Coordinated Policy Measures for Reducing the Fuel Consumption of the U.S. Light-Duty Vehicle Fleet

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June 2004

LFEE 2004-001 RP

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77 Massachusetts Avenue,
Cambridge, MA 02139

http://lfee.mit.edu/publications/reports
Publication No. LFEE 2004-001 RP

Financial support for this research was provided in part by Alliance for Global Sustainability (AGS) project on "Role of Innovative Technology in Promoting Sustainable Mobility", and MIT/AGS consortium on Environmental Challenges.

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Abstract

Fuel consumption of cars and light-duty trucks is one of the most vigorously debated issues in the U.S. While impressive gains have been made in terms of both fuel efficiency and individual vehicle fuel economy in the past two decades, the overall fuel consumption of the U.S. light-duty vehicle fleet continues to grow. Concerns about the effect of emissions from the vehicles and a significant reliance on imported oil provide legitimate reasons for government action to manage fuel consumption. The economic and societal impacts of such intervention affect different stakeholders across multiple dimensions.

This research finds that there exists no silver bullet for reducing the fuel consumption of motor vehicles in the U.S. However, there are several different policy measures available to affect the production and purchase of more fuel efficient vehicles as well as reduce the amount of driving. Qualitative and quantitative analysis of individual of policy options reveals the potential for combination of policies. A fleet model helps understand the time delay between the introduction of new fuel efficient vehicles and the reduction in fuel consumption of the fleet. Analysis of political and institutional obstacles enables an evaluation of the feasibility of a comprehensive policy package.

A reinforcing combination of different policies can increase the overall effectiveness of the proposed strategy. Such an approach aims at exploiting synergies between different measures, remove perverse incentives, and increase political acceptability of the overall strategy by spreading the impact and responsibility. An integrated policy package that combines fuel economy standards, a fee and rebate scheme for vehicles, fuel taxes and increased renewable content in fuels is evaluated as an example. Such a coordinated set of policy actions might reduce the overall fuel consumption and greenhouse gas emissions of the light-duty vehicles by 32% up to 50% in 30 years.

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Chapter 1: Problem Statement

1.1 Motivation

Over ninety-seven percent of the energy used in the U.S. transportation sector comes from petroleum. The total U.S. petroleum use has increased from 14.7 million barrels per day in year 1970 to 19.6 million barrels per day in year 2002. Currently, about 70% of the U.S. consumption of petroleum is in the transportation sector. The personal transportation system in the United States is highly dependent on the automobile. Gasoline use by cars and light trucks accounts for about 43 percent of U.S. oil consumption and about 11 percent of world oil consumption [DOE, 2004].

Domestic production of petroleum peaked in early 1970s, and the United States has been imported increasing quantities of petroleum ever since. Currently, about 55% of the petroleum is imported and by 2025 this number is expected to go up to 70%, as shown in Figure 1.1. Moreover, an increasing fraction of this supply will come from the Middle East and Organization of Petroleum Exporting Countries (OPEC). Regardless of the country of origin of oil, the pervasive use of oil in the economy makes the U.S. vulnerable to the possibility of price shocks in the oil market.

Increasing consumption of petroleum is also responsible for emissions of greenhouse gases (chiefly carbon dioxide), which contribute to global climate change. The transportation sector is the largest contributor to the emissions of CO_2 in the U.S., with about 20% of the total U.S. emissions of CO_2 generated by cars and light-trucks. These emissions are projected to grow at a rate of 1.9% per annum [DOE, 2004].

This unrelenting increase in the consumption of oil in the U.S. light-duty vehicles (cars and light-trucks) presents an extremely challenging energy and environment problem. Effective measures will have to be undertaken to reduce fuel consumption to reduce the risks to the economy and the environment.

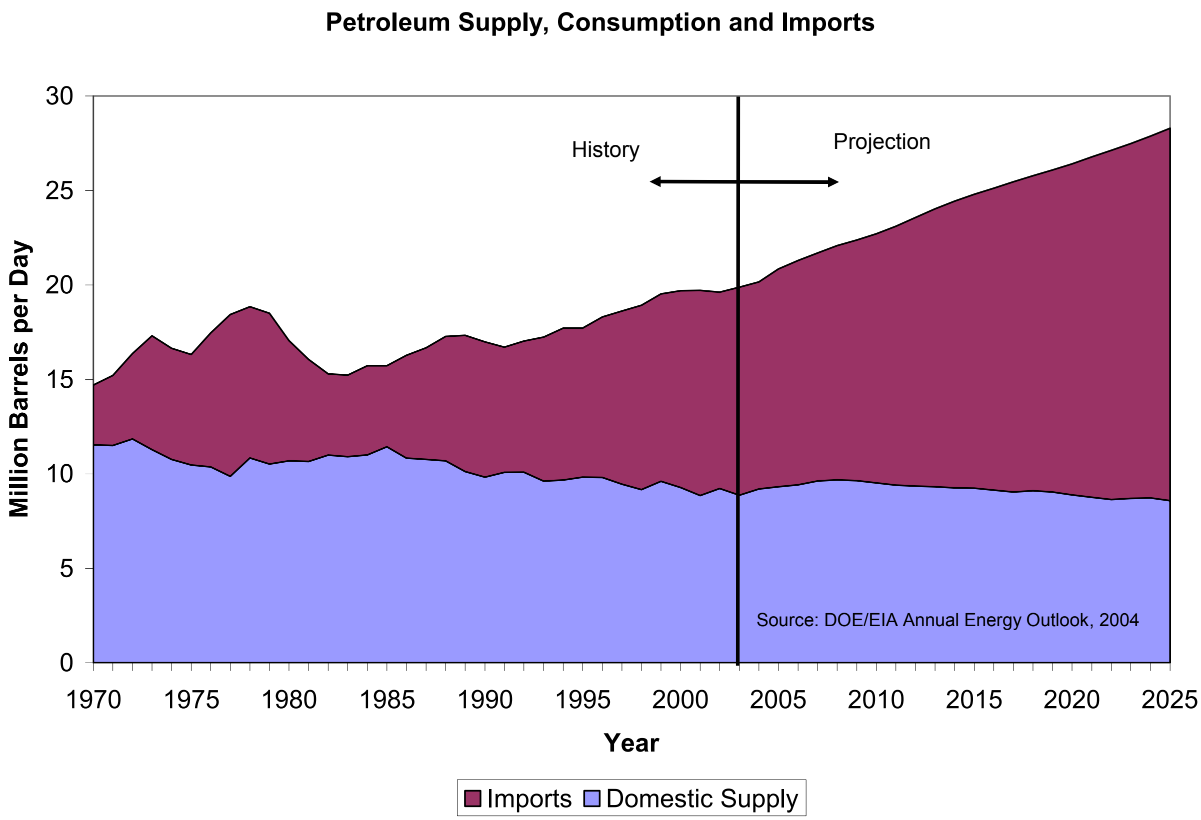


Figure 1.1 Petroleum Supply, Consumption and Imports (1970-2025) [DOE, 2004]

1.2 Objectives

The objective of this report is to elucidate policy options available to reduce the fuel consumption of U.S. light-duty vehicle fleet in the next three decades. More specifically, the we will argue that there are viable technology and policy options for making progress on this problem, but an integrated set of fiscal and regulatory strategies is essential to move us off the petroleum and greenhouse gas emissions growth path. We will attempt to demonstrate that a policy package which carefully combines market-based and regulatory measures can be used to both pull and push advanced vehicle technologies into market, as well as reduce the carbon intensity of vehicle use.

1.3 Report Overview

Chapter 2 provides the context in which the light-duty vehicle fuel consumption has grown in the period 1970-2000. The evaluation of future vehicle technologies and their possible fleet impact is based on previous work at MIT [Heywood et al., 2004]. A brief assessment of different stakeholders' position is also presented.

Chapter 3 gives a short review of different policy measures available to affect the fuel consumption. A structured qualitative assessment of individual policy measures is presented so as to enable the reader to understand potential effectiveness and implementation issues.

Chapter 4 details the case supporting the combination of different policy options so as to increase effectiveness and impact. An example of such a combination of different policy options is evaluated for its impact on reducing vehicle fuel use in the next thirty years. The limitations of such an approach and suggestions on implementation are presented.

Conclusions from this work are described in Chapter 5.

Chapter 2: The Context

2.1 Context

The current atmospheric concentration of carbon dioxide is about 370 parts per million (ppm) and rising. Stabilizing the atmospheric concentrations of CO_2 at 550ppm (twice the pre-industrial level) could reduce the risks of climate change. This will require emissions of CO_2 to peak by 2030 and reduce below 1990 levels by the end of the century [IPCC, 2001].

Transportation sector is the biggest contributor to the emissions of carbon dioxide in the United States, and emissions of CO_2 from transport have grown by about 18% during the period from 1990 to 2002 [DOE-GHG inventory, 2003]. Thus, increasing emissions of CO_2 from transportation presents a big challenge from a climate change perspective.

Greenhouse gas emissions from motor vehicles use can be approximately characterized by the following identity:

$$\text{GHG emissions} = \text{LPK}*\text{VKT}*\text{FI} \tag{2.1}$$

Where,

GHG emissions = Greenhouse Gas Emissions (tons/year)
LPK = Liters per kilometer (L/100km = 235.19/Miles per Gallon (mpg))
VKT = Vehicle kilometers Traveled (VKT in km/year)
FI = GHG Intensity of Fuel (GHG tons/Liters of fuel)

Thus, GHG emissions from motor vehicle can be attributed to the amount of driving (VKT), efficiency of driving (LPK), and the greenhouse gas intensity of the fuel (FI). Significant reductions in GHG emissions can be achieved if *all three* of the factors can be reduced. However, the three factors may interact with one another. For example, the carbon intensity of diesel as a fuel is slightly higher than gasoline, but diesel powered vehicles are typically 30% more fuel efficient than gasoline vehicles. As a result, diesel powered vehicles have significantly more greenhouse gas reduction potential relative to gasoline powered vehicles.

2.1.1 Vehicle Fuel Consumption

Vehicle fuel consumption (as measured in liters of fuel consumed per kilometer traveled) of new vehicles was reduced considerably in the seventies and early eighties due to federal fuel economy standards as well as the oil shocks of 1973 and 1979. Since the mid-eighties however, fuel consumption has stagnated at a level of 9.8 l/100km for new cars (24 mpg) and 13.7 l/100km for new light trucks (17.2 mpg.) when adjusted for on-road performance [Bassene, 2001]. The sales weighted fuel consumption of new vehicles has been decreasing during this period as a result of increasing number of light trucks in the new vehicle mix. As a result, the average fuel consumption for the light duty vehicle fleet remained roughly steady at 11.5 l/100km (20.5 mpg).

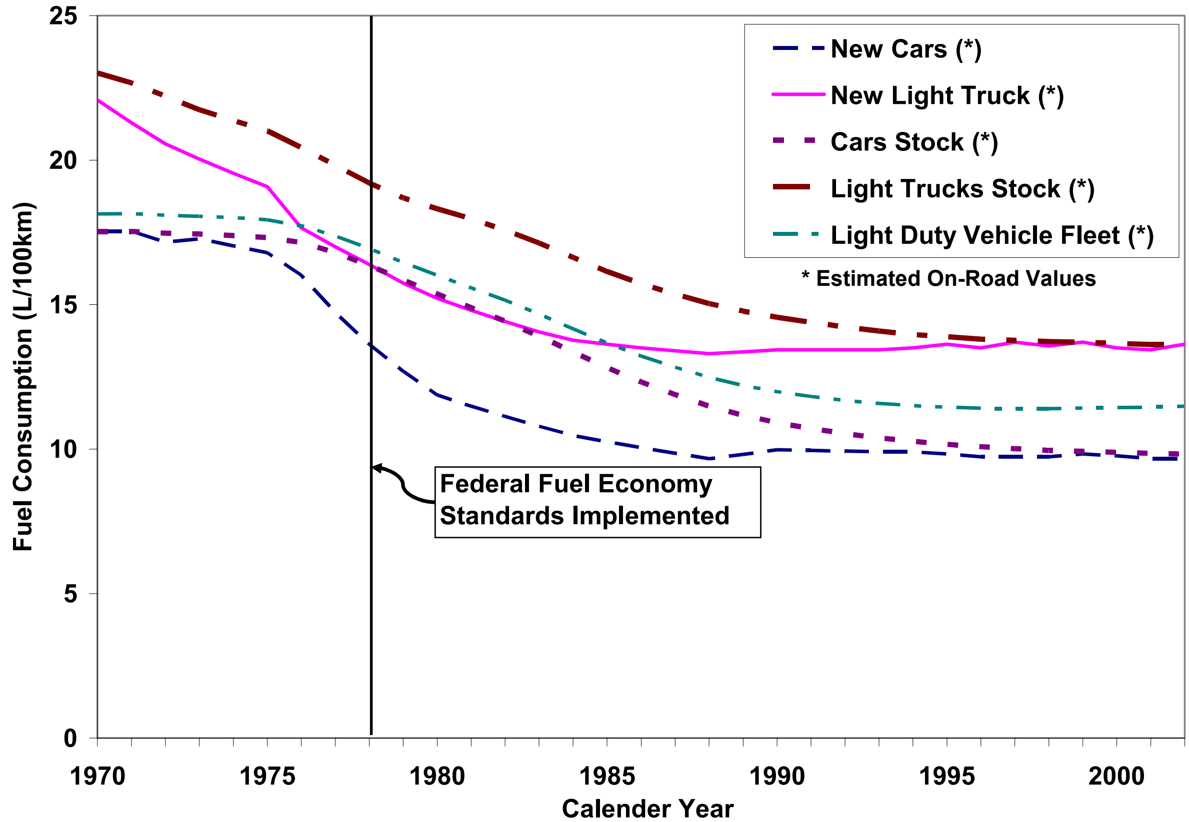


Figure 2.1 Light Duty Vehicle Fuel Consumption (1970-2002) [Adapted from Bassene, 2001]

The lack of any significant reduction in vehicle fuel consumption during the last twenty years does not imply stagnation of technology. In fact, engine and vehicle technology has been improving steadily over this entire period. The technology is, however, "fungible" in that it can be used to enable other functions (increased amenities, vehicle power and weight, etc.) rather than to improve fuel consumption performance [Plotkin, 2000]. EPA analysis of vehicle characteristics over the period 1981-2003 indicate that if the new 2003 light-duty vehicle fleet had the same average performance and same distribution of weight as in 1981, it could have achieved about 33 percent higher fuel economy [Hellman and Heavenrich, 2003].

2.1.2 Vehicle Kilometer Travel

The amount of vehicle kilometers traveled (VKT) has more than doubled in the past thirty years, as shown in Figure 2.2 [Davis and Diegel, 2003]. This growth has been steady except for the years 1973, 1979, 1980 and 1990.

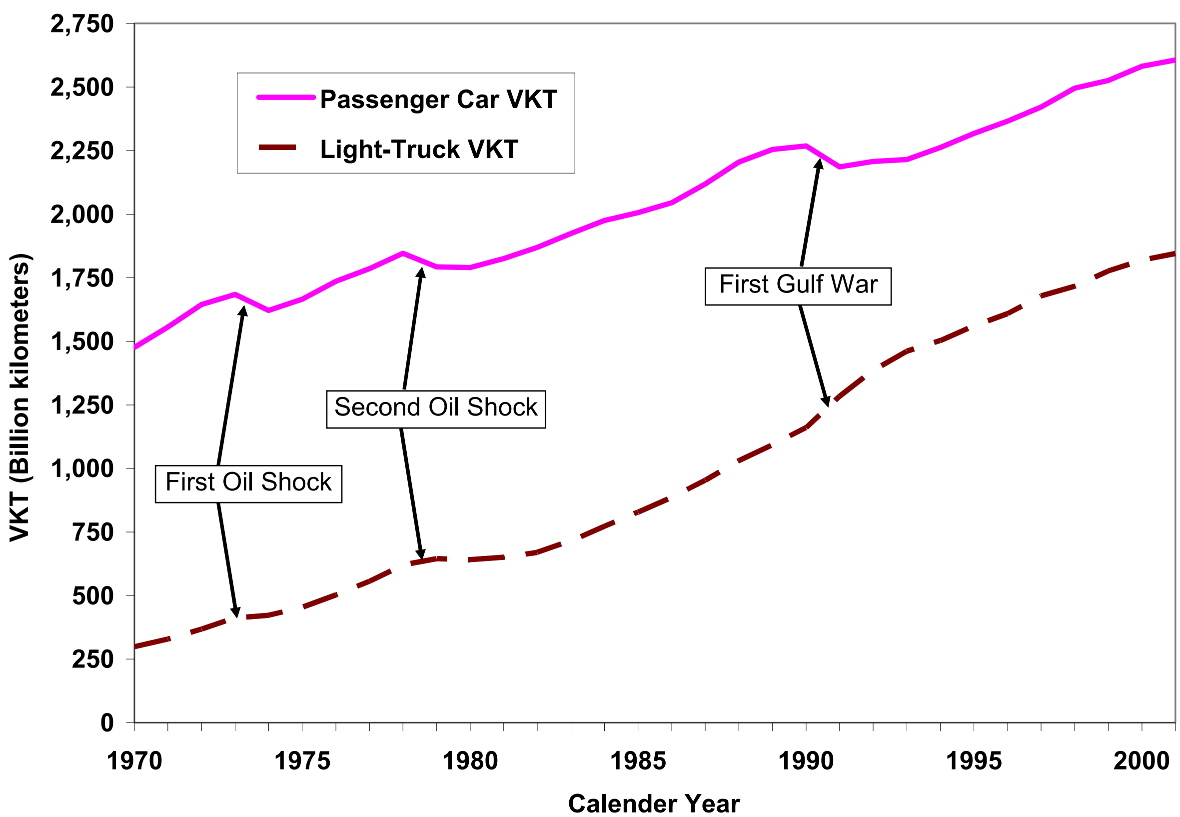


Figure 2.2 Vehicle Kilometers Traveled (1970-2001) [Davis and Diegel, 2003]

The tremendous growth in VKT can be attributed the following factors:

- <u>Increased number of vehicles</u>: The number of vehicles in the light duty fleet has increased from about 110 million vehicles in 1970 to about 230 million vehicles in 2003. Most of the growth has come in the light trucks segment, which now account for more than half of all sales as compared to about 15% of the sales in 1970. In general, light trucks consume more fuel relative to cars and, hence, have contributed significantly to the rising average fuel consumption of the light-duty vehicle fleet.

- Increased driving per year: The average amount of distance traveled per vehicle has increased considerably from 1976 to 2001. This increased driving can be attributed to increased demand for mobility as well as reduced costs of driving. When adjusted for inflation, the cost of gasoline per liter has remained essentially constant for the past thirty years, except during the oil shocks of 1970s, as shown in Figure 2.3.

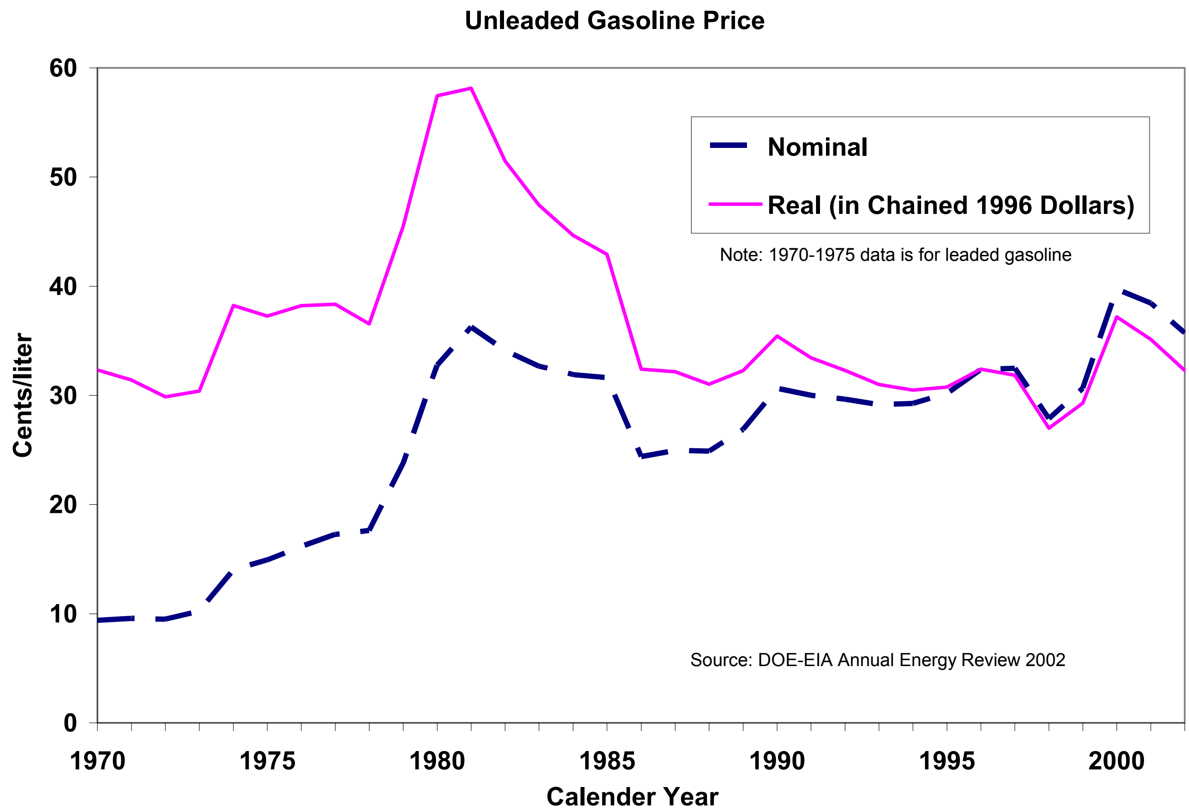
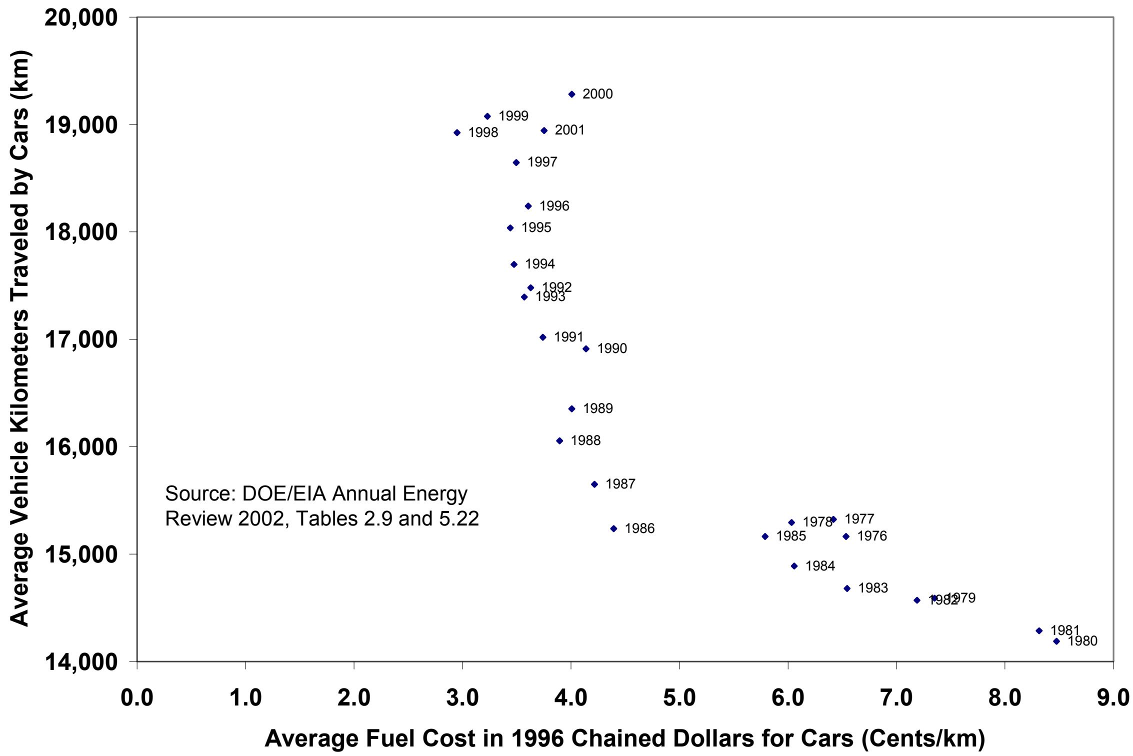


Figure 2.3 Gasoline Price in Nominal and Real Terms (1970-2002) [DOE, 2003]

During the same period, the average fuel consumption of cars and trucks has improved, resulting in lower costs of travel per kilometer. The hypothesis that this has resulted in increased driving is known as "Takeback" or "Rebound" Effect. Figures 2.4 shows the increase in average distance traveled while the average costs of driving every kilometer have reduced for both cars and trucks. The rebound effect is estimated to be on the order of 20% [Greene et al., 1999; Greening et al., 2000].



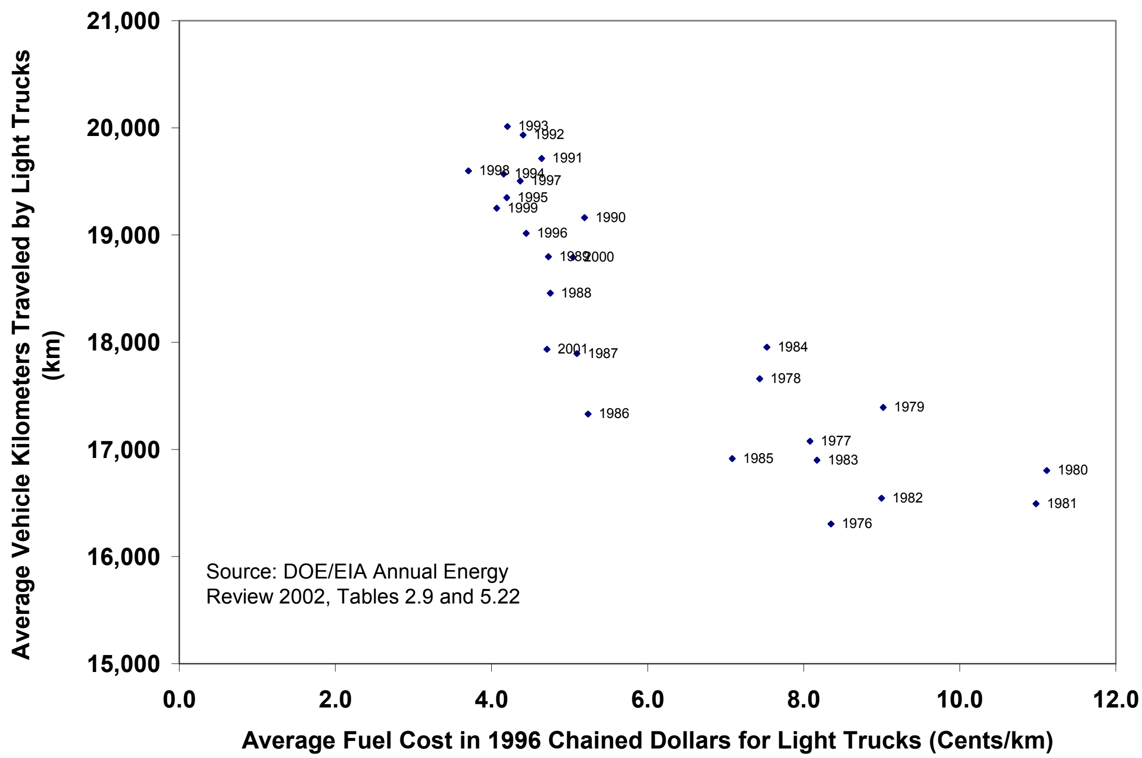


Figure 2.4 Average Vehicle kilometer Traveled Vs Average Fuel Cost per kilometer [DOE, 2003]

2.1.3 Greenhouse Gas Intensity of Fuel

Greenhouse gas intensity of fuel used in light-duty vehicle fleet has essentially not changed since most vehicles run on gasoline. Table 2.1 lists the energy and carbon intensity of some of fuels [Weiss et al., 2000; Wang, 2001]. Note that the table represents potential carbon emissions from combustion of these fuels, but not the amount of carbon released during the production of the fuels.

Table 2.1 Energy and Carbon Intensity of Different Fuels [Weiss et al., 2000; Wang, 2001]

Fuel/Energy Carrier	Lower Heating Value (LHV)	Carbon Content	
	MJ/l	gC/MJ	gC/l
Conventional Gasoline	32.2	19.6	631.12
Conventional Diesel	35.8	20.8	744.64
Natural Gas (Methane)	0.0360*	15.0	0.54
Fischer-Tropsch Diesel	33.1	20.0	662.0
Methanol	15.9	18.7	297.33
Ethanol	21.2	19.4	411.28
Hydrogen	0.0108*	0	0

* At 0^0C and one atmosphere absolute pressure

In the late 1970s, sales of new diesel cars increased rapidly to about 6%and fell equally in the early 1980s. The fraction of diesel vehicles in the new light truck sales has fluctuated around 3-6% in the past two decades. Apart from this, use of other fuels in light duty vehicles is less than 1%. Despite strong goals and incentives offered by Congress, alternative fuel vehicles have not succeeded [McNutt and Rodgers, 2003].

2.2 Technology Options

Engine and vehicle technology entering light duty vehicles has continued to get better over the years. Significant potential exists for making gains in efficiency through new technology, lighter materials and better design. Several technology and cost assessment studies have evaluated the potential of future engine and vehicle technologies to reduce energy consumption and greenhouse gas emissions [Weiss et al., 2000; An et al., 2001; NRC, 2002; Weiss et al. 2003; CARB, 2004].

The technological options available in the next twenty to thirty year time frame can be summarized as follows:

- Engine and transmission systems designed to reduce friction, pumping losses and hydraulic losses, as well as downsized for a given performance.
- Vehicle technologies aimed at light-weighting, as well as reducing aerodynamic and rolling resistance.
- Accessories designed for greater efficiency and improved engine controls.
- Development of advanced powertrain technologies such as hybrids and fuel cells.

Figure 2.5 shows the relative life cycle energy use and greenhouse gas emissions of different technologies in year 2020 as assessed by two MIT studies [Weiss et al., 2000; Weiss et al., 2003].

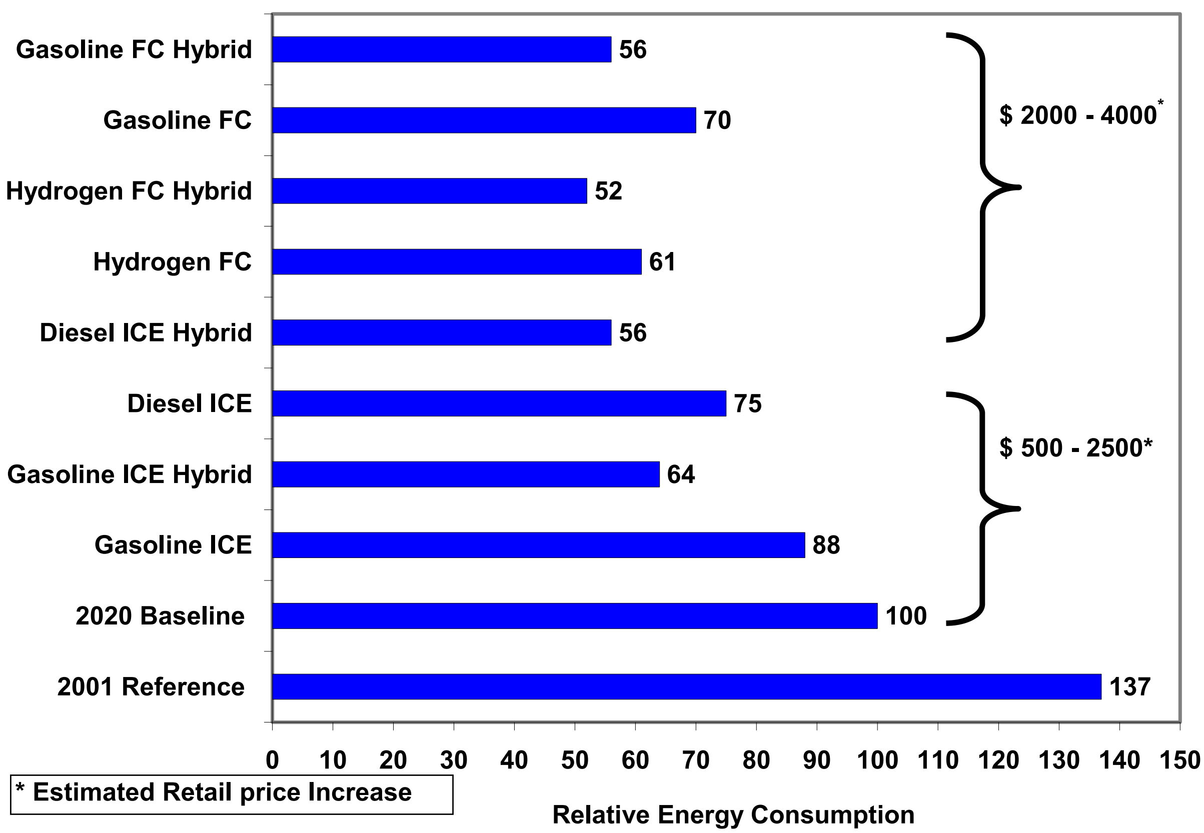


Figure 2.5 Relative Consumption of Life-Cycle Energy Use [Weiss et al., 2000; Weiss et al., 2003]

Considerable uncertainty exists in how technology will evolve over the next twenty to thirty years. The studies differ in the estimates of the exact magnitude of energy reductions possible as well as the costs of doing so. Nevertheless, the following conclusions can be drawn from these technology and cost assessments:

- Mainstream gasoline engine and vehicle technologies (ICEs) have significant potential to reduce energy consumption and greenhouse gas emissions. These technologies can improve at a rate of 1-2% a year over the next twenty years, which translates in to up to 35% reduction in energy use at constant performance and an additional cost of $500-1500.
- Diesel vehicles will be 15-20% more efficient than gasoline vehicles, but the difficulty in meeting stringent U.S. NOx emissions standards, higher cost, and consumer perception are significant obstacles.
- Hybrid electric vehicles (HEVs) can provide an additional 35-30% benefit in energy reduction at an additional cost of two to three thousand dollars as compared to evolving ICEs.
- Fuel cell technology is currently very costly and at best a few decades away in terms of making a substantial contribution to greenhouse gas emissions reductions. However, in the long term (30-50 years), fuel cells can make a difference if the hydrogen used in fuel cells is made from carbon neutral energy generation technologies such as renewable, nuclear, or from fossil fuels <u>with</u> carbon sequestration.

It is not clear if the current price of fuels in the U.S. market can justify the development of these technologies for improving fuel consumption performance. It is possible that the current trend of sacrificing efficiency improvements for faster, more powerful and bigger vehicles may continue.

2.3 Projections of Light-Duty Vehicle Fuel Consumption

The potential effects of new technologies on light-duty vehicle fuel consumption can be evaluated based on a vehicle fleet simulation model developed by Bassene [Bassene, 2001; Heywood et al., 2004]. The model used here is a car and light-truck fleet model based on vehicle sales, retirement, average fuel consumption and vehicle travel per year. The model also allows us to explore the sensitivity of fuel consumption due to growth in driving, vehicle ownership and the share of light-trucks in the fleet.

Different scenarios are used to project the fuel use of light-duty vehicles under different market and policy conditions. These scenarios also allow us to understand the magnitude of technological and policy effort that may be required to reduce fuel use of light-duty vehicle fleet to the levels of year 1990. Since most vehicle designs and production plans along with the CAFE standard levels have been fixed until year 2007, the model scenarios begin in year 2008.

2.3.1 Description of scenarios

- No Change: In this scenario, the new car and light duty truck fuel consumption remains at the levels of 2008 until 2035 (estimated on-road fuel consumption of 9.7 L/100km for cars and 12.4 L/100km for light trucks). This does not mean that vehicle technology will remain constant, but it is assumed that any improvement made in the fuel efficiency will be sacrificed for better vehicle performance and/or additional vehicle weight/amenities. This has been the trend in the light-duty vehicles for about twenty years. The no change scenario assumes that this trend will continue until 2035.

  The new vehicle sales are assumed to grow at a rate of 0.8% per year, corresponding to the rate of growth of population. Average vehicle travel is assumed to grow at a rate of 0.5% per year, while the median age of all vehicles post year 2000 is assumed to be 15 years. In addition, the share of light trucks in the new light-duty vehicle sales is assumed to level off at 60% by year 2035.
- Baseline: In the baseline scenario, it is assumed that there is a modest, but steady increase in gasoline price, fuel economy standards, and competitive pressures results in improved fuel economy. Fuel consumption of an average new gasoline ICE vehicle could decrease by about 35% in twenty years and 50% in thirty years if the performance characteristics kept constant. This assumption is consistent with the results of technology assessment [Weiss et al., 2000]. In the baseline scenario, however, it is assumed that only fifty percent of these efficiency improvements translate into reduction in fuel consumption. Thus, individual vehicle fuel consumption decreases by about 17.5% in twenty years and about 22.5% in twenty-five years as shown in Figure 2.6.
- Advanced IC Engine-Hybrids: This scenario assumes ambitious fuel economy standards, coupled with economic incentives to push and pull advanced vehicle technologies (light-weighting, better aerodynamic designs and hybridizing the gasoline ICE vehicles assumed in baseline scenario) in to the market place. Under this scenario, the simulation assumes that the fuel consumption of advanced IC engine hybrids is 61.5% of the baseline gasoline IC engine fuel consumption as shown in Figure 2.6. Three market penetration rates are assumed for advanced IC engine hybrid vehicles sales as a part of all new vehicle sales. These rates are

assumed to be rising from negligible in 2008 to 25% (low), 50% (medium) and 75% (high) in 2035.

- Composite: Under the composite scenario, it is assumed that in addition to all the factors present in the advanced IC engine-hybrids scenario, average per vehicle travel will stop growing beyond year 2008 and the rate of growth in sales of light-duty vehicles is halved to 0.4%.

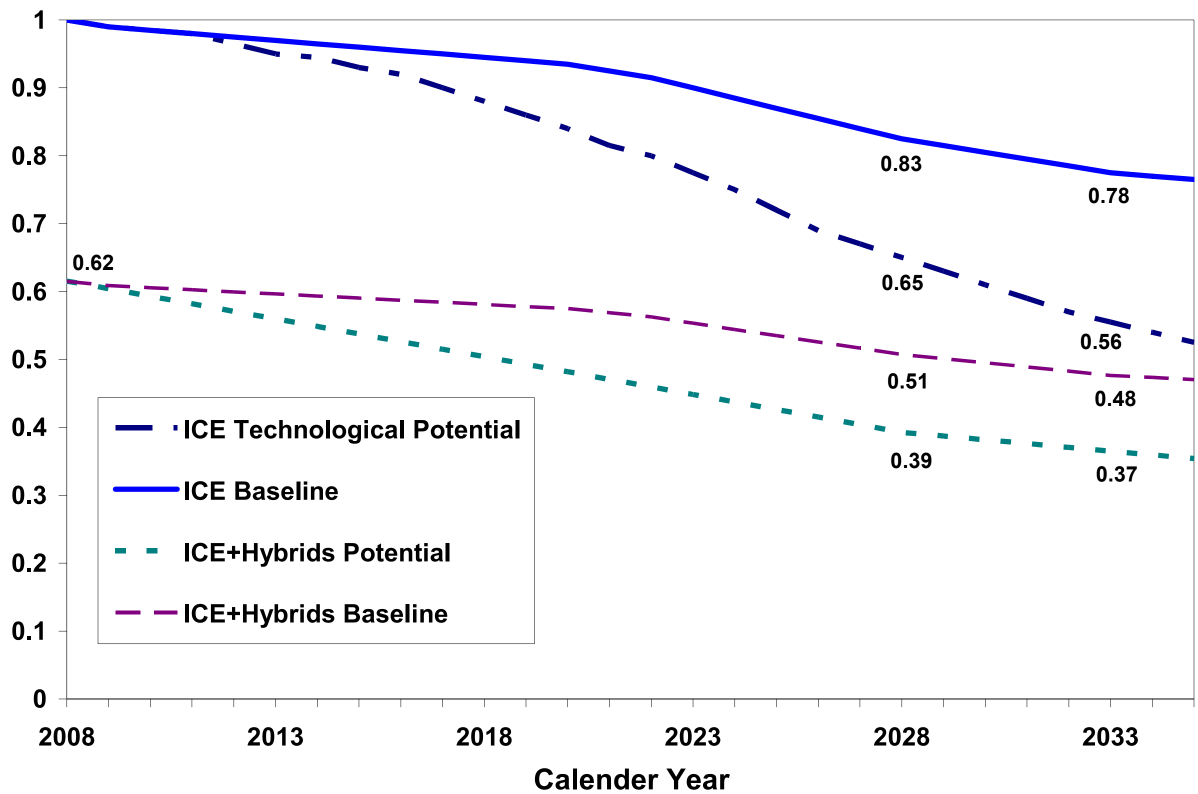


Figure 2.6 Relative Improvements in Fuel Consumption for Baseline Scenarios

2.3.2 Fuel Consumption under Different Scenarios

The projections of total fuel use under the no change, baseline, advanced ICE hybrid and composite scenarios are shown in Figure 2.7. The average fuel consumption of light-duty vehicles is shown in Figure 2.8. Under the no change scenario, the fuel consumption of the entire light-duty fleet is projected to grow to 707 billion liters per year by 2020 and 856 billion liters per year by 2035 (12.2 and 14.8 million barrels per day respectively).

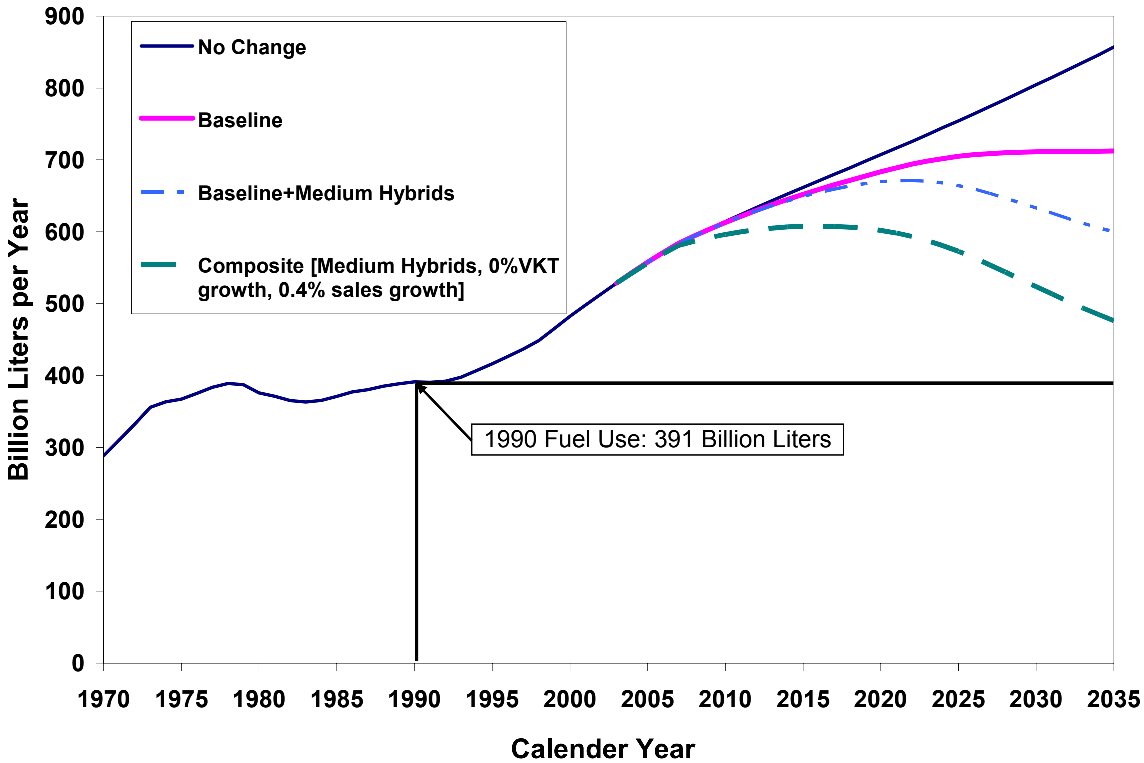


Figure 2.7 Light-Duty Fuel Use for Various Scenarios

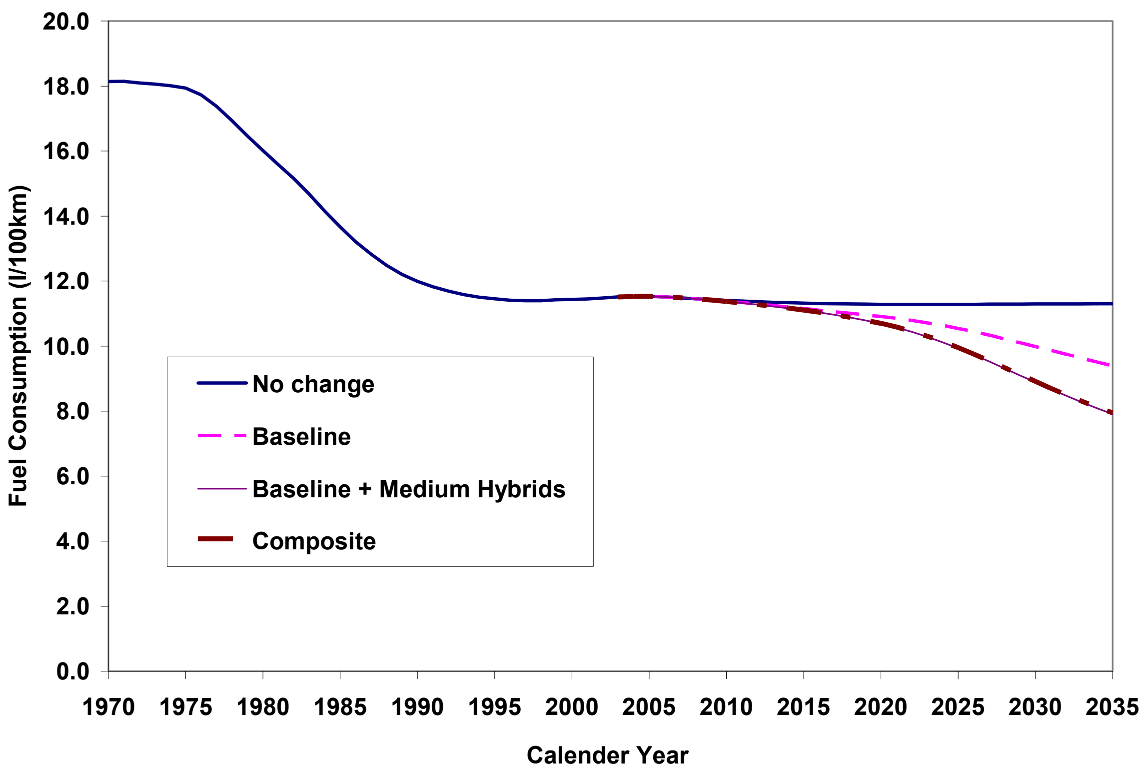


Figure 2.8 Light Duty Vehicle Fuel Consumption for Various Scenarios

Under the fuel consumption improvements assumed in the baseline scenario, growth in fuel use is considerably reduced. The total fuel use in year 2035 is projected to be 712 billion liters per year (12.2 million barrels per day). In the advanced ICE-hybrid scenario, for the case of medium penetration of hybrids into the light-duty vehicle fleet, the total fuel use peaks at about 671.5 billion liters per year in year 2022 and then declines to about 600 billion liters per year by 2035. The average fuel consumption of the fleet improves from 11.5 l/100km (~ 20 MPG) in 2003 to 7.9 l/100 km (~ 30 MPG) in year 2035. This shows that rapid deployment of advanced vehicle technologies has significant potential to reduce fuel consumption in the next thirty years.

Finally, additional developments such as reduced rates of growth of vehicle sales and annual vehicle travel in the composite scenario show substantial benefits in terms of vehicle fuel use. This result is mainly due to the slow down of growth in vehicle kilometers traveled from 7.6 trillion kilometers per year in the baseline scenario to about 6 trillion kilometers per year in the composite scenario by year 2035. The total fuel use in this scenario peaks at 608 billion liters per year in year 2016 and decreases to 476 billion liters per year in year 2035, which is less than the fuel use of light-duty vehicles in year 2000. Yet, this is still much higher fuel use than the levels of 1990 (391 billion liters per year).

These simulations show that improvements in vehicle technology and fuel consumption can play a key role in reducing the growth in light-duty vehicle fuel use. However, it takes slowing down growth in vehicle travel to achieve further reductions in fuel use. Table 2.2 summarizes the results of these scenarios.

Table 2.2 Light-Duty Vehicle Fuel Use Under Different Scenarios

Year	No Change		Baseline		Baseline + Medium Hybrids		Composite	
	Billion Liters/year	MBD*	Billion Liters/year	MBD	Billion Liters/year	MBD	Billion Liters/year	MBD
2004	543	9.36	543	9.36	543	9.36	543	9.36
2020	707	12.18	683	11.78	670	11.54	602	10.37
2035	856	14.76	712	12.27	600	10.34	476	8.21

* MBD: Million Barrels per Day

2.3.3 Effect of Delay

A delayed action scenarios represent the consequences of postponing action by five, or ten years on overall fuel consumption and greenhouse gas emissions. The purpose of these scenarios is to investigate the level of additional effort required to contain the vehicle fuel consumption in the future as opposed to taking action immediately. This scenario is evaluated for advanced ICE Engine and medium hybrid case as shown in Figure 2.9.

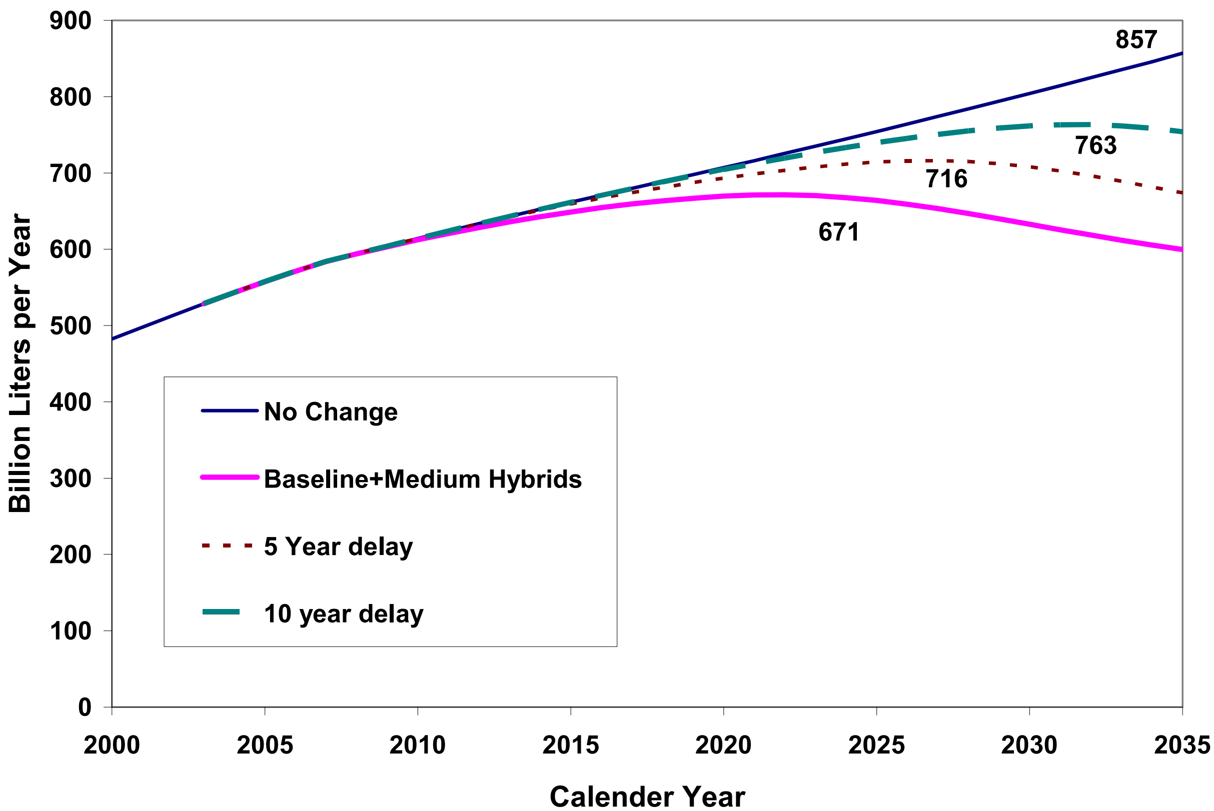


Figure 2.9 Effect of Delay in Action on Light-Duty Vehicle Fuel Use (2000-2035)

It is clear from this scenario, that delayed action results not only in shifting the problem out in time, but also makes it more difficult to address. On the other hands, even small changes made sooner could result in larger benefits than more aggressive actions taken later. This also indicates that even if inherently low CO_2 emitting or non-petroleum based fuels were to become feasible in the future, the magnitude of the problem would be much more manageable if some action is taken now, as opposed to waiting for a *cure-all*.

2.4 Receptivity, Opportunity and Capacity for Change among Stakeholders

The interactions and behavior of different players in the automotive industry makes it a highly complex socio-technical system. As with most such complex systems, the general inertia of the system against any change is very large. The main stakeholders include players such as vehicle purchasers and users, the automobile and petroleum industries, and the government at different levels.

The automobile manufacturers are a risk-averse group and oppose regulations that will create new uncertainties in the market. There is also a tendency towards *gaming the regulations* in order to avoid change in existing business practice. One example of such practice is seen in increasing the weight of light trucks beyond 8500 lbs. so that they are exempt from the fuel economy standards. Another is the slight modifications made in interior design (such as foldable back row seats) so that a vehicle could be classified as a light truck and would again be subject to lower fuel economy standards.

However, the general reluctance to change is not restricted to the automakers. The insurance companies are generally against automobile insurance reforms and will oppose schemes such as Pay-as-You-Drive (discussed in the next chapter), which have the potential to reduce the amount of vehicle travel [Wenzel, 1995]. Consumers find an ally in the fuel suppliers while lobbying against increase in fuel taxes. Consumers are also unwilling to compromise the performance, features and size of the vehicle in return for fuel economy.

Finally, low price has been the cornerstone of U.S. energy policy for a long time, and politicians are extremely reluctant to consider pricing mechanisms for conservation purposes.

Table 2.3 shows the current state of receptivity, opportunity and capacity for different stakeholders, whereas Table 2.4 shows the possible drivers for bringing about a change among the stakeholders. As seen from the tables, there are several opportunities for reducing the fuel consumption, as well as many possible avenues for bringing about change within different stakeholders. Tables 2.3 and 2.4 do not represent a comprehensive assessment of stakeholder positions, but rather give an indication of the multidimensional nature of the fuel consumption problem. Attempts to frame policy aimed at reducing the fuel consumption of U.S. light-duty vehicles must take these stakeholder positions into consideration or the resulting policy will be doomed to failure.

Table 2.3 Assessment of Receptivity, Opportunity and Capacity for Change Among Different Stakeholders

	Federal Government/ Congress	State Governments	Fuel Suppliers	Automobile Manufacturers	Vehicle Buyers/Owners	Vehicle Users
Receptivity	Low (Perceived political *price* of a system change is high)	Medium/High (States have shown a greater willingness to tackle environmental issues, specially led by California and Northeastern states)	Low (Petroleum is a large and reasonably profitable business despite all the difficulties, alternative fuels/energy sources are still expensive)	Low (Very little experience with non-petroleum based fuels or alternative propulsion systems)	Medium (Given appropriate incentives, will buy more fuel efficient vehicle)	Low (Automobile culture is deeply rooted in U.S. lifestyle)
Opportunity/ Motivation	Medium/High (Oil dependency, Greenhouse gas concerns)	Medium (Traditionally, local air pollution has been more of a concern than global climate change, however this is changing)	Low (Proven reserves of petroleum for decades, petroleum production from unconventional sources possible)	Low (Incremental improvements in existing propulsion systems possible, but market demand is low)	Low (Cost of vehicle ownership is modest)	Very Low (Cost of vehicle use is fairly small)
Capacity	High (Compliance with federal standards has always been achieved, fleetwide changes possible)	Low/Medium (Federal legislations prohibit state level fuel economy targets, Land use patterns can not be easily changed, Transportation Demand Management possible, but not popular)	Medium/Low (R&D for producing low cost biofuels, financial capability to set up Hydrogen infrastructure)	High (Alternative powertrain systems like hybrids are emerging; industry is continuously developing advanced engine and vehicle technology)	Medium (Awareness about new technologies like Hybrids is increasing)	Medium/Low (Changes in driving behavior may take a long time)

Table 2.4 Possible Drivers for Change Among Different Stakeholders

	Federal Government/ Congress	State Governments	Fuel Suppliers	Automobile Manufacturers	Vehicle Buyers/Owners	Vehicle Users
Receptivity	Oil crisis, international environmental agreements (Kyoto and similar future accords)	Possible local environmental harm due to climate change (e.g., California's action on climate change is motivated by regional concerns)	Regulations requiring higher renewables content in fuels, ultra-low sulphur diesel	Ambitious CAFE standards/ Fees for gas guzzlers - Rebates for gas sippers	Rebates for advanced technology vehicles with high fuel economy	Increased cost of driving (possibly driven by higher gas prices)
Opportunity/ Motivation	Reduced dependence on foreign oil, Mitigation of greenhouse gas effect	Reduced dependence on foreign oil, Mitigation of greenhouse gas effect	Emergence of a new market for renewable fuels, avoid regulatory fines, improve corporate image, seek new business opportunities	Avoid legal penalties, improve competitive performance, enhance image, incentives for producing more fuel efficient vehicles	Incentives for buying more fuel efficient vehicles	Fuel savings from more fuel efficient vehicles, reduced vehicle emissions, congestion, and overall environmental impact of vehicles
Capacity	Informed debate about potential modifications of existing standards, politically acceptable alternatives	Informed debate about potential modifications of existing standards, politically acceptable alternatives	Development of fuels from renewable energy sources	Consumer demand for more fuel efficient cars, development of alternative fuel infrastructure	Availability of high performance, high fuel efficiency vehicles	Increased level of public awareness about the externalities of vehicle/fuel usage

Chapter 3: Policy Options to Reduce Fuel Consumption of Light-Duty Vehicles

3.1 Policy Options

There are several externalities associated with the use of vehicles, like unpriced highway services, subsidized parking, congestion, air pollution, and accidents. These externalities are imperfectly tied to the use of fuels in the light-duty vehicles. Instead, increasing dependence on foreign oil and concerns about greenhouse gas emissions from motor vehicles are two main reasons for government intervention in the market of fuel consumption. DOE [2000] identifies different barriers to efficiency improvements in the U.S. transportation sector as underpriced fuel and services, imperfect information for consumers to make a rational choice about vehicle fuel economy, fungibility of technology and risk averseness of the vehicle manufacturers. Different policy options have been proposed to overcome these barriers [OTA, 1994]. The policy measures under consideration can be thought of as a means of providing an economic incentive (E), a regulatory requirement CAFE, a public investment (I), or some combination of these. They may be further classified as measures that provide incentives for more fuel efficient vehicles, measures that aim to change the cost structure of vehicle operation by increasing or converting some of the fixed or infrequently paid costs to usage costs, or measures aimed at shifting fuel use towards less carbon intensive fuels. Policy options selected for review are summarized in Table 3.1, and described in more detail in this chapter.

Several other policy alternatives are available at state or local level, such as increased investments in public transportation and transportation demand management (TDM) tools such as high occupancy vehicle (HOV) lanes, congestion charges, vehicle travel based fees, and telecommuting incentives. These options are not considered here but they can be helpful in reducing energy consumption of light-duty vehicles.

Table 3.1 Policy Options to Reduce Fuel Consumption of Light Duty Vehicles

Policy Measures	Type of Policy			Anticipated Response/Action
	E	R	I	
CAFE Standards: As existing /Weight (E-CAFE)/ Volume (VAFE)		●		Incorporate fuel efficient technologies, reduce average weight of vehicle fleet, reduce the spread between heavy and light vehicles
Tradable CAFE/Fuel Consumption Credits	●	●		Increase flexibility for manufacturers and reduce cost of compliance with the CAFE standards
Feebates (A system of fees and rebates related to the fuel economy/ fuel consumption of the vehicles)	●			Establish fees for less fuel efficient vehicles and rebates for more fuel efficient vehicles to create incentive to produce and purchase more fuel efficient vehicles
Emissions/Carbon Tax (Economy wide)	●			Provide incentive to purchase and use more fuel efficient vehicles by incorporating the externality costs
Fuel Tax	●			Increase the cost of operating the vehicle and reduce the vehicle miles traveled
Pay-at-the-Pump Schemes	●			Increase the cost of purchase and/or owning high fuel consumption vehicles or transfer it to the cost of motor vehicle use
Subsidies/Tax incentives	●		●	Provide incentive to purchase more fuel efficient vehicles
Government R&D investment			●	Encourage more rapid development of fuel conserving technologies
Retiring old cars	●	●		Provide incentive to purchase newer, more fuel efficient vehicles
Alternative Fuels (e.g., Cellulosic Ethanol/ Biodiesel)		●	●	Displace (some) petroleum-based fuel used for transportation
An Economic Incentive (E), A Regulatory Requirement (R), A Public Investment (I)				

3.2 CAFE Standards

The oil crisis in the early seventies forced Congress to address the issue of declining fuel economy of new cars. The corporate average fuel economy (CAFE) standards were born out of the Energy Policy and Conservation Act (EPCA) of 1975. The principle objective of the CAFE standards is to increase the fuel economy of U.S. light duty vehicles and consequently reduce the dependence on foreign oil. The legislative history of the act shows no reference to environmental considerations[1] [Chanin, 2003]. The authority to administer the program was delegated by the Secretary of Transportation to the Administrator of National Highway Transportation and Safety Administration (NHTSA). The standard for cars is set separately from that of light-trucks, as shown in Figure 3.1, and is calculated as the harmonic mean of the fuel consumption of all the vehicles sold in every model year. The penalty of not meeting the standard is set at $5.50 for every 0.1 miles per gallon shortfall. The CAFE standards have been successful to the extent that the domestic manufacturers have always met the standards without having to pay the fines.

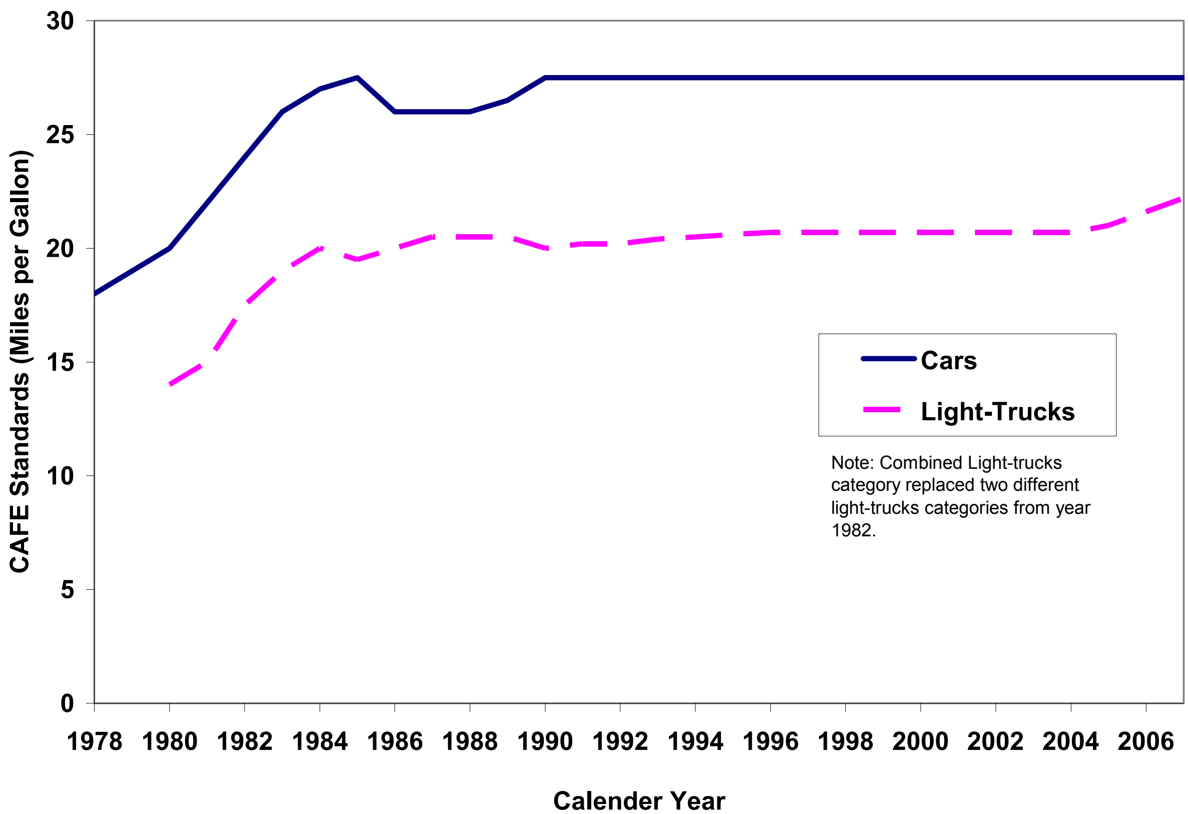


Figure 3.1 Fuel Economy Standards for Cars and Light Trucks [NHTSA, 2003]

[1] For a historical perspective of CAFE standards, see John et al. [1979].

The difficulty in setting an appropriate level of fuel economy standards arises from the fact that the marginal costs of additional fuel-saving technologies in vehicles must be offset by the marginal benefits to the consumers in terms of fuel savings, assuming that other vehicle performance characteristics stay the same.

Greene and Duleep [1993] estimate the present value of fuel savings based on on-road performance as:

$$S_i = \sum_{a=0}^{L} \left\{ \left(\frac{M_a * P_t}{(1+r)^{(a+0.5)}} \right) * \left[\left(\frac{1}{MPG_o} - \frac{1}{MPG_i} \right) * \frac{1}{Adj} \right] \right\} \tag{3.1}$$

Where:

M_a is the miles driven as a function of vehicle age *a*
P_t is the price of fuel in year *t*
r is the discount rate
MPG_i is the miles per gallon in year *i*
MPG_0 is the miles per gallon in year *0*
Adj is the adjustment factor for estimating on road performance (~ 0.85)

Important objections to CAFE standards include its implications on safety of vehicles, and the hidden costs of technical innovation associated with meeting the standards. At the same time, the standards only apply to new vehicles so that the improvement in fuel economy of the entire fleet lags significantly behind that of the new vehicles. Also, the standards, by the virtue of increasing the fuel economy, decrease the marginal cost of driving. This encourages increased driving as discussed previously. In addition, the cost of introduction of new technologies might make the new vehicles so expensive that certain consumers may hold on to their older cars (more polluting and less fuel efficient) for longer. This is the so called *jalopy effect*.

While current CAFE standards have yielded some useful benefits, they contain several inadequacies as well as some perverse incentives. The current standard provides credits for vehicles capable of running on both gasoline and an alternative fuel (E85 - Ethanol). However, very few of the dual fuel vehicles actually run on ethanol, and rarely realize the intended goal of displacing 85% of the gasoline content of the fuel. The fuel economy of the new vehicle fleet, therefore, appears to be higher than its true value [Rubin and Leiby, 2000]. The National Research Council on fuel economy recommended elimination of dual fuel credits in 2002, but recently, the National Highway Transportation and Safety Administration (NHTSA), which is responsible for CAFE standards, permitted extension of this rule until year 2008.

Several alternative designs for CAFE standards have been proposed [Hellman et al., 1986; McNutt and Patterson, 1986, OTA, 1991; NRC, 2002; NHTSA, 2003]. One such option is to require each vehicle manufacturer to improve the fuel economy of its fleet by a uniform percentage. However, this is seen as unfair to those manufacturers whose vehicles already have a better fuel economy. Another option is to have a standard based on different vehicle attributes such as interior volume (the so called Volume based Average Fuel Economy or VAFE standards), vehicle weight or a combination of these.

The enhanced CAFE (or E-CAFE) standards proposed by the NRC committee include weight based fuel economy targets. Such standards would require lighter vehicles to meet a fuel economy target proportional to their weight, but would require all the heavy vehicles to meet the same level of fuel economy. The claimed advantage of this approach is that it would induce the manufacturers to reduce the weight of heavier cars, while providing a small incentive to increase the weight of the lighter cars, resulting in increased traffic safety [NRC, 2002].

Under the current CAFE standards, manufacturers collect fuel economy credits for exceeding CAFE targets. Under a scheme of trading fuel economy credits, manufacturers would be able to buy and sell these credits. Such a scheme could be combined with any other form of the CAFE standards. Manufacturers would purchase the credits, if the cost of meeting CAFE standards is higher than purchasing the credits. This would result in lowered costs for meeting fuel economy targets [Sweeney, 2001]. Two National Research Council studies done on the subject of fuel economy standards have shown a favorable impression towards adopting such an approach. [NRC, 1991; NRC, 2002]. Similarly, CAFE standards could be combined with other measures such as feebates which are discussed below.

A comparison of different CAFE alternatives is shown in Table 3.2. The table shows that the choices involved in the design of CAFE standards create a complicated policy issue. Tradeoffs between safety, cost and fuel economy must be considered along with equity issues among different manufacturers while ensuring that the ultimate goal of improved fleet fuel economy is realized. This is far from an easy task. Table 3.3 shows a subjective estimate of the political acceptability of different forms of standard for various stakeholders.

Table 3.2 Comparison of different CAFE alternatives

	Certainty of Reducing Fuel Consumption (+ve is better)	Effect on						
		Vehicle Mass (+ve indicates increase)	Cost (+ indicates increase)	Full Line Manufacturer (+ve indicates better off)	Limited Line Manufacturer (+ve indicates better off)	Technology Forcing (+ve is better)	Safety (+ve is better)	Flexibility (+ve is better)
Current CAFE standards	+	-	+	-	+	+	?	=
Uniform mpg/percentage increase	+	-	+	=	-	+/?	?	-
Uniform car and truck standard	+/?	?/-	+	=/-	=	+/?	+/?	+/?
Weight-Based CAFE Standards	+/?	-/=	+/?	=/-	=/?	+/?	+	+/?
Volume-Based CAFE Standards	+/?	-/=	+/?	+/?	=	+/?	+/=	?
CAFE Standards with Tradable Permits	+/?	=/-	=/-	-	+	=	=	+
CAFE Standards with Feebates	+	-	=	-	+	+	?	+/=

Key: - Decrease/Negative effect ? Uncertain
+ Increase/Positive effect = Constant/No Change

Table 3.3 Potential Reactions to the alternative CAFE designs

	Domestic Manufacturers	Foreign Manufacturers	Environmental Organizations	Labor Unions
CAFE with Tradable Permits	-/=	+	-	-
Attribute-Based CAFE standards	+/=	-/=	-/=	?
Weight-Based CAFE standards	+/=	-/=	-	-
Uniform Percentage Increase	=	-	+	+
CAFE with Feebates	-	=	+	-

Key: - Negative Reaction = Uncertain/Neutral Reaction + Positive Reaction

The issue of CAFE standards is one of the most contentious issues in the U.S. transportation energy policy domain paralleled perhaps only by proposals to increase gasoline taxes. Several attempts have been made in Congress to increase the level of CAFE standards since 1985. None, however, has succeeded. In fact, in the 90s, Congress barred NHTSA from spending any money at all to study the fuel economy potential for new cars. In 2002, this moratorium was lifted and NHTSA was asked to come up with a modified form of CAFE standard to overcome its limitations. Since then, the standards for light trucks have been revised upwards slightly for years 2005-2007 [NHTSA, 2003]

3.3 Feebates

The Energy Tax Act of 1978 imposed an excise tax on cars that have very low fuel economy. As structured currently, the tax ranges from $1000 to $7500 on automobiles that get less than 22.5 miles per gallon. In 2001, the revenues from this tax, known as gas guzzler tax, were in excess of 78 million dollars [Davis and Diegel, 2003]. The gas guzzler tax can be thought of as the basic idea behind a feebate system. The concept of a feebate (a combination of "fee" and "rebate") entails charging fees to purchasers of new cars that obtain low fuel economy, and awarding rebates to those who purchase of new cars that obtain high fuel economy. The aim of a feebate program is thus to create a push-pull incentive for the production and purchase of more fuel-efficient vehicles. The judgment as to which vehicles are gas sippers and which are gas guzzlers has to be made relative to a reference level, which could be simply set at the fleet's average fuel consumption level.

The actual determination of a fee or a rebate can be made based upon a reference feebate rate. For instance, feebate rate could be fuel consumption based ($/gallons per miles) or fuel economy based ($/miles per gallon). From the perspective of fuel savings, the fuel consumption based feebate appears to make more sense. Figures 3.2 and 3.3 where the neutral point has been arbitrarily selected at 30 miles per gallon illustrate the two types of feebate scheme. Note that a fee of $55 per MPG is already present as a penalty of not meeting CAFE standards. Feebates could also be deigned by taking a class, size or weight based approach, and can be applied separately to cars and light-trucks categories.

The desirable level of feebates is around 5% of the vehicle cost in order to induce a sufficient level of response from the consumers and manufacturers [DeCicco et al., 1992]. The estimated response of the manufacturers is much bigger than that of the consumers [Davis et al., 1995]. As a result, a large rebate may not be necessary. This also means that state-level feebate programs are likely to be less effective than those at the federal level. OECD [1997] compares some of the different feebate options evaluated for U.S. and European markets.

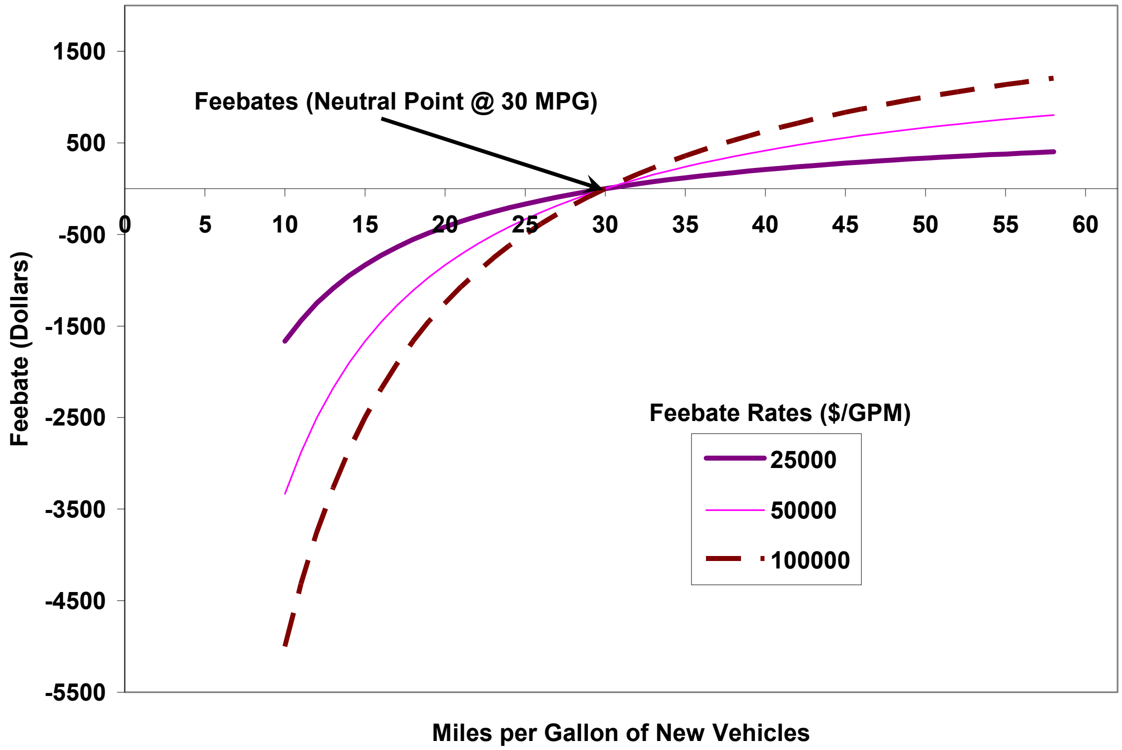


Figure 3.2 Illustration of Feebate based on Fuel Consumption

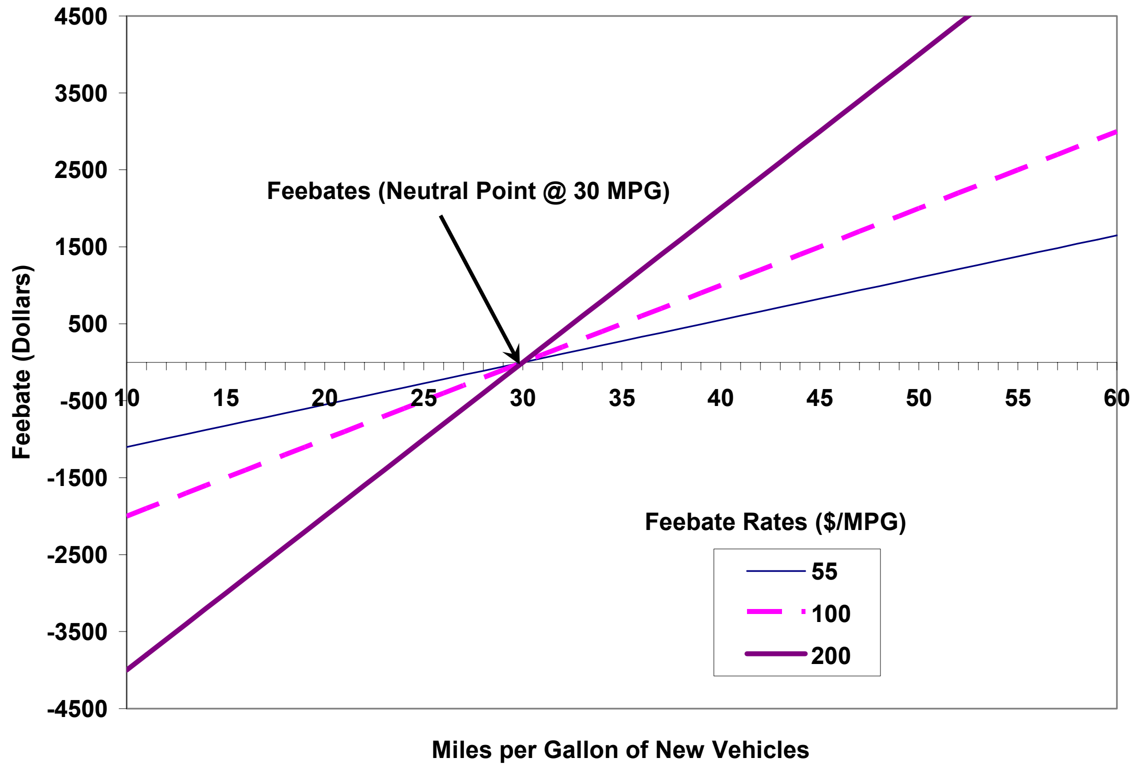


Figure 3.3 Illustration of Feebate based on Fuel Economy

The attractiveness of feebates lies in its ability to be a revenue-neutral instrument since the fees from the program could balance the rebates as well as the administrative costs. Feebates have been politically more acceptable at the state level; however no feebate program has been implemented in the U.S. so far. The California DRIVE+ proposal was passed in the assembly but was not signed by the governor. The State of Maryland adapted the same proposal as its bill; however it was preempted by the courts on the basis that they violate the federal fuel economy standards. Similar legislative attempts were made in Maine, Massachusetts, and Arizona [Davis et al., 1995]. In 2003, Senator Durbin introduced a Senate bill (S.795) to augment the gas guzzler tax with incentives for purchasing more fuel-efficient vehicles, which would make it equivalent to a feebate scheme.

Similar to the case of fuel economy standards, manufacturers must be given sufficient lead-time to adjust to the reference level of the feebates. This means that the feebates program has to be dynamic in nature. While feebate rates based upon vehicle size may seem to favor domestic manufacturers, consumers will most easily understand the feebate rates based upon mpg. As the goal of feebates aim is to increase penetration of more fuel-efficient technologies into market, some of the fuel savings will most likely be offset due to increased driving.

3.4 Carbon Tax

A carbon tax aims at internalizing the cost of carbon emissions in the price of fuel. From the perspective of economic efficiency, an economy wide carbon tax would be the most effective method of reducing greenhouse gas emissions. In the case of light-duty vehicles, such a tax may be incorporated as a part of the fuel tax.

3.4.1 Fuel Tax

The estimated environmental externality associated with one gallon of gasoline is about \$0.14 (estimates range from \$0.01 to \$ 0.25 per gallon), including the effects of supply chain. The estimated marginal costs of oil consumption translate into a cost of \$0.12 per gallon of gasoline (estimates range from \$0.02 to \$ 0.26 per gallon) [NRC, 2002]. However, the *optimal level* of tax on gasoline is difficult to determine.

Fuel taxes in the U.S. are significantly lower than in Europe and Japan. In contrast to the U.S. policy of using the revenue from fuel taxes solely for improvement of transportation infrastructure, several European nations use fuel taxes as a source of revenue to meet broader governmental budgetary needs. Figure 3.4 shows a comparison of gasoline prices in several different OECD countries.

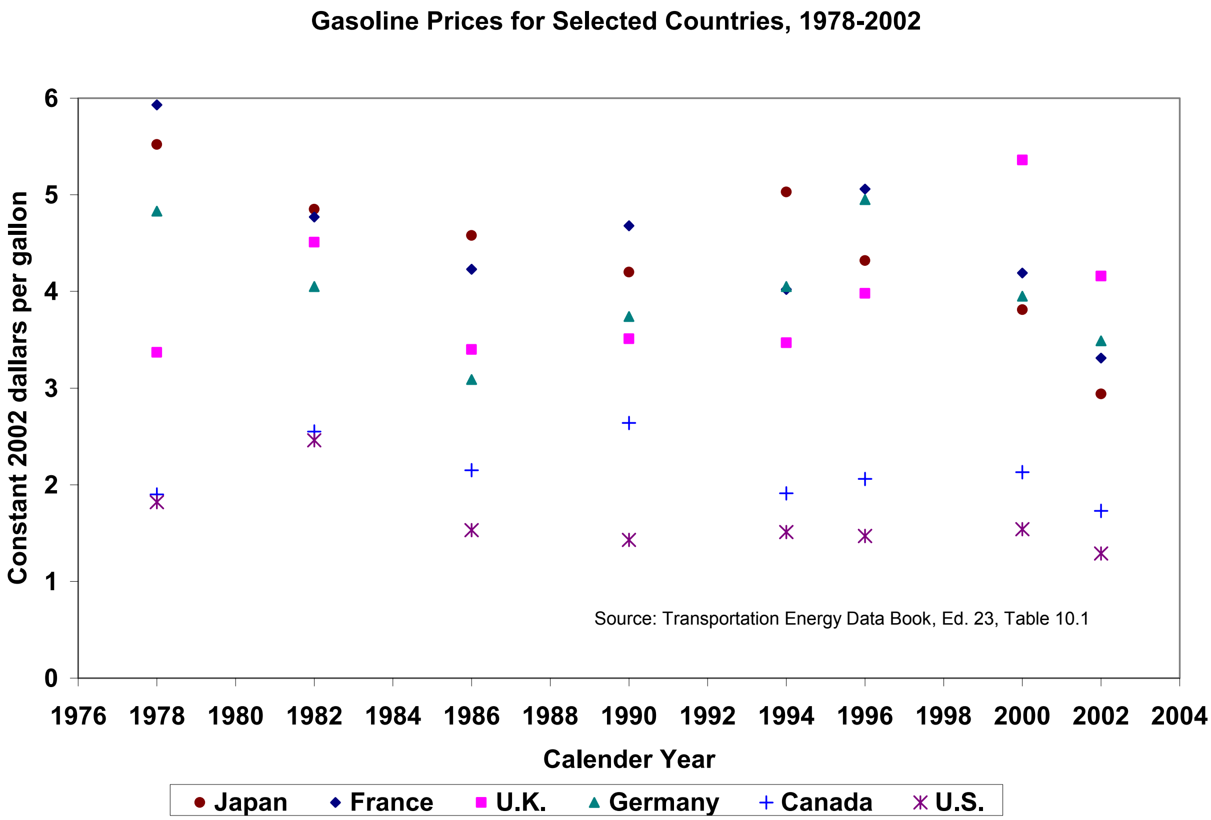


Figure 3.4 Gasoline Prices for Selected Countries (1978-2002) [Davis and Diegel, 2003]

The expected effects of fuel taxes are both reduction in vehicle miles of travel (VMT) and increased demand for more fuel-efficient cars. The effect of fuel prices on the driving distances can be calculated as [Hayashi et al. 2001]:

$$D_{t+1} = \left[1 - E_{vmt\_fuelp}\left(1 - \frac{P_{t+1}}{P_t}\right)\right] D_t \tag{3.2}$$

Where:

D_t is the driving distance in year t

P_t is the gasoline price

E_{vmt_fuelp} is the elasticity of vehicle travel with respect to fuel price

The estimates of elasticity of vehicle travel with respect to fuel price vary widely in both the short term from –0.09 to –0.2, and in the long term from -0.2 to –0.5 [Goodwin, 1992; Haughton and Sarkar, 1996; Greene and DeCicco, 2000; Nivola and Crandall, 1995].

Similarly, the estimates of elasticity of fuel economy (MPG) with respect to fuel prices vary from +0.1 to +0.2 in the short term and from +0.2 to +0.5 in the long term [Greene and DeCicco, 2000]. Figure 3.5 shows average lifetime discounted dollar expenditure on gas and oil at different gas prices. If gasoline prices were to rise by a dollar per gallon from the current level of $1.50 per gallon, there would be significant incentive to improve the fuel economy of low MPG vehicles. However, for vehicles already having fuel economy above 25 MPG, substantial increases in fuel economy will be needed to offset the additional lifetime gasoline and oil costs. Conversely, it is unattractive for the vehicle manufacturers to increase fuel economy of the higher discount rates such as those vehicles, if the gasoline price is low. Using higher discount rates than 7%, the prospects for improving fuel economy look less bright [Greene, 1998; Kleit, 2002; NRC, 2002]. Overall, the elasticity of fuel use with respect to fuel prices is likely to be in the range of -0.1 to -0.4 in the short term, and -0.2 to -1.0 in the long term [Greene, 1998]

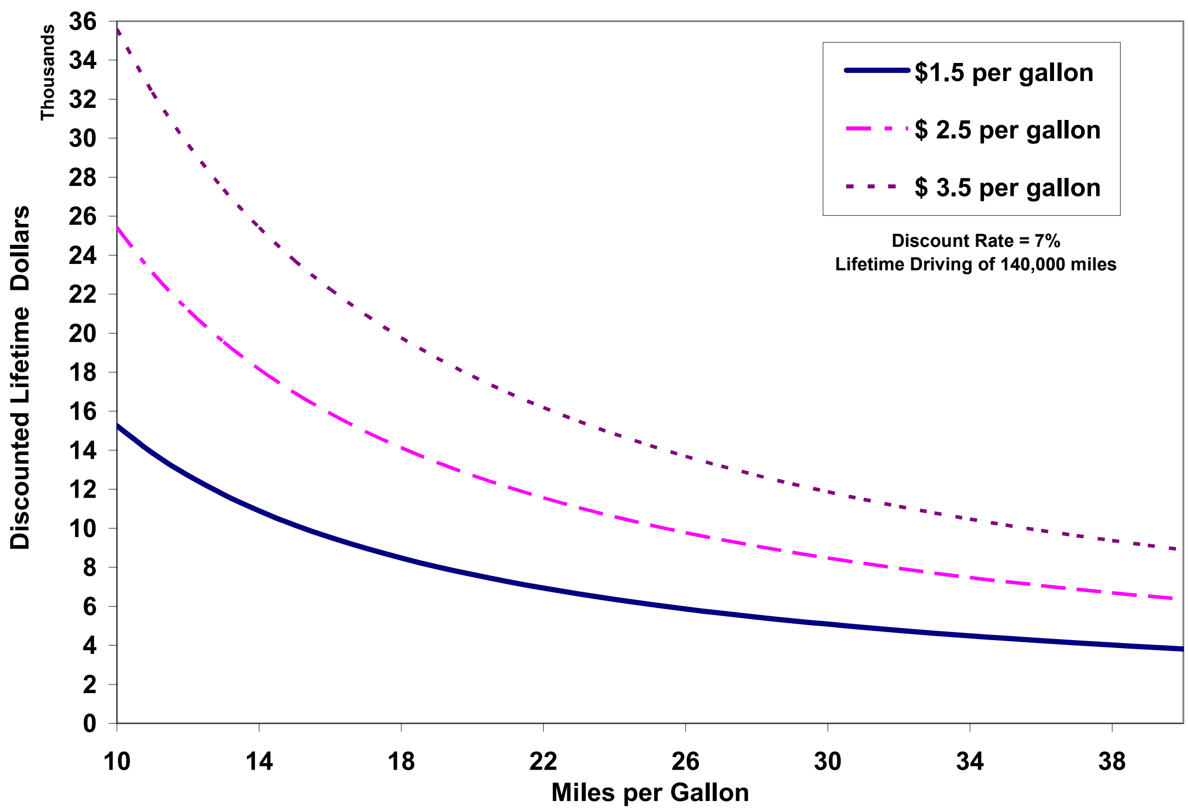


Figure 3.5 Lifetime Discounted Gas and Oil Costs at Different Fuel Prices and MPG

The two commonly cited advantages of the fuel taxes are that they less costly than regulations and they affect all the vehicles on the road. The structure to implement fuel taxes is already in place. In a comparison of different policy options to reduce fuel consumption, fuel taxes are generally shown to be economically the most efficient [CBO, 2002].

One common criticism of the fuel taxes is that they are regressive. The impact of fuel taxes on economic efficiency will depend on the distributional effects of the generated revenues. Fuel taxes in the U.S. have been used as a financing mechanism for transportation. Wachs [2003] argues that fuel taxes are in fact the most readily available, effective, efficient and equitable approach to transportation finance. Poterba has claimed that regressive effects of fuel taxes could be partly offset by explicit/earned income tax credits or other social welfare programs such as food stamp programs [Poterba, 1990].

3.5 Pay-at-the-Pump (PATP) charges

The Pay-at-the-Pump (PATP) charges, also known as Pay-as-you-Drive (PAYD) charges, aim at transferring a portion of the fixed costs of owning and operating a vehicle to a variable cost. Instead of annual or semi-annual collection of charges such as insurance premiums, registration fees, and emissions test fees, a PATP scheme collects these charges at the gas pump. The intent of PATP charges is to discourage low-value travel and promote the purchase of more fuel efficient vehicles without raising the total costs of driving for the average driver.

Figure 3.5 shows the costs of owning and operating an automobile in year 2001. The cost of vehicle insurance is roughly equal to the cost of fuel. Since depreciation is not a cash transaction, insurance premiums linked to a PATP program have the greatest potential to impact driving costs followed by registration and license fees.

A major advantage of PATP insurance scheme is that all motorists will have insurance; however uninsured drivers often come from low income households. Many households will pay much more at the pump than they will save by not paying annual registration or insurance fees, and it may be possible to lower average automobile insurance premiums [Wenzel, 1995]. Further, Allen et al. [1994] claim that a no-fault PATP insurance scheme would actually be more equitable and efficient.

A PATP program linked to insurance fees is often controversial because of the issue of insurance reforms. Trial lawyers are opposed to the no-fault PATP programs because they claim that it limits the ability of an individual to sue for non-economic damages [Wenzel, 1995]. Gruenspecht et al. [1994] provide an in-depth analysis of different groups on PATP schemes. Further, insurance and registration fees are state-dependent, so it will be difficult to coordinate a national level PATP scheme. This aspect of the PATP schemes makes it an unattractive policy option.

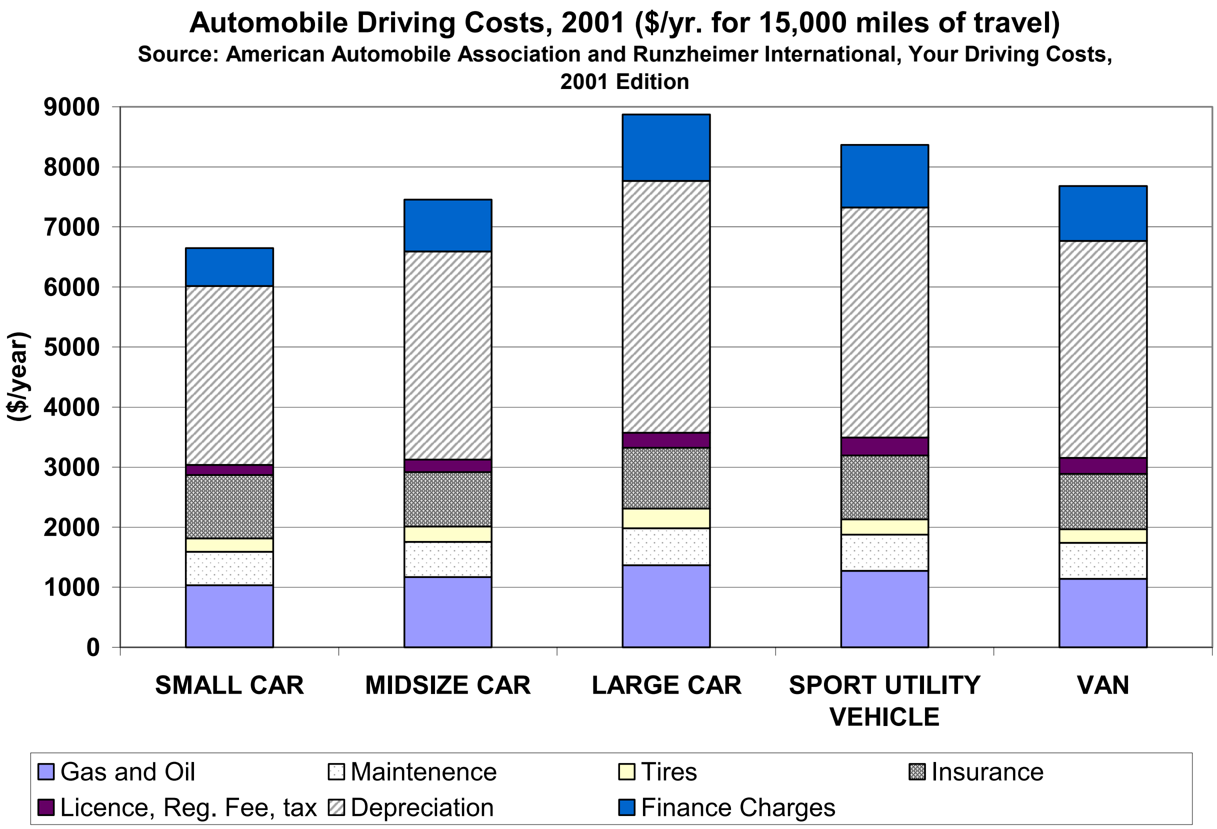


Figure 3.6 Automobile driving costs, 2001 ($/yr. for 15000 miles of travel)

3.6 Alternative Fuels

A number of alternative fuels including CNG, LPG, Ethanol, Methanol, and Hydrogen are always under consideration. The attention here is focused on ethanol from biomass. The use of ethanol as a fuel can potentially have a useful fleet-wide effect, and has a potential to reduce the full fuel-cycle emissions of greenhouse gas emissions in g/km of CO_2 equivalent by as much as 40-70%, while displacing some 10% of petroleum use [OECD, 1993].

If fossil fuels have to be used to produce and transport biomass (e.g., in fertilizers and farm equipment) then the total life cycle emissions of criteria pollutants may increase. The projected cost of cellulosic ethanol at $2.70 per gallon on an energy equivalent basis, which makes it economically unattractive. Also, since large amounts of land area will be needed for biomass production, potential effects on bio-diversity must be considered [Lave et al., 2001].

Another factor that adds to the uncertainty about the potential for alternative fuels is the acceptance by consumers of a significant shift in the type of fuel. Introduction of alternative fuels needs to be gradual to allow for the fuel distribution infrastructure to develop as well (diesels might face the same problem). The technologies to convert biomass to ethanol are yet to be demonstrated commercially on a large scale. Thus, the transition to the new fuel must be managed by coordinating the fuel manufacturers, fuel suppliers, and the vehicle manufacturers [McNutt and Rodgers, 2003]. The introduction of ethanol, however, requires no significant change in the driving behavior, assuming ease of availability of fuel.

Blending of cellulosic ethanol in conventional gasoline to displace petroleum may be an effective strategy. As Lave et al. [2001] point out all cars can currently run on E10, which is a mixture of 10 percent ethanol and 90 percent gasoline. The California Energy Commission and Air Resources Board recommended that the state set goals to blend up to 15% ethanol in gasoline by 2020 [CEC, 2003]. The amount of gasoline displaced as a result of blending ethanol can be calculated as:

$$V_{g\_d} = \left(\frac{E_{ethanol} * p}{E_{gasoline} * (1-p) + E_{ethanol} * p} \right) \tag{3.3}$$

Where:

V_{g_d} is the fraction of gasoline displaced

$E_{ethanol}$ is the energy content of cellulosic ethanol in MJ/liter

$E_{gasoline}$ is the energy content of conventional gasoline in MJ/liter

p is the percentage of cellulosic ethanol blended in gasoline by volume

If some financial incentives were to be offered, it may be possible to increasingly use up to 15 billion gallons (~ 57 billion liters) of cellulosic ethanol in gasoline by 2015-2020 [Lynd, 1997].

3.7 Subsidies/Tax Incentives

Public investment aimed at reducing fuel consumption can come in different ways, such as providing incentives to purchase more fuel efficient vehicles, providing subsidies for alternative fuels and providing financial incentives to manufactures to produce advanced technology vehicles. Broad support exists for such measures. For example, broad-based non-partisan groups such as the Energy Futures Coalition, which had members from industry, labor, environmental NGOs and politicians, endorsed the following measures [Energy Futures Coalition, 2003]:

- Incentives for purchase of fuel-efficient advanced technology vehicles tied to energy and environmental performance metrics.
- Tax credits for investment in existing facilities to produce advanced vehicles or their components, tied to energy and environmental performance metrics.
- Replacing agricultural subsidies with regulatory and financial incentives for the production of bio-based petroleum substitutes.

Some such incentives already exist. For example, a tax credit for purchasing highly fuel efficient internal combustion engine-hybrids is already in place, but will likely be phased out by 2007. Ethanol produced from corn receives $0.55 per gallon in tax subsidy. Similar incentives could be established for ethanol produced from woody biomass, which can offer even more energy benefits [Lave et al., 2001].

3.8 Research, Development and Demonstration Initiatives

The Partnership for a New Generation of Vehicles (PNGV) was launched in 1993 as a collaborative venture between the Department of Energy (DOE) and the U.S. Council for Automotive Research (USCAR). The aims of the PNGV were to:

- Develop a production-ready prototype of a mid-sized sedan that has three times the fuel economy of a comparable 1994 vehicle at a comparable cost by year 2004.
- Improve automotive manufacturing operations
- Develop and implement new technologies aimed at reducing emissions and improving recycling performance

The PNGV established a unique industry-government partnership model with investments of over 1 billion dollars per year. While it made tremendous progress on most fronts, by year 2000 it was clear that it could not meet its cost targets of developing an 80 miles per gallon vehicle prototype without sacrificing performance characteristics.

In 2002, DOE and USCAR replaced the PNGV with a new partnership called FreedomCAR, which aims at high-risk research to enable development of vehicles *that will free* *the nation's personal transportation system from petroleum dependence and from harmful vehicle emissions, without sacrificing freedom of mobility and freedom of vehicle choice* [USCAR, 2004].

Public-private partnerships such as PNGV and FreedomCAR can be helpful in developing technologies with the potential for a significant impact on vehicle fuel consumption in the long term.

3.9 Retiring Old Vehicles

Figure 3.7 shows the distribution of passenger cars by age in the United States [Wards 2000]. Clearly, the number of older vehicles on the road has increased considerably in the last two decades. Additionally, the older vehicles tend to be used more for work travel, and vehicles ten years and older generate as much as 22 percent of the total miles traveled [Pisarski, 1995]. The goals of a retirement program for old cars are to replace older, less fuel efficient and less safe vehicles with more fuel efficient and safe vehicles, and in doing so, stimulate the demand for newer vehicles. Old vehicle retirement programs may also provide an additional of reducing criteria air pollution from motor vehicles [OTA 1992].

The amount of fuel savings resulting from replacing older vehicles can be calculated as follows [ECMT, 1999]:

$$FuelSavings = \sum\left(\left[\frac{VMT_{old}}{MPG_{old}} - \frac{VMT_{replaced}}{MPG_{replaced}}\right] * L_{old}\right) \tag{3.4}$$

Where:

FuelSavings are the savings in fuel use from retiring old vehicles

VMT_{old} and $VMT_{replaced}$ are the vehicle miles traveled by old vehicle and the vehicles that replace them respectively

MPG_{old} *and* $MPG_{replaced}$ are the Miles per Gallon of the old vehicles and the vehicles that replace them respectively

L_{old} is the life remaining in the old vehicle at the time of retirement

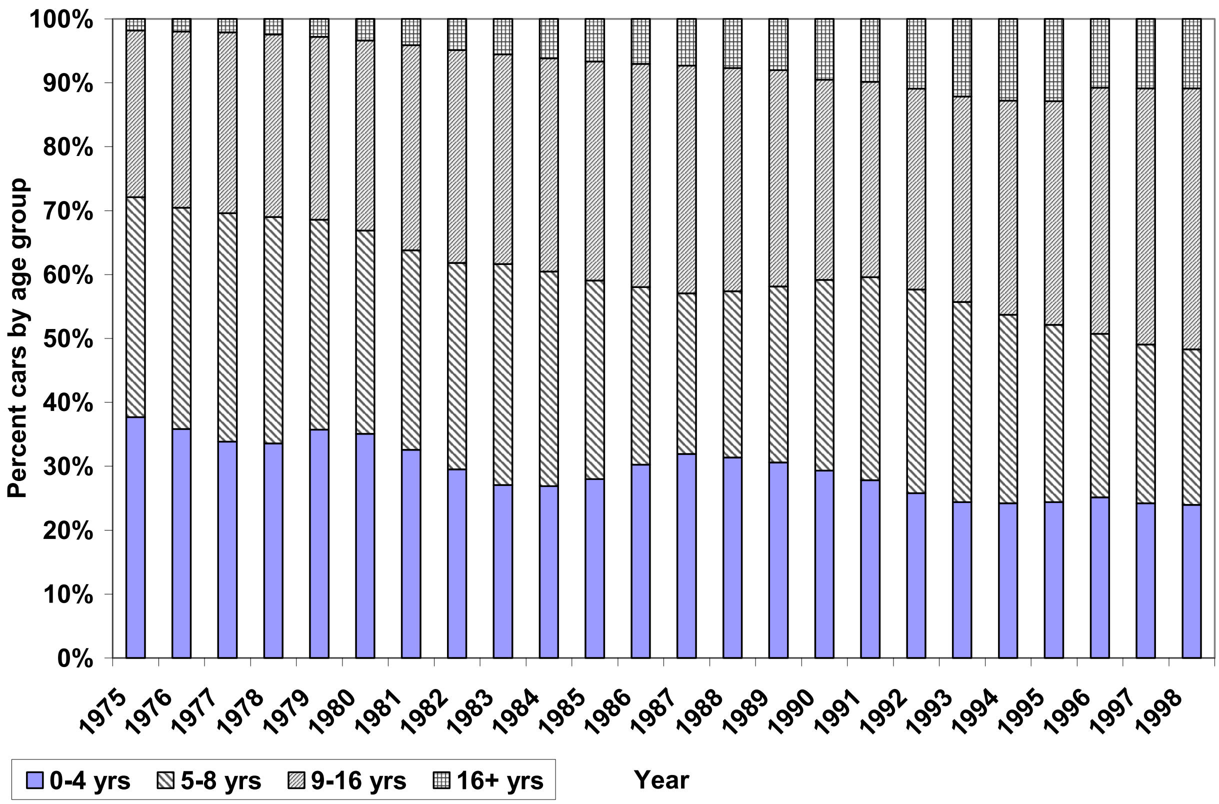


Figure 3.7 Distribution of Passenger Cars by Age in the U.S. [Ward's, 2000]

The incentive to retire old cars can be provided directly in the form of a rebate or tied to the purchase of a more fuel efficient vehicles. The earlier offers more flexibility and benefits than the former [ECMT, 1999]. The cost of incentive per vehicle is estimated to be around $500 to $1000 per vehicle. It is also possible to tie the benefits of a retirement program to credits in fuel economy standards [OTA, 1992].

Dixon and Garber estimate that the effects of an early retirement program will tend to level off over a period, as the number of older vehicles in the fleet decreases [2001]. If an early retirement program is made mandatory, then it may drive up the sales of new vehicles by increasing the prices of cars in the secondary market. The effect of this on lower income drivers will be negative, since they are more likely to own and operate older and/or second had vehicles.

3.10 Qualitative Analysis of Individual Policy Options

The economic and societal impacts of government intervention in the market for fuel use assume multiple dimensions. The usefulness of individual policy measures cannot be judged on the basis of potential fuel use and greenhouse gas emission reductions alone. Apart from the fuel consumption of vehicles, other key issues under consideration include:

- Vehicle performance: It is expected that broadly popular vehicle performance measures such as acceleration, functional capacity, accessories and amenities will improve or at least remain constant in the pursuit of a more fuel-efficient fleet.
- Safety implications: Effects of vehicle weight reduction on vehicle safety have been debated at great lengths without clear resolution. It is generally accepted that if weight reductions occurred in the heaviest of light duty vehicles, then overall safety should improve.
- Mobility implications: Implementation of certain strategies may change the purchasing, ownership, and usage patters of light duty vehicles. Consumer's essential mobility needs should be satisfied and the regressive effects of policy measures, if any, must be addressed. At the same time, the effect of different policies on other transportation issues such as criteria emissions and congestion must be considered.
- Implementation issues: The effectiveness of a policy measure will also depend upon whether such a policy can be implemented successfully in practice. Generally, policy measures which give different stakeholders more flexibility for action should prove more politically acceptable.

Different policy options under consideration are evaluated across these different criteria in Tables 3.4 and 3.5. Quantitative estimates are provided wherever possible.

Careful observation of Tables 3.4 and 3.5 reveals that there are synergies between different policy options. For example, while more fuel efficient vehicles may cause some increase in vehicle travel, this rebound effect could be offset by an appropriate increase in the fuel taxes. Not only that, but additional price at the pump makes it attractive for the automobile manufactures to reduce fuel consumption, thus lowering the risks and costs associated with meeting the CAFE standards. While the feebates and CAFE standards apply only to new vehicles, fuel taxes and alternative fuel use requirements have fleet-wide impact. While introduction of more fuel efficient technology might cost more initially, the rebates given to the more fuel efficient vehicles can reduce the economic burden on consumers. At the same time, the fees on vehicles with low fuel economy will not only discourage the consumers from buying those vehicles, but also provide incentives to the vehicle manufacturers to produce more fuel efficient vehicles. While the cost of renewable alternative fuels may be higher than gasoline currently, regulations requiring increased renewable fuel content along with government purchasing of the alternative fuel vehicles can provide economies of scale and the learning needed to reduce the cost associated with alternative fuels.

Table 3.4 Effectiveness of Policy Alternative to Reduce Fuel Consumption of the U.S. Light-Duty Vehicles

Policy Measures	Dimensions for assessing alternatives							
	Cost/ Cost effectiveness (market or full societal benefits and costs?)	Scale of applicability	Effectiveness in addressing energy issues		Effectiveness in addressing other transportation issues			
			Oil use reduction	Greenhouse gas reduction	Emissions reduction	Congestion reduction	Effect on vehicle safety	Effect on vehicle miles traveled (VMT)
CAFE	Costs of technological innovation and development necessary to meet the standards result in increased vehicle cost.	Incremental gains from new vehicles (currently affects cars and trucks separately)	Current savings of 2.8M barrels of oil/day (~ 14% of daily consumption) MPG gain from 20 to 30 saves more fuel than from 30 to 40.	In the short run, the greenhouse gas reduction is directly proportional to the reduction in oil use.	Generally, better fuel economy means lesser emissions. Stricter emissions requirements may inhibit technologies like diesel, lean-burn.	Moderate worsening of congestion due to increased driving.	Uncertain. It is likely that higher CAFE would reduce safety in vehicle-to-vehicle collision. This effect could be minimized by limiting weight& size reduction.	~ 1-2% increase in VMT for a 10% increase in fuel economy
Fuel Tax	Distributional effects: Regressive effects of fuel tax can be mitigated via other means such as explicit/earned income tax credits.	Impact on entire fleet	Depends upon the price elasticities of demand. Short run estimates –0.1 to –0.4 (gasoline) Long range estimates –0.2 to –1.0 (gasoline)	Same as above.	Moderate improvement due to reduced driving.	Moderate improvement in congestion due to reduced driving.	Modest improvement in safety due to reduced driving.	~ 1-3% reduction in VMT for a 10% increase in fuel prices

Table 3.4 (Contd.)

Policy measures	Dimensions for assessing alternatives							
	Cost/ Cost effectiveness (market or full societal benefits and costs?)	Scale of applicability	Effectiveness in addressing energy issues		Effectiveness in addressing other transportation issues			
			Oil use reduction	Greenhouse gas reduction	Emissions reduction	Congestion reduction	Effect on vehicle safety	Effect on vehicle miles traveled (VMT)
Feebates	Could be revenue neutral so that fees from more fuel consuming vehicles balance the rebates for more fuel efficient vehicles. Progressive?	Incremental gains from new vehicles	Savings due to improved overall fleet fuel economy	proportional to the oil use reduction	Generally, better fuel economy vehicles cause lesser emissions.	Moderate worsening of congestion due to increased driving.	Small	~ 1-2% increase in VMT for a 10% increase in fuel economy
Alternative Fuels: Cellulosic Ethanol/Bio Diesel	Currently expensive as compared to Gasoline (~ $2.70/gallon gasoline equivalent at the pump)	Potential to have a large scale fleet wide effect	Projections of 10+% of fuel displacement. Ambitious plans may displace a larger percentage.	40-70% reduction in full cycle CO2 emissions	Increase in life-cycle emissions, mainly due to use of fossil fuels in producing fertilizers and farm equipments. Biodiesel may have better characteristics than diesel	No Impact	No Impact	No Impact

Table 3.4 (Contd.)

Policy measures	Dimensions for assessing alternatives							
	Cost/ Cost effectiveness (market or full societal benefits and costs?)	Scale of applicability	Effectiveness in addressing energy issues		Effectiveness in addressing other transportation issues			
			Oil use reduction	Greenhouse gas reduction	Emissions reduction	Congestion reduction	Effect on vehicle safety	Effect on vehicle miles traveled (VMT)
PATP	PATP schemes involve transfer of insurance or registration fees to the pump (~ $0.1 to 0.75 per gallon)	Impact on entire fleet	Depends upon the price elasticities of demand. Short run estimates – 0.1 to – 0.4, and Long range estimates – 0.2 to – 1.0 (gasoline)	~ 9 Million Metric Tons (MMT) per year of CO_2 reduction for $0.10 per gallon of PATP charge; 32 MMT per year for $0.40 per gallon of PATP charge	Moderate improvement due to reduced driving	Moderate improvement in congestion due to reduced driving	Modest improvement in safety due to reduced driving, otherwise no direct effect	Some reduction in vehicle travel as a result of increased cost of driving
Retiring Old Cars	Financial incentives need to be created for replacement of older vehicles	Impact on replacement vehicles only	Depends upon average fuel consumption of vehicle retired and average fuel consumption of vehicle replacing it, and the life remaining in the old vehicle	Proportional to oil use reduction	Newer vehicle purchase will result in emissions reductions	No Change	As newer vehicles are more safe, overall safety may improve	Slight increase likely as newer vehicles tend to be driven more than older vehicles
RD&D	Public investment of several hundred millions of dollars per year	Across the next generation of vehicles	Significant long term impacts possible	Significant long term impacts possible	Significant long term impacts possible	No Change	Significant long term impacts possible	No direct effect. More fuel efficient technology will encourage more driving.
Manufacturer Tax Incentives	Costs will be of the tune of $2 billions over ten years	Incremental gains from new vehicles	Savings due to improvement in new fleet fuel economy	proportional to oil use reduction	Positive effect through manufacture of vehicles with better emissions performance	No effect	No effect	No effect

Table 3.5 Considerations for Implementation of Individual Policy Options

Policy measures	Considerations for Implementation							
	Rate of implementation	Scale of implementation	Flexibility	Political acceptability	Level of Co-operation needed between agencies	Technological Change	Degree of Lifestyle change required	Other Factors
CAFE	Standards must give manufacturers sufficient time to respond. Widespread penetration of new technologies requires 10-15 years.	Standards need to set at a level where, the marginal cost of additional fuel savings equals marginal benefits from savings to the consumer.	Details of standards are important and complicated. Many possible approaches. Current standards distinguish between light trucks and passenger cars.	CAFE standards are by and large the politically most acceptable means. Automobile manufacturers oppose increase in CAFE.	While EPA does the testing of car fuel economy, NHTSA is actually responsible for CAFE and highway safety issues.	Consumer demand for fuel-efficient vehicles is low at low fuel prices. CAFE drives improvement in technological efficiency. However, also encourages vehicle sales mix.	Small or uncertain. MAY require shifting towards lighter/smaller vehicles.	--
Fuel Tax	Immediate impact upon implementation, However implementation needs to be gradual	Tax equal to amount of externality generated by the fuel use ($0.02 to $0.50 per gallon). Actually, not as straightforward.	Fuel Tax is a means of decresing the incentive to drive more.	Political acceptability is currently poor.	Minimal. A fuel tax collection system is already in place.	Diminished pressure for technological advanaces. Encourages change in behavior.	Change driving habits. Evaluate other modes of transport.	--

Table 3.5 (Contd.)

Policy measures	Considerations for Implementation							
	Rate of implementation	Scale of implementation	Flexibility	Political acceptability	Level of Co-operation needed between agencies	Technological Change	Degree of Lifestyle change required	Other Factors
Feebates	Feebate levels must give manufacturers sufficient time to respond.	~5-10% of vehicle price; level of fees and rebates need to be adjusted frequently to maintain the program revenue neutral, may require a pool of money for rebates	Feebates aim at sale of new personal vehicles, based on fuel efficiency, fuel economy or emissions of carbon dioxide	Revenue neutral nature has political appeal	Feebate monitoring mechanism has to be established	Increased incentive to bring fuel efficient vehicles to market	Little or no impact	Consumer and Manufacturer response to feebates is unknown. Hoever, consumer response estimated to be smaller as compared to the manufacturers response.
Alternative Fuels: Cellulosic Ethanol/ BioDiesel	Introduction of alternative fuels must be gradual	Limited by the production capability, and the amount of subsidy needed.	Large amount of land needed for biomass production on a regular basis.	Large scale use of alternative fuels could mean increased oil security. "Bio-diversity" may be an issue.	Fuel safety and supply network must be established	Development of Alternative Fuel Vehicle (AFV) technology	Little or no impact	Consumer response to large scale changes in type of fuel unknown.

Table 3.5 (Contd.)

Policy measures	Considerations for Implementation							
	Rate of implementation	Scale of implementation	Flexibility	Political acceptability	Level of Co-operation needed between agencies	Technological Change	Degree of Lifestyle change required	Other Factors
PATP	Immediate impact upon implementation, However implementation needs to be gradual	Implementation will vary from state to state	PATP charges could be based upon Insurance, Inspection/ Maintainence, Registration fees individually or as a combination	Revenue neutral nature has political appeal, PATP often associated with insurance reforms, a very sticky issue. Opposition from trial lawyer groups	Insurance, Inspection/ Maintainence, Registration fees are mostly state affairs, however nationwide changes required for significant impact	Encourages more fuel efficient vehicles	Insurance premiums will be correlated to fuel use	It will be possible to insure everybody who purchases fuel.
Retiring Old Cars	Rate of implementation will vary from state to state	Small, and restricted to older vehicles	Limited	Potential regressive effects need to be considered	Coordination between revenue, transportation and environmental departments required	Not technology forcing, but will increase rate of technology penetration	No change	A small in crease in new vehicle sales
Rd&D	Long term pre-competitive projects (up to 10 years of development times)	A public-private partnership to conduct joint research program with an intention to innovate	Possible to set ambitious long term goals	Strong political support for projects such as Partneship for the New Generation of Vehicles (PNGV) and FreedomCar	DOE, DOT and government labs need to coordinate with industry	Technological breakthroughs possible in long run	None	Benefits of RD&D are not always seen in short term
Manufacturer Tax Incentives	Will only affect a part of new vehicle market gradually over 10-15 years.	Credits would cover "substantial percentage" of capital investment (~0.5-1.0 billion for a new factory ?)	Incentives should be performance based and technology neutral	Support from domestic automakers and unions	Revenue services, DOE and DOT will need to coordinate, some monitoring mechanism needs to be established	Encourages deployment of more fuel efficient technologies in the new vehicles	None	Automobile manufacturers have been vocal about consumer tax incentives, but not all that much about manufacturer tax credits?

3.11 Policy options pursued in other countries and at state level

3.11.1 European Policy Measures

There exists no fuel economy regulation in Europe. In July 1998, the association of European car and truck manufacturers (ACEA) made a voluntary commitment to reduce new car CO_2 emissions to achieve a new car fleet average CO_2 target of 140 g/km (~ 40 miles per gallon) by 2008 – which represents a 25% reduction from 1995 or a 33% improvement in fuel economy [ACEA, 2002]. ACEA has also promised to consider meeting a 120g/km CO2 emission target (~ 48 miles per gallon) by 2012. The industry promises fleet-wide reductions in emissions, although no penalty for missing the targets exists. One of the main reasons which brought about the voluntary agreement was the fear of stricter EU regulations. Potential exists in the U.S. for similar improvements [Plotkin et al., 2002]. For a review of policy measures discussed by several different OECD countries, see OECD [2003].

3.11.2 Japan and China: Weight based fuel economy

Japan has established weight class based fuel economy targets for year 2010. The standards will require about 22% improvement over the 1995 weight class averages, and will imply a new car fuel economy of approximately 35.5 miles per gallon by year 2010, assuming no major changes in vehicle sales mix [Plotkin, 2001]. When adjusted for the U.S. driving cycle, the fuel economy levels may appear higher.

Recently, China has also sought to establish weight class based fuel economy standards for cars [Runyan, 2004]. Sixteen weight classes based on European emissions weight categories will be established starting 2006, and different standards will e established for automatic and manual transmissions cars.

3.11.3 Efforts in the state of California

California Assembly Bill 2076 asked the California Energy Commission (CEC) and the California Air Resources Board to develop and submit to the legislature a strategy to reduce petroleum dependence in California [CEC/CARB, 2003]. The CEC/CARB report recommended that California should adopt a statewide goal of reducing demand for on-road gasoline and diesel to 15 percent below the 2003 demand level by 2020 and maintaining that level for the foreseeable future. The report of the agencies indicates that improving the fuel economy of new vehicles might be the most effective way of reducing California's dependence on foreign oil. California will have to lobby the federal administration for upward revision of CAFE standards.

California AB 1493, the first of its kind in the U.S. directs the CARB to achieve the maximum feasible and cost-effective reduction of greenhouse gases from California's motor vehicles. The bill specifically prohibited new fees or taxes on vehicles, fuel(s) or miles traveled, a ban on the sale of any vehicle category, a required reduction in vehicle weight, a limitation or reduction in the speed limit, or a limitation or reduction in vehicle miles traveled. Since many of the demand side measures are prohibited, all the reductions in greenhouse gas (GHG) emissions will have to come through technological improvements in vehicles.

The draft form of the standard released by CARB in August 2003 indicates that the standard will be based on grams per mile of CO_2. Emission of 200 grams of CO_2 per mile is roughly equivalent a fuel economy of 40 miles per gallon. Any attempt by CARB to state the standard in terms of grams per mile of CO_2 will be challenged in courts as a violation of the Energy Policy and Conservation Act (EPCA) of 1992, which prevents any state from setting its own targets for the fuel economy of vehicles sold in the state or CO_2 emission standards from motor vehicles. If, however, the Environmental Protection Agency (EPA) makes a determination that under the Clean Air Act of 1990, CO_2 can be considered an air pollutant, then the exemptions which allow California stricter air quality standards might apply to CO_2 emissions [Chanin, 2003]. Not surprisingly, the EPA has said that it lacks authority to regulate carbon dioxide and other greenhouse gases from motor vehicles [EPA, 2003].

The task of CARB in setting the regulation is further made difficult by the strict air quality standards in California. Diesel engines, which are 30% more fuel-efficient than gasoline engines, cannot meet the state's strict NOx emissions standards easily. Thus, a clear tradeoff exists between the short term health impacts of NOx versus the long term climate change impacts of the CO_2 emissions.

There is a complete absence of measures that can stimulate demand for more fuel efficient vehicles means that California's ambitions to reduce GHG emissions will have to be tempered; even though criteria pollutants have been addressed. In part, this disparity is due to public perception of the relative importance of the health effects of criteria pollutants with respect to the long term climate change effects of CO_2. Thus, consumers are much more willing to pay for technologies that reduce the former than the later. In this light, California’s approach to focus only on technology-forcing regulations may not succeed.

Chapter 4: Combinations of Policy Options

4.1 Deadlock over Policy Debate

As observed in chapter 2, the average fuel consumption of light-duty vehicle fleet in the U.S. has essentially remained constant since the late 1980s while the total fuel use has been increasing steadily. The discussion aimed at reducing fuel use has centered mainly on the CAFE standards. Moreover, there are a number of different viewpoints among different stakeholders vis-à-vis the costs and benefits of raising CAFE standards versus employing other policy measures [NRC, 1991; GAO, 2000; NRC, 2002; CBO, 2002]. As a result, there has been a virtual stalemate in the debate over reducing the fuel use of light-duty vehicles.

4.1.1 An Effort to Break the Deadlock

In early 1994, an advisory committee was established at the request of President Clinton, to discuss policy measures to reduce greenhouse gas emissions from light-duty vehicles. The committee consisted of 30 members chosen to represent all the different stakeholder groups. Officially titled as *The Policy Dialogue Advisory Committee to Assist in the Development of Measures to Significantly Reduce Greenhouse Gas Emissions from Personal Motor Vehicles,* the committee came to be known as *Car Talk*.

Unfortunately, the discussions in *Car Talk* were marred by differences of opinion over increases in CAFE standards and gasoline taxes [Eads, 1996; Bergman, 1996]. The committee met about eleven times in its one year existence but failed to reach an agreement.

When the talks failed, seventeen of the thirty committee members including some government staff members and environmental NGOs submitted a "Majority Report to the President". The so called *Majority Report* did not include any of the views of the *minority*, nor did the minority submit its own recommendations. The agenda set by the majority was indeed quite ambitious and included very strict CAFE standards coupled with a variety of transportation demand management measures [Dunn, 1998]. Due to lack of consensus, *Car Talk* sank without having any impact on the policy process.

4.2 Rationale for Combinations of Policy Measures

Clearly no one agreed upon policy option to address the fuel consumption of light-duty vehicles exists, and differences in opinion are likely to persist [McNutt et al., 1998]. So, it can be argued that the problem of fuel consumption can be addressed by a carefully selected combination of policy options that shares the responsibility among all stakeholders.

There is a two-fold argument for combining policy measures to reduce fuel consumption of light-duty vehicles. The first is that increasing vehicle fuel consumption is a market failure that necessarily requires regulatory and fiscal response. The second is that without such an integrated approach, a policy proposal may not have the necessary broad-based support to move forward. Both of these arguments are explored here.

4.2.1 Market Failure or a Failed Market?

Greene [1998] claims that the market for fuel economy is inherently *sluggish* for two primary reasons. To start with, consumers have imperfect information of the net present value of fuel savings achieved from higher fuel economy vehicles and no reasonable way of comparing it to the additional cost it imposes at the time of vehicle purchase. Moreover, fuel consumption is only one of many characteristics that consumers care about when buying a vehicle.

In addition, according to Greene, unless there are clear signals that consumers demand better fuel consumption performance, manufacturers are likely to be reluctant to invest in major technological changes aimed at reducing fuel consumption. In other words, the risk of providing better fuel consumption at an additional cost may be too high for the automobile manufactures.

As the National Research Council's Committee on Nuclear and Alternative Energy Systems (CONAES) has noted [NRC, 1979]:

> The willingness to invest in capital substitutions for energy and to practice energy conservation clearly rises or falls with changes in the anticipated price of energy. Conservation of energy represents a middle- to long-range investment; if the investment is to be made, the signals the economy reads from prices for energy must be unambiguous, and the trends reasonably predictable over the lifetimes of normal investments.

> However, because even accurate, widely noted market signals are sometimes insufficient to guide market decisions in the direction of energy conservation – as, for example, when the total cost of owning and operating a particular facility, appliance, or process is relatively insensitive to energy efficiency – prices alone cannot carry the burden of effective conservation policy.

As shown in Figures 3.5 and 3.6, the cost of fuel use is small (although not negligible) as compared to the total operating costs of a vehicle, and relatively large improvements in fuel economy (which involve additional upfront costs) are needed to reduce these costs further. So, the amount of fuel savings may be an only modestly attractive proposition for the consumers to demand less fuel consuming vehicles. According to CONAES:

> …Where energy prices are insufficient to induce the appropriate, economically rational responses from consumers – as they are, for example, in the case of the automobile – they could be supplemented by nonprice measures.

In other words, while price signal are necessary, they may not be sufficient to induce all the technological changes required to substantially reduce the fuel consumption. On the other hand, if regulatory standards are set without providing the market incentives, then the manufacturers have to bear the risks of producing vehicles with characteristics that consumers may be unwilling to accept. National Research Council's study on the effectiveness and impact of CAFE standards said in its findings [NRC, 2002]:

> There is a marked inconsistency between pressing automotive manufacturers for improved fuel economy from new vehicles on one hand and insisting on low real gasoline prices on the other. Higher real prices for gasoline – for instance, through increased gasoline taxes – would create both a demand for fuel-efficient new vehicles and an incentive for owners of existing vehicles to drive them less.

Thus, while increasing fuel economy standards alone would be a better policy than not acting at all, a combination of an increase in gasoline tax and increased fuel economy standards would be a more effective approach [Gerard and Lave, 2003].

4.2.2 Political Appeal of an Integrated Policy Approach

The escalating fuel use of light-duty vehicles presents a classic *commons* problem. It is extremely difficult to measure the value of all the different externalities caused by the fuel use. If the aim of policy were economic efficiency alone, then *getting the prices right* would help; but may not completely solve the problem as seen in the previous section. In practice, the policy process has aims beyond economic efficiency such as equity and access with respect to mobility.

Different policy approaches are criticized for different reasons. For example, one argument against the CAFE standards is that they constrain the automobile manufacturers too much. Gasoline taxes are presumed to have regressive economic effects, and so on.

Among other factors, the success of a proposed policy depends upon the real and perceived distribution of costs and benefits resulting from the policy [Wilson, 1980]. Such costs and benefits are not always monetary and perceptions of the fairness of a policy often affect whether the stakeholders find the policy legitimate and persuasive. According to Wilson, public policies can be classified into different categories depending upon the distribution of costs and benefits resulting from the implementation of the policy as shown in Table 4.1.

Table 4.1 Types of Policies based on Costs and Benefits of Policy

Types of Regulatory Activity		Costs	
		Widely Distributed	Concentrated
Benefits	Widely Distributed	Majoritarian	Entrepreneurial
	Concentrated	Client	Interest-group

CAFE standards, for example can be described as entrepreneurial because the costs of meeting the regulations fall largely upon the automobile manufacturers. Although the monetary costs may ultimately be passed on to the consumers, the risks involved in the process are borne solely by the automobile manufacturers. The benefits, on the other hand, are seen by society in the form of reduced fuel use and greenhouse gas emissions. One should not be surprised, therefore, that the automobile manufacturers oppose the CAFE standards as a means to reducing the fuel consumption.

As noted in Chapter 2, the stakeholders in this problem include vehicle purchasers and users, the automobile and petroleum industries, and the government at different levels. A policy package that attempts to spread the costs and benefits among different stakeholders may have a broader political appeal and could be perceived as a more fair approach to the regulation. Such a majoritarian policy approach seeks to generate positive commitment from all the stakeholders, without causing any one set of stakeholder groups to a large risk.

4.3 Development of a Sample Policy Package

The final conclusion of the 1997 Asilomar conference on *Policies for Fostering Sustainable Transportation Technologies* was that the overall strategy for meeting environmental quality and energy system goals must include a creative and flexible blend of regulation, pricing reform, incentives and consumer education [Lipman et al., 1998]. The aim of such a policy must be to reduce individual vehicle fuel consumption, slow the growth in vehicle travel and reduce the carbon intensity of fuel used [BEST, 2001].

Section 3.10 showed qualitatively that synergies exist between different policy options. Agras and Chapman [1999] claim that using gasoline tax and CAFE Standards together is more effective than using either policy individually. DeCicco and Lynd [1997] discuss scenarios that combine vehicle fuel economy improvements along with increased use of cellulosic ethanol. The combined impacts of policies are not necessarily additive, although some previous analyses use such an approach [NRTEE, 1998]. The extent of cross-elasticity or cross-coupling of different measures is highly uncertain. The effect of policy measures affecting the same aspect of emissions could be considered multiplicative to avoid double counting [Greene and Schafer, 2003]. DeCicco and Gordon [1995] affirm that the effect of a small increase in gasoline tax when coupled with an increased fuel economy standard will be limited to a reduction in vehicle travel, and the fuel economy standards will override the effects of improved fuel economy resulting from increased gasoline tax.

As an example of an integrated policy approach, a policy proposal combining several different policy options is discussed here, and its potential impact vehicle fleet fuel use are described. While this represents one possible example of a policy package, various other combinations with different policy options could be used creatively. The policy package described below is a representative sample that combines measures to reduce vehicle fuel consumption, slow the growth in vehicle travel, and increase renewable content of the fuel.

4.3.1 Sample Policy Packages

An effective policy package that aims at both pushing and pulling advanced vehicle technology and renewable fuels in the market might well have the following components:

- Vehicle manufacturers could be required to meet CAFE standards in the current or modified form. The key considerations would be the extent of changes in the form of the CAFE program, as well as the aggressiveness of the proposed standard. A possible increases in CAFE standards could be based on baseline and medium hybrids scenarios as discussed in section 2.3.1. The fuel economy levels corresponding to these scenarios are shown in Table 4.2. These fuel economy levels assume that about half of the potential of advanced engine and vehicle technology would be utilized in improving the vehicle fuel consumption, as shown in Figure 2.6. It is important to note that these CAFE standards would be used as a part of a policy package whose other elements are described below.

Table 4.2 CAFE Standard Levels under Baseline and Hybrids Scenarios

Year	Baseline Scenario				Medium Hybrids Scenario			
	Cars		Light Trucks		Cars		Light Trucks	
	Miles per Gallon	Liters per 100 km	Miles per Gallon	Liters per 100 km	Miles per Gallon	Liters per 100 km	Miles per Gallon	Liters per 100 km
2020	35.5	7.76	27.8	9.91	38.1	7.22	29.4	9.36
2030	41.2	6.68	32.3	8.53	53.7	5.13	39	7.07

- A revenue neutral feebates program can encourage the manufacture and purchase of more fuel efficient vehicles. Such a program consisting of fees for gas guzzlers and rebates for gas sippers could complement the CAFE program. A moderate fee/rebate rate of \$25,000/Gallons per Mile (roughly equivalent + \$400 to - \$1500 per vehicle), as shown in Figure 3.2 is considered here.
- Gasoline taxes could be increased by about 5 to 10 cents per gallon every year (~2-3 cents per liter per year). Equivalent tax credits could be granted to consumers to achieve revenue neutrality and minimize regressive impacts. Such a form of tax shifting may encourage reduction in vehicle miles traveled without causing financial burden to the vehicle users.
- Renewable content in fuels could be increased by mandating an increasing amount of cellulosic ethanol blended in gasoline. This mandate may require a cellulosic ethanol blend in gasoline of 4.5% by 2025 and 7% by 2035 on a volumetric basis. In a more aggressive action, these requirements may be doubled to 9% by 2025 and 14% by 2035. These levels correspond to a 0.25 to 0.5% increase per year in the volume of cellulosic ethanol blended in gasoline. Fuels with high renewable content could also receive preferential tax treatment with

respect to gasoline/diesel, which should encourage the fuel suppliers to make a shift towards renewable fuels.

The assumption is that the policy package will be implemented starting year 2008 and continued until year 2035. These policy measures can be combined in different proportions. The sensitivity of different combinations is evaluated through eight policy package scenarios as shown in Table 4.3. Policy scenarios 1, 3, 5 and 7 are based on fuel consumption improvements as per baseline, whereas policy scenarios 2, 4, 6, and 8 are based on fuel consumption improvements as per medium hybrids scenario.

Table 4.3 Policy Combinations Examined

Policy Measures	Policy Scenarios							
	1	2	3	4	5	6	7	8
CAFE Standards	Baseline	Medium	Baseline	Medium	Baseline	Medium	Baseline	Medium
Gasoline Tax Increase	5 ¢ per gallon per year	5 ¢ per gallon per year	5 ¢ per gallon per year	5 ¢ per gallon per year	10 ¢ per gallon per year	10 ¢ per gallon per year	10 ¢ per gallon per year	10 ¢ per gallon per year
Cellulosic Ethanol Content Increase	0.25% per year	0.25% per year	0.5% per year	0.5% per year	0.25% per year	0.25% per year	0.5% per year	0.5% per year

4.3.2 Expected Impact

The anticipated impact of such an integrated policy package is estimated as follows:

- Vehicle fleet model is used to evaluate the effect of improved vehicle fuel consumption on fuel use [Heywood et al, 2004]. No changes in vehicle sales or vehicle travel growth rates are assumed. The fuel use and vehicle travel of cars and light-trucks are calculated separately.
- The current price of gasoline is assumed to remain steady at $1.5 per gallon until 2007, when a 5 cent per gallon increment in gasoline taxes is applied. The effect of an increase in gasoline prices on vehicle travel is calculated using Equation 3.2. The elasticity of vehicle travel with respect to fuel price is assumed to be -0.3, which is a high end estimate and thereby overestimates the effect of gasoline taxes on vehicle travel. Thus, a 10% increase in gasoline prices decreases vehicle travel by 3% over a period of one year.

- The effect of decreased fuel consumption on vehicle travel is estimated through a *takeback* factor of -0.2. This *takeback* is assumed to affect all vehicles, and thus overestimates the amount of rebound effect. In quantitative terms, a 10% decrease in fuel consumption is assumed to cause an increase in vehicle travel of 2% over a period of one year. Notice that the gasoline tax increase and rebound effect estimates tend to offset one another.
- The effect of a vehicle feebate on vehicle fuel consumption is not modeled explicitly. Instead, it is assumed that the feebate neutral point will be established at the level of CAFE standards. The feebates will then provide the necessary incentive for the consumers to purchase more fuel efficient vehicles and thereby reduce the risk to the vehicle manufacturers of meeting fuel economy standards. In practice, the feebates are likely to provide an additional incentive to the vehicle manufacturers to produce more fuel efficient vehicles. Thus, the impact on vehicle fuel consumption is underestimated here.
- Increasing the proportion of cellulosic ethanol blended into gasoline is assumed to displace gasoline by volume according to Equation 3.3. Note that since the energy content of ethanol is about 2/3rd that of conventional gasoline, a 10% by volume blend of cellulosic ethanol reduces the consumption of gasoline by about 6.8%.

Figures 4.1 and 4.2 show the effect of policy combination 1 on vehicle fuel consumption and travel. The reduction in average fuel consumption of new cars and trucks is about 23.5% and that in the overall fleet fuel consumption is over 18%. As a result of increased gasoline tax, the total car travel in 2035 is only slightly higher than the current level. The total vehicle travel by light-trucks continues to increase, but at a slower rate. The reduction in overall vehicle travel from No Change scenario is about 14.2%. Under policy combination 1, the total fuel use of light-duty vehicles peaks at 610 billion liters per year (10.5 million barrels per day) in 2022 and gradually reduces 583 billion liters per year (10 million barrels per day) in 2035. Notice that this is still slightly higher than the current light-duty fuel use of about 543 billion liters in year 2004.

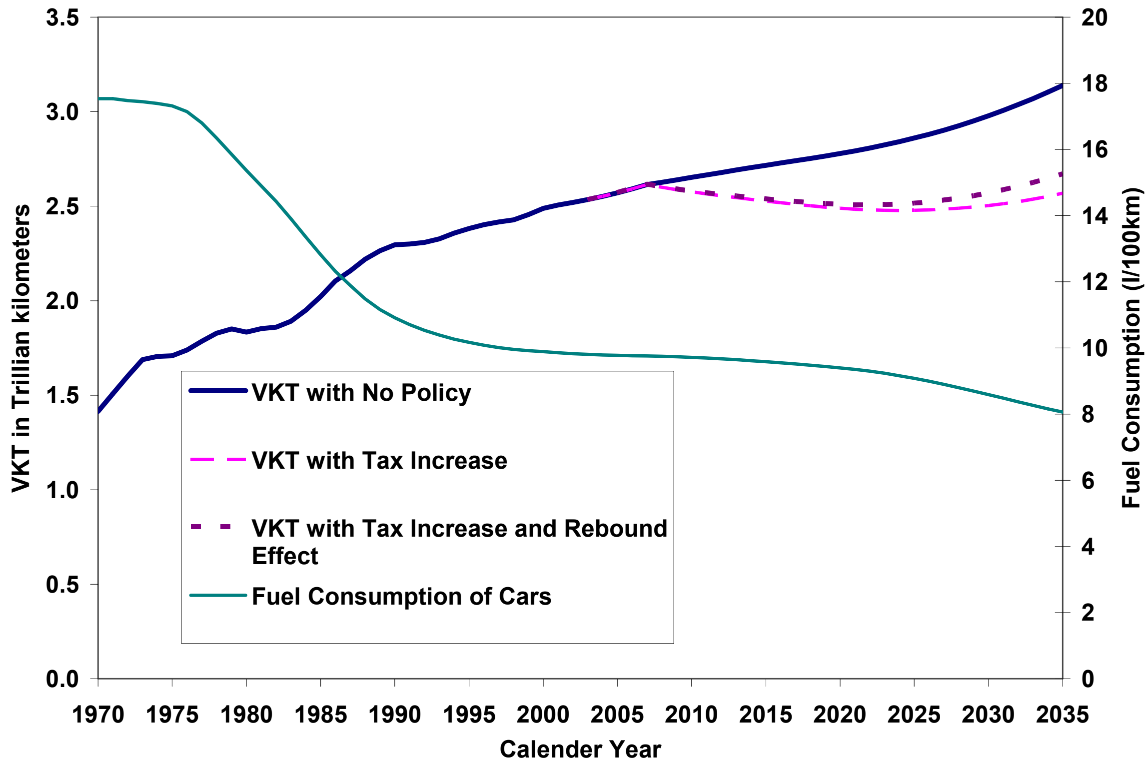


Figure 4.1 Average Fuel Consumption of New Cars and Total Car Travel (Scenario 1)

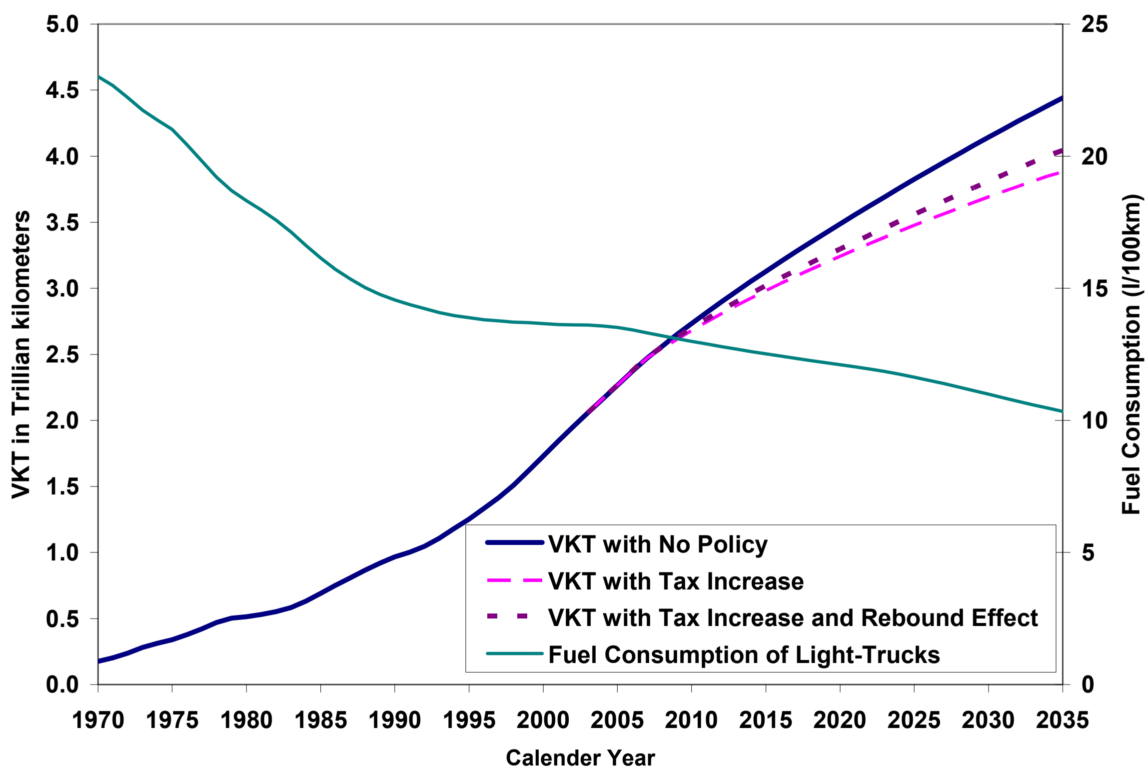


Figure 4.2 Average Fuel Consumption of New Light-Trucks and Total Light-Truck Travel (Scenario 1)

The fuel use under different policy scenarios is shown in Figures 4.3 and 4.4. Table 4.4 summarizes the results of different scenarios. Since the effect of fuel taxes on vehicle travel, and the increased ethanol content in gasoline affect entire fleet, changes in fuel use can be seen almost immediately.

Table 4.4 Light-Duty Fleet Fuel Use under different Policy Scenarios

Fuel Use (in Billion Liters per Year)*	Policy Scenarios							
	1	2	3	4	5	6	7	8
2010	596 (3.0)	595 (3.0)	593 (3.5)	593 (3.5)	580 (5.6)	579 (5.7)	577 (6.1)	576 (6.2)
2020	610 (13.8)	600 (15.2)	596 (15.7)	586 (17.1)	561 (20.7)	552 (22.0)	548 (22.5)	539 (23.7)
2035	583 (32.0)	508 (40.8)	552 (35.5)	481 (43.9)	515 (39.9)	449 (47.7)	488 (43.0)	425 (50.4)

* Numbers in brackets indicate percentage reduction in fuel use from no change

The table illustrates that potential exists to reduce the fuel use of light-duty vehicles by 13% to 23% by 2020 and by as much as 32% to 50% by 2035 relative to No Change Scenario. An integrated set of fiscal and regulatory measures designed to affect vehicle fuel consumption, vehicle travel and the non-petroleum content in fuels must be implemented in order to achieve these results.

Comparing scenarios 2 and 5, we can see that in the short term raising fuel prices may show significant effect on fuel use. In the long run, however, improvements in technology which reduce the fuel consumption of new vehicles penetrate into the entire vehicle fleet. Over a fifteen to twenty year period, this improvement in technology can deliver significant benefits. It should be noted that this is not a surprising or new conclusion [Wildhorn et al., 1976]. It does, however, reinforce the notion that both market based and regulatory instruments aimed at pulling and pushing more fuel efficient technology in to the market are needed.

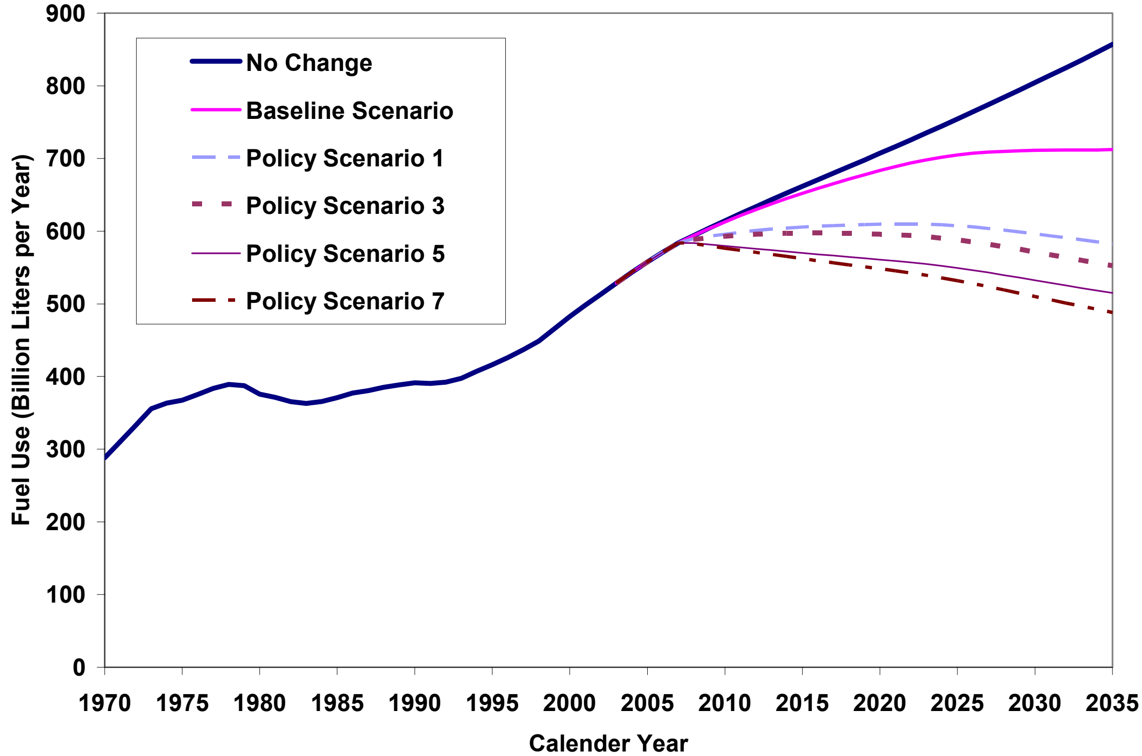


Figure 4.3 **Fuel Use for Policy based on Baseline Fuel Consumption Improvements**

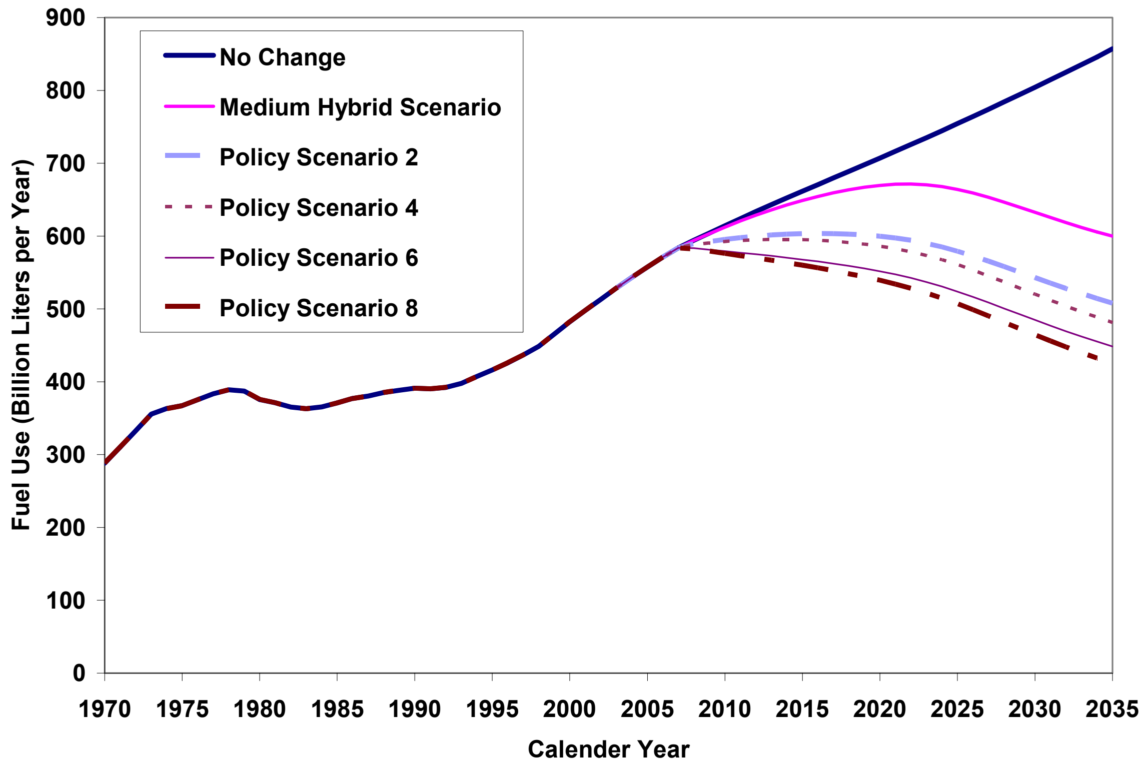


Figure 4.4 **Fuel Use for Policy based on Medium Hybrids Fuel Consumption Improvements**

4.3.3 Sensitivity Analysis

The effect of variation in elasticity of vehicle travel with respect to gasoline prices and amount of rebound effect is tested for scenario 1 as shown in Table 4.5 and Figure 4.5.

Table 4.5 Sensitivity to Vehicle Travel Elasticity and Rebound Effect for Scenario 1

Year	Fuel Use (in Billion liters per Year) Numbers in Brackets indicates million barrels per day			
	VKT Elasticity = -0.3 Rebound Effect = 20%	VKT Elasticity = -0.2 Rebound Effect = 20%	VKT Elasticity = -0.3 Rebound Effect = 15%	VKT Elasticity = -0.2 Rebound Effect = 15%
2010	596 (10.3)	602 (10.4)	595 (10.3)	601 (10.4)
2020	610 (10.5)	632 (10.9)	607 (10.5)	630 (10.9)
2035	583 (10.0)	623 (10.7)	576 (9.9)	616 (10.6)

As seen from the range of results, the rebound effect seems to have a small effect on total fuel use for the improvements in fuel economy considered here. However, the effect of gasoline tax is quite sensitive to the elasticity of vehicle travel. The difference between fuel use for elasticity of travel equal to -0.2 and -0.3 is of the order of 5%.

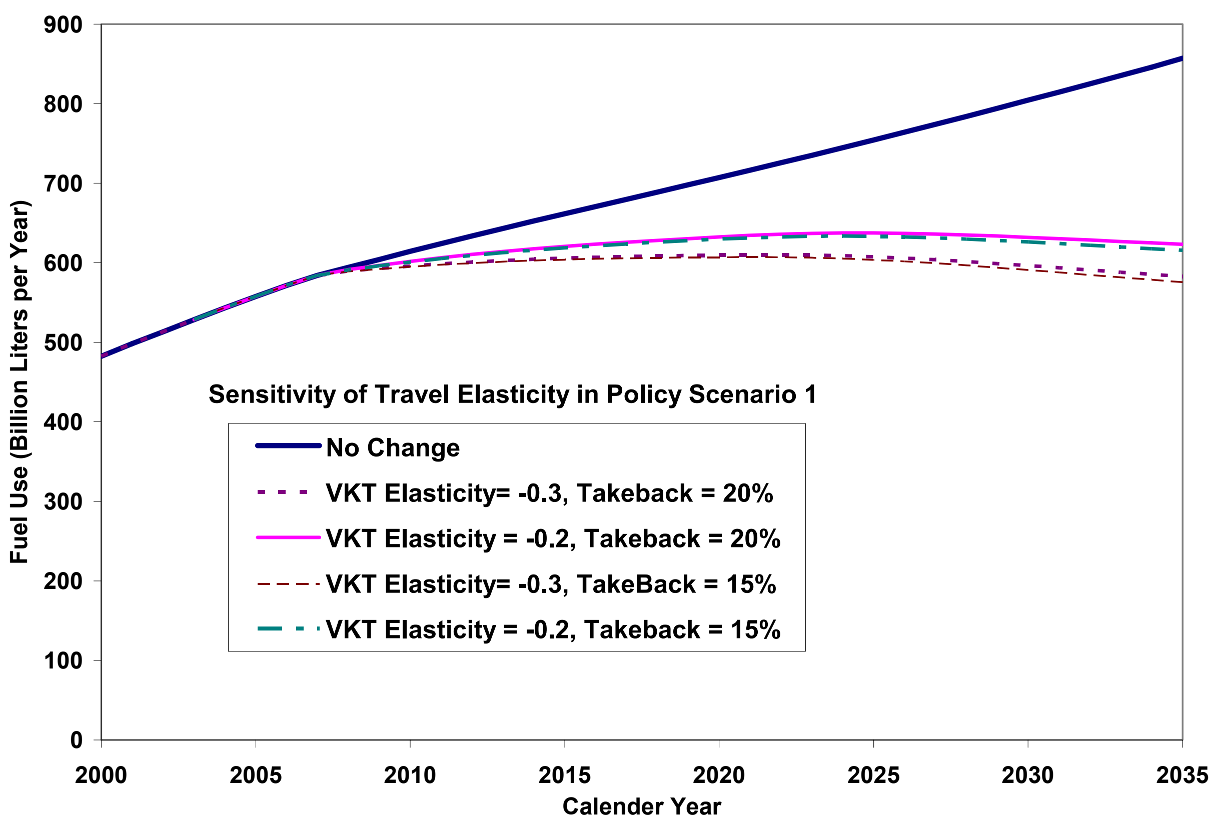


Figure 4.5 Sensitivity to Vehicle Travel Elasticity and Rebound Effect for Scenario 1

4.4 Challenges

As noted by Fulton [2001], a comprehensive policy package may be able to combine the best elements of policies aimed at different aspects of greenhouse gas emissions from motor vehicles. At the same time, it may be difficult to implement such a policy package. This is true because progress on transport related policy is usually made one step at a time, and it may not be possible to consider legislatively all the different aspects of a policy package together. Further, the authority to deal with different aspects of fiscal and regulatory aspects of transport lies with different institutions, and overcoming institutional obstacles could be a more difficult task than formulating the policy package. Nevertheless, if different aspects of policy are not considered, then it may be difficult to generate commitments from different stakeholders.

Attempts to develop a comprehensive policy may also turn in to a rather ambitious effort to influence every single aspect of motor transport. For example, in OECD's brainstorming activities on policies to achieve environmentally sustainable transportation, anywhere from 14 to 88 different policy instruments were suggested by different country groups [OECD, 2002]. Therefore attention may be focused on a small number of policy options, which nevertheless affect all the different aspects of vehicle fuel use. Also, many different small or large coalitions may come together to oppose a comprehensive policy package. It is necessary, therefore, to develop transparent policy measures. Thus, the role of public education and feedback in bringing about the necessary participation must not be neglected.

It is also possible that different policy options may indeed affect different automotive manufacturers differently, and there indeed may be some wealth transfer between different vehicle manufacturers. Fuel economy standards or feebates can be designed to minimize such competitive impacts [McNutt and Peterson, 1986; Davis et al., 1995].

Certainly, developing and implementing a combination of policy options to reduce fuel consumption of light-duty vehicles is a challenging proposition. While, this indeed is a daunting task, as noted by Johnson in the context of the future of automobile in urban environment [1992]:

> Surely, we cannot accept the notion that the only feasible approach is one that fails to get at the heart of our problems. Surely, we must continue to search for solutions that are both feasible and effective.

Chapter 5: Conclusions

5.1 Summary

The use of automobiles is pervasive in personal transportation system in the U.S. Steadily rising fuel consumption and the resulting greenhouse gas emissions from U.S. light-duty vehicles have several economic and environmental impacts. If left unchecked, fuel consumption of U.S. light-duty vehicle fleet will rise to about 860 billion liters per year (~15 million barrels per day) in year 2035 as compared to the current use of 540 billion liters per year (~9 million barrels per day). To reduce fuel consumption, significant advances in engine and vehicle technology will become available over the next two decades. If half of the total potential of engine and vehicle technologies being developed is used to reduce fuel consumption, it will be possible to have 17% to 25% reduction in annual U.S. light-duty vehicle fuel use by year 2035. In reality, the market demand for such technologies is low. Technologies that can reduce CO_2 emissions (something for which consumers are reluctant to pay) could be and have been used to improve vehicle performance (something for which consumers may be willing to pay).

There exists no single silver bullet for reducing the fuel consumption of motor vehicles in the U.S. However, there are several different policy measures available to affect the production and purchase of more fuel efficient vehicles as well as reduce the amount of driving and greenhouse gas intensity of fuel use. A reinforcing combination of different policies can increase the overall effectiveness of an integrated strategy. Such an approach aims at exploiting synergies between different measures, remove perverse incentives, and increase political acceptability of the overall strategy by spreading the impact and responsibility. A coordinated set of policy actions might result in overall fuel consumption reduction of the order of 32% to 50% when compared to the No Change scenario by year 2035.

5.2 Conclusions

The following conclusions can be drawn from this work:

- Fuel use and greenhouse gas emission reductions from U.S. light-duty vehicles cannot be achieved in practice by regulations alone. Neither will the current market forces bring about the necessary technological change needed to reduce fuel consumption.
- To reduce fuel use, U.S. light-duty vehicle policy will have to integrate fiscal and regulatory measures. A carefully designed policy package can both pull and push more fuel efficient technology into the market, as well as moderate growth in vehicle travel. An example policy proposal may wish to coordinate a steady increase in CAFE standards with a moderate but steady rise in gasoline taxes, as well as economic incentives for purchasing more fuel efficient vehicles and increased renewable content in fuels.
- The technological change needed to bring about greenhouse gas emissions reductions can come through incremental improvements in mainstream internal combustion engine, transmission and key vehicle technologies, as well as via battery/electric motor Internal Combustion engine technologies such as hybrids.
- Bio-fuels such as cellulosic ethanol have the potential to displace five to ten percent of fuel use, but will require some cost support. If implemented appropriately, this could result in three to seven percent reduction in greenhouse gas emissions from light-duty vehicles.
- Postponing action on fuel use not only shifts the problem temporally, but also requires us to deal with higher levels of fuel use than if actions were taken immediately. Since the time delays involved in vehicle fleet turnover are large, urgent action is needed to address the challenge posed by steadily increasing fuel use and greenhouse gas emissions from U.S. light-duty vehicles.

Fuel consumption of vehicles is not a strictly technical phenomenon, but is deeply intertwined with the need, use and culture of the automobile. The quest for equitable, affordable, and environmentally responsible transportation has many more research challenges in addition to this one.

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