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Report on

Economic Benefits and Feasibility of Strategies to Reduce Petroleum Consumption in California

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Executive Summary

This report analyzes the economic benefits and the feasibility of implementing Proposition 87, California's Clean Alternative Energy Act (CAEA), which will create a modest extraction fee on oil produced in California and use the proceeds (estimated at $4 billion over one decade) as research and production incentives for alternative energy, alternative energy vehicles, energy efficient technologies, and for education and training.

Based on our analysis, the CAEA will achieve the expected savings of 4 billion gallons of petroleum (equivalent to about 25 percent of current gasoline use) in 2017, and total savings of 10 billion gallons over ten years between 2007 and 2017. In achieving these savings, the CAEA will reduce greenhouse gas emissions, and local air pollution, while stimulating the California economy:

- Based on our analysis, which was conducted for a range of future oil prices, anywhere from about 10,000 to 20,000 new jobs will be created by 2025 (Figure A), and the state product in 2025 will increase by about $1.5 to $2.4 billion specifically as a result of the CAEA interventions (Figure B). The aggregate increase in income during the period 2007 to 2025 is expected to be from about $7 to $13 billion. The most likely outcomes will be at the higher end of these forecasts, given that future oil prices are expected to be at or above current prices.

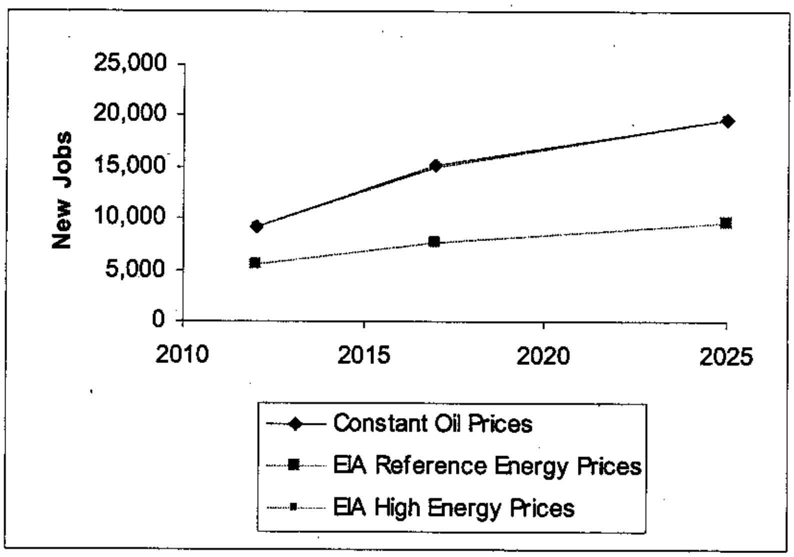

Figure A. Increase in jobs as a result of CAEA interventions (three different future oil price assumptions).

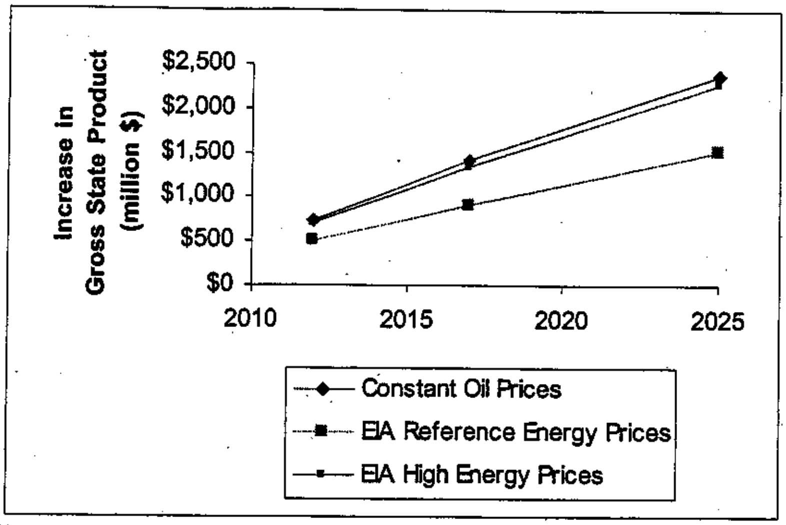

Figure B. Increase in Gross State Product as a result of CAEA interventions (three different future oil price assumptions).

- In addition, these augmentations of state product will result in increased tax revenues of $1.4 billion to $2.2 billion through 2025 (Figure C).

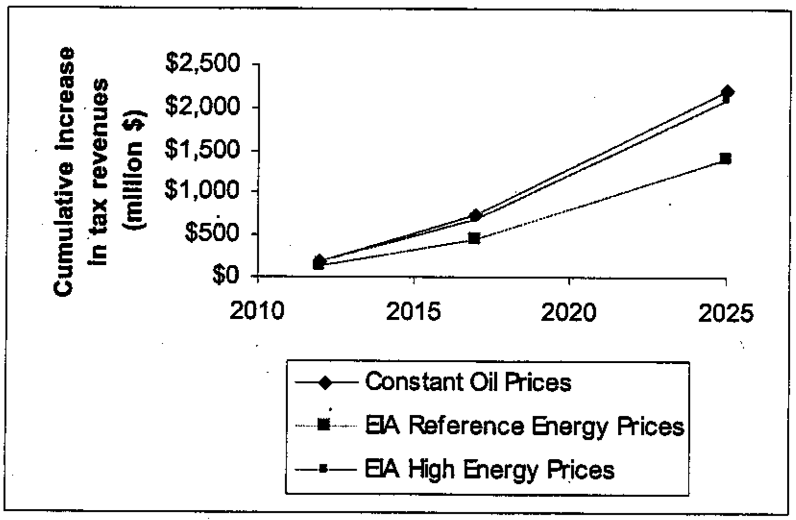

Figure C. Cumulative increase in tax revenues as a result of CAEA interventions (three different future oil price assumptions).

- While no analysis of local air pollution benefits were developed in the study, the strategy results in significant additional reductions in greenhouse gas emissions (nearly 384 million tons of cumulative emissions in CO_2 equivalent terms; see Figure D) as a result of switching to advanced vehicle technologies and alternative fuels. At least a portion of these greenhouse gas emissions reductions will be accompanied by lower air pollutants and toxics as a result of the increased shares of electrics, fuel cell vehicles, plug-in hybrids, and biodiesel. The emissions reductions will be consistent with, and thereby reduce the burden of, complementary legislation to reduce greenhouse gas emissions in California, such as AB 1493 and AB 32.

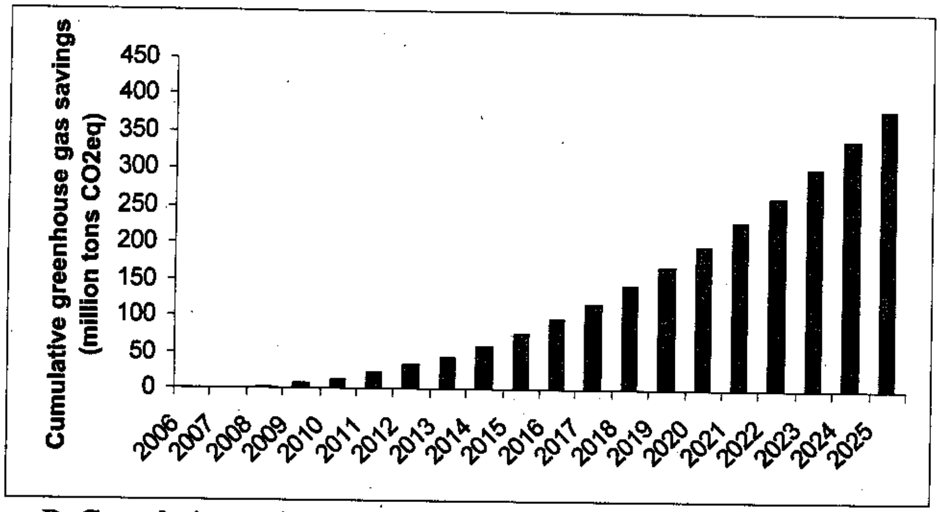

Figure D. Cumulative savings in greenhouse gas emissions as a result of CAEA interventions.

I. Introduction

Once again, petroleum is in the news, as rising global demand for transportation coincides with political instability, war and shrinking spare production capacity, pushing retail prices of gasoline to historic highs. The impacts of these events seem all too familiar from previous oil crises: the overall economy loses steam even while oil industry profits rise to unprecedented levels. Thus, while many retail businesses struggle to stay afloat and the average consumer barely manages to make ends meet[1], the combined profits of the major oil companies in 2006 are expected to reach a record $135 billion[2]. But the apparent paradox is not difficult to explain. In a tight market, all oil producers, including those with low costs of production, will benefit from world prices reflecting the most expensive means of extraction and delivery associated with the last barrel of oil supplied. In contrast, high gasoline and diesel prices provide consumers with fewer savings as well as less money left over for other purchases, which in turn reduces the ability for businesses to hire employees. Moreover, while oil producers gain what economists term "windfall profits" from high oil prices, these revenues are not necessarily recycled back into the local economy in the form of new investments.[3]

If high oil prices can cause economic pain and yet generate windfall profits for oil producers, it follows that using a modest portion of these profits to reduce net consumer expenditures will generate positive results for the local economy. This is in fact what is intended by the proposed Clean Alternative Energy Act (CAEA), which will be on the November 2006 general election ballot in California as Proposition 87. The CAEA aims to generate $4 billion over 10 years through a modest extraction fee on petroleum produced in the state, and use the proceeds to invest in clean energy programs to reduce gasoline and diesel to begin conserving 4 billion gallons annually by 2017, and conserve a total of 10 billion gallons over ten years between 2007 and 2017. In so doing, it intends to invest in new technologies, energy systems training and better management systems that will effectively improve the overall economy of the state while reducing dependence on oil imports and reducing greenhouse gas emissions as well as local air pollution.

Extraction fees on the removal of natural resources from the earth are not a novel idea. Thirty eight states, including California, assess a fee on a portion of the value of natural resources extracted, or "severed," measured by the quantity or value of the coal, iron natural gas or oil removed or produced.

The CAEA's proposal is to assess an extraction fee according to the following schedule:

- 1.5 percent of the gross value of oil from $10 to $25 per barrel.

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[1] "Inflation, gas take a toll on outlook," *Orange County Register*, June 6, 2006, Business and Financial News, p1; "Not just driving less; spending less: Shoppers' economies hurt sales of everything except necessities," *Arizona Daily Star*, May 28, 2006, Business and Financial News, p1; "Gas Prices and Rate Worries Rattle Consumer Confidence," *New York Times*, May 13, 2006, Section C, Column 2, p1.

[2] "Why You Should Worry About Big Oil," , , *Businessweek*, May 15, 2006.

[3] In fact, as noted by the *Businessweek* cited above, over the last year, "the six major oil companies spent more on share repurchases and dividends than they spent on capital investments"

- 3.0 percent of the gross value of oil from $25.01 to $40 per barrel.
- 4.5 percent of the gross value of oil from $40.01 to $60 per barrel.
- 6.0 percent of the gross value of oil above $60.01 per barrel and above.

California has already been a pioneer in developing far-reaching greenhouse gas strategies[4], including the expansive California Global Warming Solutions Act of 2006 (or AB 32)[5], as well as regulations specifically for transportation (through AB 1493)[6]. Previous analysis has established the positive economic impacts of AB 1493, that up to 55,000 jobs could be created in California in 2020[7]. For the CAEA, based on estimates from other studies, Nemet et al[8] have suggested that up to 265,000 job-years could result in a ten-year period (roughly 26,500 jobs per year).

The CAEA is a bold and timely intervention in California, the leading user of petroleum in the country. In 2005, California's gasoline consumption, at around 16 billion gallons, was about 15 percent above China's and constituted one seventh of national demand. The introduction of the CAEA will reduce gasoline and diesel demand below what even greenhouse gas emissions standards alone could achieve, which will greatly relieve the pressure on oil demand for the state and for the country as a whole.

This report examines one set of possible interventions, among many, to reduce oil consumption in California, with a focus on light and heavy-duty vehicles and the off-road sector. The analysis does not consider petroleum demand associated with air transportation, which is outside the jurisdiction of the CAEA. It uses scenario analysis to evaluate the interventions and their impacts on energy demand. The results, which include sensitivity analyses around future oil prices, show that the interventions would be able to meet CAEA targets for reduced petroleum consumption and also improve the California economy.

While there are numerous ways to reduce fuel consumption in the transportation sector, this study emphasizes only those that are relevant to the CAEA—the introduction of alternative fuels and advanced technology vehicles in the light-duty and heavy-duty vehicles categories (LDV and HDV, respectively) as well as the increased use of bio-diesel and electricity for off-road vehicles and equipment. Special attention is paid to

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[4] See for instance, Alison Bailie and Michael Lazarus, 2005: California Leadership Strategies to Reduce Global Warming Emissions, Tellus Institute report to California State Agencies, California Energy Commission, Sacramento, July 28.

[5] Assembly Bill 32, which was approved on August 31, 2006 by the Legislature, seeks have the California Air Resources Board develop a plan and implement regulations sufficient to achieve 1990 levels of greenhouse gas emissions by 2020.

[6] Assembly Bill 1493, also known as the "Pavley" bill, was signed into effect in July 2002. The California Air Resources Board has adopted final regulations in September 2004, but is currently seeking a waiver of preemption from the US Environmental Protection Agency. See http://www.arb.ca.gov/cc/cc.htm for further information.

[7] California Air Resources Board, 2004: Economic Impacts of the Climate Change Regulations, Technical Support Document, Sacramento, August 6, http://www.arb.ca.gov/cc/factsheets/august_tsd/economics_august.pdf.

[8] Gregory Nemet, Jenn Baka, and Daniel Kammen, 2006: Economic and Environmental Analysis of California's Clean Alternative Energy Act, Energy and Resources Group, UC Berkeley, April 6.

LDVs, which are responsible for over three quarters of on-road and off-road transportation energy demand in California. By introducing a mixed portfolio of the most advanced, yet viable, options for lowering gas consumption, in the form of new vehicle technologies and alternative fuels, through carefully targeted subsidies and vehicle buy-down incentives, California can meet the challenge of reducing petroleum demand by 25 percent in the next decade.

To evaluate the impacts of the various transportation options, the authors utilized a software tool known as the Long-range Energy and Analysis Planning (LEAP) model to generate two scenarios of energy demand through 2025, a Business-as-usual case and a Low Oil case. The Business-as-usual scenario took into account the California Air Resources Board's (CARB) latest regulations in the Low Emission Vehicle (LEV-II) program, which expects the sales of light-duty diesels, hybrid-electrics and zero emissions vehicles to rise over the next several years. The Low Oil scenario assumed, in addition to these changes, a combination of alternative fuels and vehicles spanning the LDV and HDV sectors as well as off-road equipment. In both scenarios, the cumulative fuel savings over 10 years exceeds the 10 billion gallons expected by CAEA, and slightly more than 4 billion gallons in 2017. While no analysis of local air pollution benefits were developed in the study, the strategy results in significant additional reductions in greenhouse gas emissions (nearly 384 million tons of cumulative emissions in CO_2 equivalent terms) as a result of switching to advanced vehicle technologies and alternative fuels. At least a portion of these greenhouse gas emissions reductions will be accompanied by lower air pollutants and toxics as a result of the increased shares of electrics, fuel cell vehicles, plug-in hybrids, and biodiesel. Moreover, the greenhouse gas emissions reductions will be consistent and complimentary with the goals of AB 1493.

To analyze the economic impacts of the interventions, the scenario results for fuel savings and capital costs were used in modeling analysis that used the results of an economic input-output model known as IMPLAN (IMpact analysis for PLANning).

II. Interventions

There are several options available to reduce petroleum use, particularly for passenger transportation, which is governed by several factors (see Figure 1). Some of these are associated with extraneous interventions like pricing, regulation and the introduction of new technologies; others by personal decisions and community planning. Together, they provide powerful means to reduce total petroleum consumption in a given economy. For instance, the fraction of petroleum content of fuel used in a given transportation system, which is normally 100 percent in a fully petroleum-based system, can be reduced by introducing alternative fuels and alternatively fueled vehicles into the transportation system. Fuel economy improvements will by definition cause a reduction in the average petroleum consumption per vehicle mile driven, for vehicles that use petroleum-based fuels or alternative fuel blended with petroleum (e.g., ethanol blends in gasoline).

There are also some very significant ways in which personal decisions and community planning can reduce petroleum consumption. In general, if more passengers fit into a single vehicle to travel a given distance, proportionately less fuel will be consumed. For instance, car-pooling can reduce an individual's fuel consumption by half or more, depending on the number of persons he or she shares their rides with. Transit can play a similar role, particularly if transit vehicles are relatively efficient in their fuel use and routing. Similarly, community planning to make land-uses more efficient as well as technologies to facilitate telecommuting and video-conferencing can greatly reduce petroleum use as well as other externalities associated with transportation, such as local air pollution, greenhouse gas emissions, congestion, accident risks, and, in the long run, even the need for new highways and the associated loss of open space.

To summarize, the following are some of the major interventions that will reduce petroleum use:

- Blending alternative fuels with petroleum products.
- Switching to alternative-fueled vehicles.
- Purchasing more fuel-efficient vehicles.
- Switching to other modes of transportation (commuter and urban rail, bus, bicycle, walking) for some or all of their transportation requirements (e.g. daily commuting, shopping, long-distance travel, etc.), including using park-and-ride schemes that mix cars and public transport.
- Car pooling.
- Using closer shopping and other facilities to reduce travel.
- Telecommuting to reduce commuting and/or long-distance travel or avoid commuting.

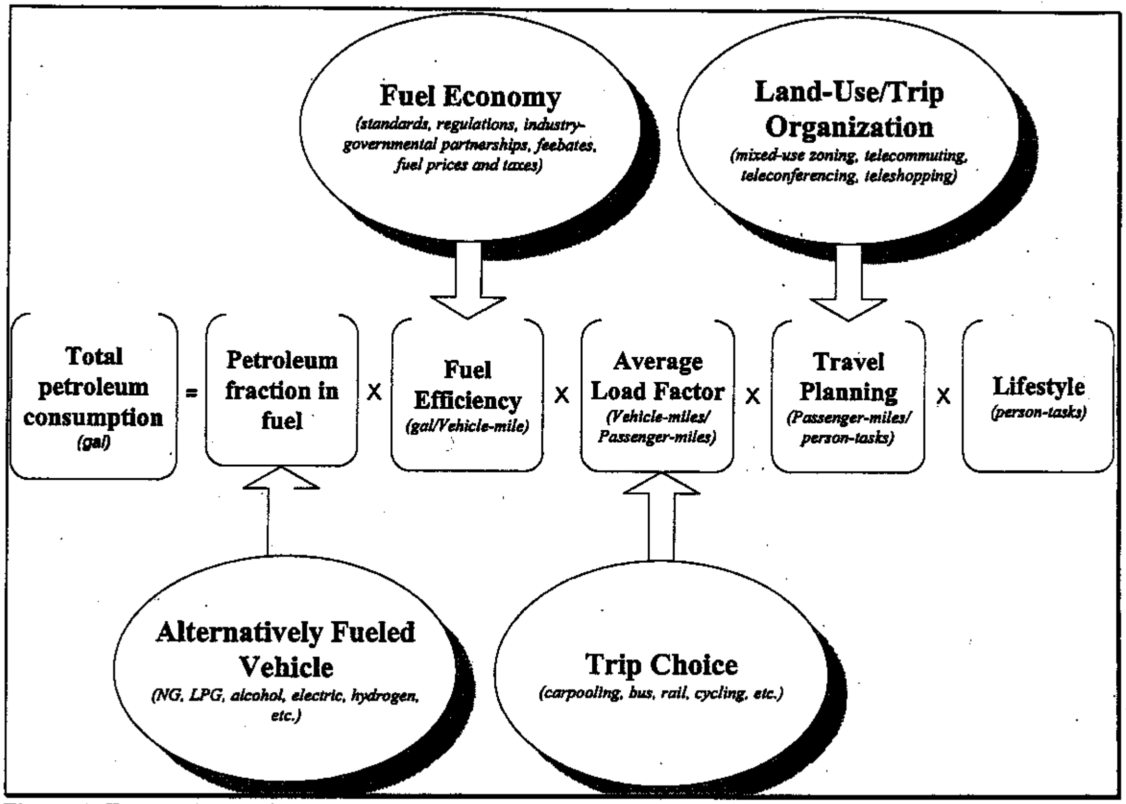

Figure 1. Factors impacting petroleum use associated with passenger travel.

The CAEA is restricted to supporting programs and measures involving the introduction of alternative fuels and advanced technology vehicles. While the Act covers both on-road and off-road uses of petroleum, it does not have jurisdiction over air travel, which is responsible for over 4 billion gallons of jet fuel demand. The CAEA will set up a Gasoline and Diesel Use Reduction account to fund market-based incentives (e.g., loans, loan guarantees, credits, and buydowns to individuals and fleets for the purchase of clean alternative fuel vehicles), production incentives for clean alternative fuel and fueling stations, including bio-fuel blends. It also proposes other accounts to support research and development, commercialization, training, and public education. In particular, school districts and local government agencies will be able to buy cheaper and cleaner running school buses, mass transit buses, waste disposal trucks, public safety vehicles and other vehicles. This will save tax dollars and improve the clean fuel and vehicle market.

Approximately two-thirds of the funds expected to be collected over ten years ($4 billion) will be used to support incentives directly, with the rest for research, training and public education. Specifically, the $4 billion in assessments on the excess profits generated by California oil producing companies will be distributed to different accounts as follows:

- 57.5% (approximately $2.3 billion) to the Gasoline & Diesel Use Reduction Account
- 26.75% (approximately $1.1 billion) to the Research & Innovation Acceleration Account

- 9.75% (approximately $400 million) to the Commercialization Acceleration Account
- 2.5% (approximately $100 million) to the Vocational Training Account
- 3.5% (approximately $140 billion) to the Administration and Public Education Account.

A. Light-Duty Vehicles

The light-duty vehicle (LDV) fleet in California comprises cars, pick-up trucks, minivans and SUVs, which almost completely turnover every 15 years or so. These vehicles account for over 75 percent of the petroleum energy demand (excluding air travel) and therefore represent the greatest potential for interventions relating to fuel and vehicle technology changes. The current vehicle fleet is dominated by gasoline-powered cars and light duty trucks using conventional internal combustion engines, with those using alternative fuels (such as ethanol blends) and other technologies like hybrid electric making up less than 3 percent of the total (Figure 2).

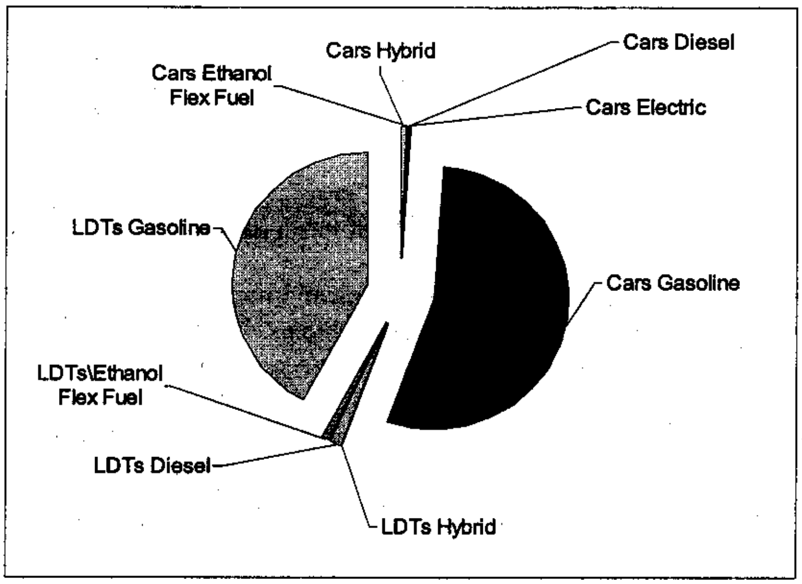

Figure 2. Composition of California light duty vehicle fleet in 2006.

Reducing annual gasoline use for this segment by nearly a quarter in ten years is therefore a significant challenge, especially if no complementary policies are conceivable to reduce or stabilize the total vehicle miles traveled (VMT). Rather, because of annual population growth of nearly 1.2 percent, the total passenger vehicle VMT is expected to increase by nearly 15 percent relative to 2006 levels by 2017. Fortunately, one piece of regulation already on the books and another awaiting legal resolution may each play important roles in reducing the rate of growth of gasoline demand over the coming decade. The first is the introduction of amendments to Low Emission Vehicle regulations (also known as LEV II) by the California Air Resources Board, which will require the sale of some zero-emission vehicles (ZEVs) as well as so-called advanced technology partial zero emission vehicles (AT-PZEVs). The former will include battery powered electric vehicles as well as fuel-cell vehicles most likely powered by hydrogen, while the latter will include some hybrid electric vehicles. In addition, together with ultra-low sulfur diesel and advanced emissions technology, light-duty diesel vehicle sales are expected to make a modest come-back in coming years. Diesel vehicles tend to be more fuel efficient in gasoline-equivalent terms. These regulatory interventions—especially the penetration of hybrids and diesels—in the light-duty fleet will have the effect of reducing the growth of petroleum use in the sector.

The greenhouse gas vehicle standards adopted under AB 1493 (and strengthened by AB 32) constitute the second regulatory factor that will further reduce demand for petroleum products. If CARB's regulations are implemented, the state will likely see increasing fuel economy standards for different classes and technologies of vehicles, phased in from 2009 and resulting in roughly 30 percent reduction in per mile greenhouse gas emissions for new vehicles sold in 2016 relative to those sold in 2002. While the regulations will not require specific technologies, they will encourage the use of improved efficiency conventional vehicles, hybrid electric, alternative fuel and advanced technology vehicles. The expected outcome is for California's petroleum consumption to stay largely flat and then dip slightly below 2006 levels by around 2016[9]. In the absence of these standards, fuel efficiency for gasoline vehicles is projected to remain nearly constant until about 2010 and to increase gradually thereafter.

We consider below some of the intervention options for LDVs.

Ethanol flex-fueled vehicles: Vehicles with internal combustion engines running on the Otto cycle (which includes most gasoline vehicles currently on the road) can generally accept up to 10 percent ethanol blended into the fuel without requiring any modifications. Beyond this level, ethanol is corrosive to the engine, fuel tank and delivery system, and exhaust manifold. Flexible fueled vehicles (FFVs) or E-85 vehicles are those built to resist corrosion and accept up to 85 percent of ethanol blended into the fuel. The 15 percent gasoline blend permits cold-starting of the engine at temperatures below 60 degrees Fahrenheit. There are about 5 million FFVs in the United States today, roughly 5 percent of which are in California. Several American manufacturers and a few Japanese and European manufacturers sell E-85 versions of conventional makes and models, with little or no price premium.

On average, roughly 6 percent of the volume of gasoline sold in California is made up of ethanol, which is primarily blended in to conform to oxygenate requirements. While only a few tens of million gallons of ethanol are currently produced in the state, there is substantial potential to produce up to a billion gallons annually, especially from agricultural and municipal waste and residual biomass resources.[10]

Electric vehicles: Battery electric vehicles (BEVs) use rechargeable batteries in place of the internal combustion engine and the fuel tank in conventional vehicles. Currently,

[9] *Ibid.*

[10] CEC (1999). Evaluation of Biomass-to-Ethanol Fuel Potential in California. Sacramento, California Energy Commission.

most BEVs in use have ranges that are too small to replace conventional vehicles entirely, and are therefore seen as primarily functioning as neighborhood vehicles. But as batteries become cheaper and more energy dense, as suggested by developments in high-performance lithium-ion and magnesium-sulfur cells using polymer electrolytes, BEVs will likely be able to achieve ranges greater than 100 miles and be more cost-effective, thereby becoming viable replacements for conventional vehicles. BEVs will play a small role in the early years of any oil reduction strategy, but with improving technology, they could become important initially as secondary vehicles and eventually as replacements for some conventional vehicles. While BEVs are likely to have a cost premium of anywhere from $5000 to $8500, part of their attractiveness is their reasonable life-cycle costs because of the substantial cost spread between the per-mile fuel costs of gasoline versus electricity.

Hybrid electric vehicles (HEV): One of the most significant innovations in motor vehicle technology in recent years is the electric hybrid, which produces 50 percent or higher improvement in fuel economy relative to conventional vehicles of similar size and weight. This dramatic increase in fuel economy is achieved by making use of power generated through regenerative braking to charge a battery, which is then used to supplement the engine's torque selectively through computer controls. The Toyota Prius and the Honda Insight are the two most popular vehicles using this technology, although other makes and models are expected to reach the market.

The plug-in hybrid vehicle (PHEV) is a variant of currently available HEVs by having a larger battery that can be charged from a regular household electrical outlet. PHEVs can thus be used for short trips of between 20 to 60 miles (PHEV20 and PHEV60, respectively) powered entirely by the battery, thereby resulting in even greater savings in gasoline consumption. A PHEV could be capable of running a large amount of its miles in all-electric mode which would also have significant positive air quality effects in urban areas With good duty cycle design, a PHEV may only need to use its engine during long trips or during heavy acceleration. While PHEVs are not yet in commercial production, several prototypes have been created, including those using aftermarket conversions for HEVs like the Prius.

LEVII regulations are likely to introduce FCVs, BEVs, PHEVs and HEVs into the fleet in coming years. FCVs and BEVs are likely to be classified as ZEVs, while PHEVs and HEVs will mostly be categorized as AT-PZEVs. Table 1 shows an estimate of their penetrations through 2020.

Model Year	AT-PZEVs	ZEVs
2005	43,000	25
2006	64,000	70
2007	73,000	80
2008	81,000	85
2009	112,000	830
2010	122,000	830
2011	133,000	830
2012	148,000	8,335
2013	148,000	8,335
2014	148,000	8,335
2015	205,000	16,660
2016	205,000	16,660
2017	205,000	16,660
2018	197,000	29,640
2019	197,000	29,640
2020	197,000	29,640

Table 1. Estimated light-duty sales of AT-PZEVs and ZEVs in California as a result of LEVII regulations (*Source: Krista Eley, Air Resources Board, personal communication, 5/25/2006*).

Hydrogen fuel-celled vehicles: At both the national and state levels, hydrogen has been heavily promoted as the next-generation fuel for light-duty vehicles to fulfill multiple goals: reducing oil dependence; reducing greenhouse gases; and reducing local air pollution. Hydrogen, like electricity, is an energy carrier and the extent to which the first two goals are satisfied depend on the sources and pathways for producing hydrogen. Considerable research and development is still needed throughout the hydrogen supply chain, from production to final conversion. Finally, fuel cell vehicles (FCVs) are still in development and their widespread use will not be guaranteed without the presence of a fueling infrastructure for hydrogen, creating what has been termed a "chicken-egg" problem.

Notwithstanding these challenges, it seems likely that in the next decade or so, the first batch of commercially produced hydrogen FCVs will be sold in California rather than elsewhere in the country, in part because of the major commitment of state government, private industry, and the research community to make this happen through initiatives such as the California Fuel Cell Partnership (www.cafcp.org) and the California Hydrogen Highway Program (www.hydrogenhighway.ca.gov).

Fuel-efficient replacement tires: Conventional replacement tires tend to have higher rolling resistance and are therefore up to substantially less efficient than original equipment tires. Fuel efficient replacement tires can provide consumers savings of up to 3 percent in fuel efficiency at relatively low incremental costs of about $9 to $22 per set and without adversely affecting tire performance. As mandated by Senate Bill 1170, the California Energy Commission is expected to provide the public information on fuel-efficient replacement tires marketed in the state[11]. Additional informational campaigns can increase the likelihood of consumers purchasing these tires.

[11] See CEC website on the California State Fuel Efficient Tire Program: http://www.energy.ca.gov/transportation/tire_efficiency/index.html

B. Heavy-Duty Vehicles

On-road heavy-duty vehicles (HDVs) comprise urban and school buses and various categories of trucks with a gross vehicle weight higher than 8,500 pounds. Most of these vehicles have significantly longer duty cycles than those in the light-duty category and are also replaced far less frequently. For instance, heavy-duty trucks are likely to undergo engine overhauls every 4-5 years, but may see as many as five such overhauls before being replaced. Consequently, a complete turnover of the vehicle stock in the heavy-duty segment of the on-road fleet may take more than two decades, implying that the penetration of new vehicle technologies will likely have a relatively low impact on petroleum use in the near-term[12]. In fact, because of the way in which heavy-duty vehicles undergo changes in morphology rather than being entirely replaced, it is more useful to quantify them in terms of total vehicle miles traveled by different technological groups than in terms of their numbers in the population. Figure 3 shows the composition of the heavy-duty vehicle segment in terms of fractions of total VMT for different technology/fuel categories. Diesel vehicles are responsible for nearly two-thirds of total VMT, while alternative technologies together constitute about 1 percent.

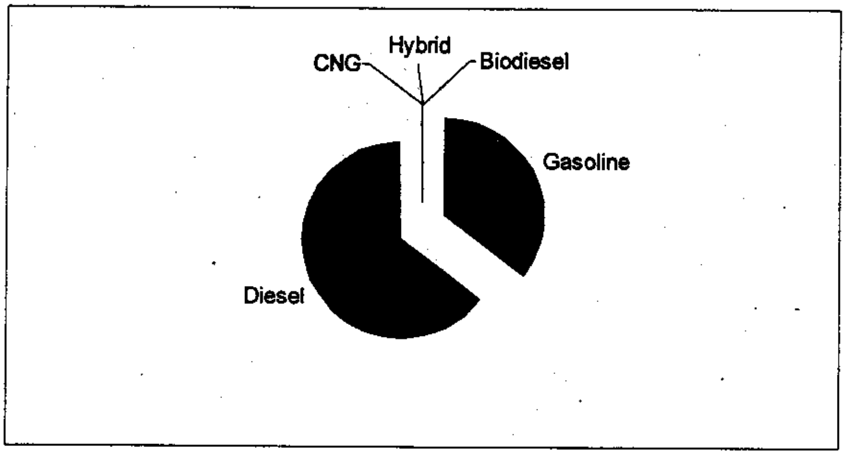

Figure 3. Composition of California heavy duty vehicle fleet (by vehicle miles traveled) in 2006.

Improved Fuel Economy: Improved engine efficiency, transmissions, and reduced rolling resistance and aerodynamic drag can result in significant enhancements in the fuel economy of HDVs. For instance, the introduction of variable geometry turbochargers, high pressure injection systems, with optimized turbo-compounding and reduced heat losses can improve engine efficiencies by over 15-20% compared with today's vehicles. Further improvements are possible with hybrid-electric power trains and reducing driving resistance[13]. Some of the increases in fuel economy, such as those associated with improved rolling resistance and reduced aerodynamic drag, are at relatively low costs compared with engine and transmission efficiency.

[12] The CAEA could, however, provide modest incentives for accelerating the introduction of more fuel efficient engines in the HDV fleet.

[13] Tobias Muster (2000): Fuel Savings Potential and Costs Considerations for US Class 8 Heavy Duty Trucks through Resistance Reductions and improved Propulsion Technologies until 2020. Cambridge, MIT Energy Laboratory.

CNG vehicles: Compressed natural gas (CNG) can be used in both light-duty and heavy duty vehicles, but we focus on their use in the HDVs because of the greater ease of utilizing CNG in fleet operations like transit and school buses. CNG vehicles are primarily a cleaner alternative to conventional gasoline and diesel from the standpoint of particulate matter and also produce less carbon dioxide per unit of energy consumed. In particular, CNG vehicles would be viable replacements for diesel-powered school-buses, which are associated with harmful particulate emissions.

Hybrid electric buses: Hybrid electric buses are a relatively recent innovation that is very promising because the duty-cycle of typical urban transit operations with constant starts and stops is well suited for switching between the internal combustion engine and battery and for taking advantage of regenerative braking technology. Hybrid-electric buses have significantly reduced drive cycle emissions and achieve fuel economy that is roughly 50-75 percent higher than conventional buses. While there are only a few diesel and gasoline hybrid electric bus models available at present, the demand from transit agencies around the world has been growing in recent years, which is likely to cause companies such as GM, Daimler-Chrysler and Toyota to join existing manufacturers such as ISE Corporation and New Flyer Industries. In California, the Long Beach Transit and the San Francisco Municipal Transportation Agency are already integrating electric hybrids into their fleets.

Biodiesel: Biodiesel is created from vegetable and animal fats and has qualities similar to petro-diesel. Soybean oil and waste vegetable oil are seen as important sources of biodiesel, although feedstock availability is a significant constraint. Although diesel engines can use up straight biodiesel, blends are more practical in large scale fueling operations. Furthermore, since biodiesel tends to form a gel at around 40 degrees F, a 20 percent blend of biodiesel with petro-diesel is the preferred option for winter use. Nationwide, the production capacity of biodiesel is nearly 400 million gallons a year, roughly 1 percent of which is used in California. With its zero sulfur content, biodiesel blends are particularly attractive to meet California's low-sulfur requirements for diesel.

C. Off-road Petroleum Demand

The off-road sector comprises a medley of equipment used in various segments of the California economy, including agriculture, construction, industry, households, leisure, the military, and ports, which together consumes about 1.5 billion gallons of petroleum-based fuels annually, primarily diesel. Given the large variety of end-uses in this sector, the simplest oil reduction strategy would be to introduce biodiesel blends for most applications, with electrification as a secondary strategy, where viable, e.g., ports, some industrial equipment, and lawn and garden devices.

III. Methods and Assumptions

For this exercise, we used an in-house end-use model known as the Long-Range Energy Alternatives Planning system (LEAP) to develop forecasts of transportation demand. LEAP is a scenario-based model that utilizes comprehensive accounting of how energy is consumed, converted and produced in a given region or economy under a range of alternative assumptions about population, economic development, technology, price, etc. LEAP uses an activity analysis framework for each sector and end-use as its basis. For the transportation sector, fuel consumption is calculated as the product of the number of vehicles, the annual average mileage (i.e. distance traveled per vehicle) and the fuel economy of the vehicles (e.g. 1/MPG). A stock turnover module was included for the light-duty vehicle sector of the LEAP application that was developed for this analysis. (A more detailed description of LEAP's methodology is available in Appendix E.)

LEAP was used to generate scenarios of energy demand: a Business-as-usual case in which no new policies other than LEVII standards are implemented; and a Low Oil case involving penetration of new vehicle technologies and alternative fuels into the fleet to reach the targets of the CAEA. No new fuel economy improvements for LDVs are assumed in either scenario. Our scenario horizon is 2025 and the base year is 2006, with interventions in the Low Oil case starting as soon as possible, except where technologies need further development, as in the case of hydrogen fuel-celled vehicles. A summary of the scenarios is shown in Table 2.

Scenario	Description
Business-as-usual	[illegible]
Low Oil	[illegible]

Table 2. Summary description of Business-as-usual and Low Oil scenarios.

In the Low Oil scenario we assume a combination of alternative technology vehicles and alternative fuels penetrating the light-duty and heavy-duty segments of the transportation sector. For LDVs, we assume the accelerated penetration of the following technologies: ethanol flex-fuel, plug-in hybrids and regular hybrids, the limited introduction of electrics and hydrogen fuel-cell vehicles in later years, and increased public awareness driving a growing market for fuel efficient replacement tires. Ethanol use in FFVs is assumed to be 20 percent in early years, ramping up to 50 percent by 2012 and remaining constant thereafter.

Our storyline is also consistent with the long-term "hydrogen vision" that Governor Schwarzenegger and several notable researchers and policy analysts in the state have endorsed, with ethanol as a convenient transitional fuel (requiring low to zero costs for vehicle technology modifications) and hybrids/electrics preparing us technologically for a hydrogen future. For this reason, we do not make natural gas or liquefied petroleum gas strong contenders for LDVs. In the heavy-duty segment, we assume modest fuel economy improvements[14] for conventional trucks relative to the Business-as-usual scenario and the accelerated penetration of CNG and the increased use of biodiesel

[14] Improved fuel economy of the HDV fleet will mainly be a secondary result of implementation of the CAEA, as greater innovation in vehicle design filters through to the commercial market for HDVs.

(assuming B-20 blends); and CNG and hybrid electric vehicles for school buses and urban buses.

Our inputs for sales and vehicle mileage data in the light-duty sector were obtained from California Energy Commission (CEC) staff. These were used in LEAP, with assumptions concerning the rate of stock turnover and fuel economy to develop the LDV energy demand scenarios. We also obtained forecasts from CARB on their estimates of true zero-emitting vehicles (ZEVs) and advanced technology-partial ZEVs (AT-PZEVs) to make assumptions about the penetration of electric vehicles and hybrids in the counterfactual scenarios. We independently obtained forecasts on diesel penetration in the LDV sector from CEC. As an example, Figure 4 shows the sales penetration of different categories of LDVs in the Low Oil scenario. Appendix A provides details of the penetration rates for vehicle categories and off-road devices and scenarios.

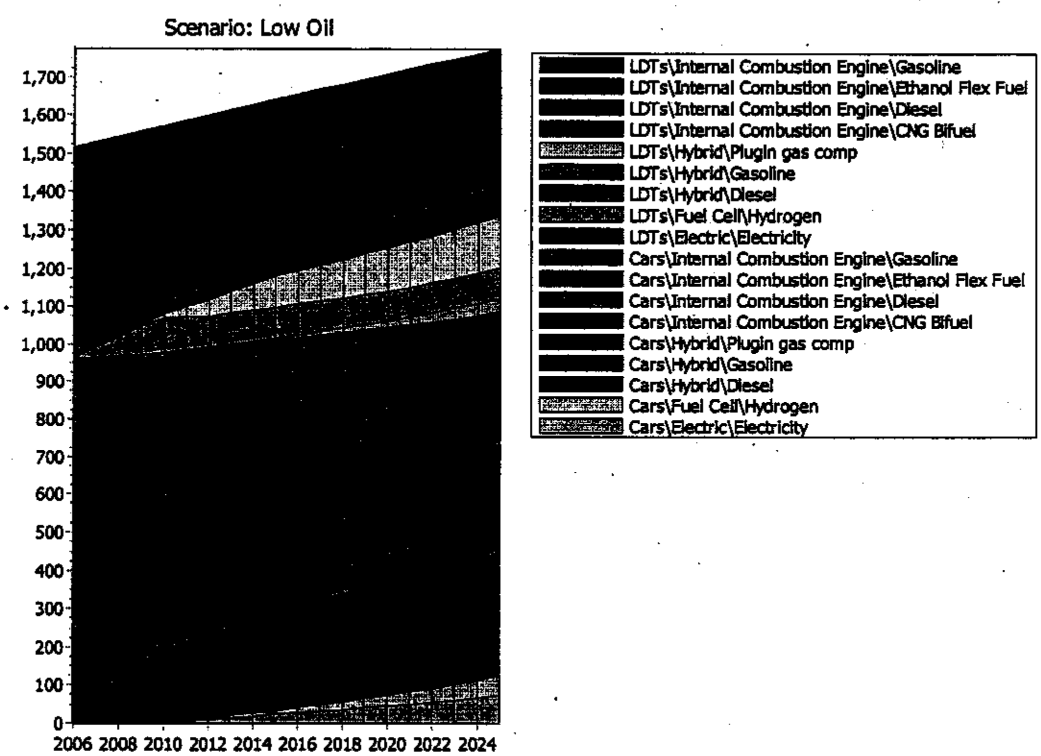

Figure 4. Penetration rates of different LDV types in Low Oil scenario.

Figure 5 shows how stocks of these different categories evolve over time for this example.

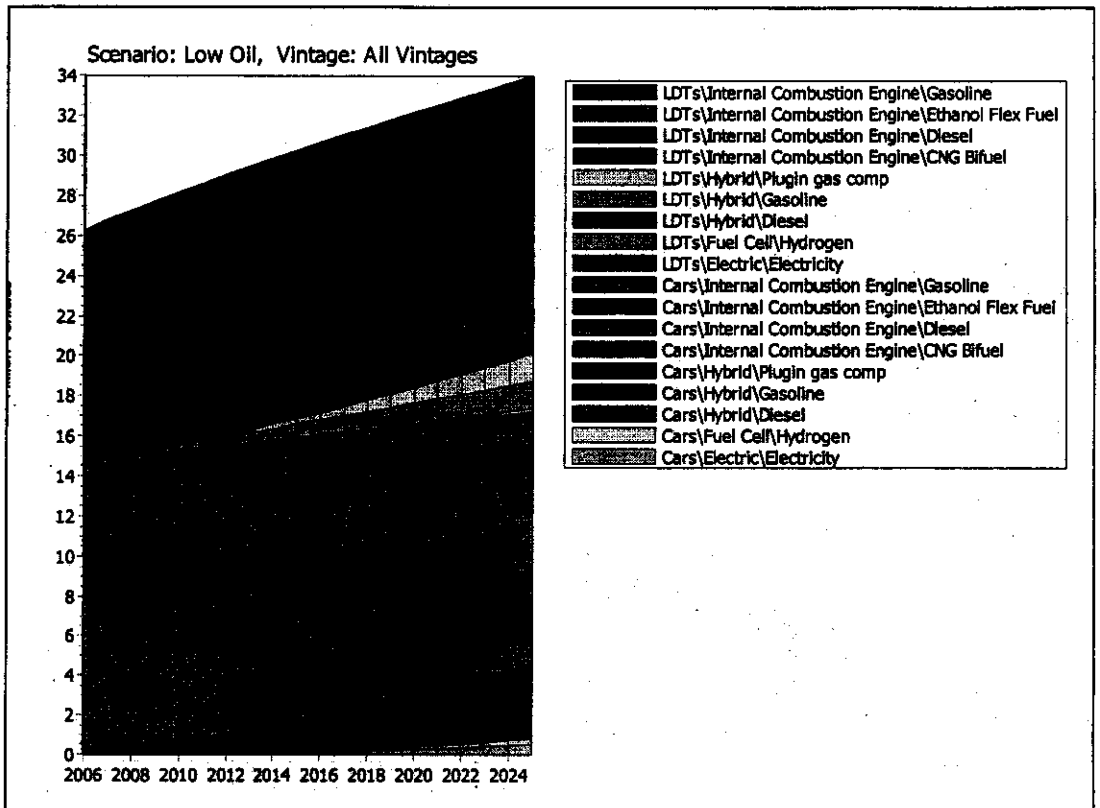

Figure 5. Stocks of different classes of cars in Low Oil scenario..

Fuel economy assumptions in the Business-as-usual scenario were derived from CEC and CARB estimates. In the Low Oil scenario, as in the Business-as-usual case, we conservatively assumed no fuel economy improvements for conventional gasoline vehicles. For other technology/fuel combinations, fuel economy improvements were based on mid-level technology assessments in the literature. Figure 6 provides an example of how fuel economy changes were treated in the Low Oil scenario for cars.

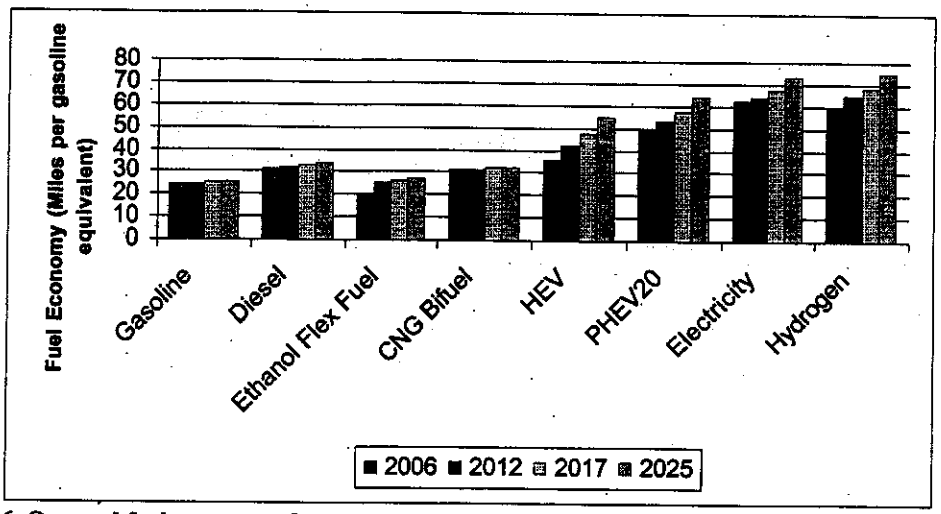

Figure 6. On-road fuel economy of new cars in the Low Oil scenario.

Figure 7 shows the total vehicle miles associated with different categories of school buses in the Low Oil Scenario, and Figure 8 shows the corresponding data for heavy duty trucks. For all the analyses, vehicle costs and fuel price data were developed by TIAX LLC using available price forecasts and existing models (see Appendix B).

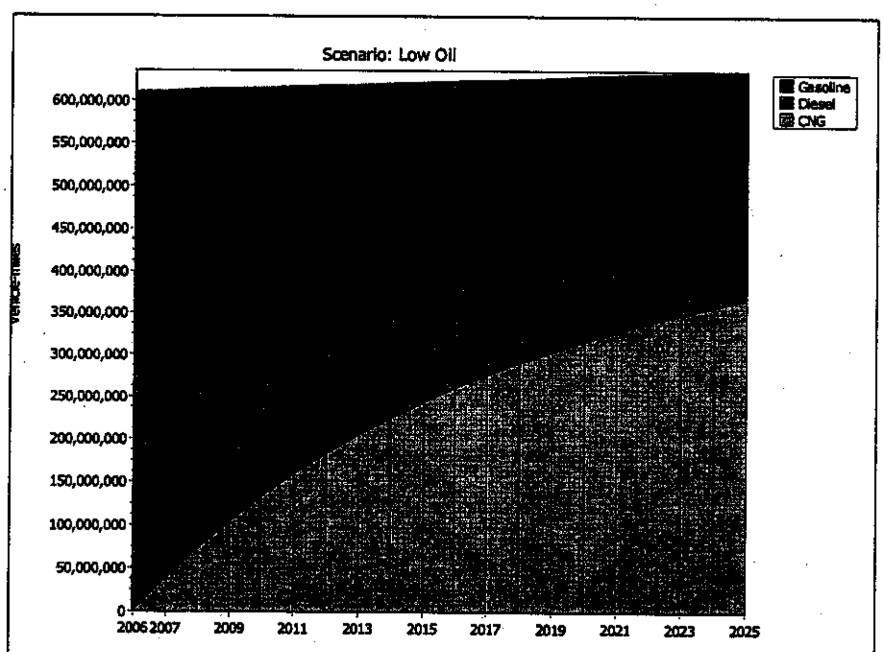

Figure 7. Activity levels (vehicle miles) for different classes of school buses in Low Oil scenario.

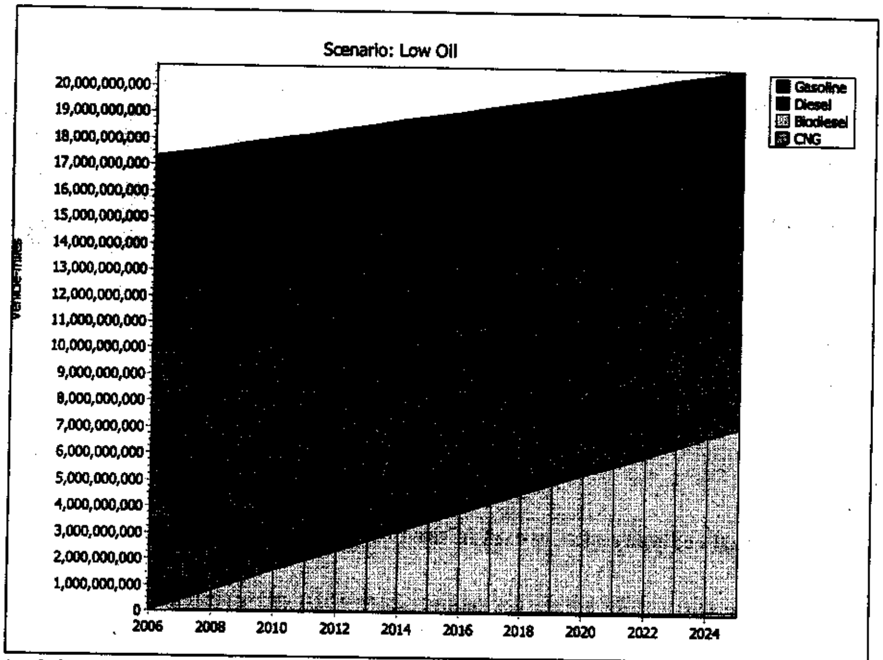

Figure 8. Activity levels (vehicle miles) for different classes of heavy duty trucks in Low Oil scenario.

Finally, Figure 9 shows how the biodiesel and electric technology increase among off-road equipment in the Low Oil scenario.

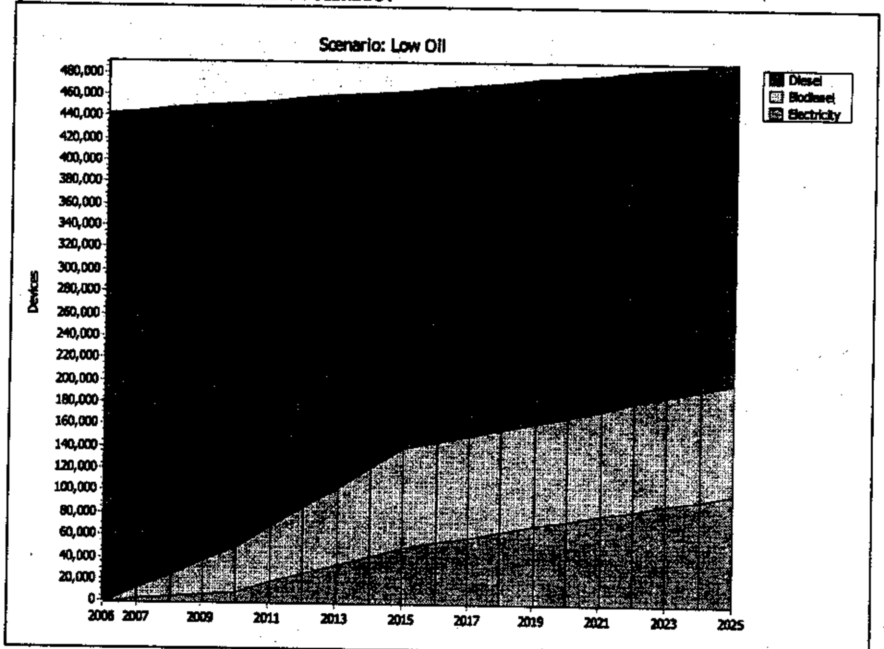

Figure 9. Penetration of different fuels and technologies in off-road equipment in Low Oil scenario.

IV. Results

Gasoline and diesel demand for the entire on-road sector are shown in Figures 10 and 11, respectively. The cumulative fuel savings in ten years exceed ten billion gallons in both scenarios.

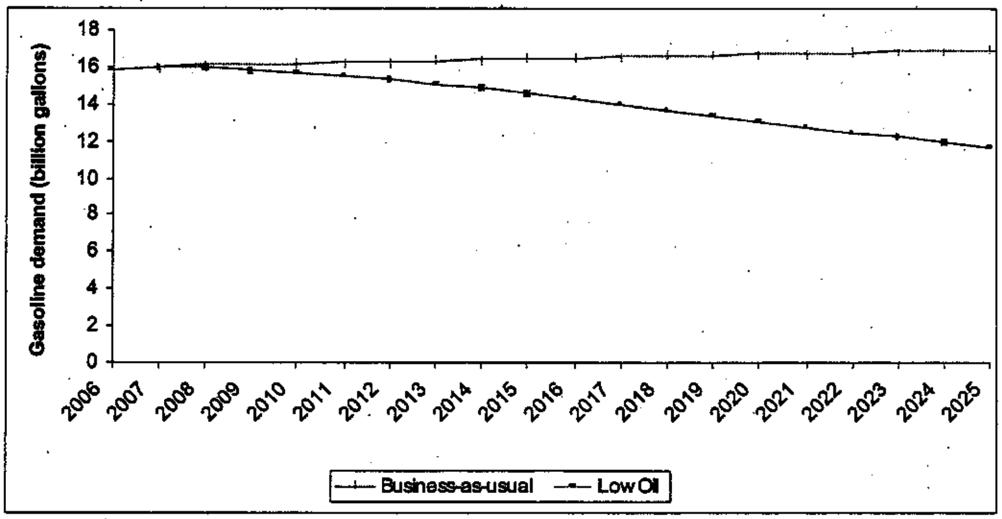

Figure 10. Gasoline demand from on-road vehicles in California for the Business-as-usual and Low Oil scenarios.

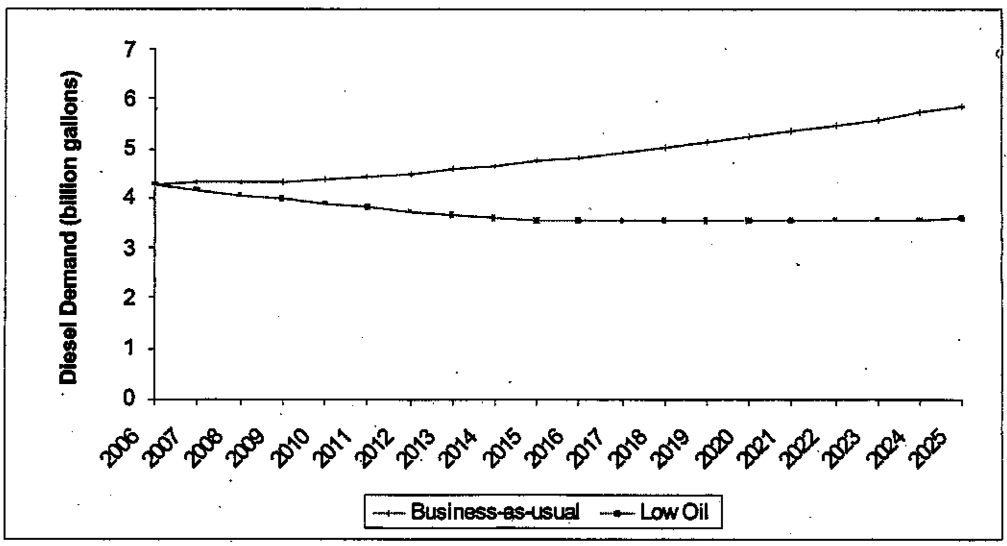

Figure 11. Diesel demand from on-road vehicles in California for Business-as-usual and Low Oil scenarios.

The savings in gasoline and diesel in 2017 in the Low Oil scenario are shown in Table 3 below.

[redacted]

Table 3. Gasoline and Diesel Savings in 2017 as a result of CAEA interventions.

Figure 12 shows the contribution of different technology/fuel combinations to achieving the gasoline and diesel savings trajectories shown in Figures 10 and 11 above.

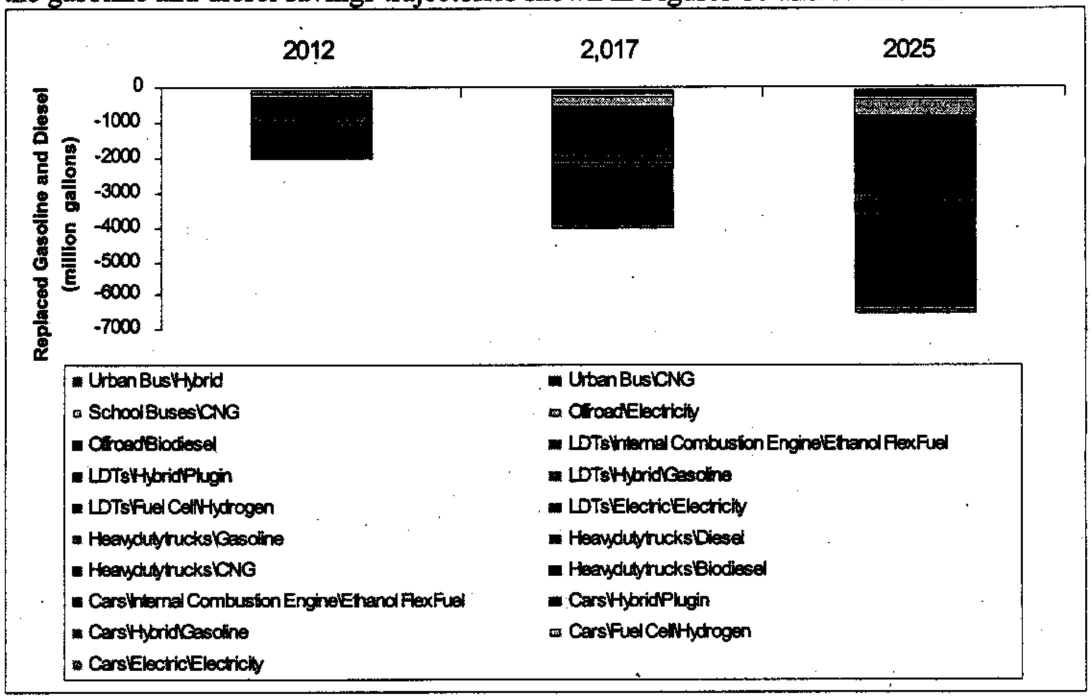

Figure 12. Contributions of different technologies and fuels to gasoline and diesel reductions in 2012, 2017 and 2025 in the Low Oil scenario.

Figure 13 shows the Low Oil scenario will also help stabilize greenhouse gas emissions at or below current levels compared to a 14 percent increase over the next two decades, resulting in a savings of about 42 million tons in CO_2 equivalent terms in 2025 and cumulative savings of nearly 385 million tons.

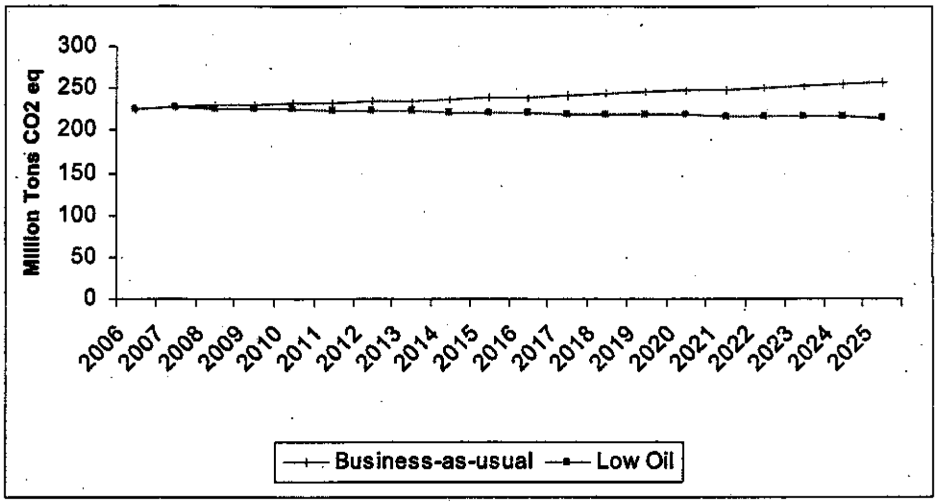

Figure 13. Greenhouse gas emissions from on-road transportation and off-road equipment in the Business-as-usual and Low Oil scenarios.

Emissions of other pollutants will also be reduced by varying amounts specifically, as a result of some of the Low Oil interventions, such as the increased use of ethanol, hybrids, electric and fuel cell vehicles. Biodiesel, replacing diesel, will cause a small increase in the emissions of oxides of nitrogen, but will reduce particulates, carbon monoxide and hydrocarbons substantially.

In order to estimate the cost savings or cost increase that would result from the interventions, we reviewed two sets of oil price forecasts from the Annual Energy Outlook (AEO) 2006 of the Energy Information Administration or EIA (http://www.eia.doe.gov/oiaf/aeo/index.html). The EIA's Reference Energy Prices Case crude oil price forecasts are lower than those predicted by the futures markets (e.g., NYMEX futures for light crude oil have hovered between $65 to $75 a barrel through 2012, whereas the Reference Case assumes $47 in 2012, albeit in 2004$). Figure 14 shows Reference Case prices compared against those in the AEO 2006 High Energy Prices Case, which seems to more closely reflect the conventional wisdom on the future of oil prices under conditions of increasing global demand and diminishing reserve capacity. Also shown in Figure 14 is a line showing constant average 2006 price (in 2004$)

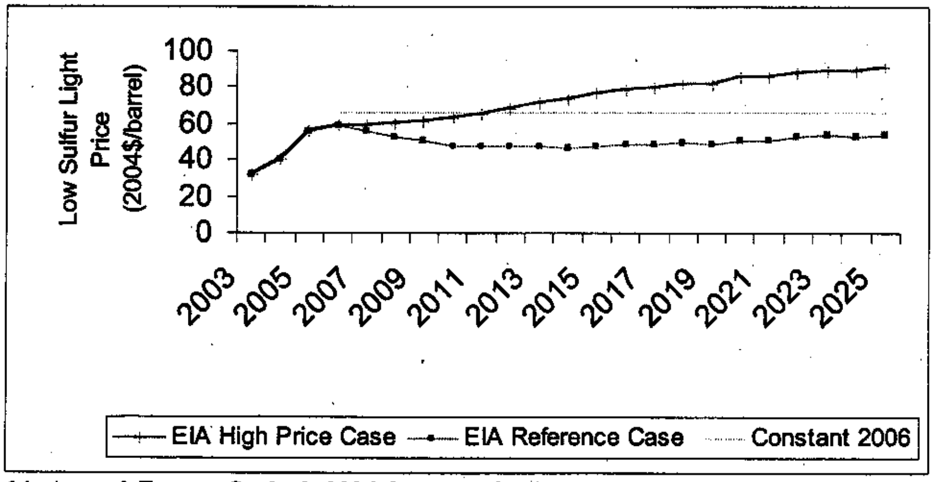

Figure 14. Annual Energy Outlook 2006 forecasts for imported low sulfur light crude oil in EIA Reference Energy Prices and High Energy Prices scenarios, along with a constant average 2006 oil price. All prices are in 2004$ (Source: Energy Information Administration).

If futures markets, which generally discount risks by entering into long-term contracts, are trading oil at prices that are no different than those today, it would be logical to conclude that there is a belief that the era of low crude oil prices is behind us[15]. We have therefore conducted sensitivity analyses around three sets of oil price forecasts: EIA Reference Energy Prices Case, EIA High Energy Prices Case (which assumes higher energy prices across the board) and a Constant Oil Price Case (which assumes that oil prices remain constant in real terms at an average 2006 price of $68 a barrel in 2005$, but other energy prices are more moderate).

We have also made assumptions concerning how approximately $2.7 billion[16] will be used in petroleum reduction programs to buy down vehicle and infrastructure costs over ten years (greater expenditures in early years as opposed to later) and how about $1 billion will be invested in research and development in California universities. Summary results of the cost savings are shown in Table 4. Infrastructure costs are not noted separately because they are incorporated into vehicle and device costs appropriately. Note that, despite its higher oil prices in later years, the High Energy Price Case has moderately fewer savings than the Constant Oil Price Case, primarily because the lower "spread" in savings in the former between oil products and alternative fuels.

[15] See, for instance, "Crude Calculations: In Oil's New Era, Power Shifts To Countries With Reserves," *Wall Street Journal,* June 14, 2006, A1.
[16] This includes $2.3 billion from the Gasoline & Diesel Use Reduction Account and about $400 million from Commercialization Acceleration Account.

[redacted]	EIA Reference Energy Prices				Run No.: SUt1	
	2012		2017		2025	
	BAU	Low Oil	BAU	Low Oil	BAU	Low Oil
[redacted]	49,361	48,224	51,241	48,353	54,395	48,738
[redacted]	44,594	45,053	47,060	48,341	51,716	53,536
[redacted]	0	-400	0	-200	0	
Total MM$	93,955	92,877	98,301	96,494	106,111	102,274
Net Savings (MM$)		-1,078		-1,806		-3,837
[redacted]	EIA High Energy Prices				Run No.: SUt1	
	2012		2017		2025	
	BAU	Low Oil	BAU	Low Oil	BAU	Low Oil
[redacted]	70,016	67,864	72,608	67,085	76,892	65,803
[redacted]	44,594	45,053	47,060	48,341	51,716	53,536
[redacted]	0	-400	0	-200	0	
Total MM$	114,610	112,517	119,667	115,227	128,608	119,339
Net Savings (MM$)		-2,094		-4,440		-9,269
[redacted]	Constant Oil Price				Run No.: SUt1	
	2012		2017		2025	
	BAU	Low Oil	BAU	Low Oil	BAU	Low Oil
[redacted]	67,970	65,793	70,484	64,866	74,670	63,434
[redacted]	44,594	45,053	47,060	48,341	51,716	53,536
[redacted]	0	-400	0	-200	0	
Total MM$	112,564	110,446	117,544	113,007	126,386	116,970
Net Savings (MM$)		-2,118		-4,537		-9,415

Table 4. Net savings in 2005$ from interventions assuming EIA Reference Energy Prices, EIA High Energy Prices, and Constant Oil Price.

Using state-level input-output analysis, we developed estimates of economic impacts of the interventions (see Table 5; see Appendix C for a description of the methodology and Appendix D for more detailed results). Figure 15 shows the same results graphically for the Constant Oil Price Case. Note that the economic results using the EIA High Energy Prices and the Constant Oil Price assumptions are very close together, compared with those using the EIA Reference Prices assumptions[17].

[17] Note that the results of the economic model that are presented here are *incremental* numbers in each of the reporting years. In comparison, in 2006 California supported an estimated *total* 15 million jobs in all industries contributing to about $1.4 trillion in personal income (Source: www.ebudget.ca.gov).

	Jobs (Actual)	Income ($MM)	GSP ($MM)
EIA Reference			
2012	5,490	$312	$503
2017	7,720	$519	$898
2025	9,671	$819	$1,508
EIA High Energy Price			
2012	9,240	$472	$706
2017	15,045	$874	$1,345
2025	19,746	$1,423	$2,277
Constant Oil Prices			
2012	9,200	$479	$739
2017	15,090	$890	$1,421
2025	19,730	$1,436	$2,381

Note: All dollar values are 2005$.

Table 5. Net economic impacts of CAEA interventions in three oil price cases.

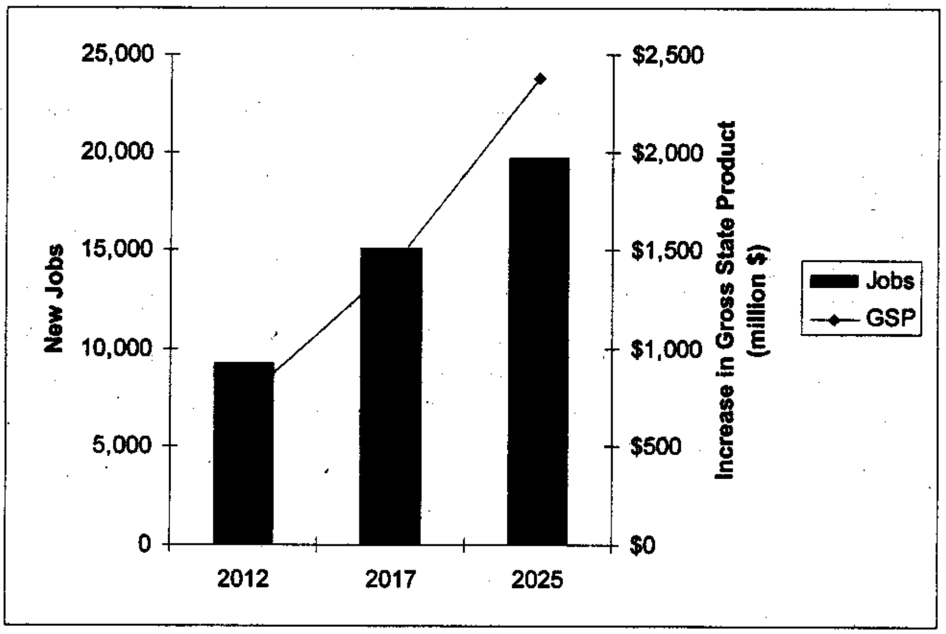

Figure 15. Projected growth in jobs and Gross State Product in California as a result of CAEA interventions (Constant Oil Price Case).

The analysis is conservative in assuming that roughly 25 percent of ethanol refining is carried out within California, and that there is no net increase in agricultural activity in the state. In addition, it makes a simplifying assumption about consumer behavior: one quarter of all new vehicle buyers will find the buy-down incentives beneficial in terms of providing them with direct savings because they would have normally purchased these vehicles at the higher costs before the discounts. The additional money available for spending will consequently circulate through the local economy and create a few additional jobs in the retail sector. In addition, the $1 billion spent on R&D expenditures would capture both direct (e.g., jobs at the universities and colleges) and indirect (e.g., goods and services purchased by the universities related to these expenditures) effects that occur when this money goes into the college/university system. However, these remain conservative estimates and do not include any additional export benefits that may occur from innovations developed over time. They also do not account for additional research funding that may be available as a result of the increased research capacity in the system.

V. Conclusions

Our results show that California can indeed achieve the goals set out in the CAEA, through a combination of advanced vehicle technologies and alternative fuels that are deployed with the help of a $4 billion fund developed on the basis of an extraction fee on oil producers. Four billion gallons of gasoline and diesel can be saved in the state in 2017. Greenhouse gas emissions will also be reduced additionally by the interventions, to a total of about 20 million tons of CO_2 equivalent gases in 2017, rising to about 38 million tons in 2025. At least a portion of these greenhouse gas emissions reductions will be accompanied by lower air pollutants and toxics as a result of the increased shares of ethanol, fuel cell vehicles, plug-in hybrids, and biodiesel. Furthermore, these emissions reductions will be consistent with, and thereby reduce the burden of, complementary legislation intended to reduce greenhouse gas emissions in California, including AB 1493 and AB 32.

The analysis also shows net positive economic impacts as a result of interventions, resulting in 10,000-20,000 additional jobs by 2025, and an increase in between about $1.5 billion to $2.4 billion in the state product in 2025. In addition, the increase in state product will result in increased tax revenues of $1.4 billion to $2.2 billion through 2025[18]. Finally, the aggregate increase in income will range from about $7 billion to $13 billion during the period 2007 to 2025. Given the high likelihood that future oil prices will be at least at or above current prices, the most plausible outcomes will be at the higher end of these forecasts.

It should be noted that the scenarios do not assume any modal shifts to transit or any reductions in personal travel as a result of land-use and behavioral changes induced by expenditures on public education, although some of this may in fact be expected to take place. Such reductions will invariably lead to further consumer savings, which will in turn be recycled through the economy. In the cost analysis, we also do not provide an estimate of the positive economic impacts of greenhouse gas emissions reductions and avoided local pollution as a result of the interventions. Furthermore, we have used conservative assumptions about the positive spin-off effects of R&D investments, which could in fact generate even more savings and jobs over the medium to long-term.

[18] Assuming 10.3% of state product is available as state and local taxes, including sales, property, income, and corporate but not fees.