

CHAPTER 4

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

Anup P. Bandivadekar and John B. Heywood

The transportation sector is the biggest contributor to the emissions of carbon dioxide (CO₂) in the United States. Emissions of CO₂ from transport have grown by about 18 percent during the period from 1990 to 2002 (U.S. Department of Energy [DOE], 2004).

Increasing emissions of CO₂ from transportation present a big challenge from a climate change perspective. There exists no silver bullet for reducing petroleum fuel use of motor vehicles in the United States. There are, however, several 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 analyses of individual policy options reveal the potential for a combination of such policies.

An integrated set of fiscal and regulatory strategies in the United States is essential to reduce petroleum consumption in transportation and transitions from the current greenhouse gas (GHG) emissions growth path to one that decreases risks from global climate change. This chapter elucidates policy options available to reduce the petroleum fuel use of the U.S. light-duty vehicle (LDV) fleet over the next three decades. More specifically, it identifies viable technology and policy options for making progress.

A policy package is proposed that combines market-based and regulatory measures to both pull and push advanced vehicle technologies into market, as well as reduce the carbon intensity of vehicle and fuel use. Such

an approach aims at exploiting synergies between different measures, removing perverse incentives, and increasing 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 new 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 use and GHG emissions of U.S. LDVs by 28 to 40 percent in 30 years from a no change, or status quo, scenario.

Light-Duty Vehicle Greenhouse Gas Emissions

Greenhouse gas emissions from motor vehicle use can be approximately estimated by Equation 4.1:

$$\text{GHG emissions} = \text{LPK} * \text{VKT} * \text{FI} \quad (4.1)$$

Where:

GHG emissions = Greenhouse gas emissions (tons/year)

LPK = Liters of fuel consumed per kilometer per vehicle, generally reported as liters per 100 kilometers (L/100km). One liter per 100km is equivalent to 235 miles per gallon (mpg).

VKT = Fleet vehicle kilometers traveled per year (km/year)

FI = GHG intensity of fuel (GHG tons/liters of fuel)

Thus, GHG emissions from motor vehicles can be attributed to the amount of driving (VKT), fuel consumption (LPK), and the GHG intensity of the fuel (FI). The largest reductions in GHG emissions are achieved if all three of the factors are 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 percent less fuel consuming than gasoline vehicles. As a result, diesel powered vehicles have significantly fewer GHG emissions relative to equivalent gasoline powered vehicles.

Vehicle fuel consumption of new vehicles, as measured in liters of fuel consumed per kilometer traveled, was reduced considerably in the 1970s and early 1980s due to the oil shocks of 1973 and 1979 and subsequent federal fuel economy standards. Since the early 1990s, however, fuel consumption has stagnated around 10L/100 km (23.5 mpg) for new cars and 13.7 L/100km (17.2 mpg) for new light trucks when adjusted for on-road performance (Heywood et al., 2004). The sales weighted fuel consumption of new vehicles has been lower during this period than in the 1980s as a result of the increasing number of light trucks in the new vehicle mix. Overall, the average on-road vehicle fuel consumption for the light-duty vehicle fleet

has remained roughly steady at 11.5 L/100 km (20.5 mpg) during the last decade.

The lack of any significant reduction in vehicle fuel consumption during the last 20 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, such as increased amenities, vehicle power, size, and weight, rather than to improve fuel consumption performance (Plotkin, 2000). The Environmental Protection Agency (EPA) has completed an analysis of vehicle characteristics over the period from 1981 to 2003 that indicates the new 2003 LDV fleet could have achieved about 33 percent higher fuel economy if it had the same average performance and same distribution of weight as in 1981 (Hellman and Heavenrich, 2003).

The amount of vehicle kilometers traveled has more than doubled in the past 30 years (Davis and Diegel, 2003). This growth has been steady except for the years 1973, 1979, 1980, and 1990. The tremendous growth in VKT can be attributed to the following factors:

- *Increased number of vehicles:* The number of vehicles in the U.S. LDV 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 accounts for more than half of all sales as compared to about 15 percent 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 LDV fleet.
- *Increased driving per year:* The average distance traveled per vehicle per year increased considerably from 1976 to 2001. This increased driving can be attributed to rising level of affluence, continuing urban sprawl, and the low costs of driving, among other factors.
- *Low cost of fuel:* The average fuel consumption of cars and trucks decreased from 1976 to 2001. When combined with flat costs of gasoline per km driven over this period (inflation adjusted), the net effect is a sharp drop in costs of travel per kilometer. The hypothesis that this has resulted in increased driving is known as the “takeback” or “rebound” effect. The rebound effect is estimated to be on the order of 20 percent (Greene et al., 1999; Greening et al., 2000).

The greenhouse gas intensity of fuel used in the LDV fleet has essentially not changed, since most vehicles run on gasoline. In the late 1970s, sales of new diesel cars increased rapidly to about 6 percent but fell in the early 1980s. The fraction of diesel vehicles in the new light truck sales has fluctuated around 3 to 6 percent in the past two decades. Apart from this, use of other fuels in LDVs is about 1 percent. Despite strong goals and incentives offered by Congress, alternative fuel vehicles have not succeeded (McNutt and Rodgers, 2004).

Considerable uncertainty exists about how technology will evolve over the next 20 to 30 years. While various studies differ in their estimates of the exact magnitude of fuel consumption reductions possible and the costs of doing so, the following conclusions can be drawn from these technology and cost assessments (Weiss et al., 2000; GM/ANL, 2001; An et al., 2001; NESCCAF, 2004):

- Mainstream gasoline internal combustion engines (ICEs) and vehicle technologies have significant potential to reduce energy consumption and GHG emissions. These technologies can improve at a rate of 1 to 2 percent annually over the next 20 years, which translates to up to 35 percent reduction in energy use at constant performance, size, and weight, at an additional cost of \$500 to \$1,500 per vehicle.
- Diesel vehicles are likely to be about 20 percent more efficient than gasoline vehicles in about two decades, but the difficulties in meeting stringent U.S. nitrogen oxide emissions standards, higher cost, and consumer perception are significant obstacles to their large scale adoption.
- Hybrid electric vehicles (HEVs), with batteries, electric motors, and ICEs, can provide an additional 30 percent benefit in energy reduction at an additional cost of \$2,000 to \$3,000 compared to the cost of conventional ICE vehicles.
- Fuel cell technology is currently very costly and probably a few decades away in terms of making a substantial contribution to GHG emissions reductions. However, in the longer term—roughly 30 to 50 years—fuel cells could make a difference if the hydrogen used in fuel cells is made from carbon neutral energy generation technologies such as renewable resources, nuclear power, or fossil fuels with carbon sequestration.

It is not clear if the current price of fuels in the U.S. market, even at levels above \$2.00 per gallon of gasoline, can justify the development of new 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.

Projections of LDV Fuel Use and GHG Emissions

The potential effects of new technologies on LDV fuel use can be evaluated based on a vehicle fleet simulation model developed by Bassene (Bassene, 2001; Heywood et al., 2004). The model examines car and light truck fleets based on vehicle sales, retirement, average fuel consumption, and miles driven per year. It allows the exploration of the sensitivity of fleet fuel use to growth in driving, vehicle ownership, and the share of light trucks in the fleet.

Different scenarios project the fuel use of LDVs under different market and policy conditions. Examining these scenarios allows us to understand

the magnitude of technological and policy efforts that may be required to reduce fuel use of the LDV fleets to the levels achieved in 1990. Since most vehicle designs and production plans along with the Corporate Average Fuel Economy (CAFE) standard levels have been fixed until year 2007, the model scenarios begin in year 2008.

Description of Scenarios

There are four scenarios used in our analysis: no change, baseline, HEV, and composite. In the no change scenario, the new on-road car and light-duty truck fuel consumption remain at the levels projected for 2008 until 2035. These levels are 9.7L/100km for cars and 12.4L/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 used to achieve better vehicle performance or compensate for additional vehicle weight resulting from new vehicle amenities and size. This has been the trend in the LDVs for at least the past 20 years. The no change scenario assumes that this trend will continue until 2035.

New vehicle sales are assumed to grow at a rate of 0.8 percent per year in the no change scenario, corresponding to the rate of growth of population. Average vehicle travel is assumed to grow at a rate of 0.5 percent 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 new LDV sales is assumed to level off at 60 percent by year 2025.

In the baseline scenario, it is assumed that there is a modest, but steady increase in gasoline price, fuel economy standards, and competitive pressures that result in improved fuel economy. Fuel consumption of an average new gasoline ICE vehicle could decrease by about 35 percent in 20 years and 50 percent in 30 years, if vehicle performance characteristics are kept constant. This assumption is consistent with the results of recent MIT technology assessments (Weiss et al., 2000; Weiss et al., 2003). In the baseline scenario, it is assumed that only 50 percent of these efficiency improvements translate into reduction in fuel consumption. Thus, individual vehicle fuel consumption decreases by about 17.5 percent in 20 years and about 23.5 percent in 25 years.

The HEV scenario assumes ambitious fuel economy standards, coupled with economic incentives to push and pull advanced vehicle technologies—such as light-weighting, better aerodynamic designs, and hybridizing ICE vehicles assumed in baseline scenario—into the marketplace. Under this scenario, the simulation assumes that the fuel consumption of HEVs is 61.5 percent of the baseline gasoline ICE fuel consumption as shown in Figure 4-1. Two market penetration rates were examined for HEV sales as a fraction of all new vehicle sales to illustrate the impact of market penetration rates. These rates were assumed to be rising from about 1 percent in 2005 to 15 percent and 50 percent in 2035, under the low and high

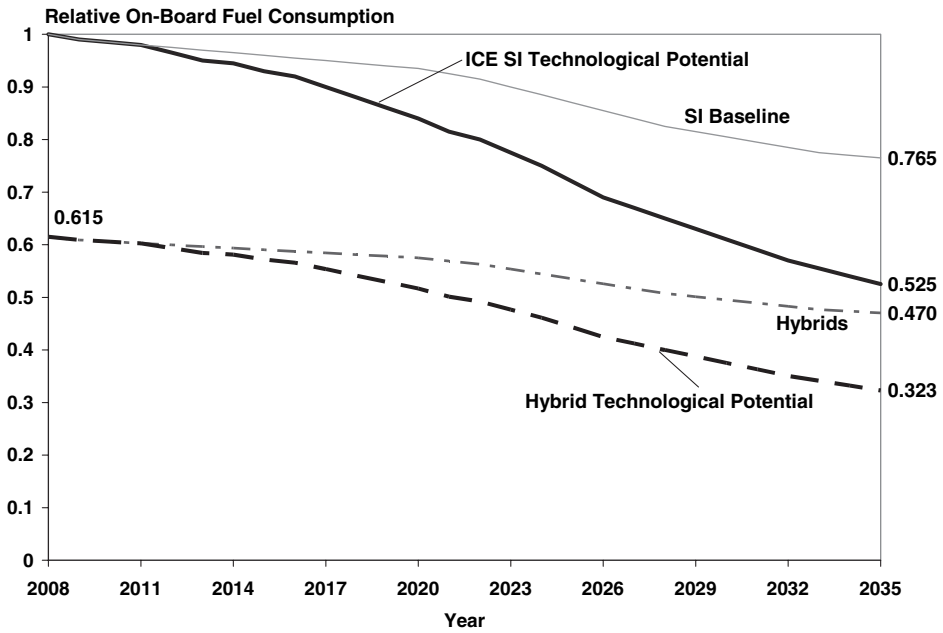


FIGURE 4-1. Relative improvements in fuel consumption for baseline scenarios.

assumptions, respectively. The high market penetration rate illustrates the upper bound in terms of reducing fuel use due to improvements in vehicle technology alone.

Under the composite scenario, it is assumed that in addition to all the factors present in the HEV scenario under the 50 percent penetration in the 2035 case, average per vehicle travel will stop growing beyond year 2008 and the rate of growth in sales of LDVs is halved to 0.4 percent.

Fuel Consumption under Different Scenarios

The projections of total fuel use under the no change, baseline, HEV, and composite scenarios are shown in Figure 4-2. The average fuel consumption of LDVs is shown in Figure 4-3. Under the no change scenario, the fuel consumption of the entire LDV fleet is projected to grow to 685 billion liters per year by 2020 and to 827 billion liters per year by 2035, or 11.8 and 14.2 million barrels per day, respectively.

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 688 billion liters per year, or 11.8 million barrels per day. In the HEV scenario, the impact of 15 percent market penetration of HEVs is found to be small relative to the baseline improvements in ICE

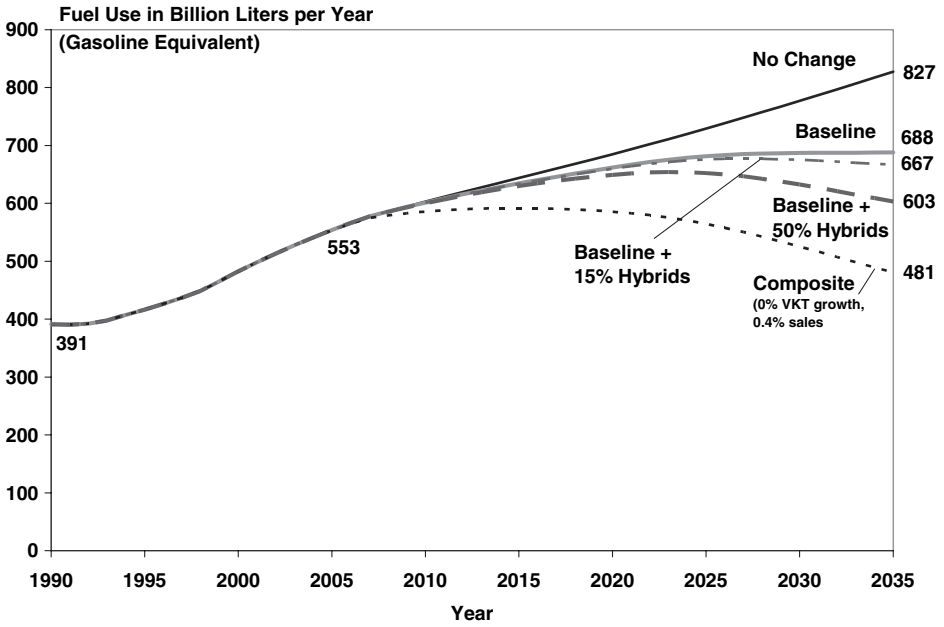


FIGURE 4-2. LDV fuel use for various scenarios.

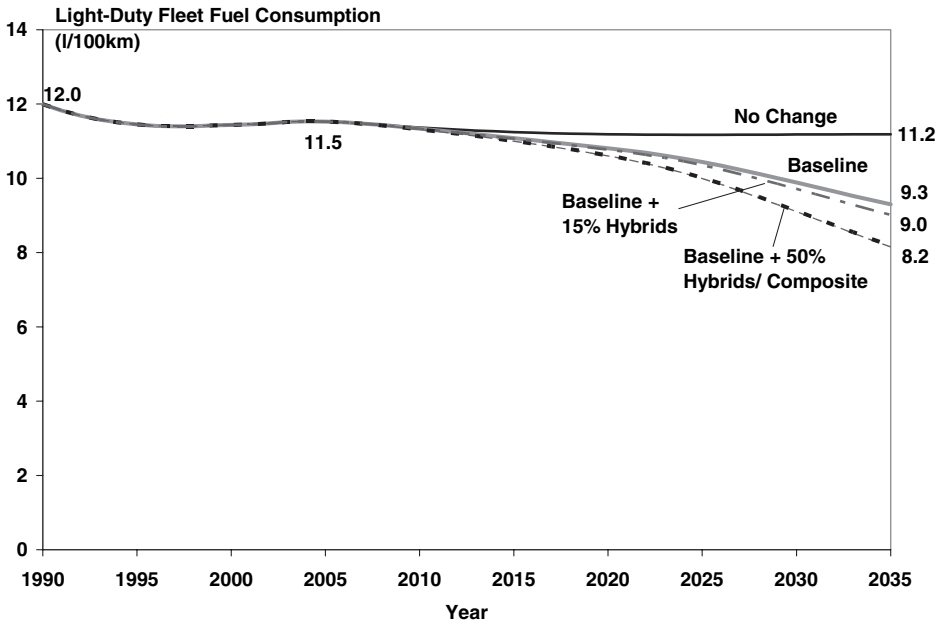


FIGURE 4-3. Light-duty vehicle fuel consumption for various scenarios.

TABLE 4-1. LDV Fuel Use under Different Scenarios

Year	No Change		Baseline		Baseline + 15% Hybrids		Baseline + 50% Hybrids		Composite	
	Billion Liters per Year	MBD*	Billion Liters per Year	MBD	Billion Liters per Year	MBD	Billion Liters per Year	MBD	Billion Liters per Year	MBD
2005	554	9.5	554	9.5	554	9.5	554	9.5	554	9.5
2020	685	11.8	662	11.4	660	11.4	649	11.2	586	10.1
2035	827	14.2	688	11.8	667	11.5	603	10.4	481	8.3

* MBD: Million barrels per day.

technology alone. In the case of high penetration of HEVs into the LDV fleet, the total fuel use peaks at about 654 billion liters per year in year 2024 and then declines to about 603 billion liters per year by 2035. The average on-road fuel consumption of the fleet improves from 11.5L/100km, or 20.4 mpg, in 2005 to 8.2L/100km, or 28.8 mpg in 2035. This shows that rapid deployment of advanced vehicle technologies has significant potential to reduce fuel consumption in the next 30 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 slowdown of growth in vehicle kilometers traveled from 7.4 trillion kilometers per year in the baseline scenario to about 5.9 trillion kilometers per year in the composite scenario by year 2035. The total fuel use in this scenario peaks at 592 billion liters per year in 2015 and decreases to 481 billion liters per year in 2035, which would be the same as the fuel use of LDVs in year 2000. Yet, this is still much higher fuel use than the 391 billion liters consumed in 1990.

These simulations show that improvements in vehicle technology and fuel consumption can play a key role in reducing the growth in LDV fuel use over the next 30 years. However, it will also take slowing down the growth in vehicle travel to achieve actual reductions in fuel use. Table 4-1 summarizes the results of these scenarios in more detail.

Effect of Delay

Delayed action scenarios were used to examine the consequences of postponing action by five or ten years on overall fleet fuel use and greenhouse gas emissions. These scenarios thus indicate the additional effort that would then be required to contain vehicle fuel use in the future as opposed to taking action immediately. These scenarios were evaluated for the HEV case as shown in Figure 4-4. As shown in the figure, the peak fuel use under the

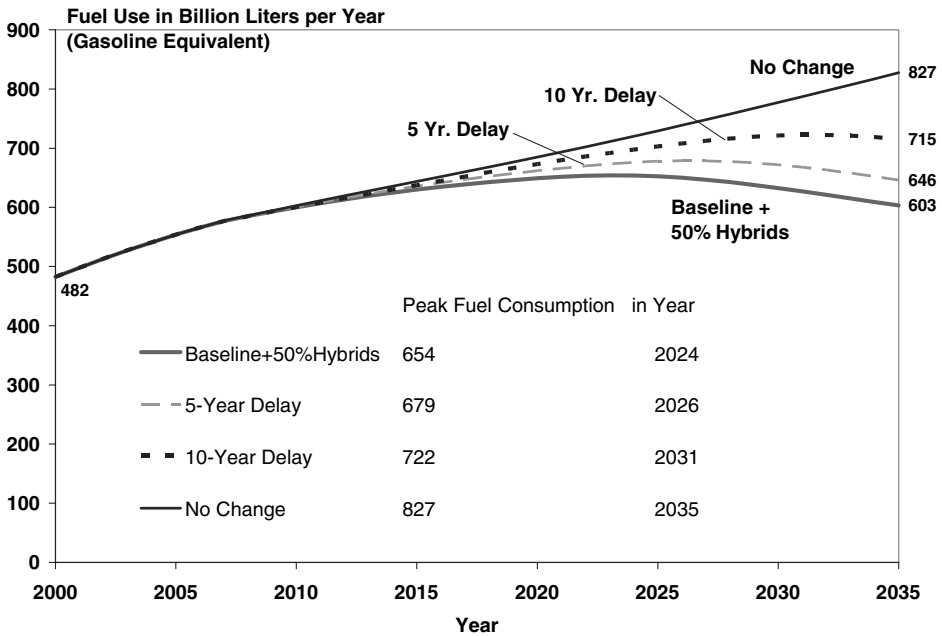


FIGURE 4-4. Effect of delay in action on light-duty vehicle fuel use (2000–2035).

50 percent HEV scenario is 654 billion liters in 2024. If action is delayed by five years, the peak in fuel use increases to 679 billion liters in 2026, whereas if action is delayed by ten years, the peak in fuel use increases to 722 billion liters in 2031.

It is clear that delayed action results not only in shifting the problem out in time, but also makes it more difficult to address. On the other hand, even small changes made sooner could result in larger benefits than more aggressive actions taken later. This also indicates that even if inherently low CO₂ emitting or nonpetroleum-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.

Policy Measures to Reduce GHG Emissions

Increasing U.S. dependence on foreign oil and concerns about GHG emissions from motor vehicles are two important reasons for government intervention in the fuel use market. The DOE 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 (DOE, 2000). Different policy

TABLE 4-2. Policy Measures to Reduce Fuel Consumption of LDVs

<i>Policy Measures</i>	<i>Type of Policy</i>			<i>Anticipated Response/Action</i>
	<i>E</i>	<i>R</i>	<i>I</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 (Economywide)	•			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).

measures 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 (R), 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 toward less-carbon-intensive fuels. Policy options selected for review are summarized in Table 4-2. A

more detailed description of individual policies can be found in Bandivadekar and Heywood (2004).

Several other policy alternatives are available at the state or local level, such as increased investments in public transportation and transportation demand management (TDM) tools, including 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 the energy consumption of LDVs.

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 the following:

- *Vehicle performance:* It is expected that broadly popular vehicle performance measures such as acceleration, functional capacity, or the deployment of accessories and amenities will improve or at least remain constant in the pursuit of a more fuel-efficient fleet.
- *Safety implications:* It is generally accepted that if weight reductions occurred in the heaviest of LDVs, then overall safety should improve.
- *Mobility implications:* Implementation of certain strategies may change the purchasing, ownership, and usage patterns of LDVs. Consumers' 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 on whether such a policy can be implemented successfully in practice. Generally, policy measures which give different stakeholders more flexibility for action should prove politically more acceptable.

Different policy options under consideration are evaluated across these different criteria in Tables 4-3 and 4-4. Quantitative estimates are provided wherever possible.

Careful observation of Tables 4-3 and 4-4 reveals that there are synergies between different policy measures. 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. Also, an increase in fuel price at the pump makes it attractive for the automobile manufacturers to reduce fuel consumption in their vehicles, thus lowering the risks and costs associated with meeting CAFE standards. While the feebates and

TABLE 4-3. Effectiveness of Policy Alternative to Reduce Fuel Consumption of the U.S. LDVs

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 on 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
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/BioDiesel	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 possible	Increase in lifecycle emissions likely, 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
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 CO2 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 on 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

TABLE 4-3. Effectiveness of Policy Alternative to Reduce Fuel Consumption of the U.S. LDVs—cont'd

<i>Policy Measures</i>	<i>Dimensions for Assessing Alternatives</i>							
	<i>Cost/Cost Effectiveness (market or full societal benefits and costs!)</i>	<i>Scale of Applicability</i>	<i>Effectiveness in Addressing Energy Issues</i>		<i>Effectiveness in Addressing Other Transportation Issues</i>			
			<i>Oil Use Reduction</i>	<i>Greenhouse Gas Reduction</i>	<i>Emissions Reduction</i>	<i>Congestion Reduction</i>	<i>Effect on Vehicle Safety</i>	<i>Effect on Vehicle Miles Traveled (VMT)</i>
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 billion 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 4-4. Considerations for Implementation of Individual Policy Options to Reduce GHGs

<i>Policy Measures</i>	<i>Considerations for Implementation</i>							
	<i>Rate of Implementation</i>	<i>Scale of Implementation</i>	<i>Flexibility</i>	<i>Political Acceptability</i>	<i>Level of Co-operation Needed Between Agencies</i>	<i>Technological Change</i>	<i>Degree of Lifestyle Change Required</i>	<i>Other Factors</i>
CAFE	Standards must give manufacturers sufficient time to respond. Widespread penetration of new technologies requires 10–15 years.	Standards need to be 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 change.	Small or uncertain. MAY require shifting towards lighter/"less bigger" vehicles.	—
Fuel Tax	Immediate impact on implementation, but 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 decreasing the incentive to drive more	Political acceptability is currently poor	Minimal. A fuel tax collection system is already in place	Diminished pressure for technological advances. Encourages change in behavior.	Change driving habits. Evaluate other modes of transport.	—

TABLE 4-4. Considerations for Implementation of Individual Policy Options to Reduce GHGs—cont'd

<i>Policy Measures</i>	<i>Considerations for Implementation</i>							
	<i>Rate of Implementation</i>	<i>Scale of Implementation</i>	<i>Flexibility</i>	<i>Political Acceptability</i>	<i>Level of Co-operation Needed Between Agencies</i>	<i>Technological Change</i>	<i>Degree of Lifestyle Change Required</i>	<i>Other Factors</i>
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. However, 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. "Biodiversity" 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.
PATP	Immediate impact upon implementation, but implementation needs to be gradual	Implementation will vary from state to state	PATP charges could be based on insurance, inspection/maintenance, 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/maintenance, 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 increase in new vehicle sales
Rd&D	Long-term precompetitive 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 Partnership 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?

CAFE standards apply only to new vehicles, fuel taxes and alternative fuel use requirements have fleetwide 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 high fuel consumption will not only discourage 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 liquid fuels may currently be higher than gasoline, 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.

Rationales for Combinations of Policy Measures

Clearly, there is no single agreed upon policy measure that would significantly reduce the fuel use of LDVs, and differences over policy measures are likely to persist (McNutt et al., 1998). Our assessment is that the vehicle fuel use problem can best be addressed by a carefully selected combination of policy measures that shares the responsibility among all stakeholders. There is a twofold argument for combining policy measures to reduce fuel consumption of LDVs. The first is that increasing vehicle fuel consumption is a market failure that necessarily requires regulatory and fiscal responses. The second is that without such an integrated approach, a policy proposal may not have the necessary broadbased support to move forward. Both of these arguments are explored in the next two sections.

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 manufacturers.

More than two decades ago, the National Research Council's Committee on Nuclear and Alternative Energy Systems (CONAES) noted the following (NRC, 1980):

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.

The cost of fuel use is small, although not negligible, when 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. Thus, the amount of fuel savings may be an insufficiently attractive proposition for the consumers to demand less-fuel-consuming vehicles. The 1980 NRC CONAES study said further, “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 signals are necessary, they may not be sufficient to induce 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. A National Research Council study on the effectiveness and impact of CAFE standards commented on this issue 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 more effective policy than not acting at all, a combination of an increase in gasoline tax and increased fuel economy standards would be a significantly more effective approach (Gerard and Lave, 2003).

Political Appeal of an Integrated Policy Approach

It is extremely difficult to measure the value of all the different externalities caused by fuel use. The escalating fuel use of LDVs presents a classic common problem. If the aim of policy were economic efficiency alone, then

TABLE 4-5. Types of Policies Based on Costs and Benefits of Policy

<i>Types of Regulatory Activity</i>		<i>Costs</i>	
		<i>Widely Distributed</i>	<i>Concentrated</i>
Benefits	Widely distributed	Majoritarian	Entrepreneurial
	Concentrated	Client	Interest-group

getting the prices right would help but might not completely solve the problem as explained 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 criticized as having 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 on the distribution of costs and benefits resulting from the implementation of the policy as shown in Table 4-5.

CAFE standards, for example, can be described as entrepreneurial because the costs of meeting the regulations fall largely on the automobile manufacturers. Although the monetary costs may ultimately be passed on to consumers, the risks involved in the process are borne solely by automobile manufacturers. The benefits, on the other hand, are seen by society in the form of reduced fuel use and GHG emissions. It should come as no surprise, therefore, that automobile manufacturers oppose the CAFE standards as the only means to reducing fuel use.

The stakeholders in this problem include vehicle purchasers and users, the automobile and petroleum industries, and governments at different levels. A policy package that attempts to spread the costs and benefits among different stakeholders is likely to have a broader political appeal and could be perceived as a more fair approach to fuel use regulation. Such a multidimensional policy approach seeks to generate positive commitment from all the stakeholders, without exposing any one set of stakeholder groups to a large risk.

Development of a Sample Policy Package

A conclusion endorsed by most participants at 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).

The previous section showed qualitatively that useful synergies exist between different policy measures. Agras and Chapman (1999) claim that using a combination of increased gasoline taxes and CAFE standards 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 assume that they are additive (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 proposal that combines several different policy measures is presented here, and its potential impact on vehicle fleet fuel use is described. While this represents one possible example of a policy package, various other synergistic combinations with different policy options could be used. The policy package example described below combines measures to reduce vehicle fuel consumption, slow the growth in vehicle travel, and increase the renewable content of the fuel.

Sample Policy Package

Vehicle manufacturers could be required to meet CAFE standards in the current or modified form as part of a policy package that aims at both pushing and pulling advanced vehicle technology and renewable fuels into the market. 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 increase in CAFE standards could be based on baseline or optimistic HEV scenarios as discussed previously. The fuel economy levels corresponding to these scenarios are shown in Table 4-6. These fuel economy levels assume that about half of the realizable improvement in advanced engine and vehicle technology would be utilized in improving the vehicle fuel consumption, as shown earlier in Figure 4-1.

TABLE 4-6. CAFE Standard Levels under Baseline and Optimistic Scenarios

Year	Baseline Scenario				Optimistic Scenario			
	Cars		Light Trucks		Cars		Light Trucks	
	Miles per Gallon	Liters per 100km	Miles per Gallon	Liters per 100km	Miles per Gallon	Liters per 100km	Miles per Gallon	Liters per 100km
2020	30.5	9.0	24.1	11.4	31.9	8.6	25.2	10.9
2030	35.4	7.8	28.0	9.8	41.5	6.6	32.8	8.4

A revenue neutral feebate 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 at the time of vehicle purchase could complement the CAFE program. A moderate fee or rebate rate of \$25,000 per gallon per mile driven is proposed. This is roughly equivalent to a fee/rebate range of +\$400 to -\$1,500 per vehicle.

Gasoline taxes could be increased by about \$0.10 per gallon every year, or roughly \$0.03 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 kilometers traveled without causing a financial burden to the vehicle users. Without such compensation, generating political support for this measure might prove difficult.

The renewable content in fuels could be increased by mandating an increasing amount of biomass-based liquid fuels blended in gasoline. This mandate may require a biomass-based liquid fuel blend in gasoline of 4.5 percent by 2025 and 7 percent by 2035 on a volumetric basis. In a more aggressive action, these requirements could be doubled to 9 percent by 2025 and 14 percent by 2035. These levels correspond to a 0.25 to 0.5 percent increase per year in the volume of biomass-based fuel blended in gasoline. Fuels with high renewable content could also receive preferential tax treatments with respect to gasoline or diesel, which should encourage fuel suppliers to make a shift toward renewable fuels. For calculations shown in this chapter, it is assumed that this requirement is fulfilled through cellulosic ethanol.

This analysis assumes that the policy package will be implemented starting in 2008 and continuing through 2035. The policies can be combined in different proportions, and the sensitivity of different combinations is evaluated through the four policy package scenarios shown in Table 4-7. Policy scenarios 1 and 3 are based on fuel consumption improvements as per the baseline, whereas policy scenarios 2 and 4 are based on fuel consumption improvements as per the optimistic HEV scenario.

TABLE 4-7. Policy Combinations Examined

Policy Measures	Policy Scenarios			
	1	2	3	4
CAFE Standards	Baseline	Optimistic	Baseline	Optimistic
Gasoline Tax Increase per Year	10¢ per gallon	10¢ per gallon	10¢ per gallon	10¢ per gallon
Cellulosic Ethanol Content Increase per Year	0.25%	0.25%	0.5%	0.5%

Calculation of Expected Impact

The anticipated impact of such an integrated policy package is estimated by the following multistep process. A 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 price of gasoline is assumed to remain at \$2.50 per gallon until 2007, when a \$0.10 per gallon per year increment in gasoline taxes is applied. The effect of fuel prices on the driving distances can be calculated as shown in Equation 4.2 (Hayashi et al., 2001).

$$D_{t+1} = \left[1 - E_{vmt_fuelp} \left(1 - \frac{P_{t+1}}{P_t} \right) \right] D_t \tag{4.2}$$

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

Past estimates of elasticity of vehicle travel with respect to fuel price have varied 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). The elasticity of vehicle travel with respect to fuel price is assumed here to be -0.2, which is a low-end estimate for the long-term effect and a high-end estimate of the short-term effect. Thus, a 10 percent increase in gasoline price decreases vehicle travel by 2 percent over a one-year period.

The effect of decreased fuel consumption on vehicle travel is estimated using a takeback factor of -0.2. This takeback is assumed to affect all vehicles and thus may overestimate the impact of the rebound effect. In quantitative terms, a 10 percent decrease in fuel consumption is assumed to cause an increase in vehicle travel of 2 percent over a period of one year.

Note 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 the CAFE standards. The feebates will then provide the necessary incentive for the consumers to purchase more fuel efficient vehicles and 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 in this analysis.

Increasing the proportion of cellulosic ethanol blended into gasoline is assumed to displace gasoline use. The amount of gasoline displaced as a result of blending ethanol can be calculated as shown in Equation 4-3.

$$V_{g,d} = \left(\frac{E_{\text{ethanol}} * p}{E_{\text{gasoline}} * (1 - p) + E_{\text{ethanol}} * p} \right) \quad (4.3)$$

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

Note that the energy content of ethanol is about two-thirds that of conventional gasoline. Therefore, a 10 percent by volume blend of cellulosic ethanol reduces the consumption of gasoline by about 6.8 percent.

Results

Figures 4-5 and 4-6 show the effect of policy combinations on LDV fleet fuel consumption and travel, respectively. The reduction in average fuel consumption of new cars and trucks in scenarios 1 and 3 is about 23.5 percent, and that in the overall fleet fuel consumption is over 16 percent. 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 the no change scenario is about 10 percent.

Fuel use under different policy scenarios is shown in Figures 4-7 and 4-8. Under policy combination 1, the total fuel use of LDVs peaks at 606 billion liters per year (10.4 million barrels per day) in 2023 and gradually reduces to 590 billion liters per year (10.1 million barrels per day) in 2035. This is still slightly higher than the current LDV fuel use of about 554 billion liters in 2005. Table 4-8 summarizes the results of the different

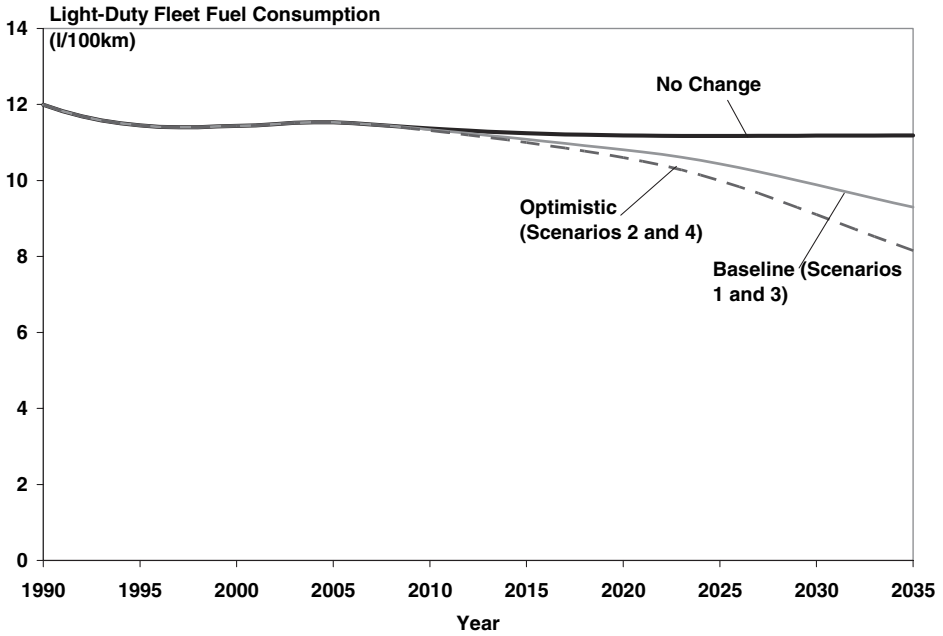


FIGURE 4-5. Average fuel consumption of light-duty vehicle fleet (1990–2035).

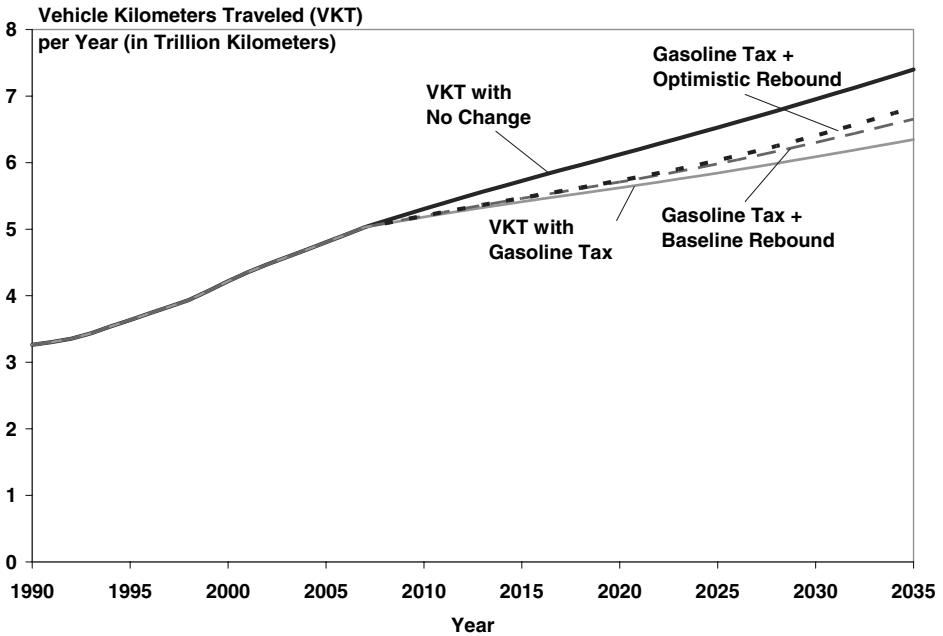


FIGURE 4-6. Total light-duty fleet travel (1990–2035).

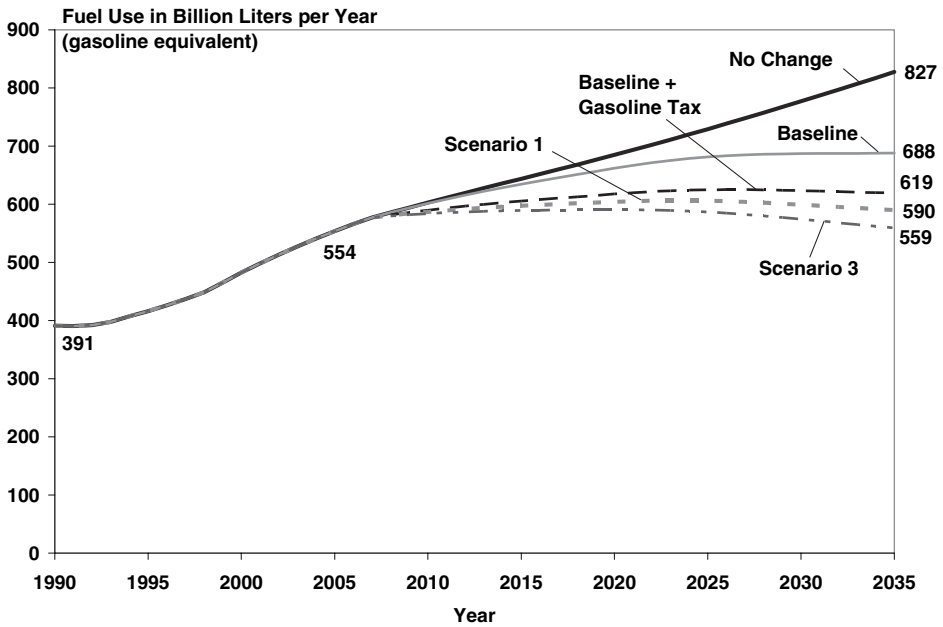


FIGURE 4-7. Fuel use for policy based on baseline fuel consumption improvements.

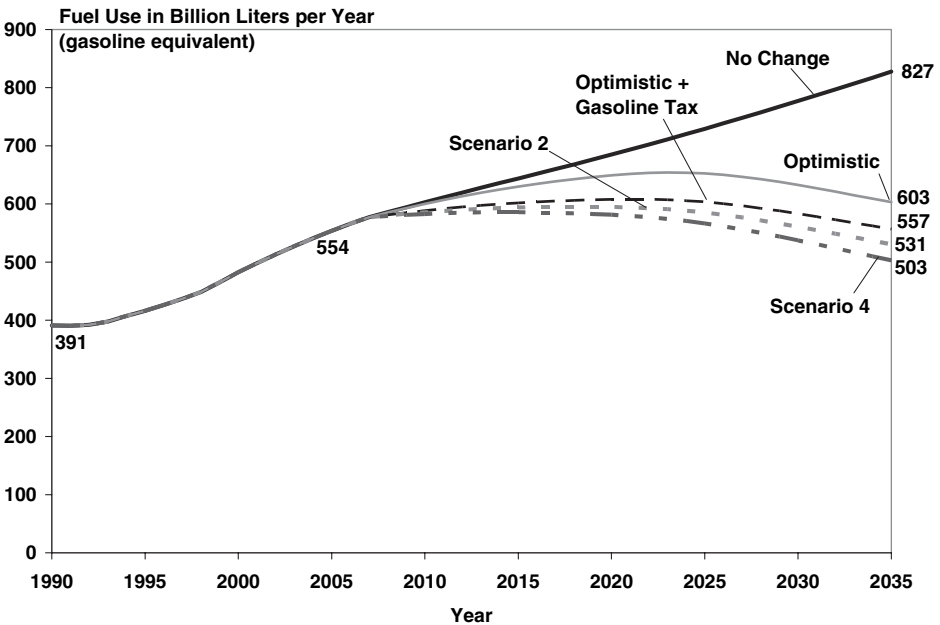


FIGURE 4-8. Fuel use for policy based on optimistic fuel consumption improvements.

TABLE 4-8. LDV Fleet Fuel Use under Different Policy Scenarios

Fuel Use (in Billion Liters per Year)*	No Change Scenario	Policy Scenarios			
		1	2	3	4
2010	603	587 (2.7)	586 (2.9)	584 (3.1)	583 (3.3)
2020	685	604 (11.8)	595 (13.1)	591 (13.8)	581 (15.1)
2035	827	590 (28.7)	531 (35.9)	560 (32.4)	503 (39.2)

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

scenarios. Since fuel taxes on vehicle travel and the increased ethanol content in gasoline affect the entire fleet, changes in fuel use can be seen almost immediately.

Table 4-8 illustrates that the potential exists to reduce the fuel use of LDVs by 12 to 15 percent by 2020 and by as much as 28 to 40 percent by 2035 relative to the no change scenario. However, an integrated set of fiscal and regulatory measures designed to affect vehicle fuel consumption, vehicle travel, and the nonpetroleum content in fuels would need to be implemented soon in order to achieve these results.

The analysis shows that raising fuel prices in the short term may well achieve significant reductions in fuel use. In the long run, however, it will be necessary that the improvements in vehicle technology which reduce the fuel consumption of new vehicles penetrate into the entire vehicle fleet. Over a 15- to 25-year period, this improvement in technology can deliver significant benefits. It should be noted that this is neither a surprising nor a 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 into the market are needed.

Sensitivity Analysis

The effect of variations in elasticity of vehicle travel with respect to gasoline prices and amount of rebound effect were tested for scenario 1 as shown in Table 4-9 and Figure 4-9.

As seen from the range of results, the rebound effect has a small impact on total fuel use for the improvements in fuel economy considered here. However, the impact of the gasoline tax increase 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 7 percent.

Challenges in Implementing a Coordinated Policy Package

As noted by Fulton (2001), a comprehensive policy package may be able to combine the best elements of policies aimed at different drivers of GHG emissions from motor vehicles. At the same time, it may be difficult to

TABLE 4-9. Sensitivity to Vehicle Travel Elasticity and Rebound Effect for Scenario 1

Year	Fuel Use (in billion liters per year) (Numbers in brackets indicate million barrels per day)			
	VKT Elasticity = -0.2 Rebound Effect = 20%	VKT Elasticity = -0.3 Rebound Effect = 20%	VKT Elasticity = -0.2 Rebound Effect = 10%	VKT Elasticity = -0.3 Rebound Effect = 10%
2010	587 (10.1)	580 (9.9)	586 (10.1)	579 (9.9)
2020	604 (10.4)	579 (9.9)	599 (10.3)	574 (9.8)
2035	590 (10.1)	546 (9.4)	576 (9.9)	533 (9.1)

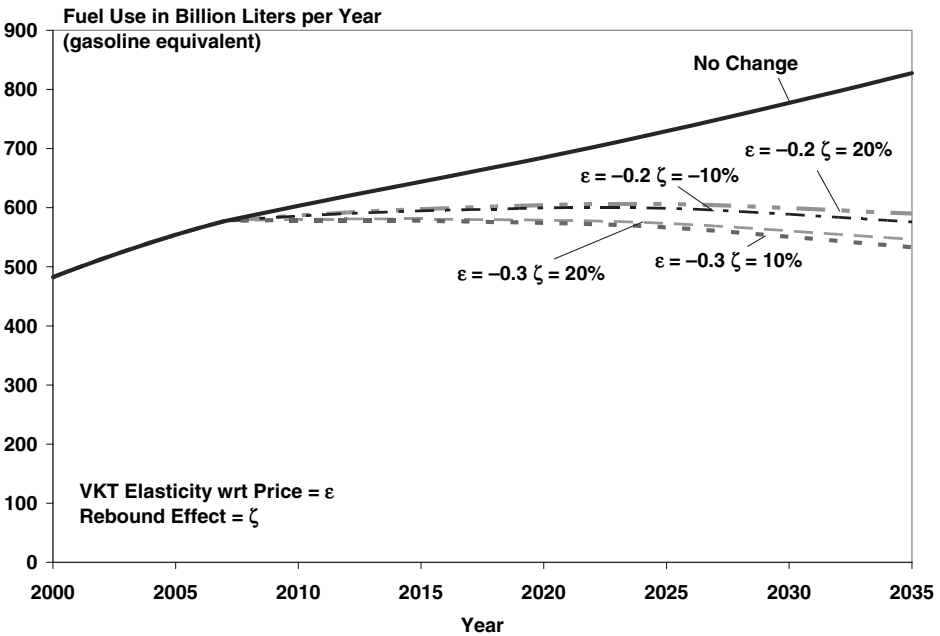


FIGURE 4-9. Sensitivity to vehicle travel elasticity and rebound effect for scenario 1.

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 policies related to transport lies with different institutions, and overcoming institutional obstacles could be a more difficult task than

formulating the policy package. Nevertheless, if a combination of different policy approaches is not considered, then it may be even more difficult to generate commitments from different stakeholders.

Attempts to develop a comprehensive policy of the type outlined here could turn into an ambitious effort to influence many aspects of motor transport. For example, in brainstorming activities at the Organization of Economic Cooperation and Development (OECD) 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 should 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 affect different automotive manufacturers differently, and there may be some wealth transfer between different vehicle manufacturers. Fuel economy standards or fees can be designed to minimize such competitive impacts (McNutt and Patterson, 1986; Davis et al., 1995).

Conclusion

This analysis indicates that fuel use and GHG emission reductions from U.S. LDVs cannot be achieved in practice by regulations alone. Neither will the current market forces bring about the necessary technological change needed to reduce fuel use significantly.

To reduce LDV fuel use, transportation policies will have to integrate fiscal and regulatory measures. A carefully designed policy package can both pull and push more fuel efficient transportation technology into the market, as well as moderate growth in vehicle travel. A set of policies that combine a steady increase in CAFE standards, a moderate but steady rise in gasoline taxes, economic incentives for purchasing more fuel efficient vehicles, and increased renewable content in fuels would be required to achieve these goals.

The technological change needed to bring about GHG emissions reductions can come through incremental improvements in mainstream internal combustion engines, transmissions, and key vehicle technologies coupled with the development and deployment of battery energy storage systems, electric motors, and ICEs integrated into advanced hybrid electric drivetrains. Biofuels, such as efficiently produced ethanol, also have the potential to displace 5 to 10 percent of transportation fuel use, but may require some cost support. If implemented appropriately, this could result in a 3 to 7 percent reduction in GHG emissions from LDVs.

Postponing action on reducing LDV fuel use not only shifts the problem forward in time, but it also results in a higher level of fuel use than if actions are taken immediately. Since the time delays involved in vehicle fleet turnover are of the order of 15 years, urgent action is needed to address the challenge posed by steadily increasing fuel use and GHG emissions from LDVs in the United States.

References

- Agras, J., and D. Chapman. "The Kyoto Protocol, CAFE Standards, and Gasoline Taxes." *Contemporary Economic Policy*, Vol. 17, No. 3, July 1999. pp. 296–308.
- An, F., J. DeCicco, and M. Ross. "Assessing the Fuel Economy Potential of Light-Duty Vehicles." SAE Technical Paper No. 2001-01-2482, 2001.
- Bandivadekar, A., and J. Heywood. "Coordinated Policy Measures for Reducing the Fuel Use of the U.S. Light-Duty Vehicle Fleet." MIT LFEE Report 2004-001-RP, 2004. Available online at http://lfec.mit.edu/public/LFEE_2004-001_RP.pdf.
- Bassene, S. A. "Potential for Reducing Fuel Consumption and Greenhouse Gas Emissions from the U.S. Light-Duty Vehicle Fleet." MIT S.M. in Technology and Policy Thesis, September 2001.
- Better Environmentally Sound Transportation (BEST). Response to BC Government Discussion Paper: "Options to Reduce Light Duty Vehicle Emissions." Vancouver, Canada, January 2001.
- Davis, S. C., and S. W. Diegel. *Transportation Energy Data Book: Edition 23*. Oak Ridge, TN: Oak Ridge National Laboratory, October 2003.
- Davis, W. B., M. D. Levine, and K. Train. *Effects of Feebates on Vehicle Fuel Economy, Carbon Dioxide Emissions and Consumer Surplus*. Washington, D.C.: U.S. Department of Energy, Office of Policy, DOE/PO-0031, February 1995.
- DeCicco, J. M., and D. Gordon. "Steering with Prices: Fuel and Vehicle Taxation as Market Incentives for Higher Fuel Economy." In Sperling and Shaheen, eds., *Transportation and Energy: Strategies for a Sustainable Transportation System*. Washington, D.C.: ACEEE, 1995. pp.177–216.
- DeCicco, J. M., and L. Lynd. "Combining Vehicle Efficiency and Renewable Biofuels to Reduce Light-Vehicle Oil Use and CO₂ Emissions." In DeCicco and Delucchi, eds., *Transportation, Energy and Environment: How Far Can Technology Take Us?* Washington, D.C.: ACEEE, 1997. pp. 75–108.
- DOE. *Annual Energy Outlook 2004 with Projections to 2025*. Washington, D.C.: Energy Information Administration, U.S. Department of Energy, January 2004.
- DOE Interlaboratory Working Group. *Scenarios for a Clean Energy Future*. ORNL/CON-476, LBNL-44029, and NREL/TP-620-29379, November 2000.
- Fulton, L. *Saving Oil and Reducing CO₂ Emissions in Transport: Options and Strategies*. Paris: OECD/IEA, 2001.
- Gerard, D., and L. Lave. "The Economics of CAFE Reconsidered: A Response to CAFE Critics and a Case for Fuel Economy Standards." AEI-Brookings Joint Center for Regulatory Studies, Working Paper 03-10, September 2003.
- General Motors, Argonne National Lab (GM/ANL). *Well-to-Wheel Energy Use and Greenhouse Gas Emissions of Advanced Fuel/Vehicle Systems—North American Analysis*, Vol. 2. <http://www.transportation.anl.gov/software/GREET/publications.html>, 2001.
- Goodwin, P. B. "A Review of New Demand Elasticities with Special Reference to Short and Long Run Effects of Price Changes." *Journal of Transportation Economics and Policy*, Vol. 26, No. 2, May 1992. pp. 155–169.
- Greene, D. L. "Why CAFE Worked." *Energy Policy*, Vol. 26, No. 8, 1998. pp. 595–613.

- Greene, D. L., and A. Schafer. "Reducing Greenhouse Gas Emissions from U.S. Transportation." Prepared for the Pew Center on Global Climate Change, May 2003.
- Greene, D. L., and J. M. DeCicco. "Engineering-Economic Analyses of Automotive Fuel Economy Potential in the United States." *Annual Review of Energy and the Environment*, Vol. 25, 2000. pp. 477–536.
- Greene, D. L., J. R. Kahn, and R. C. Gibson. "Fuel Economy Rebound Effect for U.S. Household Vehicles." *Energy Journal*, Vol. 20, No. 3, 1999. pp. 1–31.
- Greening, L. A., D. L. Greene, and C. Difiglio. "Energy Efficiency and Consumption—The Rebound Effect—A Survey." *Energy Policy*, Vol. 28, 2000. pp. 389–401.
- Haughton, J., and S. Sarkar. "Gasoline Tax as a Corrective Tax: Estimates for the United States, 1970–1991." *The Energy Journal*, Vol. 17, No. 2, 1996. pp. 103–126.
- Hayashi, Y., H. Kato, R. Val, and R. Teodoro. "A Model System for the Assessment of the Effects of Car and Fuel Green Taxes on CO₂ Emissions." *Transportation Research Part D*, Vol. 6, 2001. pp. 123–139.
- Hellman, K. H., and R. M. Heavenrich. *Light-Duty Automotive Technology and Fuel Economy Trends: 1975 Through 2003*. Washington, D.C.: Advanced Technology Division, Office of Transportation and Air Quality, U.S. Environmental Protection Agency, EPA420-R-03-006, April 2003.
- Heywood, J. B., M. A. Weiss, A. Schafer, S. A. Bassene, and V. K. Natarajan. "The Performance of Future ICE and Fuel Cell Powered Vehicles and Their Potential Fleet Impact." SAE Technical Paper # 04-P254, 2004.
- Lipman, T., D. Dantini, and D. Sperling, eds. "Policies for Fostering Sustainable Transportation Technologies: Conference Summary." University of California, Davis, UCD-ITS-RR-98-8, May 1998.
- McNutt, B., and D. Rodgers. "Lessons Learned from 15 Years of Alternative Fuels Experience: 1988–2003." In Sperling and Cannon, eds., *The Hydrogen Energy Transition: Moving Toward the Post Petroleum Age in Transportation*. Burlington, Massachusetts: Elsevier Academic Press, 2004. pp. 181–190.
- McNutt, B., and P. Patterson. "CAFE Standards—Is a Change in Form Needed?" SAE Technical Paper # 861424, 1986.
- McNutt, B., D. Greene, T. Cackette, L. Lave, and S. Peake. "Policies: Regulation." In Lipman, Dantini, and Sperling, eds., *Policies for Fostering Sustainable Transportation Technologies: Conference Summary*. University of California, Davis, UCD-ITS-RR-98-8, May 1998.
- Nivola, P. S., and R. W. Crandall. *The Extra Mile: Rethinking Energy Policy for Automotive Transportation*. Washington, D.C.: Brookings Institution, 1995.
- Northeast States Center for a Clean Air Future (NESCCAF). *Reducing Greenhouse Gas Emissions from Light-Duty Motor Vehicles*. Boston, MA: September 2004.
- National Research Council (NRC), Board on Energy and Environmental Systems. *Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards*. Washington, D.C.: National Academy Press, 2002.
- National Research Council (NRC), Committee on Nuclear and Alternative Energy Systems. *Energy in Transition 1985–2010*. San Francisco: W. H. Freeman and Co., 1980.
- National Roundtable on the Environment and the Economy (NRTEE). *Greenhouse Gas Emissions from Urban Transportation*. Background, Ottawa, Canada, 1998. Available online at: http://www.nrtee-trnee.ca/Publications/PDF/BK_Urban-Transportation_E.pdf. Last accessed May 2004.
- OECD. *Policy Instruments for Achieving Environmentally Sustainable Transport*. Paris: Organization for Economic Co-Operation and Development, 2002.
- Office of Technology Assessment (OTA). *Saving Energy in U.S. Transportation*. Paper OTA-ETI-589. Washington, D.C.: OTA, July 1994.
- Plotkin, S. *Technologies and Policies for Controlling Greenhouse Gas Emissions from the U.S. Automobile and Light Truck Fleet*. Argonne, Illinois: Center for Transportation Research, Argonne National Laboratory, January 2000.

- Weiss, M. A., J. B. Heywood, A. Schafer, and V. K. Natarajan. *Comparative Assessment of Fuel Cell Cars*. MIT Laboratory For Energy and the Environment Report, MIT LFEE 2003-001 RP, February 2003.
- Weiss, M. A., J. B. Heywood, E. M. Drake, A. Schafer, and F. AuYeung. *On the Road in 2020: A Life-Cycle Analysis of New Automobile Technologies*. MIT Laboratory for Energy and the Environment Report, MIT EL 00-003, October 2000.
- Wildhorn, S., B. Burreight, J. Enns, and T. Kirkwood. *How to Save Gasoline: Public Policy Alternatives for the Automobile*. Cambridge, MA: Ballinger Publishing Company, 1976.
- Wilson, J. Q. "The Politics of Regulation." In Wilson, J. Q. ed., *The Politics of Regulation*. New York: Basic Books Inc., 1980. pp. 357–394.