Policies to Reduce Emissions from the Transportation Sector

This brief discusses public policy tools available to reduce greenhouse gas (GHG) emissions from the transportation sector. Reducing GHG emissions from transportation, which comprise one third of total U.S. CO_2 emissions, will need to be a key part of any strategy to limit economy-wide emissions. Transportation energy use and emissions are determined by three elements: the fuels used to power the vehicles, characteristics of the vehicles themselves, and total miles traveled. Of the various transportation modes, passenger vehicles consume the most energy, followed by truck, rail and ship transport of freight, and then air travel. To reduce emissions, the sector can be included in a multi-sector cap-and-trade program or managed through sector-specific measures, or both. The critical issues for transportation policy are understanding market imperfections, where individuals are somewhat insensitive to changes in fuel price and tend to undervalue fuel economy. This makes it difficult to harness market forces (such as a cap-and-trade program) to drive investment in long-term transportation technology. To guarantee significant emission reductions from the transportation sector, especially in the short term, sector-specific policies can complement (or substitute for) the cap. These policies will need to focus on all three elements of the sector for major emission sources within the transportation sector. Policy tools include pricing policies (e.g., taxes, tolls, and congestion changes), standards (e.g., fuel economy standards), and funding for research, development, and deployment. Policies for the transportation sector will have to address several objectives at the same time: energy security and GHG reduction goals, a transition to low carbon fuels and alternative vehicle types, and an alignment of infrastructure and land use planning with GHG goals.

Reducing greenhouse gas emissions from transportation will need to be a key part of any strategy to limit overall emissions in the United States. The second largest contributor to greenhouse gas (GHG) emissions in the United States and responsible for about one third of the annual CO_2 emissions from the combustion of fossil fuels,[1] the transportation sector consists of passenger cars and light trucks, heavy duty trucks and off-road vehicles, and rail, marine, and air transport. Transportation activities also result in methane, nitrous oxide, and hydrofluorocarbon emissions.

After a short introduction, this Congressional Policy Brief contains four primary sections: the first is an overview of transportation within a cap-and-trade program and the other three are devoted to each element of the transportation sector—fuels, vehicles, and distance traveled.

Introduction

Transportation energy use and emissions are determined by three main elements: the fuels used, efficiency of the vehicles, and distance traveled. Of the various transportation modes, passenger vehicles consume the most energy (nearly 60 percent of total transportation energy use), followed by freight transport by truck, rail, and ship (about 22 percent), and air travel (almost 10 percent).[2]

PEW CENTER ON Global CLIMATE CHANGE

Support for this series was made possible through a generous grant from the Doris Duke Charitable Foundation

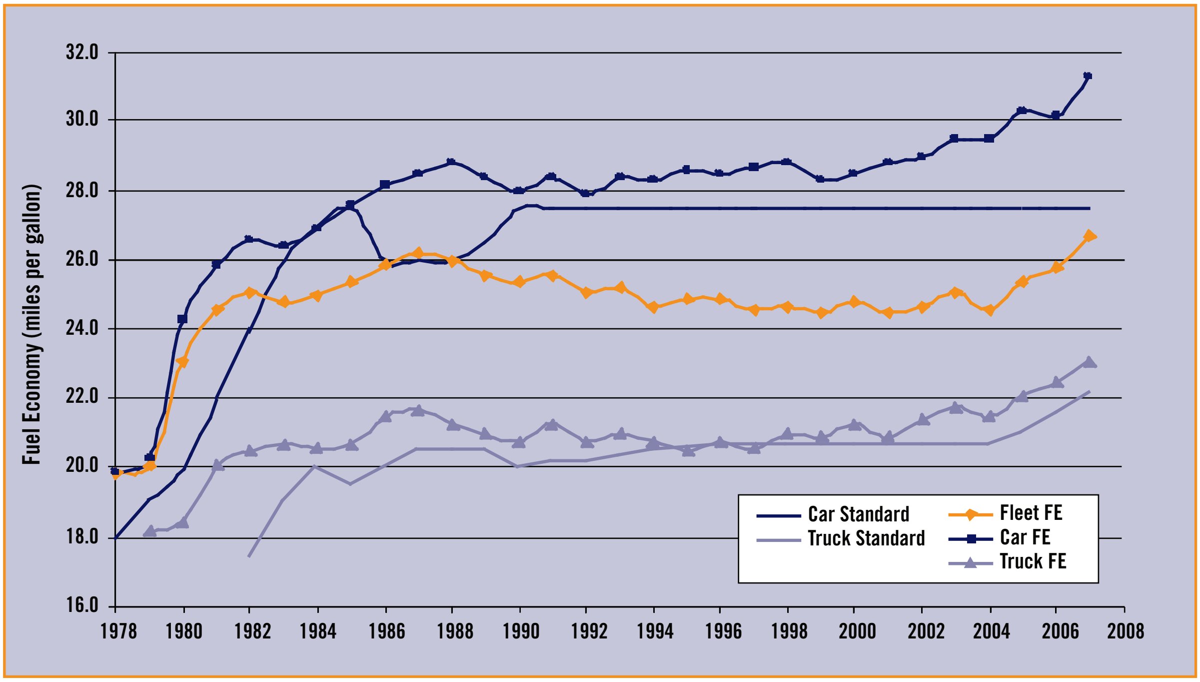
Fuels

The various transportation modes are almost entirely dependent on fossil fuels for energy: about 95 percent of energy for transportation in the United States comes from petroleum-based fuels.[3] The transportation sector in the United States accounts for more than two thirds of the 20.7 million barrels of petroleum consumed daily, 58 percent of which was imported in 2007.[4] Since the 1980s, energy consumption for transportation has increased by 33 percent; over the next 25 years, transportation is expected to drive all the expected growth in overall petroleum consumption.[5]

Efficiency

Over the last 30 years, the fuel economy of new passenger vehicles in the United States has improved significantly, increasing by more than 30 percent (see Figure 1). Yet, most of the gains occurred in the early years of fuel economy regulation, with improvements peaking in 1987, and then nearly stagnant throughout the 1990s, when technological improvements were directed to other vehicle attributes, such as power and size. The decline in new vehicle fuel economy has reversed only recently, with higher gasoline prices prompting increased demand for more efficient vehicles and higher fuel economy standards. Improvements in other modes are mixed. Some have experienced steady continuous increases in efficiency; for example, aircraft efficiency has improved at an average rate of 1-2 percent per year.[6] Efficiency in truck and waterborne freight movement, on the other hand, appear not to have improved significantly, although data on the subject are weaker.[7]

Figure 1 *Corporate Average Fuel Economy Standards and Average New Vehicle Fuel Economy, 1978-2008*



Distance Traveled

The benefit of higher fuel economy can be offset by a rapid increase in vehicle miles traveled (VMT). Over the last 30 years, passenger vehicle miles traveled increased faster than population growth, at a rate of about 2.4 percent per year, while population has only increased at about 1.1 per year.[8] The growth in other transportation modes has been similar.[9] More recent data predict a slowing in VMT growth, due to higher fuel prices and slower economic growth. The use of all transportation modes (particularly freight transport and air travel) is still projected to grow rapidly in the future.

A strategy to reduce GHG emissions from transportation will need to focus on all three elements—the fuels used to power the vehicles, characteristics of the vehicles themselves, and total miles traveled

What are the Policy Options for Reducing GHG Emissions from the Transportation Sector?

Policies focused on the transportation sector can follow one of several paths. Transportation emissions can be included in a national, multi-sector cap-and-trade program or they can be placed outside a cap-and-trade program and managed through sector-specific measures or both. The critical issue for transportation is that individuals generally undervalue fuel economy, which makes it difficult to harness market forces (such as a cap-and-trade program) to drive investment in long-term transportation technology. Thus sector-specific measures to promote energy efficiency and low carbon technologies may be needed to ensure significant GHG reductions from transportation.

Furthermore, while policies that promote low carbon fuels and more efficient vehicles can significantly reduce GHG emissions, the total GHG reductions achieved will also depend on vehicle miles traveled. If land use and VMT reduction policies are not included in a plan to reduce emissions from the transportation sector, continued growth in vehicle miles traveled can outweigh the benefits of other policies. A strategy to reduce GHG emissions from transportation will need to focus on all three elements—the fuels used to power the vehicles, characteristics of the vehicles themselves, and total miles traveled—for major emission sources within the transportation sector.

How Could Transportation be Included Within a Cap-and-Trade System?

Including transportation in a national, multi-sector cap-and-trade program has the potential to achieve overall emissions reductions at minimum total cost. Under a cap-and-trade program, sectors with higher abatement costs can buy allowances from other sectors where reductions are less expensive, lowering the overall cost of compliance.

If transportation is included in a multi-sector cap on GHG emissions, the requirement to hold emissions allowances can be placed at one of several points. If compliance is at the point where the fuels enter the economy, this would be an “upstream” approach to a cap on emissions.

In this case, crude oil producers, refiners, or importers would be required to hold allowances for the carbon content of the fuels they sell and to pass along the cost of these allowances through the supply chain. A "downstream" approach caps emissions where they are emitted into the atmosphere. Theoretically, for transportation sector emissions, drivers could be required to hold allowances for emissions from their use of fuel. However, this approach is widely regarded as administratively difficult and impractical.

Greenhouse gases can also be capped at other points in the emissions stream. For example, within the transportation sector, vehicle manufacturers could hold allowances to cover the lifetime GHG emissions of new vehicles sold, determined by estimating vehicle use and efficiency. With this approach, manufacturers can adjust prices of the vehicle to reflect the number of allowances needed to cover their lifetime emissions, thereby providing an incentive to consumers to choose vehicles with low GHG emissions. The challenge with this approach is the inability of manufacturers to accurately measure actual emissions. Manufacturers would have to rely on modeling or statistical estimations of the type, amount, and GHG emissions of the fuel used. If estimates were below true emissions, the process would weaken the effectiveness of the cap. Furthermore, after sale, manufacturers have only partial control over and information on the fuels used by vehicle owners.

In the short term, reducing emissions from transportation is expected to be more costly than other sectors.

Of the various options for incorporating the transportation sector into a cap, an upstream point of regulation—with refineries serving as allowance holders—offers the greatest administrative simplicity. Compared to more than 1400 crude oil producers, there are about 150 refiners in the United States.[10] Refiners could pass along the cost of the allowances to consumers, who would theoretically take the increased price of gasoline into account in their transportation, work and housing choices, in the long term. The Boxer-Lieberman-Warner bill (S. 3036) proposed a cap-and-trade structure that covered petroleum importers and refiners upstream; the program covered approximately 87 percent of total U.S. GHG emissions. (For a more in-depth discussion on the scope of a cap-and-trade program, see the Pew Center's Congressional Policy Brief: *Scope of a Greenhouse Gas Cap-and-Trade Program*.)

The challenge with the transportation sector is that, in the short term, reducing emissions from transportation is expected to be more costly than other sectors, with smaller impacts on fuels, vehicles, and use. Because most legislation contemplates a modest initial GHG cap, the price signal on gasoline (i.e., the increase in price due to the cost of allowances) is likely to be too small, especially in the short run, to drive changes in technologies. The cost of the carbon content does not translate into a significant portion of the retail price of gasoline.[11] Along with the small price signal, consumers are relatively insensitive to changes in fuel price, at least in the short term.

In most parts of the United States, there are few viable alternatives to vehicle travel, thus the demand for gasoline does not change significantly with a change in price. Over the long term or with a large, sustained price increase, the consumer response may be more pronounced. On the producer side of the market, there are presently few alternatives to gasoline and diesel, thus the response from suppliers may also be limited in the short term.

To guarantee significant emission reductions from the transportation sector, especially in the short term, sector-specific policies can complement (or substitute for) the cap.

To guarantee significant emission reductions from the transportation sector, especially in the short term, sector-specific policies can complement (or substitute for) the cap. The following sections provide an overview of possible policy measures that can be enacted to address fuels, vehicles, and miles traveled. It is important to keep in mind that, unlike a cap, most of these measures are intensity-based standards[12] that do not directly limit overall emissions. However, given the relatively small short-run price response expected in this sector, a standards-based approach may prove more effective, instead of—or in combination with—an overall emissions cap.

What are the Discrete Measures for the Transportation Sector?

When it comes to policy options for addressing GHGs in the transportation sector, policymakers can take action in one or all of three areas: fuels, efficiency, and distance traveled. Options for doing so are described below.

Emission Reduction Options Related to Fuels

One of the main concerns related to transportation fuels is the potential shift to fuels extracted from unconventional fossil sources (e.g., oil sands or coal), which have a higher GHG footprint than conventional gasoline or diesel.[13] Analysts predict that if present energy trends continue (i.e., demand for fuel increases and current petroleum reserves are depleted), a major transition from conventional to unconventional fossil fuels will be required before 2030.[14] While these fuels may be strategically important for energy security concerns because they are domestically available, these unconventional fuels can cause long-term environmental consequences. Policies to develop and increase low carbon fuel choices instead can mitigate GHG emissions, as well as address energy security issues.

Renewable fuel policies, low carbon fuel standards (LCFS), and fuel taxes are three measures that can be used to address the amount and type of fuel used for transportation.

Renewable Fuels Standards

The first option—a volumetric requirement for renewable fuels—requires that fuel providers sell a certain quantity of specified fuels over a certain time period. Such mandates have the advantage of offering suppliers a guaranteed market for their products, thus accelerating the penetration of new technologies. Current renewable mandates are based on the feedstock that the fuel is produced from (e.g., corn ethanol).

Many renewable fuels are also low carbon fuels. However, whether a renewable fuel is indeed a low carbon fuel on a life-cycle basis depends on a variety of factors, including characteristics of the biomass feedstock, the process of converting that feedstock into a fuel, and the combustion of that fuel in a vehicle. The potential downside to a purely volumetric approach is that producers are constrained to sell certain amounts of the fuel, without regard to its life-cycle carbon emissions.

Whether a renewable fuel is indeed a low carbon fuel on a life-cycle basis depends on a variety of factors, including characteristics of the biomass feedstock, the process of converting that feedstock into a fuel, and the combustion of that fuel in a vehicle.

Policy Implementation

The Energy Independence and Security Act of 2007 (EISA 2007) updates the federal Renewable Fuel Standard (RFS), originally enacted under the Energy Policy Act of 2005. The Act increases the previous volumetric targets for renewable fuels from 7.5 billion gallons in 2012 to 36 billion gallons by 2022. Of the total requirement for 2022, 21 billion gallons must come from "advanced biofuels," which include cellulosic ethanol and biodiesel. The updated RFS takes carbon considerations into account more than a traditional RFS, by including requirements on the life-cycle GHG profile for the various fuel types. Any new renewable production facility, including those for corn-based ethanol, must achieve at least a 20 percent GHG reduction, relative to the baseline, i.e., the average life-cycle GHG emissions for gasoline or diesel fuel. Advanced biofuels must achieve a reduction from the baseline by 50 percent or more. The U.S. EPA is also required to consider any indirect effects of increased fuel production, including significant emissions from land use changes.

The RFS attempts to ensure that real reductions in the GHG intensity of biofuels are achieved but does not create any incentives for the adoption of fuel types other than those included in the legislation. Furthermore, accounting for indirect land use impacts is very difficult and uncertain. Some believe that accounting for these impacts, especially for corn ethanol, may make it difficult, if not impossible to meet the GHG reduction requirements of the standard.[15]

Several U.S. states have also implemented policies to promote biofuel use. Currently, 37 states provide incentives promoting ethanol production and use and nine states have also enacted their own renewable fuels standards.[16]

Outside of the United States, the European Union Directive 2003/30/EC sets initial targets for biofuel use, which are being revisited under a January 2008 energy and climate package. This proposal sets a goal of 10 percent renewable fuel use by 2020, coupled with sustainability criteria, which would require that biofuels be produced on lands without high carbon stock or a high biodiversity value and result in a minimum GHG savings based on fuel type.[17] Moving forward, although volumetric mandates based on feedstock can push advanced biofuels (e.g., algae-derived biodiesel) into the market by giving suppliers a guaranteed level of sales per year, a more direct and thus effective way to ensure reductions in the carbon intensity for all transportation fuels is a low carbon fuel standard, as discussed below.

Low Carbon Fuel Standard

The second policy option for fuels is a performance standard (e.g., a low carbon fuel standard, or LCFS), which would set targets for reductions in life-cycle GHG intensity[18] for the entire transportation fuel pool. A LCFS would specify the carbon intensity for transportation fuels, on average, for a given year, usually expressed as a percent reduction from a baseline (e.g., GHG intensity in 2015 must be five percent lower than 2005 levels). The GHG intensity for a fuel is calculated on a life-cycle basis, which includes the emissions from production or extraction, processing, and combustion of the fuel.

This policy allows manufacturers to produce and retailers to purchase the mix of fuels that most cost-effectively meets the standard. Any entity that reduces GHG intensity by more than the requirement for that year can generate and sell credits. Fuel providers can comply with the LCFS by meeting the intensity standard for that year, buying credits, using banked credits, or borrowing from the next year.

A LCFS provides a level playing field, if based on the appropriate life-cycle emissions accounting, for all transportation fuels that may be used in the future, including cellulosic ethanol, electricity, or hydrogen.

A LCFS provides a level playing field, if based on the appropriate life-cycle emissions accounting, for all transportation fuels that may be used in the future, including cellulosic ethanol, electricity, or hydrogen.

Policy Implementation

To address some of the concerns with biofuel mandates, California is in the process of implementing a low carbon fuel standard. California Executive Order S-1-07 (issued on January 18, 2007) sets a goal of reducing the carbon intensity of passenger fuels statewide by a minimum of 10 percent by 2020.[19] Several other states, including Massachusetts and those in the midwest, are also currently considerng a LCFS under the climate change initiatives.

Box 1 *Unintended Consequences of Biofuels Production*

As biofuels attract new interest and investment, concerns are growing about competing objectives for water and land resources. These competing objectives include two significant issues: producing adequate food at reasonable prices and limiting indirect land use change and deforestation. Governments, scientists, environmental groups, and others are recognizing the need for improved methods to account for GHG emissions and other impacts caused by using plants to produce transportation fuels. In particular, better estimates of emissions due to land-use changes are needed. With concerns about the impact of biofuels production on food prices, the development and use of non-food feedstocks, particularly waste streams, is also needed.

As mentioned previously, the Boxer-Lieberman-Warner Bill (S. 3036) included a GHG cap on fuels as part of an economy-wide cap-and-trade program, as well as a Low Carbon Fuel Standard. The proposed LCFS leaves the current RFS intact and sets a target of 5 percent below the 2005 average carbon intensity for transportation fuels by 2023 and 10 percent below by 2028. Any reductions thereafter would be based on a study of the LCFS and its efficacy in the previous years.

Tax on Transportation Fuels

A tax on transportation fuels is another possible policy mechanism that can be used to reduce emissions from transportation fuels. The tax can be differentiated according to fuel type (e.g., gasoline or ethanol) or based on the calculation of life-cycle GHG emissions for the fuel. Linking the tax to the GHG intensity of the fuel (in dollars per ton of CO_2-equivalent per unit of energy) can drive technological innovation in low carbon

Box 2 *Understanding the Effect of Gas Prices*

Understanding consumer sensitivity to gasoline price changes has been the subject of considerable scrutiny for many years. The general belief is that consumers are not very responsive to price changes in the short term because they have few transportation options. Over time, however, consumer response increases because people can adjust—buy new cars, find alternative transport mechanisms and even relocate. Consumer response can determine the effectiveness of policy measures; for example, pricing mechanisms that increase the cost of gasoline may be ineffective in reducing consumption if consumer response to the price signal is limited. Estimates of gas price elasticity—the sensitivity of consumers to a change in prices—vary. One study found that elasticity of vehicle miles traveled with respect to fuel costs was -0.1 in the short run and increasing to -0.2 or more over the long run.[i] This means that in the short run, with a 10 percent change in gas prices, consumers will drive 1 percent less. Studies also indicate that the responsiveness of consumers has decreased over time.[ii]

Looking at recent data, gas prices have increased by nearly 80 percent since January 2007, with the majority of the increase in the first half of 2008. In June 2008, U.S. average retail gasoline prices went past the $4/gallon-mark in most areas, 33 percent above June 2007 prices.[iii] Compared to the previous year, VMT decreased by 4.7 percent. The decrease in VMT has been coupled with other behavioral changes as well, such as an increase in mass transit ridership: 5.2 percent in the second quarter of 2008 compared to the previous year,[iv] and a decrease in sales of larger vehicles and light trucks, which have lower fuel economy. In the first six months of 2008, car sales dropped only 1.6 percent, while truck sales have dropped 18 percent.[v] It is too early to assess the longer term behavioral shifts due to the high gas prices, but the response seems to be more significant than previously expected, with effects in areas other than VMT.

[i] Parry, Ian W.H., et al., *Should CAFE Standards Be Tightened?*, Resources for the Future, Discussion Paper 04-D63, December 2004.

[ii] Hughes, Jonathan, et al., *Evidence of a Shift in the Short-Run Price Elasticity of Gasoline Demand*, Center for the Study of Energy Markets, Paper CSEMWP-159, Feb 2007. Small, Kenneth and Kurt Van Dender, *Long Run Trends in Transport Demand, Fuel Price Elasticitiies and Implications of the Oil Outlook for Transport Policy*, OECD/ITF, Discussion Paper No. 2007-16, December 2007.

[iii] U.S. EIA, *Retail Gasoline and Diesel Prices*, September 29, 2008. Found at http://tonto.eia.doe.gov/dnav/pet/pet_pri_gnd_dcus_nus_m.htm.

[iv] APTA, *Transit ridership report: Second quarter 2008*, September 2008. Found at http://www.apta.com/research/stats/ridership/index.cfm.

[v] Green Car Congress, *Total US LDV Sales Down 18.2% by Volume in June 2008; Down 10.1% For First Six Months*, July 1, 2008. Found at http://www.greencarcongress.com/2008/07/total-us-ldv-sa.html.

fuels. The lower the carbon intensity, the less tax would be incurred.

A tax also provides a price signal to consumers to shift their purchasing behavior. If clearly labeled at the pump, the tax sends a more direct message to consumers that reducing fuel consumption or selecting fuels with low GHG footprints is important. The effectiveness of the price signal depends on the availability of low carbon fuel options. Thus complementary policies, such as a tax, that accelerate the development of low carbon fuel options could work synergistically with a cap-and-trade program.

The key challenge for vehicles is to encourage market penetration of alternative vehicle technologies that increase fuel economy and significantly reduce GHG emissions.

The revenue from a tax could be used to increase funding for transportation infrastructure, transit, and other means to reduce miles traveled. Tax proceeds could also be redistributed to assist low-income groups for which a tax on fuels would represent a larger fraction of disposable income than for higher income groups.

Although a tax might help reduce the growth in vehicle miles traveled by increasing the cost of driving, a tax sufficiently high to impact VMT is likely to encounter political obstacles.

One idea that has been discussed in recent literature calls for a price floor once gasoline prices begin to fall from recent high levels. Once the price would fall below a certain amount, a tax would maintain prices at that established level—both serving as an incentive to promote conservation and also as a source of revenue that could be dedicated to alternative fuels, VMT measures, and other policies. For a more in-depth discussion on the use of taxes to reduce GHG emissions, see the Pew Center's Congressional Policy Brief, *Tax Policies to Reduce Greenhouse Gas Emissions*.

Policy Implementation

Currently, there are motor fuels taxes at local, state, and federal levels, usually differentiated by fuel type (gasoline, diesel, gasohol, liquefied petroleum gas, liquefied natural gas, etc.). Federal tax revenues are deposited in the Highway Trust Fund (HTF), which serves as the main source of funding for federal highway and transit programs. The majority of state tax revenues are also used to fund transportation expenditures.[20] The federal tax rate for gasoline is 18.3 cents per gallon, while state gasoline tax rates range from 8 cents in Alaska to 34 cents in Washington state.[21] The federal tax rate has not been increased since 1993 and is not indexed to inflation. The HTF was initially predicted to reach a negative balance in 2009, but is now expected to run out by October 2008 due to lower than expected gasoline sales in the first part of 2008.[22] Thus, a review of the federal gasoline tax appears to be necessary, even without the added impetus brought on greenhouse gas legislation.[23]

Emission Reduction Options Related to Efficiency

Policies to reduce GHG emissions from vehicles have focused on improving vehicle efficiency, with some research and development (R&D) into alternative vehicle technologies. Measures in this area can include standards, pricing policies and funding for technology R&D. The key challenge with vehicles is to encourage market penetration of alternative vehicle technologies that increase fuel economy and significantly reduce GHG emissions.

Pricing Policies

Pricing policy options include feebates, taxes on inefficient vehicles, and tax credits for purchase of fuel-efficient vehicles. Although feebates have not yet been used extensively in the United States, they are a promising policy option. Like the vehicle standards discussed below, a feebate can be formulated in terms of fuel economy (fuel consumption per unit distance) or carbon emissions. The manufacturer (or the purchaser) pays a fee for any vehicles produced (or purchased) that are less efficient than the target for fuel economy or GHG emissions. Any vehicle produced or sold that is more efficient than the target receives a rebate. The value of the fee or rebate can increase in proportion to the divergence from the targeted value. The fee or rebate is expected to induce a change in consumer purchase decisions more effectively than fuel economy. The feebate changes the initial purchase price of a vehicle, which has a larger impact on consumer decisions compared to the monetary savings from higher fuel economy that would accrue over the long run.[24]

Feebates provide a continuing incentive for manufacturers to improve fuel economy, in contrast to regulatory standards which, once they are met, offer no incentive for further improvement. With a feebate, improving efficiency results in lower fees or higher rebates.[25] Studies of feebate systems find that the majority of improvements in fuel economy are likely to come from the adoption of technology and only partly from a shift in the sales mix of vehicles.[26] The structure of a feebate system can be revenue neutral, revenue enhancing, or at a net cost to the government. An alternative to feebates is to increase taxes or offer credits to purchasers based on specific vehicle characteristics instead of fuel economy or GHG emissions. This type of a policy would pick certain vehicle technologies (e.g., flex-fuel vehicle, hybrid drivetrain, etc.) and create incentives (or disincentives) for purchase. Like a feebate, a tax or credit can be an effective way to change consumer decisions, based on a price signal at the time of purchase.

Policy Implementation

France recently enacted a feebate program that awards a rebate to purchasers of vehicles that emit less that 130 g CO_2/km (about 30 percent of the current market) and requires a fee from purchasers of vehicles that emit above 160 g CO_2/km (about 25 percent of the market). The amount of the fee or rebate is determined based on distance from the above target points (fees are higher as the distance from the target increases); rebates range from €200-1,000 and fees from €200-2,600. Vehicles that emit between 130-160 g CO_2 fall in a “neutral zone” that has neither a fee nor rebate.[27] Also, purchasers of extremely low emission vehicles (below 60 gCO_2/km) receive a special rebate of €5,000 (US$7,300); this bonus was enacted as part of the feebate program discussed above and designed to create an incentive for the adoption of electric vehicles. Both Denmark and Israel are also currently considering tax polices to create incentives for the purchase of electric vehicles.

In the United States, the gas guzzler tax, enacted under the Energy Tax Act of 1978, requires manufacturers to pay a tax on cars that fail to meet certain fuel economy levels. This tax is separate from CAFE standards and displayed on the window sticker on new cars. Trucks, SUVs and minivans are not covered under the gas guzzler tax, since these vehicles were not widely available for non-commercial purposes in the late 1970s.[28]

More recently, tax credits have been used to spur the market penetration of hybrid and clean diesel technologies. The Energy Policy Act of 2005 provides a federal income tax credit for the purchase of new hybrid and diesel vehicles that meet Tier 2 emissions standards from 2006-2010. The credit begins phasing out as a manufacturer sells more than 60,000 of the eligible vehicles.[29] The Economic Stabilization Act of 2008 (H.R. 1424) includes a new tax credit of $7,500–$15,000 for plug-in electric vehicles up to 26,000 lbs in gross vehicle weight.

In the United States, vehicle standards have been the main mechanism for reducing transportation emissions of conventional air pollution, and California and other states are proposing to use them to reduce GHG emissions as well.

Standards

In the United States, vehicle standards have been the main mechanism for reducing transportation emissions of conventional air pollution, and California and other states are proposing to use them to reduce GHG emissions as well. Increasing vehicle fuel economy standards also has the effect of lowering GHG emissions from what they otherwise would have been, because GHG emissions are closely related to fuel use.Vehicle fuel economy standards can be expressed in miles per gallon (mpg) or kilometers per liter (km/l). Vehicle fuel economy can be improved by increasing energy efficiency of the drivetrain (engine and transmission) and by decreasing the amount of energy needed to move the vehicle (through reducing weight, aerodynamic drag, and rolling resistance).

Vehicle emissions standards limit the tailpipe emissions from a vehicle, as well as from air conditioning, and are typically expressed as grams of CO_2 equivalent per kilometer (gCO_2e/km). An emissions standard creates an incentive to reduce all GHG emissions from motor vehicles and produce vehicles that use low carbon energy sources at the same time.[30] A GHG standard also gives manufacturers more flexibility than a fuel economy standard; rather than being tied to a fuel efficiency improvement, manufacturers can use a variety of technologies to achieve greater GHG mitigation.[31]

Policy Implementation

Around the world, vehicle standards are being used as a way to reduce fossil fuel use and GHG emissions. In the United States, the Corporate Average Fuel Economy (CAFE) program has regulated light duty vehicle fuel economy for the last 30 years. Enacted under the Energy Policy and Conservation Act (EPCA) of 1975, CAFE sets fuel economy standards for new cars and light trucks. Figure 1 shows the CAFE standards from 1978 to 2007. In 2007, the Energy Independence and Security Act increased CAFE standards, which for passenger cars had been stagnant since 1988. This revision to the standards requires that new passenger cars and light trucks, on average, achieve a combined fuel economy of 35 mpg by 2020. The National Highway Traffic Safety Administration (NHTSA) recently issued a Notice of Proposed Rulemaking for the standards.[32]

In 2002, California adopted its own vehicle GHG emissions standard.[33] This regulation would require a 30 percent reduction in fleet-wide GHG emissions of new vehicles by model year 2016, and depending on what assumptions are used, this is equivalent to a fuel economy of 35.7 mpg by 2016 for the California fleet of new vehicles. Analysis from the California Air Resources Board shows that the California GHG standards, if applied nationally, would be equivalent to a fuel economy for new vehicle fleet of 32.3 mpg by 2016 and 39.2 mpg by 2020, higher than the 35 mpg mandated by the new CAFE standards.[34]

As of September 2008, sixteen other states have announced their intention to adopt California's standards; however, implementation of these standards, which would have applied starting in model year 2009, has been delayed. In April 2007, the U.S. Supreme Court ruled in *Massachusetts v. EPA* that EPA can use its authority to regulate GHGs under Section 202 of the Clean Air Act. Under Section 209 of the Act, California is allowed to go beyond established federal standards for motor vehicles, but it must first seek a waiver from EPA. In December 2007, the EPA denied this request and California has sued EPA to reverse the denial. This decision may be reversed by a future EPA, through passage of new legislation in Congress, or through a ruling in favor of California on the lawsuit.

The fuel economy of new vehicles can be improved significantly through incremental changes in conventional vehicle technology…as well as through the introduction of alternative vehicles and fuels.

Vehicle Technologies

The fuel economy of new vehicles can be improved significantly through incremental changes in conventional vehicle technology (such as changes in engine and transmission design), as well as through the introduction of alternative vehicles and fuels. These alternatives include vehicles powered by hydrogen or electricity. In these cases, GHG emissions resulting from production of hydrogen or electricity would, however, need to be taken into account in some way. Although there is considerable potential to decrease the fuel consumption of new vehicles, increasing the efficiency of the entire transportation sector will take significantly longer, due to the slow turnover rate of transportation equipment.

Hybrid-electric vehicles, one of the alternative vehicle technologies already in use, represent a first step in the transition from fossil-fuel powered, internal combustion engines. Over the last few years, hybrids have gained increased market share. With recent gasoline price increases, consumers are looking for more efficient vehicles, and manufacturers have offered more hybrid vehicle types and models. Hybrids, currently less than 3 percent of new vehicle sales, are expected to make up nearly 8 percent of vehicle sales by 2015.[35]

There are many possible configurations for a hybrid vehicle. At the basic level, a hybrid has an internal combustion engine complemented by an electric motor that supplies power for acceleration and allows the engine to be shut down during idling or deceleration. A battery captures energy during regenerative braking that is later used by the electric motor.[36] Different hybrid configurations are suitable for different use patterns—city driving, short distance commutes, or long distance travel.

Improvements in hybrid design and battery technology can smooth a transition to plug-in hybrid-electric vehicles (PHEV) and electric vehicles, which still remain several years away from mass-market deployment. Key hurdles for both are battery capacity, durability, and cost. With respect to GHG emissions, the benefit of PHEVs will depend on how the electricity is generated. With the average U.S. electric power generation profile, a plug-in with a 40-mile electric range would result in a CO_2 reduction of about 15 percent relative to a regular hybrid.[37] If powered by electricity from low carbon sources, the CO_2 reduction from using PHEVs could be even greater. A cap-and-trade program is a critical way to introduce low carbon electricity generation technologies. By the time there are a significant number of plug-in electric vehicles on the road, the cap will have lowered overall GHG emissions from electricity generation.

Hydrogen, which can be burned in a traditional internal combustion engine or converted into electricity in a fuel cell, is seen as another possible replacement fuel for the transportation system, since it releases no CO_2 upon combustion. Hydrogen internal combustion engines are up to 15 percent more efficient than similar gas engines.[38] Hydrogen oxidized in fuel cells produces electricity to power the vehicle. Fuel cells promise a two- to three-fold increase in efficiency and emit only water vapor on use. Similar to electric vehicles, on-board storage of hydrogen to obtain sufficient vehicle range before refueling is a challenge. Hydrogen vehicles can partially compensate for this problem by being significantly more efficient than gasoline engines, thus requiring the storage of less on-board energy.

Federal policy efforts in this area can include funding for research and development (R&D) and industry partnerships. For example, DOE's FreedomCAR and Fuel Partnership is a collaborative effort among the agency, the U.S. Council for Automotive Research (USCAR) partners, and several energy companies to develop emissions-free cars and light trucks. Collaborative R&D efforts, like these, should initially focus on research on critical issues for alternative technologies (e.g., battery technology for PHEVs) to achieve faster market penetration and deeper GHG reductions. As these critical issues are resolved, funding should shift to development and deployment of system infrastructure to support use of the particular fuel or vehicle type.

Other Transportation Modes

In addition to passenger vehicles, heavy-duty trucks, buses, aircraft, trains, and marine vessels also contribute to transportation sector emissions. Buses and heavy-duty trucks are used in both local and long-distance transportation. Engine improvements, weight reduction, and transmission enhancements can improve the fuel economy for new heavy-duty tractor-trailers by 25 to 50 percent.[39] Since idling accounts for a significant proportion of fuel use, idle reduction technologies, such as auxiliary power units and other battery technologies, could also significantly reduce fuel use.

Low sales volumes and varied product configurations and applications make it difficult to set standards for these vehicles. In the United States, annual sales in the heavy-duty sector are less than five percent of the light duty vehicle sales.[40] EISA 2007 directs the National Academy of Sciences and the Department of Transportation to examine fuel economy standards for medium- and heavy-duty trucks and based on this analysis, implement standards at the maximum feasible level. In 2006, Japan enacted standards for heavy duty vehicles weighing more than 7,000 lbs, with an overall goal of reducing the fuel consumption, on average, of these vehicles 12 percent below 2002 levels by 2015.[41]

This sector can also benefit from programs that quantify and create incentives for HDV operators to use the most efficient equipment and operations. For example, EPA's SmartWay Transport Partnership works with freight operators to monitor and reduce fuel consumption, GHG emissions, and air pollutants. Similar efforts can be directed to other modes, such as metropolitan areas with large bus fleets. Policies for heavy duty vehicles should address fuel economy and the efficiency of auxiliary equipment (such as cab heaters and air conditioners that are used when the vehicle is stationary), as well as driving behavior and logistics.

The remaining modes of transportation—air, rail, and water—comprise a small percentage of total transportation emission. Air travel emits about 2-3 percent of global GHG emissions and has reduced its energy intensity by about 60 percent over the last 30 years. However, like the growth in passenger vehicles emissions, overall air traffic emissions have increased due to increased miles traveled. The aviation sector could benefit from technologies and procedures to better navigate aircraft and improve air traffic management, as well as from more efficient engines and aircraft aerodynamics and the use of alternative fuels in the longer term. Modes, such as rail and marine, could also make use of technological advances, such as improvements in diesel engine efficiency and hybrid technologies.

Emission Reduction Options Related to Distances Traveled

The impact of policies to lower the carbon content of the fuel supply and increase vehicle efficiency will be more effective if they are coupled with measures to reduce vehicle miles traveled. Until recently, the number of miles traveled had consistently grown since the 1950s and far exceeded population growth. Population growth accounts for only about 25 percent of the increase in VMT, while changes in spatial configuration of residential and business land uses, along with changes in driver behavior (longer and more frequent trips, more single-occupant vehicles) are responsible for the remaining 75 percent of the increase.[42]

This section outlines several areas for VMT reduction, through more efficient travel patterns, increased vehicle occupancy rates, pricing strategies, augmentation of low carbon transportation modes, and changes in land development patterns. A brief discussion of the appropriate federal role for achieving these reductions follows.

Improving Efficiency of the Current Transportation System

Improving the efficiency of travel can decrease GHG emissions without a significant infrastructure investment. Newer technologies, such as GPS systems for trucks and improved air traffic management for aviation can help drivers and pilots take more direct, less congested routes from origin to destination. Such systems are already being used to a limited extent, but much more could be done. These technologies, coupled with driver education to improve in-use efficiency, can save both time and fuel.

Another potential strategy to reduce VMT is through increasing the occupancy rate of vehicles. In 1969, the average occupancy was 2.2 persons per vehicle, which had dropped to 1.6 in 2001.[43] For work commutes, it is even lower, about 1.1 occupants per vehicle. This has lead to 10 trillion "empty seat" miles on U.S. highways, a phenomenon that some experts have described as the world's greatest oil reserve.[44] Increasing vehicle occupancy has been a difficult challenge, and carpooling programs have had limited success in the United States, although more recent experience indicates that with sustained increases in the costs of transportation, carpooling becomes a more viable option. For example, in the first six months of 2008, the retail price of gasoline increased by nearly 33 percent, going above $4/gallon in many areas. Preliminary data and anecdotal evidence show that the use of carpooling and high occupancy vehicle (HOV) lanes has increased over this same period, as consumers respond to the price increases.[45]

Carpooling programs have had limited success in the United States, although more recent experience indicates that with sustained increases in the costs of transportation, carpooling becomes a more viable option.

Increasing the Costs of Transportation

Another option for reducing VMT is to increase the extent to which costs borne by travelers depend on miles traveled. Since most of the highway infrastructure is provided as a public good, transferring some of the costs of transportation to consumers can induce the behavioral changes that lead to more efficient driving patterns.

One possible measure is to establish tolls and congestion charges. Studies suggest that tolls could reduce VMT by up to 20 percent on highways and 10 percent on other roads.[46] Because of the challenges with increasing vehicle occupancy, HOV lanes can be modified to a toll system based on vehicle occupancy. Single-occupancy vehicles could still use these high occupancy toll (HOT) lanes, but would pay a higher toll than vehicles with multiple passengers. An alternative strategy—congestion pricing—charges drivers a higher toll on certain roadways (for example, in a central business district or city center) during peak times. The price signal is intended to influence drivers to take mass transit or reschedule their trip to non-peak times.

Reducing congestion also has the benefit of lowering fuel consumption and GHG emissions by smoothing traffic flows and decreasing the time spent idling.

Congestion pricing has been used successfully in many places—London, Singapore, Stockholm, and Oslo—and was recently proposed for parts of New York City, but strongly opposed by the state's legislature.[47] Congestion charges and tolls can also suffer from the rebound effect; that is, as congestion decreases, the ease of travel increases as well, thereby increasing travel to a small degree. Furthermore, pricing some roads and not others may shift traffic to non-toll roads. Thus, the effectiveness of such policies will depend on coverage and available alternatives to road travel.

In the longer-term, it may be possible to shift some of the transportation demand to less GHG-intensive modes such as rail and other mass transit systems.

Shifting the Fixed Costs of Transportation

Two strategies to shift the fixed costs of travel to variable costs are insurance rates linked to VMT and carsharing programs. Pay as you drive insurance (PAYD) links insurance premiums to miles traveled and could reduce driving by 10 to 12 percent, based on one estimate.[48] With PAYD, the annual insurance fee is converted to a per mile fee that takes into consideration the regular rate factors, include driver age and history and vehicle type. PAYD rewards drivers who rarely use personal vehicle transport and creates an incentive to instead use other transportation modes. An alternative to PAYD insurance is pay-at-the-pump (PATP). Under PATP, drivers pay for their insurance when they buy fuel for their vehicles, typically as a surcharge on fuel price. The amount of the surcharge would depend on insurance coverage. Proposed amounts have been in the range of 30 to 50 cents per gallon.[49]

Carsharing shifts the one-time cost of vehicle purchase to "per use" basis, and like PAYD, can be a strategy to decrease the growth in VMT. Carsharing programs have gained prominence in recent years, especially among individuals in urban areas who prefer not to invest in the costs of full-time car ownership.[50] Typically, carsharing companies maintain a fleet of vehicles, across major access points in an urban area, for example, near a transit station or large apartment complex. Individuals sign-up for membership to such a service and can easily reserve vehicles and pay for the rental through hourly rates or subscription plans. Carsharing fleets can complement transit service and also offer the potential to facilitate the introduction of alternative vehicle types.

Alternative Transportation Modes

In the longer-term, it may be possible to shift some of the transportation demand to less GHG-intensive modes such as rail and other mass transit systems. The federal government has a unique ability to spur this development through transportation funding formulas, particularly by shifting funds from highway construction to transit development. Transit improvements need not be limited to urban areas. Improving transit accessibility at the regional level, especially in high traffic corridors, could also have a large impact on VMT.[51] Mass transit can reduce light duty vehicle travel and also promotes high-density, mixed-use development along transit routes. These land use changes, which form another part of long-term VMT reduction strategies, are discussed next.

Land Use Planning and Development

Land use planning, in the long run, has the potential to have a significant impact on GHG emissions. Compact and mixed-use development reduces travel, by putting housing, shopping and businesses within short distances of each other. There are numerous benefits of compact development. These include preserving farmland and open space, protecting water quality, providing more opportunity for physical activity, and creating more convenient and livable communities.[52] Making use of existing unused or poorly used land within developed areas—e.g., through infill and brownfield development—results in lower costs and reduces the need for infrastructure extensions to outlying areas.

Compact development also facilitates a more frequent and convenient mass transit system. Transit-oriented development (TOD) combines higher density, compact development near a major transit stop and is designed to support transit, bicycle, and walking trips, without excluding automobiles. In general, VMT can be reduced around a transit-centered development by 20-30 percent compared to more typical development.[53]

This type of concentrated land use can generate both public and private revenue. For example, in Arlington County, VA, the Rosslyn-Ballston corridor has focused development, over the last two decades, along five closely spaced rail stations.[54] This project has resulted in increased land value around transit stations and higher county revenues—about 8 percent of the county's land area generates now 33 percent of the revenues. Most importantly, residents of the area have higher transit use than average—about 50 percent take transit to work, and 73 percent walk to the stations.[55]

The Federal Role

Implementing direct measures to decrease VMT has proved challenging. In the United States, all three levels of government are involved in decisions that affect VMT. Although the federal government provides a substantial portion of the funding for transportation infrastructure, states make decisions regarding the use of those funds, while localities are responsible for land use and zoning decisions, which affect spatial configurations of residence and work locations. Coordinating decisions among these three levels can prove challenging and will require strong political leadership.

Programs to increase the efficiency of the current transportation system can benefit from federal technology research and development, and from federal funding of more efficient transportation systems. These measures can include intelligent traffic control systems (e.g., ramp metering, centrally controlled signaling, etc.) and improved air traffic control systems. For a program like PAYD or PATP insurance, government partnerships with insurance providers to create standardized monitoring and implementation systems can ease implementation for all users.

As discussed previously, federal transportation funding comes from the Highway Trust Fund, financed by the motor fuel excise tax. The current structure creates a disincentive to reduce gasoline consumption, since it reduces the funds available for highway and transit infrastructure development. As gasoline consumption decreases, in the future, due to a shift to low-GHG alternative fuels, a new revenue source for funding the transportation system will be needed. Pricing tools, such as congestion charges and tolls that also reduce VMT, are one option.

Although land use planning and zoning laws are generally under local jurisdiction, the federal government can provide direction as to how to take GHG emissions into consideration. Policies should be reevaluated and aligned to create incentives for changing development patterns to ones that minimize travel or allow for non-motorized travel (i.e., walking and biking) or use of mass-transit systems. At the federal level, environmental impact statements can require that planners take energy and climate change components into consideration for new transportation or development plans. EPA and related government agencies could develop tools and methods for measuring these impacts. At the state and local level, a review of land use policies and zoning laws is necessary to deal with both climate change mitigation and adaptation.

Key Design Questions

Policies to reduce GHG emissions from the transportation sector are a necessary part of any climate change mitigation plan. There are many cost-effective options that can be implemented in the short term, while deeper reductions in emissions from the transportation sector will require greater shifts, including alternative vehicle technologies and fuels and changes in behavior and land use patterns. A comprehensive policy now will pave the way for these to be adopted in the future and help achieve the GHG reductions needed to mitigate adverse impacts from climate change. In the cases where responsibility for implementation of these various programs crosses federal, state and local jurisdictions, the federal government can provide funding, along with guidelines on how to take GHG emissions into consideration in the planning process.

Some key design questions to consider when designing policies for the transportation sector include:

- How can we achieve our energy security and GHG goals at the same time?
- What is the best combination of policies to provide a continuing incentive to reduce GHG emissions, even if energy prices decline?
- How can policy measures for fuels and vehicles be aligned to create complementary incentives?
- What are the roles of hydrogen, electricity, and biofuels in reducing transportation's GHG emissions, in the long run? What is the best research, development, and deployment strategy for bringing these alternatives successfully into the market?
- How can effective policies for the other one third of transportation GHG emissions (i.e., those from other than passenger vehicles) be formulated and carried out?
- What are potential opportunities to align transportation funding with GHG goals under the reauthorization of the Surface Transportation Act?

End Notes

[1] U.S. EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006*, Washington, DC, April 2008.

[2] U.S. EIA, *Annual Energy Outlook 2008*, Table A-7. Found at http://www.eia.doe.gov/oiaf/aeo/pdf/0383(2008).pdf.

[3] U.S. EIA, *Annual Energy Review 2007*, Table 2.1e. Found at http://www.eia.doe.gov/emeu/aer/pdf/pages/sec2_8.pdf.

[4] U.S. EIA, Table: Petroleum Product Supplied, July 28, 2008. Found at http://tonto.eia.doe.gov/dnav/pet/pet_cons_psup_dc_nus_mbblpd_a.htm.

[5] A growth of approximately 10 percent from 2005-2030. See U.S. EIA, 2008.

[6] Penner, Joyce E., et al., *Aviation and the Global Atmosphere*, IPCC, 1999. Found at http://www.grida.no/Climate/ipcc/aviation/index.htm.

[7] Greene, David and Andreas Schafer, *Reducing GHG Emissions from U.S. Transportation*, Pew Center on Global Climate Change, May 2003.

[8] TRB, *Toward a Sustainable Future: Addressing the Long-Term Effects of Motor Vehicle Transportation on Climate and Ecology*, National Academies Press, 1997.

[9] U.S. air travel increased five-fold from 1970 to 2000 and ton-miles of freight has also doubled over the past thirty years. See Greene, 2003.

[10] U.S. EIA, 2007.

[11] For example, a $20 per ton of CO_2e allowance price would translate into only a 20 cent increase in the price of a gallon of gasoline, which represents a smaller change than the variability normally seen in the market. This same allowance price would have a much larger effect on other fossil fuels, such as natural gas and coal.

[12] Intensity standards set a target for the amount of carbon emitted per unit of energy consumed. Thus with higher energy use, emissions can still increase under intensity-based policies.

[13] "Conventional oil includes liquid hydrocarbons of light and medium gravity and viscosity, occurring in porous and permeable reservoirs. …Unconventional oil comprises deposits of greater density than water (heavy oil), viscosities in excess of 10,000 cP (oil sands), and occurrences in tight formations (oil shale). Ultimately, the distinction between conventional and unconventional resources is based on technology and economics." See Greene, David, et al., Have we run out of oil yet? Oil peaking analysis from an optimist's perspective, *Energy Policy* Vol. 34, 2006, pp. 515-531.

[14] Greene, 2006.

[15] Two recent studies have taken an initial look at the indirect land use impacts due to biofuel production. See Fargione, Joseph, et al., Land Clearing and the Biofuel Carbon Debt, Sciencexpress, February 2008, and Searchinger, Timothy, et al., Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Emissions from Land Use Change, Sciencexpress, February 2008.

[16] See Pew Center on Global Climate Change, http://www.pewclimate.org/what_s_being_done/in_the_states/map_ethanol.cfm.

[17] European Commission, Proposal for a Directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources, January 23, 2008. Found at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52008PC0019:EN:NOT.

[18] GHG intensity (also carbon or CO_2 intensity) is generally defined as the amount of carbon emitted per unit of energy consumed.

[19] For more information on California's LCFS program, visit http://www.arb.ca.gov/fuels/lcfs/lcfs.htm.

[20] See, for example, http://www.tdot.state.tn.us/GasTax/ and http://www.lao.ca.gov/ballot/2006/1A_11_2006.htm.

[21] Federation of Tax Administrators, Motor Fuel Excise Tax Rates, January 1, 2008. Found at http://www.taxadmin.org/fta/rate/motor_fl.html.

[22] Voorhees, Josh, DOT chief seeks immediate $8B bailout for highway account, *E&E News PM*, September 5, 2008.

[23] The Natural Surface Transportation Policy and Revenue Study Commission recommends increasing federal and state motor fuels taxes and indexing it to inflation to deal with rising construction costs and necessary transportation improvements over the next 15 to 20 years. As vehicles become more efficient and are powered by alternative energy sources, e.g. electricity, they recommend a transition to alternative revenue streams after the 2025-timeframe. National Surface Transportation Policy and Revenue Study Commission, *Transportation for Tomorrow*, Washington, DC, December 2007.

[24] Greene, 2003.

[25] Gallagher, Kelly et al., *Policy Options for Reducing Oil Consumption and Greenhouse-Gas Emissions from the U.S. Transportation Sector*, Belfer Center for Science and International Affairs, Summer 2007.

[26] McManus, Walter, *Economic Analysis of Feebates to Reduce Greenhouse Gas Emissions from Light Vehicles for California*, University of Michigan Transportation Research Institute, UMTRI-2007-19-2, May 2007.

[27] Green Car Congress, France to Institute Vehicle Feebate Based on CO_2 Emissions; $7,300 Bonus for Electric Cars, December 7, 2007. Found at http://www.greencarcongress.com/2007/12/france-to-insti.html.

[28] U.S. EPA, Gas Guzzler Tax. Found at http://www.epa.gov/fueleconomy/guzzler.

[29] Some analysts claim that this 60,000 limit was overly complicated for consumers and that probably weakened the impact of the incentive. For more information about the tax credits, see IRS, Summary of the Credit for Qualified Hybrid Vehicles. Found at http://www.irs.gov/newsroom/article/0,,id=157557,00.html; and Diesel Technology Forum, Federal Clean Diesel Tax Credit. Found at http://www.dieselforum.org/policy-insider/energy-efficiency/federal-clean-diesel-tax-credit/.

[30] Kopp, Raymond, *Transport Policies to Reduce* CO_2 *Emissions from the Light-Duty Vehicle Fleet,* Resources for the Future, November 2007.

[31] Gallagher, 2007.

[32] Average Fuel Economy Standards Passenger Cars and Light Trucks Model Years 2011-2015, Proposed Rule, 73 Fed Reg 24352–24487, May 2, 2008.

[33] California Office of the Governor, Governor Davis Signs Historic Global Warming Bill, July 22, 2002. For full text of the bill, visit http://www.arb.ca.gov/cc/ccms/documents/ab1493.pdf.

[34] *California Air Resources Board, Comparison of GHG reductions for the U.S. and Canada under U.S. CAFE Standards and CARB GHG Regulations*, Sacramento, CA, February 2008.

[35] U.S. EIA, 2008.

[36] Regenerative braking captures the kinetic energy of the vehicle that is lost during braking and stores it for later use, usually in a battery.

[37] Kliesch, James, and Therese Langer, *Plug-In Hybrids: An Environmental and Economic Performance Outlook*, ACEEE, Report Number T061, September 2006.

[38] Greene, 2003.

[39] Greene, 2003.

[40] Davis, Stacy, Susan W. Diegel, and Robert G. Boundy, *Transportation Data Energy Book: Edition 27*, Oak Ridge National Lab, 2008.

[41] Green Car Congress, Japan to Issue World's First Fuel Economy Standards for Large Trucks and Buses, September 30, 2005. Found at http://www.greencarcongress.com/2005/09/japan_to_issue_.html.

[42] Ewing, Reid et al., *Growing Cooler: the Evidence on Urban Development and Climate Change*, Urban Land Institute, 2007.

[43] National Household Travel Survey, INKLINGS: Preliminary Results from the 2001 NHTS. Found at http://nhts.ornl.gov/2001/presentations/inklings/index.shtml.

[44] Greene, 2003.

[45] See Jesdanun, Anick, High gas prices make motorists click on carpool sites, *USA Today*, August 12, 2008. Found at http://www.usatoday.com/tech/webguide/2008-08-12-carpool-websites_N.htm; Dallas Area Rapid Transit, NEWS RELEASE: 400,000 daily trips on buses, trains and HOV lanes, September 25, 2008. Found at http://www.dart.org/news/news.asp?ID=811.

[46] Greene, 2003.

[47] Confessore, Nicholas, $8 Traffic Fee for Manhattan Gets Nowhere, *New York Times*, April 8, 2008.

[48] Environmental Defense Fund, *Pay-As-You-Drive (PAYD) Auto Insurance*, May 5, 2008. Found at http://www.edf.org/article.cfm?ContentID=2205.

[49] Khazzoom, J. Daniel, *Pay-at-the-Pump (PATP) Auto Insurance: Criticisms and Proposed Modifications*, Resources for the Future, Discussion Paper 99–14–REV, May 2000.

[50] Shaheen, Susan A., et al., Carsharing in North America: Market Growth, Current Developments, and Future Potential, *Transportation Research Record*, No. 1986, 2006.

[51] Greene, 2003.

[52] Ewing, 2007.

[53] Dierkers, Greg, et al., *CCAP Transportation Emissions Guidebook: Part One—Land Use, Transit & Travel Demand Management,* Center for Clean Air Policy, 2007.

[54] Reconnecting America and the Center for Transit-Oriented Development, TOD 101: *Why Transit-Oriented Development And Why Now?* Found at http://www.reconnectingamerica.org/public/download/tod101full.

[55] Christie, Les, New Yorkers are top transit users: More than half ride subway or bus to work, *CNNMoney.com*, June 13, 2007. Found at http://money.cnn.com/2007/06/13/real_estate/public_transit_commutes/index.htm.

Pew Center on Global Climate Change
2101 Wilson Blvd. • Suite 550 • Arlington, VA 22201
Phone 703.516.4146 • Fax 703.841.1422

Printed on recycled paper

www.pewclimate.org