

Strategies to Reduce Greenhouse Gas Emissions from Transportation Sources

A broad array of literature discusses potential strategies for reducing greenhouse gas emissions from transportation. This section discusses strategies that might be considered as part of a national effort to reduce greenhouse gas emissions from highway transportation. It identifies strategies, summarizes conclusions from the literature, and addresses sources of uncertainty and topics of debate. The section is designed to provide information useful for decision-makers to weigh the advantages and disadvantages of various strategies.

5.1 UNCERTAINTY IN RANKING STRATEGIES

As discussed in Section 4, the Policy Dialogue Advisory Committee could not reach consensus on the most appropriate measures to reduce greenhouse gas emissions from personal motor vehicles. Although this report addresses strategies and their potential, it neither ranks strategies on the basis of potential emissions reductions or cost-effectiveness nor recommends that specific strategies become US policy. Ranking of strategies can be misleading for a number of reasons:

- ◆ *Strategies can vary in their degree of stringency*—A fuel tax of \$.10 per gallon will have a different effect on emissions than a tax of \$1.00 per gallon, and will have correspondingly different economic repercussions. Fuel economy standards could be set at various levels, as could subsidies for various alternative fuels.ⁱ
- ◆ *Estimates of effectiveness rely upon key economic and behavioral assumptions, which are somewhat uncertain*—Strategy effectiveness depends upon the response of travelers to changes in prices (usually expressed in terms of price elasticities), non-monetary travel costs (such as travel time), and land use. Estimates from different sources may not be strictly comparable if they use different assumptions. Alternative assumptions about economic parameters and determinants of travel demand can lead also to very different results in assessing policy impacts.ⁱⁱ
- ◆ *The effectiveness of strategies varies over time*—The timeframe for analysis is an important consideration. A strategy that involves significant time lags may not be effective in meeting goals for the year 2000 but may be more effective for the year 2010, 2020, or beyond. In addition, effectiveness can change over time for many strategies. For example, in the near-term, an increase in the price of fuel may encourage individuals to reduce travel. Over longer periods of time, individuals may shift to more fuel-efficient vehicles, which lowers fuel cost per mile. This lower fuel cost per mile could then lead to some rebound in travel and reduce the effectiveness of future fuel price increases.

ⁱ As a result, it is difficult to make judgments regarding the relative potential of different strategies without defining specific scenarios.

ⁱⁱ Assuming that gasoline demand and fuel economy are very sensitive to fuel prices leads to the conclusion that fuel taxes may be relatively more effective than fuel economy standards. On the other hand, assuming that travel is relatively insensitive to travel costs leads to the conclusion that fuel economy standards may be more effective than pricing strategies.

Since data from various sources are often not strictly comparable, a ranking of strategies based on emissions reduction potential and cost-effectiveness estimates from literature is not provided in this report. Rather than adding value to the debate, rankings may encourage decision-makers to rule out certain strategies that may be useful in specific contexts or in combination with other strategies.

Decision-makers do not need to rely on a one-or-the-other approach. They may wish to implement a spectrum of strategies, since it is likely that one strategy alone will be insufficient to reach transportation-sector goals, and different strategies may be suitable for different circumstances.ⁱⁱⁱ Certain strategies may be complementary or synergistic.^{iv} Various issues, such as non-greenhouse gas emission benefits, economic impacts, and costs, may influence political acceptability and ease implementation. Ultimately, decision-makers may wish to judge strategies on a number of attributes.

Attributes of Strategies for Decision-Makers to Consider

In order to consistently examine strategies, this section provides a summary of the following information for each of these strategies:

- ◆ Primary Target;
- ◆ Approach;
- ◆ Timing;
- ◆ Level of Implementation;
- ◆ Effectiveness Factors; and
- ◆ Implementation Issues.

Primary Target—There are three primary means to reduce greenhouse gas emissions from personal vehicle travel:

- ◆ Reduce vehicle travel;
- ◆ Increase fuel economy; and
- ◆ Switch to fuels with a lower life-cycle carbon content.^v

Carbon emissions associated with transportation are simply a product of three factors:

$$\text{Grams of carbon} = \text{miles traveled} \times \frac{\text{gallons}}{\text{mile}} \times \frac{\text{grams of carbon}}{\text{gallon}}$$

These categories are useful since there is a body of knowledge with each: VMT reduction strategies, fuel economy, and alternative fuels.

ⁱⁱⁱ The Majority Report to the President by the Policy Dialogue Advisory Committee noted that even if a stringent version of a single policy (such as a very high gasoline tax or carbon tax) could theoretically yield desired emissions reductions, such an approach would probably not be cost-effective, equitable, reliable, or politically realistic. A package is more robust if it includes a range of measures.

^{iv} For example, a land use strategy, such as implementing zoning to increase densities in metropolitan areas, may work well with a strategy to increase investment in mass transit.

^v In addition to carbon emitted from the burning of fossil fuels, carbon is also emitted through upstream processes associated with transportation, such as fuel extraction, processing, and distribution, as well as vehicle manufacturing and other activities that support transportation. “Life-cycle carbon emissions” refers to the amount of carbon emitted through fuel combustion and all of these upstream processes.

Approach—There are various approaches to achieve a target, which range from voluntary efforts to mandatory actions. Approaches may fall along the following continuum (Exhibit 5-1):

Exhibit 5-1. Strategy Approaches



For example, if one wishes to reduce vehicle travel, a range of options exists. A mandatory “no drive days” policy could be implemented, requiring that vehicles with certain license plate numbers not be used on certain days of the week. Alternatively, the program could be voluntary, relying on economic incentives or education to encourage individuals not to drive on certain days.

Timing—Some strategies, such as road pricing, have an immediate impact on travel behavior. Others, like land use planning measures, may not have observable impacts for many decades. This report assesses whether a strategy could reach its full effectiveness in the near-term (under 5 years), mid-term (5-15 years), or long-term (more than 15 years).

Level of Authority—Some strategies, such as land use planning, have been historically reserved for local decision-making authorities, while other decisions, such as fuel economy mandates on vehicle manufacturers, are more naturally suited to national authorities. Many strategies may see involvement at multiple levels, as is the case of gasoline taxes, which are imposed by federal and state governments. In cases where the public role is most suited to local control, a national strategy for greenhouse gas reduction may involve federal funding, incentives, education, mandates, or guidance to encourage local adoption of strategies.

Effectiveness Factors—The effectiveness of strategies depends on factors that can be altered by public policy—such as the level of taxes set—as well as factors that cannot be controlled—such as consumer responses to price increases. This section provides a brief discussion of the key factors that determine strategy effectiveness. If available, quantitative estimates of potential emissions reductions are presented.^{vi}

Implementation Issues—Political feasibility, equity, and financial concerns can greatly impact the ability of decision-makers to implement a strategy. On the other hand, non-greenhouse gas emissions benefits, such as congestion relief, air quality improvement, and economic benefits, may encourage policy acceptance and adoption. This section discusses issues that could impede or support smooth implementation.

The following section discusses numerous strategies. They are grouped based on the target of the strategy, as shown in Exhibit 5-2.

^{vi} Caution should be exercised when comparing quantitative estimates of greenhouse gas emissions reductions. Estimates from different sources may not be strictly comparable if they use different assumptions about travel, demand elasticities, or other factors that influence effectiveness.

Exhibit 5-2. Strategies to Reduce Greenhouse Gas Emissions from Motor Vehicles

Vehicle Travel Focused	Fuel Economy Focused	Carbon Content/Fuels Focused
<p>Travel Pricing</p> <ul style="list-style-type: none"> ◆ Road pricing ◆ VMT fees ◆ Fuel pricing * <p>Provision for Alternative Modes:</p> <ul style="list-style-type: none"> ◆ Transit investment ◆ Bicycle support strategies ◆ HOV lanes ◆ Park-and-ride facilities <p>Parking Management:</p> <ul style="list-style-type: none"> ◆ Parking pricing ◆ Mandatory parking cash-out ◆ Parking supply limits <p>Land Use Planning</p> <ul style="list-style-type: none"> ◆ Increasing density, mix of uses, and transit-oriented development ◆ Pedestrian environment improvements <p>Other VMT-reduction Measures:</p> <ul style="list-style-type: none"> ◆ Telecommuting ◆ Compressed work weeks ◆ Restrictions on vehicle use 	<p>Improving Traffic Operations</p> <ul style="list-style-type: none"> ◆ Traffic flow improvements ◆ Speed limits ◆ Driver education <p>Vehicle Technology Improvements +</p> <ul style="list-style-type: none"> ◆ Mandates on new vehicle fuel economy (CAFE) ◆ Research and development on fuel economy <p>Changing Vehicle Purchase/Retirement Decisions:</p> <ul style="list-style-type: none"> ◆ Disseminate fuel economy information ◆ Vehicle efficiency tax or feebates ◆ Emissions-based vehicle registration fees ◆ Vehicle retirement/buyback programs 	<ul style="list-style-type: none"> ◆ Alternative fuel vehicle (AFV) mandates ◆ Research and development on fuels and AFVs ◆ Carbon taxes or differential taxes for fuels <p>Notes:</p> <p>* Fuel pricing may reduce VMT and improve vehicle fuel economy. It is discussed once in order to reduce repetition. All strategies that reduce travel may also improve fuel economy as a secondary effect (by reducing traffic congestion).</p> <p>+ Vehicle technology improvement efforts have involved study of alternative fuel vehicles in addition to improvements to conventional gasoline vehicles.</p>

Strategies can be grouped and sorted in various ways depending on the purpose of the discussion. The grouping of strategies itself is not particularly significant since decision-makers should not select strategies or determine policy based on a categorization scheme. However, categorization of strategies is useful to emphasize the commonalities among different strategies.^{vii}

5.2 VEHICLE TRAVEL REDUCTION STRATEGIES

Vehicle travel reduction strategies attempt to reduce greenhouse gas emissions by reducing miles traveled in personal motor vehicles. Reductions in fuel consumption occur with the elimination of trips, reduction in trip lengths, or the replacement of vehicle trips with trips on alternative modes that consume less energy. A secondary impact of reducing vehicle travel is often reduced traffic congestion, which improves fuel economy for vehicles that remain on the road. Most of these strategies fall under the terms, “Transportation Control Measure” (TCM) or “Transportation Demand Management (TDM).^{viii} Although there may be a federal presence in encouraging or mandating some of these measures, most TCMs require local implementation.

^{vii} This report does not imply that each of these targets is effective or that decision-makers should attempt to meet all three targets. Rather, these are three methods that could potentially reduce greenhouse gas emissions.

^{viii} Transportation control measures are often discussed in the context of criteria pollutant emissions. Sixteen TCMs are specifically listed in the 1990 Clean Air Act Amendments.

Vehicle travel reduction strategies may be divided into the following categories:

- ◆ Travel pricing mechanisms;
- ◆ Provision of alternative modes;
- ◆ Parking management;
- ◆ Land use planning measures; and
- ◆ Other measures.

5.2.1 TRAVEL PRICING MECHANISMS

Motor vehicle travel involves a cost to the user in terms of both monetary price as well as the value associated with the time spent in travel. Faced with alternative modes of transportation and routes, individuals make travel decisions on the basis of the variable costs that are incurred each time a trip is made.^{ix} Vehicle travel demand is inversely related to the user-perceived variable cost of vehicle travel—as costs increase, the demand for motor vehicle travel decreases. The inverse nature of the relationship between travel demand and travel cost serves as the rationale for pricing and tax strategies designed to curb motor vehicle travel.

The effectiveness of policies designed to increase travel costs depends on the response of travel demand to travel price. This response is estimated by the *elasticity* of vehicle miles traveled (VMT) with respect to its variable cost, which represents the percent change in VMT associated with a certain percent change in variable user costs per mile.^x In some cases, market strategies involve shifting a previously subsidized cost onto drivers or making a previously fixed cost into a variable cost. Economic theory suggests that incorporating the full social costs of travel into its price will result in a more efficient level of travel.^{xi}

The economic literature contains a range of elasticity estimates of VMT to variable costs, ranging from about -0.20 to nearly -1.00.² For example, a study by Dahl from the 1980s suggested a long-run elasticity of VMT to its variable costs of -0.95, which means that a 10 percent increase in variable travel costs will result in a 9.5 percent decrease in vehicle miles traveled.³ However, some more recent estimates suggest less responsiveness to price. A 1996 study by Haughton and Sarkar suggested that long-run elasticities of vehicle travel with respect to variable

Effectiveness Estimate—The Majority Report to the President by the Policy Dialogue Advisory Committee to Recommend Options for Reducing Greenhouse Gas Emissions from Personal Motor Vehicles estimated that encouraging a shift of state and local road subsidies to cost-of-driving (VMT fees) could reduce greenhouse gas emissions by 30 million metric tons by 2005.¹

^{ix} Fixed costs, like auto ownership and most insurance costs, do not vary with the amount of travel.

^x An elasticity is a dimensionless parameter that measures the percentage change in a factor that will be caused by a 1-percent change in some other factor. An elasticity of VMT to its variable costs of -0.38 implies that a 1-percent increase in the variable cost of travel will produce a 0.38 percent reduction in VMT.

^{xi} If variable user costs do not account for the full marginal costs of travel, then individuals will travel more than the efficient level, resulting in a loss to consumer surplus. Variable user costs may not account for marginal social costs if there are externalities, such as air pollution, that create a cost to society but are not perceived by individuals when making driving decisions.

costs of travel may be -0.38 .^{xii} This elasticity predicts that a 10 percent increase in per-mile fuel costs results in only a 3.8 percent reduction in VMT.⁴ Not every recent study reports elasticity estimates this low.

Fuel prices affect both vehicle travel and fuel economy. In the near-term, drivers react to increased fuel prices by driving less; over longer periods, higher fuel prices also encourage individuals to purchase more fuel-efficient vehicles. The first effect can be measured in terms of the elasticity of VMT to fuel-cost-per-mile, since fuel price is a component of the variable cost of travel. The second effect can be measured in terms of the elasticity of fuel economy to fuel price.

These two effects may be expressed in one measure, called the elasticity of fuel consumption to fuel price (also called the “own price elasticity of fuel demand”). This value reflects the extent to which fuel price increases yield fuel consumption decreases. Estimates of the elasticity of fuel consumption to fuel price also exhibit a significant range.⁵

Elasticity estimates are very important, since they affect the projected relative effectiveness of pricing strategies versus other strategies. In addition, the level of adoption of pricing mechanisms is an important consideration since pricing that is imposed only on certain trips, time periods, or facilities may encourage shifts in the spatial and temporal distribution of trips, rather than the elimination of vehicle trips.

A number of pricing mechanisms designed to reduce vehicle travel is described below. These include:

- ◆ ROAD PRICING;
- ◆ VMT FEES; and
- ◆ FUEL PRICING

As with most types of taxes and fee increases, these pricing mechanisms have important political ramifications that constrain implementation. Furthermore, equity issues have been cited as implementation barriers. As a result, questions remain as to whether there is the political will to broadly implement these measures.

ROAD PRICING

Primary Target	Approach	Timing	Level of Implementation
Reduce Vehicle Travel	Economic Incentive	Near-term Effect	Local, State

Description of Strategy

Roadway pricing involves the use of fees to increase the price of driving in specific facilities or on roadways, or within specific regions. Drivers who have more flexibility in their trip choices (therefore placing a lower value on a specific route or time) will switch to less expensive options, which can include other non-priced roads or alternate modes (such as transit, high-occupancy vehicles, bicycling, or walking). Congestion pricing is a specific type of road pricing where the per trip charge varies by the time of day, based on changes in the demand for travel and resulting congestion. Congestion pricing may encourage

^{xii} The elasticity estimates presented here were derived from Dahl and Haughton and Sarkar’s regression analyses, which presented an elasticity of VMT to fuel cost-per-mile. Elasticity of VMT to variable travel costs was estimated by dividing the elasticity of VMT to fuel cost-per-mile by the fuel cost share of variable costs, not including travel costs. Fuel costs were assumed to be 58 percent of variable costs per mile, from American Automobile Association. *Your Driving Costs*. 1996 Edition.

drivers to switch their time of travel to less congested times, resulting in a more even distribution of traffic throughout the day.

Road pricing is usually assessed at one or more points along a road. Currently, twenty states have toll roads, bridges, or tunnels with costs averaging between \$0.02 and \$0.10 per mile.⁶ Toll booths traditionally have been pricing points in these systems; however, automation is playing an increasingly large role in road pricing. Road pricing often occurs at specific facilities such as bridges, tunnels, or similarly small and easily controlled segments of road. Cordon pricing is a related measure, which may be applied to a larger region where congestion is a severe problem. Cordon pricing establishes a series of pricing points in a ring around the congested area, whether it be a central business district or a greater metropolitan area. Motorists are charged as they enter the cordoned area.

Effectiveness Factors

Road pricing has the potential to reduce VMT across the entire in-use motor vehicle fleet, unlike some other pricing mechanisms that only affect new vehicles. The effectiveness of road pricing as a greenhouse gas reduction strategy depends on a number of factors, including:

- ◆ Level of fee that would be charged;
- ◆ Current cost of driving per mile;
- ◆ The responsiveness of travelers to the price of travel (measured in terms of price elasticity); and
- ◆ The nature and extent of pricing.

Road pricing directly addresses the demand for travel. As discussed earlier, the impact of travel pricing depends on the elasticity of VMT to the variable price of travel, which is a subject of debate. A 1991 study conducted for the Southern California Association of Governments investigated the potential congestion impacts of facility and area pricing schemes. Assuming an elasticity of -0.33, the study examined a fee of \$0.15 to \$0.25 per mile within the 800 miles of congested freeways in the region during a four-hour a.m. peak. This fee was estimated to increase speeds by 10 to 20 percent and to reduce VMT by 8 to 12 percent (600 to 900 million VMT annually).⁷

Since there are many possible ways to implement road pricing, the nature and extent of pricing affects the level of greenhouse gas reductions achieved by the strategy. Roadway fees may be applied based on miles traveled, as is practice on many turnpikes. If roadway fees are varied by the time of day, they are likely to have greater impacts on congestion than on VMT, since vehicles will be encouraged to make temporal shifts in addition to modal shifts in their driving patterns. While these temporal shifts do not reduce VMT, the improved flow of traffic does result in lower emissions of greenhouse gases and greater fuel efficiency. Fees based on vehicle occupancy create an incentive to carpool.

Effectiveness as a national strategy will depend upon the degree to which states and localities adopt road pricing on individual roads. Unlike some other market based measures, road pricing generally only affects a segment of vehicle travel, since pricing typically is imposed only on specific facilities rather than uniformly on all roads. Road pricing would most readily be applied only to interstates and other freeways, which comprise less than a quarter of all vehicle miles traveled nationwide, but up to 40 percent in major metropolitan areas.⁸ Road pricing may be most effective in regions that offer alternative modes such as transit and that facilitate ridesharing. In places where there are few alternatives to vehicle travel and where ridesharing is difficult due to dispersed land use patterns, road pricing will be less effective.

Timing

Road pricing has an immediate effect on traveler behavior, encouraging a shift to higher occupancy vehicles and alternative transport modes. Effectiveness may change over time if significantly high levels of road pricing encourage residential or commercial relocation.

Implementation Issues

The use of roadway pricing has been facilitated in recent years by significant advances in technology that can reduce operational costs, radically improve traffic movement (by eliminating the need to stop at toll plazas), and facilitate toll collection and enforcement. The major innovations include automatic vehicle identification (AVI), which utilizes vehicle-mounted transponders and roadside sensors, and automatic toll collection (ATC), which often uses pre-paid monthly balances to facilitate billing.

Low public acceptance can be a crucial roadblock to implementation of roadway pricing measures. Road pricing may be politically unpopular for a number of reasons. First, charging a fee on facilities that have traditionally been free often generates public dissatisfaction.^{xiii} Perhaps the leading objection to road pricing is that this measure is regressive and would disproportionately affect lower-income drivers. In the case of congestion pricing, drivers who could not alter their time of their trips due to inflexible work schedules would have no option but to pay the fees.^{xiv} A cordon zone pricing system around a central business district or downtown could conflict with land use strategies that seek to encourage employment in developed areas, though the land use impacts of cordon pricing are still being debated.

Several US cities are either planning or have recently implemented single lane pricing projects, most commonly high occupancy toll (HOT) lane projects, which permit single occupant vehicles (SOVs) to use high occupancy vehicle (HOV) lanes during peak-travel periods if they are willing to pay a charge. HOT lanes may be a means to introduce the concept of pricing in an acceptable way to the public. In fact, HOT lane projects in Los Angeles (State Route 91 Express Lanes) and San Diego (I-15 HOV/Express Pass Lanes) have not met with serious public resistance since opening in December 1995 and November 1996, respectively.

AVI technology and toll systems that identify the time and location of vehicles traversing pricing points may be viewed as an invasion of privacy for individuals. Although the privacy issues may be solved with technology that allows accounting to be done in-vehicle (by deducting value from an on-board debit card) rather than centrally, failure to address privacy issues could make implementation more difficult.

Despite these significant political-feasibility hurdles, states and localities may wish to adopt road pricing because it yields localized benefits. The benefits of road pricing include improved regional air quality, more efficient use of the highway network, and improved travel reliability. In addition, revenues from road pricing may be used to fund other transportation investments or needs.

^{xiii} However, when the public receives an improvement in some aspect of travel in exchange for a fee, the trade-off is generally viewed more favorably. In severely congested parts of California, some roadway pricing proposals have been implemented because of the perception that the potential time savings would be well worth the price. Significant public outreach and education explaining the project and how the revenues would be used also have helped to achieve public acceptance.

^{xiv} In response to income inequity, it is possible to establish a system of rebates for lower-income drivers. Another option which has received much attention in the literature is the option of providing a lifeline—a certain allotment of free or lower priced trips that would conceivably allow low-income drivers to continue their daily commutes. These options would apply to drivers who meet specific income qualifications and would not be difficult to implement with AVI and ATC technologies.

VMT FEES

Primary Target	Approach	Timing	Level of Implementation
Reduce Vehicle Travel	Economic Incentive	Near-term Effect	Unknown

Description of Strategy

A VMT fee refers to a charge that is levied on an annual or semi-annual assessment based on the number of vehicle miles traveled per year. This system could work in tandem with existing vehicle registration fees and inspection and maintenance programs.

Effectiveness Factors

VMT fees target reductions in vehicle miles of travel. Unlike road pricing measures where costs can be reduced by switching travel times, use of routes, or type of vehicle used, the only way for an individual to reduce costs under this measure is to drive less, thus reducing traffic and emissions. VMT fees do not, however, discourage peak-period driving (since every mile costs the same regardless of when it is driven) or encourage a shift to cleaner burning engines. They are not facility- or time-specific and so affect the entire vehicle fleet.

Effectiveness as a national greenhouse gas emissions strategy depends upon:

- ◆ Level of fee that would be charged per mile;
- ◆ Current cost of driving per mile;
- ◆ Responsiveness of travelers to the price of travel (elasticity of demand for VMT); and
- ◆ Extent of adoption nationwide (number of states that adopt VMT fees or Federal adoption).

Some economists believe that even though these fees are charged per mile of travel, drivers may not respond as strongly to VMT fees as to other travel pricing measures since the fees would only be charged on an annual basis or semi-annual basis. A 1994 study conducted for the Puget Sound Regional Council analyzed the potential impacts of VMT fees in the Puget Sound area as well as in the San Francisco Bay area. The fees ranged from \$0.01 to \$0.05 per mile and yielded 9.3 to 11 percent decreases in VMT and 8 to 20 percent decreases in carbon dioxide.⁹

Timing

Travel pricing should have an immediate effect on traveler behavior, encouraging a shift to higher occupancy vehicles and alternative transport modes. Implementation may require some time since this strategy has not been implemented in the US to date; consequently, there is no experience upon which to build.

Implementation Issues

Like other market-based measures, VMT fees raise concern regarding political feasibility and issues of equity. Taxpayers may suffer “sticker-shock” when they receive their VMT fee assessments. A fee of \$0.05 per mile results in an annual VMT tax assessment of over \$566 for the average vehicle (which traveled 11,329 miles in 1995).¹⁰ A household with two vehicles could easily receive a tax bill of over \$1,000 annually in association with this VMT fee. Even if other taxes are reduced, this “new tax” could be extremely unpopular. In addition, such taxes may be regressive in nature, unless designed to take equity

into account.^{xv} Developing a system to accurately assess vehicle miles traveled and address odometer tampering could be difficult. Despite significant implementation hurdles, states may wish to implement VMT fees because they have local benefits, including reduced traffic congestion and air pollutant emissions.

FUEL PRICING

Primary Target	Approach	Timing	Level of Implementation
Reduce Vehicle Travel Increase Fuel Economy	Economic Incentive	Near-term Effect	Federal, State, Local

Overview of Strategy

Fuel taxes have long been used in this country to recover road construction and maintenance costs. However, in recent years, raising federal and/or state fuel taxes has increasingly been viewed as a potential tool to reduce VMT and improve fuel efficiency. Currently fuel taxes comprise 30 to 40 percent of fuel prices, but a very small percentage of total car ownership costs.¹¹ Fuel tax advocates point out that American gasoline prices are a mere fraction of those in other industrialized nations, where the price of a gallon of gasoline can cost \$2 to \$3 more than in the US.¹² In addition to a conventional gas tax, there are alternative methods to increase the price of gasoline, which would have similar effects. Pay-at-the-pump insurance is a measure in which a portion of auto insurance costs would be collected through a per gallon premium on gasoline. Such a measure would convert a fixed cost of driving into a variable cost.

Effectiveness Factors

The effectiveness of fuel taxes as a national greenhouse gas emissions strategy depends upon:

- ◆ Level of the gas tax increase; and
- ◆ Long-term responses to the price of fuel, such as reductions in travel and increases in vehicle fuel economy.

Changes in fuel tax prices have two long-term effects:

- ◆ Increasing fuel prices raises the price of travel per mile, which encourages consumers to reduce vehicle miles of travel (measured in terms of the elasticity of VMT with respect to fuel-cost-per-mile).
- ◆ Since the amount paid for fuel is directly proportional to the amount of fuel consumed, fuel pricing provides incentives for the purchase of more efficient vehicles (measured in terms of the elasticity of fuel economy with respect to the price of fuel).

The effectiveness of fuel pricing depends on consumers' responses to increases in the price of fuel. Advocates of higher fuel taxes point to their ability to levy the costs at the source of the activity, thus making the cost more visibly related to the act of driving. Fees that are separated from their root behavior

^{xv} While flat VMT fees may be regressive in nature, proposals have been developed to remedy this problem. One concept, called a "lifeline mileage" would provide drivers with some allotment of free miles, such as 2,000 miles per year, to allow a driver to commute to work daily at no cost. Another pricing option would begin with a certain allotment at no cost and assess a higher cost for each graduated level of vehicle miles. For example 1 to 2,000 miles at no cost; 2,000 to 5,000 miles at \$0.25 per mile; and 5,000 to 10,000 miles at \$0.40 per mile. Utility providers such as water suppliers already use this type of graduated fare structure.

may be less effective in influencing changes in that behavior. The oil crises of the 1970s are often cited as an indication of the enormous sensitivity of the American public to radically increased gasoline prices. However, some economists argue that scarcity and uncertainty about future price shocks played more of a role in those situations than price.¹³ This argument is reflected in elasticity estimates for gasoline demand.

Elasticity estimates in economic literature have a significant range. Estimates from Dahl (1986), suggest that the elasticity of fuel demand to fuel price may be -0.81, meaning that a 10 percent increase in fuel price leads to an 8 percent decrease in fuel consumption. Large price elasticities, such as this estimate, suggest that tax policies to reduce fuel consumption could be successful.¹⁴ However, Haughton and Sarkar's study (1996) yields an elasticity of -0.38, suggesting that a 10 percent increase in fuel price leads to less than a 4 percent decrease in fuel consumption.¹⁵ Many recent studies suggest lower effectiveness of fuel pricing than some of the older studies. For example, Gately (1993) estimated a long-run fuel price elasticity of -0.21 for fuel price increases.¹⁶ Some analysts postulate that consumers are now less responsive to fuel prices since fuel prices account for a much smaller portion of travel costs per mile than in the past, due in part to historical improvements in vehicle fuel economy and falling real gasoline prices.¹⁷

Some economists suggest that price increases on the order of 5 to 10 percent are ineffective, since fuel prices can vary by that much at different gas stations within an area as small as a few blocks or over a time period as short as a year.¹⁸ However, even if the elasticity of VMT with respect to gasoline prices is small, the impact of gasoline taxes may be significant relative to other policy instruments, since the emission reduction benefits are realized across the entire motor vehicle fleet.

Timing

An increase in fuel taxes should have an immediate effect on traveler behavior, encouraging a shift to higher occupancy vehicles and alternative transport modes. This option can be implemented relatively quickly since existing legal mechanisms and institutional authorities exist, and there is experience with this strategy.

Implementation Issues

Increasing fuel taxes would not require the introduction of a new pricing mechanism, only a readjustment in the rate of the current system. As a result, a fuel-tax increase would be easy to administer and collect. However, setting the appropriate rate of taxation to achieve a specific result is significantly more difficult. A pay-at-the-pump insurance program could be more complicated to design since it involves reimbursing insurance companies. Both the federal and state governments have experience with fuel taxes.

Although the federal government and all states levy gas taxes, the idea of increasing gas taxes may draw considerable political opposition. The contentious political debate surrounding the increase in the federal gas tax of \$0.04 per gallon in 1996 suggests that large gas tax increases necessary to significantly reduce greenhouse gas emissions may be difficult. Some analysts have suggested that prices would have to be raised by more than \$1.00 per gallon to have a large effect on national emissions.¹⁹ Other researchers have estimated that to reduce CO₂ emissions from light-duty vehicles to 1989 levels by 2000, the federal gas tax would need to increase from \$0.09 to \$0.40 per gallon by 2000 and \$0.50 by 2010 (in 1989 dollars).²⁰ An analysis of gas taxes by DRI (1991) indicated that to hold emissions level, the gas tax would need to rise by \$0.28 per gallon in 2000 and by \$0.48 per gallon in 2010.²¹ Such large increases present a major political challenge. Furthermore, price increases designed to affect behavior may be viewed more negatively than those designed to finance infrastructure.²²

In addition to political pressures, increasing fuel taxes can create border issues. If the higher costs are levied over a small region, residents of that region will tend to drive to other areas to purchase less

expensive fuel, undermining the goals of the measure. Even when a tax is levied on a large region or a state, border communities will still face this possibility. Unless the measure is applied at the federal level, some consideration would have to be given to potential border problems.

Equity concerns can also be an important barrier to implementation of this strategy. Low-income commuters, drivers with no alternative mode available, and those whose work requires significant auto travel would be disproportionately affected by an increase in the gas tax.

Since gas taxes raise travel costs, they could impair economic activity that depends on transport. However, economic theory suggests that taxes that account for externalities can enhance the overall efficiency of the economy. In addition, gas taxes raise revenues that can serve state or national investment needs.

5.2.2 PROVISION FOR ALTERNATIVE MODES

Actions that provide or improve alternatives to single occupancy vehicle (SOV) travel may reduce dependency on personal vehicles and encourage shifts away from vehicle use. Alternatives to SOV travel include transit, bicycling, and ridesharing. Improvements to travel time, reliability, frequency of service, and comfort of these alternatives reduce the relative costs of these modes compared to SOV travel. A national greenhouse gas reduction strategy may include investment in the following:

- ◆ TRANSIT;
- ◆ BICYCLE-SUPPORT FACILITIES;
- ◆ PARK-AND-RIDE FACILITIES; and
- ◆ HIGH OCCUPANCY VEHICLE (HOV) LANES.

Decision-making for these investments is local in nature, often reflecting needs determined by states and metropolitan planning organizations. However, there may be a federal role in encouraging investment in alternative modes.

TRANSIT INVESTMENT

Primary Target	Approach	Timing	Level of Implementation
Reduce Vehicle Travel	Infrastructure Investment	Mid-term Effect	Federal, State, Local

Description of Strategy

Investment in transit buses and railways may involve a range of projects, including:

- ◆ *System/Service Expansion*—Expansion may include the addition of new fixed guideway, express bus, local bus, or paratransit services to extend geographic coverage.
- ◆ *System/Service Operational Improvements*—Improvements include splitting routes, transfer improvements, schedule coordination, and increased vehicle frequency. In addition, service can be improved through the addition of passenger amenities, such as the addition of bus shelters, station improvements, safety and security enhancements, vehicle comfort improvements (air conditioning and seating), signage, and elderly/handicapped access.

Effectiveness Factors

Since transit is a motorized form of transportation, the effectiveness of transit investment at reducing greenhouse gases depends on the following factors:

- ◆ The level of improvement in transit frequency, coverage, or amenities;
- ◆ The extent to which increased transit investment reduces motor vehicle fuel consumption (which depends on the extent to which transit causes shifts in mode of travel, improvements in traffic flow, and any offsetting increases in travel due to improved traffic flow); and
- ◆ The extent to which any increases in transit fuel consumption offset these reductions.

There is some debate about the extent to which transit investment can reduce personal vehicle travel. When developing a new transit system, planners generally assume that ten trips on the new system will eliminate fewer than ten auto trips since some of the transit trips are new trips induced by building the new system and others have been captured from other transit systems or routes. Some warn that mass transit will have little effect at encouraging drivers to change their mode of travel since it is not compatible with most US automobile users' travel needs for flexibility and convenience, nor is it compatible with existing low-density land use patterns. On the other hand, others claim that transit has a "magnifying effect" in reducing auto travel since transit affects land use in ways that reduces the need to travel. An analysis conducted by the Natural Resources Defense Council (NRDC) and the Sierra Club suggests that each new transit mile traveled replaces four to eight miles of auto travel due to changes in land use that might result from transit development.²³ Assumptions about the degree to which transit eliminates vehicle trips affect estimated emissions benefits.

In addition, by encouraging people to switch modes, transit could improve traffic flow in some areas. Improved traffic operations could reduce fuel consumption per mile, but also could encourage additional drivers to take to the road, which would offset some of the VMT reduction.

Since transit is a motorized form of transportation, net reductions in emissions depend on the level to which increased transit fuel consumption offsets reduced energy consumption from personal vehicles. If new transit lines only carry a small number of passengers, the average energy savings from transit may be minimal (or even negative) on specific routes. Data from the US Department of Energy suggest that on a national basis average energy use per passenger mile, and thus net CO₂ emissions, is higher for transit than for the automobile travel, as shown in Exhibit 5-3:

Exhibit 5-3. Comparative Energy Consumption of Autos and Transit

Mode	BTU per passenger mile
Automobiles	3,593
Rail Transit	3,687
Transit Buses	4,374

Source: US Department of Energy. *Transportation Energy Data Book*. 15th Edition, Table 2.15, p.2-25.

These statistics indicate that transit expansions should be planned carefully to target areas with sufficient ridership. The effectiveness of transit is closely related to land use patterns. High-capacity transit is often not cost-effective for suburb-to-suburb trip patterns, which are prevalent in urban travel. The increasing importance of non-work trips also implies that an increasing portion of travel is not part of the traditional transit commuter markets.²⁴ Improvements in transit routing, publicity, and service to underserved areas may attract ridership without requiring the operation of additional vehicles.

The effectiveness of transit to reduce greenhouse gas emissions may be small at the national level. Transit comprises a small portion of national travel—only 0.9 percent of total passenger miles in the US in 1994.²⁵ An analysis by Apogee Research, Inc. suggested that transit improvements can reduce VMT by up to 2.6 percent in metropolitan areas, and most likely by only 1.0 percent.²⁶ Despite these small effects, a

significant portion of the literature suggests that transit is an important supporting measure for a variety of transportation control measures (TCMs), including road and fuel pricing. At the national level, emissions effects will depend upon the extent of increases in transit service feasible in urbanized areas. Vanpools, paratransit, and demand-responsive transit may be more appropriate for less urbanized areas.

Timing

Changes in transit bus routing and frequency can be implemented quickly. Infrastructure-intensive development of new fixed-route transit would take many years to reach completion, and changes in land use patterns resulting from transit would occur over a much longer time frame.

Implementation Issues

A key implementation concern with transit is the financial cost involved, particularly for fixed rail systems. In addition, fixed rail systems may expose a variety of planning and environmental concerns, as with any major transportation investment.

On the other hand, local areas may look upon transit favorably due to its potential benefits for congestion relief and improvements in air quality. In addition, transit provides mobility for segments of the population such as the young, the elderly, and the disabled, who are less likely to have access to automobiles. Transit is also seen as a potential tool for reorienting metropolitan land use patterns and for revitalizing urban central areas that have lost population and employment.

BICYCLE SUPPORT FACILITIES

Primary Target	Approach	Timing	Level of Implementation
Reduce Vehicle Travel	Infrastructure Investment	Near-term Effect	Local

Description of Strategy

Strategies that enhance the environment for bicycles and bicycling as an alternative to single occupancy vehicles (SOVs) include:

- ◆ Development of bicycle routes, lanes, or paths;
- ◆ Provision of lockers, racks, other storage facilities, and ancillary facilities (such as showers, and clothing lockers);
- ◆ Integration with transit, either at stations or on vehicles;
- ◆ Educational, media, and promotional campaigns, including provision of bicycle maps; and
- ◆ Hiring of a local government or employer-site bicycle coordinator.

Effectiveness Factors

The potential of bicycle-support strategies to reduce greenhouse gas emissions depends on:

- ◆ The extent to which bicycle investment causes shifts in modes of travel;
- ◆ The extent to which metropolitan areas adopt bicycle-investment strategies; and
- ◆ Improvement in traffic flow (which could encourage some offsetting vehicle traffic).

Most estimates of VMT reduction from bicycle and pedestrian strategies are relatively low.²⁷ Bicycle trips are generally limited to short trips. In addition, the potential number of trips that individuals may shift to bicycle is constrained by weather conditions, topography, and individual health and fitness. Any improvements in traffic flow due to bicycling could reduce carbon emissions further. However, improved traffic flow could encourage additional vehicle travel, which could offset some of the direct VMT reduction.

Estimates of VMT reductions from bicycle projects suggest that for a metropolitan area, bicycle projects may reduce regional VMT from under 0.01 percent to over 3 percent, with the latter figure assuming capital construction of facilities and an already existing favorable land-use configuration.^{xvi}

Timing

Design and construction of bicycle facilities such as bicycle trails and provision for bicycle lanes can take a number of years, whereas supporting measures, like provision of bicycle racks may be implemented immediately. Effects on travel should be near-term or almost immediate.

Implementation Issues

Bicycle projects are generally implemented at the local level, often with some funding from state and/or federal sources. Local governments, developers, or individual employers may invest in bicycle-support strategies. Funding constraints may be a key issue given a variety of funding needs for various types of transportation investments. In addition, land issues, such as taking right-of-way corridors that could be used by other modes, could be barriers to implementation.

Improved bicycle facilities may provide additional recreational opportunities and improve mobility for those without access to motorized vehicles. In addition, bicycling is an entirely “clean” form of transportation that emits no pollution. For the individual, bicycling may result in improved physical fitness and personal satisfaction.

PARK-AND-RIDE FACILITIES

Primary Target	Approach	Timing	Level of Implementation
Reduce Vehicle Travel	Infrastructure Investment	Near-term Effect	State, Local

Description of Strategy

Park-and-ride lots serve as a collection point for individuals in carpools, vanpools, and various types of shuttle services, and may serve bus or rail transit. The goal of investment in park-and-ride facilities is to

^{xvi} According to Harvey and Deakin’s 1991 study for the San Francisco Bay area, a bicycle support strategy could result in a 0.01 to 0.02 percent reduction in regional VMT. An estimate of traffic calming and bicycle investment in the Washington, DC region by Replogle suggested that it could result in a 0.9 percent reduction in VMT in 2000 and a 3.5 percent reduction by 2010.

encourage use of these modes rather than single occupancy vehicles (SOVs). Park-and-ride lots may be connected to high occupancy vehicle (HOV) lanes or express transit service.

Effectiveness Factors

Factors that influence national effectiveness include:

- ◆ Degree to which park-and-ride facilities reduce vehicle travel;
- ◆ Scope of program (i.e., number of facilities constructed); and
- ◆ Improvement in traffic flow (which could encourage some offsetting vehicle traffic).

The emissions-reduction potential of park-and-ride facilities is limited because they reduce only the length of vehicle trips, not vehicle trip-making (individuals must drive to the parking facility). In addition, they are primarily suited to reduce long-distance commute travel in urbanized areas, which is only a portion of VMT. Increases in carpooling could also come at the expense of transit ridership. Secondary improvements in traffic flow due to reduced VMT could reduce carbon emissions further. However, improved traffic flow could encourage additional vehicle travel and offset some of the direct VMT reduction from carpooling and transit use.

A review of the literature by Apogee Research, Inc. (1994) found that park-and-ride lots might be effective at reducing regional VMT in metropolitan areas by between 0.1 and 0.5 percent.²⁸ This estimate is within the range of many other conventional TCMs. On a national basis, the percent reduction in VMT may be somewhat smaller since park-and-ride lots are most appropriate for mid- to large-size metropolitan areas and would not be as effective in rural areas or small towns.

Timing

Park-and-ride lots should yield near-term effects, which may increase somewhat over time as individuals develop arrangements to carpool or vanpool. Construction may take a number of years.

Implementation Issues

Primary concerns with developing park-and-ride facilities include financial costs, as well as environmental issues related to planning and design, such as the need for additional right-of-way and noise barriers. However, park-and-ride lots may receive relatively little public opposition. By encouraging ridesharing and transit use, park-and-ride lots may reduce traffic congestion and alleviate regional air quality problems.

HIGH OCCUPANCY VEHICLE (HOV) LANES

Primary Target	Approach	Timing	Level of Implementation
Reduce Vehicle Travel	Infrastructure Investment	Mid-term Effect	State, Local

Description of Strategy

High occupancy vehicle (HOV) lanes are specific lanes designated for use only by vehicles carrying two or more individuals (HOV-2) or three or more individuals (HOV-3). HOV lanes encourage carpooling and vanpooling by reducing travel time and reversing the time penalty generally incurred in picking up passengers. HOV lanes also reduce travel time for transit buses. They may be developed on freeway or arterial facilities. Lane restrictions are often limited to peak-hour driving periods.

Effectiveness Factors

The effectiveness of HOV lanes depends on the following factors:

- ◆ Extent to which HOV lanes reduce vehicle travel (encourage carpooling at the expense of SOV travel);
- ◆ Improvement in traffic flow;
- ◆ Indirect effect of reduced highway congestion to induce additional vehicle travel; and
- ◆ Scope of program (i.e., number of facilities constructed).

By improving travel times on congested routes, HOV lanes can be a significant incentive to rideshare. However, the benefits of HOV lanes may be diminished if they encourage carpooling at the expense of transit. Some individuals may divert from transit to carpools with the addition of lanes.

A number of analyses suggest that the net benefits of HOVs are positive. A study of HOV lanes on Interstate 5 in Seattle determined that adjusting for the growth in households and income, the increase in vehicles from 1978 to 1989 was less than had been projected originally without the HOV lanes for each year after the HOV lanes became available. It projected that the benefits increased over time, with a 6 percent reduction of VMT in 1984 to a 35 percent reduction in 1989.²⁹

HOV lanes are mainly effective at reducing peak-period travel on highly congested freeways and arterials. The regional effect of HOV lanes is generally smaller than the reduction in any one corridor. Apogee Research, Inc. estimated that HOV lanes could reduce regional VMT by up to 1.4 percent in major metropolitan areas.³⁰ National effects would likely be somewhat smaller since HOV lanes would not be implemented in small towns and rural areas.

Timing

HOV facilities should yield short-term results, which may build somewhat over time as individuals develop arrangements to carpool or vanpool. Construction may take a number of years.

Implementation Issues

Primary concerns with developing HOV lanes include financial costs, as well as environmental issues related to planning and design (such as the need for additional rights-of-way and noise barriers). In addition, there may be issues involving setting the proper HOV restrictions, and there may be some public discontent if HOV status is placed on lanes that were once open to all traffic. On the other hand, by encouraging ridesharing and transit use, HOV lanes may reduce traffic congestion and alleviate regional air quality problems.

5.2.3 PARKING MANAGEMENT

Parking is an essential component of vehicle travel. One must be able to find a space and be willing to pay the price to park in order to use a vehicle. Parking management strategies attempt to reduce vehicle travel by increasing the user costs associated with parking, in terms of monetary price, travel time, or convenience. Parking management may involve increasing the monetary price of parking or limiting supply such that individuals need to search longer for parking or park further from their destinations. It may also involve preferential treatment for carpools.

Parking management strategies include:

- ◆ PARKING PRICING;
- ◆ MANDATORY PARKING CASH-OUT; and
- ◆ PARKING SUPPLY LIMITS.

PARKING PRICING

Primary Target	Approach	Timing	Level of Implementation
Reduce Vehicle Travel	Economic Incentive	Near-term Effect	Local

Description of Strategy

A parking pricing strategy would increase the user costs of driving by increasing the level or extent of parking pricing. Measures include increasing fees at municipal facilities or adding parking meters to previously free on-street spaces. Taxing private-parking operators can also raise the market price of all parking facilities within a region.

Effectiveness Factors

The effectiveness of parking pricing as a greenhouse gas strategy depends upon:

- ◆ The response of drivers to parking prices (reflected by price elasticities);
- ◆ The level of pricing increase; and
- ◆ The extent of pricing.

Case studies of employer-based programs that involved raising employee parking fees to market rates have shown significant decreases in vehicle use, in the range of a 26 to 81 percent decrease in solo driving. Case studies of differential parking rates for SOVs and HOVs also show significant reductions in vehicle travel. A 1996 study examined eight employer programs in California, where parking measures have received considerable attention. The study found that, on average, the employers reduced VMT by 12 percent per employee per year as a result of the program.³¹

Some economists have found that parking charges may have a greater effect on travel behavior than other costs since parking charges are often incurred on a trip-by-trip basis (a separate money transaction must be undertaken with each trip), unlike fuel purchases and other operating costs which are made periodically. A review of parking studies by Feeney (1988) suggests that there is great variation in the parking price elasticities quoted but that a number of studies provide estimates from -0.20 to -0.32.³² However, some case studies of parking pricing have shown mixed results at reducing VMT since commuters merely shifted parking location to unpriced spaces.³³

Adding parking meters to on-street spaces and increasing municipal parking charges may be effective in places where drivers depend on these facilities. Most employment sites and commercial establishments, however, provide free parking to their employees and customers. As a result, individual drivers may not be aware of the increase in parking prices in cases where parking is subsidized. The national effect of parking pricing depends upon the extent of local adoption of this strategy.

Timing

Parking pricing would have an immediate effect on travel behavior. Most pricing measures could be implemented relatively quickly.

Implementation Issues

Businesses may be hesitant to implement parking pricing for fear that it will drive away customers or reduce employee satisfaction. Drivers view parking charges with disfavor and may seek out alternative spaces for parking if pricing is not imposed uniformly. Some analysts encourage the implementation of parking pricing policies on a region-wide basis rather than by individual employer in order to prevent overflow parking on residential streets or surrounding lots. However, few areas have made such efforts.

Municipalities may wish to expand parking pricing since it provides revenues to local government, which can be used for a variety of needs. It also can reduce congestion, air pollution, and other externalities associated with vehicle travel. Case studies suggest that parking pricing strategies are most effective in areas where transit is already available. The option of alternative modes to vehicle travel increases the extent of modal shift. Similarly, van- and carpool creation can be increased when supporting services such as rideshare and park-and-ride are offered.³⁴

MANDATORY PARKING CASH-OUT

Primary Target	Approach	Timing	Level of Implementation
Reduce Vehicle Travel	Economic Incentive	Near-term Effect	Federal, State, Local

Description of Strategy

About 95 percent of those who commute to work by automobile in the US use free parking provided by their employers, and nearly all vehicle trips for non-commute purposes also include free parking.³⁵ Part of the reason for this high rate is that the US tax code has subsidized employer-provided parking by exempting employer parking costs from federal and most state income and payroll taxes as a fringe benefit, provided the employer does not offer cash salary in lieu of the parking space. The Tax Relief Act of 1997 removed the restriction against offering taxable cash in lieu of tax-exempt parking benefits. A “mandatory parking cash-out” policy would make mandatory what the new tax law made possible. It would require employers who provide subsidized parking to also offer their employees the option of receiving taxable income instead of parking. Since employees would be given the choice between a parking space and taxable income, they would perceive the opportunity cost of driving to work in terms of the income forgone.

Effectiveness Factors

Although documented experience with the parking cash-out concept is limited, its effectiveness in reducing auto use can be estimated based on experience with parking charges. Factors that affect national emissions include:

- ◆ Current cost of driving per mile;
- ◆ The response of drivers to increases in the opportunity cost of driving (reflected by price elasticities); and
- ◆ The degree to which employers adopt cash-out policies (strategy could be limited to large employers).

A number of studies have suggested that a national mandatory parking cash-out policy may result in significant reductions in travel and fuel consumption. An evaluation of a mandatory parking cash-out program in California used an elasticity of VMT to the out-of-pocket variable costs of travel of -0.16 based on parking pricing studies. Using this elasticity assumption, a mandatory cash-out program in California was estimated to reduce VMT and gasoline consumption by about 10 percent from Los Angeles Central-Business-District commuters.³⁶ Assuming elasticities of home to work VMT with respect to cost of 0.1 to 0.2, the Climate Change Action Plan estimated that reforming the federal tax subsidy would reduce light-duty VMT by approximately 25 billion miles, or 1.1 percent, in the year 2000.³⁷

The national effect on greenhouse gas emissions depends upon the extent to which employers actually offer the cash-out to their employees and the alternative transportation options available to employees.

Timing

Effect on behavior should be in the very near term.

Implementation Issues

Implementing a parking cash-out policy may be simpler than congestion pricing or other efforts to raise the price of travel, since it does not require technically complex forms of paying for road use or congestion. A parking cash-out program might garner less political resistance from the public than other market-based programs since it does not directly increase costs for employees. States may wish to implement a mandatory cash-out policy as a measure to reduce congestion and improve air quality. Eliminating the tax subsidy would also generate tax revenue, as a result of some employees accepting taxable income in lieu of parking, which could be used for transportation or other programs.

Still, some implementation problems may be significant. The state of California passed a mandatory parking cash-out measure for large employers, but it has been largely unenforced. There have been difficulties in assessing the value of parking in many cases where parking is bundled with the building lease. In other cases, a firm may own both the building and the parking facility or have committed to a multi-year lease.

PARKING SUPPLY LIMITS

Primary Target	Approach	Timing	Level of Implementation
Reduce Vehicle Travel	Regulation or Incentives	Long-term Effect	Local

Description of Strategy

A number of policy instruments are available for government to attempt to limit the supply of parking for SOVs, including:

- ◆ Maximum parking-supply ratios in zoning;
- ◆ Reduced or eliminated minimum-parking ratios in zoning;
- ◆ Area-wide parking caps; and
- ◆ Restriction of access to parking at certain times of the day, for certain durations, or to certain classes of users (i.e., preferential parking for HOVs).

Parking supply measures that involve zoning are regulatory in approach, but no more restrictive than zoning codes that are common for development. In fact, eliminating or reducing minimum parking ratios reduces restrictions and allows the market more control over parking supply. Ordinances may also provide incentives to developers, such as allowing increases in development density in return for reduced parking supply.

Effectiveness Factors

The effectiveness of parking supply measures depends on:

- ◆ How required parking supply relates to parking demand (parking supply restrictions will have little effect if they are set too high);
- ◆ Rates of growth in development; and
- ◆ The extent of local adoption nationwide.

Experience with a number of parking supply management techniques shows mixed effectiveness. For example, case studies of preferential parking for HOVs at Arkansas State Government in Little Rock, Hallmark Cards in Kansas City, Government Employees Insurance Company in Bethesda, and the US Pentagon showed increases averaging about 100 percent in carpool rates. However, preferential parking at numerous employment sites in downtown Seattle and Sunnyvale, CA showed little use of preferential spaces. Most evaluations are based on specific local examples.³⁸

Similarly, an analysis of parking supply ratio programs shows mixed effectiveness. A 1995 analysis of maximum parking supply ratios in downtown Portland by Apogee Research, Inc. found that this policy may have reduced parking supply and VMT.³⁹ Since 1975, when the policy was adopted, Class A office space has more than doubled and the number of employees working downtown increased by more than 30 percent, while the number of parking spaces increased by only 12 percent, and the average number of off-street parking spaces per worker has dropped from 0.44 to 0.38. The US EPA reported a successful parking supply program in Bellevue, Washington in the early 1980s. The city reduced its minimum-parking requirement from three to five spaces to two spaces per 1,000 square feet of office space, and instituted a flexible minimum. In some cases, developers requested parking supplies less than the minimum, suggesting that they were willing to reduce parking supply.⁴⁰

However, a recent case study of zoning restrictions on parking supply in Atlanta, Georgia, found that such policies can be ineffective. To attract new development and to improve transit ridership around Midtown rail transit stations, Atlanta has used for two decades Special Public Interest Districts (SPIDs), which offer developers no minimum parking supply ratios. The researchers found that there was no significant difference in parking ratios between buildings constructed inside or outside of SPIDs. In fact, the average ratio inside SPIDs (2.1 spaces per 1,000 square feet) was slightly higher than outside SPIDs (2.0 spaces per 1,000 square feet). The authors postulated that competitive market conditions and financier considerations led to approximately equal parking ratios. In addition, there was a proliferation of parking throughout Midtown, as owners of vacant land built surface lots. Since the SPID policy does not manage total parking supply, the authors concluded that without areawide parking supply efforts, policies patterned after Atlanta's SPID program will have limited success in improving transit ridership.⁴¹

Clearly, the relationship of parking supply to demand and the extent and level of parking supply restrictions will affect a policy's success. Area-wide parking caps that are set above levels of parking demand will have little effect on reducing travel. In addition, parking supply ratios in zoning are limited because they only affect new development. If maximum parking supply ratios are too restrictive, they may encourage development to shift to areas that are not within the bounds of the restriction.

Timing

Parking supply restrictions may require a long time frame to demonstrate a significant effect on national emissions. While restrictions may have a great impact on a particular building or development, even greatly restricted parking supply for new developments could have a minor effect on altering patterns regionally, since existing developments and their parking facilities are already in place.

Implementation Issues

Generally, parking supply restrictions must be implemented at the local level; there is a minimal role for federal or state involvement. Despite potential benefits to air quality and congestion, localities may be averse to adopting parking supply strategies. There have been relatively few documented cases of localities restricting parking supply in commercial areas as a VMT reduction strategy. Parking and auto access tend to be viewed as positive amenities by developers and businesses. Local business districts are often leery to implement programs that reduce vehicle demand—even if conditions are highly congested—due to concerns about business demand. Limited parking could reduce business, as individuals will choose to shop in stores and eat in restaurants that have ample parking. In addition, homeowners feel that demand for parking from commercial areas could spill over to residential areas if adequate parking levels are not supplied.

The direct monetary cost of most parking supply restrictions is negligible if it involves changes in zoning requirements. However, enforcement against meter feeding and parking over time limits in timed zones may be an important element in implementation. For developers, reduced parking supply minimums could result in reduced construction costs. For example, an evaluation of the costs and benefits of reduced parking requirements in King County, Washington, estimated savings in construction costs for structural lots at \$4,200 per space and annual operation and maintenance at \$200 per year.⁴²

5.2.4 LAND-USE PLANNING

The goal of land use planning as a greenhouse gas reduction strategy is to shape development patterns to encourage less vehicle travel and fuel consumption. Land use measures may be examined at both the neighborhood (micro) level and the regional (macro) level.

The layout and development patterns of neighborhoods and sites can take various forms. For example, the physical layout of a neighborhood may include a mix of land uses or separation of uses. A community may be designed to create an environment conducive to travel by transit, bicycles, and walking or one conducive to vehicle travel. Micro-level measures that might reduce fuel consumption from transportation include:

- ◆ Increasing density and mix of uses to provide opportunities for pedestrian trips, trip-chaining, and transit access;
- ◆ Orienting higher-density development around commercial centers, transit lines, and community facilities to encourage non-motorized trips; and
- ◆ Supporting pedestrian and bicycling activity through facilities for non-motorized modes such as sidewalks and bike lanes, urban design improvements, and traffic calming.

Neighborhoods that exhibit many of these characteristics are often referred to as “pedestrian-oriented development” or “transit-oriented development.” “Neotraditional design” refers to a development pattern that replicates the design of older urban areas before the advent of the automobile, and often involves grid-street networks, mixed use development, and pedestrian amenities.

Regional development can also take various forms. Regional development can be either concentrated or decentralized. It may contain a few large employment centers or multiple small activity centers. It may be oriented toward transit corridors or dispersed throughout a broad area. Since most individuals do not work within their own neighborhoods, levels of vehicle travel are affected by the regional dispersion of employment and residential development, and the existence of regional travel options. Macro-level measures that might reduce fuel consumption include:

- ◆ Increasing the compactness of metropolitan areas;
- ◆ Focusing regional development around transit networks; and
- ◆ Providing a sub-regional balance of jobs and housing, so that individuals do not need to commute long distances.

Specific tools outlined in the literature include the following:

- ◆ Site-based tools—developer incentives, zoning requirements, development standards (density standards, requirements for mixed uses, grid street requirements; area or sector plans); and
- ◆ Regional planning tools—urban growth boundaries, concurrency requirements, and location efficient mortgages (LEMs).

Quantitative relationships among land use, travel, and fuel consumption have been examined by various researchers. Although land use patterns may account for 40 to 50 percent of urban-travel variations across cities, there are many challenges to altering land use patterns, and some researchers suggest that even significant changes in urban spatial structure may bring about travel reductions of no more than 12 percent.⁴³ At least one simulation of comprehensive land use measures and travel pricing in Portland, Oregon, has suggested greenhouse gas reductions of nearly 8 percent relative to what they would have been without these measures. Although these estimated reductions are significant and exceed many estimates of the potential of conventional transportation demand management (TDM) measures, various conclusions

have been drawn about the effectiveness of strategies that attempt to alter land use patterns.⁴⁴ It is difficult to isolate the effect of individual land use strategies since they often occur in combination, and they may have synergistic effects. Land use strategies are discussed below under the following headings:

- ◆ STRATEGIES TO INCREASE DENSE, MIXED USE, AND TRANSIT-ORIENTED DEVELOPMENT; and
- ◆ ENHANCEMENTS TO THE PEDESTRIAN ENVIRONMENT.

STRATEGIES TO INCREASE DENSE, MIXED USE, TRANSIT-ORIENTED DEVELOPMENT

Primary Target	Approach	Timing	Level of Implementation
Reduce Vehicle Travel	Regulation or Incentives	Long-term Effect	Local

Description of Strategy

Increasing land use mixing involves locating land uses with complementary functions close enough to one another such that travel distances are minimized. Focusing dense development on transit stations and corridors provides the density necessary for efficient mass transit service and encourages transit use. In combination, these land use patterns may reduce vehicle travel by allowing individuals to walk or take transit among housing, shopping, and employment; to reduce vehicle trip lengths; and to combine trips rather than taking separate vehicle trips. A regional land use strategy might target new development to specific transit corridors or encourage infill development in existing communities and raise transit ridership sufficiently to realize a net reduction in greenhouse gases.

A variety of policies may be used to achieve land use goals. Policies may be either regional in scope, such as urban growth boundaries and concurrency requirements, or more localized in nature, such as developer incentives and zoning.

Effectiveness Factors

The effectiveness of strategies that attempt to alter development densities, mixes, and orientation depend on:

- ◆ Expected growth and development patterns;
- ◆ The effectiveness of policies to alter development patterns;
- ◆ Behavioral and attitudinal forces (whether people demand mixed use, dense development); and
- ◆ The effect of land use patterns on vehicle travel and speeds.

Most of the land use literature has focused on the last factor. A number of regional analyses of alternative development patterns and transportation investments have suggested that more compact, transit-focused development patterns result in less vehicle travel than dispersed development patterns.⁴⁵ For example, a study of alternative patterns of future residential development in the Baltimore region found that under a centralized pattern (in which a significant portion of anticipated residential growth was allocated to areas within the region’s “development envelope”), daily vehicle miles of travel (VMT) were reduced by 0.9 percent and severely congested VMT was reduced by 1.7 percent compared to the adopted base plan. A decentralized pattern resulted in an increase in daily VMT of 1.8 percent and an increase in severely congested VMT of 1.6 percent compared to the base case.⁴⁶ The benefits of compact development may have been understated since the benefits were estimated using traditional transportation demand models that do

not assume vehicle trip generation rates are affected by land use and also do not account for pedestrian and bicycle trips.

Work in the Portland, Oregon, region is noteworthy because of its sophisticated travel demand model systems that include sensitivity to land uses and extensive use of land use data. In the Region 2040 process, alternative land use patterns were examined. In the base case, the urban areas expanded by more than half their current size. In the Growing Up alternative, all urban growth was maintained inside the current urban growth boundary. The results of simulations suggest that the Growing Up scenario doubled the amount of regional transit travel from 3 to 6 percent, and reduced regional VMT by 16.7 percent compared to the base scenario.⁴⁷

In addition to simulation studies, empirical comparisons of various neighborhoods have been used to suggest that higher density, mixed use, and transit-oriented communities are associated with increased shares of transit and pedestrian travel and reduced VMT. For example, a 1994 study of the San Francisco Bay Area households found that households in newer suburban communities had substantially higher vehicle trip generation rates, a higher proportion of drive alone trips, and a lower percentage of public transportation trips than households in traditional communities.⁴⁸ Similarly, a 1996 study that examined travel diaries of residents in three Seattle mixed-use neighborhoods concluded that the pedestrian share of work trips was 11.3 percent in mixed-use communities, as opposed to 3.6 percent in King County as a whole.⁴⁹ An analysis of odometer readings from 27 California communities suggested that residential density and access to public transportation were the two urban form factors that most reliably predicted household auto travel behavior, and that doubling residential density reduced annual auto mileage per capita by 20 percent.⁵⁰ Similarly, an analysis of trips reported in the 1990 National Personal Transportation Survey (NPTS) found that each doubling in density reduced VMT per capita by 28 percent over the entire urban range of densities.⁵¹

Despite significant consensus that traditional and transit-oriented communities are associated with less vehicle travel than planned unit (suburban) development, there is disagreement on the total energy use implications of increasing density since denser areas are also often associated with reduced average travel speeds.⁵² In addition, nearly all of the empirical studies on land use and travel are cross-sectional. These studies show how variations in land use are associated with variations in VMT but do not prove a causal relationship or show how changes in one variable would result in changes in another. Resident self-selection may explain much of the observed correlation, since people who do not like to drive or cannot drive might tend to seek out high density neighborhoods with good transit access. Thus, some researchers assert that some studies do not support conclusions about how changes in structure will affect travel patterns.⁵³

Finally, there is some uncertainty about the effectiveness of planning strategies to alter land use. The amount of development that can be shaped by land use strategies depends on growth in population and employment and on preferences for various types of development styles. The effect of a strategy depends on the extent to which it changes development decisions. For example, an urban growth boundary that is large may not do much to encourage infill development. Developer incentives for higher-density development may not be effective if developers do not feel the market will support such plans.

Timing

Since most land-use strategies primarily affect new development, there may be considerable time lags between the implementation of land use strategies and effects on vehicle travel.

Implementation Issues

Most land-use planning in the US occurs at the local level. Implementation of effective land-use strategies generally requires regional coordination, which may be difficult to achieve. Among the political issues that might arise is what jurisdiction could assume responsibility for establishing and enforcing an urban growth boundary. An equally sensitive issue is who would ensure that municipal zoning conforms with regional development goals. Land-use initiatives often suffer from both not-in-my-backyard (NIMBY) resistance at the local level and a lack of common vision on the ideal metropolis.⁵⁴ For example, infill development, the addition of mixed use developments, and high densities are often opposed by home-owners of established single-family neighborhoods, who are afraid that multi-family housing in their vicinity will have an adverse effect on property values.⁵⁵ On the other hand, communities may wish to implement land use strategies to meet a variety of goals, including preservation of open spaces, downtowns, and older communities; reduction of traffic congestion; and enhancement of accessibility.

ENHANCEMENTS TO THE PEDESTRIAN ENVIRONMENT

Primary Target	Approach	Timing	Level of Implementation
Reduce Vehicle Travel	Regulation; Infrastructure Investment	Mid-term Effect	Local

Description of Strategy

Efforts to enhance the safety and pleasantness of the pedestrian environment include the provision of sidewalks, clearly marked crosswalks, walk signals, and median strips. Pedestrian enhancements can also be a component of a larger scale design plan and may include the addition of lighting, benches, shade trees, and streetscapes designed with a pedestrian focus. Design elements may involve placing porches and home entrances in the foreground and garages and driveways further back on residential properties. In commercial areas, they may involve focusing stores to the street with window displays, reduced building setbacks, and incorporating pedestrian entrances rather than requiring individuals to walk through parking lots or garages. In addition, slowing vehicle traffic through traffic-calming measures can improve pedestrian safety.

Effectiveness Factors

People often drive short distances because pedestrian connections are often lacking. The effectiveness of pedestrian strategies to reduce emissions depends on:

- ◆ The extent to which pedestrian improvements cause shifts from vehicle trips to pedestrian trips; and
- ◆ The length of trips.

Modeling done in Portland, Oregon suggested that the pedestrian environment may be a significant factor in determining automobile ownership. In addition, it may also influence daily auto VMT and vehicle trips per person.⁵⁶ In the LUTRAQ study, a pedestrian environment factor (PEF) was developed that measures ease of street crossing, sidewalk continuity, street connectivity, and topography, with a qualitative assessment on a scale of four to twelve. Each unit increase in PEF resulted in a reduction in 0.7 vehicle miles traveled daily per household.⁵⁷ Similarly, the Maryland National Capital Parks and Planning Commission (M-NCPPC) has shown that pedestrian and bicycle friendliness is a significant factor in determining work trip mode choice.⁵⁸

Empirical analyses have come to similar conclusions. For example, a comparison of employment sites in Southern California found that areas perceived as safe and aesthetically pleasing had lower levels of drive-alone commute trips and higher proportions of transit, bicycle, and walk trips than sites perceived as less pedestrian-friendly.⁵⁹ A recent study compared two Puget Sound area neighborhoods that were similar in terms of gross residential density and intensity of commercial development. It found that the neighborhood with a high level of pedestrian network connectivity had almost three times as much pedestrian activity as the one with a low level of pedestrian connectivity.⁶⁰

Unlike transit and carpooling, walking is a non-motorized form of transportation, so none of the emissions reduced from less vehicle travel are offset by additional pedestrian activity. The potential VMT reduction from shifting vehicle trips to walking is somewhat limited because the maximum walking trip is generally short.

Timing

Pedestrian-oriented measures can have an immediate effect in encouraging pedestrian activity and reducing vehicle travel through the addition of sidewalks, traffic calming measures, and sidewalk lighting. Other measures that focus on new development may involve significant time lags from strategy implementation to full effect.

Implementation Issues

Improving the pedestrian-environment is primarily limited to policies by local government that influence developers and individual property-owners. Other benefits of an enhanced pedestrian environment include improved quality of life, public safety (pedestrian traffic may deter crime), and physical fitness.

5.2.5 OTHER VEHICLE TRAVEL REDUCTION MEASURES

Other strategies to reduce vehicle travel demand typically rely on voluntary measures by individuals, employers, or communities. Some of these measures focus on commute travel and involve employer/employee relations. Government policy may include incentives, education, and information to encourage voluntary measures. Specific strategies include encouraging:

- ◆ TELECOMMUTING;
- ◆ COMPRESSED WORK HOURS (OR OTHER ALTERNATIVE WORK ARRANGEMENTS); and
- ◆ RESTRICTIONS ON VEHICLE USE.

TELECOMMUTING

Primary Target	Approach	Timing	Level of Implementation
Reduce Vehicle Travel	Education and Information	Near-term Effect	Employer-Based

Description of Strategy

Telecommuting has been defined as the partial or complete substitution of telecommunications services for transportation to a conventional workplace.⁶¹ Telecommuters utilize computer and tele-communications equipment to work from home or a local telecenter close to home. By telecommuting, employees may either eliminate work trips entirely or shorten their length significantly.

The goal of a telecommuting strategy is to increase employer and employee awareness of and remove barriers to telecommuting in order to increase use. Since telecommuting involves individual places of employment, public policy tends to be limited to education, encouragement, and promotion. These tend to be voluntary programs, and government may develop incentives to increase use. Thus far, telecommuting policies have been limited to the following:⁶²

- ◆ Adoption of telecommuting by public agencies;
- ◆ Consideration of telecommuting programs as a transportation control measure for purposes of certifying compliance with air-quality regulations; and
- ◆ Fostering of these voluntary actions through research on benefits and information about how to set up work rules.

The promotion of greater use of telecommuting is Action #21 in the *US Climate Change Action Plan*.

Effectiveness Factors

The effectiveness of a telecommuting strategy depends on three factors:

- ◆ The degree to which telecommuting reduces vehicle travel and improves traffic flow;
- ◆ Indirect increases in travel from improved traffic flow and increased dispersion of development; and
- ◆ The degree to which public efforts increase the rate of adoption by employers.

Although telecommuting can reduce vehicle travel for those that participate, its effect is limited for a number of reasons. In particular, telecommuting only targets commute travel, which is only about one quarter of total vehicle miles traveled.^{xvii} Telecommuting is feasible for only a portion of all workers—primarily information workers—and those that participate will often only eliminate one to three days of commute per week. In addition, some of those that participate may have taken transit or carpools in the past. Trips previously chained with the work trip will still need to be made.

^{xvii} Personal travel accounts for about 75 percent of total highway vehicle travel (Energy Information Administration, 1990), and the journey to work accounts for about 32 percent of personal vehicle travel (Nationwide Personal Travel Survey).

Indirect effects offset some of the reduction in commute travel. Reduced congestion may induce additional vehicles to use highways. In addition, telecommuting may exacerbate trends toward increased geographic dispersion of residences and places of employment, which would increase driving distances for non-commute trips. Despite these countervailing effects, a scenario analysis conducted by the US DOE suggests that the net benefits of telecommuting are positive. The countervailing effects of latent demand and increased urban sprawl reduced the potential effect on fuel consumption by 55 percent. However, fuel consumption would be reduced by over 1.5 billion gallons and carbon dioxide emissions would be reduced by 11.6 million metric tons.⁶⁴

The *Climate Change Action Plan* estimated that a national strategy to promote telecommuting, including the implementation of a Federal telecommuting pilot project, could reduce 3.3 billion VMT and save 170 million gallons of motor fuel by the year 2000.⁶⁵ These figures were estimated by assuming a relatively modest increase in telecommuting rates due to the program; however, they did not account for induced travel or increased travel due to increased sprawl associated with telecommuting.

Telecommuting is projected to increase even in the absence of any coordinated government actions. It is unclear to what extent public efforts can encourage additional adoption of telecommuting by private employers.

Timing

Public efforts to encourage telecommuting could have a near- to mid-term effect on emissions. Some time lags will occur between implementation of the public incentive and actual participation in telecommuting programs because employers may be somewhat slow to acquire necessary telecommunications equipment or it may take some time for a community to develop a neighborhood telecenter and attract corporate participation.

Implementation Issues

Implementation of a telecommuting program requires expenditures for computers and telecommuting equipment, which may be incurred by the employee or employer. A program that utilizes a neighborhood telecenter may be more expensive than home-based commuting, and may involve government financing. Generally, however, public costs are small.

The exact nature of the social effects of widespread telecommuting are not well understood because telecommuting is a recent phenomenon.⁶⁵ However, it is believed that telecommuting may yield benefits in terms of increased employee effectiveness and productivity, higher morale and job satisfaction, decreased absenteeism and sick time, and decreased overhead costs (since less office space may be needed).⁶⁶ Utilization of more advanced technology can stimulate economic growth and contribute to productivity throughout the economy. Increased telecommuting is likely to reinforce trends toward the dispersal of economic activities and population, and may raise important issues concerning disparities between workers with the option of telecommuting and those for whom telecommuting is not feasible.

COMPRESSED WORK HOURS

Primary Target	Approach	Timing	Level of Implementation
Reduce Vehicle Travel	Education and Information	Near-term Effect	Employer-Based

Description of Strategy

Compressed work hours is a program that allows individuals to work more hours per day and fewer days per week. A typical program involves working 10 hours, 4 days a week, rather than 8 hours, 5 days a week. For each employee working under this schedule, this strategy eliminates one round-trip to work each week. In addition, the change in daily work hours can often reduce peak-period travel. Like telecommuting, the strategy has been limited to education and encouragement or pilot programs at government worksites.

Effectiveness Factors

The effectiveness of efforts to encourage compressed work hours depends on the following factors:

- ◆ The degree to which compressed work hours reduces commute vehicle travel for those who participate;
- ◆ Effects on traffic flow;
- ◆ Increases in trip-making on days off from work;
- ◆ Indirect increases in travel from improved traffic flow; and
- ◆ The degree to which public efforts increase the rate of adoption by employers.

Compressed work hours programs have many of the same limitations of telecommuting programs—commute travel is only a small portion of total transportation emissions, it only reduces travel one day per week or every two weeks, not all employees will be able to participate, and there may be some offsetting increases in travel. It also is not clear to what extent government efforts will induce adoption by private employers.

According to EPA's Transportation Control Measures Information Documents, there is only one example in the literature where the transportation impacts of a coordinated compressed work-hours program have been systematically documented. Denver participated in a federal employee compressed work-week experiment from 1978-1981. Findings were favorable. Among employees participating, there was a 15 percent reduction in commute VMT, and a shifting of peak arrival and departure times. There was little change in modal share. Overall, participants reduced household VMT by almost 16 percent. Although there was some increase in non-work trips during the employees' day off, this was offset by a drop in weekend VMT.⁶⁷

Timing

Public efforts to encourage compressed work hours and flexible work schedules would have a near-term effect on emissions. In most cases, employers could implement such programs relatively quickly. The effectiveness of these programs might increase over time as employers become more familiar with the programs.

Implementation Issues

Costs of implementing compressed work hours are relatively low for employers and government. Government at all levels may participate in education and incentives to promote alternative work arrangements.

Substantial levels of use of alternative work arrangements could reduce congestion. Alternative work arrangements may also reduce the need for highway capacity expansion, thereby saving capital and maintenance costs, urban land, and travel time for individuals.

VOLUNTARY RESTRICTIONS ON VEHICLE USE (NO DRIVE DAYS)

Primary Target	Approach	Timing	Level of Implementation
Reduce Vehicle Travel	Education and Information	Near-term Effect	Local

Description of Strategy

No-drive days refer to programs aimed at restricting the use of vehicles on specific days of the week. Although several foreign cities, such as Athens, Mexico City, and Santiago, as well as the Republic of Singapore have established mandatory no-drive days or severe restriction on driving during certain time periods, all US programs to date have been voluntary and in many cases encourage alternatives to single-occupancy vehicles.⁶⁸ These programs may either tie the no-drive day to license plate numbers or to days during which air quality is forecast to be particularly poor.

Effectiveness Factors

The effectiveness of programs to restrict vehicle use depends on:

- ◆ The approach taken—whether restrictions are mandatory, voluntary, or utilize incentives;
- ◆ The degree to which voluntary programs or incentives affect driving behavior; and
- ◆ The extent of adoption of programs nationwide.

According to EPA, it is difficult to measure the effectiveness of no-drive day programs. The voluntary nature of no-drive days inherently limits their potential effectiveness.⁶⁹ EPA notes that voluntary programs have the most participation during “challenge” periods in which participants receive recognition and prizes for successfully participating. These programs use incentives as an approach; in addition, education about problems associated with travel, such as smog and associated health costs, may spur individual action.

Timing

Restrictions on vehicle use and education and incentives to encourage travelers to voluntarily reduce vehicle use should have an immediate effect on traveler behavior.

Implementation Issues

No-drive days, whether voluntary or mandatory, are generally implemented at the regional level. Because they are typically voluntary in nature, they avoid costs of monitoring and enforcement. However, these programs tend to function most effectively with some incentives to induce participation, which may require

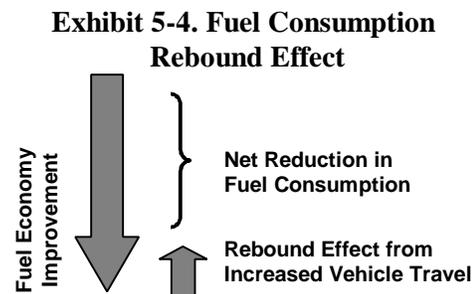
some minor costs. In addition, media participation can be important. Often, the media and employers will volunteer to participate in promotion efforts.

Primary benefits of no-drive days include air quality improvement and congestion relief. According to EPA's Transportation Control Measures Information Documents, an additional benefit is that the programs can draw communities together and improve education about pollution that helps in the effectiveness of other programs.

5.3 FUEL-ECONOMY-FOCUSED STRATEGIES

In addition to reducing vehicle travel, a second target that can achieve reductions in greenhouse gas emissions from transportation is the improvement in the fuel economy of vehicles. Since emissions of CO₂ are directly proportional to the amount of fuel burned, any improvements in fuel efficiency reduce greenhouse gas emissions per mile proportionately. Fuel economy is generally expressed in terms of miles per gallon (mpg). Since demand for vehicle travel is expected to grow as a result of rising population and income, it would not be possible to stabilize fuel consumption from motor vehicles without improving fuel economy. Fuel economy can be improved by improving traffic flow and by improving vehicle technologies. Strategies can either “push” vehicle manufacturers to produce more efficient vehicles or “pull” them by encouraging individuals to demand more fuel-efficient vehicles.

Although fuel economy improvements reduce fuel consumption, these improvements can lead to a “rebound effect” as shown in Exhibit 5-4. An increase in mpg reduces the fuel cost-per-mile of travel. Lower variable costs of travel lead to increases in VMT. Some estimates suggest that this “rebound effect” may be 10 to 15 percent of the emissions reduction resulting from the improved fuel economy.⁷⁰ Some studies provide higher estimates of the elasticity of VMT with respect to fuel efficiency improvements in the range of 0.2 to 0.3, meaning that for every percentage gain in fuel efficiency, consumers increase vehicle use by 0.2 to 0.3 percent.⁷¹ Differences in elasticity assumptions can have significant implications on the relative effectiveness of fuel economy strategies versus fuel and travel pricing strategies.



5.3.1 IMPROVING TRAFFIC OPERATIONS

For a given vehicle, on-road fuel economy is a function of average speed and acceleration. At low speeds, a greater proportion of energy to the engine goes to internal engine friction and to operating accessories such as power steering and transmission, oil and water pumps, and air conditioners. Braking directly translates the vehicle's momentum into heat energy.⁷² Since characteristics of highway congestion—low travel speeds, increased braking and accelerations, idling—are associated with increased fuel use, strategies to reduce congestion and improve traffic flow can reduce greenhouse gas emissions.

At speeds above 55–60 mph, increasing aerodynamic drag causes fuel economy to decline. Oak Ridge National Laboratory is currently conducting tests of light-duty vehicles to characterize their fuel consumption over most of their operating ranges, to represent fuel economy as functions of vehicle speed and acceleration. Preliminary tests showed over 20 percent of fuel economy loss occurs between 55 and 75

mph.⁷³ This fuel economy loss is similar to losses estimated from earlier studies in the 1970s and 1980s.^{xviii} Thus, policies to limit speeds to 55 mph may be used to reduce greenhouse gas emissions.

The effect of travel characteristics on fuel economy is reflected in the shortfall between vehicle sticker fuel economy and actual on-road fuel economy. Strategies that attempt to reduce fuel consumption and emissions by affecting traffic conditions may include:

- ◆ TRAFFIC FLOW IMPROVEMENTS;
- ◆ LIMIT FREEWAY SPEEDS TO 55 MPH; and
- ◆ DRIVER EDUCATION.

TRAFFIC FLOW IMPROVEMENTS

Primary Target	Approach	Timing	Level of Implementation
Improve Fuel Economy	Infrastructure Investment	Near-term Effect	State, Local

Description of Strategy

Traffic flow improvements encompass a wide range of programs to smooth traffic flow, reduce idling, and eliminate bottlenecks:

- ◆ *Signalization improvements* can reduce intersection delay on arterials and other routes in urbanized areas.
- ◆ *Incident management* and advanced traffic sensing technologies allow faster response time to remove breakdowns and accidents from the road.
- ◆ *Intelligent Transportation Systems (ITS)* encompass a range of technologies that develop more intelligent vehicles and transportation infrastructure, including use of real-time information on traffic conditions, directions to unfamiliar places, and identification of alternate routes.

Effectiveness Factors

The effectiveness of signalization and other traffic flow improvements depends on the following factors:

- ◆ Existing levels of congestion/current traffic speeds and operational conditions;
- ◆ Technical ability of traffic signals, incident management, and ITS to alleviate congestion;
- ◆ Extent of increase in vehicle travel; and
- ◆ Extent of investment in and adoption of traffic flow improvement measures.

Although traffic flow improvements can lead to significant reductions in delay on particular routes and at particular times, fuel savings will be reduced by a smaller percentage since delay only consumes a portion of vehicle fuel over the course of a trip. For example, a new traffic control signal system in Los Angeles was estimated to reduce signal delays by 44 percent, vehicle stops by 41 percent, and fuel consumption by 13 percent. A study of retiming several Virginia signal systems estimated that it would reduce stops by 25

^{xviii} However, two previous studies by the Federal Highway Administration indicated maximum fuel efficiency was achieved at speeds of 35 to 45 mph. Preliminary data from the ORNL study suggest that maximum efficiency may occur at higher speeds, near 55 mph.

percent, travel time by 10 percent, and fuel consumption by 4 percent.⁷⁴ California’s Fuel Efficient Traffic Signal Management program, which optimized 3,172 traffic signals through 1988, documented an average reduction in vehicle stops of 16 percent and in fuel use of 8.6 percent in the affected areas.⁷⁵ Since one-fifth of total VMT in California is traveled on streets controlled by traffic signals, statewide implementation with comparable success would potentially save 1.7 percent of total highway fuel consumption. Effectiveness might be limited, however, since improving traffic flow lowers the “time” costs of travel, which might encourage additional vehicle travel.

The national effect of signalization and other traffic flow improvements depends on the extent of adoption by local areas. There appears to be large potential for implementation of traffic signalization improvement projects and other traffic flow improvements, given increasing highway congestion. The Institute of Transportation Engineers estimated in 1989 that 74 percent of the approximately 240,000 signalized intersections in the nation’s urban areas needed upgraded physical equipment or improved signal timing. A 1990 review of 24 signal systems by the Federal Highway Administration found that 21 systems did not meet the minimum standards of performance.⁷⁶

Timing

Signalization can be improved quickly through technology, which should have an immediate effect on traffic conditions. Many regions are currently investigating and are in the initial phases of deploying mechanisms to integrate traffic control systems and ITS technologies.

Implementation Issues

States and localities may support investment in signalization and other traffic flow improvements for potential congestion benefits. For example, an analysis of a new signal system implemented at 365 intersections in Orlando, Florida showed a 56 percent reduction in vehicle stops and delays.⁷⁷ Implementation concerns that have surfaced include institutional barriers regarding integrating signal timing plans across jurisdictions and technological needs such as fiberoptic networks to relay real-time traffic information.

LIMIT FREEWAY SPEEDS TO 55 MPH

Primary Target	Approach	Timing	Level of Implementation
Improve Fuel Economy	Regulation	Near-term Effect	Federal, State

Description of Strategy

Beyond 55 miles per hour, fuel economy is generally a decreasing function of speed for both cars and trucks. The national 55 mph speed limit, repealed in 1995, was originally passed by Congress in 1974 as an energy conservation measure. A greenhouse gas reduction strategy would be to re-apply the national 55 mph speed limit or encourage states to voluntarily limit speeds on interstates and freeways to 55 mph.

Effectiveness Factors

The effectiveness of speed limits as a national carbon dioxide emissions reduction strategy depend on:

- ◆ The differential in fuel economy at different speeds;
- ◆ The number of highways where speed limits are maintained or limited to 55 mph; and

◆ Stringency of speed enforcement.

EPA estimates that traveling at 65 mph as compared to 55 mph lowers fuel economy over 15 percent.⁷⁸ Preliminary testing of vehicles at Oak Ridge National Laboratory for US DOT suggest that an increase in speed from 55 to 65 mph may reduce fuel economy by over 11 percent and that increasing from 55 to 70 mph may reduce fuel economy by over 23 percent.⁷⁹

In addition to the technical efficiency of vehicles, the effectiveness of a national speed limit depends upon enforcement and compliance with the maximum speed. According to FHWA statistics for Fiscal Year 1993, the average speed on urban interstates with a posted 55 mph speed limit was 58.5 mph, with 70.0 percent of traffic exceeding 55 mph. On rural interstates with a posted speed limit of 55 mph, the average travel speed was 66.9 mph, with 78.1 percent of vehicles exceeding 55 mph.⁸⁰

Various estimates of energy savings from the national 55 mph limit indicate that despite imperfect compliance, it may reduce national fuel consumption on highways by about 1 to 3 percent.⁸¹ A 1984 study by the National Research Council (NRC) concluded that in 1983, the national speed limit reduced highway fuel consumption by about 2.2 percent.⁸²

Timing

Re-application of the national speed limit in the near term may be unlikely given that it was repealed in 1995 as part of the law designating the National Highway System. However, states may choose individually to limit highway speeds to 55 mph. Speed limits have an immediate effect on travel speeds and emissions levels.

Implementation Issues

Adjusting speed limits is simple for states and imposes minimum public-sector costs. However, for drivers, time is a major cost associated with travel. Lowering speed limits imposes a substantial cost on drivers. On the other hand, there are a number of non-greenhouse gas benefits that could encourage re-introduction of lower speed limits. In particular, a reduced speed limit has been advocated as a traffic safety measure. One study estimated that the 55 mph speed limit saved 3,000 to 5,000 lives annually in the early years after its implementation and 2,000 to 4,000 annually during the early 1980s.⁸³ There has not been consensus on the safety implications of recent increases in speed limits. Traveling at 55 mph may also be promoted as a means to reduce emissions of some criteria pollutants.

DRIVER EDUCATION

Primary Target	Approach	Timing	Level of Implementation
Improve Fuel Economy	Education and Information	Near-term Effect	Federal, State, Local

Description of Strategy

An education strategy would involve the development of courses for commercial truck drivers and private motorists or the inclusion of information on fuel-efficient driving practices—such as reduced idling time and quiet accelerations—into driver education programs. A broader education program might involve information to discourage vehicle idling or to promote off-peak travel for discretionary trips (reducing congestion). Education helps the driver to associate an economic incentive with efficient driving, since it shows the driver that improved fuel economy results in decreased fuel expenditures.

Effectiveness Factors

The effectiveness of driver education programs depends upon:

- ◆ The number of drivers that are reached by such programs;
- ◆ The extent to which these programs yield long-term changes in driver behavior; and
- ◆ The extent to which the behavioral changes reduce emissions.

The Department of Energy's Driver Energy Conservation Awareness Training program developed in the late 1970s for commercial truck drivers and private motorists demonstrated potential fuel economy improvements of approximately 10 percent for both groups.⁸⁴ These results suggest that there is potential for efficiency improvements through these programs. On the other hand, it may be increasingly difficult for drivers to change driving habits. As the real cost of gasoline has fallen since the late 1970s, drivers may be less responsive to adjusting driving behavior in order to reduce fuel costs. No recent evidence was found on the potential of such a program.

Since energy efficiency training never became incorporated into the official curricula for licensing, the number of people reached by these programs to date has been small. Effectiveness as a national greenhouse gas strategy would depend on the extent of adoption of such programs in driver education curricula.

Timing

Driver education would have an immediate effect on fuel consumption as drivers adjust their driving practices. There is evidence that the effectiveness of training falls as time from training increases; therefore training must be conducted on a periodic basis or be refreshed over time.⁸⁵

Implementation Issues

There are modest up-front costs to develop curricula and training materials. Generally, education programs are accepted by the public if well designed. In addition to reducing greenhouse gas emissions, driver education programs would reduce emissions of criteria pollutants, which also are affected by idling, accelerations, and decelerations.

5.3.2 VEHICLE TECHNOLOGY IMPROVEMENT

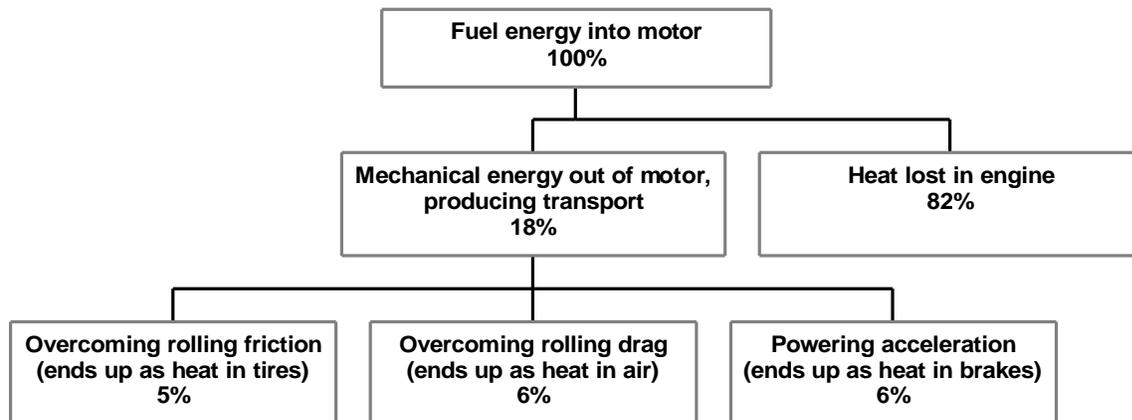
Improving the efficiency of conventional vehicles has been advanced as a means to reduce fuel consumption.^{xix} Some vehicles consume less fuel per mile than others under equivalent driving conditions due to physical attributes of the vehicle—size, weight, and technology. However, fuel economy is only one of the many factors that designers consider when developing a vehicle, and only one of the factors that consumers consider when making vehicle purchase decisions. Recent consumer trends have been toward the purchase of more light trucks (e.g. minivans, pick-up trucks, sport utility vehicles), which generally get fewer miles per gallon than automobiles.⁸⁶ As a result, measures to encourage vehicle manufacturers to develop more fuel-efficient vehicle technologies have been advanced.

A starting point for assessing the potential role of vehicle technologies in reducing greenhouse gases is to examine the degree to which fuel economy improvements are technically feasible and can be

^{xix} Vehicle technology advances that would use alternative fuels, such as electric vehicles, are discussed in Section 5.4 of this report.

commercialized. A number of redesign options have been identified to increase the fuel economy of the conventional internal combustion engine (ICE) vehicle. Exhibit 5-5 illustrates the consumption of energy from gasoline in an average of highway and urban driving cycles, ignoring the secondary factors of bearings and accessories.

**Exhibit 5-5. Energy Consumption by Gasoline-Powered Vehicles
(Average of Highway and Urban Driving Cycles)**



Under high power, the engine efficiency may rise to 30 percent, but under typical driving, efficiency is closer to 15 percent than the 18 percent shown. About one-third of the mechanical energy goes into rolling friction, one-third into air drag (closer to three-fourths at steady highway speeds), and one-third into heating the brakes to decelerate the car (more in urban driving).

Vehicle redesign to improve fuel economy must address the components of energy use and loss. Vehicles would use less fuel if engine efficiency increased, if lower weight and better tires gave less tire drag, if vehicle aerodynamics were improved, and if lower weight or regenerative braking saved some braking loss. Some key technology improvements being considered for introduction or wider application in US markets include the following:^{xx}

Engine Technologies—Engine improvements would improve mechanical efficiency. Some improvements that could enhance the efficiency of all types of engines include:

- ◆ *Boosting*—Boosting refers to the use of a turbocharger or supercharger to pressurize cylinder intake air, allowing more fuel to be burned and greater power to be delivered by an engine of a given displacement. Although typically applied to enhance power performance, boosting can increase fuel economy if engine displacement is reduced while maintaining fixed vehicle performance.

^{xx} Note that the state-of-the-art in technology is constantly advancing. This report summarizes recent literature that identifies various technological improvements but may fail to represent some of the emerging or more speculative technologies that are less well documented.

- ◆ *Idle off*—Idle off allows the engine to be turned off when no power is demanded, such as when a vehicle is stopped, braking, or coasting.

The use and improvement of different types of engines holds the potential for fuel savings.

- ◆ *2-stroke engines*—Two-stroke engines offer potential fuel economy improvements of 15 to 20 percent over four-stroke engines of comparable power since power from a cylinder is delivered on every revolution of the crankshaft, in contrast to once every two revolutions for a four-stroke engine.⁸⁷ This results in higher efficiency and superior specific output and power-to-weight ratios. A technical challenge for two-stroke engines is meeting NO_x emissions requirements.
- ◆ *Improvements to efficiency of 4-stroke gasoline engines*—Energy savings are possible in conventional four-stroke gasoline engines through a variety of technological improvements, such as overhead camshafts, variable engine control, and reduced engine friction.⁸⁸ A *four-valve engine* (four valves per cylinder) permits an engine to be replaced by a smaller engine with equivalent performance (e.g. a 4- or 6-cylinder engine could replace a 6- or 8-cylinder engine of equivalent performance). Higher peak-power output means that power needs can be met with an engine of smaller displacement, which also lowers total engine friction. Multi-valve engines are nearly universal in Japan and widespread in Europe, but still relatively uncommon in the US.⁸⁹ *Variable engine control* may involve variable displacement or variable valve control (VVC), which permits valve positions to be controlled depending on operating conditions, permitting a more optimal management of induction and exhaust processes. A *four-stroke direct-injection stratified charge (DISC) gasoline engine* reduces fuel flow at part load by injecting fuel directly into each cylinder at high pressures in such a way that the fuel/air mixture is stratified, with high fuel concentrations near the spark plug to maintain stable combustion. The combination of zero throttling losses, low fuel use at light loads because of very lean fuel mixture, and more precise control of combustion yields substantial fuel efficiency improvements.
- ◆ *Diesel engines*—Diesel direct-injection engines offer a 25 to 40 percent fuel-economy improvement over similar displacement spark-ignition engines because of their much higher compression ratios, high part-load efficiency, inherently lean operation, and amenability to turbocharging.⁹⁰ However, this translates into a smaller carbon emissions reduction (about 10 to 20 percent) since diesel fuel has a higher carbon content per gallon than motor gasoline. European automakers have advanced many of the diesel engine's traditional disadvantages, such as noise, smoke, poor acceleration, and cold start problems. However, the most important obstacle is exhaust emissions, especially NO_x and particulate matter.

Transmissions—Transmission improvements would improve fuel economy since an optimal synchronization of the transmission with the engine is required to maximize the amount of time an engine operates near peak efficiency.

- ◆ *Continuously variable transmission (CVT)*—CVT allow engines to operate at the maximum efficiency under a given load and rev the engine when more power is needed.
- ◆ *Optimal transmission control*—Transmission optimization could be implemented through electronic control, termed Aggressive Transmission Management (ATM).
- ◆ *Adding gears*—A five or six-speed automatic would keep the engine operating at as low RPM as possible, subject to smoothness and driveability constraints.

Load Reduction—Load includes air and tire resistance, inertia and braking (related to vehicle mass), plus accessories such as heating, air conditioning, and power steering. Reducing load reduces the engine’s power-producing requirements and the transmission’s power-transmitting requirements.

- ◆ *Weight reduction*—Extensive use of aluminum and other light-weight materials in suspension and other components, as well as redesigns to seats, bumpers, and other components could potentially reduce vehicle weight significantly. ^{xxi} A 30 percent reduction in weight may be feasible without compromising passenger comfort, safety, or performance.⁹¹
- ◆ *Reduced rolling resistance*—Rolling resistance can be reduced through improved design of differential gears in axles, steerable rear wheels and better wheel design. In addition, high-pressure and narrower tires can contribute to lower rolling resistance but may negatively affect vehicle handling. There is potential to reduce rolling resistance by about 30 percent without compromising passenger comfort, safety, or performance.⁹²
- ◆ *Improved aerodynamics*—Reductions in aerodynamic drag coefficients of vehicles can be achieved by styling, reducing the area of air intakes for engines and air conditioning, reducing protrusions, making windows flush with body panels, and covering the underside of the vehicle with smooth sheet material. For most vehicle types, there is potential to reduce vehicle wind resistance by 30 percent without radically altering shape or affecting passenger comfort.⁹³
- ◆ *Reduced accessory loads*—A number of concepts have been proposed as a means to reduce accessory loads, in particular, to improve air conditioner efficiency. Such concepts may play an increasing role in improving vehicle fuel economy as the rest of the vehicle becomes more fuel-efficient.

Regenerative Braking—Regenerative braking would allow the vehicle to recapture energy that would otherwise dissipate as heat.

An estimate of the fuel economy potential of vehicle technology improvements is summarized in Exhibit 5-6. Note that percent improvement in fuel economy does not equal percent reduction in fuel use or CO₂ emissions.^{xxii}

^{xxi} An advanced car (like Ford’s PNGV prototype, the P-2000), will weigh about 2000 lbs, compared to a typical car weight of about 3300 lbs (US EPA. “Light-Duty Automotive Technology and Fuel Economy Trends through 1996.”), which is a 39 percent weight reduction. However, these prototypes use very expensive materials like carbon fiber composites and magnesium, which may not be commercially acceptable due to high cost.

^{xxii} The percent increase in fuel economy tends to be larger than the percent reduction in fuel use and carbon emissions. For example, an increase from 20 mpg to 25 mpg is a 25% increase in fuel economy. This change yields a 20% decrease in fuel consumption (to travel 100 miles requires 5 gallons in the first case and 4 gallons in the second case). The higher the starting mpg, the less fuel is saved per equivalent increment of fuel economy gain. Percent reduction in carbon dioxide emissions also differs if fuel with a different carbon-content is used, such as diesel.

Exhibit 5-6. Fuel Economy Improvement Potential of Conventional Vehicle Technologies

Technology	Fuel Economy Improvement Potential^{xxiii}
2-stroke engines	15% to 20% (compared to 4-stroke engines of similar power output)
4-stroke direct injection stratified charge engines	18% to 23%
Direct-injection diesel engines	25% to 40% (compared to similar displacement gasoline engines)
Continuously variable transmissions (CVTs)	3% to 10%
Lightweight materials: aluminum, magnesium, plastics, composites, powdered metals	10% to 20% (assuming weight reductions of 30% without compromising safety, comfort, or performance)
Reduced rolling resistance	5% to 8% (assuming 30% reduction in rolling resistance)
Improved aerodynamics	5% to 15% (based on reduction in wind resistance of up to 30% without radically changing vehicle shape or restricting comfort)

Source: US Department of Energy, Office of Energy Efficiency and Renewable Energy. *Scenarios of US Carbon Reductions: Potential Impacts of Energy Technologies by 2010 and Beyond*. Prepared by Interlaboratory Working Group on Energy-Efficient and Low-Carbon Technologies. September 22, 1997.

Other advanced alternatives, including use of hybrid-electric or fuel cell power trains, potentially offer an efficiency advantage over conventional internal combustion engine (ICE) drivetrains. These alternatives are discussed in Section 5.4 of this report. Recent efforts by automobile manufacturers to develop and begin marketing hybrid-electric vehicles in Japan and the US by the end of this millennium show promising potential. In particular, hybrid-electric vehicles, which use two drivetrains (an internal combustion engine running on gasoline or alternative fuels and a battery-driven electric drivetrain), have shown considerable gains in mile-per-gallon ratings.

A few studies have examined the potential of these various technologies in an attempt to assess the “technological potential” for fuel economy improvements for the future model-year vehicle fleets. These estimates range from conservative to optimistic. From the conservative perspective, SRI International (1991) estimated that further increases in fleet fuel economy are likely to be less than 3 mpg within 10 years since major gains have already been achieved, safety and emissions standards will degrade fuel economy, and consumers prefer vehicle characteristics that conflict with fuel economy.⁹⁴ From the optimistic perspective, large increases in fleet fuel economy, 45 mpg and higher, have been estimated to be readily obtainable by existing or soon-to-be-available technology.⁹⁵ Several studies provide assessments of the fuel economy improvements achievable through technologies. Exhibit 5-7, on the following page, summarizes six studies.

In 1995, sales-weighted fuel economy estimates were 28.2 mpg for new passenger cars and 20.4 mpg for new light-duty trucks. These studies suggest that major fuel economy improvements of up to 80 percent by 2005-2010 are possible using currently available technologies.^{xxiv} The Partnership for a New Generation of Vehicles (PNGV) has set even higher goals toward improvements in fuel economy.

^{xxiii} Some of the potential technologies listed may have additive or cumulative effects toward gains in fuel economy improvement in conventional vehicles, the extent of which is not yet fully known.

^{xxiv} Note that these studies are a number of years old, so the year of achievement may need to be adjusted to reflect intervening years. Conversely, new technological developments may signify that greater fuel economy gains are feasible. Not all of the estimates are independently derived.

Exhibit 5-7. Estimated Potential for Fuel Economy Improvements

Source	Year Achievable	Scenario	Fuel Economy (mpg)
Difiglio, Duleep and Greene (1990) ⁹⁶	2000	Cost Effective	36.4
		Maximum Technically Achievable	39.4
National Research Council (1992) ⁹⁷	2001	Technically Achievable	31–33
		Automobiles	
	2006	Light-trucks	24–25
		Technically Achievable	
DiCicco and Ross (1993) ⁹⁸	2002-2005	Automobiles	35–37
		Subcompact	39–44
		Large	30–33
		Light-trucks	26–28
Office of Technology Assessment (1994) ⁹⁹	2001	High technological certainty	40–43
		Medium technological certainty (incorporates measures ready for commercialization)	47–50
		Low technological certainty (assumes use of technologies in advanced stage of development)	53–56
Office of Technology Assessment (1995) ¹⁰⁰	2005	No new regulations, rising oil prices	32.9
		With higher CAFE standards	35.5
		Maximum Current technology	38.2
National Research Council (1998) ¹⁰¹	2004	With higher CAFE standards	37.1
		Advanced technologies	45–55
Office of Technology Assessment (1995) ¹⁰⁰	2005	Mid-size car (best-in-class):	38.8*
		Average estimate of technology benefit	
Office of Technology Assessment (1995) ¹⁰⁰	2005	Optimistic estimate of technology benefit	41.7*
		Mid-size car (best-in-class):	53.2-59.0*
Office of Technology Assessment (1995) ¹⁰⁰	2015	Average estimate of technology benefit	
		Optimistic estimate of technology benefit	
National Research Council (1998) ¹⁰¹	2004	Attainment of PNGV targets for preproduction prototypes	80*

*Note: The Office of Technology Assessment (1995) estimates are for "best-in-class" vehicles; the National Research Council (1998) estimate is for preproduction prototypes. Other estimates are for the new car fleet, unless otherwise noted.

The PNGV goal is by 2004 to produce a mid-size family sedan prototype with up to three times the fuel efficiency of comparable 1994 vehicles (implying a fuel economy of approximately 80 miles-per-gallon) that meets customer needs for quality, performance, and utility. While the National Research Council's 4th Annual Independent Review of PNGV found that some of the year 2000 concept vehicle attributes will probably fall short of established targets, the preproduction prototypes are expected to meet the targets by 2004.¹⁰²

Although fuel economy improvements reduce greenhouse gas emissions per VMT, there are several factors that can offset these emission reductions:

- ◆ Higher fuel economy can raise vehicle prices, which could reduce fleet turnover causing less fuel-efficient vehicles to remain on the road longer.
- ◆ Improved fuel economy lowers the fuel cost of driving per mile, which could encourage additional vehicle travel (rebound effect).

A major change in design would most easily gain public acceptance if the new designs do not significantly degrade amenities in terms of space (interior volume), performance, safety, reliability, and convenience in refueling, and if they can be made available at competitive prices.

Public policies may either “push” vehicle manufacturers to improve technologies or “pull” them by influencing consumer behavior and preferences. Two primary strategies to push vehicle technology include:

- ◆ VEHICLE FUEL ECONOMY MANDATES, SUCH AS CORPORATE AVERAGE FUEL ECONOMY STANDARDS (CAFE); and
- ◆ SUPPORT FOR RESEARCH AND DEVELOPMENT (R&D) ON VEHICLE TECHNOLOGIES.

These strategies are described below.

MANDATES ON NEW VEHICLE FUEL ECONOMY (CAFE STANDARDS)

Primary Target	Approach	Timing	Level of Implementation
Improve Fuel Economy	Regulation	Mid-term Effect	Federal

Description of Strategy

The Corporate Average Fuel Economy (CAFE) standards require each automobile manufacturer to meet a minimum fuel efficiency standard for all cars and light trucks sold by that manufacturer in the US in a model year. There are separate CAFE standards for automobiles and light trucks. Established under the 1975 Energy Policy and Conservation Act, CAFE standards required the fuel economy of new cars to increase from about 14 mpg in the early 1970s to 27.5 mpg by 1985, which is the current standard. New light truck fuel economy standards have increased from 17.2 mpg in 1979 to 20.7 mpg in 1997.¹⁰³ Although a number of OECD countries with domestic automobile industries have adopted voluntary fuel economy standards, only the US standards provide legal sanctions for failing to meet the standards.¹⁰⁴

Raising CAFE standards has been advanced as a policy to spur vehicle manufacturers to increase vehicle fuel economy. Regulation is justified on the basis of a market failure, since consumers do not take into account the full costs of fuel use when purchasing a vehicle. In addition to the existing system of CAFE standards where all manufacturers are required to meet the same minimum standard, a number of options for raising CAFE standards have been identified, including:

- ◆ Require automakers to raise their fuel economy by a uniform percentage over that attained in a base year;
- ◆ Base company standards on the attributes of each company’s fleet at the time standards are to be met (i.e., a volume average fuel economy (VAFE) standard would base standards on the interior volume of vehicles);
- ◆ Change the light truck/car definition; and
- ◆ Increase the CAFE light truck weight limit.

Effectiveness Factors

The effectiveness of increasing CAFE standards depends on a number of factors. In particular, effectiveness depends on the extent to which the standards do the following:

- ◆ Increase new vehicle fuel economy compared to their levels without the standards;
- ◆ Reduce the rate of turnover in the vehicle fleet (by increasing prices);
- ◆ Cause shifts between cars and light trucks (by altering relative prices); and

◆ Cause an increase in vehicle miles traveled (rebound effect).

Manufacturers weigh fuel economy against other factors in vehicle design. While there is agreement that the years in which the CAFE standards took effect coincided with a large increase in the fuel economy of the US new-car fleet—from 17.2 mpg in 1976 to 27.9 mpg in 1986—one must examine how automakers would have reacted in the absence of standards. This comparison is difficult since real gasoline prices tripled between 1973 and 1980, but have since declined, and a number of other factors have affected consumer vehicle purchasing decisions.¹⁰⁵

Some industry analysts have concluded that the CAFE standards implemented in the late 1970s and early 1980s increased fuel economy only about 1.0 to 1.5 mpg beyond the level that would have been achieved without them, while others conclude that the standards improved economy by 4 to 5 mpg or more.¹⁰⁶ Although some have claimed that increases in the price of gasoline in the late 1970s were largely responsible for fuel economy improvements, statistical analysis of manufacturer's CAFE achievements shows strong evidence that the standards were a constraint for many manufacturers and were significantly more important than gasoline prices.¹⁰⁷ Graphs of actual versus required levels of corporate fuel economy show that Ford, General Motors, and to a lesser extent Chrysler, increased their fleet fuel economy in virtual lockstep with the levels required. On the other hand, the levels of the Japanese and other foreign manufacturers producing small, high-fuel-economy cars (those not affected significantly by the standard but more by gasoline prices) vacillated and sometimes fell during the same period.¹⁰⁸ In addition, the increase in fuel economy in that period was more rapid than that for fuel price.

During the 1990s, as the real price of fuel has fallen, fleet fuel economy for cars and light trucks has consistently hovered near the CAFE levels, suggesting that the standards have been an important constraint against lower fuel economy.^{xxv} Since fuel prices are low and the American public has shown relatively little interest in fuel economy in recent years, increased CAFE standards have been identified as a measure to push vehicle fuel economy improvements that the marketplace would not otherwise provide.

The majority report by the Presidential advisory committee on reducing greenhouse gas emissions from motor vehicles estimated that increasing the CAFE standards starting in 1998 would result in the most significant reductions in greenhouse gas emissions. Under their recommended policy, CAFE standards would reach 45 mpg for new cars and 34 mpg for new light trucks by 2007. These targets correspond to standards increasing annually by 1.5 mpg per year. Their analysis suggested that CAFE standards (in combination with feebates) could reduce greenhouse gas emissions by 36 million metric tons of carbon in 2005 and 117 million metric tons in 2015.

There are several factors that can offset emission reductions. There is evidence that CAFE standards result in higher vehicle prices.¹⁰⁹ If CAFE standards are inconsistently applied to cars and light trucks, then higher prices could shift sales of autos to light trucks. While light duty vehicle trucks made up 17 percent of new vehicle sales in 1972, this share has grown to 41 percent in 1997.¹¹⁰ Since the standard for light trucks is much lower than that for automobiles, the shift to trucks has reduced fuel savings.^{xxvi} In addition, price increases could reduce fleet turnover causing less fuel efficient vehicles to remain on the road longer, although this is less of a consideration today since average vehicle fuel economy has been relatively flat since the mid-1980s. An offsetting rebound effect for VMT may be of more concern.

^{xxv} CAFE standards have been constant for autos since 1990. From 1990 to 1995, new sales-weighted fuel economy for autos has been basically flat.

^{xxvi} This issue could be addressed by increasing light truck CAFE standards.

Timing

Development of a new vehicle model typically takes three to four years. As a result, manufacturers need to be given a few years of lead time in order to meet new standards, or they would need to abandon or redesign platforms before the end of life cycles.¹¹¹ Although the standards would have an immediate effect on new vehicles' fuel economy, the full effect of CAFE standards is not seen for many years until substantial portions of the whole fleet turns over.

Implementation Issues

A number of issues have been raised regarding the implementation of new CAFE standards. In particular, issues of safety and economic impact have been important. Many have argued that increased CAFE standards will encourage smaller vehicles that might be less safe than larger vehicles. According to the Office of Technology Assessment (OTA), although small cars need not be unsafe, the bulk of statistical evidence argues that, given current design, the car fleet could be less safe if all vehicles were somewhat smaller than they are today.¹¹² Still, new safety technologies might be implemented to ensure maintenance of passenger safety.

Due to concerns about effects of CAFE standards on US auto manufacturers and incentives created by the regulations, a variety of options for raising these standards have been identified, including measures that would challenge all auto manufactures to increase fuel economy or base standards on vehicle attributes. A uniform minimum CAFE standard on all manufacturers does not force makers of primarily small cars to improve significantly, and the US auto industry has argued a minimum standard would be harmful to American manufacturers. Although the American Automobile Manufacturers Association (AAMA) estimated over 210,000 jobs would be lost in the auto industry by 2001 due to new CAFE standards, the American Council for an Energy Efficient Economy (ACEEE) estimated that new standards would increase employment by 244,000, including 47,000 in the auto industry, by 2010 from enhanced efficiency in the economy.

Despite concerns by the auto industry, to some extent the regulatory approach of CAFE has been viewed as politically more acceptable than raising fuel taxes as a means of reducing fuel consumption since it appears to "place the burden of compliance on manufacturers and not on the consumer."¹¹³ Although some argue that fuel-efficiency standards entail changes in vehicle characteristics that consumers do not like, fuel-economy regulations to date have been well-received by consumers, since they have been achieved largely without major changes in size and power of vehicles.¹¹⁴

RESEARCH AND DEVELOPMENT TO IMPROVE FUEL ECONOMY

Primary Target	Approach	Timing	Level of Implementation
Improve Fuel Economy	Incentive for Manufacturers	Long-term Effect	Federal, Private Sector

Description of Strategy

The goal of research and development (R&D) is to support the development and implementation of new technologies that could improve fuel economy and reduce greenhouse gas emissions. The economic argument for national investment in R&D is that vehicle manufacturers would under-invest in fuel economy technologies due to a market failure in which consumers under-value fuel economy. R&D holds the potential to advance numerous innovations. A number of current efforts focuses on use of alternative fuels

for highway vehicles, such as battery-powered electric vehicles, which are discussed in the next section on alternative fuels.

Passenger cars and light trucks are the prime focus of most current R&D efforts. The Partnership for a New Generation of Vehicles (PNGV) is the cornerstone of US research and development for light-duty vehicles. A joint venture of the US Government and the US Council for Automotive Research (a research consortium formed by General Motors, Ford, and Chrysler), the PNGV has a long-range goal to develop technologies that will assist the development of vehicles with up to three times the fuel efficiency of today's mid-size family sedan (implying fuel economy of about 80 mpg), at an equivalent life-cycle cost (vehicle purchase plus operating costs) that meets customer needs for quality, performance, and utility.^{xxvii} Major improvements in aerodynamics, friction reduction, and lightweight materials will be essential to this effort. PNGV is examining conventional, hybrid electric, and fuel cell technologies. As work progresses, priorities will be established among various technologies.

The US DOT and DOE are currently supporting heavy-duty vehicle engine research with a goal to achieve a 50-percent improvement in fuel efficiency.¹¹⁵

Effectiveness Factors

The effectiveness of R&D as a means to reduce national emissions depends upon the extent to which:

- ◆ Technology is pushed beyond levels that would have been achieved without the investment;
- ◆ Market penetration of these technologies is achieved by private-sector commercialization;
- ◆ Policies are included to ensure that new fuel efficient technology is applied to improving fuel economy rather than increasing power and size; and
- ◆ Vehicle miles traveled increase through a “rebound effect.”

A vehicle that is three times as fuel efficient as today's vehicles would significantly reduce greenhouse gas emissions from transportation, even after accounting for a rebound effect.

Timing

If PNGV's goal of developing production prototypes by 2004 is reached, production of “new generation” vehicles could begin by 2006-2007. With adequate commercialization, enough vehicles could be on the road by 2010 to have a measurable effect on national emissions.¹¹⁶ However, the current portfolio of R&D programs is heavily weighted toward longer-term technologies, apparently reflecting US policy that government's R&D role should be weighted toward long-term opportunities.¹¹⁷

Implementation Issues

Public investment in R&D raises issues about the appropriate role of government in researching, and designing vehicles. It also raises issues about potential shifts in market power among or away from traditional vehicle manufacturers and changes in employment patterns and national economic activity. The public is generally receptive or neutral toward investment in R&D since R&D does not directly or immediately increase the price of travel or attempt to change behavior and attitudes.

^{xxvii} Two other goals are to improve the competitiveness of US vehicle manufacturing and to rapidly deploy cost-effective incremental technology improvements.

Deployment of the vehicle technologies and fuels under consideration in the PNGV program could both require and precipitate a very wide range of infrastructure changes, some of which could emerge as major barriers to implementation. Prominent examples could include supply and procession of raw materials, manufacturing of vehicle components, vehicle assembly, vehicle maintenance and repair, emergency response, vehicle recycling and disposal, and fuel production and distribution. In addition, research into the structural performance of lightweight vehicles will need to be supplemented with research focused on the safety performance of some powertrain components if overall vehicle safety is to be well-understood prior to deployment.

5.3.3 CHANGING VEHICLE PURCHASE/RETIREMENT DECISIONS

These strategies attempt to influence the types of vehicles individuals purchase and use, but without providing a direct push to vehicle manufacturers to improve vehicle technology. Rather, these strategies affect individual vehicle purchase and retirement decisions, and attempt to pull along technological improvements as vehicle manufacturers respond to consumer desires. Examples include:

- ◆ DISSEMINATION OF FUEL ECONOMY INFORMATION;
- ◆ VEHICLE EFFICIENCY TAXES OR FEEBATES;
- ◆ FUEL ECONOMY- (OR EMISSIONS-) BASED VEHICLE REGISTRATION FEES; and
- ◆ VEHICLE BUYBACK PROGRAMS.

DISSEMINATE FUEL ECONOMY INFORMATION

Primary Target	Approach	Timing	Level of Implementation
Improve Fuel Economy	Education and Information	Mid-term Effect	Federal, Private Sector

Description of Strategy

The goal of disseminating fuel economy information is to influence consumer-purchasing decisions on vehicles and tires. By making buyers aware of the differences in fuel economy among vehicles and tires, they will be more likely to take fuel economy into account in their purchase selection since better fuel economy means lower fuel costs over the long-run of owning a vehicle.

The Energy Policy and Conservation Act of 1975 established a fuel economy information program for passenger cars and light trucks that requires the estimated city and highway fuel economy to be prominently displayed on a window sticker for all new cars. It also required that a *Gas Mileage Guide*, listing fuel economy ratings of all makes and models be prominently displayed and available in new car dealer showrooms. Strategies that would build upon this existing program include developing:

- ◆ A fuel economy information program for heavy duty vehicles; and
- ◆ A tire labeling program.

A fuel economy information program for heavy-duty vehicles would provide information to allow freight carriers as well as governments (fleets of garbage trucks and buses) to incorporate fuel cost considerations into their vehicle purchase decision. There currently is no standard basis for comparing fuel economy across makes, models, and configurations of heavy trucks. A tire labeling program would help consumers identify tires that have low rolling resistance and, therefore, provide better fuel economy. Under the *Climate Change Action Plan*, the US has committed that the US DOT would develop a tire-labeling

program mandatory for most light-duty vehicle tires and, if possible, establish a voluntary labeling program for heavy-duty truck tires.

Effectiveness Factors

The effectiveness of a fuel-economy information program depends on:

- ◆ The number of vehicle/tire purchases annually;
- ◆ The extent to which education affects purchasing behavior; and
- ◆ The extent to which selected vehicles/tires yield fuel economy improvements.

No data have been found that estimate the carbon reduction impact of a fuel economy program for heavy-duty vehicles. Since heavy-duty vehicles make up a small portion of the total highway fleet, the potential may be somewhat limited. In addition, it is not known to what extent the program would actually influence vehicle purchasing decisions, since other considerations, such as size and performance, may dominate the selection decision, and purchasers of heavy trucks may be more aware of fuel economy differences among vehicles than consumers of light-duty trucks.

For light-duty vehicles, consumers often purchase replacement tires that have 20 percent more rolling resistance than original-equipment tires, reducing their vehicles' fuel economy by up to 4 percent.¹¹⁹

Although the response of consumers to fuel economy information is not precisely known, evidence suggests that information programs may have a small effect on consumer behavior.

An assessment of the light-duty vehicle labeling program suggests that many consumers are not aware of fuel economy even with the program. One study found that only 26 percent of 1988 and 1989 new vehicle purchasers were aware of the *Gas Mileage Guide*, and only 4 percent consulted it before making a purchase.¹²⁰ Two-thirds knew of the fuel economy label, and half got information from it. Evaluation shows that consumers who are aware of fuel-economy information purchase cars that are about 2 mpg more efficient than those who are not, but it is not known to what extent this is a result of the program and to what extent this may be self-selection bias.¹²¹ In recent years, fuel economy does not appear to be a prime consideration in vehicle selection. Gas costs per mile have fallen significantly, and the cost advantage of choosing higher fuel economy is relatively small in the context of the total costs of owning and operating a car, especially when one discounts future fuel savings.¹²²

The Climate Change Action Plan estimated that a tire labeling program would result in the purchase of 20 million additional fuel-efficient tires, out of a total replacement market of about 120 million tires, in the year 2000. Assuming market penetration of 7.5 percent for light-duty vehicles and 11.0 percent for heavy-duty vehicles, and an increase in on-road fuel economy of 4.0 percent for light-duty vehicles and 7.0 percent for heavy-duty vehicles, this strategy would reduce carbon emissions by 1.5 million metric tons (mmtCe) in the year 2000.¹¹⁸

Timing

There will be a time lag for consumer education programs to reach full effectiveness since they only affect new vehicle and replacement tire purchases, not the entire in-use vehicle fleet.

Implementation Issues

Implementation of these programs would involve a mandate on dealerships and manufacturers to provide the fuel-economy labels and information. Generally, education programs do not suffer from problems of political acceptance and are not very costly.

VEHICLE EFFICIENCY TAXES AND FEEBATES

Primary Target	Approach	Timing	Level of Implementation
Improve Fuel Economy	Economic Incentive	Mid-term Effect	Unknown

Description of Strategy

The idea of an efficiency tax is to provide an incentive for manufacturers to produce and for customers to purchase fuel-efficient vehicles. Two pricing mechanisms have been identified to achieve this objective:

- ◆ A tax on fuel-inefficient vehicles (e.g., a “gas-guzzler” tax), and
- ◆ A “feebate” program that both taxes fuel-inefficient vehicles and offers rebates that lower the purchase price of fuel-efficient vehicles.

Although taxes and feebates have generally been discussed in the context of vehicle purchases, the application of these concepts to the purchase of tires has also been identified as a policy option.^{xxviii} Since low rolling resistance tires tend to be more expensive than other tires, a rebate for purchases of tires that have rolling resistance below a set point and fees for rolling resistance levels above the set point would encourage sales of low rolling resistance tires. A plan can be designed to be revenue-neutral or revenue-generating.

Feebates for vehicles can be structured in a variety of ways. They can be scaled to fuel economy or fuel consumption, or a measure of one or the other normalized to a measure of vehicle size, such as interior volume, wheelbase, or according to EPA size classes. The purpose of normalizing is to provide a pull to improve technology and design within each size class and to avoid disadvantaging domestic manufacturers whose model lines are concentrated on larger vehicles. However, a limitation of grouping vehicles into categories is that it provides a strong incentive for manufacturers to grow vehicles at the upper range of a group into the next group, which would have a lower average fuel economy. Gas-guzzler taxes are already being imposed in the United States and affect roughly 1.4 percent of automobile sales.¹²³

Effectiveness Factors

The effectiveness of taxes and feebates on greenhouse gas emissions depends on:

- ◆ The level of taxes and feebates;
- ◆ Responsiveness of vehicle manufacturers to the tax or feebate;
- ◆ Responsiveness of consumer vehicle/tire choice decisions to vehicle/tire price;
- ◆ Number of new vehicle sales annually/change in the rate of turnover in the vehicle fleet;
- ◆ Shifts between vehicles of different sizes or between cars and light trucks; and

^{xxviii} The Majority Report of the Policy Dialogue Advisory Committee proposed a feebate policy for purchase of tires based on rolling resistance.

- ◆ Increases in vehicle miles traveled (due to reduced fuel costs per mile).

Estimates of the effectiveness of feebate programs are unclear due to uncertainties in the response of consumers and manufacturers to the incentives. ACEEE estimated a small consumer response—on the order of 1 mpg fleet improvement—to a \$300/mpg feebate, assuming no long-term effects on manufacturers.¹²⁴ On the other hand, some analyses suggest that over 90 percent of the fuel economy improvement from vehicle purchase price strategies would come from changes in vehicle designs and offering by manufacturers and only 10 percent from direct consumer reactions.¹²⁵ Lawrence Berkeley Laboratory (LBL) estimated that a relatively moderate feebate (e.g., one that awarded a \$500 differential between a 20- and a 25-mpg car) can achieve substantial fuel economy improvements (e.g., a 15 percent improvement in new car fuel economy by 2010 over levels expected without feebates).¹²⁶

OTA suggested that effectiveness is not well understood since models of manufacturers' reactions include treatment of the auto manufacturers as one large entity rather than as multiple companies. In addition, models do not account for manufacturers' desire to optimize long term investments rather than to immediately capture as many feebate dollars as possible. While these uncertainties also apply to analysis of fuel economy regulations, the analysis of feebates attempts to understand how companies will behave in a market situation in the absence of regulatory constraints that mandate specific fuel economy averages.¹²⁷

The majority report of the advisory committee on emissions from motor vehicles estimated greenhouse gas reductions from a feebate on replacement tires based on rolling resistance would be 3 mmtCe by 2000, 4 mmtCe by 2010, and 5 mmtCe by 2025.

If gasoline prices are stable or rise only slowly, and the feebate causes fuel economy to rise more than fuel price, then the cost per mile of driving will fall. The resulting “rebound” effect of increased VMT would offset some of the emissions savings.

Timing

Feebates/rebates could be implemented quickly. However, since feebates/rebates affect only new vehicle sales, it would take a number of years for a full impact to be observed as the vehicle fleet turns over. Consumers have an immediate effect through their selection of vehicles. It would take somewhat longer for vehicle manufacturers to adjust their product.

Implementation Issues

Efficiency taxes/rebates can be structured to be revenue-neutral or revenue-generating for governments such that administrative costs are covered. Any form of taxes/rebates may distort consumer behavior, and potentially reduce welfare in ways that cannot be easily measured. However, these programs may lead also to fuel savings and cost reductions for drivers. For example, the majority report of the Policy Dialogue Committee estimated that fuel savings from a revenue-neutral feebate on tires would produce fuel cost reductions of \$7 billion for drivers over the four-year tire life.¹²⁸

Finally, the impact of efficiency taxes/rebates on automobile manufacturers is likely to be significant, changing the structure, conduct, and performance of this important industry. To avoid disadvantaging domestic manufacturers, feebate structures can incorporate vehicle size and separate cars from light trucks.¹²⁹

FUEL ECONOMY BASED VEHICLE REGISTRATION FEES

Primary Target	Approach	Timing	Level of Implementation
Improve Fuel Economy	Economic Incentive	Mid-term Effect	State

Description of Strategy

Fuel economy based registration fees involve a surcharge on vehicle registration fees or license fees based on vehicle fuel economy. A similar measure, such as registration fees that vary on vehicle age may accelerate the rate of vehicle turnover, resulting in use of more fuel-efficient vehicles. Currently, registration fees are collected by states in constant rates that do not vary by type of light-duty vehicle or vehicle age. Sometimes referred to as emissions taxes, the concept involves variable registration fees that reflect the emissions rate of a particular vehicle or may attempt to reflect actual yearly emissions. In the latter case, the program must account for miles of travel, as with a VMT fee. Although emissions-based fees have generally been discussed in connection with criteria air pollutants, a charge based on fuel consumption may be feasible. These charges could be assessed on an annual or semi-annual basis.

Effectiveness Factors

Effectiveness depends on:

- ◆ The level and frequency at which the emissions fees are charged;
- ◆ Responsiveness of consumer vehicle decisions to life-cycle vehicle price;
- ◆ Number of new vehicle sales annually/change in the rate of turnover in the vehicle fleet;
- ◆ Shifts between vehicles of different sizes or between cars and light trucks; and
- ◆ Increases in VMT (due to reduced fuel costs per mile).

Consumer responses to an increase in vehicle registration fees are likely to be smaller than responses to a direct increase in the purchase price of a vehicle (e.g., a feebate) since consumers discount future payments (e.g., value them less than current payments). In addition, vehicle registration fees have a less direct effect on vehicle manufacturers compared to vehicle purchase price measures. In order for these fees to be effective at influencing consumer decisions, the fees may need to be significant.

Timing

Although emissions fees may be assessed annually, they only have an effect on greenhouse gas emissions to the extent that they alter vehicle purchase decisions. As a result, it will take many years to achieve the full effects since the average lifetime of an auto is nearly 14 years.¹³⁰

Implementation Issues

These fees could involve significant increases in government revenues, which may encourage their adoption by states. On the other hand, like other pricing measures, increased vehicle registration fees raise concern regarding political feasibility and issues of equity.

VEHICLE RETIREMENT/BUYBACK PROGRAMS

Primary Target	Approach	Timing	Level of Implementation
Improve Fuel Economy	Economic Incentive	Near-term Effect	State, Local, Private Sector

Description of Strategy

Since newer vehicles tend to be more efficient than older vehicles, the retirement of older vehicles and sales of new vehicles will increase average fleet fuel economy. Retirement or scrappage of older vehicles can be encouraged through buyback programs that offer a financial inducement to voluntarily remove a vehicle from use. The idea of encouraging retirement of older vehicles was first proposed as a strategy to reduce air pollution because a small portion of old vehicles produce a disproportionate share of emissions.¹³¹

Effectiveness Factors

The effectiveness as a greenhouse gas strategy depends on the following factors:

- ◆ Number of vehicles retired annually due to the program;
- ◆ Usage characteristics of older vehicles; and
- ◆ Average fuel economy of retired vehicles compared to replacement vehicles.

There are significant limitations to the potential of vehicle retirement programs as a greenhouse gas emissions strategy. Although fuel economy doubled from 1974 to 1985, the fuel economy of new passenger cars in the US has not improved significantly since the mid-1980s.¹³² In addition, fuel economy does not deteriorate rapidly as vehicles age. Fuel economy is likely to deteriorate by only about 10 percent over a period of 15 years.¹³³ Since there is a small differential between the fuel economy of newer and older vehicles, removing older vehicles from the road will result in very small improvements in average fleet-vehicle fuel economy.

In addition, vehicle use tends to decline with vehicle age so that a typical automobile 10 years and older will be driven only half as many miles as a new vehicle.¹³⁴ If demand for driving is sensitive to driving costs, then people with newer, more fuel efficient replacement vehicles will drive them more than the cars they sold.

Timing

A vehicle buyback program would have an immediate greenhouse gas effect through the removal of older, less fuel-efficient vehicles.

Implementation Issues

Urban areas may wish to consider vehicle retirement programs as part of a strategy to reduce criteria pollutant emissions since new vehicles produce significantly less pollution than cars manufactured 20 years ago. The 1990 Clean Air Act Amendments specify programs to encourage voluntary retirement of pre-1980 light-duty vehicles as a transportation control measure that can help urban areas to reach attainment of national ambient air quality standards. Old autos are high criteria pollutant emitters since they were manufactured with no or much less stringent emissions controls compared to new vehicles. Retirement of older vehicles may be a useful supporting strategy to increase the rate of fleet turn-over, which can support other policies to improve new-vehicle fuel economy, such as CAFE standards, feebates, and gas taxes.

5.4 REDUCED CARBON CONTENT (ALTERNATIVE FUEL) STRATEGIES

A third target to reduce greenhouse gas emissions is to switch to fuels that have a lower life-cycle carbon content than conventional gasoline. All fuels have unique carbon contents that reflect the amount of carbon emitted per unit of energy consumed during combustion. Greenhouse gas emissions are also produced during upstream activities associated with transportation, such as fuel production, fuel distribution, feedstock transport, methane leaks, and production and assembly of vehicles. In addition to carbon dioxide, fuel use and upstream processes generate other greenhouse gases, such as methane.^{xxx}

The use of low life-cycle carbon fuels offers an opportunity to reduce greenhouse gas emissions without relying on substantial reductions in transportation demand. The Energy Policy Act of 1992 (EPACT) lists a variety of fuels not derived from crude oil that are considered alternative or replacement fuels: methanol, natural gas, liquid petroleum gas, ethanol, hydrogen, and electricity. In addition, reformulated gasoline is conventional gasoline that has been rebled to reduce criteria pollutant emissions. Although many of these fuels have lower carbon-contents than conventional gasoline, on a life-cycle basis, not all alternative fuels reduce greenhouse gas emissions.^{xxx}

DOE recently estimated the full fuel cycle carbon dioxide emissions of conventional gasoline and four alternative fuels. Of the five fuels examined, compressed natural gas (CNG) produced the lowest level of CO₂ emissions, followed by liquefied petroleum gas (LPG) and ethanol from corn, as shown in Exhibit 5-8.¹³⁵

Exhibit 5-8. DOE's Estimated Fuel Cycle Carbon Dioxide Emissions per Vehicle Mile Traveled (grams/mile)

Fuel	Vehicle Use	Upstream	Total Emissions
Gasoline	272.4	74.9	347.3
Methanol from Natural Gas	270.4	112.7	383.1
Ethanol from corn	301.1	24.4	325.5
Compressed natural gas	204.7	43.5	248.2
LPG from oil and gas	235.4	28.1	263.5

Note: This table presents results only for carbon dioxide, not other greenhouse gases.

Source: US Department of Energy. Energy Information Administration. Alternatives to Traditional Transportation Fuels 1994: Volume 2, Greenhouse Gas Emissions. August 1996. p.16.

The same study found that although compressed natural gas (CNG) produced less carbon dioxide than conventional gasoline, it produced significantly more methane, a much more powerful greenhouse gas.¹³⁶ Of the five fuels examined, ethanol from corn produced the largest nitrous oxide emissions across the total fuel cycle. DOE's methodology for estimating full fuel cycle emissions paralleled a framework established earlier by Delucchi, who examined full fuel cycle emissions for over twenty different fuels and fuel sources (i.e., ethanol from corn, ethanol from wood).¹³⁷

Upstream emissions are an important component of carbon dioxide emissions from transportation. Battery-powered vehicles produce no greenhouse gas emissions during vehicle use. However, greenhouse gases can

^{xxx} These emissions can be converted into carbon equivalent using global warming potentials.

^{xxx} For policy development and target setting, it is important to note that national inventories of greenhouse gas emissions only include emissions from travel in the transportation sector's inventory. Fuel processing and other upstream effects are counted as industrial sources.

be emitted from the energy source used to produce the electricity stored in the vehicle's batteries. If electric vehicles are recharged from power supplied by coal-fired power plants, total fuel cycle CO₂ emissions are higher than for gasoline vehicles. Battery-powered electric vehicles emit less on a full fuel cycle basis if they use hydroelectric, natural gas, nuclear, or solar power for generation of electricity.¹³⁸

In theory, fuels from biomass (e.g., ethanol and methanol from wood, ethanol from corn) have zero life-cycle carbon emissions since carbon is absorbed in the growth of raw materials and then released during combustion. However, cultivation and conversion of biomass into fuel also require energy consumption. Other renewable resources (e.g., solar, hydroelectric) theoretically have zero life cycle emissions.

When examined over the full fuel cycle, the greenhouse gas emission benefits of many alternative fuels are minimal. Upstream emissions, however, are uncertain and would change depending on the scale of adoption of alternative fuels. Economies of scale in fuel processing and distribution could reduce emissions per mile as the market for alternative fuels expands.¹³⁹ The efficiency of alternative fuel vehicles (AFVs) also may differ from that of conventional vehicles, which would affect carbon emissions. A strategy to reduce carbon emissions by switching fuel sources would need to focus on the development and use of low life cycle carbon fuels.

The use of some alternative fuels requires major vehicle redesign. Alternatives to the conventional combustion engine vehicle include:

- ◆ *Battery electric vehicles*—These vehicles use high-energy-density batteries as their sole power source.
- ◆ *Hybrid vehicles*—These vehicles combine two power sources: a high-energy-density battery or ultracapacitor, and a small internal combustion engine or generator. The small internal combustion engine could be used to continually charge the battery and address the range limitations of batteries.
- ◆ *Fuel cell vehicles*—These vehicles use a fuel cell, which is a device that converts chemical energy directly into electrical energy without combustion. It is a simple electrochemical device with no moving parts that generates electricity by harnessing the reaction of hydrogen and oxygen to make water. The vehicle holds a storage tank containing hydrogen or a hydrogen-carrying substance, such as methanol. Since hydrogen can be made from solar or wind energy, a fuel cell operating on hydrogen from these sources has zero greenhouse gas emissions. If the hydrogen is generated from other sources, however, significant levels of greenhouse gases may be produced.

Alternative fuel fleet programs have been designed primarily to reduce reliance on imported oil. Criteria pollutant emissions reductions necessary to meet attainment of national ambient air quality standards (NAAQS) are also a major force pushing regions to use reformulated gasoline and to examine alternative-fueled vehicles. Aside from the considerable weight of the NAAQS in encouraging alternative fuel vehicle use, there are a number of strategies to encourage use of alternative fuels or reformulated gasoline, including:

- ◆ LOW CARBON/ALTERNATIVE FUEL VEHICLE (AFV) MANDATES;
- ◆ RESEARCH AND DEVELOPMENT ON FUELS/ ALTERNATIVE FUEL VEHICLES; and
- ◆ CARBON TAXES AND OTHER MARKET INCENTIVES.

LOW CARBON/ALTERNATIVE FUEL VEHICLE MANDATES

Primary Target	Approach	Timing	Level of Implementation
Reduce Carbon Content	Regulation (including government regulating itself)	Mid-term Effect	Federal, State, Local

Description of Strategy

Mandates can be set either on vehicle manufacturers to produce an alternative-fuel vehicle (AFV) or on certain vehicle customers—specifically government agencies and other large fleets—to purchase AFVs powered by low life-cycle carbon fuels. The purpose of fleet procurement requirements is to create initial market demand to spur development and commercialization of AFV technologies and infrastructure. These mandates would need to be targeted at AFVs with low life-cycle carbon emissions to achieve greenhouse gas reductions.

The Energy Policy Act of 1992 (EPACT) and Presidential Executive Order 12844 require minimum AFV purchases for federal government vehicle fleets. In March 1996, the US DOE published a final rule to implement AFV acquisition requirements for state government and fuel provider fleets, as directed in the EPACT. For states or state agencies, the rulemaking specifies that of the new light-duty vehicles acquired annually, the following percentages must be AFVs (Exhibit 5-9):

Exhibit 5-9. Mandates for Percent of State Vehicle Purchases that Must be AFVs under DOE Rule

1997	1998	1999	2000	After 2000
10%	15%	25%	50%	75%

Source: US Department of Energy. Energy Information Administration. *Alternatives to Traditional Transportation Fuels 1995*. December 1996. p. 29.

California's pilot-test program, the Low Emission Vehicle (LEV) Program, requires minimum sales of zero emission vehicles (ZEVs) and average emission standards that must be met through flexibly combined sales of vehicles in different emission categories. This program could reduce carbon emissions if vehicles are powered by low carbon sources.

Effectiveness Factors

The effectiveness of alternative-fuel vehicle mandates depends on the following factors:

- ◆ Scope and extent of the mandate (which should correspond with feasibility, given constraints on technology and cost);
- ◆ Number of new vehicle sales annually/vehicle fleet turn over rate;
- ◆ Consumer acceptance of new technologies and fuels; and
- ◆ Differential between greenhouse gas emissions of alternative fuels and conventional gasoline.

Alternative-fuels programs appear to have substantially increased the number of AFVs in operation in the US. The Energy Information Administration reports that the number of AFVs in use in the US has increased by over 32 percent from 1992 to 1995, from about 251,350 to 333,049. The number of AFVs in use is expected to increase at an annual rate of 7.6 percent between 1995 and 1997 primarily due to minimum AFV purchase requirements for Federal government vehicle fleets and for state and local fleets.¹⁴⁰ These vehicles still comprise a very small portion of the total vehicles in use.

Ultimately, the effectiveness at reducing greenhouse gases depends on the type of vehicles and fuels used. Alternative fuel mandates have primarily been designed to reduce reliance on imported oil and LEV mandates have been identified as a means to improve air quality. Greenhouse gas reduction depends on use of low life-cycle carbon fuels.

Timing

Use of wide-scale alternative fuels is constrained by time lags associated with investment requirements. For example, the research and development necessary to bring alternative-fuel production capacity on-line is time-intensive, as well as the appropriate infrastructure that must be in place to enable the use of alternative fuels. Moreover, the economic feasibility and marketability of such fuels adds to the time it would take to achieve the wide-scale usage of alternative fuels.¹⁴¹

Implementation Issues

Replacing gasoline with alternative fuels involves a number of transitional barriers and costs associated with immature technologies. In particular, impediments to AFV use include supplier and consumer unfamiliarity, new operational complexities, training needs, less frequent realization of economies of scale in production, and lack of necessary infrastructure.¹⁴²

RESEARCH AND DEVELOPMENT ON FUELS AND ALTERNATIVE-FUEL VEHICLES

Primary Target	Approach	Timing	Level of Implementation
Reduce Carbon Content	Incentive for Manufacturer	Long-term Effect	Federal, Private Sector

Description of Strategy

The goal of research and development (R&D) is to provide a “push” to support the development and implementation of new vehicle technologies using low carbon fuels. Some of these efforts have focused on battery powered and fuel-cell powered vehicles. R&D could also focus on reducing upstream emissions from processing of alternative fuels.

A number of efforts are supporting R&D, including the Partnership for a New Generation of Vehicles (PNGV), described in Section 5.3.2. The US Advanced Battery Consortium (USABC), established in January 1991, has been developed to concentrate efforts on battery development for electric vehicles. The USABC consists of the Big Three US auto manufacturers (Chrysler, Ford, General Motors), the Electric Power Research Institute, the US DOE, and five major US electric utilities. The mid-term Advanced Battery Technology goals were to double the range and performance of electric vehicles compared to that of current battery technology in the mid-term, and develop a battery competitive with internal combustion engine vehicles in the long-term.¹⁴³ Approximately \$260 million were committed to the Consortium from 1991 to 1996.

Effectiveness Factors

Like R&D efforts to improve conventional vehicle fuel economy, the effectiveness of R&D efforts aimed at AFVs depends on the extent to which it:

- ◆ Pushes technology beyond levels that would have been achieved without the investment; and
- ◆ Supports market penetration of these technologies.

Timing

There are some near-term goals for improvements in battery and fuel cell technology that may be achievable. However, the widespread acceptance and use of electric, fuel-cell, and hybrid vehicles would most likely be a long-term response. There are multiple constraints that currently limit potential commercialization, including cost, limited range, time for recharging current-generation batteries, durability, limited speed, safety concerns, and the need for an entirely new infrastructure in the form of charging stations and equipment. These concerns are being addressed under existing research efforts but may take significant time to resolve.

Implementation Issues

Public investment in R&D raises issues about the appropriate role of government in researching and designing vehicles. It also raises issues about potential shifts in market power among or away from traditional vehicle manufacturers and changes in employment patterns and national economic activity. The public is generally receptive or neutral toward investment in R&D, since it does not directly or immediately increase the price of travel or attempt to change behavior and attitudes.

CARBON TAXES AND DIFFERENTIAL TAXES FOR ALTERNATIVE FUELS

Primary Target	Approach	Timing	Level of Implementation
Reduce Carbon Content, Improve Fuel Economy, Reduce Vehicle Travel	Economic Incentive	Near-term Effect and Long-term Effect	Federal, State

Description of Strategy

A carbon tax is a levy on fuel that ties the tax level directly to the carbon content of the fuel. A carbon tax would be broad-based, so that it would affect fuels used in all sectors. A related fuel tax strategy is to reduce existing taxes for “clean” or alternative fuels. Until the year 2000, a 5.4¢ exemption of federal gasoline taxes exists for fuels containing at least 10 percent ethanol. In theory, differential tax rates provide an incentive for commuters to switch to alternative-fuel vehicles.

Effectiveness Factors

A carbon tax reduces carbon dioxide emissions in multiple ways. By increasing fossil fuel prices generally, it encourages more efficient use of energy and reduced vehicle travel. By changing relative prices of fuels, it encourages a shift in consumption from high-carbon fuels to low carbon-content fuels. Since carbon taxes address all components that contribute to carbon emissions, they are more efficient than simple fuel taxes at reducing carbon emissions.¹⁴⁴

Effectiveness in reducing national emissions depends upon:

- ◆ The level of the tax; and

- ◆ Responses to the price of various fuels (in terms of travel demand, fuel economy, and type of fuel).

A number of economic models have examined the relationship between tax rates and emission levels, and a range of estimates has been suggested for the appropriate level of a carbon tax. Within the transportation sector, carbon taxes will function like conventional gasoline taxes except to the extent that they encourage switching to lower carbon fuels. While the availability of alternative fuels and vehicles is increasing, limited availability may present a significant barrier to using lower carbon fuels. The response to the tax could be amplified by using revenues to fund alternative technologies and energy-efficient infrastructure. One study found that a significantly lower tax rate would be required to achieve emissions reductions if the revenues were earmarked for carbon abatement measures rather than general revenues.¹⁴⁵

Timing

A carbon tax would have a near-term effect on emissions stemming from near-term reductions in vehicle travel. Improvements in vehicle fuel economy and shifts to alternative fuels would take significantly longer.

Implementation Issues

Ideally, by raising fuel prices to account for negative externalities, a carbon tax will yield a more efficient economy. However, by raising prices on all energy consumption, they could reduce economic productivity. A carbon tax would have most negative effect on industries highly dependent on fossil fuels. Carbon taxes could also be viewed as a fiscal benefit to governments, since such a broad-based tax can raise substantial revenues. The Congressional Budget Office estimated that a national carbon tax of \$70 per ton would raise net revenues of \$72.5 billion annually.¹⁴⁶

The idea of a carbon tax has surfaced in national political debate over the past decade. The Bush Administration's National Energy Strategy considered but rejected a tax of \$135 per ton of carbon.¹⁴⁷ Early in Clinton's first term, the Administration indicated that it was considering a broad-based energy tax, but this was not included in the budget package. A number of states have implemented tax incentives for alternative fuels, and interest in new revenue sources suggests that there is potential for state adoption of carbon taxes.¹⁴⁸

5.5 SUMMARY ASSESSMENT

Recent policy debate on energy consumption from the use of light-duty vehicles is often characterized as a choice between those who favor higher fuel taxes and those who place greater emphasis on regulating vehicle fuel economy. This report suggests that decision-makers are not limited to one-or-the-other policy responses. A variety of different strategies are available to reduce carbon dioxide and other greenhouse gases from highway vehicles, which need to be closely examined in terms of their effectiveness and implementation feasibility. Strategies can have different targets, be implemented at various levels of government, and be devised with various levels of stringency. Some strategies may work in a complementary fashion and have multiple benefits, which should be considered.

Although this section does not recommend specific strategies for implementation, it highlights some of the concerns that decision-makers may wish to examine when selecting strategies. This literature review suggests a number of conclusions:

- ◆ *Decision-makers will be faced with many uncertainties when selecting strategies.* There is considerable uncertainty about the full costs and benefits of various strategies, as well as about the political and practical limits to a given strategy. In addition, economic and behavioral relationships that determine strategy effectiveness are not precisely known. An assumption that gasoline demand and fuel economy are very sensitive to fuel prices leads to the conclusion that fuel taxes may be relatively more effective than fuel economy standards. On the other hand, assuming that travel is relatively insensitive to travel costs leads to the conclusion that fuel economy standards may be more effective than pricing strategies. Economists disagree on these elasticity values, yet they are critical to the estimation of strategy effectiveness. Using different elasticity estimates from the literature can entirely reverse the ranking of policies by CO₂ and other greenhouse gas emissions impacts.¹⁴⁹ Decision-makers should expect to operate under uncertainty and recognize the range of effects that might be achieved by various strategies.
- ◆ *Some factors that affect strategy effectiveness may themselves be affected by policy development.* The effectiveness of strategies depends on a variety of factors. Some factors cannot be changed directly, such as individual responses to travel pricing and vehicle pricing. Other factors are at the discretion of policy makers, such as the level of price increases, infrastructure investment, and mandates. The number of variables that influence strategy effectiveness suggests that scenario analysis is necessary to identify ranges of potential emissions reductions that are practical.
- ◆ *Different strategies can be effective over different time periods.* Since different strategies are suited to emissions reductions over various time periods, decision-makers should recognize the timing of strategy effects when setting targets and developing policies. In general, strategies that focus on driver behavior will tend to have a near-term effect. Strategies focused on vehicle technologies will have an intermediate effect since it will take a number of years for improved technologies to be developed and then be brought into the vehicle fleet in significant numbers. Finally, land-use changes yield significant results only over a longer time frame.

A variety of groups have tried to identify and assess strategies for reducing greenhouse gas emissions from highway transportation, including policies and initiatives already underway. However, consensus on national policy has been difficult to attain, and further research is needed regarding uncertainties about the full costs and benefits strategies and their subsequent implications. For example, the Policy Dialogue Advisory Committee established by President Clinton to examine measures to reduce greenhouse gas emissions from personal motor vehicles could not develop consensus on the most appropriate package of measures. This report has acknowledged throughout that there are many difficulties in ranking strategies and developing consensus on policy. Selection of strategies involves decisions that could have political, economic, and lifestyle ramifications. Many strategies also offer potential multiple benefits beyond greenhouse gas reduction. Uncertainty about possible strategies in the US may also make it difficult to reach conclusions about the relative effectiveness of various policies for other countries.¹⁵⁰ By identifying the issues that decision-makers will need to consider, this report can serve as a basis for continuing policy dialogue to confront the threat of potential global climate change.

Exhibit 5-10 summarizes the previous discussion of strategies and their components:

Exhibit 5-10. Summary of Strategies and their Characteristics

Strategy		Primary Target	Approach	Timing	Level of Implementation
Travel Pricing	Road Pricing	Reduce Vehicle Travel	Economic Incentive	Near-term Effect	State, Local
	VMT Fees				Unknown
	Fuel Pricing	Reduce Vehicle Travel Increase Fuel Economy			Federal, State, Local
Provision of Alternative Modes	Transit Investment	Reduce Vehicle Travel	Infrastructure Investment	Mid-term Effect	Federal, State, Local
	Bicycle Support Facilities			Near-term Effect	Local
	Park & Ride Facilities				State, Local
	HOV Lanes			Mid-term Effect	State, Local
Parking Management	Parking Pricing	Reduce Vehicle Travel	Economic Incentive	Near-term Effect	Local
	Mandatory Parking Cash-out				Federal, State, Local
	Parking Supply Limits		Regulation or Incentives		Long-term Effect
Land Use Planning	Dense, Transit-Oriented Development	Reduce Vehicle Travel	Regulation or Incentives	Long-term Effect	Local
	Enhance Pedestrian Environment		Regulation; Infrastructure Investment	Mid-term Effect	Local
Other VMT-reduction Measures	Telecommuting	Reduce Vehicle Travel	Education and Information	Near-term Effect	Employer-Based
	Compressed Work Hours				Employer-Based
	No-Drive Days				Local
Improving Traffic Operations	Traffic Flow Improvements	Improve Fuel Economy	Infrastructure Investment	Near-term Effect	State, Local
	Limit Freeway Speeds to 55-mph		Regulation		Federal, State
	Driver Education		Education and Information		Federal, State, Local
Vehicle Technology Improvement	CAFE Standards	Improve Fuel Economy	Regulation	Mid-term Effect	Federal
	R&D to Improve Vehicle Fuel Economy		Incentive for Manufacturer	Long-term Effect	Federal, Private Sector
Changing Vehicle Purchase/Retirement Decisions	Disseminate Fuel Economy Information	Improve Fuel Economy	Education and Information	Mid-term Effect	Federal, Private Sector
	Vehicle Efficiency Taxes and Feebates		Economic Incentive		Unknown
	Fuel Economy based Vehicle Registration Fees				State
	Vehicle Retirement/Buyback Programs			Near-term Effect	State, Local, Private Sector
Reduced Carbon Content (Alternative Fuels)	Alternative Fuel Vehicle (AFV) Mandates	Reduce Carbon Content	Regulation	Mid-term Effect	Federal, State, Local
	R&D on Fuels and AFVs		Incentive for Manufacturer	Long-term Effect	Federal, Private Sector
	Carbon Taxes and Differential Taxes for Alternative Fuels	Reduce Carbon Content Improve Fuel Economy Reduce Vehicle Travel	Economic Incentive	Near-term Effect Long-term Effect	Federal, State

¹ *Majority Report to the President by the Policy Dialogue Advisory Committee to Recommend Options for Reducing Greenhouse Gas Emissions from Personal Motor Vehicles.*

² The following reports and studies examine travel price elasticities (note that many of these studies examine fuel price elasticities, which can be converted into travel price elasticities):

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