs.

[12] Energy Commission *Analysis of the Department of Motor Vehicles 2003 Vehicle Registrations.*

[13] ORNL *Future Potential of Hybrid and Diesel Powertrains in the U.S. Light-Duty Vehicle Market*, August 20, 2004.

[14] *Forecast of California Transportation Energy Demand 2005-2025* Energy Commission CEC 600-2005-008.

[15] David L. Green, *Future Potential of Hybrid and Diesel Powertrains in the U.S. Light-Duty Vehicle Market* ORNL, August 20, 2004.

[16] Energy Commission used a proprietary contractor survey data on about 75 percent of all California retail service stations in 1998-1999 and found that about 24 percent of these sites dispensed diesel fuel. These sites were concentrated in cities and urban counties. Thus, the existing accessibility of diesel fuel is not assumed to limit the market growth for diesel vehicles.

[17] 2002 and 2004 conversations with refinery industry knowledgeable people and Energy Commission staff (Mr. Ramish Ganeriwal, Energy Commission staff, Mr. Anthony Finizza, AJF Consulting).

[18] Service Report, *The Impacts of Increased Diesel Penetration in the Transportation Sector*, Office of Integrated Analysis and Forecasting, EIA, DOE, August 1998.

[19] A 30 percent light-duty diesel penetration would reduce gasoline 21.7 percent, increase diesel demand 51.8 percent. Service Report, *The Increased Diesel Penetration in the Transportation Sector*, Office of Integrated Analysis and Forecasting, EIA, DOE, August 1998. http://www.eia.doe.gov/oiaf/servicerpt/intro.html.

[20] Http://www.arb.ca.gov/aqd/weekendeffect/weekendeffect.htm and the Journal of the Air & Waste Management Journal, July 2003. http://www.awma.org/journal/past-issue.asp?month=7&year=2003.

OPTION 1G - REDUCED VEHICLE DAY-LIGHTING

Summary

This analysis examines petroleum reduction that might be achieved by limiting the use of daytime running lights (DRLs), fog lamps, and other optional lights.

The analysis estimates that the petroleum savings from limiting the use of DRLs would not exceed 1 percent and would defeat the more important societal safety function they provide. Daytime visibility and avoidance of head-on or sideswipe multiple car accidents is the primary function of DRLs. Additionally, a general trend towards low energy/high luminosity lamps is occurring in the automobile market. Lower energy use in these lamps may be hastened by regulatory proceedings underway to correct for unintended glare. A proposed safety regulation will limit the luminosity of DRLs used in the United States (U.S.) in the near future.

DRLs

Eight vehicle manufacturers selling cars in the U.S. include DRLs as a standard feature on new vehicles. One offers DRLs as an option, and General Motors Corporation (GM) offers retrofit kits that can be installed not only on GM, but other vehicle brands as well.[1] The DRL system typically activates headlamps at reduced intensity (and therefore reduced energy use) during daylight hours to keep a driver's vehicle highly visible to other vehicles (and pedestrians) and reduce multiple car daytime collision risk.

The National Highway Traffic Safety Administration (NHTSA) reports that extra fuel consumed with the use of DRLs is "a fraction of a mile per gallon," while the Insurance Institute for Highway Safety cites a range of $3 to more than $40 per year in extra fuel cost (a consolidation of costs reported by GM and Transport Canada).[2] The Institute for Road Safety Research of Netherlands (SWOV) reports 0.9 percent additional fuel use for DRLs based on European programs that have been in effect for several years.[3] A Swedish study completed in 2002 estimated a fuel economy penalty range of 0.5 to 1.5 percent for various approaches among member nations of the European Union in implementing DRL programs.[4] A recent study in Switzerland under "real world" Swiss driving conditions in European design gasoline passenger cars indicated about 0.8 percent fuel use when adjusting reported results to DRL use conditions.[5]

The Safety Benefits vs. Energy Use of DRLs

The crash avoidance and life saving effectiveness of DRLs is documented in multiple assessments of mandatory, voluntary, and proposed programs in both Europe and North America. These studies clearly show driver and passenger lives saved by decreasing the number of multiple car and "angled" (left hand turns) accidents during daylight hours.[6] While mandatory in Canada, in the U. S. DRLs are not mandatory. GM petitioned the NHTSA in 2001 to initiate a rulemaking requiring all U.S. automakers to install DRLs on new vehicles.[7]

"Energy savings" versus "lives saved" trade-off studies on DRLs can not be found in current literature. The most obvious strategy for fuel savings, to not use DRLs, would defeat the more important public policy safety objective that has been achieved and reported. The second most obvious strategy is that of increasing the efficiency of DRL lamps. This is now taking place, with the development and introduction of higher efficiency (more lumens per watt) lamps employing xenon high intensity discharge (HID) and emerging light emitting diode (LED) technologies.[8] In addition, complaints of glare from DRLs during daylight hours has led to a NHTSA rulemaking process that would limit luminosity of DRLs to about half of that currently in use.[9] If the rule becomes final, NHTSA's action will hasten an indirect energy savings effect by requiring higher efficiency DRLs.

Automotive Lighting Energy Use

Actions could also be directed at discouraging inefficient or excessive use of existing fog or other "add-on" lamps, which generally consume more energy than DRLs. However, data is lacking regarding the number, power range, and frequency of installation and use of extra lamps.[10] Additional study beyond the rather narrow review presented here would be required.

The NHTSA has also opened a rulemaking addressing the problem of glare from extra headlamps and auxiliary lamps used at nighttime, a separate and more comprehensive look at all vehicle lamps, not including DRLs. NHTSA has received numerous complaints from U.S. drivers concerning HID lamps which have a characteristic blue/white light that is both annoying and disabling.[11] This rulemaking is also examining glare from high mounted lamps on sport utility vehicles, pickup trucks, and vans; light that is reflected into passenger compartments from side and rear view mirrors on passenger cars and other classes of vehicles. The outcome of this proceeding could lead to additional restrictions on lamp luminance and thus future automotive lighting energy use trends. No final rule has been proposed by NHTSA as of April 2005.

Conclusion

The energy use associated with DRLs is low, and on the order of 1 percent of fuel use (or less). Market trends show a downward trend in energy consumption in new technology lamps for headlamp applications including DRLs. With safety and crash avoidance as the reason for DRL use, any actions that would discourage their use would be inappropriate. NHTSA actions are likely to further decrease energy use once a new rule regulating luminosity from DRLs is finalized.

Further Study and Analysis Recommendation

Further analysis is needed to determine California consumer behavior and frequency of excessive use of automotive lights of all kinds, excepting DRLs. Such a study should focus on Californians' purchase habits regarding optional lighting the frequency of purchase and use of extra lights installed "after market" by consumers or businesses, and the particular atmospheric conditions (fog, haze, dust, poor light, etc.) and behavior leading to either purposeful or inadvertent excessive use of these lights.

Endnotes

[1] DRLs are standard on all 1999 GM, Volvo, Lexus, Volkswagen, Mercedes Benz, Saab, Subaru, and Suzuki models as well as some Toyota models. Insurance Institute for Highway Safety- www.hwysafety.org/safety.org/safety_facts/qanda/drl.htm.

[2] http://www.hwysafety.org/safety_facts/qanda/drl.htm#5.

[3] www.swov.nl/en/swovschrift/09/the_safety_effects_of_daytime_running_lights.htm.

[4] *Daytime Running Lights* (2002), Deliverable 3: Final Report, contract NO. ETU/B27020B-E3-2002-DRL-S07.18830, TNO Human Factors, TNO, Delft, Netherlands

[5] Patrik Soltic and Martin Weilenmann, (2002), *Influence of Electric Load on the Exhaust Gas Emissions of Passenger Cars* Eleventh International Symposium.Transport and Air Pollution, Graz, Austria, June 19-21, 2002. Staff divided a reported 1.6 percent increase in fuel consumption by two to account for typical DRL lamps in use in the U.S. (80 watts for two lamps).

[6] Power point presentation of Longhorne, et al. *An Assessment of the Crash Reduction Effects of Passenger Vehicle Daytime Running Lamps* National Center for Statistics and Analysis, DOT-NHTSA, June 11, 2003.

[7] GM press release *New General Motors Study Shows Daytime Running Lamps Continue to Reduce Crashes* October 28, 2003. GM reports that they have sold more than 30 million vehicles with DRLs in Canada and the U.S.

[8] Traditional tungsten incandescent and halogen filament lamps are being replaced by lower energy use xenon HID lamps and more recently LED lamps. The European automotive lighting company Hella will install LED based lamps in their headlight pod to serve the DRL function for the Audi A8 W12 in 2004-2005. The power consumption is report as 8 watts per unit or 16 watts for the vehicle. This in comparison to low beam headlamp energy use of 160 watts or more (staff estimate). Source: Hella HG Hueck & Co.of Germany, Annual Report 2003-2004. www.hella.com

[9] See NHTSA Docket 1998-4124 and 63 Federal Register (FR) 42348. www.dms.dot.gov

[10] A search of the literature found a study of fog lamp frequency of installation and use in two southeast Michigan communities. Available at http://dmses.dot.gov/docimages/p62/133159.pdf

[11] See NHTSA Docket 1998-4820 www.dms.dot.gov

OPTION 1H - TRUCK STOP ELECTRIFICATION

Summary

This option assumes implementation of an incentive-based or regulatory strategy intended to reduce idling by medium- and heavy-duty vehicles. For this analysis, on-road medium- and heavy-duty vehicles are defined as vehicles weighing greater than 14,000 pounds gross vehicle weight.

Idling by trucks in the medium- and heavy-duty vehicle classes consumes about one billion gallons of diesel fuel annually in the United States (U.S.).[1] In California, nearly 200 million gallons of diesel fuel are wasted by vehicles in this class but especially heavy trucks from extended idling. It is estimated that long-haul trucks idle their engines eight hours a day on average. The California Air Resources Board (CARB) estimates that about 68,000 trucks with sleeping compartments operate in California and engage in extended duration idling.[2] Extended duration idling pollutes the air and wastes fuel. Driven by public policy goals and business motivations to reduce air pollution and fuel consumption, several strategies and technologies are being implemented to reduce heavy-duty truck idling in California. Recently, CARB and several agencies, including municipalities, have adopted regulations to limit truck idling to no more than five minutes.[3]

Two categories of technologies are being pursued to reduce truck idling. On-board technologies rely on the integration of electric appliances and other equipment onto truck platforms to take advantage of plug-in at truck stops. For this analysis, on-board technologies also include the electrification of transport refrigeration units (TRUs).[4] Off-board technologies rely on an infrastructure that offers conditioned air and other amenities such as internet access from a truss and air conditioning units over the parking spaces.

These technology offerings are likely to impact petroleum demand in California in varying degrees. In the near-term (one to five years), truck idling reduction technologies are likely to reduce California's on-road diesel demand by about 1 percent. In the mid-term (five to twelve years) or by 2010, truck idling reduction is projected to reduce California's on-road diesel demand by 2 to 3 percent. In the long-term (12 or more years) or by 2025 idling reduction technologies are likely to reduce California's on-road diesel demand by 7 to 10 percent or 62 million to 300 million gallons of the state's on-road diesel demand.

Scenarios Description

Two scenarios are considered for this analysis. A *Business-As-Usual* (BAU) scenario assumes modest penetration of on-board and off-board truck idling reduction technologies of 2 percent per year and modest fixed infrastructure deployment annually.[5] The aggressive case assumes a penetration of 10 percent annually and a robust fixed infrastructure deployment.

BAU Scenario

This scenario assumes that no significant integration of on-board truck idling reduction occurs in the immediate future (one to five years from now). Today's high incremental cost ($7,000 to $12,000)[6] for the on-board technology is a barrier to moderate adoption of the technology in significant numbers in the market place. Off-board technology idling reduction infrastructure is deployed at 250 spaces per year through 2025.

Aggressive Scenario

This scenario assumes that all heavy vehicles eligible for the combination of on-board technology and off-board technology are taking advantage of their availability. Both technologies are deployed as described later in the methodology. The scenario assumes that the combination of fuel savings, volume production, and incentives that eliminate or reduce the incremental cost to end-users spur the adaptation of the technology in suitable applications. Research indicates that the incremental cost of the on-board idling reduction technologies is likely to drop by 60 to 80 percent by the 2017 to 2025 timeframe when a mature market for this product is expected to develop. Similarly, developers project the cost of off-board idling reduction infrastructure technologies will drop by 50 percent within five to seven years to $7,500 to $8,500 per parking space.[7] Original equipment manufacturers will offer electric and on-board truck idling reduction technologies on all new product offerings in compliance with applicable regulations.[8] These factors make it possible that over 90 percent of the eligible truck parking spaces at California truck stops will feature a combination of on-board and off-board truck idling reduction infrastructure by 2025.

Methodology

This analysis used two approaches to estimate the potential petroleum reduction from reduced truck idling and the derivative costs and benefits. Results of both approaches are combined.

The first approach estimates petroleum savings from electrifying about 10,000 commercial truck parking spaces at California truck stops based on the deployment of the off-board infrastructure.

For the first approach, staff assumed a truck parking space utilization of 70 percent over a 24-hour period and one gallon per hour[9] of avoided diesel fuel due to reduced idling. The BAU Scenario assumes 250 new parking spaces are electrified each year. By 2025, 6,000 truck parking spaces feature the off-board infrastructure. The *Aggressive Scenario* assumes 1,000 new parking spaces are electrified each year from 2005 through 2015 when 10,000 spaces are electrified. The electrified spaces are held constant through 2025.

The second approach estimates petroleum savings from the use of on-board technologies in the 68,000 trucks equipped with sleeper compartments operating in California. On-board technologies rely on the availability and the integration of electric appliances on board the truck. Petroleum reduction from this approach derives from the widespread integration of electric appliances onto truck platforms and the availability of electrical outlets at truck stops for plug-in operation.

For the second approach, staff assumed on-board electric technologies are integrated and enter the market at the rate of 2 percent per year of the 68,000 trucks in California with sleeper compartments. Staff further assumed that the plug-in infrastructure is deployed at 250[10] truck parking spaces annually through 2025. Space utilization of 70 percent over a 24 hour period and one gallon per hour of avoided diesel fuel due to reduced idling are the same as for the off-board infrastructure. The BAU Scenario assumes 250 new parking spaces are electrified each year. By 2025, 6000 truck parking spaces feature the off-board infrastructure. The *Aggressive Scenario* assumed on-board electric technologies are integrated and enter the market at the rate of 10 percent per year of the 68,000 trucks in California with sleeper compartments.

The combination of the two approaches provides the basis for the petroleum reduction projections, benefits, and costs, where applicable.

Technology Status

Off-board technologies provide heating, ventilation, heating, and air conditioning (HVAC) and electricity to trucks which connect to delivery hoses connected to a truss structure over truck parking spaces. Drivers turn off their engines and connect the hose to the truck cab using a $10 template. Drivers pay an hourly fee ($1.25 to $1.50) for time connected and services provided. With nearly 1,000 truck parking spaces at commercial truck stops featuring this system, off-board technologies are in the semi-commercial deployment stage.

On-board technologies integrate electric appliances on trucks. Trucks equipped with electrical appliances are able, for a fee, to connect to electrical outlets at truck stops. On-board technology packages also feature energy storage devices (batteries) to support reduced idling away from truck stops. On-board technologies are in the development stage.

Key Input Parameters and Values

The key inputs for this option are the incremental cost of truck idling reduction technologies compared to the conventional diesel engine platform. Several industry and government sources, including Argonne National Laboratory, estimate the incremental cost for on-board truck idling reduction technology ranges between $7,000 to $12,000.[11, 12, 13] The dominant developer of off-board idling reduction technology reports per space infrastructure cost of $12,000 to $15,000.[14] Staff assumes this cost drops by half by the year 2015 due to economies of scale, volume production, and learning curve effects. Another key input in the analysis is the reduction in fuel used from the implementation of the idling reduction technology.[15]

This analysis amortizes the incremental cost, where applicable, over the fuel consumed during the useful life of the vehicle and application. This treatment reduces the cost savings to the consumer or end-user of the technology. Similarly, maintenance cost items are applied on a per gallon basis. We assume that the maintenance cost for the off-board idling reduction technology is absorbed by the infrastructure developer and service provider. We assume that the maintenance cost for the on-board truck idling reduction technology is borne by the truck operator. For this analysis, the benefit to the consumer is adjusted by subtracting this cost from the annual cost savings to the consumer arising from the truck idling reduction technology.

Results

The impacts of the truck idling reduction option are summarized in Tables 1-4. The results in the tables are for the BAU and *Aggressive Scenarios* used to characterize the possible futures this option provides under three fuel price levels. A low fuel price of $1.85[16] and a high fuel price of $2.18[17] are used.

Table 1. Petroleum Reduction and Benefits for Truck Stop Electrification for Low Fuel Price and 5 Percent Discount Rate

Efficiency Option or Scenario	Displacement in 2025, Billion Gallon Gasoline Equivalent	Reduction from Base Case Demand, Percent	Highest Cumulative Benefit or Change, Present Value, 2005-2025, 5% Discount Rate, Billion $2005				
			A	B	C	D	A+B+C+D
			Direct Non-Environmental Benefit	Change in Government Revenue	Direct Environmental Net Benefit	External Cost of Petroleum Dependency	Direct Net Benefit
BAU	0.06	0.30	0.4	(0.06)	0.06	0.03	0.37
Aggressive	0.35	1.7	2.4	(0.28)	0.26	0.14	2.52

Table 2. Petroleum Reduction and Benefits for Truck Stop Electrification for Low Fuel Price and 12 Percent Discount Rate

Efficiency Option or Scenario	Displacement in 2025, Billion Gallon Gasoline Equivalent	Reduction from Base Case Demand, Percent	Highest Cumulative Benefit or Change, Present Value, 2005-2025, 12% Discount Rate, Billion $2005				
			A	B	C	D	A+B+C+D
			Direct Non-Environmental Benefit	Change in Government Revenue	Direct Environmental Net Benefit	External Cost of Petroleum Dependency	Direct Net Benefit
BAU	0.06	0.3	0.13	(0.03)	0.06	0.03	0.19
Aggressive	0.35	1.7	0.59	(0.11)	0.26	0.14	0.88

Table 3. Petroleum Reduction and Benefits for Truck Stop Electrification for High Fuel Price and 5 Percent Discount Rate

Efficiency Option or Scenario	Displacement in 2025, Billion Gallon Gasoline Equivalent	Reduction from Base Case Demand, Percent	Highest Cumulative Benefit or Change, Present Value, 2005-2025, 5% Discount Rate, Billion $2005				
			A	B	C	D	A+B+C+D
			Direct Non-Environmental Benefit	Change in Government Revenue	Direct Environmental Net Benefit	External Cost of Petroleum Dependency	Direct Net Benefit
BAU	0.06	0.3	0.52	(0.06)	0.06	0.03	0.49
Aggressive	0.35	1.7	2.4	(0.28)	0.26	0.14	2.52

Table 4. Petroleum Reduction and Benefits for Truck Stop Electrification for High Fuel Price and 12 Percent Discount Rate

Efficiency Option or Scenario	Displacement in 2025, Billion Gallon Gasoline Equivalent	Reduction from Base Case Demand, Percent	Highest Cumulative Benefit or Change, Present Value, 2005-2025, 12% Discount Rate, Billion $2005				
			A	B	C	D	A+B+C+D
			Direct Non-Environmental Benefit	Change in Government Revenue	Direct Environmental Net Benefit	External Cost of Petroleum Dependency	Direct Net Benefit
BAU	0.06	0.3	0.2	(0.03)	0.06	0.03	0.26
Aggressive	0.35	1.7	0.9	(0.11)	0.26	0.14	1.19

For the BAU Scenario, truck idling reduction using a combination of on-board and off-board idling reduction technologies reduces California's on-road diesel demand by 62 million gallons or about 0.3 percent in 2025.

Net-Direct benefits to the state under this scenario and a 5 percent discount rate and low fuel price of $1.82 per gallon are estimated to be $0.37 billion in 2025. Net-Direct benefits to the state under this scenario and a 12 percent discount rate and low fuel price of $1.82 per gallon are estimated to be $0.19 billion in 2025.

Net-Direct benefits to the state under this scenario and a 5 percent discount rate and high fuel price of $2.18 per gallon are estimated to be $0.49 billion in 2025. Net-Direct benefits to the state under this scenario and a 12 percent discount rate and low fuel price of $2.18 per gallon are estimated to be $0.26 billion in 2025.

Aggressive Scenario

For the *Aggressive Scenario*, truck idling reduction using a combination of on-board and off-board idling reduction technologies reduces California's on-road diesel demand by 300 million gallons or about 10 percent in 2025.

Net-Direct benefits to the state under this scenario and a 5 percent discount rate and low fuel price of $1.82 per gallon are estimated to be $2.52 billion in 2025. Net-Direct benefits to the state under this scenario and a 12 percent discount rate and low fuel price of $1.82 per gallon are estimated to be $0.88 billion in 2025.

Net-Direct benefits to the state under this scenario and a 5 percent discount rate and high fuel price of $2.18 per gallon are estimated to be $2.52 billion in 2025. Net-Direct benefits to the state under this scenario and a 12 percent discount rate and high fuel price of $2.18 per gallon are estimated to be $1.19 billion in 2025.

Key Drivers and Uncertainties

The following key drivers and uncertainties are identified and known to affect this option.

- Potential cost savings from integrating truck idling reduction technologies
- Cost to replace new battery or other energy storage device maintenance for on-board systems
- Market acceptance of on-board technologies
- Market acceptance of off-board technologies
- Durability and reliability
- Manufacturer field support and warranty

Endnotes

[1] Stodoldky, F.; Gaines, L.; Ayas, A. *Analysis of Technology Options to Reduce the Fuel Consumption of Idling Trucks* Argonne National Laboratory. ANL/ESD-43. June 2000.

[2] *Initial Statement of Reasons: Public Hearing to Consider the Adoption of Heavy-duty Vehicle Idling Emission Reduction Requirements* CARB, December 5, 2003.

[3] Ibid.

[4] Transportation Refrigeration Units are devices used to cool high-value or perishable items being transported. These devices operate on small auxiliary diesel engines. Replacing them with electric units would eliminate pollution associated with their operation and save fuel.

[5] Calculated historical penetration rate of selected technologies onto vehicle platforms. Ward's Automotive.

[6] *Idling Reduction Technologies for Heavy Duty Trucks: Technology Introduction Plan* Idaho National Engineering and Environmental Laboratory, May 13, 2004.

[7] Bob Wilson, IdleAire Technologies, October 2004 - Personal Communication.

[8] *Initial Statement of Reasons: Public Hearing to Consider the Adoption of Heavy-duty Vehicle Idling Emission Reduction Requirements* CARB, December 5, 2003.

[9] Argonne National Laboratory, EPA estimate that the average heavy-duty truck consumes about 1 gallon per hour of engine idling.

[10] 250 spaces is the historical rate at which the dominant developer has deployed the idling reduction infrastructure in California under a combination of incentives and funding initiatives.

[11] *Initial Statement of Reasons: Public Hearing to Consider the Adoption of Heavy-duty Vehicle Idling Emission Reduction Requirements* CARB, December 5, 2003.

[12] Stodolsky, F., Gaines; L., Ayas, A. *Analysis of Technology Options to Reduce the Fuel Consumption of Idling Trucks* Argonne National Laboratory. ANL/ESD-43, June 2000.

[13] *Briefing on Electric Transportation Technologies* California Electric Transportation Coalition, August 2004.

[14] Ibid.

[15] Analysis of the Truck Inventory and Use Survey from the Truck Size and Weight Perspective for Trucks with Four-Axles or Less.

[16] *Summary of Retail Price Scenarios for 2025* Energy Commission staff, February 24, 2005.

[17] Ibid.

OPTION 1I – LOW VISCOSITY LUBRICATING OIL

Summary

Engine oil is the life blood of a vehicle. Not following the manufacturer recommended oil change intervals or using the wrong type of oil can void a vehicle warranty and can result in lower fuel economy.

To better understand the characteristics of the different types of engine oil on the market today (conventional, synthetic, energy conserving, etc.) the Society of Automotive Engineers (SAE) and the American Petroleum Institute (API) have established several ways to classify engine oil. These are shown in the donut shaped logo on the oil container label.

Performance Ratings

The “API Service” classification (**SM**) is a two-letter code that defines the oil performance characteristics under different engine loads, speeds and temperatures. The letter “S” designates the oil is for gasoline engine use. The second letter “M” indicates the application.

Recently API announced the new engine oil service classification (**SM**) that can provide full engine protection for all gasoline vehicle types. “Engine oils meeting the new SM service category designation are designed to provide improved oxidation resistance and deposit protection, better wear protection, and better low-temperature performance over the life of the oil...and may also qualify as having Energy Conserving properties.”[1] The current oil classifications in use for gasoline engines are SM & SL, designed for all gasoline automotive use, and SJ, designed for 2001 and older vehicles.

Viscosity

The SAE classification in the center of the donut shaped logo indicates the oil viscosity. The higher numbers indicate thicker oil. Oil classified with a “W,” such as 10W, indicate the oil viscosity when the engine is cold during winter conditions, whereas, a number rating without a “W” describes the oil viscosity during normal engine temperatures in non-winter conditions. Most vehicle manufacturers recommend multi-grade oil (i.e. 10W-30), due to its suitable flow properties during winter and warmer weather.

Fuel Economy Rating

The third part of the label classification is the “Energy Conservation” term. Oils are rated on their ability to reduce the amount of fuel consumed while driving. Those that are at least 1.5 percent better than standard reference oil are rated as “Energy Conserving.” If the oil is at least 2.7 percent better, it will be labeled as “Energy Conserving II.” Oils with this rating are designed to reduce internal engine friction and improve fuel economy.[2]

Petroleum Reduction

Petroleum reductions are occurring now as “at least ten automakers recommend the use of new energy conserving oils for their current and older gasoline powered vehicles: DaimlerChrysler, Toyota, Nissan, Mazda, Isuzu, Ford, Honda, General Motors, Suzuki, and Subaru.”[3] These oils meet more stringent energy conserving requirements and in most cases have either “Energy Conserving” or “Energy Conserving II” listed on the bottom section of the donut shaped logo on the oil container.

As a result of automakers recommending the use of new energy conserving oils in vehicles sold since 2002, staff assumed that the fuel economy gains from these vehicles will be captured in the base case of the CALCARS model. For purposes of this report, there is no additional petroleum reduction from vehicles 2002 or newer.

Additionally, it is difficult to identify petroleum reduction from older vehicles using the more energy efficient oil for several reasons: 1) vehicle data is not readily available, 2) older vehicles may not function as well with a different grade or viscosity of oil than was originally recommended, and 3) as a vehicle ages it tends to experience reductions in fuel economy due to irregular maintenance after the vehicle warranty period expires and from normal wear-and-tear. When considering these issues and comparing them with the possible improvement in fuel economy using the more energy efficient oils, they offset each other producing insignificant petroleum reduction results over the base case.

Description

No significant petroleum reduction.

The petroleum reduction resulting from new vehicles (2002 and newer) using Energy Conserving Oil is included in the U.S. Environmental Protection Agency (EPA) fuel economy rating and is therefore included in the CALCARS base case. Older vehicles do not pose any significant petroleum reduction. Energy conserving oil is available commercially and used in typical day-to-day vehicle operation.

Key Input Parameters and Values

N/A

Results

N/A

Key Drivers and Uncertainties

N/A

Endnotes

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[1] API online media center article titled: *API Introduces New Gasoline Engine Oil Service Category SM*; January 5, 2005, http://api-ec.api.org/media/index.cfm, March 21, 2005.

[2] 1994 SAE Handbook, vol. 1, Materials, Fuels, Emissions and Noise, *Classification of Energy-Conserving Engine Oil For Passenger Cars, Vans and Light-Duty* Trucks- *SAE J1423.*

[3] API *Oils Meeting News ILSAC GF-4 Engine Oil Standard Available* September 14, 2004, http://api-ec.api.org/media/index.cfm March 25, 2005.

OPTION 2A - HYDROGEN

Hydrogen is not a fuel but an energy carrier used to transfer energy from one place to another. This distinction allows a variety of feedstocks for applications in which their use would be otherwise difficult, such as coal or water for light-duty vehicles.

Hydrogen has to have an energy source such as solar, wind, nuclear, or conventional power, to produce it and a feedstock to provide the hydrogen. The pathways for hydrogen production can be divided into three major categories by energy source: fossil-based hydrogen, renewable-based hydrogen, and nuclear-based hydrogen. The many potential combinations, illustrated in Table 1, make it difficult to determine the pathways that will be the choices for the future.

Table 1. Hydrogen Production Options

Raw Feedstocks	Processed Feedstocks	Process Options	Process Energy Source Options
• Fossil Fuels Natural Gas Coal Oil • Renewables Crops Biomass • Water	• Direct Use • Syngas • Gasoline • Diesel • Methanol • Ethanol • Ammonia • Biodiesel • Biogas • Sugars	• Steam Reforming • Partial Oxidation • Gasification • Pyrolysis • Electrolysis • Photoelectro-chemical • Aerobic Fermentation • Anaerobic Fermentation	Thermal/Electricity Source • Fossil Fuels • Renewables • Nuclear

The potential for hydrogen to be developed from such a wide variety of feedstocks is promoting worldwide interest. Countries can develop hydrogen from sources which they have abundance, using thermal and electricity options that are the least expensive for them. Collaborations of government agencies and private industries have formed, from statewide (California Fuel Cell Partnership or CaFCP) to worldwide (International Partnership for the Hydrogen Economy) to increase the use of hydrogen as an energy carrier.

The National Academy of Sciences National Research Council's Committee on Alternatives and Strategies for Future Hydrogen Production and Use believes for hydrogen transportation, the four most fundamental challenges to be overcome are:

- Durable, safe, and environmentally desirable fuel cell systems and hydrogen storage systems have to be developed.

- Hydrogen infrastructure has to be provided for the light-duty vehicle user.
- The cost of hydrogen production from renewable resources has to be sharply reduced.
- CO_2 by-products of hydrogen production from coal have to be captured and sequestered.[1]

Currently, hydrogen is commonly produced from natural gas using steam methane reforming. This feedstock is not produced from domestic sources in amounts that could support the amount of hydrogen needed for transportation use. Thus, any reductions in petroleum imports would be offset by an increase in natural gas imports.

The cost of hydrogen produced from natural gas will depend on the plant size, the efficiency of the system, and the cost of natural gas. The National Academy of Sciences has estimated the effects of the price of natural gas on the cost of hydrogen at plants of three different sizes as illustrated in Table 2. The costs of hydrogen are based on current steam methane reforming technology.

Table 2. Conversion of Natural Gas to Hydrogen

Size of Plant	Natural Gas Price ($/mmBtu)						
	$2.50	$3.50	$4.50	$5.50	$6.50	$7.50	$8.50
	$ per kg Hydrogen (No CO_2 Sequestration)						
1.2 Million kg Hydrogen per Stream Day	$0.68	$0.86	$1.03	$1.21	$1.38		
0.024 Million kg Hydrogen per Stream Day	$1.03	$1.21	$1.38	$1.56	$1.73		
480 kg Hydrogen per Stream Day			$3.04	$3.28	$3.51	$3.75	$3.98

*CO_2 sequestration may raise the cost of hydrogen by approximately 11 percent to 20 percent depending on plant size and natural gas price.

Research continues on feedstocks or energy sources for hydrogen production to be used as a source of hydrogen. To gain perspective on the relative scale of producing hydrogen from various sources, Tables 3a and 3b were derived from the United State's (U.S.) Department of Energy (DOE) summary of hydrogen production from domestic resources. About 242 kg of hydrogen per vehicle per year[2] or 0.27 short tons of hydrogen per vehicle per year[3] is a basic assumption in the DOE analysis. The values in column (a) represent 100 percent going to the production of the hydrogen. Thus, over six times as much biomass and three times as much coal will be needed to produce the same amount of hydrogen as natural gas, given current technologies. Similarly, over twice as much as nuclear energy will be required to produce hydrogen from water with wind or solar energy.

Table 3a. Potential Hydrogen Production from Reforming or Partial Oxidation Processes

Feedstock	(a) Amount Required Per Vehicle Per Year if Providing 100% of Feedstock Requirement (tons)	(b) Total Amount Required for 30,000 Vehicles (tons)	(c) 2003 Amounts Used or Produced in California (tons)
Natural Gas	0.63	19,000	7,565,503 [a]
Biomass	4.00	120,000	10,970,345 [b]
Coal	2.07	62,000	0

[a]Includes amounts used for electricity production.
[b]Biomass residue calculated from California agricultural statistics on acreage (California Agricultural Statistics Services and County Agricultural Commissioners annual reports) and UC Davis data on residue tons per acre.

Table 3b. Potential Hydrogen Production From Water Electrolysis

Source of Electricity	(a) Amount Required Per Vehicle Per Year if Providing 100% of Electricity Requirement (Megawatts)	(b) Total Electricity Required for 30,000 Vehicles (Megawatts)	(c) 2003 California Gross System Power[4] (Megawatts)
Wind	0.0037	111	486
Solar	0.0049	148	85
Nuclear	0.0014	43.2	4052

Technology options for using hydrogen as a transportation fuel are also varied. Hydrogen gas can be burned in an internal combustion engine (ICE) and gasoline can provide the hydrogen for a fuel cell. Determining market penetration dates is fraught with uncertainty. As seen in Table 4, DOE has targeted 2015 to make the decision whether to continue commercialization based on the ability of hydrogen technology to meet customer requirements at that time. The timelines shown do not include research and development being conducted in other countries through the International Partnership for the Hydrogen Economy. Technology breakthroughs outside California or the U.S. would impact domestic critical path decisions.

Table 4. Timelines for Transition to Hydrogen

Year	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
CaFCP[5]	65 fuel cell vehicles			300 fuel cell vehicles and stations to support them (includes 7 buses)																	
DOE Hydrogen Program Plan	Research and development programs										Go/No-go commercialization decision										
						Transition of programs to marketplace															
	Govt. fleets					Other vehicle fleets										Vehicle market intro.					
	Hydrogen from advanced processing of natural gas																				
						Hydrogen from gasification of coal (85%)/biomass (15%) with sequestration credits from growing cycle of biomass															
						Hydrogen from electrolysis of water using nuclear and renewable fuels															
ISHRI[6]						Production of low-cost hydrogen from domestic coal with the capture and sequestration of CO_2															

Hydrogen Development Worldwide

A partial list of worldwide hydrogen projects illustrates the commitment of financial and scientific support to develop and commercialize the necessary technologies.

- The Japanese government has committed to install over one million fuel cells in family houses and to have 50,000 fuel cell vehicles on the road by 2010.

- Mazda Motor Corporation plans road tests between 2005 and 2007 for a dual-fuel hydrogen rotary engine featuring an electronically controlled hydrogen gas direct injection system. Rotary engines, less fuel efficient than reciprocating engines on gasoline, are more efficient than standard engines on hydrogen. Mazda also installed a hydrogen filling station in Hiroshima, Japan.

- In Iceland, hydrogen buses are being tested.

- Australia is converting thousands of postal bikes to fuel cells.

- After a five-year evaluation period, the Italian government approved service use of a 60kW fuel cell and battery hybrid bus for the city of Turin.

- The world's largest hydrogen filling station, capable of filling more than 100 vehicles per day, has opened in Berlin, Germany. Aral (a subsidiary of Deutsche BP) is offering hydrogen alongside gasoline and diesel at a conventional filling station.

- The Michelin Group of France and the Paul Scherrer Institute of Switzerland have developed a prototype lightweight fuel cell vehicle. The weight of the car's materials allows its fuel consumption to be spectacularly low.

- The U.S. Army has been working on a high-performance, off-road fuel cell vehicle for high mobility in stealth operations. The vehicle runs on compressed hydrogen and can reach 40 miles per hour, twice as fast as conventional gasoline ICE all-terrain vehicles.

Hydrogen for Transportation

In transportation, hydrogen can be used with fuel cell vehicles and ICE with modifications, including vehicles that run on natural gas or propane. Hydrogen and natural gas blends may provide a transition to hydrogen-powered vehicles.

Fuel Cell Vehicles

Several types of fuel cells are being developed, but the one being considered in transportation applications is the Proton Exchange Membrane (PEM) fuel cell. The PEM fuel cell has a high power density, operates at low temperatures, permits adjustable power output, and allows quick start-ups.[7]

PEM fuel cell vehicles use hydrogen gas stored on the vehicle in gaseous or liquefied form in tanks, or liquid fuels converted to hydrogen using an on-board reformer.

Since 2000, 65 light-duty fuel cell vehicles have been traveling California roads for demonstration and testing through the CaFCP. The companies and models are:

- DaimlerChrysler – F-Cell, based on the European Mercedes-Benz A-Class
- Ford – Focus FCV
- General Motors – Hy-wire and HydroGen3
- Honda – FCX
- Hyundai Motor Company – Santa Fe FCEV
- Nissan
- Toyota – FCHV-4
- Volkswgen – Touran HyMotion

Table 5 provides information on two fuel cell vehicles reported in the U.S. Environmental Protection Agency's (EPA) Fuel Economy Guide.

Table 5. 2005 Fuel Cell Vehicles

Listed in EPA Fuel Economy Guide[8]

	Honda FCX	Ford Focus FCV
Miles/kg Hydrogen	51 to 62	48 to 53
Range	190 miles	200 miles
Vehicle Class	Subcompact	Compact
Type of Fuel Cell	PEM	PEM
Motor	80 kW DC brushless	65 kW AC induction
Energy Storage	9.2 farad ultracapacitor	180 V NiMH battery

Fuel cell vehicles can use direct hydrogen or an on-board reformer using ethanol, methanol, or gasoline. The preponderance of data is associated with direct hydrogen (compressed or liquefied) use. This analysis will focus on this technology. However, it is possible fuel cell vehicles will be introduced using gasoline reformers to gain the benefits of increased fuel economy and decreased emissions while using existing gasoline fueling infrastructure.

An additional public benefit of the fuel cell vehicle technology is the concept of the "skateboard" chassis with "snap-on" bodies. The possibility of extremely compact all-electronic designs through the elimination of mechanical parts could decrease the cost of vehicle production. The benefits associated with this aspect of fuel cell technology will be developed during the transition phase to the marketplace, currently projected to be between 2010 and 2020.

Hydrogen in ICE

Getting an ICE to run on hydrogen is not difficult. The challenge is getting an ICE to run well on hydrogen.

If hydrogen is mixed with natural gas, both can be stored in the same tank. Liquid hydrogen must be stored in a separate vessel because of its extremely low temperature. If used with liquid fuels such as gasoline or diesel, hydrogen has to be stored separately and mixed prior to ignition. [9]

To test the potential for reduced emissions and increased fuel economy with hydrogen-compressed natural gas (CNG) blends, the Arizona Public Service Company (APS), Electric Transportation Applications, and the DOE's Advanced Vehicle Testing Activity tested four vehicles:

1. A Dodge Ram Wagon van, a factory produced dedicated CNG vehicle[10];

2. A 2000 model year Ford F-150, factory equipped with a CNG engine that was modified to run on a 30 percent hydrogen with CNG blend[11];

3. A 2001 model year Ford F-150, factory equipped with a gasoline engine that was modified to run on a 30 percent hydrogen with CNG blend initially and later, on a 50 percent hydrogen with CNG blend[12]; and

4. A 1998 model year Mercedes Sprinter van, factory equipped with a 2.4 liter gasoline engine that was converted in Germany to operate on pure hydrogen[13].

Emissions comparisons on the Fords were made against a similar gasoline vehicle, using California emission requirements as a reference. The 50 percent hydrogen blend vehicle was tested at the Clean Air Vehicle Technology Center in California. Further work needs to be conducted, but overall, emission reductions were achieved, particularly in the 50 percent hydrogen blend. Total hydrocarbon emissions showed a 7.5 percent drop and carbon dioxide was reduced by almost 30 percent. Where tracked, fuel economy gains were made proportional to the amount of hydrogen in the blend. The Mercedes Sprinter van was only operated for about 4,000 miles; therefore the fuel economy may be erroneously high. The tests concluded a re-tuned, factory dedicated CNG vehicle can provide operating results comparable to a gasoline vehicle converted for hydrogen blends. Also, the CNG vehicle required less work to run well on hydrogen than the ICE vehicle.

Ford Motor Company has developed an ICE optimized to burn hydrogen instead of gasoline. The engine can reach an overall efficiency of about 38 percent, about 25 percent more fuel-efficient than a typical gasoline engine, and its emissions are nearly zero. The engine is based on Ford's 2.3 liter engine used in the Ford Ranger. Supercharging allows the hydrogen ICE to deliver the same power as its gasoline counterpart.[14]

The Difficulty in Estimating Future Hydrogen Penetrations

Future hydrogen vehicles include various combinations such as:

- ICE using hydrogen gas,
- ICE using a hydrogen and natural gas mix,
- Proton exchange membrane (PEM) fuel-cell stack using an on-board reformer and a liquid fuel such as methanol, ethanol, or gasoline, and
- PEM fuel-cell stack using direct hydrogen generated off-board and stored on the vehicle in compressed or liquid form.

The hydrogen vehicles of the future may also be any or all of the above combinations. The cost increment depends on the variations. A direct hydrogen fuel cell vehicle with a 60-kW PEM and a 25-kW battery will cost more than a direct hydrogen fuel cell vehicle with a 25-kW PEM and a 60-kW battery.[15]

In modeling the cost effectiveness of various zero-emission vehicle technologies such as hybrid electric, electric, and hydrogen fuel cell vehicles; RAND Corporation estimated production volumes that could impact cost would not be achieved until 2020.[16]

In October 1999, DOE, the California Air Resources Board (CARB), and the California Energy Commission (Energy Commission) co-sponsored a workshop to answer the question: *What has to be done, beginning today, to implement a hydrogen fuel infrastructure so that when hydrogen vehicles become market-ready in 3-5 years, the infrastructure needed for on-board direct use of hydrogen will be available?* In summary, the workshop and subsequent planning meetings identified (1) the rate of hydrogen technology development and (2) the interplay between market forces and social concerns as the key drivers that would determine the role of hydrogen in plausible energy futures.

Key uncertainties identified were:

- the nature of hydrogen technology development,
- the rate of hydrogen technology development, and
- how social concerns such as environmental quality and energy security affect competitive market forces that determine fuel choice and the commercial success of advanced technologies.[17]

Six years later, hydrogen fuel cell vehicles are being tested and demonstrated in limited numbers. An equally limited number of ICE vehicles are being run on hydrogen. To advance the number of vehicles penetrating the market significantly prior to 2020 will require fundamental breakthroughs in both fuel cells and hydrogen production.

Assumptions for Vehicle Penetration Scenarios

Due to the uncertainties of hydrogen technology development, values for fuel displacement, consumer savings, and changes in government revenue are preliminary numbers that will be revised in future reports. It is assumed three types of hydrogen vehicles will be introduced in California, first for fleet use and then to the public market.

1. Natural gas vehicles optimized to use between 30 percent to 50 percent hydrogen (by volume) – average 30 miles per gasoline gallon equivalent (gge).

2. ICE designed for 100 percent hydrogen – 30 miles per gge.

3. PEM fuel cell vehicles using direct hydrogen, with full market penetration occurring in 2020 – 74 miles per gge.

The gge was determined for the various fuel mixtures using the following values defined by the National Conference of Weights and Measures.[18]

- CNG: 2.57 kg/gge
- 30% hydrogen blend by volume: 2.41 kg/gge
- 50% hydrogen blend by volume: 2.22 kg/gge
- Hydrogen: 1.04 kg/gge

Shell Hydrogen is collaborating with General Motors to demonstrate refueling infrastructure technology. The company's goal is to provide hydrogen alongside traditional fuels. Their plan is for networks of stations between 2010 to 2020. ChevronTexaco and BP have also announced similar involvement to provide hydrogen infrastructure.

ICE Using Direct Hydrogen

Fuel economy for hydrogen and hydrogen-natural gas blend vehicles were estimated using a combination of the gge's, EPA fuel economy ratings for compressed natural gas vehicles, data from Ford regarding their hydrogen optimized ICE, and operational data from APS operating summaries.

Fuel cost ranges for the hydrogen blends were based on the relative percentages of hydrogen and natural gas. Table 6 summarizes the average petroleum reduction and direct non-governmental benefits for the hydrogen ICE vehicle option.

Table 6. Average Petroleum Reduction and Direct Non-Governmental Benefits for Hydrogen ICE

	Average Conventional Fuel Displaced (Billions Gallons)	Average Consumer Savings 12% to 5% Discount Rate	Average Change in Government Revenue 12% to 5% Discount Rate
2005 to 2010	0.009	($8) to ($9)	($4) to ($5)
2005 to 2020	0.761	($375) to ($742)	($166) to ($446)
2005 to 2025	1.544	($841) to ($2,075)	($357) to ($1,191)

Fuel Cell Vehicle Using Direct Hydrogen

With current technologies, direct hydrogen use in a fuel cell provides the highest efficiency. The hydrogen storage options for the lowest cost during the period of 2005 to 2015 will probably be compressed or liquefied hydrogen.

Argonne National Laboratories Fuel Cell Program established energy storage requirements for three vehicle platforms (compact car, mid-size car, and sport utility vehicle) using 2005 to 2007 fuel cell technologies. Argonne's Center for Transportation Research (CTR) developed baseline models, assuming compressed hydrogen and PEM fuel cell systems. The models showed the fuel economy of the mid-term hydrogen fuel cell vehicles to be 2.5 to 2.7 times the fuel economy of the current conventional gasoline ICE on the same vehicular platform.

Argonne used a 320-mile driving range between refueling. This data was used to estimate the relationship between fuel economies of hydrogen fuel cell vehicles and their ICE counterpart. Table 7 summarizes relative fuel economy data for fuel cell and ICE vehicles.

Table 7. Relative Fuel Economy of Fuel Cell Vehicle to ICE Vehicle

	Compact Car	Mid-Size Car	SUV
Modeling Range	320 miles	320 miles	320 miles
Compressed Hydrogen Used	4.3 kg	5.1 kg	6.4 kg
Fuel Cell Vehicle Economy	74 miles/kg	62 miles/kg	50 miles/kg
Conventional ICE Fuel Economy	28 miles/gallon	23 miles/gallon	20 miles/gallon
Ratio[19]	2.64 gallons gas/kg hydrogen	2.7 gallons gas/kg hydrogen	2.5 gallons gas/kg hydrogen

Incremental cost estimates of $9,000 to $11,000 made by Arthur D. Little for the 2010 to 2020 time period were used. The number of vehicles was assumed to be 10 percent of the estimated U.S. population of 3 million vehicles by 2020. Both vehicle and hydrogen production technologies are assumed to be in transition to full commercialization during the period of this analysis. Table 8 summarizes average petroleum reduction and direct non-environmental benefits for a hydrogen fuel cell vehicle.

Table 8. Average Petroleum Reduction and Direct Non-Environmental Benefits for Hydrogen Fuel Cells

	Average Conventional Fuel Displaced (Billions Gallons)	Average Consumer Savings 12% to 5% Discount Rate	Average Change in Government Revenue 12% to 5% Discount Rate
2005 to 2010	0.000	($1) to ($1)	($0) to ($0)
2005 to 2020	0.310	($148) to ($429)	($40) to ($101)
2005 to 2025	0.759	($456) to ($1,735)	($149) to ($436)

Endnotes

[1] National Academy of Sciences *The Hydrogen Economy: Opportunities, Costs, Barriers, and R&D Needs*, 2004.

[2] Number derived from *DOE Hydrogen Posture Plan* and verified with current fuel cell vehicle ranges of 48 to 51 miles per kilogram (approximately 12,000 to 15,000 miles per year travel).

[3] Approximately 907.185 kg per short ton hydrogen.

[4] http://www.energy.ca.gov/electricity/gross_system_power.html April, 27, 2005.

[5] California Fuel Cell Partnership 2005 Program Plan, January 25, 2005.

[6] Integrated Sequestration and Hydrogen Research Initiative.

[7] Arthur D. Little *Projected Automotive Fuel Cell Use in California* October 2001.

[8] DOE *Fuel Economy Guide for 2005 model year vehicles*.

[9] Hydrogen Use in Internal Combustion Engines, College of the Desert, December 2001.

[10] Karner, Don and Francfort, James *Dodge Ram Wagon Van – Hydrogen/CNG Operations Summary*, Idaho National Engineering and Environmental Laboratory (INEEL), INEEL/EXT-03-00006 January 2003.

[11] Karner, Don and Francfort, James *Low-Percentage Hydrogen/CNG Blend Ford F-150 Operating Summary*, INEEL, INEEL/EXT-03-00008 January 2003.

[12] Karner, Don and Francfort, James *High-Percentage Hydrogen/CNG Blend Ford F-150 Operating Summary*, INEEL, INEEL/EXT-03-00007 January 2003.

[13] Karner, Don and Francfort, James *Hydrogen-Fueled Mercedes Sprinter Van Operating Summary*, INEEL, INEEL/EXT-03-00009 January 2003.

[14] Ford Motor Company – Hydrogen Internal Combustion, www.ford.com/en/innovation/engineFuelTechnology/hydrogenInternalCombustion.htm.

[15] Rand, *Driving Emissions to Zero: Are the Benefits of California's Zero Emission Vehicle Program Worth the Costs?*, MR1578 (2002).

[16] Ibid.

[17] National Renewable Energy Laboratory, *Integrated Hydrogen Fuel Infrastructure Research and Technology Development*, NREL/CP-570-28890 (2000).

[18] INEEL, DOE FreedomCAR & Vehicle Technologies, *Advanced Vehicle Testing Activity* operating summaries, January 2003.

[19] The fuel economy ratios were checked against data provided by Arthur D. Little in their report, *Projected Automotive Fuel Cell Use in California* – (data from 2000 technology) for a hypothetical 600 mile range:

Compressed Hydrogen Fuel Cell Vehicle	0.90 miles/MJ hydrogen
Conventional ICE Vehicle	0.43 miles/MJ gasoline
Ratio	2.1 gasoline/hydrogen

OPTION 2B – ELECTRIC BATTERY

Description

In 1990, the California Air Resources Board (CARB) adopted low-emission vehicle standards that required automobile manufacturers to offer a minimum percentage of zero-emission vehicles (ZEVs) for sale. The most recent amendments to those standards, the ZEV Regulation, require that certain automobile manufacturers make ZEVs available in California.[1] The ZEV program encouraged the development of advanced technologies, but the ZEV market did not develop as fast as was anticipated. As a result, automakers signed Memoranda of Agreement that resulted in about 2,000 electric vehicles being demonstrated in California fleets.

In 2000 and 2003, the ZEV regulations were modified to provide automakers additional flexibility by allowing credits for low-speed electric vehicles and partial ZEVs (PZEVs). The minimum percentage has been reduced since the ZEV program inception, and although other types of vehicles have been granted partial credit toward meeting the ZEV requirements, manufacturers must still produce, and offer for sale, a “pure” ZEV.[2]

At this time, it is not clear what types of electric vehicles will be used to meet ZEV requirements. It appears there will be significant flexibility allowed the automakers to achieve ZEV compliance strategies. Currently, chemical-battery (where the electricity or fuel for the vehicle is stored) electric vehicles are the ZEV technology closest to commercialization. However, the ZEV requirements may be fulfilled by a combination of grid- and non-grid-connected hybrids, fuel cell vehicles, and any vehicles certified as PZEVs, as well as chemical-battery electric vehicles. Within this context, the markets for chemical-battery electric vehicles will be created by regulations requiring vehicle emissions to be zero. These vehicles are already included in the base case forecast at the levels required by California’s low-emission vehicle standards.

The definition of electric vehicle has evolved since the start of the low-emission vehicle program. Electric vehicles used to be defined in relation to the internal combustion engine light-duty vehicle as a full-function electric car. Since then, both on-road (e.g. low-speed vehicles and electric buses) and non-road equipment (e.g. forklifts and airport ground support) have entered the market.[3] Some vehicles, such as low-speed vehicles, can perform well in both on-road and non-road niche markets, but are usually given credit only for the petroleum displacement within one niche. If a CARB proposal for requiring electric golf carts in non-attainment areas is factored in, an electric low-speed vehicle would replace not only a portion of internal combustion vehicle use, but gasoline golf cart use as well. The non-attainment areas in Table 1 were evaluated for potential electric golf cart and low-speed vehicle populations. The fuel displaced is evaluated in the non-road section.

Table 1. Golf Cart and Specialty Vehicles/Carts Population in Non-Attainment Counties[4]

Non-Attainment County	Year Required for Attainment	Golf Cart Population 2006 Estimate	Low-Speed Type Vehicle Population 2006 Estimate	Fuel Consumption (Gallons/Year)
Sacramento	2013	371	356	Diesel 25,387 Gasoline 229,234 LPG 2,613
San Diego	2009-2014	708	1,300	Diesel 93,085 Gasoline 484,960 LPG 9,582
San Joaquin	2013	240	236	Diesel 16,925 Gasoline 165,083 LPG 1,742
San Francisco	2007	101	142	Diesel 10,155 Gasoline 65,946 LPG 1,045
Imperial	2007	34	213	Diesel 15,232 Gasoline 34,549 LPG 1,568
Los Angeles	2021	2,159	1,585	Diesel 113,395 Gasoline 1,297,327 LPG 11,673
Ventura	2010	371	165	Diesel 11,847 Gasoline 214,871 LPG 1,220
Totals		3,984	3,997	Diesel 286,026 Gasoline 2,491,970 LPG 29,443

Two classes of low speed electric vehicles will be the focus of this analysis – Neighborhood Electric Vehicles (NEVs) and City Electric Vehicles (CEVs).

NEVs are defined by the National Highway Traffic Safety Administration as low speed vehicles. NEVs typically have a top speed of about 25 miles per hour. The NEV is designed for short-distance travel in confined residential and city areas. NEVs are approved for city streets with speed zones up to 45 miles per hour.

A CEV is designed for higher speeds of 35 to 40 miles per hour. The CEV can accommodate up to four passengers.

Previous studies found that these chemical-battery electric vehicles may have only a marginal impact on gasoline consumption when measured against a light-duty highway-capable gasoline vehicle. However, those studies assumed battery replacements expensive and short lived. Further, the "equivalent" gasoline vehicle had poor fuel economy in the low-speed operating conditions of the NEV or CEV.

Staff analysis made different assumptions. Both the NEV and CEV are in a niche use for which they are well designed and the gasoline vehicle is poorly suited. NEVs have great popularity in retirement communities, military bases, and commercial and government fleets. They have been used with great success for several years and have been virtually maintenance free with strong performance records. Gasoline vehicle efficiencies and performance drops significantly at the speeds of the NEV and CEV. NEVs and CEVs are highly maneuverable in tight conditions and produce no tailpipe emissions. Over 30,000 NEVs have been sold in the United States (U.S.) and Europe. For the 2005 model year, over 3,000 CEVs have been ordered in the U.S. and Europe.[5]

User studies have found the NEV is used as a daily replacement for more than two-thirds of the short-distance trips formerly taken with an internal combustion engine vehicle.[6] Even when the NEV trips may be on the golf course, the vehicle is a replacement for a gasoline-powered cart. NEVs are more likely to be carrying more than one person.

For 2005, four models of NEVs and two models of CEVs are listed for sale in California as ZEVs. The specifications are shown in Table 2.[7]

Table 2. California NEV and CEV Prices and Specifications

	NEV	CEV
Price	\$7,000 to \$9,000	\$15,500
Batteries	Six 12-volt, lead acid	Fourteen 12-volt, lead acid
Top Speed	25 mph	25 mph to over 35 mph
Range	30 miles per charge	50 miles per charge

The Massachusetts Division of Energy Resources accumulated more than 200,000 miles on a variety of fleet electric vehicles.[8] The U.S. military has also conducted extensive tests on electric vehicles over several years. The results for NEVs and small electric vehicles such as the Honda EV Plus and the Solectria Force (Geo Metro body) show long battery durability for these small vehicles.[9] Therefore, we assume the battery will last the life of the vehicle or 15 years.

The scenario for number of vehicles follows the CARB projections of ZEVs. The current population of California's low-speed vehicles is approximately 15,000. The scenario assumes the majority of the ZEV requirement will be met by PZEVs and Advanced Technology PZEVS (ATPZEVs) in the short-term and new zero-emission technologies from 2015 to 2025. However, low-speed vehicles will continue in popularity within their niche.

Incremental cost per vehicle ranges from $15,500 (CEV is purchased in addition to a conventional vehicle) to -$6,500 (NEV replaces a small conventional vehicle). The vehicle fuel economy for both types of vehicle is 5.8 miles/kWh. Electricity rates range from $0.10/kWh to $0.12/kWh.[10]

The conventional fuel vehicle's fuel economy is estimated based on low-speed, stop-and-go driving conditions.[11] Both conventional and low-speed electric vehicles have a 15-year life. The chemical batteries do not require replacement during the life of the vehicle. In the scenario where a conventional vehicle is replaced by the low-speed vehicle, there is a positive consumer savings, but total gasoline displacement remains small because of the limited number of vehicles and limited use (miles per year).[12]

Using these assumptions, Staff developed the values shown in Tables 3 and 4.

Table 3. Average Petroleum Reduction and Direct Benefits for NEVs and CEVs

	Average Conventional Fuel Displaced (Billions Gallons)	Average Consumer Savings 12%-5% Discount Rate	Average Change in Government Revenue 12%-5% Discount Rate
2005 to 2010	0.024	$3 to $4	($5) to ($7)
2005 to 2020	0.284	$8 to $19	($25) to ($55)
2005 to 2025	0.698	$16 to $50	($42) to ($114)

Table 4. Petroleum Reduction and Benefits for NGVs and CEVs

Alternative Fuel Option or Scenario	Displacement in 2025, Billion Gallon/Year Gasoline Equivalent	Reduction from Base Case Demand, Percent	Highest Cumulative Benefit or Change, Present Value, 2005-2025, 5% Discount Rate, Billion $2005				
			A	B	C	D	A+B+C+D
			Direct Non-Environmental Net Benefit	Change in Government Revenue	Direct Environmental Net Benefit	External Cost of Petroleum Dependency	Direct Net Benefit
NEVs and CEVs	0.1	0.48	1.11	(0.11)	0.06	0.03	1.09

Uncertainties

- Since niche market electric vehicles are driven by regulations requiring ZEVs, any change to the regulations will impact the number of vehicles produced.
- Incremental vehicle costs depend on vehicle production volumes and sales.

Endnotes

[1] CARB, Final Regulation Order, *The 2003 Amendments to the ZEV Regulations*, March 2004, http://www.arb.ca.gov/regact/zev2003/zev2003.htm.

[2] California Environmental Protection Agency, CARB, *California Exhaust Emission Standards and Test Procedures for 2005 and Subsequent Model Zero-Emission Vehicles, and 2001 and Subsequent Model Hybrid Electric Vehicles, in the Passenger Car, Light-Duty Truck and Medium-Duty Vehicle Classes* August 5, 1999.

[3] California Electric Transportation Coalition *Report on the Electric Vehicle Markets, Education, RD&D and the California Utilities' LEV Programs* Final Report FR-02-109 March 22, 2002.

[4] NONROAD2004 model runs conducted for specified non-attainment counties and year 2006, by equipment description and engine type.

[5] www.prnewswire.com/cgi-bin/stories.pl?ACCT=104&STORY=/www/story/06-20-2003/00019690.

[6] Green Car Institute, *Study of NEV User Behavior in California*, July 2003.

[7] www.driveclean.ca.gov/en/gv/vsearch/cleansearch_result_des.asp?vehicleid=163.

[8] Massachusetts Division of Energy Resources, *EV Progress Report: Summer 1998,* March 1998.

[9] Energy Efficiency and Renewable Energy, Federal Energy Management Program, *Federal Technology Alert* DOE Publication DOE/EE-0280.

[10] Electricity rates based on an average of 2004 to 2016 Energy Commission forecasts from IOU data. The lower rate ($0.10/kWhr) was adjusted down by $0.02 to reflect potential savings from off-peak charging rates.

[11] Bluewater Network, October 28, 2002, *Fuel Economy Falsehoods.*

[12] Numbers used in assumptions based on conservative values produced through surveys for the Electric Vehicle Consumer Awareness Program, prepared for DOE and the Energy Commission (April 2001) and PRNewswire, *DaimlerChrysler's GEM Neighborhood Electric Vehicle Sales in California Top 10,000 Mark*, June 20, 2004.

OPTION 2C - GRID-CONNECTED HYBRID ELECTRIC VEHICLES

Summary

Grid-connected hybrid electric vehicles (HEVs), also known as plug-in hybrids (PHEVs), are a viable option for reducing petroleum use. These vehicles are powered with both petroleum fuel and electricity from the grid. They can be designed with varying amounts of all-electric range, depending on the anticipated needs of drivers, policy goals, and economic factors.

The introduction of grid-connected HEVs would require little or nothing in the way of infrastructure improvements—a vehicle can be adequately charged on a nightly basis using existing 120 volt electrical outlets.[1] Maintenance of the vehicles would be similar to currently-available HEVs, which is in turn similar to conventional vehicles.

PHEVs use significantly less gasoline than conventional vehicles. If 10 percent of the cars sold in California are replaced with PHEVs, approximately 525 to 725 million gallons of gasoline could be saved each year, depending on the all-electric range of the vehicles used.[2]

As with any technology that reduces petroleum fuel use, PHEVs would result in a loss of government revenue in the form of reduced collection of fuel excise taxes.

Because of the additional, more expensive materials used in making PHEVs, this option also comes with an incremental cost to the consumer. A mid-sized PHEV would cost approximately $4,200 to $8,300 more than its conventional counterpart, again depending on the all-electric range built into the vehicle.[3] Based on this incremental vehicle cost and the fuel savings predicted, there could be a net additional cost to consumers for using these vehicles.

Description

Grid-connected HEVs use much of the same technology deployed in current HEVs, but can also draw electricity from the grid to recharge their batteries. This gives them the ability to travel a limited distance using electricity as the primary “fuel”; when this all-electric range is exhausted, normal (petroleum-fueled) HEV operation resumes. Because 63 percent of consumers’ daily trips are less than 60 miles in length,[4] a significant portion of grid-connected HEV use could be in all-electric mode.

Two types of grid-connected HEVs are considered:

- PHEV 20, an HEV with a 20-mile all-electric range
- PHEV 60, an HEV with a 60-mile all-electric range

Grid-connected HEVs are essentially a combination of two existing technologies: gasoline-electric hybrid vehicles and battery electric vehicles. There will likely be only minor technical difficulties involved in developing PHEVs, though there will be an incremental cost compared to a conventional gasoline vehicle. Both gasoline and electricity are readily available for use in grid-connected HEVs.

The PHEVs considered in this analysis have performance characteristics similar to conventional vehicles of the same size and function. Also, the vehicles would not have to be fueled with gasoline as often. In focus groups, consumers have shown a preference for charging at home over fueling at a gas station.[5]

Key Input Parameters and Values

To perform this analysis, staff used a spreadsheet model of the state's light-duty vehicle population called the FUTURES Model.[6] Conventionally-fueled mid-sized cars in the model were compared to the Electric Power Research Institute's predicted characteristics of mid-sized PHEV 20s and PHEV 60s. Resulting fuel savings and incremental costs were then extrapolated for all vehicles in California. The staff assumed the state's greenhouse gas (GHG) emission standard is in effect.

For this analysis, vehicle deployment was scaled to assume that 10 percent of vehicles sold by 2022 will be grid-connected HEVs.

High and low potential gasoline fuel costs were considered. Fuel costs used in the analysis were:

1. For the maximum cost: an average of "high" fuel costs over the years 2004-2025 from the FUTURES Model.

2. For the minimum cost: an average of "low" fuel costs over the years 2004-2025 from the FUTURES Model.

High and low potential electricity fuel costs were also considered. Electricity costs used were:

1. For the maximum cost: an average of electricity rates projected by the Energy Commission over the years 2004-2016.

2. For the minimum cost: an average of electricity rates projected by the Energy Commission over the years 2004-2016, multiplied by 0.6 to account

for the 40 percent discount offered to electric vehicle owners for off-peak EV charging.

Results

As shown in Table 1, replacing 10 percent of California's cars with PHEV 60s or PHEV 20s could save 4.9 percent or 3.7 percent of our base-case gasoline demand, respectively. While a mid-sized car with this technology would cost about $4,000 to $8,000 more than a comparable conventional car, some of this cost would be recovered by the reduced fuel use.

Over the next 20 years, consumers buying PHEV 20s would recover much, though not necessarily all, of the incremental cost of their vehicles. Those purchasing PHEV 60s would not achieve the same economic benefit, in the absence of additional factors.

One such possible factor, not quantified here, is the ability to provide regulation services for the power grid. In short, this would mean using the vehicles' batteries to supply small amounts of power to the grid, in order to keep the grid's voltage and frequency consistent. If this technology were developed and adopted, it could potentially improve plug-in hybrids' economics for consumers and government alike.

Table 1. Petroleum Reduction and Benefits for Grid-Connected HEVs

Alternative Fuel Option or Scenario	Displacement in 2025, Billion Gallon Gasoline Equivalent	Reduction from Base Case Demand, Percent	Highest Cumulative Benefit or Change, Present Value, 2005-2025, 5% Discount Rate, Billion $2005				
			A	B	C	D	A+B+C+D
			Direct Non-Environmental Benefit	Change in Government Revenue	Direct Environmental Net Benefit	External Cost of Petroleum Dependency	Direct Net Benefit
PHEV 20	0.55	2.64	0.62	(0.11)	0.13	0.08	0.72
PHEV 60	0.73	3.5	(0.40)	(0.36)	0.4	0.21	(0.16)

Key Drivers and Uncertainties

Because the PHEV is compared to a conventional gasoline vehicle with GHG control technology, the amount of fuel reduction potential for the PHEV is much lower than compared to today's vehicle. California's GHG standard results in much higher fuel economy for the conventional vehicles this option is being compared to, making the option comparatively more expensive and less beneficial in terms of petroleum displacement. If the GHG standard is not in effect, the grid-connected hybrid vehicles would show a larger benefit in both areas.

Batteries for PHEVs are expensive and account for much of the incremental costs associated with this option. If the price of batteries decreases, due to a technological advance or other reason, there would be a corresponding decrease in the incremental vehicle cost.

Gasoline price also has a significant effect on the economics of these vehicles. As the price of gasoline rises, a decision to purchase grid-connected HEVs become more economically viable.

Endnotes

[1] Electric Power Research Institute, *Comparing the Benefits and Impacts of Hybrid Electric Vehicle Options.*

[2] Values for petroleum reduction are calculated from EPRI's grid-connected hybrid vehicle fuel efficiency figures, and fuel use and fuel economy predictions found in the following document: California Energy Commission (Energy Commission), *Forecasts of California Transportation Energy Demand 2005-2025 in Support of the 2005 Integrated Energy Policy Report*.

[3] Electric Power Research Institute, *Comparing the Benefits and Impacts of Hybrid Electric Vehicle Options*. Adjusted for inflation, and compared to the base price of more-expensive, more fuel-efficient cars of the same type required by Pavley regulations.

[4] Electric Power Research Institute, *Comparing the Benefits and Impacts of Hybrid Electric Vehicle Options.*

[5] Ibid.

[6] Derived from data contained in: Energy Commission, *Forecasts of California Transportation Energy Demand 2005-2025 in Support of the 2005 Integrated Energy Policy Report.*

OPTION 2D - CNG FOR LIGHT-DUTY VEHICLES

Summary

In this option the staff evaluates the cost-benefit potential of compressed natural gas (CNG) light-duty vehicles in comparison to average gasoline vehicles.

The National Energy Policy Act of 1990 requires certain energy providers and government fleets to purchase alternative fuel vehicles (AFV). When buying new vehicles, these fleets must currently buy 75 percent of them from AFV offerings. CNG vehicles would satisfy the federal AFV requirement.

Status

CNG vehicles are commercially available in limited quantities and vehicle models. While over 400 models of gasoline vehicles are offered for sale in model year 2005, only five models of CNG vehicles are available. Table 1 provides examples of light-duty CNG vehicles that are currently available or have recently been commercially available.[1] Over the last five years approximately 4,000 light-duty CNG vehicles were sold annually to fleet operators and private consumers in California.[2]

A number of market barriers continue to limit the penetration of CNG vehicles in California's population of light-duty vehicles. A CNG vehicle typically has reduced driving range compared to a gasoline vehicle. The relatively sparse availability of CNG refueling infrastructure accessible to the public, compared to petroleum fuels, further discourages private vehicle ownership.

To overcome the limited public fueling infrastructure, Honda recently began offering an optional home refueling system for their CNG vehicles for approximately $2,000.[3] Alternatively, the system may be leased by the homeowner from the automobile dealership at a monthly cost estimated to be in the range of $34 to $79, depending on the availability of state and local incentives. For homes with existing natural gas delivery, the refueling system has an installation cost estimated to be in the range of $500 to $1,500.[4]

Additionally, relatively low vehicle sales result in higher unit costs for CNG vehicles compared to gasoline vehicles. Fuel tanks capable of high pressure gas storage add significantly to incremental vehicle cost for CNG. These factors also reduce the number of CNG vehicle models offered by manufacturers.

Table 1. Recent Models of Light-Duty CNG Vehicles

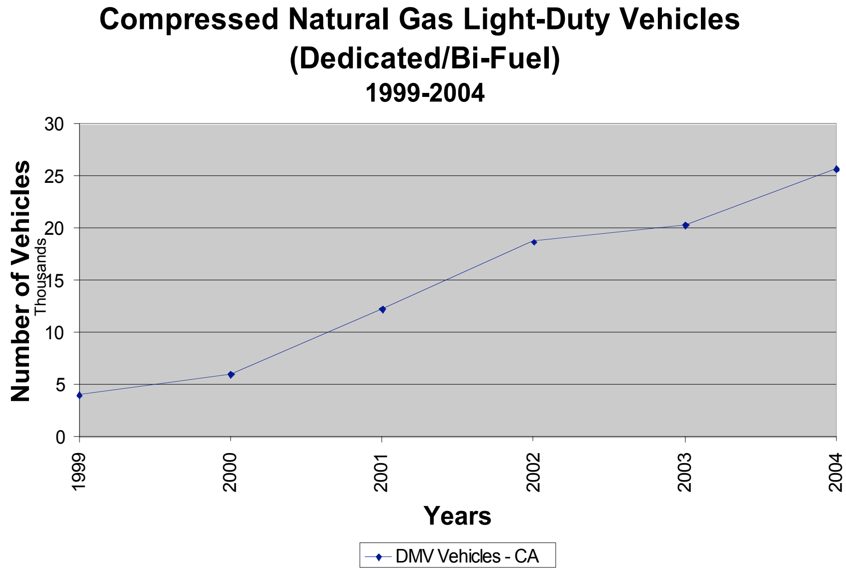
Maker	CNG Vehicle	Engine Displacement	Type of Natural Gas Engine
Current Light-Duty Vehicles Available			
GM	♦ C2500 Silverado 2WD ♦ K2500 HD Silverado 4WD ♦ C2500 HD Sierra 2WD ♦ K2500 HD Sierra 4WD	6.0 Liter V8	Dedicated CNG
Honda	♦ Civic GX	1.7 Liter L4	Dedicated CNG
Discontinued Light-Duty Vehicles			
Acura	♦ MDX SUV	3.5 Liter V6	Dedicated CNG
Daimler-Chrysler	♦ R-am Van / Wagon 2500 ♦ Ram Van / Wagon 3500	5.2 Liter V8	Dedicated CNG
Ford	♦ Crown Victoria Sedan	4.6 Liter V8	Dedicated CNG
Ford	♦ F-Series Light Duty Pickup	5.4 Liter V8	Bi-Fuel CNG / Gasoline
Ford	♦ Econoline E-450 Cut Away ♦ Econoline Van / Wagon ♦ F-Series Light Duty Pickup	5.4 Liter V8	Dedicated CNG
GM	♦ Express / Savana	5.7 Liter V8	Bi-Fuel CNG / Gasoline
GM	♦ Chevy Cavalier Sedan	2.2 Liter L4	Bi-Fuel CNG / Gasoline
Toyota	♦ Camry Sedan	2.2 Liter L4	Dedicated CNG

Assumptions

The staff assumed that a home refueling device is available and manufacturers increase production of CNG vehicle models, compared to our base case. Consistent with other options, CNG light-duty vehicles displace gasoline light-duty vehicles that average 22.7 miles per gallon.[5]

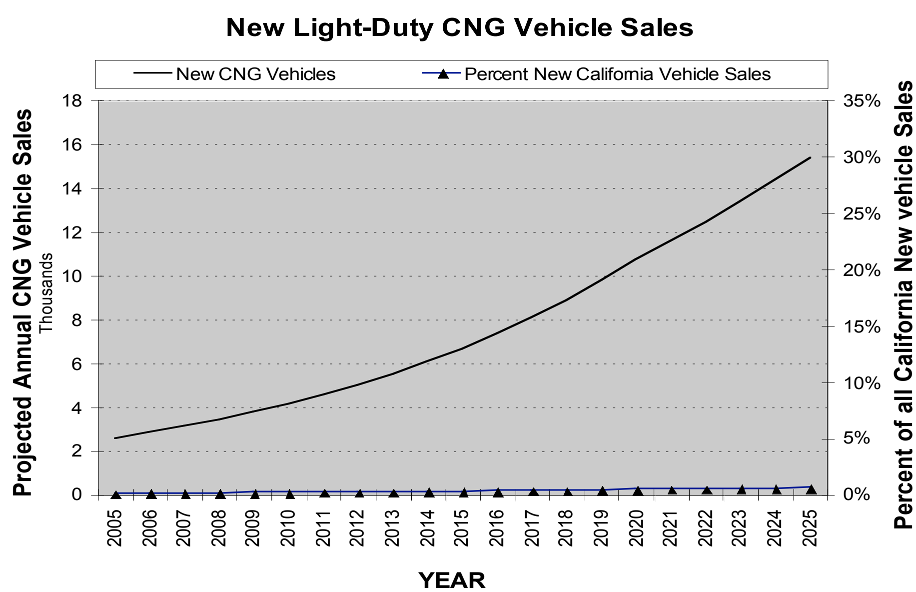
Light-duty CNG vehicles appear to be market-ready at this time. The staff believes CNG vehicles will penetrate the gasoline vehicle market if fuel and other operational savings offset their more costly vehicle purchase prices. To date, this has not been the case and sales have been limited. Over the past five years, annual light-duty CNG vehicles sales have increased approximately 50 percent each year. Chart 1 illustrates the annual sales rate and the cumulative CNG vehicle population over the past five years.[6]

Chart 1



However, due to the discontinuation of their CNG vehicle lines by various vehicle manufacturers, the staff assumes a 10 percent annual increase in light-duty CNG vehicles sales through 2025 (Chart 2). This rate of increase is dependent on many variables such as the price and availability of natural gas fuel and future light-duty CNG offerings from vehicle manufacturers.

Chart 2



The staff assumed that incremental costs of light-duty CNG vehicles are reduced from today's $4,500 to $6,025 per vehicle to a lower range due to economies of scale.[7] Staff assumed average incremental costs of $2,500 to $5,000 per vehicle. In a full market driven scenario, where significant numbers of CNG vehicle sales occur, the incremental costs would be zero. The incremental cost includes on-board storage tanks that are estimated to cost $1,000 to $1,500.

Because of the limited range associated with CNG vehicles, the staff assumed the need for a home refueling unit (previously described). This unit requires 800 watts of electrical power and will deliver natural gas at a fill rate of 0.42 gasoline gallon equivalent per hour.[8] The Civic GX has a fuel capacity of eight gallons gasoline equivalent (at a pressure of 3,600 pounds per square inch, gauge).[9]

Petroleum Reduction

Based upon the 10 percent CNG light-duty vehicle penetration rate assumed for the fuel substitution options, the amount of gasoline reduction produced by this option is shown in Table 2a and Table 2b. The California Air Resources Board (CARB) adopted a greenhouse gas (GHG) emissions standard for light-duty vehicles [AB 1493 (Pavley), Chapter 200, Statutes of 2002]. The GHG emissions standard requires reductions of GHG equivalent emissions beginning in 2009. The standard is currently in litigation. Scenarios were performed with and without the CARB GHG emissions standard in place. Results for all light-duty CNG vehicles available for model year 2005 (GMC Truck/Van, Honda Civic) are shown in Table 2a. Results for the CHG Honda Civic GX are shown separately in Table 2b.

Table 2a. Average Petroleum Reduction and Direct Non-Environmental Benefits for CNG Light-Duty Vehicles

Assumption of a 10% Annual CNG Light-Duty Vehicle Penetration	Average Conventional Fuel Displaced (Millions Gallons)	Average Consumer Savings Discount Rate (Million $)		Average Change in Government Revenue Discount Rate (Million $)	
		12%	5%	12%	5%
2005 to 2010					
With GHG Standard					
• Low Fuel Price	63.19	($46.97)	($70.06)	($4.55)	($6.78)
• Very High Fuel Price	63.19	($46.97)	($70.06)	($4.55)	($6.78)
Without GHG Standard					
• Low Fuel Price	63.19	($46.97)	($70.06)	($4.55)	($6.78)
• Very High Fuel Price	63.19	($46.97	($70.06)	($4.55)	($6.78)
2005 to 2020					
With GHG Standard					
• Low Fuel Price	418.94	($154.08)	($329.02)	($15.26)	($32.77)
• Very High Fuel Price	418.94	($154.08)	($329.02)	($15.26)	($32.77)
Without GHG Standard					
• Low Fuel Price	418.94	($154.08)	($329.02)	($15.26)	($32.77)
• Very High Fuel Price	418.94	($154.08)	($329.02)	($15.26)	($32.77)
2005 to 2025					
With GHG Standard					
• Low Fuel Price	770.25	($200.39)	($508.66)	($19.97)	($51.06)
• Very High Fuel Price	770.25	($200.39)	($508.66)	($19.97)	($51.06)
Without GHG Standard					
• Low Fuel Price	770.25	($200.39)	($508.66)	($19.97)	($51.06)
• Very High Fuel Price	770.25	($200.39)	($508.66)	($19.97)	($51.06)

Table 2b. Average Petroleum Reduction and Direct Non-Environmental Benefits for Honda Civic GX CNG Vehicle

Assumption of a 10% Annual CNG Light-Duty Vehicle Penetration	Average Conventional Fuel Displaced (Millions Gallons)	Average Consumer Savings Discount Rate (Million $) 12%	5%	Average Change in Government Revenue Discount Rate (Million $) 12%	5%
2005 to 2010					
With GHG Standard					
• Low Fuel Price	30.23	($43.01)	($64.01)	($2.59)	($3.85)
• Very High Fuel Price	30.23	($22.88)	($34.05)	($2.59)	($3.85)
Without GHG Standard					
• Low Fuel Price	30.23	($43.01)	($61.54)	($2.59)	($3.85)
• Very High Fuel Price	30.23	($22.88)	($32.75)	($2.59)	($3.85)
2005 to 2020					
With GHG Standard					
• Low Fuel Price	180.96	($128.06)	($267.87)	($8.00)	($16.91)
• Very High Fuel Price	180.96	($68.29)	($142.94)	($8.00)	($16.91)
Without GHG					
• Low Fuel Price	180.96	($128.06)	($267.87)	($8.00)	($16.91)
• Very High Fuel Price	180.96	($68.29)	($142.94)	($8.00)	($16.91)
2005 to 2025					
With GHG Standard					
• Low Fuel Price	324.60	($163.09)	($403.76)	($10.28)	($25.75)
• Very High Fuel Price	324.60	($87.02)	($215.60)	($10.28)	($25.75)
Without GHG Standard					
• Low Fuel Price	324.60	($163.09)	($403.76)	($10.28)	($25.75)
• Very High Fuel Price	324.60	($87.02)	($215.60)	($10.28)	($25.75)

Because the projected non-environmental benefit is negative, consumers choosing a CNG vehicle must find or accept additional benefits to make such a purchase worthwhile. When environmental net benefits and the external cost of petroleum dependency are included in the overall net benefit value, the final cost-benefit result is more competitive with the comparison gasoline vehicle. Nevertheless, the final result implies that an implementation strategy that offsets the negative consumer benefit would have to be developed if the estimated gasoline reduction is to be achieved. The strategy would have to provide additional positive consumer benefits, sufficient in magnitude to at least make the direct non-environmental benefit neutral. Table 3a and Table 3b numerate the direct benefits from 2005 model year CNG Light-Duty Vehicles (GMC truck/van and Honda Civic GX) combined and Honda Civic GX separately.

Table 3a. Petroleum Reduction and Benefits for CNG Light-Duty Vehicles

Petroleum Reduction and Benefits for Selected Alternative Fuel Scenarios							
Alternative Fuel Option or Scenario	Displacement in 2025, Billion Gallon Gasoline Equivalent	Reduction from Base Case Demand, Percent	Highest Cumulative Benefit or Change, Present Value, 2005-2025, 5% Discount Rate, Billion $2005				
			A	B	C	D	A+B+C+D
			Direct Non-Environmental Benefit	Change in Government Revenue	Direct Environmental Net Benefit	External Cost of Petroleum Dependency	Direct Net Benefit
2005 Model Year CNG Light-Duty Vehicles							
2025 Low Petroleum Fuel Price w/GHG Standard	.08262	0.39	($623.25)	($51.06)	(0.007)	0.016	(674.36)
2025 Highest Petroleum Fuel Price w/GHG Standard	.08262	.056	($394.08)	$51.06)	(0.001)	0.016	(445.13)
2005 Honda GX CNG Vehicle:							
2025 Low Petroleum Fuel Price w/GHG Standard	.03378	0.16	($403.76)	($25.75)	0.003	0.015	(429.49)
2025 Highest Petroleum Fuel Price w/GHG Standard	.03378	0.23	($215.60)	($25.75)	0.003	0.015	(241.37)

Table 3b. Petroleum Reduction and Benefits for CNG Light-Duty Vehicles

Petroleum Reduction and Benefits for Selected Alternative Fuel Scenarios							
Alternative Fuel Option or Scenario	Displacement in 2025, Billion Gallon Gasoline Equivalent	Reduction from Base Case Demand, Percent	Highest Cumulative Benefit or Change, Present Value, 2005-2025, 12% Discount Rate, Billion $2005				
			A	B	C	D	A+B+C+D
			Direct Non-Environmental Benefit	Change in Government Revenue	Direct Environmental Net Benefit	External Cost of Petroleum Dependency	Direct Net Benefit
2005 Model Year CNG Light-Duty Vehicles							
2025 Low Petroleum Fuel Price w/GHG Standard	.08262	0.39	($245.68)	($19.97)	(0.007)	0.016	(265.64)
2025 Highest Petroleum Fuel Price w/GHG Standard	.08262	.056	($155.09)	$19.95)	(0.007)	0.016	(175.03)
2005 Honda GX CNG Vehicle:							
2025 Low Petroleum Fuel Price w/GHG Standard	.03378	0.16	($163.09)	($10.28)	0.003	0.015	(173.35)
2025 Highest Petroleum Fuel Price w/GHG Standard	.03378	0.23	($87.02)	($10.28)	0.003	0.015	(97.28)

Key Drivers and Uncertainties

Below are the key uncertainties in this analysis:

- The number of vehicles that consumers would purchase given that CNG vehicles have a reduced range and a higher incremental cost compared to conventional gasoline powered vehicles.

- To what extent consumers would consider the benefits of a home-refueling device due to the additional cost added to the already higher incremental cost of the vehicle. The home refueling device is less of an issue for the

GMC trucks and vans since their use appears to be in a fleet application where central fueling would occur.

- The cost of large quantities of CNG stations necessary to support a significant increase of natural gas vehicles.

- Manufacturer interest in producing additional numbers of CNG vehicles.

Endnotes

[1] *Fuel Economy Guide 2000-2005* www.fueleconomy.gov, (April 10, 2005).

[2] DMV Vehicle Information, 8/26/04 Cenzer gaseous vehicle.

[3] *Honda and Fuel Maker Strengthen Alliance to Make Natural Gas Vehicle Home Refueling a Reality*, 2004, http://automobiles.honda.com/info/news/article.asp?ArticleID=2004090950646, (April 10 2005).

[4]Dee-Ann Durbin, Associated Press *Honda offers retail natural gas vehicle* Sacramento Bee, April 21, 2005; http://www.sacbee.com/24hour/autos/story/2332079p-10554243c.html

[5] Average fuel economy of the following (*Fuel Economy Guide 2004-2005*) gasoline vehicles that have a CNG counterpart:

`05 Honda Civic HX	City: 35 MPG	Hwy: 40 MPG	Average=37.09
`05 Chevy Silverado/GMC Sierra 2500	City: 16 MPG	Hwy: 20 MPG	Average=17.58
`05 Chevy Express/GMC Savana Van	City: 15 MPG	Hwy: 19 MPG	Average=16.57
`04 Crown Victoria	City: 17 MPG	Hwy: 25 MPG	Average=19.86
			Overall average=22.77

The EPA *Fuel Economy Guide* assumes driving at 55 percent city and 45 percent highway.

[6] DMV Vehicle Information 8/26/04 *Cenzer Gaseous Vehicle*.

[7] Economies of scale occur within a firm when mass producing a good results in lower average cost *(internal economies of scale)* or within an industry *(external economies of scale)* as a result of improved logistics with skilled labor, parts, services, and transportation.

[8] Fuelmaker Corportation, *Phill-Fuel Your Car at Home,* April 26, 2005; http://www.myphill.com/faq.htm.

[9]American Honda Motor Company, 2005 Civic GX NGV, April 26, 2005; http://automobiles.honda.com/models/specifications_full_specs.asp?ModelName=Civic+GX&Category=3.

OPTION 2E - LIQUID PETROLEUM GAS

Summary

Liquid Petroleum Gas (LPG), also known as “propane” in reference to its primary constituent, has long been used as an alternative fuel in the transportation sector. Typically, commercial offerings of LPG-fueled light-duty cars and light trucks have been limited to bi-fuel vehicles, which can run on either LPG or gasoline using the same engine but separate fuel systems. Bi-fuel propane engines are convenient to the fleet operator by allowing the use of either gasoline or LPG depending on fuel availability.

Due to its dual-fuel nature, the LPG bi-fuel vehicle is not optimized to run on either fuel. Thus, the bi-fuel vehicle suffers from decreased fuel efficiency performance compared to that of a dedicated LPG vehicle or a conventional gasoline vehicle.[1] For example, a 2004 Ford F-150 Truck (bi-fuel) experiences a 1.34 miles per gallon (mpg) fuel economy loss when running on gasoline compared to the same vehicle powered by a gasoline only system.[2]

As of 2005 no new LPG light-duty cars and trucks are being produced commercially. However, a limited number of California Air Resources Board (CARB) certified LPG retrofit systems are approved and may be available for 1995 and older model year light-duty vehicles[3]. These kits range in price from $2,500 to $5,000. The discontinuation of commercial production of light-duty LPG vehicles and the limitations on retrofits continue to be barriers for propane as a major light-duty vehicle transportation fuel. Also, the relative high cost of certifying new retrofit kits for use in California has discouraged companies from producing such kits.[4]

Similarly, since LPG vehicle refueling infrastructure is limited in California, it is assumed that a significant number of LPG bi-fuel vehicles are operating on gasoline. The number of these vehicles on the road in California is difficult to quantify since no new vehicles are in commercial production and the vehicle population is decreasing with age. Due to these limitations, it is unlikely that any significant California petroleum reduction will result from LPG transportation technology in the light-duty vehicle sector in the foreseeable future.

Petroleum Reduction

Near-term petroleum reduction could result if existing niche fleets of LPG bi-fuel light-duty vehicles are provided with more convenient access to LPG and their usage rate is increased. For example, the California Department of Transportation (Caltrans) operates a fleet of over 1,300 Ford F-150 bi-fuel LPG pickups running solely on gasoline.[5]

Caltrans has joined with the Department of General Services to significantly increase the use of propane in those vehicles.[6] Under the California Energy Commission (Energy Commission's) Alternative Fuel Infrastructure Program, new propane stations are being installed to help Caltrans with its LPG fueling options.[7] These vehicles would potentially displace over 1,227,960 gasoline gallons annually.

- Caltrans bi-fuel fleet: 1,300
- Vehicle miles per year: 15,000
- mpg (bi-fueled/gasoline): 15.88
- Gasoline gallons displaced yearly: 1.23 million

It could be assumed that as other bi-fueled LPG vehicle fleets start utilizing LPG similar volumes of petroleum reduction would result.

Description

Due to the discontinuation of commercially available light-duty LPG vehicles, it is not possible to evaluate future petroleum displacement from this vehicle technology in the light-duty vehicle sector. Ongoing monitoring is needed regarding commercialization of future light-duty propane-fueled vehicle and engine platforms. Strategic infrastructure support should continue, focused on fleets that have current bi-fueled vehicles.

LPG may play a larger role in the medium-duty and heavy-duty vehicle sectors, due to the current availability of original equipment manufacturer vehicles and vehicles retrofit kits. Additional information on medium-duty and heavy-duty LPG potential is addressed in the *2005 Alternative Fuels Commercialization Report*.[8]

Key Input Parameters and Values

N/A

Results

N/A

Key Drivers and Uncertainties

N/A

Endnotes

[1] Energy Commission *California Clean Fuels Market Assessment, 2003,* pg 30.

[2] 2004 F-150 Truck (using gasoline) Bi-fuel version 15.88 mpg vs percent, gasoline version 17.22 mpg, net fuel economy savings -1.34, 2004 EPA *Fuel Economy Guide*.

[3] http://www.arb.ca.gov/msprog/aftermkt/altfuelsys.doc, rcastro@arb.ca.gov March 17, 2005.

[4] William Platz, *Clean Fuel USA*, presentation to the Energy Commission, October 12, 2004.

[5] Estimated numbers supported by California Department of Motor Vehicle data, Gary Occhiuzzo, Energy Commission.

[6] Energy Commission, Volume II of draft consultant's report on State Fleet Fuel Efficiency (SB 1170), prepared by TIAX, January 2003.

[7] Details about these propane stations are described in *California Alternative Fuels Infrastructure Program Evaluation*, a draft Consultant's Report by TIAX for the Energy Commission.

[8] Energy Commission *2005 Alternative Fuels Commercialization Report* LPG/Propane Section, CEC 600-2005-020.

OPTION 2F – ETHANOL BLEND (E-10)

Summary

This paper examines the use of ethanol as a blending component in California gasoline for projected gasoline demand through 2025. *Business–as-Usual* (BAU) and *Aggressive* ethanol blending scenarios are analyzed and petroleum displacement results reported for three gasoline price projections.

Under the BAU base case scenario, annual ethanol demand is about 900 million gallons per year, providing petroleum displacement of about 5 percent of projected gasoline demand by 2025. The *Aggressive Scenario* assumes 10 percent ethanol blending with a resultant demand of 1.4 billion gallons per year and 9 percent petroleum displacement. This is about 40 percent of California's 2020 alternative fuel use goal, and about 30 percent of the 2030 goal, by 2025.[1]

In the BAU scenario, California blends ethanol under current state and federal regulations consistent with base case on-road gasoline demand projections under California's greenhouse gas (GHG) standard.[2] The *Aggressive Scenario* assumes that 10 percent ethanol blending, as opposed to the current 5.7 percent, becomes standard practice and remains at that level through 2025.

Background and Description

The following subsections focus on the status and maturity of ethanol use as a blending component in California gasoline. Subsequent analyses and projections of ethanol demand towards achieving the *2003 Integrated Energy Policy Report* recommended alternative fuel use goals, rely heavily on recent ethanol blending practices in California in a post Methyl Tertiary Butyl Ether (MTBE) world.

MTBE Phase-Out

California reformulated gasoline with MTBE (CaRFG2) was found to be unsuitable for use in California due to environmental risks associated with groundwater contamination from leaking underground gasoline storage tanks. Governor Gray Davis ordered the removal of MTBE from California gasoline through Executive Order D-5-99, issued on March 25, 1999. With the complete phase-out of MTBE by December 31, 2003, CaRFG3 became the only oxygen-containing gasoline available to California consumers and businesses.

At its peak use, 104,000 barrels per day of MTBE (nearly 4.4 million gallons per day), on average, were blended to make CaRFG2. This volume represents

10.8 percent of the CaRFG2 produced by California refiners for the third quarter of 2000.[3] ConocoPhillips was the first refiner to eliminate MTBE in its gasoline in 2002, more than a year ahead of the phase-out deadline. Companies completing the phase-out process in the fourth quarter of 2003 included Tesoro and ChevronTexaco at their northern California refineries, and two Valero refineries in northern and southern California. In 2003, fourth quarter daily average MTBE use plummeted to just 1.1 percent of CaRFG, or 11,500 barrels (483,000 gallons) per day prior to the December 31, 2003 deadline.[4]

Federal Clean Air Act and National Ambient Air Quality Standard

Under the Federal Clean Air Act (CAA), California and other states are subject to federal reformulated gasoline requirements in non-attainment regions of the country. Since several regions within California do not comply with the 8-hour National Ambient Air Quality Standard (NAAQS) for ozone, California's gasoline must contain 2 percent (weight) oxygen year-round until these regions come into, and can maintain, compliance with the standard.[5]

In 2004, 80 percent of California gasoline became subject to the federal requirements as a result of the re-designation of San Joaquin Valley as a "severe" ozone non-attainment region. The San Joaquin Valley joined the Los Angeles area South Coast Air Basin (SCAB) as another geographical region subject to the federal requirement. The SCAB has until 2021 to come into attainment for the NAAQS for ozone, given its higher "extreme" designation, while the San Joaquin Valley has until 2013, under its "severe" designation.

Assuming that the San Joaquin Valley comes into compliance in 2013, about 60 percent of California's gasoline would then be required to contain oxygen based on gasoline demand in the SCAB through 2021. However, California's 1999 request for waiver from the oxygen provisions of the CAA may ultimately be granted by the U.S. Environmental Protection Agency (EPA) or, alternatively, proposed federal energy legislation may replace the oxygen requirement with a Renewable Fuels Standard (RFS). Thus, it is not clear that federal requirements for oxygen in gasoline can be counted on to assure continued use of ethanol through the year 2025 in California.[6] On the other hand, limited segregation capability of the distribution infrastructure, need for adequate levels of octane in gasoline, combined with long term contracts for ethanol delivery by the railroads to refiners, currently limits the desire and ability of refiners to produce and market non-oxygenated gasoline on any significant scale in the near term.[7]

Gasoline and Ethanol Demand in 2004

California gasoline consumption in 2004 was 15.9 billion gallons, over 97 percent of which was California Blendstock for Oxygenate Blending (CARBOB) blended with

5.7 percent ethanol to create CaRFG3.[8] About 2.5 percent of the gasoline consumed was non-oxygenated CaRFG produced and distributed in the San Francisco Bay Area.[9]

Ethanol use in 2004 is estimated at 900 million gallons, up from 623 million gallons in 2003 and 112 million gallons in 2002.[10] While 20 percent of California gasoline could have been produced and sold without an oxygenate in 2004, nearly all California refiners chose to produce a CARBOB suitable for ethanol blending.[11]

The BAU Scenario assumes that refiners will retain the current aggregated industry CaRFG3 production trends to meet contracted gasoline volume commitments, CARBOB/CaRFG trading agreements with partners and federal oxygen requirements simultaneously, blending 90 percent of CaRFG with ethanol through 2025. The other 10 percent of the gasoline is assumed to be non-oxygenated fuel in non-federal gasoline regions.[12] This 90/10 percent split is assumed to remain at the same level due to distribution and infrastructure constraints.

Petroleum Infrastructure Improvement Trends

Beginning in 2002, about 70 petroleum products terminals were upgraded with additional storage capacity, ethanol receiving capability, and modifications to loading racks to facilitate CaRFG3 blending and truck loading for delivery to retail outlets. These upgrades cost the California refiners and terminal operators about $700 million and involved modest upgrading at some California refineries.[13] These investments complemented the nearly $3.5 to 4 billion in major refinery upgrades that occurred in 1995 through1996 to comply with the California Air Resources Board's (CARB's) Phase II reformulated gasoline regulations.

The rail system delivering ethanol to California from the Midwest was upgraded in 2003 by directing rail deliveries to major receiving terminals in the state. In October 2003, the Burlington Northern Santa Fe (BNSF) railroad company created dedicated 95-car unit trains that deliver 2.9 million gallons of ethanol to the Lomita Rail Terminal in Watson on a continuous basis. Four trains deliver ethanol sequentially every 3.5 days, returning to a Midwest gathering location.[14] Union Pacific Railroad company instituted a combination of single car, multiple car, and unit trains providing a flexible method of moving ethanol from a central location in Nebraska to northern and southern California storage yards.[15] Staff has assumed that such improvements will continue and keep pace with any level of increased ethanol demand in the future, including 10 percent ethanol blending in CaRFG3 through 2025.[16]

In 2004, about 10 percent of the ethanol used in CaRFG3 was delivered by ship from Caribbean Basin Initiative (CBI) countries as well as Brazil. Under the terms of the CBI, up to 7 percent of the previous year's United States (U.S.) domestic ethanol production may be imported into the U.S. tariff free. Even though southern California port maritime traffic is projected to become more congested in coming years, ethanol deliveries by ship are relatively infrequent compared to daily traffic in and out of the ports. Staff expects that ethanol deliveries by ship will continue at 10 percent of demand (or less) under any future ethanol blending practice in California.

U.S. Ethanol Supply and Price Trends

Ethanol Supply

By early 2006, 17 new ethanol production facilities and two expansions at existing Midwest ethanol plants will add about 700 million gallons of new capacity, bringing domestic production capacity up to 4.4 billion gallons per year.[17] The 2004 through 2005 capacity growth trends of just under 20 percent per year are consistent with California Energy Commission (Energy Commission) surveys of U.S. ethanol production capacity.[18] In 2004, 11 new plants with 409 million gallons of capacity started production. There were four plants with rated capacity of 45 million gallons per year; three in Iowa and one in South Dakota. On average, plant rated capacity is 40 million gallons per year[19], with each producing enough ethanol to blend with about 700 million gallons of CaRFG3 (at 5.7 percent ethanol concentration), supplying two weeks of CaRFG3 demand at 2004 gasoline consumption rates. Thus, California ethanol demand could be supplied by the equivalent of 20 Midwest ethanol plants representing about one-quarter of all U.S. plants in operation today.

This ethanol production capacity growth trend in the Midwest is enough to support an increase in ethanol use to 7.7 to 10 percent in California, as well as, increased discretionary ethanol blending in other U.S. markets.[20] The 10 percent blending, under early implementation of an aggressive 2010 ethanol blending scenario, would increase California's ethanol demand to about 1.5 billion gallons a year in 2005 through 2006, assuming that the current practice of supplying 97 percent of the state with ethanol blended CaRFG3 is retained over the next two years.[21] This new demand of about 630 million gallons would absorb most of the 700 million gallons of capacity scheduled to come on-line in 2005 and early 2006. Assuming these plants achieve nameplate capacity[22] and the price of ethanol (net tax incentive) remains favorable to CARBOB and other blending components, California could attract as much new ethanol supply as it requires in the near future.[23]

Ethanol Price Trends

While ethanol prices have fluctuated over the years, refiners and marketers who buy and blend ethanol in gasoline receive an incentive in the form of partial forgiveness of the federal fuel excise tax applicable to gasoline currently amounting to 51 cents per gallon of ethanol blended. Enacted in 1978, the federal incentive had the effect of roughly equalizing the cost of ethanol to refinery gasoline blending components, thus making ethanol an economic blending component in gasoline. Traditionally, ethanol has been sold on a long-term cash contract basis.[24] In 2005, the

Chicago Board of Trade and the Chicago Mercantile Exchange offered corn-based ethanol futures contracts as an alternative means for both producers and buyers to hedge against ethanol price fluctuations.

With a projected 700 million gallons of additional ethanol production available by early 2006, the prospects for competitively-priced ethanol to sustain existing and emerging blending markets are high. In fact, current market conditions indicate an excess of ethanol with few new markets identified in 2005.[25] Absent opportunities in new reformulated gasoline or other mandated markets, excess ethanol supply will be absorbed through new discretionary blending in gasoline or as E-85 (85 percent ethanol with15 percent gasoline) in Fuel Flexible Vehicles (FFVs). The current 71 to 81 cent per gallon discount for ethanol in California relative to wholesale non-oxygenated gasoline and CARBOB indicates excess supply of ethanol, where ethanol production is growing faster than its demand for blending into gasoline on the West Coast and other regions. Thus, current refinery blending economics are favorable to maximize ethanol blending, absent other considerations such as the need to offset higher oxides of nitrogen (NOx) emissions from greater use of ethanol when blending gasoline using CARB's predictive model.

Key Assumptions

In this analysis, the key assumptions driving increased levels of ethanol blending in CaRFG3 for BAU and *Aggressive* ethanol blending scenarios include:

- The price of ethanol remains favorable relative to gasoline and gasoline blending components (e.g., alkylate) needed to make CaRFG3 through 2025.[26]

- All regulatory fuels issues related to ethanol blending in California are resolved before 2010 and result in the ability of California refiners to more easily produce CARBOBs suitable for ethanol blending up to 10 percent (volume).[27]

- 90 percent of California's gasoline market is supplied with CaRFG containing 10 percent ethanol.

- Assumes non-mandated (discretionary) blending of ethanol under a waiver from the federal oxygen-in-gasoline requirement, and creation of regional renewable fuel credit trading that may result under a federal RFS that does not appreciably impact ethanol use in California.[28]

- Existing petroleum infrastructure can accommodate an increase in ethanol movement through the system up to 10 percent ethanol with no significant additional costs through 2025.

- Delivery of ethanol from the Midwest by rail and a small increment of foreign ethanol supplies will account for most of California's needs, with an additional 200 to 400 million gallons per year provided by in-state producers by 2025.[29]

- A fuel economy loss in the California fleet of 1.3 percent in the transition year is assumed. This corresponds to the energy loss when blending ethanol at 10 percent rather than 5.7 volume percent.

Results

Table 1 displays the results of the analysis for base case (5.7 percent ethanol blending) and aggressive scenarios involving 10 percent ethanol blending to 2025. As discussed in the preceding sections, recent trends in the supply and price of ethanol make continued ethanol blending an attractive strategy before 2010, and on through 2025 subject to caveats and uncertainties discussed in the following section.

Table 1. Ethanol in California Reformulated Gasoline*

Scenario Description	2005		2025	
With GHG standard	*Ethanol Use*		*Ethanol use*	
5.7 % Blending (Base Case)	*Million Gallons*	*Percent of Gasoline Demand*	*Million Gallons*	*Percent of Gasoline Demand*
Low Price	*900*	*5.5*	*815*	*5.1*
High Price			*800*	*5.1*
Very High Price			*790*	*5.1*
10 % Blending (Aggressive)				
Low Price			*1450*	*9.0*
High Price			*1420*	*9.0*
Very High Price			*1400*	*9.0*
Without GHG standard				
5.7 % Blending (Base Case)				
Low Price	*900*	*5.5*	*977*	*5.1*
High Price			*934*	*5.1*
Very High Price			*910*	*5.1*
10 % Blending (Aggressive)				
Low Price			*1740*	*9.0*
High Price			*1660*	*9.0*
Very High Price			*1620*	*9.0*

*Ethanol volumes based on 90 percent of California's gasoline market in 2025, 97.5 percent of market in 2005.

Given the state GHG standard and *Base Case* ethanol blending, gasoline demand is forecast to peak in 2009-2010, and then slowly decline through 2025 resulting in a decrease in ethanol use by 2025 relative to 2005. For the *High Price* scenario, 800 million gallons of ethanol are consumed, thus, about a 100 million gallon per year decline relative to 2005. Under the 10 percent *Aggressive Blending* scenario, ethanol use jumps to about 1.4 billion gallons per year or 9 percent of CaRFG on-road demand. This scenario would require a modest 400 million gallons of new ethanol supply over 20 years.

Without the state GHG standards, significantly higher volumes of ethanol are needed to meet the increasing on-road CaRFG demand, primarily in the aggressive scenario. For *Base Case Blending* under the *High Price* scenario, ethanol use is within 1 to 2 percent of 2005 demand, while *Aggressive Blending* would require just over 800 millions gallons of new ethanol supply over 20 years.

Table 2. Petroleum Reduction and Benefits for Ethanol Blends at 5 Percent Discount Rate

Petroleum Reduction and Benefits for Ethanol Blends at 5 Percent Discount Rate							
Alternative Fuel Scenario	Displacement in 2025, Billion Gallon/Year Gasoline Equivalent	Reduction from Base Case Demand, Percent	*Costs and Benefits, Present Value, 2010-2025, 5 Percent Discount Rate, Billions $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
E10 Blending ($1.78 per gallon gasoline)	0.50	2.6	0.0	(2.6)	2.1	0.6	0.1
E10 Blending ($1.92 per gallon gasoline)	0.49	2.6	0.0	(2.5)	2.0	0.6	0.1
E10 Blending ($2.15 per gallon gasoline)	0.48	2.6	0.0	(2.5)	2.0	0.6	0.1

Table 3. Petroleum Reduction and Benefits for Ethanol Blends at 12 Percent Discount Rate

Petroleum Reduction and Benefits for Ethanol Blends at 12 Percent Discount Rate							
Alternative Fuel Scenario	Displacement in 2025, Billion Gallon/Year Gasoline Equivalent	Reduction from Base Case Demand, Percent	*Costs and Benefits, Present Value,2010-2025, 12 Percent Discount Rate, Billions $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
E10 Blending ($1.78 per gallon gasoline)	0.50	2.6	0.0	(1.3)	1.0	0.3	0.0
E10 Blending ($1.92 per gallon gasoline)	0.49	2.6	0.0	(1.3)	1.0	0.3	0.0
E10 Blending ($2.15 per gallon gasoline)	.048	2.6	0.0	(1.2)	1.0	0.3	0.1

The costs and benefits analysis in Tables 2 and 3 indicate positive *Direct Net Benefits* for the E-10 option relative to *Base Case* ethanol blending at 5.7 volume percent. In this analysis, consumer cost impact (*Direct Non-Environmental Benefits*) was set to zero implying a drop in the price of E-10 relative to E 5.7 of about 2.5 cents per gallon. Gasoline pool swelling effects would further reduce imported gasoline blending component demand and market-clearing price, thus further reducing cost impact on the consumer.[30]

Key Drivers and Uncertainties

Several outstanding issues and uncertainties could limit the potential for increased use of ethanol blending in CaRFG by 2025. However, because of minimum octane requirements, commitments and investments to date by refiners, terminal operators, independents and gasoline wholesalers, California's common carrier pipeline operator, and the railroads; and nascent investment in ethanol production; the likelihood of continuation of a significant level of ethanol blending through 2025 is likely. Some of the uncertainties and challenges are:

- The availability and price of ethanol relative to other gasoline blending components.

  Comment: The increased demand for ethanol to meet California's blending requirements is expected to raise the market-clearing price for ethanol, relative to the *Base Case*. No additional analysis has been performed to quantify this change. Supplies of ethanol over the forecast period are expected to be adequate to meet demand.

- The availability and price of gasoline imports.

  Comment: The increased concentration of ethanol in gasoline from 5.7 to 10 percent by volume is assumed to occur over a short period of time (less than one year). Not only will his transition increase the demand for ethanol, but at the same time, the demand for gasoline needed to blend with ethanol will decline. It is assumed that this one-year decline in gasoline demand will result in a temporary decrease of gasoline imports. Relative to the *Base Case*, the market-clearing price of gasoline imports is expected to temporarily decline.[31] No additional analysis has been performed to quantify this change. Supplies of gasoline imports over the forecast period are expected to be adequate to meet demand.

- Change in fuel economy.

  Comment: Increasing the concentration of ethanol in California's gasoline to 10 percent will lower energy content by 1.3 percent. As a result, motorists would need to consume a slightly greater quantity of gasoline to travel the same distance, compared to the *Base Case*. Therefore, the transition from 5.7 to 10 percent ethanol blends will result in an additional one-year jump in gasoline demand of 1.3 percent above the normal forecasted demand increase. The additional increase in demand translates to an additional cost for the transition year only.

- The outcome of the CARB staff review and update of the *Predictive Model*.

  Comment: Given data in hand and recent changes in refinery operations allowing some blending at higher oxygen levels, higher level ethanol has been demonstrated using the current (1999) version of the *Predictive Model*. Some ethanol blending above 7 percent is now occurring in Northern California, If review and updating of the *Predictive Model* result in changes that show predicted emissions of NOx are not as great at higher oxygen levels, blending gasoline with ethanol at concentrations of 10 percent by volume will be easier, compared to the *Base Case*.

- The outcome of the CARB staff's effort to quantify[34] the impact that permeation emissions from vehicles using CaRFG containing ethanol and identification of mitigation approaches to assure that air quality benefits of CaRFG2 are retained.

  Comment: Since CARB is obligated to preserve the air quality benefits of CaRFG achieved under Phase 2 gasoline regulations, staff believes that mitigation measures will be identified and implemented.

- The likelihood that California is granted a waiver from CAA oxygen requirements, in combination with a nationwide RFS with a regional credit trading option.

  Comment: A Federal Minimum Oxygen Requirement could result in a California gasoline market with a 50/50 split between non-oxygenated and ethanol blended gasoline, notwithstanding infrastructure constraints and fungibility/segregated storage issues in pipelines and terminals. This scenario would result in a decreased quantity of ethanol blended with California's gasoline, relative to today.

- The impact on ethanol price from the creation of a 200 to 400 million gallon per year in-state ethanol production industry.

  Comment: Creation of the in-state industry will provide local supplies of ethanol and could place downward pressure on the price of imported ethanol while contributing to the state's economic growth.

Endnotes

[1]Given the uncertainty of future ethanol and gasoline prices, reformulated gasoline regulations, pending federal actions regarding renewable fuels, and disposition of congress towards extension of the federal blenders' tax credit post 2010, only qualitative discussions of confidence in projected market volumes of ethanol as a blending component in gasoline are included in this analysis. No formal risk analysis has been included.

[2] Staff Report *Forecasts of California Transportation Energy Demand 2005-2025* Report # 600-2005-008, April 2005.

[3] Staff Report *Quarterly Report Concerning MTBE Use in California Gasoline* July 1 through September 30, 2000, Report to the Legislature, Report No. P300-00-005v3, November 2000. http://www.energy.ca.gov/mtbe/documents/2000-12_MTBE_3RD_QTR_REPORT.PDF.

[4] Staff Report *Quarterly Report Concerning MTBE Use in California Gasoline* October 1 through December 30, 2003, Report to the Legislature, Report No. P300-03-001v4, February 2004. http://www.energy.ca.gov/mtbe/documents/2003_MTBE_4TH_QTR_REPORT.PDF.

[5] EPA link to NAAQS for ozone is http://www.epa.gov/air/criteria.html. Oxygen requirements in federal gasoline regulations that are applicable to all states not in compliance with the NAAQS for ozone can be found at http://www.epa.gov/otaq/rfg.htm.

[6] Since CARB gasoline regulations are permissive with regard to the oxygen content in gasoline, it is assumed that refiners would choose to blend ethanol at "economic levels", meaning that the availability and costs of gasoline blending components would determine the oxygen content. The national RFS (currently envisioned by congress would mandate renewable fuels (e.g., ethanol and biodiesel) to be used at increasing volumes to the year 2013. Credit trading would allow companies to meet their obligations by buying and/or selling RFS credits with/ without producing or selling renewable fuels.

[7] Staff recognizes that the outcome of California's request for waiver from the CAA oxygen in gasoline requirement could have a large influence on the use of ethanol in future years. However, staff assumes that CARBOB movement to terminals, CaRFG3 distribution (including inability to use California's common carrier pipeline system) and a lack of segregated storage at terminals constrains refiners, distributors and independent marketers from offering multiple CARBOBs or non-oxygenated CaRFG and a single CARBOB for ethanol blending. The exception to this is that some refiner's may choose to offer some non-oxygenated gasoline or RFG at their refinery truck racks or proprietary terminals (with direct pipeline link) when blending economics are favorable.

[8] Summary of 2004 taxable gasoline sales provided by the California Board of Equalization (with the exception of the month of December). December 2004 gasoline volume sales are estimated based on gasoline sales trends for the months of November and December in prior years.

[9] Energy Commission Petroleum Industry Information Reporting Act (PIIRA) database.

[10] Staff assumed that refiners blended ethanol at between 5.8 and 5.9 volume percent to assure compliance with the federal minimum 2 percent weight oxygen requirement (5.7 volume percent ethanol). Staff used 5.7 percent (volume) ethanol blending for all projections in the BAU Scenario.

[11] The most important factor leading to almost exclusive production of CARBOB for ethanol blending in 2004 was the transition process from multiple grades of two different California reformulated gasolines (CaRFG2 with MTBE and CaRFG3 with ethanol) in the petroleum pipeline, storage, and retail distribution infrastructure. The complexity of adding a third non-oxygenated CaRFG in the transition process would have overwhelmed segregated storage capacity at terminals and pipeline

delivery capability. California refineries are also limited in their ability to store three different CaRFGs or CARBOBs prior to scheduled shipments in the common carrier (Kinder Morgan) pipeline system.

[12] Over time, staff has assumed that refiners will begin to produce a third non-oxygenated CaRFG (to replace CaRFG2) but that the volume of this additional "flavor" of gasoline will be limited because of segregated storage and related infrastructure issues as well as limitations imposed on the practice due to CARBOB trading obligations between refiners. Staff assumes that this practice may largely manifest itself as distribution from refinery truck racks or proprietary petroleum products terminals, but that it will never exceed 10 percent of California's gasoline demand. Non-oxygenated CaRFG can be moved through the pipeline system.

[13] Energy Commission Petroleum Industry Information Reporting Act (PIIRA) data base.

[14] BNSF http://www.thesoydaily.com/BiodieselBiobased/bnsf10012004.asp.

[15] Union Pacific Railroad, http://www.uprr.com/customers/ag-prod/faq.shtml.

[16] According to BNSF sources, current deliveries of ethanol to southern California represent only 2 percent of the rail traffic in the region, and they do not anticipate problems in delivering adequate ethanol to meet needs in the future. Union Pacific Railroad advertises their commitment to adequate service to meet the needs of ethanol clients in California.

[17] Staff estimate based on review of existing construction projects as summarized by the Renewable Fuels Association and BBI international. http://www.ethanolrfa.org/eth_prod_fac.html and http://www.bbiethanol.com/plant_production/.

[18] http://www.energy.ca.gov/reports/2003-10-21_600-03-017F.PDF Energy Commission staff updated its survey in August, 2004.

[19] In 2004, five plants in Iowa, two in Nebraska, two in Wisconsin, and one each in Illinois and South Dakota began production. Average capacity of these plants was just under 40 million gallons per year. In 2005, average capacity for 14 plants coming on line by year end is estimated to be the same, though one plant at 110 million gallons per year capacity will be the largest dry mill in the U.S. when it starts producing ethanol.

[20] In 2004, discretionary blending (as opposed to mandatory blending under federal or state regulations) amounted to 29 percent of all ethanol blended in gasoline in the U.S. Refinery economics, free market competition, and the price of ethanol drive this type of blending. When trends in ethanol prices are low and/or gasoline blending component prices are high, opportunities for new "discretionary blending" markets materialize. Many of these markets are in Midwest states where incentives are provided either for blending ethanol into gasoline or for ethanol production (producer's incentive).

[21] Production of CARBOB for 10 percent ethanol blending is not feasible using the current version of California's Predictive Model (PM). Limited ethanol blending at 7.7 percent is possible. Staff is aware of two California refiners who have the ability to produce a complying CARBOB for this higher level of ethanol blending. Staff has confirmed that one refiner in northern California is currently blending and distributing 7.7 percent ethanol CaRFG from the refinery truck rack in full compliance with CARB California reformulated gasoline requirements. In 2005, CARB staff will be updating the PM to include emissions data from 1999-2005 model year vehicles as well as other needed updates. CARB staff will make additional changes as well and establish criteria defining "preservation of air quality benefits" as required by SB 989 (Sher, 1999). This updating process of the PM may provide additional flexibility for refiners to blend at higher ethanol concentrations (up to 10 percent by volume).

[22] Staff has found that the new dry mills being constructed in the Midwest typically have the ability to produce at 105 to 120 percent of design capacity relatively soon after plant start-up. (for example, see Broin Inc. plant performance statistics: http://www.broin.com/partners.asp.

[23] California gasoline prices are the highest among all regions of the continental U.S. http://www.eia.doe.gov/oil_gas/petroleum/data_publications/wrgp/mogas_home_page.html. Given the price of CaRFG relative to other U.S. markets, California RFG represents the highest value market for ethanol blending in the U.S., with perhaps the exception a few low gasoline demand states with mandated ethanol use and generous state incentives. Incremental ethanol production capacity that comes on-line in the future is likely to find California the most attractive market through 2025, if CaRFG retains its position as the highest priced gasoline in the U.S. for most of the next 20 years.

[24] Typical contracts for ethanol between Midwest producers and California clients come in several forms. They are either indexed to CaRFG spot wholesale prices, to NYMEX gasoline prices, or come at a fixed price. Ethanol prices under these types of contracts are typically at a discount to gasoline ranging anywhere from 20 to 80 cents after taking the federal fuel excise tax credit into consideration. Typically, the contract is six months in duration roughly corresponding to winter and summer gasoline specifications in California's ozone non-attainment regions. Ethanol contract prices closely follow spot ethanol market trends and can be compared with gasoline blending component prices; See http://www.energy.ca.gov/gasoline/graphs/component_prices.html. This price chart shows ethanol at a 37 cent discount to CARBOB, on average, in 2004. The relative ethanol price advantage in early 2005 has risen to 80 cents as a result of a steep upward trend in CARBOB price combined with a declining ethanol price. Ethanol contracts indexed to the NYMEX were at minus (-10) cents per gallon in early 2005 (personal communication with a California wholesale ethanol broker, March 1, 2005).

[25] With CaRFG spot prices at a premium of 10 to 20 cents over New York RFG in February and March of 2005, the resultant price advantage for a California blender of ethanol in gasoline can be seen to be 51 (federal fuel excise tax forgiveness) + 10 (10 cent discounted contract price indexed to NYMEX) + 10 or 20 cents (differential between CaRFG and NYMEX RFG) = 71 to 81 cents. Should this price differential persist, new discretionary blending is expected, or in mandated markets such as California's, blending above 5.7 percent may emerge to absorb some of the excess supply.

[26] Ethanol marketers have advised Energy Commission staff that ethanol has rarely been priced at the full value of the federal excise tax incentive (as high as 53 cents; in 2005 it is 51 cents) in typical indexed contracts. If ethanol was fully valued by refiners/blenders at gasoline value, then an indexed contract would include a + 51 cent adder, the value of the excise tax credit in 2005.

[27] These activities include updating California's PM by CARB staff, successful identification of measures that mitigate permeation emissions associated with ethanol use in CaRFG3, specification changes or creation of a California Phase 4 (CaRFG4) gasoline the generates additional air quality benefits, and actions that assure retention of air quality benefits achieved with CaRFG2 as required by SB 989 (Sher, 1999).

[27] These activities include updating California's PM by CARB staff, successful identification of measures that mitigate permeation emissions associated with ethanol use in CaRFG3, specification changes or creation of a California Phase 4 (CaRFG4) gasoline the generates additional air quality benefits, and actions that assure retention of air quality benefits achieved with CaRFG2 as required by SB 989 (Sher, 1999).

[28] California's request for a waiver from the oxygen provisions of the CAA, and enactment of a national RFS requirement could impact the degree of ethanol blending in future years. According to recent modeling using a generic California refinery model, an oxygen waiver could provide an opportunity for a 50/50 split of non-oxygenated and oxygenated in the CaRFG market based on refinery economics and certain assumptions about the price of ethanol and competing hydrocarbon (gasoline) blending components, however, the report author cautioned that the model can

"over-optimize" since it does not capture individual refinery capabilities and octane position, and limitations within California's petroleum products delivery infrastructure. Thus, staff assumes these factors lead to continued use of ethanol at 90 percent of the gasoline market through 2025. Source: *Analysis of the Production of California Phase 3 Reformulated Gasoline With and Without an Oxygen Waiver* MathPro Inc., prepared for the EPA, Contract EPA P.O. 0W-2026-NASX, January 19, 2001.

[29] Assumes capital investments by the railroads to improve service to California will be recovered in their freight rate structures in future years. However, rates for ethanol delivery are anticipated to continue on a downward trend as additional efficiencies are realized with higher ethanol volumes, and general capital improvement projects system wide.

[30] While potential gasoline pool swelling in a California refinery has not been verified through use of a generic California refinery model, staff believes that swelling up to 1 percent may be possible as a result of dilution effects, additional octane and possibly other effects associated with increased ethanol use beyond 5.7 percent blending.

[31] "Market-clearing price" is phrase common in economics referring to a price that causes supply and demand to be equal.

[32] At the November 18, 2004, hearing of the CARB staff acknowledged responsibility to return to the board in about a year with optional measures to offset the effects of permeation emissions, as required by law. Staff formally reviewed the findings of the Coordinating Research Council's Permeation study, and acknowledged that analysis would be required to "find an appropriate temporal and spatial distribution of emissions" based on vehicle activity and fuel temperature data. See CARB transcript at www.arb.ca.gov/board/mt/mt111804.txt, pages 120-129.

OPTION 2G - ETHANOL HI-CONTENT BLEND (E85)

Summary

This analysis examines the use of E-85 (a mixture of 85 percent ethanol and 15 percent gasoline) in flexible fuel vehicles (FFVs). Analyses of the *Business-as-Usual* (BAU) and *Aggressive Scenarios* lead to low and high petroleum displacement projections in the year 2025.

Under the BAU Scenario, FFV production ceases in 2009 and there is no significant use of E-85 for petroleum displacement through 2025. Under the *Aggressive Scenario,* production of FFVs continues and results in 1.0 to 1.2 billion gallons of petroleum displacement by 2025.

Background and Description

Unlike gasoline blended with ethanol, E-85 is not widely available at retail gasoline stations and fleet dispensing facilities in California.[1] One retail station exists in San Diego. Additionally, Lawrence Berkeley National Laboratory, Lawrence Livermore National Laboratory, and Vandenberg Air Force Base dispense fuel to FFVs owned and operated by federal agencies. Nevertheless E-85 is a commercial fuel with growing use in other states, particularly those in the Midwest. Minnesota has the largest number of E-85 dispensing facilities, with 112 publicly accessible retail station sites, while the United States (U.S.) as a whole has 272 outlets in 28 states.[2] FFVs have been fully commercialized since 1993, with cumulative production of ethanol-compatible FFVs expected to exceed five million vehicles in 2005.

FFV Production and Cost

General Motors Corporation (GM) is offering six light truck and sport utility vehicle (SUV) FFV models in California for the first time in 2005. With anticipated sales of 45,000 GM vehicles in 2005, the population of FFVs in California is expected to exceed 300,000 by the end of the year.[3] The line-up of 2005 models includes 24 different sedans, station wagons, pickup trucks, minivans, and SUVs manufactured by GM, Ford, DaimlerChyrsler, and Nissan.[4] As in previous years, most new FFV models are priced the same as their gasoline counterparts, with a few exceptions. For 2005, the Dodge Stratus FFV costs $850 more than the gasoline version, while the Daimler Chrysler Ram pickup truck FFV is listed at $785 above the gasoline truck. The GM Sierra pickup is listed at $321 above the gasoline model. The remaining 21 FFVs are priced the same as their gasoline counterparts.

Extension of Alternative Fuel Manufacturing Incentive Through the 2008 Model Year

Effective October 1, 2004, the National Highway Traffic Safety Administration (NHTSA) finalized a rulemaking that extended the alternative fuel vehicle (AFV) manufacturing incentive created by the Federal Alternative Motor Fuels Act of 1988.[5] In extending the life of the incentive, NHTSA concluded the following:

" We have determined that extension of the CAFE incentive appropriately balances the Nation's need to continue to encourage investment in alternative fuel infrastructure and the risk that the Nation's alternative fuels system may never become self-sustaining. The recent proliferation of E85 refueling stations, the recent Congressional support for ethanol as an alternative fuel, and the recent expansion of public awareness and acceptance campaigns to encourage ethanol use all imply a continuing increase in E85 use and the ultimate success of the program created by Congress in AMFA, at least as far as ethanol-based fuels are concerned. The current status of the program does not support its abandonment by terminating the CAFE incentive that has sparked its development to date." [6]

FFV production trends are anticipated to continue through the 2008 model year, primarily as a result of the extension of this incentive.[7] For 2005 through 2008 models, manufacturers of FFVs and other "dual-fuel" vehicles, such as bi-fuel compressed natural gas (CNG) and propane vehicles, earn Corporate Average Fuel Economy (CAFE) credits, based on the non-petroleum content of the alternative fuel, not to exceed 0.9 miles per gallon (mpg).[8] The credit gives the manufacturer a higher CAFE value, for passenger car and light truck fleets, based on the number of AFVs manufactured as FFVs and dedicated vehicles. Dedicated AFVs (those capable of operating on only ethanol, methanol, natural gas, or propane) and electric vehicles are not subject to a CAFE credit cap. Dedicated vehicles have not, however, contributed any substantive CAFE credits to GM, DaimlerChrysler, and Ford Motor Company.[9] The AFV CAFE credits provide manufacturers with a CAFE compliance strategy that has a significant monetary value when large numbers of vehicles are produced.[10]

Without the FFV CAFE incentive for the 2009 model year and beyond, automakers may elect to cease production of FFVs when the $400 marginal value of the CAFE compliance credits is no longer available. For purposes of this analysis, staff assumed no FFV production for 2009 and beyond in the *BAU Scenario.* Likewise, staff assumed that, in the *Aggressive Scenario*, several factors lead to increased production of FFVs in the United States (U.S.). Production will grow from 1,000,000 vehicles in 2005 to 1,700,000 by 2025.

Meeting Future Emissions Requirements

The emissions certification process for FFVs is more complex than for gasoline only or dedicated AFVs, because FFVs must be certified on both gasoline and E-85. California's emissions standards and testing procedures are different from those at the federal level and usually require manufacturers to meet more stringent standards and procedures.

All automakers producing FFVs have been able to achieve California Low Emission Vehicle (LEV) I or LEV 2 tailpipe and evaporative emissions standards. LEV II regulations became effective in 2004 and automakers have the flexibility to choose LEV 1 or LEV 2 regulations to emissions-certify their vehicles for several more years.[11] However, in the future, automakers will have to certify under the LEV 2 regulation and meet zero emission vehicle (ZEV) requirements through the certification of a mix of partial zero emission vehicles (PZEVs), advanced technology – partial zero emission vehicle (AT-PZEV) and a small fraction of ZEVs.[12]

According to automakers, achieving the PZEV standard in an FFV will be challenging.[13] Staff's review of literature from industry suppliers indicates promising available technology that may help automakers achieve PZEV evaporative emissions requirements. Of particular note is the availability of new materials and fabrication techniques that minimize permeation emissions.[14] In addition, developments in fuel systems materials to meet 15–year, 150,000 mile emissions durability requirements appear possible. These materials have undergone long-term exposure testing with a range of ethanol/gasoline, methanol/gasoline, and other gasoline and fuel additives, including peroxides.[15]

Staff believes that automakers will weigh the costs of achieving emissions requirements in FFVs against the development costs associated with other alternative fuel and advanced technologies. Emissions, performance, reliability, customer satisfaction, and internal cost goals for various alternative fuel product offerings will be established. Over the years, incremental costs associated with FFVs have remained low relative to other options.[16] Staff believes that there is room for automakers to incur additional emissions control costs, if such costs are required to overcome the unique issues associated with emissions certification of FFVs on E-85 and gasoline under LEV 2 regulations.[17]

Ethanol Supply and Price Trends

Ethanol Supply

A combination of in-state production and imports from Midwest states and foreign sources could provide adequate supplies of ethanol for the combination of high level (E-10) ethanol blending in California gasoline and E-85 use in FFVs. The California

Energy Commission (Energy Commission) and the California Air Resources Board (CARB) staff project that an adequate supply of ethanol could be made available from California, Midwest states, and foreign sources providing 4.6 billion gallons of ethanol in 2030.[18]

This supply would support about four million FFVs using an E-40 fuel (or half time use of E-85), while the rest of the fleet operated on E-10.[19] The analysis indicated that California ethanol demand would be 20 percent or less of projected U.S. ethanol supply through 2030.[20] The analysis presented here envisions California ethanol demand at levels lower than those in the AB 2076 analysis. Under the *Aggressive Scenario* in this analysis, 1.0 to1.2 billion gallons of petroleum displacement is envisioned in 2025.

A Renewable Fuel Standard (RFS) introduced as part of new energy legislation by Congress in 2005, includes proposals for six to eight billion gallons of renewable fuel use by the year 2012. This is likely to foster a continuation of ethanol plant construction in the U.S. should the RFS become law.[21]

There appears to be excess supply of domestic ethanol in 2005 that is likely to carry into 2006, based on plants scheduled to come on line and new ethanol plant development projects.[22] Since it is anticipated that California will be the highest value market for ethanol for the foreseeable future, it will likely attract all the ethanol it needs for a combination of ethanol blending in gasoline and E-85 use in FFVs.[23]

Ethanol Price

Should the long-term trend of higher California gasoline prices (relative to other states) persist, as predicted under Energy Commission transportation fuel price scenarios for the *Integrated Energy Policy Report*, then California will remain the highest value market for ethanol whether it is blended into gasoline or used to formulate E-85 for use in FFVs, or used for blending with diesel.

Even under a nationwide Methyl Tertiary Butyl Ether (MTBE) ban scenario, and incentives for ethanol production and use in other states, California's ability to "bid away" ethanol supplies is likely because of the 15 to 35 cent higher retail cost of the state's gasoline relative to gasoline markets in other states.[24]

Cost of Blending E-85 in California in 2005

Given the lower cost of ethanol relative to the higher price of gasoline in California, an E-85 market could emerge based on these blending economics when compared to opportunities for higher level ethanol blending in gasoline.[25] With April 2005, ethanol spot prices in northern and southern California at around $1.25 per gallon, or $0.76 per gallon net (of federal tax incentive) basis, E-85 could be formulated by an ethanol blender at a cost of $0.93 per gallon.[26] On a gasoline gallon equivalent (gge) energy basis, this cost is $1.30 per gge or 60 cents lower than the current wholesale cost of gasoline.

With these wide price differentials favoring ethanol over reformulated gasoline and gasoline blending components, staff believes market conditions are right for establishing near-term E-85 dispensing facilities, in California. Important changes in tax law will benefit blenders of E-85 as well in 2005 and allow collection of the full value of the federal ethanol blenders' incentive for the first time in 2005.[27]

E-85 Supply Infrastructure and Outlets

As described in the companion analysis titled *Ethanol Blend (E10),* California's petroleum infrastructure currently has all the storage and equipment needed to blend reformulated gasoline at terminals and transport it to retail stations and fleet clients. This infrastructure can provide E-10 blending as well as blending for an emerging E-85 market, but will require some expansion and capital investment not yet evaluated by staff.

What is lacking in California today is significant E-85 dispensing capability for retail and fleet fueling. Currently, four fleet entities and one retail facility have been granted research and development status by the CARB to install and operate an E-85 dispenser.[28] Significant expansion of E-85 fueling in California can only occur when one or more of these facilities receive CARB certification of a vapor recovery system under the Enhanced Vapor Recovery (EVR) program adopted by the CARB in 2000.[29] With manufacturers focused on retail gasoline outlet vapor recovery certification, required in over 9,000 retail gasoline stations, a special effort to certify one E-85 system will likely be required.[30] Vandenberg Air Force Base is pursuing certification as required by CARB, however, staff is not aware of the extent of certification activities being pursued by the four fleet operators that have been granted research and development status.[31]

Fostering E-85 Availability in California

Progress in establishing E-85 dispensing facilities at fleet and retail locations in California could commence once EVR-certified E-85 dispensers and associated vapor recovery equipment are available. With the current focus on upgrading gasoline dispensing facilities by 2010, several years will be required to establish E-85 fueling on any significant scale. Staff believes that 10 to 20 percent of retail gasoline locations would need to offer E-85 to foster large scale consumer acceptance of E-85. This would mean E-85 availability at between 900 and 1,800 retail locations. 2015 might be a reasonable target date for this number of E-85 locations.

Existence of successful business approaches to foster E-85 availability in the Midwest could serve to guide stakeholders in establishing E-85 availability at retail and fleet-fueling facilities in California.[32] Approaches employed in Minnesota illustrate the kind of progress that can be achieved with state incentives and major participation from stakeholders in planning and implementation Minnesota has achieved the greatest progress both in educating the public about E-85 and fostering E-85 availability for businesses, local jurisdictions, and state agencies. Several of the 12 co-operatively owned Minnesota ethanol plants are blenders/wholesalers of E-85 and provide fuel to surrounding communities as well as to the larger Twin Cities metropolitan area.[33]

E-85 is accessible in Minnesota at 112 retail outlets with 12 additional sites in process to dispense E-85 this year.[34] Many stakeholders have contributed to the progress in establishing this network of E-85 stations.[35]

Key Assumptions

In this analysis, the key assumptions driving increased levels of E-85 use in FFVs for the BAU and *Aggressive Scenarios* include the following:

- The price of E-85 remains competitive with gasoline on a gge price basis through 2025 and the fuel substitution ratio (E-85 gallons to replace one gasoline gallon) in an FFV is 1.34.[36]
- The federal 51 cent per gallon incentive for blending of ethanol is extended and retained through 2025.[37]
- Increased production of ethanol in California and the Midwest meets new ethanol fuel market demand for high ethanol content blending.[38]
- Regulatory issues with regard to emissions in FFVs, including certification to PZEV standards and evaporative emissions concerns are resolved, possibly at some additional cost to automobile manufacturers.[39]
- The certification of one or more EVR systems for E-85 at service stations is achieved by 2006, making deployment of E-85 dispensing facilities possible in retail and fleet fueling operations.[40]
- Creation of a coalition of stakeholders to educate consumers and fleet owners about FFVs and E-85 fuel use, as well as establishing necessary procedures to create a E-85 network.[41]
- Growth in the FFV population under a BAU scenario that continues through the 2008 model year, but ceases in 2009, as the “sunset” clause for dual-fuel vehicle CAFE credits takes effect. As a result, the FFV

population gradually decreases through 2025 as FFVs are retired from the fleet of California vehicles.[42]

- Growth in the FFV population under an *Aggressive Scenario* that assumes production of FFVs through 2025 resulting from extension of CAFE credits for dual fuel vehicles, market forces, or other incentives.[43] FFVs represent 15 percent of new vehicle sales for the period 2013 through 2025.

- E-85 fuel utilization by FFV owners increases over a ten year period, beginning in 2005, then remains constant through 2025.

- Existing California petroleum infrastructure that can accommodate an increase in ethanol movement through the system (excluding the common carrier pipeline) and ethanol blending in California Blendstock of Oxygenate Blending (CARBOB) and E-85 for delivery by truck to outlets, without significant additional per gallon blending costs through 2025.

- Delivery of Midwest ethanol by rail and incremental supplies of foreign ethanol meeting most of California's ethanol demand.

- 200 to 400 million gallons per year of in-state ethanol by 2015.[44]

Results

Tables 1 and 2 summarize the *Aggressive Scenario* results for petroleum reduction and benefits of E-85 FFV use for a 5 percent and 12 percent discount rate, respectively.

Table 1. Petroleum Reduction and Benefits for E-85 FFVs at 5 Percent Discount Rate

Alternative Fuel Option	Displacement in 2025, Billion Gallon/Year Gasoline Equivalent	Reduction from Base Case Demand, Percent	Highest Cumulative Benefit or Change, Present Value, 2005-2025, 5% Discount Rate, Billion $2005				
			A	B	C	D	A+B+C+D
			Direct Non-Environmental Benefit	Change in Government Revenue	Direct Environmental Net Benefit	External Cost of Petroleum Dependency	Direct Net Benefits
Low Fuel Price	1.2	5.7	0	(1.4)	0.2	0.6	(0.6)
Highest Fuel Price	1.0	4.7	0	(0.7)	0.6	0.6	0.5

Table 2. Petroleum Reduction and Benefits for E-85 FFVs at 12 Percent Discount Rate

Alternative Fuel Option	Displacement in 2025, Billion Gallon/Year Gasoline Equivalent	Reduction from Base Case Demand, Percent	Highest Cumulative Benefit or Change, Present Value, 2005-2025, 12% Discount Rate, Billion $2005				
			A	B	C	D	A+B+C+D
			Direct Non-Environmental Benefit	Change in Government Revenue	Direct Environmental Net Benefit	External Cost of Petroleum Dependency	Direct Net Benefits
Low Fuel Price	1.2	5.7	0	(0.5)	0.1	0.2	(0.3)
Highest Fuel Price	1.0	4.7	0	(0.3)	0.3	0.3	0.3

Results for the BAU scenario are not included in the *Costs and Benefits Analysis* since FFV production is assumed to cease in 2009. Staff assumed that in this scenario, investments in making E-85 available for 600,000 FFVs would not be economically attractive to blenders and suppliers. In this situation, staff assumed that fuel use is limited to no more than 5 percent of the FFV fleet at a 50 percent utilization rate. This would imply an E-85 demand of about 14 million gallons per year and ethanol demand of 12 million gallons per year. This quantity of ethanol is just over 1 percent of California's 2004 ethanol demand.[45]

Under the *Aggressive Scenario*, petroleum reduction of 1.0 to1.2 billion gallons per year is achieved in 2025 due to the FFV population growth and increase in E-85 utilization rate. This range can be compared with the ethanol blending in gasoline option of 0.48 to 0.50 billion gallons petroleum displacement in 2025.

Key Drivers and Uncertainties

Several remaining issues and uncertainties could limit the growth of E-85 use and the FFV population in California in the 2005 to 2025 time period.

- Margins on E-85 under low gasoline prices and/or competition from higher value discretionary ethanol/gasoline blending markets in the U.S. could hamper the development of an E-85 market in California.

  Comment: Assuming a low gasoline price scenario at $1.80 per gallon, ethanol wholesale price in California would need to be $1.36 per gallon or 85 cents per gallon (net of fuel excise tax incentive) to compete with gasoline on an energy equivalent basis. In 2004, California spot railcar ethanol averaged about $1.64 per gallon or $1.12 net of tax incentive.[46]

- Loss of the federal subsidy for ethanol after 2010 could affect development of ethanol production and availability for E-85 use in FFVs.

  Comment: Commercial scale, low cost cellulosic ethanol will not be available for many years as the technology is just approaching the first phase of commercial demonstration. Thus, corn-based or imported ethanol would be diverted to higher value gasoline blending markets after 2010.

- FFV product offerings could cease as CAFE credits expire at the end of the 2008 model year and PZEV emission requirements could move manufacturers to develop other advanced technology options to comply with California LEV 2 emission requirements.

- Without consumer education and an aggressive approach to establishing E-85 fueling facilities, little use of ethanol as E-85 relative to that for gasoline blending will occur before 2015.

  Comment: Numerous Minnesota stakeholders have achieved success in establishing an E-85 program and network of dispensing facilities for the state's 100,000 FFVs. California can likely apply approaches taken and lessons learned in Minnesota.

- The number of FFVs in California fleets, and a strategy to target those vehicles for E-85 fueling, has not been established.

  Comment: Such an undertaking might be the most expedient way to bring visibility to E-85 and establish sites for eventual acceptance and use by consumers.

- Lack of co-ordination among current E-85 site operators under CARB Research and Development status may impede the enhanced vapor recovery certification process of E-85 dispensing systems.

Endnotes

[1] Ethanol in the form of E-85 (85 percent ethanol and 15 percent gasoline) is designed for use in ethanol compatible FFVs (E-FFVs). Unlike "dedicated" AFVs that are designed for the exclusive use of E-85, M-85, propane, or natural gas, FFVs can operate on gasoline, alcohol, or any mixture of gasoline alcohol.

[2] www.eere.energy.gov/afdc/infrastructure/station_counts.html E-85 station count adjusted for new Minnesota stations and current as of May 9, 2005. For a separate listing of existing and planned Minnesota E-85 stations see www.cleanairchoice.org/outdoor/E85InCounty.asp?City=City.

[3] According to data in the California Department of Motor Vehicles Registration Database, about 234,000 FFVs were registered in California as of October 22, 2004. FFVs have been owned and operated by California consumers and fleet operators since 1989. About 15,000 methanol compatible FFVs (M-FFVs) were sold through the 1997 model year, primarily Ford Taurus and GM Lumina models. A shift to E-85 compatible FFVs (E-FFVs) occurred first in 1996 when Ford offered 3300 ethanol and 2000 methanol compatible FFVs (M-FFVs). Large commercial sales of FFVs began in 1998 with Chrysler Corporation's E-FFV "Caravan" (minivan). Over 147,000 FFV Caravans were manufactured in the 1998 model year. Ford Motor Company built and sold 190,000 E-FFVs Ranger pickups in 1999. GM followed suit in the 2000 model year with 98,000 E- FFV Chevy S-10 and GM Sonoma pickups. GM, Ford, and DaimlerChrysler together produced 672,000 FFVs in 2000 and over one million FFVs in 2003. Over four million E-85 compatible FFVs are on U.S. highways in 2005. California's share of FFVs is lower than its market share of gasoline vehicles (12 percent) because most FFV models have been offered in other states before being offered in California consumers and fleet operators.

[4] The full listing of 2005 model year FFVs as well as prior model year offerings is available at www.E85Fuel.com.

[5] www.nhtsa.dot.gov/cars/rules/CAFE/Rulemaking/AMFAFinalRule2004.htm.

[6] Ibid., Section IX, Conclusion.

[7] The Alternative Motor Fuels Act (AMFA) of 1988 created manufacturing incentives in the form of "CAFE credits" to encourage production of vehicles dedicated to or capable of operating on alternative fuels for reasons of national energy security and over dependence on foreign sources of petroleum. The Program became effective with the 1993 model year for methanol, ethanol, natural gas, and propane dedicated and "dual-fuel" vehicles, as well as electric vehicles. Dual-fuel vehicles, those capable of operating on gasoline and alternative fuel, include FFVs as well as bi-fuel natural gas and propane vehicles.

[8] Dual-fuel vehicles, those capable of operating on gasoline and alternative fuel, include FFVs. Dual Fuel vehicles are limited to a CAFE credit "cap" of 1.2 miles per gallon through the 2004 model year, and a 0.9 mpg cap for 2005-2008 model years. Dedicated AFVs are subject to neither cap nor sunset clause in AMFA, thus, hypothetically, a manufacturer could produce only dedicated E-85 vehicles and achieve a CAFE rating for passenger cars under AMFA of 15 mpg/(0.15)=100 mpg (this number is roughly comparable to the EPA combined city/highway fuel economy for the 2005 Ford Explorer, Chevy Tahoe, and GM Yukon when operating on E-85). For comparison, if a hypothetical fleet of ethanol FFVs were manufactured instead, half-time use of gasoline is assumed and for purposes of calculating the CAFE fuel economy. The resultant CAFE value is calculated as a harmonic average using the fuel economy values associated with 1) gasoline, and 2) E-85. While achieving 15 mpg with E-85 in combined city and highway driving as measured in the EPA cycles (Title 40-CFR), these same vehicles achieve 19.5 mpg when using gasoline. Thus, the hypothetical FFV fleet would be rated at 32.6 mpg, however, for purposes of compliance with CAFE regulations, the FFV fleet would

revert to a CAFE rating of 16.9 mpg after the 2008 model year, unless the credit cap was extended or restored in the 2009 model year by Congress.

[9] Large numbers of AFVs are required to generate significant CAFE credits. As of 2005, only FFVs have been produced in sufficient volume to generate credits approaching exceeding the CAFE credit “cap” of 1.2 mpg (2003 and earlier) 0.9 mpg (2004-2008). NHTSA rulemaking document *Availability of Alternative Fuel Vehicles* 2000, www.nhtsa.dot.gov/cars/rules/rulings/CAFE/alternativefuels/availability1.htm).

[10] The marginal value of avoided CAFE fines calculated by Rubin and Leiby (1998) is about $600 for FFVs and around $1200 for dedicated AFVs. Since FFVs can be manufactured at an incremental cost to gasoline vehicles of around $200 to $400, a business case can be made for production volumes of FFVs up to the 0.9 MPG credit cap available through the 2008 model year.

[11] All GM 2005 FFVs achieve California ULEV emissions: http://www.gm.com/automotive/innovations/altfuel/emissions/ *Ford Motor Company FFVs achieve California LEV and ULEV standards*: https://www.fleet.ford.com/showroom/emissions_certificates/EmissionsReport.asp?VehicleType=All&ModelYear=2005&FuelType=Ethanol%20Flex%20Fuel&Model1=All&EngineSize=All.

[12] PZEV is characterized by having very low or near “zero” evaporative emissions in addition to SULEV certified tailpipe emissions. An AT-PZEV is an advanced technology PZEV and is characterized by SULEV emissions and other features of a ZEV. http://www.arb.ca.gov/msprog/zevprog/factsheets/calemissions.pdf.

[13] *E85 Alternative Fuel and Flexible Fuel Vehicles in California* Presentation by Gary Herwick and Phil Lampert, Energy Commission Stakeholders Workshop, October 12, 2004.

[14] For example, blow molded plastic tanks can be constructed to greatly lengthen the path that permeation emissions would have to take to escape through the walls of a fuel tank: http://www.inergyautomotive.com/publi/inerg_contlib.php?maPage=26@maRub=3.

[15] *Fuel Trends and Technology* Update Newsletter, Dupont Automotive and Dupont Dow Elastomers, Winter 2003.

[16]Personal communication with Gary Herwick (GM, retired) April 21, 2005.

[17] Staff believes that the marginal value of CAFE credits for FFVs ($600 – See footnote 10) provides manufacturers a cushion to engineer and implement the necessary technology for emissions control under LEV II standards. While the marginal value of CAFE credits can be $1000 and more for dedicated AFVs, dedicated AFV volumes have not been large enough to contribute to CAFE compliance strategy, whereas FFVs (because of volume production) have.

[18] *Attachment C - Ethanol Supply Demand Analysis*, *Appendix C Petroleum Reduction Options*, *Reducing California's Petroleum Dependence,* CEC Report #600-03-005 August 2003. www.energy.ca.gov/fuels/petroleum_dependence/documents/600-03-005A3_ATTACHMENT_C.PDF.

[19] Ibid., page C-3.

[20] Ibid., Table C-1, page C-2.

[21] U.S. Senator Lugar of Indiana Press release, March 17, 2005: U.S. Senator Dick Lugar and 18 other Senators introduced the Fuels Security Act of 2005 that included provisions that would more than double the production and use of domestic renewable fuels including ethanol, biodiesel, and fuels produced from cellulosic biomass. http://lugar.senate.gov/pressapp/record.cfm?id=233735.

[22] There are 17 plants under construction in April 2005 and many more in the planning stages. See BBI International and the Renewable Fuels Organization (RFA) websites www.bbiethanol.com/ and http://www.ethanolrfa.org/. An indicator of excess supply can be seen in the voluntary (discretionary) ethanol blending market. In 2004, following California and east coast phase-out of MTBE, ethanol used for discretionary blending was about 1.05 billion gallons or 29 percent of all use. Projections for 2005 indicate mandated ethanol blending market volumes unchanged from 2004; however, new supplies will increase ethanol available for voluntary blending to about 1.5 billion gallons or 38 percent of all 2005 ethanol use. Information from RFA and VeraSun Energy.

[23] As of mid April 2005, California wholesale gasoline is at 30 cent premium to NYMEX futures. *Platts OPR Extra,* Monday, April 18, 2005, www.platts.com . California retail gasoline price trends in 2005 on average are 20 cents per gallon higher than the rest of the U.S. based on recent EIA/DOE gasoline price data, thus, at least in the short term, the California gasoline market will attract sellers of gasoline blending components and ethanol because of the likely higher gasoline margins in this market.

[24] Platt's *OPR Extra*; *CaRFG differential to NYMEX gasoline in January 2004 - April 2005*.

[25] CARB Predictive Model for California Phase 3 reformulated gasoline currently limits increasing the oxygen content (ethanol content) in gasoline with the possible exception of limited blending at 7.7 volume percent ethanol by a few refiners. Staff believes that this practice is likely to be limited to a few refiners that can produce CARBOB for ethanol blending at 7.7 percent and distribution from their refinery rack only. The practice would require additional segregated storage as well. Supposing 10 percent of CaRFG can be distributed and sold this way before 2010, new demand in shifting from 5.7 to 7.7 percent blending would amount to 20 million gallons per year, a 2 percent incremental demand above California's 900 million gallons of ethanol use in 2004.

[26] Assumes gasoline spot or rack price at $1.90 per gallon and the full value of the federal tax incentive (51 cents per gallon) applied to the ethanol portion of E-85.

[27] Prior to 2004, potential marketers of E-85 could not take full advantage of the blenders tax credit because of federal tax rules limiting the blenders ability to collect the tax credit when ethanol exceeds 10 percent in gasoline. The imposed Income tax refund mechanism effectively limited the value of the tax credit to between 60 and 80 percent of what a blender could receive through direct blending of ethanol into gasoline at 10 volume percent or less. With the passage of the Volumetric Ethanol Excise Tax Credit (VEETC) in the American Jobs Creation Act of 2004 (H.R. 4520), the full value of the excise tax credit will apply equally to all ethanol blending levels up to 85 percent ethanol. The Act also extended the ethanol tax incentive to December 31, 2010 at 51 cents per gallon and extended eligibility for the small producers tax credit to co-operatively owned ethanol plants. http://www.e85fuel.com/front_page/veetc/veetc_implementation121404.pdf.

[28] The four fleets involve three federal operations and one municipal utility (Sacramento Municipal Utility District) fleet in Sacramento. Vandenberg Air Force Base, Lawrence Berkeley National Laboratory, and Lawrence Livermore National Laboratory have all installed above ground E-85 storage tanks for fleet vehicle use only. One publicly accessible E-85 dispenser can be found at the San Diego Regional Transit Center.

[29] CARB EVR Program requires significant upgrades to all gasoline vapor recovery components and systems at all gasoline service stations in California over a 10-year period that began in 2000. The regulatory program is staged in seven specific elements culminating with the installation of In-Station Diagnostics no later than June 2010. E-85 fuel meets the definition of "gasoline" for purposes of the EVR regulation and thus E-85 dispensing systems are subject to requirements applicable to gasoline.

[30] Personal communication with Mr. Rodriquez of Emco Wheaton, October 12, 2205. Mr. Rodriquez indicated that because of the complexity and time required (180 days minimum) to satisfy regulatory

requirements for certification of a system, few manufacturers if any could commit time to certifying an E-85 system. Gasoline vapor recovery systems certification activities are currently top priority for the industry. Staff concludes that that certification process for an E-85 system may require one year or longer to complete, once industry participants/stakeholders are committed to the process.

[31] Personal Communication between Mike McCormack (Energy Commission) and Jose Guerrero (CARB), EVR Program staff on October 15, 2004.

[32] As an example, VeraSun Energy has partnered with Get-N-Go station to make E-85 available in Sioux City, South Dakota. VeraSun, owner/operator of the largest U.S. dry mill ethanol plant located in Aurora, South Dakota, has introduced an E-85 fuel named "VE85" through the Get-N-Go station chain. By May 5, 2005, 35 stations had been converted to dispense the fuel, and six stations offered the fuel to consumers that day. See www.verasun.com press release dated May 6, 2005. Holiday Stationstores, CENEX, Ashland Marathon, ConocoPhillips, and others have applied successful approaches in establishing E-85 dispensing capability in Minnesota and other Midwest states as well.

[33] Chippewa Valley Ethanol Company LLC. website: www.cvec.com, May 2005 Newsletter.

[34] http://www.cleanairchoice.org/outdoor/E85Fuel.asp and http://www.cleanairchoice.org/outdoor/
E-85 is largely distributed in the Midwest by multi-state convenience store operators, and several major refiners through branded stations. For example, CENEX and franchisees operate 34 stations, and Holiday Stationstores has 21 outlets offering E-85 in Minnesota and adjoining states.

[35] Stakeholders include the American Lung Association of Minnesota, the Twin Cities Clean Cities Coalition, DOE Clean Cities, the National Ethanol Vehicle Coalition, five Minnesota state agencies, Minnesota Corn Growers Association, Ford, DaimlerChrysler, GM, four cities including St. Paul and Minneapolis, and additional entities.

[36] The fuel substitution ratio of 1.34 represents the gasoline to E-85 fuel economy ratio of all 2005 new FFVs as derived from EPA 2005 model year certification data. The number also happens to be very close to the volumetric energy content ratio of gasoline to E-85.

[37] If cellulosic ethanol is aggressively pursued, ethanol production costs could be lowered dramatically once the technology matures. The federal tax incentive should decrease over time in this scenario, thus restoring revenue to the U.S. Treasury currently forgiven as a means to support ethanol production in the U.S.

[38] It is assumed that California gasoline prices remain higher than those in the rest of the U.S. through 2025. Thus, California remains the highest value market for petroleum and gasoline blending components including ethanol, and competing alternative fuels such as E-85. It is further assumed that even with occasional spikes in spot ethanol prices, California will always attract adequate supplies of ethanol even if many other states elect to incentivize ethanol (e.g. reduction of fuel excise taxes). Staff assumes that California gasoline price differential relative to the Gulf and East Coasts in general, will be higher than the "bid away" price of ethanol from these other states.

[39] Because FFVs are commercial today, competition and antitrust considerations make it difficult to ascertain exact plans of the automakers regarding upcoming new FFV products, engineering strategies and associated costs to achieve compliance with California new car emissions requirements.

[40] In discussions with CARB staff, Energy Commission staff concludes that enhanced vapor recovery certification of E-85 dispensing systems is possible, and that one or more stakeholders will take the initiative to certify one or more systems in 2005 or 2006.

[41] This could be an expansion of California's current ethanol working group providing stakeholder input for the *2005 Integrated Energy Policy Report* proceeding.

[42] Production of FFVs is likely to occur after 2009 even if CAFE credits fail to be retained in the longer term because of the broad support for FFV technology and ethanol based fuels in Midwest states. Staff has not attempted to estimate the impact that other states might have on future FFV production by GM, Ford, DaimlerChrysler, Nissan, and other manufacturers of FFVs.

[43] A more aggressive approach involving the use of tax incentives, such as that employed in Brazil to incentivize FFV production over standard Brazilian "gasohol" vehicles, could double or quadruple this number. Szwarc, *2005 Flex Fuel Vehicles in Brazil* power point presentation, Arlington, Virginia. February.

[44] Alfalfa and sugar beet growers in the Imperial Valley have been pursuing the development of a sugar cane to ethanol industry for about four years and could provide significant ethanol supplies. Project proponents have estimated ethanol volumes in excess of 400 million gallons from Imperial Valley alone. Not included in this estimate is cellulosic based ethanol that could be produced from California's vast biomass and municipal waste resources.

[45] If a very aggressive E-85 consumer education program was instituted and half of FFV owners purchased E-85 50 percent of the time (assuming an unknown but adequate number of convenient E-85 outlets), then E-85 demand would jump to 140 million gallons per year with corresponding ethanol demand of 120 million gallons, or 13 percent of California's 2004 ethanol demand for gasoline blending. Beyond 2008, E-85 use would gradually decline as older FFVs were retired from the fleet.

[46] On the other hand, $1.36 per gallon with an allowance of 15 cents for transportation indicates a Midwest ethanol plant gate price of $1.21 per gallon. Thus, even under the low gasoline price scenario lasting ten years in the price range of $1.75 to $1.80, a new 40 million gallon per year dry mill in the Midwest) stands to be profitable. If gasoline prices followed the high ($2.10 per gallon) or very high price scenario ($2.20 per gallon and higher), ethanol producer profitability approaches historical highs.

OPTION 2H - LNG AND CNG FOR MEDIUM- AND HEAVY-DUTY VEHICLES

Description

This paper updates the prior analysis contained in the *California Strategies to Reduce Petroleum Dependency (AB 2076)* report.[1] This paper explores a regulatory or incentive-based strategy intended to increase the use of natural gas in medium- and heavy-duty on-road vehicles. The analysis also assumes, based on staff monitoring of research and development activity by government and industry, negligible change in the status, implementation rate, and cost to implement advanced natural gas engine technologies onto heavy-duty vehicle platforms, since the prior analysis. The analysis period ends in 2025 rather than 2030 as in the previous analysis.

Background

On-road medium- and heavy-duty vehicles are defined as vehicles weighing greater than 8,500 pounds of gross vehicle weight. Expanded use of alternative fuels in medium-duty and heavy-duty trucks using more efficient, advanced natural gas engine technologies can reduce projected diesel fuel use from this sector. This Option explores the use of compressed natural gas (CNG) in medium-duty vehicles and liquefied natural gas (LNG) or CNG in heavy-duty vehicles. Each would replace a vehicle normally fueled with diesel.

Medium-duty and heavy-duty trucks move much of the nation's goods and are considered vital to the economy. Medium-duty trucks tend to be used in shorter trips with central refueling and hence are more likely to use CNG than LNG. Heavy-duty vehicles are used both for shorter trips and longer trips. They are more suited for LNG than CNG, because LNG has a volumetric energy content closer to diesel than does CNG. Much more diesel fuel is used by heavy-duty vehicles in long trips where central fueling is not an option.

Natural gas medium- and heavy-duty vehicles are an attractive environmental option to diesel fueled vehicles because they emit fewer criteria pollutants and toxic components. However, the limited availability of refueling facilities and typically higher vehicle purchase prices have affected the sale of this fuel option in these applications.

Staff limited this option to dedicated CNG and LNG vehicles in order to evaluate maximum diesel displacement. Dual fueled and bi-fueled vehicles would cost more to purchase as they have both a diesel and a CNG or LNG fueling system. Since they would use diesel, they would displace less diesel fuel. Furthermore, staff assumed that in a mature market condition, as discussed below, the cost of using natural gas would be significantly less than the cost of using diesel.

Status of Natural Gas Medium- and Heavy-Duty Vehicles

Some medium- and heavy-duty trucks use natural gas (NG) instead of diesel fuel. A small amount of pilot diesel fuel is used to initiate the combustion. Efforts are under way to limit the amount of pilot diesel fuel needed, and to minimize emissions. Today's economics tend to favor diesel fuel and opportunities to use NG are limited. Municipal vehicles, including trash haul applications, street sweepers, and utility trucks have all been demonstrated. Heavy-duty applications of NG include grocery stores such as Raley's and Von's using CNG, and line-haul trucking such as Harris Ranch with LNG.

Staff determined weighted-averages of the year 2000 vehicle fuel economies for the existing relevant diesel vehicle classes using several sources. In the analysis, staff began with base case vehicles that achieve12.7 miles per gallon (mpg) of diesel in Class 3-6 vehicles, and 6.5 miles per gallon of diesel in Class 7-8 vehicles.[2]

NG and NG vehicle stake holders have joined forces to establish two working groups to advance the state of NG heavy-duty vehicles. One is working to improve the vehicles, and the other is working to improve fueling infrastructure.

The U. S. Department of Energy (DOE) and other stake holders are working jointly to improve the performance of medium-duty and heavy-duty NG vehicle technologies.[3] Their near-term objective was to deploy one Class 3-6 by 2004 and one Class 7-8 vehicle by 2007, both will be designed to be commercially viable and meet year 2007 emissions targets while significantly advancing the performance capability of NG in these applications. Funding needs to continue this effort is $7 million in 2006 and 2007. They do not specifically identify efficiency targets. However, the performance goal is to match the efficiency of comparable diesel engines. If funded, they expect that vehicles developed under this program will lead to commercial offerings to achieve limited market scope with current incentive programs aimed at reducing emissions or displacing petroleum fuels.

Many of the stakeholders are also involved in improving the refueling infrastructure in an effort to build the market for NG vehicles.[4] This effort focuses upon improved gas compression methods and component integration for CNG and lowering the cost of LNG production by developing small-scale LNG production technology and lower cost equipment. Ensuring safety and reliability are important aspects of this work.

Assumptions and Methodology

Diesel demand reductions in 2010, 2020, and 2025 from on-road heavy-duty vehicles are estimated based on projected sales of NG heavy-duty vehicles, associated improvements in advanced NG engine fuel economy, existing and projected vehicle populations, infrastructure costs and other assumptions. Key assumptions and common methodology are summarized below.

- Fuel economies and vehicle miles traveled are weighted across vehicle classes.

- All new NG vehicles sold by 2020 are fully competitive with conventional diesel vehicles on performance, reliability and durability bases, and meet prevailing emission standards. Compression ignition-based LNG vehicles meet prevailing fuel economy performance of diesel engines. Spark ignition-based CNG engine platforms meet 95 percent of prevailing diesel engine fuel economy performance, due to heavier on-board fuel tanks and throttling losses associated with spark ignition.

- All new vehicles sold replace diesel-fueled vehicles because diesels dominate the vehicle population segment considered.

- Variable penetration rates in all vehicle classes with higher rates in some classes and time periods than others.[5]

- Certain costs are associated with achieving the assumed penetration rates and estimated petroleum displacements for NG vehicles. These include incremental capital cost, incremental fuel cost, incremental operation and maintenance costs and an incremental infrastructure cost. These costs vary among vehicle classes.

Near-Term Market or Business-As-Usual (BAU) Scenario

We define a near term market to account for current penetrations of NG vehicles through the year 2010, which is also the transition year to the matured market discussed later. These commercially available vehicles meet the prevailing emission standards and satisfy the demand in several niche and emerging applications. In a near term market, staff assumed that 2005 incremental capital costs of medium-duty CNG vehicles averaging $9,000 prevail through 2010. Similarly, it is assumed that the incremental cost of CNG and LNG Class 7-8 heavy-duty vehicles averaging $28,767, prevail through 2010. These costs are expressed in 2004 dollars.

We also assume that the sales of NG vehicles through 2010 is a nominal 2 percent of the vehicle population as these products benefit from several favorable factors. These factors include local and state government incentives, fuel cost advantage and $9,000 to $18,000 in reduced incremental cost compared to competing diesel products. The incremental price reduction comes from the corresponding price increase for competing medium- and heavy-duty diesel vehicles to meet the prevailing emission standards.

Mature Market or Aggressive Scenario

In a mature market, staff assumed that research and development (R&D) successfully reduces incremental capital costs of medium-duty CNG vehicles from a high of $11,000 in 1997 to $2,000 by 2025. Likewise, staff assumed that R&D successfully reduces incremental capital cost of CNG Class 7-8 heavy-duty vehicles from a high of $45,000 in 1997 to $11,000 by 2025. Similarly, the incremental capital cost of LNG Class 7-8 heavy-duty vehicles decreases from $28,767 in 1997 to $4,700 by 2025. All are expressed in 2004 dollars.

Staff developed CNG fuel costs using the same approach described in Option 2D, CNG for Light-Duty Vehicles. First, we used the California Energy Commission's (Energy Commission's) commercial end-use price forecast from 2004 to 2022, adjusted with plus and minus one standard deviation (scaled to gasoline price variability) to determine a range of NG commodity prices, assuming commercial operation of public refueling facilities. These were $0.53 to $0.77 per therm of gas. Next, we added expected capital recovery for station upgrades (estimated from current NG utility tariffs for CNG at utility-owned public refueling stations, with scaling to account for larger volume throughput) and added expected electricity and maintenance charges, based upon existing NG utility tariffs. This added another $1.03 to $1.13 per therm of gas. Next, we added state and federal fuel excise taxes, sales tax and NG regulatory fees to arrive at a final CNG price range of $1.56 to $1.90 per therm (equivalent to $2.14 to $2.61 per gallon of diesel on an energy content basis, expressed "DGE" or $1.88 to $2.29 per gallon gasoline equivalent).

For LNG staff developed the fuel price estimate for in-state production and out-of-state supplies for the California market.

For in-state production, we used the Energy Commission's commercial end-use price forecast from 2004 to 2022, adjusted with plus or minus one standard deviation (scaled to gasoline price variability) to determine a range of NG commodity prices, assuming commercial operation of public refueling facilities. These were $0.53 to $0.77 per therm of gas. We then converted this cost per therm to the cost per LNG gallon. Next, we added expected liquefaction and delivery cost of $0.23 to $0.39 per LNG gallon. We then added state and federal fuel excise taxes, sales tax and a retail markup of $0.119, $0.06 and $0.09 to arrive at final LNG per gallon price range of $1.01 to $1.39. This is equivalent to $1.55 to $2.17 per gallon of DGE without the markup. With the markup, the price on a diesel gallon equivalent basis ranges from $1.64 to $2.29.

For out-of-state production, we used the Energy Commission's commercial end-use price forecast from 2005 to 2025 for core gas cost, adjusted with plus and minus one standard deviation (scaled to gasoline price variability) to determine a range of NG commodity prices, assuming commercial operation of public refueling facilities. The core gas cost is on an LNG gallon basis. These were $0.45 to $0.76 per LNG gallon. Next, we added expected liquefaction and delivery cost of $0.45 to $0.76 per LNG gallon. We then added state and federal fuel excise taxes, sales tax and a retail markup of $0.119 and $0.06 to arrive at final LNG per gallon price range of $1.25 to $1.64. This is equivalent to $1.92 to $2.57 per gallon of DGE without the markup. With the markup, the price on a diesel gallon equivalent basis ranges from $2.09 to $2.73.

Penetration Rates and Scenarios

Developing a future vehicle penetration scenario for advanced, medium- and heavy-duty natural gas vehicle technologies is complex and challenging due to the number of factors that influence the penetrations and the overall scenario period. We used a simplified approach by limiting the total NG vehicle penetration to a maximum of 15 to 25 percent of the total vehicle population in the year 2025 for the BAU and *Aggressive* cases respectively. These maximum penetrations are historical values observed in the transit bus segment where NG vehicle technologies have been most successful. An average ramp up schedule of 2 percent of the existing vehicle population is used to estimate the penetration rates from 2008 to 2025 to achieve the new NG vehicle population. This period is divided further into three segments: 2008 to 2010; 2011 to 2020; 2021 to 2025. The 2005 to 2007 period penetrations are negligible (<1 percent of the existing vehicle population) as they are limited to prototype, demonstrations, and field trials.

The penetration period is divided into segments based on clearly defined factors. A minimum penetration rate of 1 percent of the vehicle population is assumed. This minimum rate is taken as half of the 2 percent nominal historical vehicle population growth rate reported in the 1996 World Vehicle Forecast and Strategies.[6] This rate corresponds to 14.3 percent of the new vehicle sales.

The penetration periods are defined based on regulatory milestone events, technology phase-in, maturation and availability, and alternative fuel infrastructure deployment. A more detailed description of the rationale used to formulate these penetration periods is provided below.

Superimposed onto the penetration period determinants are two key factors that interact to define the likely penetration scenarios for the analysis: Cost to meet the emission standards and consumer hesitation due to uncertainty about reliability, durability and expected performance in the early years.

Cost to Meet Emission Standards

Based on published industry information and analysis of costs to comply with emission standards by the U.S. Environmental Protection Agency (EPA),[7] the supporting analysis found that advanced NG vehicles in the matured market are likely to cost up to $15,000 more than NG vehicles manufactured before 2010. The post 2010 incremental cost is in addition to today's declining incremental vehicle costs of $11,000 (Class 3-6 vehicles) to $28,000 (Class 7-8 vehicles) for fuel system and on-board storage compared to conventional diesel vehicles. These higher but declining incremental costs are assumed to influence consumer purchase decisions and therefore modulate advanced vehicle penetrations. Comparably higher costs for diesel engines to meet the 2007 emission standards suggest price parity and even price advantage may materialize for medium- and heavy-duty NG vehicles in a range of applications. Literature reviews and industry data suggest that by the year 2010, Class 3-6 heavy-duty NG vehicles are likely to achieve price parity with comparable diesel engines.[8] Similarly, by 2010, available data suggest Class 7 and 8 NG vehicles are likely to achieve price parity or enjoy a price advantage over comparable diesel vehicles.[9] By 2025, NG vehicles in the full range of medium- and heavy-duty vehicle classes 3 through 8 are price competitive with their diesel counterparts.[10] The narrowing costs between the NG vehicles and competing diesel vehicles make the NG vehicles relatively attractive.

Consumer Hesitation

Historically, consumers hesitate to embrace a new technology until its reliability, durability and performance expectations are proven. This is even more so for heavy-duty NG vehicles that are employed in mission-driven applications. This market reality is expected to constrain the penetration of the advanced NG vehicles for up to the first three years after each product introduction.

These factors influenced the penetration rates in the three penetration periods. The following penetration scenarios are likely to emerge as a result of these factors individually and combined, during the three penetration periods the 2002 to 2025 planning period is divided into.

1. In the 2005-2007 time frame sales of advanced new NG vehicles are negligible, limited to prototypes, field trials and demonstrations. This penetration period is negligible for purposes of this analysis.

2. In the 2008-2010 period, we assumed the penetration rate of 1 percent and 2 percent of the vehicle population in the target year or 14.3 percent to 28.6 percent of the new vehicle sales for the BAU and *Aggressive Scenario* cases respectively. During this period, consumers buy 2.0 gm NOx per brake-horsepower-hr NG and diesel products, now in the market for five years, to hedge against the higher priced 0.2 gm NOx engines entering the market. As a consequence, sales of 0.2 gm NOx NG and competing diesel vehicles

decline sharply due to product performance uncertainties and customer purchase hesitations.

3. In the 2011-2020 period, we also assumed a penetration rate of 1 percent and 2 percent or 14.3 to 28.6 percent of new vehicle sales for the BAU and *Aggressive* cases respectively. During this period, vehicle sales are driven by fleets replacing aging 4.0 gm and 2.5 gm NOx NG and diesel engines.

4. In the 2021-2025 period, the nominal penetration rate continues as more fleets purchase newer vehicles to replace aging vehicles and to take advantage of the potential fuel savings from potential efficiency improvements and fuel costs (i.e., NG versus diesel fuel).

Results

The general impact on California's diesel and gasoline demand from using medium- and heavy-duty NG vehicles is summarized in Tables 1-4. *Net-Direct Benefits* to the state are characterized by *Direct-Non-Environmental Benefits*, a *Change in Government Revenue* due to reduced fuel taxes, *Direct Environmental Net Benefits* and the *External Cost of Petroleum Dependency*.

Table 1. Petroleum Reduction and Benefits for Medium- and Heavy-Duty NG Vehicles for Low Fuel Price and 5 Percent Discount Rate

Alternative Fuel Option or Scenario	Displacement in 2025, Billion Gallon Gasoline Equivalent	Reduction from Base Case Demand, Percent	Highest Cumulative Benefit or Change, Present Value, 2005-2025, 5% Discount Rate, Billion $2005				
			A	B	C	D	A+B+C+D
			Direct Non-Environmental Benefit	Change in Government Revenue	Direct Environmental Net Benefit	External Cost of Petroleum Dependency	Direct Net Benefit
Business As Usual	1.1	5.3	1.4	(1.3)	0.22	0.76	1.08
Aggressive	1.72	8.3	2.65	(2.48)	0.36	1.24	1.77

Table 2. Petroleum Reduction and Benefits for Medium- and Heavy-Duty NG Vehicles for Low Fuel Price and 12 Percent Discount Rate

Alternative Fuel Option or Scenario	Displacement in 2025, Billion Gallon Gasoline Equivalent	Reduction from Base Case Demand, Percent	Highest Cumulative Benefit or Change, Present Value, 2005-2025, 12% Discount Rate, Billion $2005				
			A	B	C	D	A+B+C+D
			Direct Non-Environmental Benefit	Change in Government Revenue	Direct Environmental Net Benefit	External Cost of Petroleum Dependency	Direct Net Benefit
Business As Usual	1.1	5.3	0.47	(0.66)	0.22	0.76	0.79
Aggressive	1.72	8.3	1.0	(1.2)	0.36	1.24	1.4

Table 3. Petroleum Reduction and Benefits for Medium- and Heavy-Duty NG Vehicles for High Fuel Price and 5 Percent Discount Rate

Alternative Fuel Option or Scenario	Displacement in 2025, Billion Gallon Gasoline Equivalent	Reduction from Base Case Demand, Percent	Highest Cumulative Benefit or Change, Present Value, 2005-2025, 5% Discount Rate, Billion $2005				
			A	B	C	D	A+B+C+D
			Direct Non-Environmental Benefit	Change in Government Revenue	Direct Environmental Net Benefit	External Cost of Petroleum Dependency	Direct Net Benefit
Business As Usual	1.1	5.3	0.27	(1.33)	0.22	0.76	(0.08)
Aggressive	1.72	8.3	0.59	(2.48)	0.36	1.24	(0.29)

Table 4. Petroleum Reduction and Benefits for Medium- and Heavy-Duty NG Vehicles for High Fuel Price and 12 Percent Discount Rate

Alternative Fuel Option or Scenario	Displacement in 2025, Billion Gallon Gasoline Equivalent	Reduction from Base Case Demand, Percent	Highest Cumulative Benefit or Change, Present Value, 2005-2025, 12% Discount Rate, Billion $2005				
			A	B	C	D	A+B+C+D
			Direct Non-Environmental Benefit	Change in Government Revenue	Direct Environmental Net Benefit	External Cost of Petroleum Dependency	Direct Net Benefit
Business As Usual	1.1	5.3	0.02	(0.6)	0.22	0.76	(0.3)
Aggressive	1.72	8.3	0.01	(1.2)	0.36	1.24	(0.4)

BAU Scenario

For the BAU Scenario, medium- and heavy-duty CNG and LNG vehicles reduce California's on-road diesel demand by 1.25 billion gallons or about 5.3 percent of the state's on-road gasoline and diesel demand in 2025.

Under this scenario, a 5 percent discount rate and low diesel fuel price of $1.82 per gallon, consumers are estimated to save $1.37 billion in 2025. The corresponding outcomes under this scenario, a 5 percent discount rate and high diesel fuel price of $2.18 per gallon, consumers save an estimated $0.27 billion in 2025. There is a loss in government revenue of $1.33 billion for both.

Under this scenario, a 12 percent discount rate and low diesel fuel price of $1.82 per gallon, consumers are estimated to save $0.53 billion in 2025. The corresponding outcomes under this scenario, a 12 percent discount rate and high diesel fuel price of $2.18 per gallon are estimated to be a $0.02 billion loss to consumers and $0.66 billion loss to government in 2025.

Aggressive Scenario

For the *Aggressive Scenario*, medium- and heavy-duty CNG and LNG vehicles reduce California's on-road diesel demand by 1.72 billion gallons or about 8.3 percent of the state's on-road gasoline and diesel demand in 2025.

Under the scenario of a 5 percent discount rate and low diesel fuel price of $1.82 per gallon, consumers are estimated to save $2.7 billion in 2025. There is a loss in government revenue of $2.48 billion. The corresponding outcomes, under the scenario of a 5 percent discount rate and high diesel fuel price of $2.18 per gallon, are estimated to be $0.59 billion in consumer savings in 2025. There is a loss in government revenue of $2.48 billion.

Under the scenario of a 12 percent discount rate and low diesel fuel price of $1.82 per gallon, consumers are estimated to save $1.02 billion in 2025. The government loses $1.2 billion in 2025. The corresponding outcomes, under the scenario of a 12 percent discount rate and high diesel fuel price of $2.18 per gallon, are estimated to be $0.014 billion in consumer savings and a $1.2 billion loss to government in 2025.

Key Drivers and Uncertainties

1. Assuming fuel economy of NG vehicles approaches that of diesel fueled vehicles.

2. Assuming NG vehicles are as fuel efficient as corresponding diesel vehicles.
3. Assuming Vehicle class distribution does not change.
4. Assuming vehicle miles traveled are the same for diesel and NG vehicles (affects demand reduction and incremental operating costs).
5. Assuming a more rapid fleet turnover in the years 2015-2025 as vehicle fleet ages and replacement is justified by lower operating cost from more fuel-efficient vehicles.

Endnotes

[1] *California Strategies to Reduce Petroleum Dependency* (AB 2076), Energy Commission and CARB, December, 2001.

[2] These are the weighted average fleet vehicle fuel economies determined in several analyses including the report *Profile and Segmentation of Medium and Heavy Vehicle Purchase Patterns and Current and Projected Populations* MacKay & Company, February 1995.

[3] Next-Generation NG Vehicle Program, Vehicle Working Group Workshop and Meeting, October, 2001.

[4] NG Vehicle Infrastructure Working Group and Vehicle Working Group, Summary of Recommendations to Overcome NG Vehicle Infrastructure Technology Obstacles, September 2001.

[5] As used in this analysis, vehicle penetration rate means a percentage of new vehicles entering the existing fleet population. For this scenario, 100 percent of new vehicles sold meet the assumed fuel economy targets used in the analysis. It is estimated that new vehicle sales are fewer than 10 percent of the existing population in any given year. The penetration rate is varied to reflect rapid turnover of the vehicle population. A higher penetration rate is assumed to occur in the years 2015-2025 from aging and the availability of more fuel-efficient vehicles. A composite vehicle class distribution is used in estimating the vehicle penetrations.

[6] Pemberton, Max. 1996 World Vehicle Forecasts and Strategies: The Next 20 years: A Special Report Covering the Period from 1960-2015. Ward's Communications. Pemberton Associates, Warwickshire, UK, 1996.

[7] *Regulatory Impact Analysis: Control of Emissions of Air Pollution from Highway Heavy-duty Engines* EPA, document EPA 420-R-00-10, July 2000.

[8] *California Strategies to Reduce Petroleum Dependency* (AB2076), Energy Commission and CARB, December, 2001.

[9] Ibid.

[10] Ibid.

OPTION 2I – GAS-TO-LIQUID AND COAL-TO-LIQUID DIESEL FUEL

Summary

In this option, staff considers various scenarios that would result in greater use of gas-to-liquid (GTL) and coal-to-liquid (CTL) diesel fuels. Blends of GTL or CTL fuels with petroleum diesel are considered the likely application for California's transportation fuels market. Staff evaluates the cost and benefits of a 10 cents per gallon subsidy applied to the GTL and CTL portion of a diesel fuel blend.

Overview

Natural gas is playing an increasingly important role in the global energy mix.[1] The earth has enormous reserves of natural gas and the extent of known reserves is increasing. Some natural gas reserves are under-utilized. Over the years, energy companies have accumulated large assets of "stranded gas," natural gas reserves that cannot economically be brought to market due to their distant locations. These stranded gas assets are candidates for future GTL production facilities.

The U.S. has enormous coal resources. Through CTL technology, the country potentially has over 1.5 trillion barrels of oil, using coal and shale deposits which offer energy security and energy diversity benefits. This volume is significantly greater than the estimates of 685 million barrels of oil reserves in the Middle East.[2] Both GTL and CTL are important and necessary stepping stones for the possible progression to biomass-to-liquid (BTL) derived fuels, which is discussed in detail in the *Renewable Diesel*[3] staff paper.

GTL and CTL fuels are made by the Fischer-Tropsch reaction, which converts gas into a synthetic diesel-like fuel. Recent advances in Fischer-Tropsch processes and GTL and CTL technologies promise environmentally clean, competitively priced diesel fuel. The GTL and CTL processes can produce a fuel identical in quality, physical properties, and specifications to traditional diesel.

Lower-cost fuels from GTL processes were commercially proven in 1996-1998.[4] This accomplishment sparked significant interest with nearly every major oil company. Today there are at least four new, multi-billion-dollar GTL plants which are either in the engineering-planning stage or under construction. The first of the new generation of GTL plants, using the improved process, is scheduled to begin production in 2006.

Background

Processing natural gas into petrochemicals has been a commercial option for many decades. Converting natural gas into gasoline or diesel has been slower to reach commercial status because it is much more expensive. The process for converting natural gas to gasoline or diesel was discovered in 1923 by Franz Fischer and Hans Tropsch. This chemical reaction is called the “Fischer-Tropsch” reaction and the resultant fuel is called either Fischer-Tropsch Diesel (a U.S. Department of Energy term) or gas-to-liquid (an industry term).

The GTL process has benefited from several improvements developed in the 1980s and mid-1990s, separately, by Sasol, Syntroleum, ARCO and Exxon. Since 1995 there has been a flurry of worldwide activity by nearly every major oil company with natural gas holdings to build GTL plants. Sasol Synfuels Incorporated significantly improved their commercial process in 1998. Since then, the capital expenditure cost of GTL has dropped from over $40,000 to less than $20,000 per barrel.[5] By comparison, new (world scale) petroleum refinery capital expenditures are $15,000 to $16,000 per barrel.[6] Conservative estimates of $24,000 to $26,000 per barrel for GTL are commonly cited in literature. As new GTL plants are built, these values are expected to decrease.

The United States Department of Energy (U.S. DOE) considers GTL to be 96-100 percent non-petroleum. In addition, U.S. DOE asserts that GTLs being substantially non-petroleum provides some energy security benefit.[7] According to U.S. General Accounting Office analysis, a GTL fuel’s non-petroleum nature could be more important than where it is produced.[8] Source diversity offered by GTL production from remote natural gas sources provides greater diversity of oil production within and among geographic regions that benefits all market participants.

U.S. DOE did not find that Fischer-Tropsch Diesel (FTD) yields “substantial environmental benefits" within the meaning of section 301(2) of the Energy Policy Act of 1992 (EPACT).[9] A finding that a candidate fuel offers ”substantial environmental benefits" is necessary to designate it as an alternative fuel under section 301(2). U.S. DOE will keep its FTD rulemaking docket active so that stakeholders may submit new data and information relevant to FTD. DOE will evaluate the data periodically to make future decisions with regard to FTD designation as an alternative fuel.

Coal-to-liquid (CTL)

Coal can also be gasified, then chemically converted into a diesel fuel via a Fischer-Tropsch chemical reaction. The process has been commercially used for over 20 years in South Africa. CTL is not a renewable fuel, but its process is amenable to commercial scale biomass-to-liquid (BTL) plants. At a minimum, the carbon dioxide

(CO_2) emissions from future CTL plants are assumed to be at the same level as those from conventional petroleum refining. Proponents claim that CO_2 mitigation technology exists and is optimally suited for CTL plants. In the *Renewable Diesel Vehicles*[10] staff paper, staff evaluates BTL plants presuming that CTL plants are built first and subsequently fed with biomass as favorable economics and environmentally policies are adopted.

Current and Future Plants

The three currently operating GTL plants use natural gas or coal and a late-1980's technology. Currently 80 percent of all GTL is produced using coal but all new plants planned internationally will use natural gas. At least four plants in the engineering design or construction stage target production for 2005-2012. Total new production is advertised at over 400,000 barrels per day, up to 75 percent of which can be diesel. The rest will be naphtha, waxes, or other petrochemicals. All the new proposed GTL plants will produce diesel, which is the most economic GTL fuel to produce and which has strong worldwide demand growth, especially for premium diesel.

In October 2003, Royal/Dutch Shell Group announced its agreement to construct a 140,000 barrel per day, $5 billion GTL plant in Ras Laaffan, Qatar. This new plant will use Shell's second generation proprietary Fischer-Tropsch catalysts, which were proven in Shell's Malaysia plant. Soon after Shell's announcement, Exxon and then ConocoPhillips made their own announcements for similarly sized GTL plants.

On July 14, 2004, Exxon Mobil Company Subsidiary announced its agreement to build the world's largest GTL plant, also in Ras Laaffan, Qatar. Exxon Mobil expects this $7 billion plant will produce 150,000 barrels per day of GTL products using Exxon's patented AGC-21 GTL process.

Two CTL projects are underway in the U.S.; one in Iowa and one in Wyoming (in the feasibility study stage), with the intended diesel products transported to California's markets by rail.

Properties of GTL Produced Fuels

Regardless of the feedstocks (natural gas, coal, or biomass) used in a Fischer-Tropsch GTL technology, the resultant fuel properties are superior to conventional ultra-low sulfur petroleum diesel. The GTL fuel properties listed in Table 1 illustrate some of the differences, when compared to California Air Resources Board (CARB) compliant diesel.

Table 1. GTL Fuel Properties Comparison

Fuel Properties	Cal Average Petroleum Diesel	GTL Diesel
Sulfur (ppm)	<15 & 130 State Avg.	0-5
Cetane No.	42 - 52	70+
Aromatics (%)	21	0-3

Emission reductions, with the use of neat GTL based on the average of six test programs, are shown in Table 2. Based on Shell's emission testing of GTL blends relative to European diesel, the most cost-effective blends for maximum emissions reduction are 30 to 50 percent GTL blends. However, specific testing is lacking for California's diesel reference case. Table 2 lists the typical emission reductions, using neat GTL fuel, from various test programs. However, based on CARB's Diesel Toxicity Reduction Program's requirement of retrofitted aftertreatment systems after 2010, no emission reduction is likely with the use of GTL fuels.

Table 2. GTL Exhaust Emission Reductions Relative to CARB Diesel

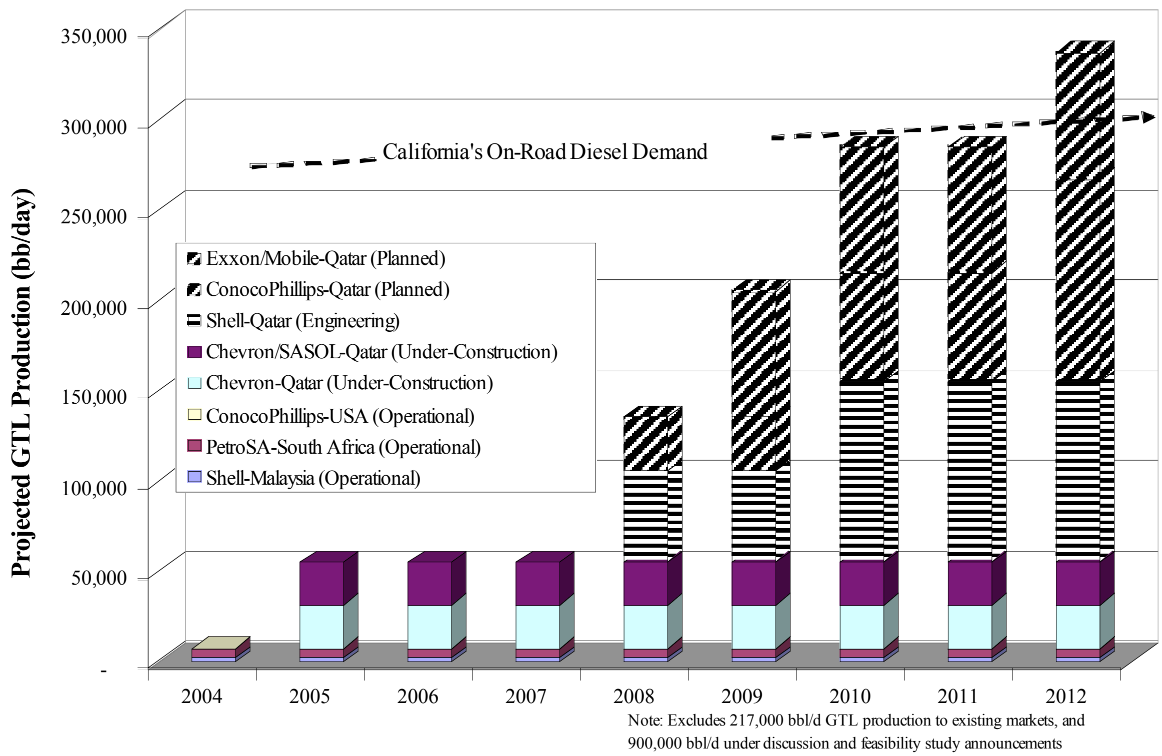
	Hydro-carbons	Carbon Monoxide	Oxides of Nitrogen	Particulate Matter	Carbon Dioxide
GTL (neat)	25 %	35 %	10 %	30 %	0-10 %[11]

According to the U.S. Environmental Protection Agency (EPA), a diesel fuel formulated with GTL derived from natural gas would normally satisfy federal requirements for registration as a baseline diesel fuel.[12] No federal limitation exists on the amount of GTL fuel that can be combined with petroleum diesel.

Supply

By 2010, worldwide production of GTL may increase significantly. Between now and 2012, some sources forecast GTL production to equal or exceed California's on-road diesel demand. (See Fig. 1) Although this new supply will flow to profitable markets and generally not to California, the state could establish policies that improve the prospects of using GTL to meet growing diesel demand.

Fig. 1 **Estimated Gas to Liquid Production of Diesel**



California Opportunity

From 1993 to 1998 four California refiners blended small quantities of GTL intermittently. When GTL costs were favorable, refiners could profitably blend GTL with U.S. EPA compliant diesel to make higher value CARB diesel. Small quantities of GTL blends, around 30 percent blended with petroleum diesel, were typically used during this period. GTL fuel can be blended in any ratio and generally maintains compliance with diesel fuel specifications.

Today, 5,000 barrels per day of GTL fuel is commercially available, but none is being used in California. On a few rare occasions in 2003, refineries blended GTL to produce diesel or bunker oil. This practice, however, has been largely discontinued, especially since Shell has created a GTL market in Thailand.

Shell markets Pura Diesel^{TM}, a blend of GTL fuel with conventional diesel, in over 150 retail stations in Thailand. In this market, consumers use this product in diesel vehicles to reduce smoke emissions. In major cities in Thailand, fines are issued to operators of diesel vehicles that produce excessive smoke. To avoid these fines, some drivers of diesel vehicles are prepared to pay a premium for this product.

While some consumers in Thailand will pay a premium for GTL fuel, Shell does not believe that this will be the case in other markets. In most markets, such as California, the majority of demand for diesel is from commercial users. These users are generally very price sensitive, operating on small margins, and experience suggests they will not pay a price premium for GTL fuel.

Since 2000, GTL demonstrations in California have shown very positive results. However, despite GTL's ease of use, and the benefits of reduced emissions and non-petroleum use, no state agencies or private consumers use this fuel today. In 2001, interested fleets could not use GTL as an emissions compliance mitigation strategy due to the fuel's lack of CARB emissions verification, and absence of air quality management policies accepting GTL's use as a mitigation or fleet compliance option.

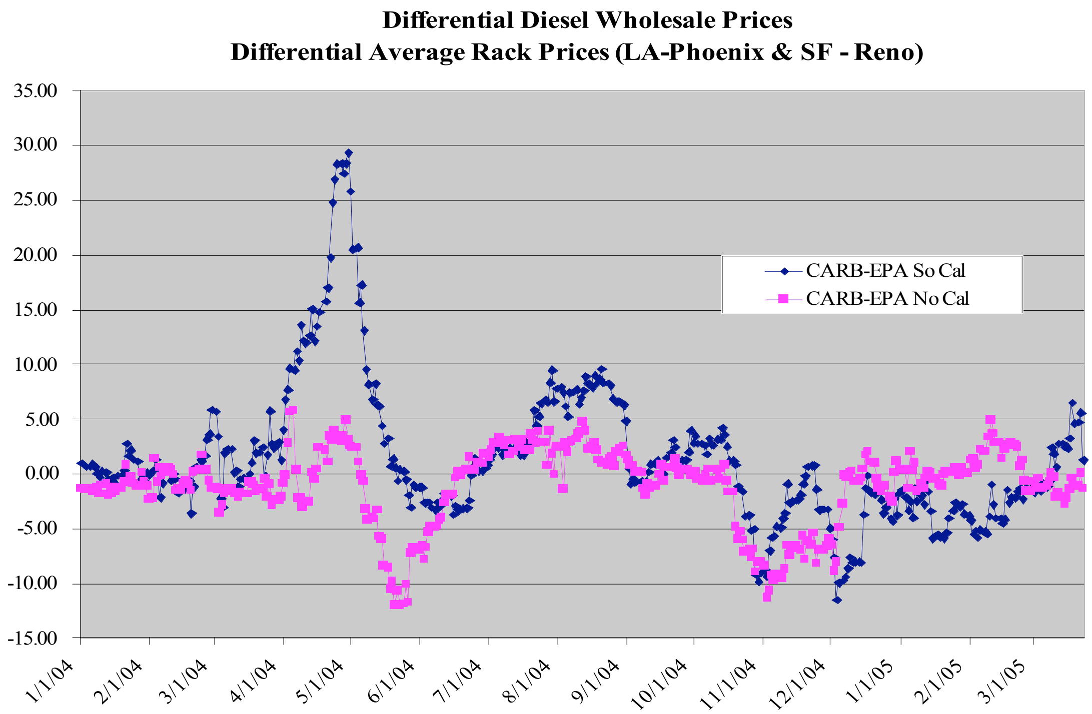
Status

Today, the major barriers to widespread use of GTL fuel are its higher cost and lack of availability. However, the first of the new wave of advanced GTL plants is scheduled to produce fuel this year and more plants are anticipated in 2007-2009.

Several refiners imported small volumes of GTL fuel from 1993 through 1998 to blend with heavier, less desirable crude oil to make greater volumes of California's unique low-aromatic diesel. CARB regulations require that diesel sold in California be limited to 10 percent by weight total aromatics, or meet an alternative formulation that produces equivalent emission benefits (i.e., an alternative formulation has 21 percent aromatics and 52 Cetane). Generally, all diesel sold in California meets CARB's optional specifications for total aromatic content and cetane number in lieu of the 10 percent diesel aromatic content.

Periodically, GTL fuel was economically blended when there was a sufficient price differential between CARB and U.S. EPA diesel. However, usually lower-price conventional crude sources exist and it is too risky to match the few high diesel price opportunities with the long lead time for GTL deliveries. Fig. 2 shows the differential wholesale rack price for CARB diesel and U.S. EPA diesel supplied in and out of California. For 2003 through 2005, the rack price of U.S. EPA diesel was significantly (over 5 cents per gallon) higher than CARB diesel 22 percent of the time[13] in Southern California. These price differentials can represent a GTL opportunity, however, blending GTL into lower grade fuels to make CARB diesel does not appear to be a consistently attractive option by itself.

Fig. 2



Assumptions

Given California's higher gasoline demand (61 percent of total demand) compared to diesel demand (18 percent of total demand), staff does not expect significant use of GTL beyond intermittent uses and plant turn-around practices unless demand significantly shifts away from gasoline and towards diesel. For California's market, staff foresees significant GTL use to be dependent on the increased use of light duty diesel vehicles (see the *Light-Duty Diesel Vehicles*[14] staff paper for more details). It is assumed that lower-priced conventional crude sources will always be available to refiners in California and that GTL, given its highly sought-after fuel properties, will command a premium price, at least at the refinery level.

For this analysis, staff assumes that, in 2008, GTL fuel is available to refineries at 5 cents per gallon over conventional, petroleum-derived diesel. This cost premium is expected to linearly decline to 2 cents within 10 years as additional GTL capacity is built and most conventional refineries (worldwide) are configured to produce ultra-low sulfur diesel fuel.

Staff estimated the ratio of GTL diesel blended with U.S. EPA diesel to comply with CARB specifications for an alternative diesel formulation. Typical values for the total aromatic content and cetane numbers (CN) for GTL fuel and U.S. EPA diesel are shown in Table 3. Based upon these specifications and a finished blended diesel with 20 percent aromatic content and a CN of 55, the ratio of GTL diesel to be blended with U.S. EPA diesel is 1:2 (one gallon of GTL is blended with two gallons of EPA diesel). The resulting mixture can be called GTL33. The desired aromatic and cetane values are within the ranges for CARB alternative diesel formulation specifications.[15]

If the suitable blending ratio of GTL fuel to U.S. EPA diesel is 1:2, the value of GTL fuel as a blendstock can be calculated from the sum of the wholesale price of U.S. EPA diesel and three times (a gallon of GTL fuel can used to produce three gallons of CARB diesel) the price differential between CARB and U.S. EPA diesel. For this example, the calculated GTL fuel value would have a range of $1.70 to $1.80 per gallon (before taxes).

Table 3. Diesel Fuel Specifications

Component	**Percentage**	**Aromatic Content, %**	**Cetane No.**	**Wholesale Price/gallon, $**
EPA Diesel	66.7	30	42.5	1.45
GTL Fuel	33.3	0	80	1.60
Blended Diesel (GTL33)	100	20	55	1.50

The wholesale cost differential between GTL fuel and CARB diesel is assumed to be 10 cents per gallon.[16] Because the blending value of GTL brackets this cost, GTL fuel can be an attractive blending component to produce CARB diesel.

Staff assumed that a refinery would blend GTL with lower-quality, less-processed streams to produce a higher quality CARB or U.S. EPA diesel fuel. Additionally, the refiner is assumed to save 2 cents per gallon in avoided processing (hydrotreating). A GTL tax subsidy of 5 cents per gallon (+/- 3 cents) of GTL is assumed. These subsidies could be funded by either 1) establishing tax parity for GTL fuels with compressed natural gas, liquid natural gas, and propane fuels, or 2) establishing a blender's credit similar to ethanol fuel sales. Consequently, the 33 percent GTL blended fuel would have 1.65 cents higher cost GTL base, 0.66 cents less refining expense, and 1.65 cents less excise tax, for a total of 0.66 cents less cost per GTL blended gallon of fuel. The final GTL fuel would retail at the identical price as CARB diesel.

Staff examined the cost effectiveness of GTL fuel under a mature market condition, which may be just emerging for this fuel by 2020. A present value calculation was performed on the incremental cost of using GTL33 over the life of a heavy-duty vehicle compared to conventional CARB diesel. Vehicle life was assumed to be 15 years. With the possible exception of a fuel price increment, the analysis used no other incremental costs related to vehicle acquisition or deployment of fueling infrastructure.

The analysis for a mature market assumes that the incremental cost of GTL fuel is 15 cents per gallon higher than U.S. EPA diesel. The U.S. EPA diesel that would be blended with the GTL fuel is assumed to cost 5 cents per gallon less than CARB diesel. From the refiners' perspective, the resulting three gallons of CARB diesel cost would have the equivalent cost of conventionally produced diesel.

Beginning in 2008, the use of GTL33 grows until it becomes the normal diesel fuel standard by 2019. At this time, the entire diesel fuel supply sold in California becomes GTL33. Thus, in this scenario, one-third of the projected base case diesel demand would be met by GTL fuel and the remaining balance by conventional petroleum diesel.

Life Cycle Emissions Considerations

Staff reviewed various life cycle analyses (LCAs) of the greenhouse gas (GHG) emissions from the production and distribution of GTL fuels. Results vary from GTL production being either GHG neutral to a plus or minus 10 percent penalty/benefit.[17] Considering all the referenced studies, staff assumed for this analysis that GTL fuel production will be GHG neutral and evaluated plus or minus 5 and 10 percent. The plus or minus 10 percent values fully capture the ranges of variation GHGs attributed to GTL production cited in the studies, and the plus or minus 5 percent captures the range of uncertainty that staff views as the most appropriate. To the extent that GTL fuels enables greater use of light duty diesels, an additional 30 percent reduction in GHG is possible.

Results

The results are shown in Tables 5 and 6 based on the Table 4 GTL & CTL assumed penetration rates. The results show that retailing GTL and CTL fuels at nominal petroleum based prices with a 10 cents/gallon subsidy applied provide net benefits with the assumed values for petroleum reduction and environmental impacts.

Table 4. Diesel Reduction from GTL and CTL Diesels

	Year		
	2015	**2020**	**2025**
Annual Reduction (millions of gallons of diesel)	571	878	1650
Reduction From Base Case Demand (percent)	15	20	33

Table 5. Petroleum Reduction and Benefits for GTL and CTL Diesel at 5 Percent Discount Rate

Alternative Fuel Option or Scenario	Displacement in 2025, billion gallon gasoline equivalent	Reduction from Base Case Demand, percent	Highest Cumulative Benefit or Change, Present Value, 2005-2025, 5% discount rate, Billion $2005				
			A	B	C	D	A+B+C+D
			Direct Non-Environmental Benefit	Change in Government Revenue	Direct Environmental Net Benefit	External Cost of Petroleum Dependency	Direct Net Benefit
Low Fuel Price ($1.88/gal diesel)	1.7	33	0	(0.2)	0.1	0.9	0.8
High Fuel Price ($2.20/gal diesel)	1.6	33	0	(0.2)	0.1	0.9	0.8
Highest Fuel Price ($2.43/gal diesel)	1.7	33	0	(0.2)	0.1	0.9	0.8

Table 6. Petroleum Reduction and Benefits for GTL and CTL Diesel at 12 Percent Discount Rate

Alternative Fuel Option or Scenario	Displacement in 2025, billion gallon gasoline equivalent	Reduction from Base Case Demand, percent	Highest Cumulative Benefit or Change, Present Value, 2005-2025, 12% discount rate, Billion $2005				
			A	B	C	D	A+B+C+D
			Direct Non-Environmental Benefit	Change in Government Revenue	Direct Environmental Net Benefit	External Cost of Petroleum Dependency	Direct Net Benefit
Low Fuel Price ($1.88/gal diesel)	1.7	33	0	(0.08)	0	0.43	0.35
High Fuel Price ($2.20/gal diesel)	1.6	33	0	(0.08)	0	0.43	0.35
Highest Fuel Price ($2.43/gal diesel)	1.7	33	0	(0.08)	0	0.43	0.35

Key Drivers and Uncertainties

The projected demand for GTL fuel depends on the following outcomes and assumptions:

- The worldwide production capacity for GTL fuel is built as shown in Figure 1. It is reasonable to assume that investment in additional production capacity is likely when crude oil prices are sustained at $20 per barrel or higher. The pace of investment would increase with higher oil prices.

- Sufficient numbers of light- duty diesel vehicles are sold in the U.S. and California to create enough market-pull for GTL.

- GTL fuel would flow to California if its value were sufficiently attractive for distributors and refiners. This can be assured if the fuel excise tax placed on diesel blended with up to 33 percent GTL fuel was reduced by 1 to 3 cents per gallon (effectively, a 2 to 6 cent per gallon reduction in the cost of GTL 100). This should give refiners a sufficient economic advantage to use GTL fuel to produce a diesel fuel meeting California's alternative diesel formulation requirements.

- GTL needs tax parity with compressed natural gas, liquid natural gas and liquid propane gases for it to compete in California's petroleum market. Can legislation be passed that brings Excise Tax Parity to GTL fuels?

Endnotes

[1] Sasol SynFuels International, November 1998.

[2] Dr. Theodore Barna, Clean Fuel Initiative, Department of Defense, Congressional Briefing. February 2005.

[3] See *Options to Reduce Petroleum Fuel Use Addendum*, Option 2J Renewable Diesel Fuels, May 2005, CEC 600-2005-024 AD.

[4] Sasol commercially demonstrated the advanced slurry bed reactors in 1997.

[5] Meeting with Syntroleum Corporation June 26, 2000.

[6] Staff conversation with Chevron Oil Company staff, June 13, 2000.

[7] Discussion of Issues Pertinent to Rulemaking to Designate Fischer-Tropsch Diesel Fuel as Alternative Fuel Under Sec. 301 (2) of the Energy Policy Act of 1992, U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, July 2002. p. 4.

[8] The U.S. General Accounting Office (GAO) determined: "In essence, the economic cost of oil price shocks depend largely upon the rise in the price oil coupled with the nation's dependence on oil consumption, rather than the level of imports. As long as market forces prevail, the price of domestic and world oil will be the same and will rise and fall with changes in the world oil market conditions." ENERGY SECURITY, Evaluating U.S. Vulnerability to Oil Supply Disruptions and Options for Mitigating Their Effects, GAO/RCED-97-6, December 1996, p.3.

[9] Notice of proposed notice of availability of status review, February 14, 2005, Federal Register.

[10] See *Options to Reduce Petroleum Fuel Use Addendum*, Option 2J Renewable Diesel Fuels, May 2005, CEC 600-2005-024 AD.

[11] Life Cycle Analysis's completed post 2002 conclude that GTL's global warming gas emissions are at par with conventional diesel to slightly less, depending on the market and co-products produced. PriceWaterhouseCoopers – studies of a Qatar GTL plant supplying fuel to Europe and USA.

[12] "Personal Communication" (e-mail) with Jim Caldwell, U.S. EPA, June 20, 2002. Baseline Diesel Requirements contained in Title 40 CFR 79.56(e)(3)(ii)(A).

[13] Only 8 percent of the time was EPA rack price more than 10 cents/gallon during 2003-3/2005.

[14] See *Options to Reduce Petroleum Fuel Use Addendum*, Option 1F Light-Duty Diesel Vehicles, May 2005, CEC 600-2005-024 AD.

[15] [www.arb.ca.gov], Certified Alternative Diesel Formulations, February 2002.

[16] The wholesale price of CARB diesel is derived from the long-term retail price used in the base case demand analysis, $1.65 per gallon. The retail price results from a (wholesale price + retail margin + federal excise tax + state excise tax) x (state sales tax rate). The wholesale price would include margins for producing and distributing the fuel to consumers, $.15 per gallon. The federal and state excise taxes for diesel fuel are $0.243 and $0.18 per gallon, respectively. A state sales tax rate of 7.75 percent was employed.

[17] Michael Wang, ANL, Greet Model; GM Well-to-Wheels Analysis of Energy Use and Greenhouse Gas Emissions of Advanced Fuel/Vehicle Systems – European Study, September 27, 2002.;

European Commission Joint Research Centre, Well-To-Wheels Analysis of Future Automobile Fuels and Powertrains in the European Context, January 2004.; PriceWaterhouseCoopers, Shell Middle Distillate Synthesis, Update of a Life Cycle Approach to Assess the Environmental Inputs and Outputs, and Associated Environmental Impacts, of Production and Use of Distillates from a Complex Refinery and SMDS Route, May 21, 2003.; PriceWaterhouseCoopers, Sasol-Chevron.; ConocoPhillips; Five Winds International, Gas to Liquids, Life Cycle Assessment Synthesis Report, December 2004.

OPTION 2J - RENEWABLE DIESEL FUELS (BIODIESEL AND OTHER BIOGAS-TO-LIQUID FUELS)

Description

This option examines the status of renewable diesel fuels and possible state actions that may lead to their expanded use. Renewable diesel fuels are 1) biodiesel, 2) biomass-to-liquid (BTL), and 3) thermal conversion process (TCP) fuels.[1] The staff performed a cost benefit analysis for these fuel options assuming 20 cents per gallon premium cost over conventional diesel for up to a 20 percent renewable content. This analysis considers broadening the definition of what qualifies for additional tax credits, and extending the term, under the American Jobs Creation Act of 2004 (Pub. L. 108-357).

Background

Renewable diesel fuels are produced from a variety of resources, and are used either as a blend or as a pure (neat) fuel. However, for this analysis, renewable diesel fuels are considered as blends up to 20 percent. All three renewable fuels offer greenhouse gas (GHG) reduction potential. However, according to a recent European study, the advanced biomass conversion fuels (BTL & TCP) were found to have greater GHG reduction potential for similar energy use than biodiesel.[2] These renewable fuels share three advantages:

- They do not require any unique distribution infrastructure except what is necessary to transport them to refineries or fuel depots;

- They require little or no modifications to existing infrastructure and new vehicles; and

- Being mixable with conventional fuels, they can be used in various proportions depending on their local and seasonal availability.

Future use of renewable fuels is particularly important with the significant growth in demand anticipated worldwide and statewide for transportation fuels. The U.S. Department of Energy's (DOE's) Energy Information Administration (EIA) projects that the nation's dependence on foreign oil will grow from today's 53 percent share to 70 percent by 2025.[3] This frames the context of using domestic fuel sources to increase supply and reduce future risk resulting from increased reliance on foreign oil.

Discussion on Renewable Diesel Fuels Options

Biodiesel

In the United States (U.S.), biodiesel is typically made from soybean oil, recycled cooking oils, and animal fats. However, palm or rapeseed oils, are used in other countries. Biodiesel is made by reacting these materials with alcohol (usually methanol). Biodiesel generally has characteristics that make it superior to common diesel fuel. It has relatively low aromatics and sulfur content. This improves its emission performance when used in engines. Biodiesel also has a relatively high cetane rating of 52, making it a good fuel in compression ignition engines (also called diesel engines). A 2 percent by volume biodiesel blended into conventional, petroleum-derived diesel provides an alternative fuel with improved lubricity.[4]

Biodiesel can be used in most applications in the same manner as conventional petroleum diesel. In cold weather, diesel fuel and biodiesel can cloud or even gel. Low blends of biodiesel generally react to cold weather very similar to diesel. Solutions for winter operability with biodiesel and blends are much the same as conventional diesel fuel. Also, there may be some materials compatibility issues with seals and gaskets in engines manufactured before 1994 when blends higher than B20 are used. The current practice is to limit the percentage of biodiesel to no more than 20 percent (B20) to avoid these problems.

Today, most major engine companies have stated that the use of blends up to B20 will not void their parts and workmanship warranties. This includes blends below 20 percent biodiesel, such as the 2 percent (B2) or 5 percent (B5) biodiesel blends that are becoming more common. Biodiesel is presently produced, marketed, and used in California, but less than five million gallons of biodiesel were used in California in 2004. Biodiesel's maximum diesel displacement is frequently characterized, by the biodiesel industry, as a 5 to 10 percent diesel displacement option on a nationwide basis.

Biodiesel contains 7 percent less energy per gallon than California Air Resources Board (CARB) diesel. For this analysis, staff assumed an energy content (lower heating value) of 118,200 British Thermal Units (BTUs) per biodiesel gallon,[5,6] and for conventional CARB diesel 127,500 BTUs per gallon.

The DOE Office of Transportation Technologies has estimated the net energy balance for biodiesel production as one gallon of petroleum fuel is required to produce 3.37 gallons of biodiesel.[7] Additionally, the DOE and the U.S. Department of Agriculture completed a Lifecycle Inventory Study for Biodiesel and concluded the overall lifecycle emissions of carbon dioxide (a major GHG) from biodiesel are 78 percent lower than the overall carbon dioxide emissions from petroleum diesel. Biodiesel has successfully completed the U.S. Environmental Protection Agency's

(EPA's) Tier 1 and Tier 2 Health Effects Studies. It also has an established American Society for Testing and Materials (ASTM) fuel specification, ASTM D6751.

BTL Diesel

BTL Diesel is produced from a broad range of feedstocks, including animal waste, wood wastes, crop residuals, plastics, tires, treated sewage sludge, and other hydrocarbons. The BTL fuel is produced through a biomass gasification process. For example, wood or other dense biomass waste is gasified and converted into a liquid using a Fischer-Tropsch reaction. The liquid can then be refined into a high quality diesel blendstock with a cetane rating of 75 or higher and zero aromatics and sulfur content. To date, BTL has been produced in Europe (6,500 barrels per day), but none is produced in the U.S. Based on a small BTL pilot plant built in Germany, BTL fuel is anticipated to have 0-30 percent higher costs than diesel.[8] BTL has the potential to be the most productive per acre of the renewable diesel fuel options and produces a higher quality fuel. However, BTL production has significant capital cost, plant complexity, and risk compared to conventional crude production and refining. A recent *European Wells-to-Wheels* study determined that BTL has significant GHG emissions reduction potential.[9]

TCP Fuel, Also Referred as Hydrous Thermal Upgrading (HTU)

TCP is produced from a broad range of feedstocks, including animal waste, animal carcasses, wood wastes, agricultural waste, plastics, tires, sewage sludge, and other waste containing hydrocarbons, fats, carbohydrates, or protein. The liquid produced is light renewable oil. The TCP process uses pressure and temperature to break down and then further process the feed in a refinery coker unit. The TCP produces a diesel-like crude oil that may be used directly or refined into conventional diesel fuel. Several TCP demonstration plants operating in the U.S. and Europe show promise and the economics appear competitive with forecasted gasoline and diesel prices.[10] The staff opinion is that the TCP process fuel has the potential to provide the lowest cost biofuel option.

Note: Although not fully evaluated, the Jatrophia tree is another potential biomass source that may be applicable to California. D1 Oil's Ltd. is promoting this additional biofuel diesel source. Although not as productive as palm oil, the most productive oil bearing plant per hectare, this potential biofuel can be grown on more arid, poor soil conditioned areas which significantly increases its petroleum displacement potential. The D1 Oil Company is claiming rights to 37,000 hectare of land in Africa, India, and Southeast Asia for Jatropha production. D1 Oil has announced that it will assist the Indian state of Tamil Nadul to promote the cultivation of Jatropha on 33 million hectares of degraded land which is available for reclamation. Each hectare can produce 3,000 liters of oil (800 gallons). The D1 Oil Company also has options for plantation rights for an additional 6 million hectares. In aggregate, 40 million hectares of land could produce 32 billion gallons/year of diesel fuel.[11]

Status

Biodiesel

In 2004 in the U.S., 27 commercial biodiesel plants produced over 33 million gallons.[12] Neat biodiesel has a retail price of $2.75 per gallon depending on purchase volume and delivery costs.[13] Presently, B20 retails for 13 to 22 cents per gallon more than petroleum diesel.[14,15] However, in 2004, federal legislation was enacted providing a 1 cent per gallon reduction in fuel excise tax for each percentage point of biodiesel used in diesel fuel, limited to 20 percent.[16] This legislation effectively reduces the cost of biodiesel for blenders by up to $1.00 per gallon for two years.

The DOE is conducting research to reduce the cost of producing biodiesel and to expand supplies using novel feedstocks and new production technologies. A portion of the work is directed at reducing oxides of nitrogen (NO_x) exhaust emissions.

BTL

No commercial scale production of BTL fuel exists in the U.S. today. Worldwide, a few small demonstration facilities have produced small quantities of BTL. New large scale plants are under development in China and the European Union (EU) using timber as a feed source. At a recent conference, BTL was characterized at a slightly higher (7 percent) price than conventional diesel, yet significantly lower than biodiesel prices.[17] Recent federal excise tax credits are limited to biodiesel and do not apply to other renewable fuels like BTL. Remedies include expanding and extending the blender's credit for all renewable fuels to bring parity.

TCP

One commercial plant exists in Carthage, Missouri (Changing World Technology and Con Agri Foods) producing 4-7 million gallons/year of #4 crude oil made from the turkey processing plant waste. In 2005 the plant sold this crude oil [with 300 parts per million (ppm) sulfur crude oil] to a local refinery at an introductory market price of $28 per barrel – in a $35/barrel petroleum market. This refinery may further process the crude with other petroleum into conventional diesel fuel. At a recent European conference, the TCP process, referenced as HTU, was characterized with a slightly higher price (7 percent) than conventional diesel, but 30 percent lower price than conventional diesel by 2015-2025.[18] However, TCP fuel cost is highly dependent on other value-added streams, which leads to great uncertainty on its final fuel cost in America. In America, unlike in Europe, there is no ban on feeding animal waste to animals, consequently the TCP plant secures animal waste at a cost instead of revenue to the plant. Compounding this is the federal excise tax credits that are limited to biodiesel and do not apply to the TCP processed fuels.

The TCP allows the food processing industry to address several of its environmental, health, and economic issues. Changing World Technology claims that if the TCP process were applied to U.S. agriculture waste residues, estimated by the EPA to be in excess of six billion tons, up to four billion gallons of fuel could be produced. Applying the TCP process to California's 35 million tons of paper, plastics, organics, and tires, Changing World Technology claims they could produce 2.2 billion gallons of diesel fuel. The existing TCP plant's design simplicity and product upgrading through refineries are viewed as positive attributes.

The potential supply of renewable diesel fuels is shown in Table 1. The volumes in this table are technically feasible, but uncertain.

Table 1. Potential Volumes of Renewable Diesel (million gallons/year) [19]

Year	Biodiesel[1]	BTL	TCP	Total Renewable	20% CA Diesel
2005	30	0	7.5[1]	37.5	640
2015	65	Unknown	1,000[2]	2,065	800
2025	700	Unknown	2,200[2]	2,900	1,000
[1] National Supply [2] California Supply [20]					

Assumptions

The staff assumed a 20 percent renewable diesel content goal is achieved with the expansion (and extension) of biodiesel tax credits similar to what is offered in the 2004 American Jobs Creation Act and that all renewable-based fuels receive the credit. However, for very large, capital intensive projects like BTL and HTU plants, a two-year support window is insufficient. Consequently the staff assumed that the tax credits were extended for up to 10 years to help cover the debt costs. The incentive is worth 1-cent per gallon per percent renewable content - with a 20 percent cap. This effectively provides a dollar subsidy per neat renewable gallon.

The staff assumed that biodiesel ranging from B2 to B5 is an accepted industry standard for California diesel fuel. Staff envisioned the TCP and BTL sources are used to make up the balance of the 20 percent displacement goal. However, B20 and higher blends use is assumed to be discretionary where available and cost-effective. Fleets complying with the Energy Policy Act of 1992 – currently using B20 – are envisioned to use any renewable fuel blend of 20 percent. Examples of combinations include blends from either biodiesel, TCP, BTL, or any combination of the three.

The staff assumed that biodiesel use increases from 2005 through 2010 reaching a maximum of 5 percent (150 million gallons) statewide displacement. In the earlier years, the national supply of biodiesel may limit the volume that could be used as a blending agent, although supplies should be sufficient for the full 5 percent blending rate by 2010. In the mature biodiesel market, blends up to 5 percent are assumed to use less than 10 percent of the projected national supply of B100.

All renewable diesel fuels discussed herein are assumed to be compatible with existing diesel engines without modification up to 20 percent. There is no incremental cost related to vehicle purchase. The existing diesel fuel retail infrastructure is also assumed to store and dispense renewable diesel fuel blends without modification. However, the terminals and racks may incur an additional storage and dispenser cost that staff estimates at $50,000[21] - $500,000 per terminal facility (biodiesel only). It is unclear if the TCP and BTL fuels will have additional storage cost at the refinery; staff assumed there were none for the analysis.

Table 2 shows the estimated exhaust emission reductions from renewable diesel fuels used in this analysis. Negative numbers indicate increased emissions. Preliminary test results indicate that these reductions are possible. Biodiesel generally has exhaust emission reduction in proportion to its concentration.[22] NOx emissions from biodiesel blends are comparable to CARB diesel[2] or slightly higher.[23,24] The range in emission levels vary, depending on the feedstock used to produce the biodiesel and the quality of the petroleum diesel used in the mixture.

CARB's Diesel Toxicity Reduction Program has established a goal to reduce the diesel fleet's exhaust particulate matter 75 percent by 2010. This reduction is envisioned by requiring retrofitted aftertreatment devices, which reduce particulate matter (PM), hydrocarbon (HC), carbon monoxide (CO) emissions greater than 85 percent. From 2007-2010 cleaner renewable diesel fuel emission reductions may occur. However, post 2010, the staff assumed that CARB meets its goal without the use of renewable diesel fuels by 2010.

Table 2. Assumed Exhaust Emission Reduction with Renewable Diesel Fuels on Non-Aftertreatment Equipped Diesel Engines

Fuels	HC	CO	NOx	PM	CO_2	Toxics
Biodiesel Neat[1]	67%	48%	-10%	47%	0%	50%
Biodiesel B20[1]	20%	10%	-2%	24%	0%	10%
Biodiesel B5[2]	5%	2.5%	-0.5%	6%	0%	2.5%
Biodiesel B2[2]	2%	1%	-0.2	2.4%	0%	1%
Thermal Conversion Process[3]	0%	0%	0%	0%	0%	0%
Biomass-to-Liquid (100%)[4]	25%	40%	10%	30%	0%	50%
Biomass-to-Liquid (15%)[4]	3.75%	6%	1.5%	4.5%	0%	7.5%

1. CARB's Staff Report: *Initial Statement of Reasons Proposed Amendments to the California Diesel Fuel Regulations*, June 6, 2003, pg. 92. Adopted May 10, 2004, CARB referenced to EPA: December 2000. Regulatory Impact Analysis: Heavy Duty Engine Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements. Chapter III pg. 2. EPA420-R-00-026.
2. Energy Commission linear extrapolation from B20 values.
3. TCP fuels have not been emission tested; however, the fuel is processed and sold as conventional diesel fuel. Staff assumes the fuel has the same exhaust emissions as ultra-low sulfur diesel fuel.
4. Energy Commission averaged four neat-GTL test program results and linearly extrapolated to a 15 percent blend.

Cost Assumptions

In this analysis, the staff assumed that all renewable diesel fuels are the same retail cost as conventional diesel. This is made possible by sufficient governmental incentives enabling competitive pricing and governmental policy that seek some minimum renewable fuel content.

Table 3 shows the staff-assigned percent displacement and resulting volumes of fuel used for this analysis.

Table 3. Assumed Diesel Reduction From Renewable Diesel Fuels

	Year		
	2015	2020	2025
Annual Reduction (Million Gallons)	300	880	1,000
Reduction From Base Case Demand (Percent)	5	20	20

Results

Tables 4 and 5 display the results for diesel reduction from all renewable diesel fuels. Table 4 shows the results assuming a 5 percent discount rate, in 2005 dollars. Table 5 assumes a 12 percent discount rate. In both tables, three fuel costs, (referred to as low, high, very high) were determined by the Energy Commission's

Fuels Office and contained in *Forecasts of California Transportation Energy Demand 2005-2025*.

Table 4. Petroleum Reduction and Benefits for a 20 Percent Renewable Diesel Use (5 Percent Discount)

Petroleum Reduction and Benefits for Selected Alternative Fuel Scenarios							
Alternative Fuel Option or Scenario	Displacement in 2025, Billion Gallon Gasoline Equivalent	Reduction from Base Case Demand, Percent	Highest Cumulative Benefit or Change, Present Value, 2005-2025, 5% Discount Rate, Billion $2005				
			A	B	C	D	A+B+C+D
			Direct Non-Environmental Benefit	Change in Government Revenue	Direct Environmental Net Benefit	External Cost of Petroleum Dependency	Direct Net Benefit
Low Fuel Price ($1.88 / gal diesel)	1.0	20	0	(0.8)	0.7	0.6	0.5
High Fuel Price ($2.20/gal diesel)	1.0	20	0	(0.8)	0.7	0.6	0.5
Highest Fuel Price ($2.43/gal diesel)	1.0	20	0	(0.8)	0.7	0.6	0.5

* Petroleum reduction was valued at 13 cents/gallon gasoline equivalent.

Table 5. Petroleum Reduction and Benefits for a 20 Percent Renewable Diesel (12 Percent Discount)

Petroleum Reduction and Benefits for Selected Alternative Fuel Scenarios							
Alternative Fuel Option or Scenario	Displacement in 2025, Billion Gallon Gasoline Equivalent	Reduction from Base Case Demand, Percent	Highest Cumulative Benefit or Change, Present Value, 2005-2025, 12% Discount Rate, Billion $2005				
			A	B	C	D	A+B+C+D
			Direct Non-Environmental Benefit	Change in Government Revenue	Direct Environmental Net Benefit	External Cost of Petroleum Dependency	Direct Net Benefit
Low Fuel Price ($1.88/gal diesel)	1.0	20	0	(0.3)	0.3	0.3	0.3
High Fuel Price ($2.20/gal diesel)	1.0	20	0	(0.3)	0.3	0.3	0.3
Highest Fuel Price ($2.43/gal diesel)	1.0	20	0	(0.3)	0.3	0.3	0.5
* Petroleum reduction was valued at 13 cents/gallon gasoline equivalent.							

Key Drivers and Uncertainties

The key uncertainties in this analysis involve the following:

- Staff needs to assess the economic feasibility of feedstocks for attaining a 20 percent diesel displacement goal. Other impediments to expanding renewable diesel production and use need to be accurately quantified.

- The investment needed to establish a production capacity to meet a 20 percent diesel displacement goal is unknown.

- It is likely that any reduction in fuel excise tax used to support the higher cost of renewable diesel fuels would have to be offset by higher revenues from another source.

- The long-term production cost of renewable diesel is unclear as production technology improves, higher cost feedstock are likely to evolve perhaps matching process improvements developed over time.

Endnotes

[1] Not considered for this analysis but recognized as an additional potential fuel source is a very similar process that recycles mixed plastics wastes into crude oil, several plants are built in other countries (i.e. Poland) and producing over one million barrels of crude oil annually. See H.SMARTTech. http://www.ciwmb.ca.gov/part2000/Events/02Conf/ConvTech/Plastic.htm.

[2] *Well-to-Wheels Analysis of Future Automotive Fuels and Powertrains in the European Context*, European Commission, Joint Research Centre, Version 1b, January 2004, pg. 19.

[3] DOE - presentation to Congress 2005.

[4] DOE, Office of Transportation Technologies, [http://www.ott.doe.gov/biofuels/renewable_diesel.html].

[5] *2004 Biodiesel Handling and Use Guidelines*, DOE, Energy Efficiency and Renewable Energy, DOE/GO-102004-1999 September 2004, p. 5.

[6] DOE, Alternative Fuels Data Center, http://www.afdc.doe.gov/altfuel/bio_papers.html, May 2002; The stated range from about 117,000 to 124,000 btu per gallon comes from different rounded values published in papers found at this website.

[7] DOE, Office of Transportation Technologies website *Biodiesel Benefits*.

[8] Comparison was made relative to California Diesel whole sale prices experienced in 2004 ($1.00-$1.75 per gallon), assuming BTL cost of $1.75-$1.92/gallon based on a 300-6,000 bbl/day BTL plant in Alaska.

[9] *Well-to-Wheels Analysis of Future Automotive Fuels and Powertrains in the European Context*, European Commission, Joint Research Centre, Version 1b, January 2004, pg. 19.

[10] Peter Jansen, NTO, Netherlands, Innovative Biofuel Production Process: *Fischer-Tropsch Process and Hydro Thermal Upgrading, EU China Workshop on BioFuels*, November 4-5, 2004, http://europa.eu.int/comm/research/energy/pdf/35_peter_jansen_en.pdf.

[11] Peter Mullins, *Increasing Demand fore Biofuel Engines*, Diesel & Gas Turbine Worldwide, January-February 2005, pg. 42-45.

[12] National Biodiesel Board.

[13]Biodiesel (neat) prices Los Angeles CA, $2.75, San Francisco, $2.77, and U.S. Average $2.64 (pre taxed, and pre tax incentive) Alternative Fuels Index reported April 14, 2005. Diesel rack price $1.95/ gallon, Spot was $1.88, and Retail was $2.71, $2.63, $2.68 Northern, Central, and Southern California Source: *Energy.ca.gov gasoline and diesel prices*.

[14] Ibid.

[15] Peter Jansen NTO, Netherlands, EU China Workshop on BioFuels, European Commission Presentation, shows the Cost of Transportation Fuels, RME Biodiesel at 25 €/GJ ($5.64/gallon) compared to 6-7 €/GJ ($1.35-$1.58/gallon) for Gasoline and Diesel. http://europa.eu.int/comm/research/energy/pdf/35_peter_jansen_en.pdf

[16] American Jobs Creation Act of 2004, (Pub. L. 1.8-357) (Act).

[17] Peter Jansen, NTO, Netherlands, Innovative Biofuel Production Process: *Fischer-Tropsch Process and Hydro Thermal Upgrading, EU China Workshop on BioFuels*, November 4-5, 2004, http://europa.eu.int/comm/research/energy/pdf/35_peter_jansen_en.pdf.

[18] Peter Jansen, NTO, Netherlands, Innovative Biofuel Production Process: *Fischer-Tropsch Process and Hydro Thermal Upgrading, EU China Workshop on BioFuels*, November 4-5, 2004, http://europa.eu.int/comm/research/energy/pdf/35_peter_jansen_en.pdf.

[19] Supply projections based upon communication between Energy Commission staff Gary Yowell and Dr. K. Shaine Tyson, National Renewable Energy Laboratory, August 2001.

[20] Assumes that 100 percent of California's 35 million tons from paper, plastics, organics, and tires is used to produce oil. Cited 1999 Statewide Waste Composition Study. Changing World Technologies, Inc. Presentation to Los Angeles City, on Municipal Solid Waste to Oil Presentation, April 21, 2005.

[21] Per Scott Hughes, Hughes Consulting, cost estimate for a 20,000 gallon tank likely for a small terminal.

[22] Thomas D. Durbin, et. al., Final Report, *Evaluation of the Effects of Biodiesel and Biodiesel Blends on Exhaust Emission Rates and Reactivity-2*, Center for Environmental Research and Technology, College of Engineering, University of California, Riverside, CA, August 2001.

[23] Clark, N.N., et al., *Transient Emissions Comparisons of Alternative Compression Ignition Fuels*, West Virginia University, submitted to 1999 SAE Congress.

[24] Starr, M.E., *Influence on Transient Emissions at Various Injection Timings, using Cetane Improvers, Biodiesel, and Low Aromatic Fuels*, 1997, SAE Technical Paper No. 972904.

OPTION 2K – HEAVY-DUTY HYBRID ELECTRIC VEHICLES

Summary

Heavy-duty hybrid electric vehicles (HHEVs) combine internal combustion engines running on gasoline, diesel, natural gas, or hydrogen with an electric motor to improve vehicle fuel economy by 50 to 100 percent[1] or more. A computer determines the most efficient combination based on operating conditions and driver demand. The standard engine size is reduced, for example, from a six cylinder version to a four cylinder version, because of the added power provided by the electric motor. Energy storage devices such as batteries or ultra-capacitors capture and store energy during regenerative braking operations. The best opportunities for hybrid electric powertrains exist with heavy vehicles in Classes 3-7 or vehicles with a gross vehicle weight rating (GVWR) of 14,000 lbs to 33,000 lbs.[2] However, there are opportunities in selected Class 8 applications.

Suitable for a number of niche applications such as transit buses, garbage trucks, and package/beverage delivery vehicles, HHEVs are likely to impact petroleum demand in California in varying degrees. In the near-term (one to five years), the impact will be negligible. In the mid-term (5 to 12 years) or by 2010, HHEVs may represent less than one-tenth of 1 percent of the on-road heavy vehicles and reduce diesel consumption by 3.5 million gallons representing a reduction of 0.15 percent in on-road diesel demand. The impact is minor. In the long-term (12 or more years) the impact is likely to be modest. By 2025 HHEVs are projected to make up less than 1 percent of California's heavy-duty vehicle population and reduce 12.4 million gallons of diesel fuel representing a 0.54 percent reduction of the state's on-road diesel demand.

Hydraulic hybrid technology was also reviewed for this analysis. Although hydraulic hybrids appear to offer efficiency improvement benefits, minimal research and development work for this technology makes it less likely to have any impact on petroleum displacement, compared to HHEVs, over the analysis horizon.

The impact of the HHEV option compared to the petroleum option is summarized in Tables 1-4. Tables 1-4 show results for the Business-As-Usual (BAU) and *Aggressive Scenarios* used to characterize the possible futures this option provides under three fuel price levels. A low fuel price of $1.85[3] and a high fuel price of $2.18[4] are used. The midrange price of $1.99, the average of the low and the high is also used. The BAU and *Aggressive Scenarios* are discussed later.

Table 1: Petroleum Reduction and Benefits for Heavy-Duty Hybrid Electric Vehicle for Low Fuel Price and 5% Discount Rate

Alternative Fuel Option	Displacement in 2025, Billion Gallon Gasoline Equivalent	Reduction from Base Case Demand , Percent (Net Gasoline and Diesel)	Cumulative Benefit, Present Value 2005-2025, 5% Discount Rate, Billion $2005				
			A	B	C	D	A+B+C+D
			Direct Non-Environmental Benefit	Change in Government Revenue	Direct Environmental Net Benefit	External Cost of Petroleum Dependency	Direct Net Benefit
Business As Usual	0.02	0.09	(0.32)	(0.02)	0.02	0.009	(0.03)
Aggressive	0.05	0.22	(0.45)	(0.03)	0.03	0.01	(0.04)

Table 2: Petroleum Reduction and Benefits for Heavy-Duty Hybrid Electric Vehicle for Low Fuel Price and 12% Discount Rate

Alternative Fuel Option	Displacement in 2025, Billion Gallon Gasoline Equivalent	Reduction from Base Case Demand , Percent (Net Gasoline and Diesel)	Cumulative Benefit, Present Value 2005-2025, 12% Discount Rate, Billion $2005				
			A	B	C	D	A+B+C+D
			Direct Non-Environmental Benefit	Change in Government Revenue	Direct Environmental Net Benefit	External Cost of Petroleum Dependency	Direct Net Benefit
Business As Usual	0.02	0.09	(0.39)	(0.02)	0.02	0.009	(0.38)
Aggressive	0.05	0.22	(0.57)	(0.01)	0.03	0.01	(0.54)

Table 3: Petroleum Reduction and Benefits for Heavy-Duty Hybrid Electric Vehicles for High Fuel Price and 5% Discount Rate

Alternative Fuel Option	Displacement in 2025, Billion Gallon Gasoline Equivalent	Reduction from Base Case Demand , Percent (Net Gasoline and Diesel)	Cumulative Benefit, Present Value 2005-2025, 5% Discount Rate, Billion $2005				
			A	B	C	D	A+B+C+D
			Direct Non-Environmental Benefit	Change in Government Revenue	Direct Environmental Net Benefit	External Cost of Petroleum Dependency	Direct Net Benefit
Business As Usual	0.02	0.09	(0.07)	(0.02)	0.02	0.009	(0.06)
Aggressive	0.05	0.22	(0.06)	(0.03)	0.03	0.01	(0.05)

Table 4: Petroleum Reduction and Benefits for Heavy-Duty Hybrid Electric Vehicles for High Fuel Price and 12% Discount Rate

Alternative Fuel Option	Displacement in 2025, Billion Gallon Gasoline Equivalent	Reduction from Base Case Demand , Percent (Net Gasoline and Diesel)	Cumulative Benefit, Present Value 2005-2025, 12% Discount Rate, Billion $2005				
			A	B	C	D	A+B+C+D
			Direct Non-Environmental Benefit	Change in Government Revenue	Direct Environmental Net Benefit	External Cost of Petroleum Dependency	Direct Net Benefit
Business As Usual	0.02	0.09	(0.15)	(0.02)	0.02	0.009	(0.14)
Aggressive	0.05	0.22	(0.20)	(0.01)	0.03	0.01	(0.17)

Scenarios Description

HHEVs operate with different fuel and powertrain configurations at different levels of hybridization. HHEVs may operate on gasoline, diesel, natural gas, or hydrogen in parallel or series configuration. HHEVs may be mild or full hybrids. While still an emerging technology, HHEVs are historically deployed in transit bus and trash truck applications. Federal Express has teamed with Eaton Corporation to deploy a diesel hybrid electric package delivery vehicle.[5] Future applications are not likely to expand to applications such as long-haul vehicles.

Two scenarios are considered for this analysis. The BAU scenario assumes modest penetration of no more than 1 percent per year[6] of the combined population of transit buses. This scenario also assumes negligible penetration of the refuse and package delivery segments. The *Aggressive Scenario* case assumes a moderate penetration of 2 percent[7] of the combined population of transit buses, refuse trucks, and package delivery vehicles.[8]

Business-As-Usual Scenario

This scenario assumes that no significant hybrid vehicle technology integration on heavy vehicle platforms occur in the immediate future (one to five years from now). Today's high incremental cost ($15,000 to $100,000)[9] of HHEVs compared to conventional types is a barrier to adoption of the technology in significant numbers in the market place. Few customers are aware of the option. Other potential end users may hesitate to acquire a new transportation technology. These two factors keep HHEVs small in numbers and demonstration applications.

Aggressive Scenario

This scenario assumes that 10 percent[10] of the vehicle classes and platforms with driving cycles that make sense for HHEVs adopt the technology. The scenario assumes that the combination of fuel savings, volume production, and incentives that eliminate or reduce the incremental cost to end users spur the adaptation of the technology in suitable applications. Research indicates that the incremental cost of the HHEV is likely to drop by 60 to 80 percent by the 2017 to 2025 timeframe when a mature market for this product is expected to develop. These factors combine to produce an increase in HHEVs from around 100 today to nearly 1,000 in the state's vehicle population by 2017.

Key Input Parameters and Values

The key inputs for this option are the incremental cost of the technology compared to conventional diesel engine platform. Argonne National Laboratory estimates that the incremental cost for Class 3-5 HHEV will approximate $3,00 by 2020; and the estimated incremental cost for Class 6-7 HHEV is projected to approximate $3,300 by 2020.[11] Another key input in the analysis is the 50 percent to 100 percent increase in the fuel economy of the base vehicle.[12,13] These factors affect a third crucial input, the HHEV market penetration rate and population in this analysis. This analysis amortizes the incremental cost, where applicable, over the fuel consumed during the useful life of the vehicle and application. This treatment reduces the cost savings to the consumer or end user of the technology. Similarly, maintenance cost items are applied on a per gallon basis. We assume that the maintenance cost for the HHEV is the same as the standard diesel vehicle because there is negligible data documenting the maintenance cost of HHEVs. For this analysis, the benefit to the consumer is adjusted by subtracting this cost from the annual cost savings to the consumer arising from the more efficient vehicle technology.

Key of Assumptions

- Series hybrid configurations dominate the population of HHEVs because most hybrid electric propulsion systems being developed in the United States (U.S.) feature a series arrangement.[14]

- Based on historical product development, prototyping, and commercialization trends, we also assume that the likely application for HHEVs is transit and trash truck applications with moderate penetration into the package delivery vehicle segment. Other opportunities for HHEV technology are the airport Ground Service Equipment, Utility/Specialty equipment, airport parking lot, and car rental shuttles.

Results

Business as Usual Scenario

For the *Business as Usual Scenario*, heavy-duty hybrid electric vehicles reduce California's on-road diesel demand by 18.2 million gallons or about 0.09% of combined diesel-gasoline demand in 2025.

Net-Direct Benefits to the state under this scenario and a 5 percent discount rate and low fuel price of $1.82 per gallon are estimated to be a loss of $0.03 billion through 2025. *Net-Direct Benefits* to the state under this scenario and a 12 percent discount rate and low fuel price of $1.82 per gallon are estimated to be a loss of $0.38 billion through 2025.

Net-Direct Benefits to the state under this scenario, a 5 percent discount rate and high fuel price of $2.18 per gallon are estimated to be a loss of $0.06 billion through 2025. *Net-Direct Benefits* to the state under this scenario, a 12 percent discount rate and high fuel price of $2.18 per gallon are estimated to be a loss of $0.14 billion through 2025.

Aggressive Scenario

For the *Aggressive Scenario*, heavy-duty hybrid electric vehicles reduce California's on-road diesel demand by 49.5 million gallons or about 0.22 percent of combined on-road diesel-gasoline demand in 2025.

Net-Direct Benefits to the state under this scenario and a 5 percent discount rate and low fuel price of $1.82 per gallon are estimated to be a loss of $0.04 billion through 2025. *Net-Direct Benefits* to the state under this scenario, a 12 percent discount rate and low fuel price of $1.82 per gallon are estimated to be a loss of $0.54 billion through 2025.

Net-Direct Benefits to the state under this scenario, a 5 percent discount rate and high fuel price of $2.18 per gallon are estimated to be a loss $0.05 billion in 2025. *Net-Direct Benefits* to the state under this scenario, a 12 percent discount rate and high fuel price of $2.18 per gallon are estimated to be a loss of $0.17 billion through 2025.

KEY DRIVERS AND UNCERTAINTIES

The following key drivers and uncertainties are identified and known to affect this option.

- Potential cost savings from hybridization.
- Higher fuel economy of 50 percent to 100 percent more than the standard diesel engine platform[15].
- Cost to replace new battery or other energy storage device maintenance.
- Market acceptance.
- Durability and reliability.
- Manufacturer field support and warranty.

Endnotes

[1] *New Fedex Express Hybrid Electric Trucks Begin Service* Press Release, March 30, 2004.

[2] An, Feng et al. *Scenario Analysis of Hybrid Class 3-7 Heavy Vehicles* Argonne National Laboratory, SAE Paper 2000-01-0989.

[3] *Summary of Retail Price Scenarios for 2025* California Energy Commission (Energy Commission) staff, February 24, 2005.

[4] Ibid.

[5] *New Fedex Express Hybrid Electric Trucks Begin Service* Press Release, March 30, 2004.

[6] Beverage Delivery and Regional Heavy Distribution Working Group, Hybrid Truck Users Forum, http://www.calstart.org/programs/htuf/Parcel_&_Delivery_Working_Group_Pop_Up.html

[7] Calculated historical penetration rate of selected technologies onto vehicle platforms. Ward's Automotive.

[8] Ibid.

[9] Ibid.

[10] Personal Communication with Mike Simon of ISE Corporation on January 27, 2005.

[11] An, Feng et al. *Scenario Analysis of Hybrid Class 3-7 Heavy Vehicles* Argonne National Laboratory, SAE Paper 2000-01-0989.

[12] http://www.auto-careers.org/diesel_hybrid_info.htm.

[13] 21st Century Truck Program, U.S. Department of Energy, October 2001.

[14] An, Feng et al. *Scenario Analysis of Hybrid Class 3-7 Heavy Vehicles* Argonne National Laboratory, SAE Paper 2000-01-0989.

[15] Parcel and Delivery Working Group, Hybrid Truck Users Forum presentations http://www.calstart.org/programs/htuf/Parcel_&_Delivery_Working_Group_Pop_Up.html.

OPTION 2L - ETHANOL IN DIESEL FUEL

Summary

This analysis examines the use of ethanol in California diesel fuel in moderate growth and higher growth cases, leading to low and high ethanol use estimates in 2010 and 2025. The analysis makes both on-road and off-road projections of ethanol use.

Under moderate and higher growth cases, the combined use in 2025 of ethanol in on-road and off-road fleets is about 22 and 52 million gallons per year, respectively. Expressed as diesel petroleum displacement, these values become 13 million and 31 million gallons per year diesel gallon equivalent, respectively. These values are below 1 percent of the on-road diesel demand in 2025.

Given the developmental status of the ethanol in diesel, no costs and benefits analysis has been performed for the analysis provided here.

Background and Description

The use of ethanol in diesel fuel, up to a maximum of 15 percent by volume, has been researched for many years. The E-diesel Consortium, formed in 2001, is comprised of stakeholders having an interest in developing a pathway to commercial use and acceptance of ethanol in diesel fuel in the United States (U.S.).[1]

Ethanol in diesel, trademarked under various names including *E-diesel*, *O2 Diesel,* and *Oxydiesel,* can have ethanol content of 7 to 10 percent by volume, and higher. A proposed American Society for Testing and Materials (ASTM) specification includes an upper bound of 15 percent by volume ethanol. A consensus on the ASTM standard will be required for any significant expansion of commercial projects in the post-2010 timeframe. Such a standard may be operative by the end of 2006.[2]

Status of Technology

The ethanol in diesel option has been under active development with many demonstration and evaluation activities initiated in the late 1990s, and laboratory research before then. While both on-road and off-road applications have been explored, ethanol in diesel for general on-highway use in passenger cars and light-duty trucks appears unlikely for the foreseeable future. Automakers view this fuel as experimental and its use in passenger vehicles problematic due to fuel vapor flammability and related safety issues.[3]

On the other hand, centrally fueled fleet applications have been identified as the logical place for this fuel. In fleet environments, vehicle modifications, implementation of safety measures, training of personnel, and upgrading of supply tanks and associated equipment can be undertaken without the complexities (and costs) associated with dispersed use of the fuel in the larger petroleum infrastructure. Studies show that fire and explosion risks can be minimized with proper equipment, so that risks for a fleet operation using ethanol in diesel blends are no greater than those associated with the use of gasoline.[4]

In comparison to conventional diesel fuel, E-diesel contains ethanol and proprietary additives that stabilize the mixture, assuring that ethanol is always in solution and providing lubricity and cetane enhancement where required. The proprietary additive concentration is in the 0.5 to 5 percent volume range and is produced by companies specializing in the fuel and oil additive business.[5]

Ethanol/Diesel Blends for Emission Control

Application of ethanol diesel blends in California is driven in part by emission reduction potential in the existing fleet of on-road centrally fueled and off-road agriculture, construction, commercial, and mining applications. The 2025 combined diesel market volume is estimated at about 1.2 billion gallons, about 680 million gallons of which is projected diesel use in centrally fueled on-road fleets.

Currently, one company, O2 Diesel Inc., is seeking status under the California Air Resources Board’s (CARB) *Diesel Emission Controls Strategies Verification Program* to qualify ethanol in diesel at one or more levels of emission control. Based on emissions data provided by O2 Diesel and reviewed by CARB, this fuel is currently verified at level one (provides at least a 25 percent reduction in particulate matter).[6] Data and observations also show a significant decrease in visible smoke from fleet diesel engines using the fuel in the Port of Los Angeles.

Ethanol in Diesel Blend Use in California Fleets

Since ethanol in diesel blends does not have an ASTM specification, they are not considered commercial fuels by California’s fuel quality regulating agency. Nevertheless, several fleets are operating under *Developmental Engine Fuel* status, a designation provided by the Division of Measurements and Standards of the California Department of Food and Agriculture (CDFA) that permits use of the “developmental fuel” for a limited time in designated fleets.

Long Beach Container Terminal, Inc. is operating 60 pieces of heavy equipment used in moving ship containers at the Port of Long Beach. Their annual consumption of the O2 Diesel blend will be about 600,000 gallons.[7] Other fleets using the same fuel are located in Tulare, Fresno, and the Los Angeles area involving refuse truck, transit, road maintenance, and construction activities.[8]

Key Assumptions Affecting Ethanol Use

In this analysis, several factors are assumed that will affect the use of ethanol in diesel in centrally fueled on-road and off-road fleets. These are:

- Federal tax laws and incentives that provide equal treatment for all market niches where ethanol blending can occur.[9]

- The type and size of on-road and off-road fleets selected as target markets for ethanol in diesel applications.

- For the moderate growth case, engine manufacturer issues remain and acceptance of the option limits deployment relative to the higher growth case. Market penetration of less than 10 percent is achieved at 7.7 percent blending in 2010.

- In the higher growth case, engine manufacturers resolve some concerns and broader acceptance with higher blending levels (10 percent blending) is achieved. Market penetration of 25 percent is achieved in both on-road and off-road applications by 2025.

- For both growth cases, it is assumed that if the U. S. Environmental Protection Agency (EPA) Tier 2 health effects testing is determined to be necessary, the testing is funded in a timely manner, and that the outcome is positive.

- For both growth cases, the long term durability issues are found not to be a problem based on results of current on and off-road fleet use of ethanol in diesel blend.

- An ASTM specification is ultimately agreed upon by the consensus group and the Division of Measurement and Standards of CDFA adopts that specification.

- Verification of ethanol diesel blends as an alternative diesel fuel under the CARB Diesel Risk Reduction Program is retained through 2025 based on emissions test data that continues to show significant emissions reductions.

Results

Table 1 displays moderate and higher growth estimates of ethanol-in-diesel use for on-road and off-road centrally fueled fleets. Market penetrations during the intermediate years were assumed to increase more quickly in the higher growth cases with 15, 20, and 25 percent market share in 2015, 2020, and 2025, respectively. In the moderate growth cases, the off-road centrally fueled fleet market penetration was assumed to remain constant at 10 percent over the same period, while on-road centrally fueled fleet penetration was assumed to increase to 12, 17, and 21 percent, respectively.

Table 1. Ethanol in Diesel Blends in Centrally Fueled On-Road and Off-Road Fleets

Fleet Application	**2010***		**2025***	
On–Road Centrally Fueled	***Equivalent Diesel Gallons Displaced***	***Ethanol Volume***	***Equivalent Diesel Gallons Displaced***	***Ethanol Volume***
Moderate Growth	***1.8***	***3.0***	***6.6***	***11.0***
Higher Growth	***2.7***	***4.5***	***10.2***	***17.0***
Off-Road Centrally Fueled				
Moderate Growth	***2.4***	***4.0***	***6.6***	***11.0***
Higher Growth	***6.0***	***10.0***	***21.0***	***35.0***

* All volumes are expressed in million of gallons. One gallon ethanol = 0.6 gallons diesel equivalent

Key Drivers and Uncertainties

Issues and uncertainties could limit the growth of ethanol in diesel blends in California. These issues are not impeding current California fleet programs; however, resolution of open technical issues is necessary to achieve more aggressive market penetration goals, including higher ethanol content, in the longer term (2025).

- An ASTM standard needs to be finalized for ethanol in diesel blends to make broad acceptance of the option a possibility. The E-diesel Consortium is the lead organization facilitating this process.

- The blending economics of ethanol in diesel must remain favorable over the long term.[10]

- Engine manufacturers' concerns regarding the impact of ethanol on engine lubrication, fuel oxidation, and biological stability are concerns that could impact engine performance, durability, and thus, new engine warranty policy.[11]

- Current on-road projects are considered to be “demonstration projects” by EPA. Until health effects testing requirements, if requested by EPA, are completed, the expansion of on-road centrally fueled fleet applications will be limited.[12]

Endnotes

[1] http://e-diesel.org The current membership includes three ethanol producers, a corn grower, and marketing associations from five states that include the national association, two fuel additive/technology companies, and two national laboratories, among others.

[2] Personal communication with Robert E. Reynolds, co-coordinator of the E-Diesel Consortium, May 3, 2005.

[3] Safety issues, primarily vapor space flammability in fuel tanks, and fire risk in vehicle collisions, limit on-road fuel application. On-road centrally fueled fleet operations such as transit buses, municipal waste haulers, and similar operations are better suited to the fuel application.

[4] Waterland, L.G. et.al. *Safety and Performance Assessment of Ethanol/Diesel Blends (E-Diesel)* TIAX, LLC prepared for the National Renewable Energy Laboratory under Subcontract No. KLCI-1-31025-07, Report # NREL/SR-540-34817, September 2003.

[5] Lubrizol Corporation, O2 Diesel, Inc., and Octel Starreon LLC. are additive companies that provide specialty chemicals for use in ethanol/diesel applications.

[6] Data presented by James Peeples of O2 Diesel Inc. at the October 12, 2004 IEPR Non-Petroleum Fuels: Working Group Conference, California Energy Commission, Sacramento, California. CARB verified O2 Diesel's emission reduction at 20 percent reduction in particulate matter (PM) and 1.6 percent reduction in NOx emissions, subject to conditions of verification. See California's Diesel Risk Reduction Program on the CARB Website at http://www.arb.ca.gov/diesel/dieselrrp.htm.

[7] www.O2diesel.com Press release dated December 13, 2004.

[8] The County of Tulare has 198 diesel powered road maintenance, construction, and towing vehicles that "could" operate on ethanol gasoline blends. This fleet is purported to use about 300,000 gallons fuel a year according to a press release from O2 diesel date Dec 8, 2004.

[9]With the passage of the Volumetric Ethanol Excise Tax Credit (VEETC) in the American Jobs Creation Act of 2004 (H.R. 4520), the full value of the excise tax credit will apply equally to all ethanol blending in all applications on- and off-road. The act also extended the ethanol tax incentive to December 31, 2010 at 51 cents per gallon of ethanol blended. http://www.e85fuel.com/front_page/veetc/veetc_implementation121404.pdf.

[10] Historically, ethanol has been priced relative to gasoline in either indexed or fixed (three to six month) price contract form. It is likely that diesel fuel will remain at a premium to gasoline, and that ethanol will continue to be priced relative to gasoline. Under these conditions, ethanol blending in diesel should remain very attractive over the long term.

[11] Research is needed to address these issues and additional on-going materials compatibility research is needed so that engine manufacturers will warranty operation on these fuels. Currently, no heavy-duty engine manufacturer will warranty engines under the proposed ASTM specification. Downstream Alternatives (2003) *Fuels Specifications and Fuel Property Issues and their Potential Impact on the Use of Ethanol as a Transportation Fuel* Phase III Project Deliverable Report, prepared for Oak Ridge National Laboratory Ethanol Project under subcontract No. 4500010570, December 16, 2002.

[12] On-road applications are likely to be limited to centrally fueled fleets, and no entity appears to be proposing use of ethanol in diesel fuel in existing or future light-duty diesel powered passenger cars or on-road light trucks.

OPTION 2M–NON-ROAD OPTIONS

Introduction

This is a preliminary assessment of opportunities in non-road and off-road equipment for petroleum use reduction and alternative fuel use in California. Fuel use trends are examined for the period 2004 to 2025, using a model specifically created to assess emissions impacts and fuel use trends associated with non-road use of petroleum-based and alternative fuels. The analysis examines potential efficiency improvement, fuel switching, and several alternative fuel opportunities beyond existing trends created by current regulatory programs. These regulatory programs target new non-road/off-road engines for emissions reductions and are providing some energy benefits in the form of improved engine efficiency.

Preliminary results indicate that between 22 million to 1.1 billion gallons of fuel (gasoline and diesel) may be saved through the use of alternative fuels such as biodiesel, electrification, natural gas (NG), ethanol, and liquefied petroleum gas (LPG), and through gasoline to diesel shifting and engine efficiency gains.

Additional analysis is recommended to better identify and quantify subcategory "niche market" opportunities in the non-road/off-road sector.[1] Potential benefits and costs associated with the technology improvements and alternative fuel advances need to be established, and a formal cost benefit analysis applied at the subcategory level.

Background

Diesel and gasoline engines are used in a broad range of applications beyond their use in on-highway (or on-road) passenger cars and trucks. This includes a diverse array of self-propelled equipment and some stationary equipment that moves or can be moved from one location to another. Agricultural tractors, construction bulldozers, backhoes, trains, ships, shipyard cargo movers, agricultural water pumps, and lawnmowers are examples of non-road equipment powered by gasoline or diesel engines.

In contrast to on-road engines for cars and trucks, non-road engines can be as small 2.5 horsepower for a lawnmower or as massive as 100,000 horsepower for an ocean-going container ship.[2] Another defining characteristic of the non-road sector is the sheer number of engine models and configurations needed to meet the diversity of applications. In 2001, the U. S. Environmental Protection Agency (EPA) issued 159 emissions certifications for on-highway diesel engines, while 661 certifications were issued for off-road gasoline and diesel engines.[3]

In general, off-road engines have varying lifetimes because of the diversity in their size and use characteristics. Engine upgrading or replacement opportunities are driven by many factors with median life expectancy being one of the more important considerations. For example, recreational marine engines have a median life of 20 years, while snowmobiles and off-road motorcycles have a median life of 9 years, and all-terrain vehicles (ATVs) have a median life 13 years. Given the preliminary nature of this study, no attempt was made to analyze the quickest path to maximum petroleum displacement based on median life considerations. On the other hand, current regulatory programs in progress have durations on the order of 10 years and are expected to cause complete replacement of some classes of equipment. Examination of the impacts of EPA and California Air Resources Board (CARB) regulatory programs as they have and will force efficiency improvements and alternative fuel use in the off-road sector is a logical starting point for identifying future additional opportunities.

Regulatory Drivers of Technological Change in the Non-Road/Off-Road Sector

In 1994 and 1998, the EPA established emissions standards controlling oxides of nitrogen (NOx), carbon monoxide, particulate matter (PM), and hydrocarbon emissions for the non-road sector. The CARB also established non-road emissions standards in 1993 and again in 2000.

The federal regulations were applicable to off-road diesel engines nationally beginning with 1996 models and Tier 1 standards. Tier 2 standards were phased in during 2001 to 2006, and Tier 3 standards will be phased in during the 2006 to 2008 time period.[4] The two harmonized regulations will reduce non-road emissions dramatically over a relatively short 10 year period, resulting in an 82 percent reduction in NOx emissions from new off-road diesel engines in the 175 to 750 horsepower range. Nationwide, EPA projects a 50 percent drop in the off-road NOx emissions amounting to 1.5 million tons per year (4,100 tons per day) when compared to the 1995 NOx inventory.[5] In comparison, CARB projects 16 percent additional NOx reductions and 60 percent additional PM reductions per day over the federal regulations.[6]

EPA developed a NONROAD model, incorporating the effects of both the federal and California off-road emissions control programs that analyzed future impact on emissions, and reduction in fuel consumption from efficiency improvements associated with newer technology diesel and gasoline engines as well as some alternative fuel use.

Fuel Use in Non-Road /Off-Road in California: 2004 to 2025[7]

Staff applied the NONROAD model to select and analyze subcategories of non-road/off-road equipment. These categories are:

- Agriculture
- Commercial and Industrial-- commercial equipment, industrial equipment, and lawn and garden maintenance equipment
- Construction and Mining
- Personal and Recreational-- residential lawn and garden equipment, recreational vehicles, recreational marine equipment (outboard/inboard), personal watercraft, snowmobiles, off-road motorcycles, ATVs, golf carts (also in commercial & industrial), and snowmobiles
- Logging
- Airport-- support and maintenance equipment
- Railroad-- support and maintenance equipment

California-specific runs were then performed for the years 2004, 2010, 2020, and 2025, providing historic as well as future trends in gasoline and diesel engine populations among the various subcategories as well as fuel use. The results are summarized in Table 1.

Table 1. Historical and Projected Gasoline and Diesel Use by Sector

	Gasoline[a]				Diesel[a]			
	2004	2010	2020	2025	2004	2010	2020	2025
Agriculture	2,184	2,218	2,406	2,512	93,524	106,479	128,125	138,931
Commercial & Industrial	402,803	417,830	494,413	534,971	233,571	279,503	355,177	392,537
Construction & Mining	13,234	12,145	12,328	12,480	528,988	610,079	745,512	813,017
Personal & Recreational	232,558	250,073	278,834	291,480	22,554	26,195	32,243	35,272
Logging	956	959	1,214	1,349	8,351	7,915	7,187	6,821
Airport	307	298	313	329	11,249	14,248	19,242	21,738
Railroad	157	164	172	180	2,479	2,954	3,744	4,139

a. All fuel use is in thousands of gallons per year.

Table 1 shows that historical diesel and gasoline use for 2004 in the non-road/off-road sector is significant when compared with on-road petroleum use in California. In 2004, the non-road sector categories used 850 million gallons of diesel and about 645 million gallons of gasoline. Alternative fuels were also used in 2004, with 19 million gallons of natural gas and 212 million gallons of LPG consumed.[8]

For 2004, off-road diesel represented 27 percent of the total 3.4 billion gallons of diesel consumed, while off-road gasoline use was a more modest 4 percent of total gasoline consumption. LPG use, expressed as energy equivalent diesel gallons (dge) was 146 million gallons, or 2.8 percent of 2004 combined on- and off-road diesel use. LPG use (dge) was more significant, 14 percent, when compared to the total off-road diesel consumption of about one billion gallons (diesel plus dge propane). NG use was almost insignificant, representing less than 1/10 of 1 percent of on-road gasoline use, and less than 3 percent of the off-road gasoline use.

In projecting fuel use to 2025, the NONROAD model indicates diesel use at 1.4 billion gallons per year, representing a 65 percent growth from 2004. However, relative to on-road diesel growth (5.5 billion gallons per year) under the high price greenhouse gas (GHG) scenario, off-road diesel use decreases to 20 percent of the combined on- and off-road diesel use in 2025. In contrast, off-road gasoline use is 843 million gallons for a growth of 31 percent relative to almost unchanged on-road gasoline consumption in 2025, but still only 5 percent of the combined on- and off-road gasoline use. LPG grows to 300 million gallons per year (200 million dge), a 45 percent increase, but remains almost unchanged at 14 percent of the off-road diesel use.

Options for Petroleum Use Reduction

Gasoline to Diesel Engine Shifting

Table 1 illustrates that the commercial and industrial category is the only off-road category where significant efficiency could be gained by switching to diesel engines.[9] This sector consumed 41 percent of the off-road diesel and gasoline in 2004. Typically, diesel engines achieve 25 to 35 percent higher thermal efficiency than gasoline engines. If this sector were to migrate to all diesel engines in 2025, the potential fuel savings would be about 535 million gallons of gasoline saved, minus the increase in diesel use adjusted for efficiency gain (30 percent assumed). In this example, the net benefit is 177 million equivalent gasoline gallons saved. In 2025, this represents a modest 1 percent of the on-road gasoline use (15.3 billion gallons under the high price GHG scenario). Even if this was found to be a practical option after close examination of the 930,000 engines (2004) that would be replaced, there are no other opportunities for this strategy in other off-road categories.[10]

Alternative Fuel Use Strategies

A. Ethanol blended at 10 percent in gasoline.

All gasoline powered equipment could operate on California reformulated gasoline (CaRFG) containing between 5.7 and 10 percent ethanol by volume in 2025. Assuming the highest ethanol blending level of 10 percent, about 81 million gasoline gallons equivalent per year of CaRFG would be saved relative to a hydrocarbon only (non-oxygenated CaRFG). For comparison, this amount would be equivalent to about 0.5 percent of the on-road fuel use.[11]

B. LPG

Doubling LPG use in the commercial and industrial category in 2025 would displace about 200 million gallons of diesel equivalent, representing just under a 20 percent drop in off-road diesel use from what it would have been that year (1.4 to 1.2 billion gallons per year). For comparison, this represents 4 percent of the on-road diesel use.

C. Biodiesel

Biodiesel blended at 20 volume percent (or B20) in agricultural, commercial and industrial, construction, and mining equipment represents a “fill-and-go” strategy that could be implemented relatively quickly.[12] In 2025, these three sectors consume 95 percent of the off-road diesel or 1.34 billion gallons a year. At full penetration, B20 use would displace 270 million diesel gallons or 19 percent of 2025 off-road diesel use. This is 6.4 percent of the on-road diesel use that year. At 50 percent penetration, the corresponding volume is 135 million gallons of diesel or about 3.2 percent of on-road diesel use.

D. Ethanol in Diesel (E-diesel)

E-diesel use could complement or be an alternative to biodiesel blending. Assuming a maximum of 10 percent ethanol in diesel with adjustment for energy content, ethanol would displace 135 million gallons of diesel, but actually cause engine fuel consumption to increase by 4 percent because of the lower energy content of ethanol relative to diesel.

E. Hydrogen

Ford Power Products will be introducing hydrogen-fueled internal combustion engines to the industrial marketplace. The targeted market areas are airline ground support equipment where emission levels are strictly regulated and power generation applications where minimal vibration and engine wear are desirable.[13] Further analysis is required to determine potential fuel savings and costs from the hydrogen option in 2025.

F. Electricity

According to a study by Arthur D. Little, there are about 300,000 units of electric non-road equipment, ranging from forklifts to airport ground support equipment in existence today.[14] A combination of regulations and population growth could increase the numbers, as shown in Table 2. The table represents the maximum impact to the utilities.

Current non-road electric equipment uses components and technology that are, in general, older and more inefficient than available newer technology. With regenerative braking, better motors, software controlled battery charging, and advanced battery systems, there is a potential for products that are 50 to 100 percent more efficient.

Table 2. California Non-Road Electrification Potential[15]

Electric Drive Technology	Annual Estimated Fuel Displaced During 2010-2015, (Million Gallons/Year)
Fork Lifts, Lift Trucks	300 – 540
Airport Support Equipment	Not calculated
Burden Carriers, Turf Trucks	60 – 80
Sweepers, Scrubber, and Varnishers	30 – 40
Lawn and Garden Equipment	110 – 275
Total	500 – 935

Regulatory requirements can be used as a planning tool to determine markets for equipment in impacted areas. For example, the non-attainment areas shown in Table 3 were evaluated for potential electric golf cart and low-speed vehicle populations. 2006 was arbitrarily chosen based on the year required for attainment.

Table 3. Golf Cart and Specialty Cart Populations for Ozone Non-Attainment Areas

Ozone Non-Attainment/County	Year Required for Attainment	Golf Cart 2006	Specialty Cart 2006	Fuel Consumption (Gallons/Year)
Sacramento	2013	371	356	Diesel 25,387 Gasoline 229,234 LPG 2,613
San Diego	2009-2014	708	1,300	Diesel 93,085 Gasoline 484,960 LPG 9,582
San Joaquin	2013	240	236	Diesel 16,925 Gasoline 165,083 LPG 1,742
San Francisco	2007	101	142	Diesel 10,155 Gasoline 65,946 LPG 1,045
Imperial	2007	34	213	Diesel 15,232 Gasoline 34,549 LPG 1,568
Los Angeles	2021	2,159	1,585	Diesel 113,395 Gasoline 1,297,327 LPG 11,673
Ventura	2010	371	165	Diesel 11,847 Gasoline 214,871 LPG 1,220
Totals		3,984	3997	Diesel 286,026 Gasoline 2,491,970 LPG 29,443

By 2025, the population of diesel/gasoline golf carts and low-speed specialty carts in the current non-attainment counties is projected to be 4,892 and 11,205, respectively, using 462,201 gallons of diesel and 3,146,134 gallons of gasoline per year.

Other Fuel Saving Strategies

Engine Efficiency

Gains may be made with improved engine efficiencies and substituting four-stroke engines for two-stroke engines in ATVs, snowmobiles, specialty vehicles, and off-road motorcycles. Further analysis is required to determine fuel savings and costs from this option.

Table 4 represents potential fuel savings, assuming each alternative fuel option achieves market penetration independent of the other options. The relative market penetration shares by each alternative fuel option were not evaluated at this stage of this analysis.[16] The costs related to the individual market penetrations were not fully evaluated for this report and therefore, no cost/benefit analysis is included with the options.

Table 4. Projected Fuel Savings for 2025

2025	Diesel/ Gasoline Baseline Use (Millions of Gallons)	CNG	LPG	Electric	Biodiesel	Ethanol
Agriculture	139 3		0.009			
Air Ground Support	22/0.3		0.4	Not Calculated		
Commercial	120/168	8	19			
Construction & Mining	813/13		2	11		
Industrial	191/2	14	208			
Lawn & Garden (Commercial)	82/365		3	166		
Lawn & Garden (Residential)	0/114					
Logging	7/1			409		
Pleasure Craft	34/99					
Railroad	4/0.2			100		
Recreational	2/78					
Totals	1,412/843	22	233	1,106	130[a]	81[a]

[a] Specific categories for projected fuel savings were not determined.

Endnotes

[1] The expression “non-road” is used to describe an expansive group of non-highway vehicles and equipment that consume gasoline, diesel, and alternative fuels. The expression “Off-road” is a more restrictive expression referring primarily to the land-based subcategory of non-road vehicles and equipment such as bulldozers, agricultural tractors, and harvesting equipment, commercial and industrial, and other categories. In this analysis we exclude all “non-road” not land based categories including ships, barges, tug boats, locomotives, military vehicles and equipment, and aircraft.

[2] See Briggs and Stratton Company and Wartsila –Sulzer engine products at www.briggsandstratton.com and www.bath.ac.uk/~ccsshb/12cyl/.

[3] *Diesel-Powered Machines and Equipment: Essential Uses, Economic Importance and Environmental Performance* published by the Diesel Technology Forum, www.dieselforum.org,June 2003.

[4] Ibid., pages 15-17.

[5] Ibid. page 17.

[6] Off-Road Equipment http://www.arb.ca.gov/msprog/moyer/offrd.pdf May 5, 2005.

[7] Staff used the EPA’s NONROAD model to generate population, and projected emissions and fuel use estimates for future years. The model calculates past, present, and future populations, fuel use, and emissions for all non-road equipment categories except commercial marine, locomotives, and aircraft. The NONROAD model was developed as an aid for state Implementation Plans, required by the 1990 Clean Air Act Amendments and other regulatory needs. The 2004 version of NONROAD incorporates California specific emission requirements, existing and proposed.

[8] The NONROAD output table for alternative fuels is reproduced here:

Projected Compressed Natural Gas (CNG) & LPG Use by Sector

	CNG/LPG[a]			
	2004	2010	2020	2025
Agriculture	92/10	0/9	0/8	0/8
Commercial & Industrial	21,283/209,420	14/207,644	26/272,935	28/297,775
Construction & Mining	5/2,282	0/2,251	0/2,498	0/2,674
Personal & Recreational	0/125	0/125	0/124	0/124
Logging	0/0	0/0	0/0	0/0
Airport	0/333	0 / 353	0/461	0/519
Railroad	0/8	0/8	0/8	0/9

a. CNG has been converted to gasoline gallons equivalent (gge) using 0.0011 as the conversion factor. A number of 0 may represent a value less than .5. In the text, LPG was converted to diesel gallons equivalent (dge) using a divisor of 1.5 gallons LPG per gallon of diesel.

[9] Many factors would be examined in choosing potential gasoline to diesel engine switching options. Staff has bounded the potential fuel savings but has not examined the myriad of decisions that equipment and engine manufacturers, and potential users would have to make to bring about such a result. The true market size could range from 100 percent in particular subcategories to 0 percent in others.

[10] Construction and mining is the next largest fuel consuming category at 34.9 percent of diesel and gasoline fuel consumption in 2004. However, this category has 275,000 pieces of equipment of which more than 98.5 percent are already powered by diesel engines.

[11] A survey would be required to determine the extent of durability and compatibility issues with ethanol blended gasoline. Additional research and development will be required by some manufacturers before they will warranty their engines and equipment when using the fuel. Since an ASTM specification does not currently exist for ethanol/diesel blends, this option may take some time to penetrate target markets.

[12] The term “fill and go” is the notion that very few or no modifications are required on the vehicle or engine to use the alternative fuel. In reality, some minor low cost modifications may be required for certain options. The term is probably most applicable to biodiesel. Ethanol in diesel requires some equipment modifications beyond those required with biodiesel.

[13] Ford Motor Company news release *Ford Motor Company To Display Hydrogen Technology at 2005 GSE Expo* http://media.for.com March 2, 2005.

[14] Arthur D. Little, Inc.*Report on the Electric Vehicle Markets, Education, RD&D and the California Utilities’ LEV Programs* Final Report FR-02-109, March 22, 2002.

[15] California Electric Transportation Coalition *Briefing on Electric Transportation Technologies* August 2004.

[16] The projections may be refined using the NONROAD2004 model. For example, the populations for golf carts can be projected by county to correspond to non-attainment areas. The regulatory requirements can be superimposed on the projections to provide probable electric golf cart populations.

OPTION 3A – PUBLIC TRANSIT

Summary

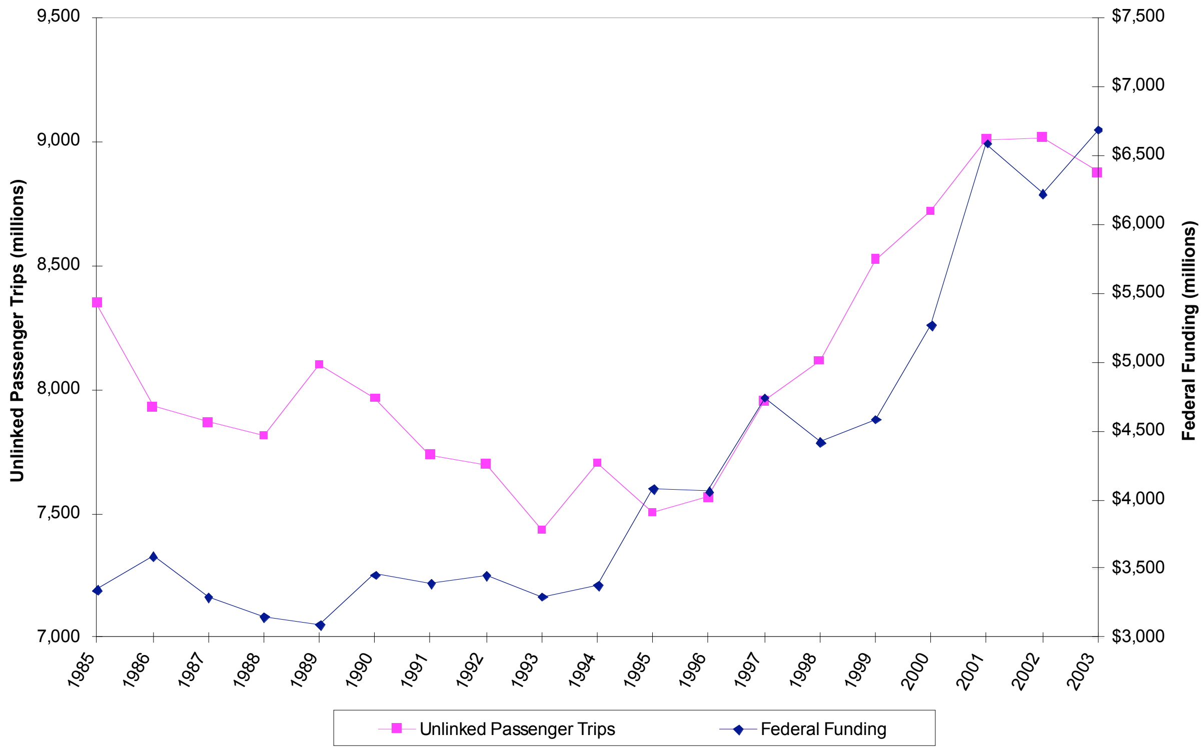
California's dependence on petroleum is projected to continue to increase over the next two decades. As the population of California increases and the number of people on the road increases, California must develop alternatives to mitigate the impacts of the growing population. Public transportation use decreases the number of vehicles on the road, reduces the use of petroleum fuels, and reduces pollution in California. Therefore, increasing the use of public transportation is a key component of attaining these goals.

The number of passenger trips on public transportation is declining is California and the number of bus revenue miles is not growing. These trends can be directly related to California's economic slow down. As revenues from government and tax sources declined and operating expenses grew, public transit agencies have reduced service levels and increased fare. Transit agencies are working to finding way to increase ridership and mitigate the impacts of stagnant revenues.

Introduction

In an effort to stimulate the use of public transportation, the federal government has increased its funding of transit agencies nationwide. Figure 1 shows the increase in unlinked passenger trips and federal funding. The specific use of federal funding is dependent on the needs of the transit agency and community and represents only one source of transit agency funding. Between 1985 and 2003, the federal government increased funding by 100 percent. However, unlinked passenger trips, defined as the number of passengers who board public transportation vehicles, only increased 6.3 percent.[1] Passengers included in unlinked passenger trip numbers are counted each time they board transit vehicles regardless of the distance traveled.[2]

Figure 1
Federal Funding and National Unlinked Passenger Trips



In 2003, bus service comprised nearly 60 percent of the passenger trips on national public transportation agencies receiving federal funding.[3] Bus service is one of the most important and versatile segments of the public transportation system both nationally and in California. This evaluation discusses unlinked passenger trips and bus revenue miles for national and California transit agencies' bus systems and is organized into the following sections:

- Data Evaluation
- Uncertainties Associated with Data
- Identification and Discussion of Current Trends
- Future Trends and Recommendations to Increase Bus Passenger Trips in California

Data Evaluation

Transit agencies who receive funds from the Federal Transit Administration Urbanized Area Formula Program must report selected transit data to the National Transit Database (NTD) program.[4] Both national and California data were evaluated from the collected NTD program data. National information was obtained from the *2003 National Transit Summaries and Trends* (NTST) report.[5] The California information on unlinked passenger trips and bus revenue miles was obtained from the California NTD profiles. Additionally, American Public Transportation Association (APTA) information was used as a secondary evaluation of unlinked passenger trips in California to verify the results.[6]

The national evaluation included data for a 13-year period from 1991 to 2003. As of 2003, 613 national transit agencies submitted data to the NTD program.

Information on 73 California transit agencies was available using NTD profile summary information. Because information for 14 transit agencies was not complete for the entire five years evaluated, only 59 agencies were included in the trend evaluations.

Because the Los Angeles County Metropolitan Transportation Authority (MTA) data values comprised nearly a third of the total evaluated data, the resulting trends may be excessively impacted by the MTA data. Therefore, two evaluations were performed on the California specific NTD profile data, one including the MTA data and a second excluding the MTA data. The two evaluations were compared to confirm the trends observed were indicative of California unlinked passenger trips and bus revenue miles.

The nine years of APTA data was available for unlinked passenger trips only. Although data was collected for 27 transit agencies, only 15 transit agencies' data was complete and used for this evaluation.

Uncertainties Associated with Data

The information obtained from the NTD profiles is reported directly from the transit agencies and should, therefore, represent accurate data. However, because only transit agencies who receive federal funds are required to submit information to the NTD program, the data for this evaluation is comprised of only a portion of all transit agencies. In addition, transit agencies operating nine or fewer revenue vehicles may receive waivers for submitting information. In 2003, the California transit agencies obtaining a waiver from reporting detailed information were the City of Vacaville, Camarillo Area Transit (CAT), Davis Community Transit (DCT), the City of Benicia, and the Placer County Transit (PCT).[7]

The NTD profile evaluation also discusses data points that were questionable. These data points were deemed to be questionable because of inadequate responses by transit agencies to issues that arose during the validation process. Though these numbers have been identified as questionable, they have been included in this evaluation and only consisted of three data points for unlinked passenger trips and six data points for bus revenue miles. Because these nine data points make up a very small fraction of the evaluated data, the trends are minimally impacted.

It should also be noted, that because these agencies partially rely on federal funding as a source of revenue, trends will be impacted by changes in that funding stream. This fact would result in an overemphasis of federal funding as a cause of observed trends. However, since transit agencies have diverse revenue sources, impacts due to changes in federal funding would be diminished. In general, the transit agencies included in this evaluation are among the largest in California and are representative of California.

APTA data is derived primarily from member transit agencies and is supplemented with additional transit agency data. Because the organization's membership includes only a subset of the total transit agencies in the nation, the data would reflect the composition of the organization and not necessarily the nation or California. The limited number of California transit agencies with APTA data, 15 agencies, introduces additional uncertainties. Although this number is only a fraction of the total agencies in California, a cursory evaluation indicates they would be a good representation of California as a whole because four of the five largest transit agencies are included.

Identification and Discussion of Current Trends

This section displays the results of both the California and the national data evaluations. As discussed earlier, two evaluations were performed on the California-specific NTD data: one including the Los Angeles MTA data and one without. These two evaluations were performed to determine if the MTA data exceedingly influenced the California trends.

California NTD Trends Including MTA Data

Figure 2 and Figure 3 show the unlinked passenger trips and bus revenue miles for the 60 California transit agencies evaluated, respectively. The California NTD data with the MTA included show an increase in both passenger trips and mileage until 2002. The data showed an annual growth rate of 2.24 percent from 1999 to 2002 for unlinked passenger trips in California. However, from 2002 to 2003 there was a drop in the unlinked passenger trips of 3.62 percent. From 1999 to 2003, the California transit agencies total bus revenue miles increased at an annual rate of 3.97 percent. It should be noted the rate of growth decreased significantly to 0.18 percent from 2002 to 2003.

Figure 2
Total Unlinked Passenger Trips for 60 California Transit Agencies

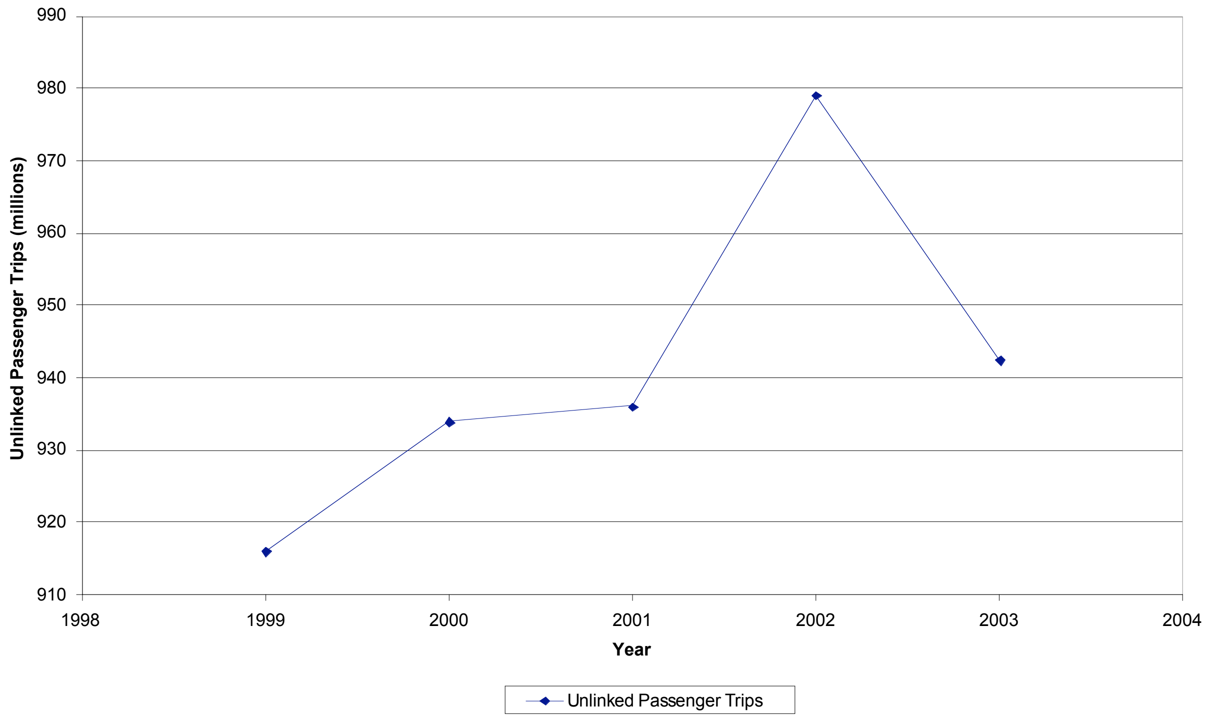
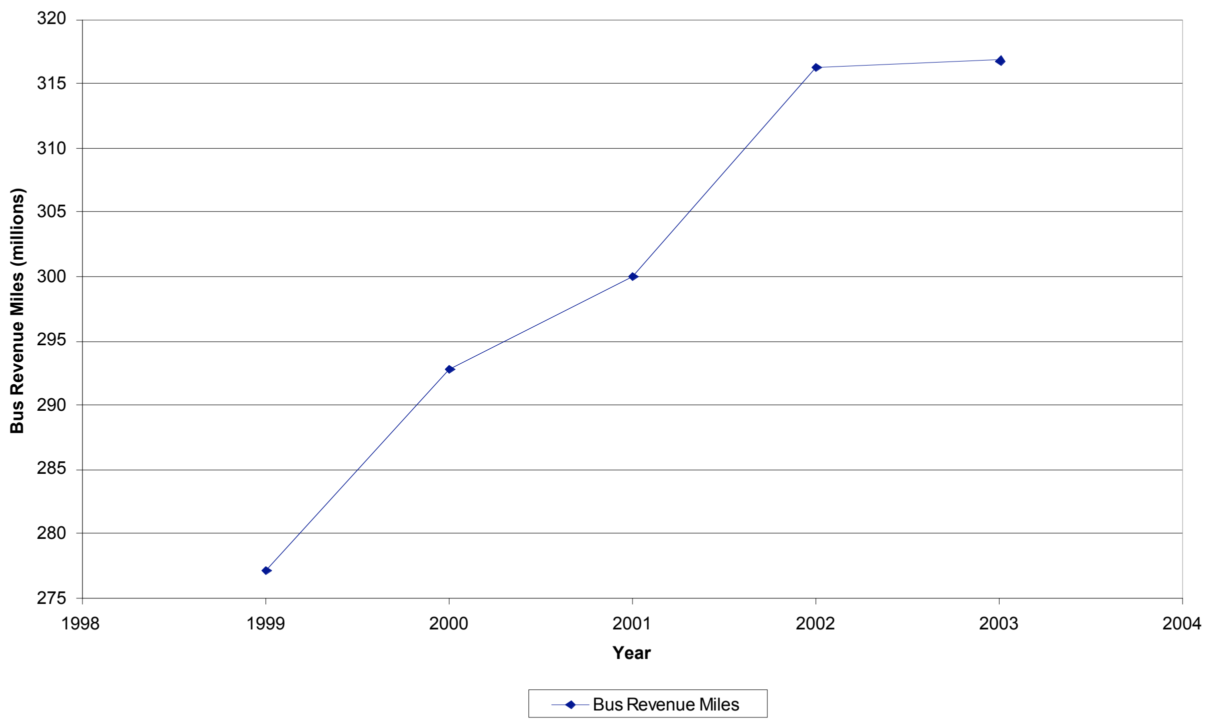


Figure 3
Total Bus Revenue Miles for 60 California Transit Agencies



California NTD Trends Excluding the MTA Data

Figure 4 and Figure 5 show the unlinked passenger trips and bus revenue miles for the 59 California transit agencies evaluated. An evaluation of the California NTD data, excluding the MTA data, shows an increase in unlinked passenger trips of 2.62 percent until 2002. The data then shows a decrease in unlinked passenger trips of 3.94 percent from 2002 to 2003. The data for bus revenue miles shows an annual growth rate of 3.42 percent from 1999 to 2003.

Figure 4
Total Unlinked Passenger Trips for 59 California Transit Agencies

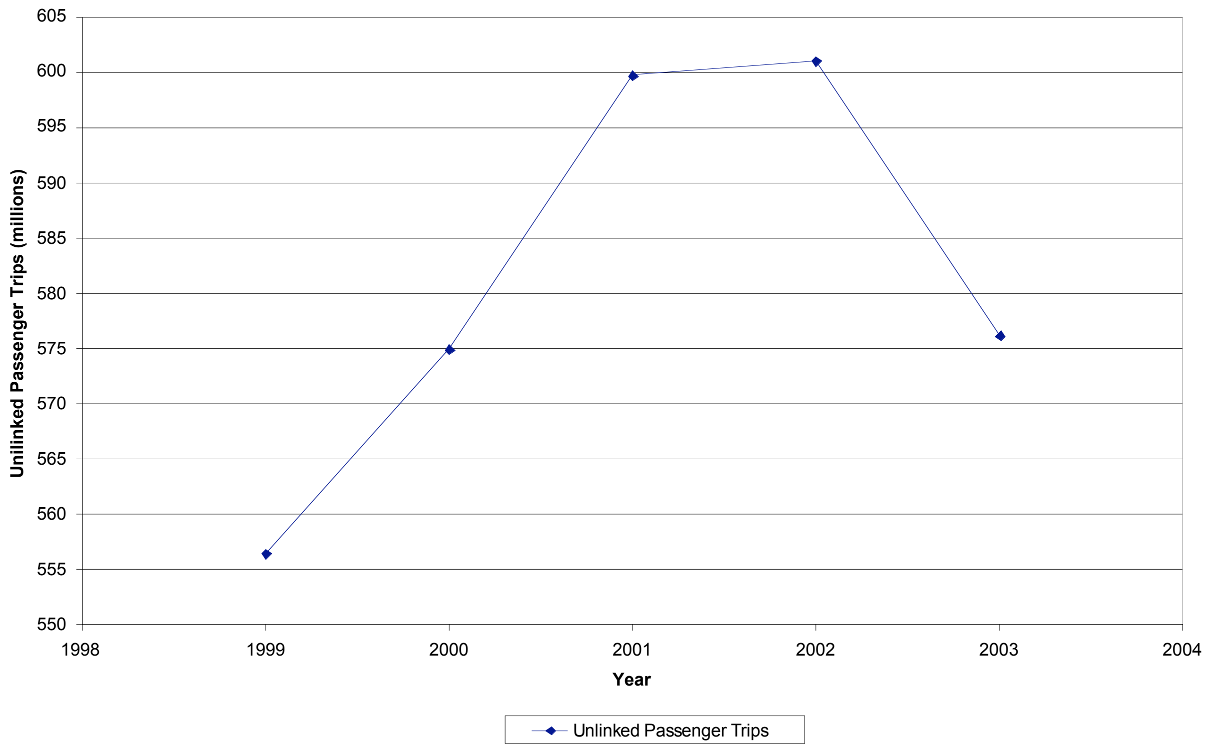
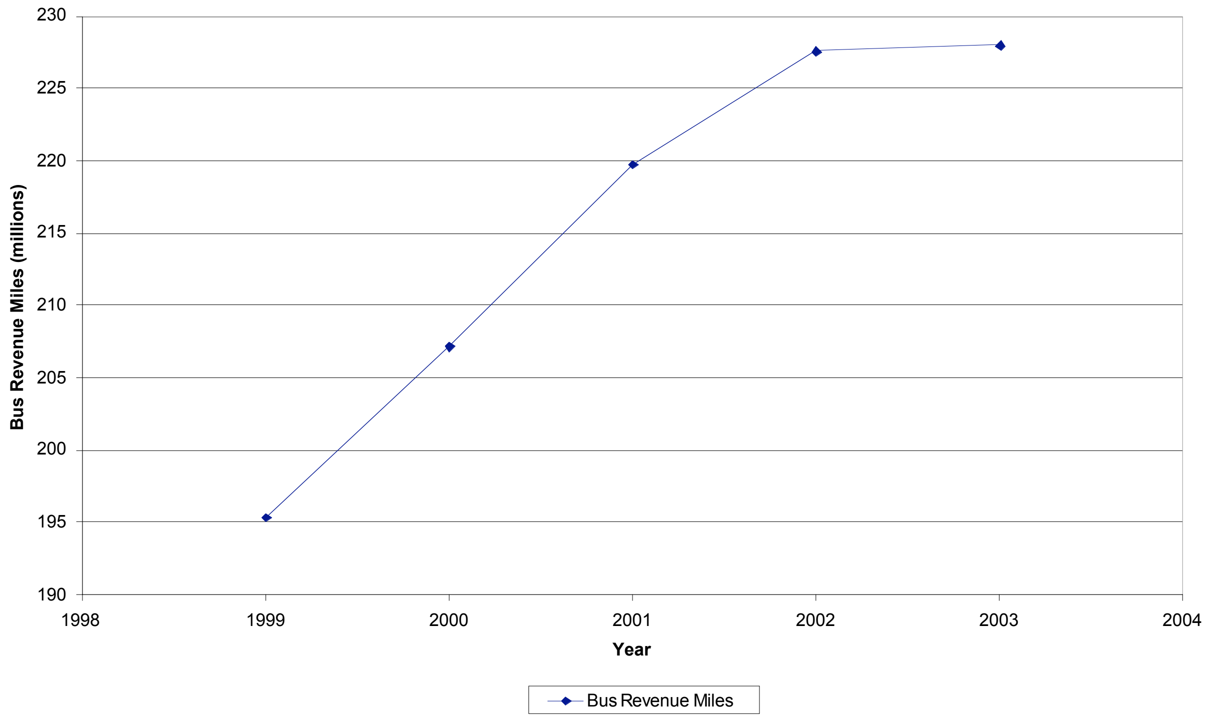


Figure 5
Total Bus Revenue Miles for 59 California Transit Agencies



The evaluation of the California NTD data, both excluding and including the MTA data, indicate similar results and do not indicate the MTA data greatly influenced the California trends observed. In recent years, both evaluations show the number of unlinked passenger trips decreasing and the number of bus revenue miles staying constant.

APTA Data for California Transit Agencies

Figure 6 shows the APTA passenger data from 1995 to 2003 for 15 California transit agencies. This information was obtained from the APTA Transit Ridership Reports for the fourth quarter of the respective year.[8] Only passenger information for buses directly operated by transit agencies was included, information was not included from agencies who only contracted bus services. Of the 27 California transit agencies with APTA data, only 15 had complete data for the nine year period and were evaluated. These 15 transit agencies included four of the five largest California agencies.

The California-specific APTA data in Figure 6 also shows an increase in unlinked passenger trips and bus revenue miles as seen in the NTD data, but only until 2001. Between 1995 and 2001, the total unlinked passenger trips increased by 13.3 percent. In the two years following 2001, however, unlinked passenger trips decreased by 11.7 percent.

Figure 6
Unlinked Passenger TripsAPTA Data for 15 California Transit Agencies

NTST Information

Figures 7 and 8 show information from the 2003 NTST report for a 13-year period and correlates well with the recent California data.

The NTST report shows an increase in unlinked passenger trips from 1996 to 2002 and then a decrease from 2002 to 2003. The average annual percent increase for the unlinked passenger trips from 1996 to 2002 was 2.65 percent. Between 2002 and 2003, the national unlinked passenger trips annually decreased by 2.30 percent. Interestingly, prior to 1996 the number of unlinked passenger trips decreased by 1.36 percent annually. However, unlike the California specific data, the national bus revenue mileage has increased at an average rate of 1.62 percent annually.

Figure 7
National Unlinked Passenger Trips

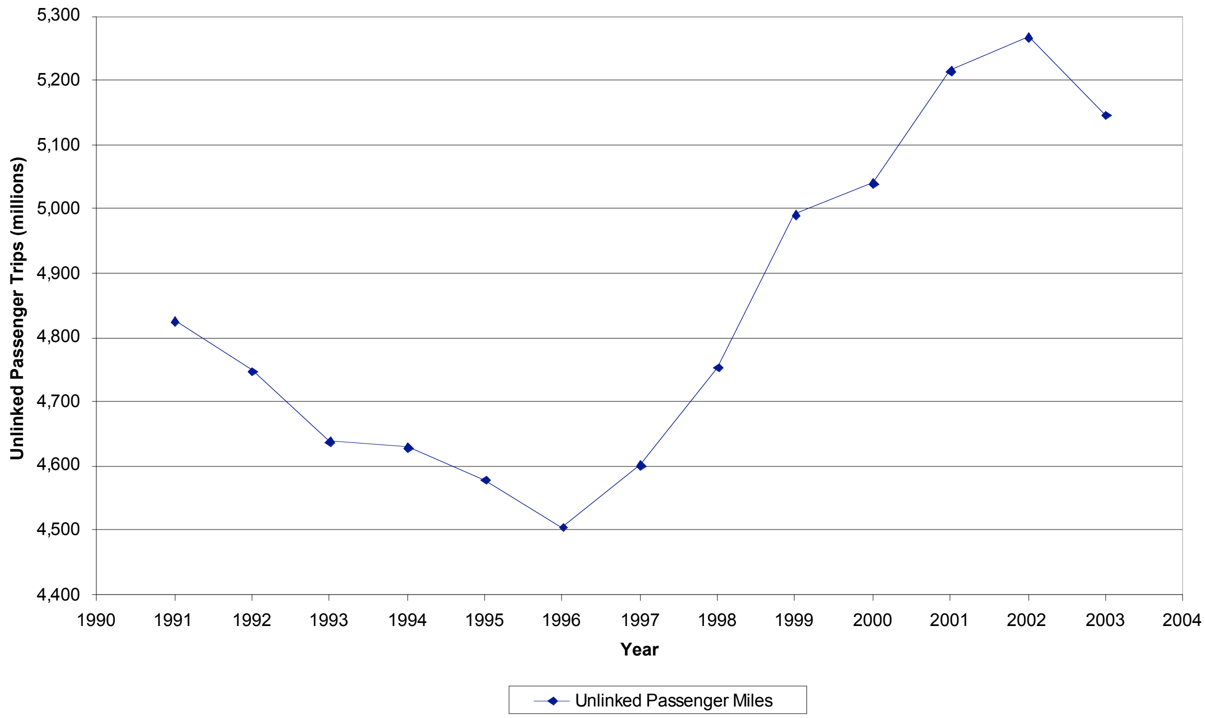
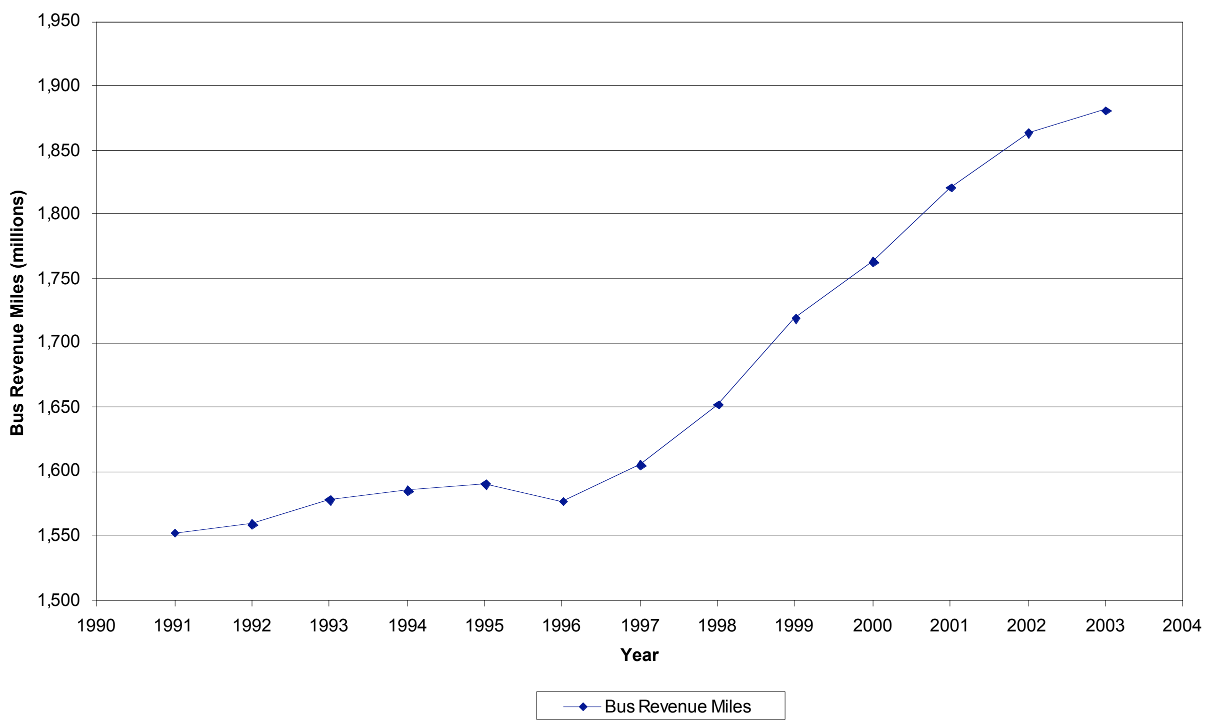


Figure 8
National Data for Bus Revenue Miles



Reasons for Current Trends

The decrease in the number of passenger trips and the flat bus revenue miles growth is directly related to the slowdown in the economy. These trends are referenced in the budgets of the largest California transit agencies.

A review of seven California transit agency budgets for Fiscal Year (FY) 2002 through 2004 indicates that transit agency revenues come primarily from governmental sources, taxpayer sources, and passenger fares. All three revenue sources were impacted by California's slow economy. The San Francisco Municipal Transportation Agency's (MUNI) FY 2004 budget states, "Offsetting [fare and parking rate] increases are reductions in almost all other revenue categories, driven by the effects of the continued economic downturn."[9] The Santa Clara Valley Transportation Authority (VTA) reported ten consecutive quarters of declining receipts starting in the fourth quarter of FY/2000.[10]

Primarily in response to decreased revenues from government and tax sources, transit agencies have had to reduce services, decrease staff levels, and increase fares.

Transit agencies have had to reduce service levels to consolidate services to those routes providing the greatest amount of revenue and which need the most coverage. MTA reported it was decreasing the total bus service hours by 3 percent in FY 2004.[11] Alameda-Contra Costa Transit District (AC Transit) implemented service reductions in June 2003, December 2003, and June 2004.[12] In FY 2004, San Diego's Metropolitan Transit Development reduced service levels to save $300,000 annually.[13]

Reducing working forces have also been used frequently to reduce overall expenditures. MTA, in its FY 2004 budget, decreased its staff level by 104 positions and froze all wages except those union members who have scheduled pay increases.[14] For FY 2004 MUNI reduced its staff by 24.5 operating positions and 68 grant-funded positions.[15]

Transit agencies have increased fares to compensate for decreasing fare revenues. In Los Angeles, the MTA increased the monthly pass price from $42 to $52 starting January 1, 2004.[16] In MUNI's FY 2004 budget, information showed the majority of their fares were increased 25 percent and the parking fees were increased 17 percent.[17] In an effort to maintain the revenues from fares, AC Transit increased their fares in September of 2002 and 2003.[18] VTA increased its fares mid-year 2004 and at the beginning of 2005.[19]

Future Trends and Recommendations to Increase Bus Passenger Trips in California

Until revenue sources return, California transit agencies will be under continued strain to maintain service levels, passenger levels, and fares. Decreases in revenue and increases in operating costs, particularly fuel costs, will continue to impact service levels and fares and, consequently, will continue to impact the number of passengers riding California transit agency buses.

Transit agencies are doing what they can to increase ridership. For example, in 2002, MTA was able to increase the number of passengers by 35 percent on a specific line by decreasing the travel times by 25 percent.[20] This success indicates it is possible to increase passenger trips in some areas by concentrating efforts on high volume routes and introducing express routes. This method alone is not enough, however. Additional steps need to be taken to ensure transit agencies in California can meet the growing demands.

Recommendations

To mitigate the adverse consequences of continued population growth and transportation challenges confronting California, as well as decrease California's dependency on petroleum fuels, lower pollution, and decrease congestion, the Energy Commission should:

1. Investigate potential dedicated funding sources for transit agencies to decrease the impacts of economic downturns on the transportation industry.

2. Perform research on the benefits to consolidating transit agencies to minimize the impacts of a slow economy on small transit agencies.

3. Work with the California Department of Transportation to evaluate the benefits of implementing Bus Only Lanes, priority bus right-of-ways, targeted express routes, guaranteed ride home programs, and general land use policies.

4. Perform additional research on transit agency plans to increase passengers, evaluate effectiveness, and work to disseminate the information to other transit agencies who may benefit from that knowledge.

Endnotes

[1] National Transit Database 2003 NTST, pg. 3; 2003 NTST Table of Charts, pg 1.

[2] From APTA website. http://www.apta.com/research/stats/ridershp/definitions.cfm.

[3] 2003 NTST Table of Charts, pg. 61.

[4] Transit Profile information obtained from the NTD Program website. http://www.ntdprogram.com/NTD/ntdhome.nsf/Docs/NTDPublications?OpenDocument.

[5] NTD Program, *2003 National Transit Summaries and Trends*.

[6] APTA, *Quarterly Transit Ridership* fourth quarter reports. http://www.apta.com/research/stats/ridershp/riderep/indexus.cfm.

[7] 2003 NTD Program – Transit Profiles, Appendix B Transit Agencies Receiving Reporting Waivers (Approved by FTA), p. 1
http://www.ntdprogram.com/NTD/Profiles.nsf/Docs/2003All/$File/2003AppB.pdf

[8] APTA website. http://www.apta.com/research/stats/ridershp/riderep/indexus.cfm

[9] MUNI, *FY2004 Operating Budget*, p. 12.

[10] VTA, Board Memorandum, *FY 2003-04 & FY 2004-05 Operating Budget*, p. 2.

[11] MTA, *FY04 Adopted Budget*, p. I-2.

[12] AC Transit, FY 2004-2005 Budget information. http://www.actransit.org/pdf/aboutus_2004.pdf

[13] San Diego's Metropolitan Transit Development Board of Director's Meeting, March 11, 2004, p. 3.

[14] MTA, *FY04 Adopted Budget*, p. I-1.

[15] MUNI, *FY2004 Operating Budget*, p. 13.

[16] MTA, *FY04 Adopted Budget*, p. I-1.

[17] MUNI, *FY2004 Operating Budget*, p. 16.

[18] AC Transit, FY 2004-2005 Budget information. http://www.actransit.org/pdf/aboutus_2004.pdf

[19]VTA, Board Memorandum, *FY 2003-04 & FY 2004-05 Operating Budget*, p. 2.

[20] MTA, *FY02 Budget Summary*, p. 1-21.