Testimony to the
United States Senate Finance Committee

TECHNOLOGY-NEUTRAL INCENTIVES FOR ENERGY-EFFICIENT LOW GREENHOUSE GAS EMITTING VEHICLES

by

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Good morning Mr. Chairman, Senators and distinguished guests. Thank you for the opportunity to offer my views on the pros and cons of technology-neutral energy and environmental incentives. I will confine my remarks to the area I know best, which is the transportation sector, addressing primarily incentives for energy efficient and low greenhouse gas (GHG) emitting vehicles.

For most energy and environmental policy goals, performance-based, technology-neutral incentives (and standards) are superior to those that target a specific technology. Performance-based incentives allow the widest scope for innovation, and permit market forces the greatest latitude to select and implement cost-effective solutions. Because of our limited ability to foresee technological solutions that are possible but do not yet exist, it is almost always more effective and economical to specify the energy or environmental objective rather than a specific means of achieving it. Well designed fiscal incentives provide a clear and consistent signal to the market to make continuing progress toward energy goals. In certain cases they can even correct limitations of the marketplace.

Performance can be measured in different ways: e.g., energy use, petroleum consumption, or GHG emissions.[1] The choice could be important because some fuels that would help reduce petroleum dependence (e.g., coal-derived gasoline) would increase full fuel cycle GHG emissions unless by-product carbon dioxide (CO_2) were captured and sequestered. Choosing GHG emissions as a metric however, would substantially benefit energy security since the preponderance of measures for reducing GHG emissions from transportation vehicles will also reduce oil dependence.

[1] Of course many other measures of merit are possible, as are combinations of measures.

Why Vehicle Incentives Can Help Achieve Energy Goals

The market system is the fundamental mechanism by which we will achieve our national energy goals. However, markets run into difficulties in several areas. Emissions of GHGs from the combustion of fossil fuels are a near-perfect example of a public good externality that requires public policy solutions. At the center of our oil security problem is the monopoly influence of the OPEC cartel. The nationally owned oil companies controlling four out of five barrels of the world's proved reserves and well over half of the world's ultimately recoverable resources of conventional oil create oil price shocks, inflate world oil prices and in the process appropriate hundreds of billions of dollars of wealth from oil consuming economies. By my estimates, oil dependence cost our economy between $700 and $800 billion dollars in 2008. The market problem here is not externalities but monopoly power, and fiscal policies alone are not likely to solve the problem (Leiby, 2007).

Markets for energy efficiency in general, and the market for automotive fuel economy in particular, also have important limitations. As a general rule, more efficient automotive technologies cost more and deliver benefits in the form of future fuel savings. The estimated cost of increasing the fuel economy of an average U.S. passenger car based on the 2002 National Research Council (NRC) fuel economy study is illustrated by the red dotted line in Figure 1. The expected present value of future fuel savings is shown as a solid gray line. Of greatest interest to the consumer is the difference between the two, the expected net present value. This increases to a maximum of about $400 at 35 miles per gallon (MPG), the point at which the marginal cost of increasing fuel economy exactly equals the marginal value of expected fuel savings. Figure 1 reflects private costs only; motor fuel taxes are included but no values are attached to reducing GHG emissions or oil dependence.

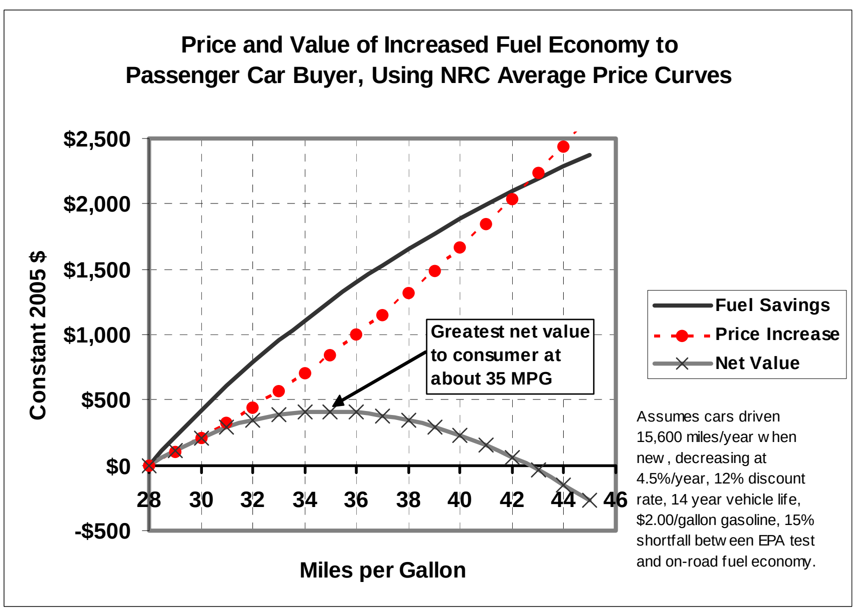

Figure 1. Illustrative Private Cost and Expected Benefit of Increasing Passenger Car Fuel Economy. (Greene, German and Delucchi, 2009)

Figure 1 represents future fuel savings as a known quantity. However, consumers view future fuel savings as uncertain due to ambiguity about future energy prices, the validity of official fuel economy estimates, vehicle life expectancies, future vehicle travel and other factors. When the uncertainty about future payoffs is considered, the net value of increasing fuel economy at each higher fuel economy level becomes a probability distribution, as shown in Figure 2. As Figure 2 shows, if fuel prices are low and the vehicle's rated fuel economy is not realized, the consumer might actually lose money despite the expected gain of $405.

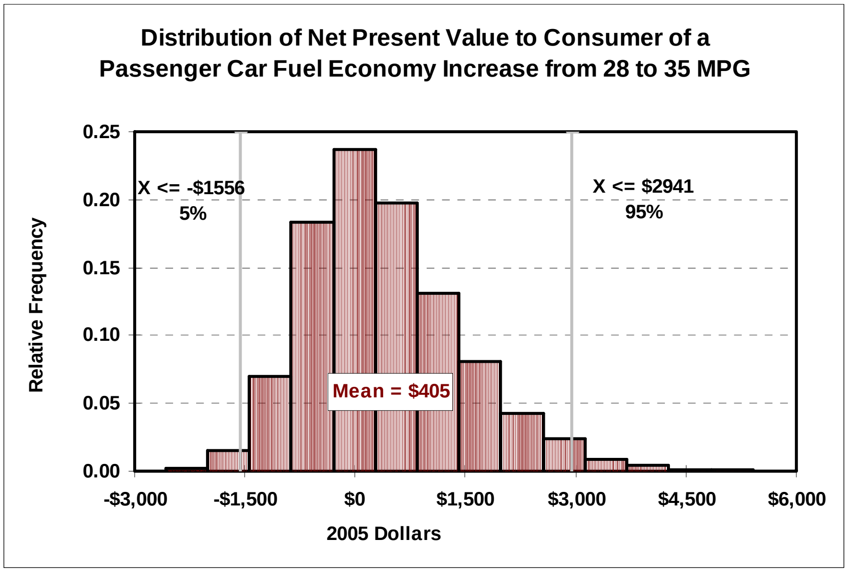

Figure 2. Distribution of Net Present Value to Consumer of an Increase in Passenger Car Fuel Economy from 28 to 35 MPG. (Greene, German and Delucchi, 2009)

Nobel prize-winning economic research conducted over the past three decades has established that, in general, consumers are loss-averse. That is, they weight potential losses from a risky bet more heavily than potential gains. When the inherent loss-aversion of typical consumers is taken into account, technologies that are cost-effective in terms of their expected payoff appear to be too risky. Using the same data and assumptions of the 2002 NRC study of the CAFE standards (NRC, 2002) but applying a typical loss-aversion function (Tversky and Kahneman, 1992) changes the perceived value of the fuel economy bet from an expected net gain of $405 to a perceived loss equal to -$32 (Figure 3).

The implications of uncertainty and loss-aversion match up almost exactly with the views expressed to the 2002 NRC committee by auto manufacturers, who stated that consumers were willing to pay only for technologies which paid back their cost in 2 to 4 years. If one assumes that consumers value future fuel savings using a simple 3-year payback rule, future fuel savings are undervalued by a factor of 2, or more. Again using the same cost data and assumptions of the 2002 NRC report, we find an expected value of fuel economy improvement of almost zero from 28 to 35 MPG (Figure 4). The undervaluing of energy efficiency (relative to expected savings) due to uncertainty and loss-aversion is very likely pervasive, affecting not only automobiles but all energy using consumer durable goods. It also almost certainly discourages appropriate levels of investment in energy efficiency research and development.

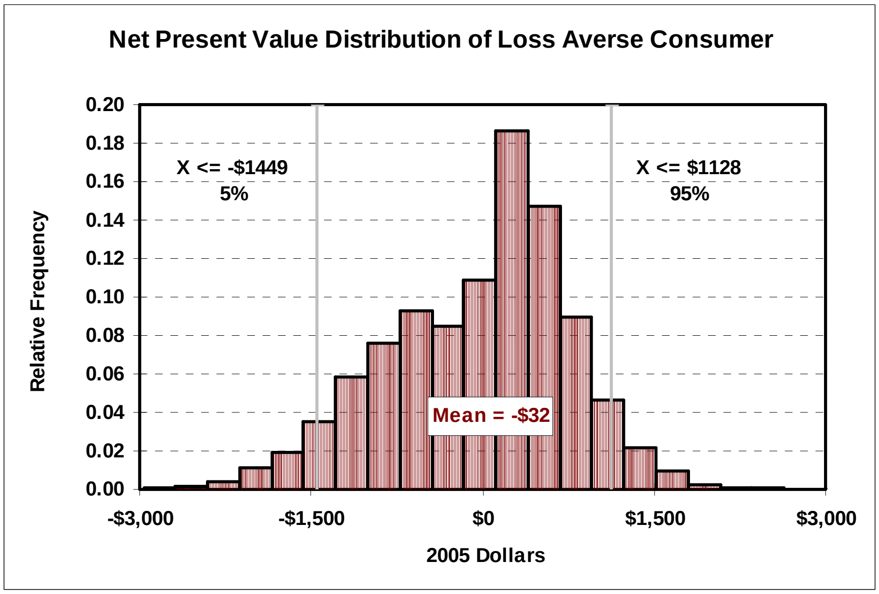

Figure 3. Perceived Value Distribution of the 25% Increase in Passenger Car Fuel Economy for a Loss-Averse Consumer. (Greene, German and Delucchi, 2009)

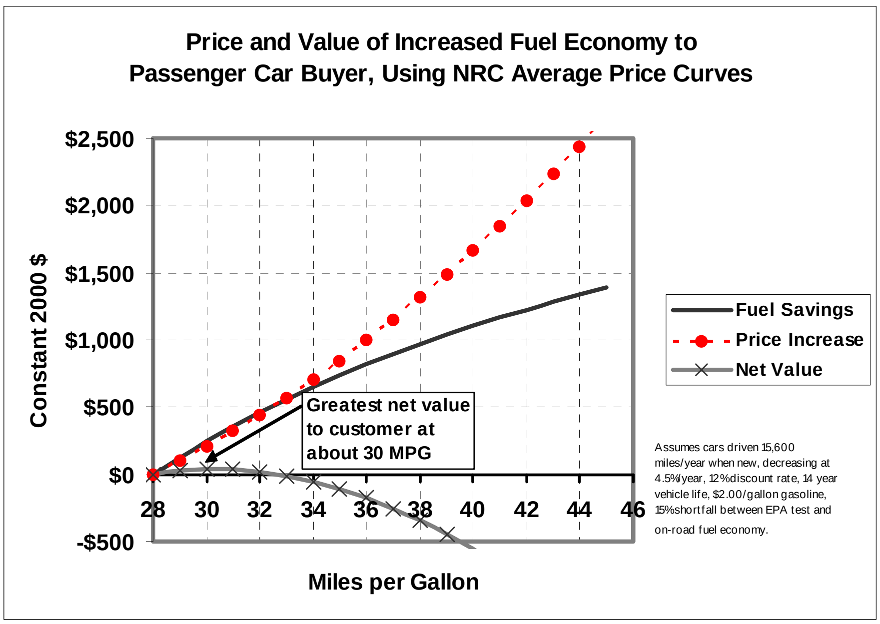

Figure 4. Private Cost and Expected Benefit of Increasing Passenger Car Fuel Economy Using a Simple 3-Year Payback Rule. (Greene, German and Delucchi, 2009)

The phenomenon of uncertainty and loss-aversion in the market for fuel economy does not constitute a market failure in the usual sense. Rather it exacerbates the market failures of environmental externalities and oil market monopolization and its energy security consequences. It weakens the market response to fuel price signals, such as a tax on gasoline. At the same time it creates an opportunity for public policy to achieve a greater response than would be possible with externality pricing alone through the use of regulations or fiscal incentives to promote vehicle efficiency and GHG mitigation.

Examples of Successful Technology-Neutral Policies in Transportation

Motor vehicle emissions standards established by the State of California and the U.S. Environmental Protection Agency pursuant to the Clean Air Act, set performance goals for criteria pollutants but did not specify the technologies that should be used to achieve them. The motor vehicle industry responded with unanticipated technologies, such as the three-way catalyst, multi-point fuel injection and computerized control of combustion that reduced emissions by orders of magnitude. A passenger car meeting California's SULEV standard in 2005 emitted one one-thousandth (0.001) of the smog-producing hydrocarbons of a passenger car manufactured in 1960 (Sakai, 2009).

The federal Corporate Average Fuel Economy standards likewise did not specify the technologies manufacturers should use to nearly double passenger car fuel economy over 1975 levels by 1985, and to increase light truck fuel economy by more than 50% (Figure 5). Manufacturers responded with a range of technological solutions, from front wheel drive and lighter-weight unibody designs to reduced engine friction and 4- and 5-speed transmissions.

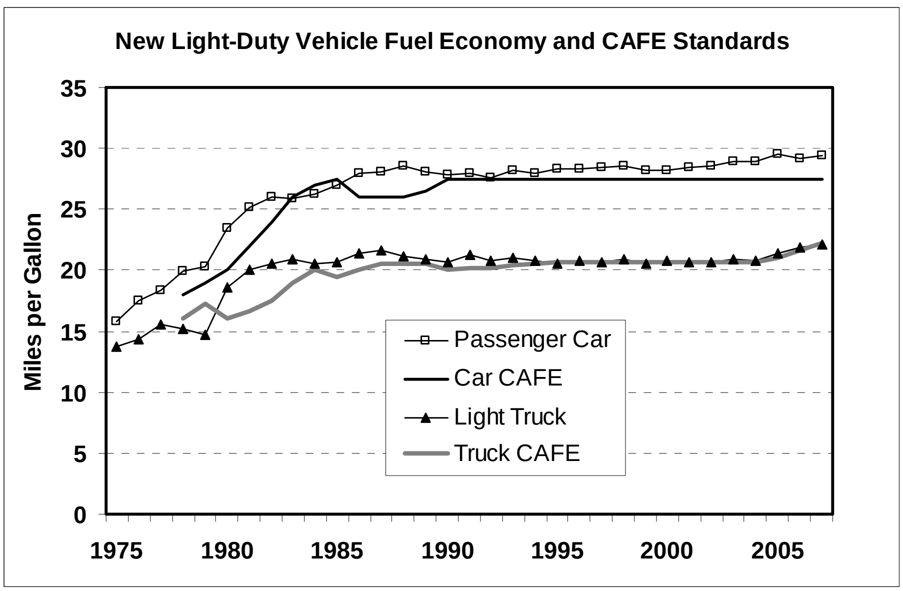

Figure 5. New Passenger Car and Light Truck Fuel Economy and Standards. Source: U.S. EPA (2008) "Light-Duty Automotive Technology and Fuel Economy Trends: 1975-2008.

Improvements in new vehicle fuel economy gradually increased the fuel economy of the on-road fleet by more than 50%, as the vehicle stock turned over (Figure 6). The result was a clear decoupling of vehicle travel and energy use, beginning at about the same time the standards took effect in 1978 (Figure 7). U.S. motorists are today consuming on the order of 75 billion gallons less fuel each year than they would have had fuel use continued to increase in direct proportion to vehicle travel.

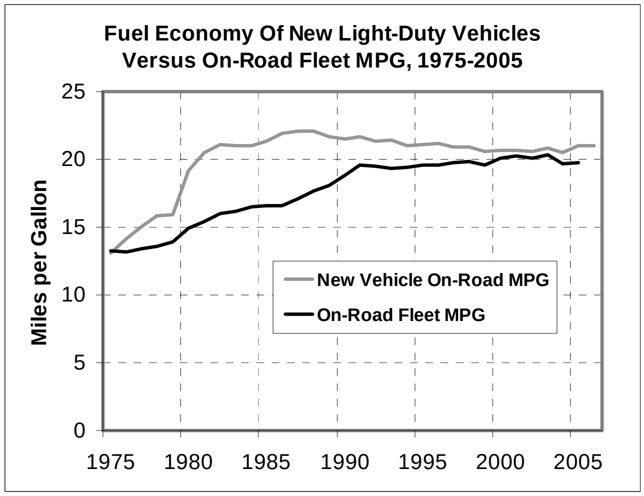

Figure 6. Fuel Economy of New Light-duty Vehicles & On-Road Fleet MPG, 1975-2007
Sources: U.S. EPA (2008), table 1, and U.S. DOT/FHWA (2007),
Highway Statistics 2007, table VM-1.

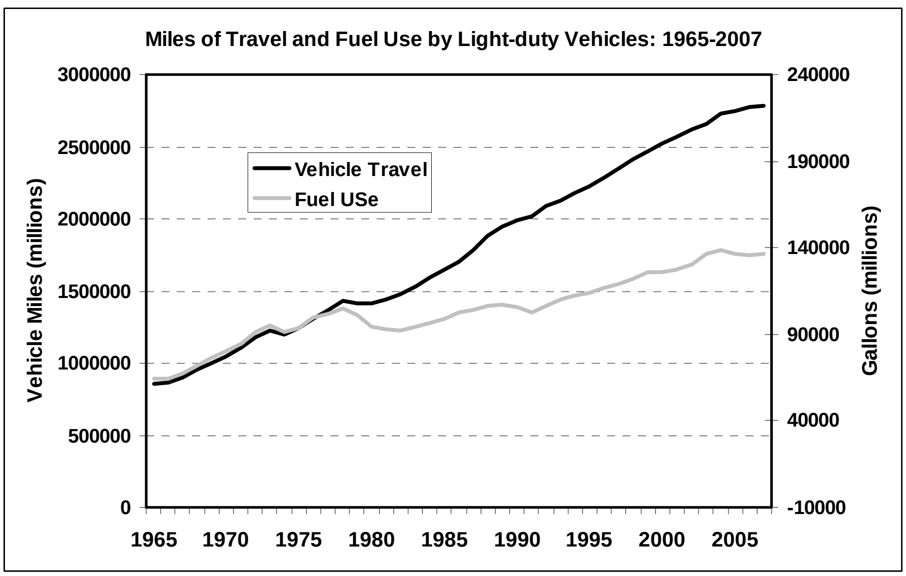

Figure 7. Light-duty Vehicle Travel and Fuel Use: 1965-2007
Source: U.S. DOT/FHWA (2007), *Highway Statistics 2007* and earlier, table VM-1.

On the fuel side, California's clean fuel standards were initially pegged to the lower emission performance of methanol in comparison to gasoline. Fortunately, the standards were formulated in terms of pollutant emission requirements rather than picking methanol as the winning fuel. Energy companies responded by inventing reformulated gasolines that achieved the same environmental goals at lower cost.

Examples of technology-neutral fiscal incentives in the transport sector are scarcer.[2] Although it is a flawed policy, the U.S. gas-guzzler tax is nonetheless technology neutral, and appears to have had a powerful impact. The policy is flawed, in my view, because it applies only to passenger cars and not light trucks, and because it provides only for taxes on energy-intensive vehicles but no incentives for energy efficient vehicles. Still, it appears that the gas-guzzler tax convinced manufacturers to improve the fuel economy of larger passenger cars such that no mass-market passenger car has had to pay the tax (Greene et al., 2005).

New Options: Feebates and Carbon Prices

Can we replace our current patchwork of tax incentives for alternative fuels and vehicles (incentives for HEVs, PHEVs, natural gas, electric, flex-fuel, E85, for fuel economy, etc.) with a simpler yet more flexible and more efficient, technology-neutral incentive structure? The answer, I think, is a qualified yes. On the vehicle side, it should be possible to replace nearly all of our current incentives with a more effective unified vehicle incentive system, usually referred to as a "feebate" system. On the fuel side we can create a system for pricing carbon, whether it is a carbon tax or carbon cap-and-trade system. Both policies are technology neutral and can provide appropriate incentives for improving energy efficiency and de-carbonizing transportation's energy sources.

Feebates consist of a graduated rebate for energy efficient or low-GHG-emitting vehicles and a graduated levy on energy intensive or high-GHG-emitting vehicles, relative to a benchmark. The concept is very flexible: feebate systems can be formulated in an infinite number of ways. The simplest and perhaps most efficient, is to set a constant rate of rebate or tax per unit of petroleum use or GHG emissions per mile. A constant rate is economically efficient, in that it values every gallon of fuel saved or ton of GHGs mitigated equally.

The benchmark determines which vehicles pay a fee and which receive a rebate. It can be as simple as a single point for all vehicles or as complex as the reformed CAFE footprint function. Feebate systems can be designed to be revenue neutral, in which the fees finance the rebates, revenue enhancing or a net subsidy. At times when a stimulus to the automotive industry could benefit the entire economy, feebates could be structured as mainly or entirely a rebate system for energy efficient, low GHG emitting vehicles. By using an attribute-based benchmarking system, such as the NHTSA now uses in its reformed CAFE standards, equitable impacts on manufacturers could be designed into the system.

Regardless of where the benchmark is set, the feebate rate provides the market signal to automobile manufacturers to adopt advanced technology up to the point where the marginal cost equals the marginal value of fuel saved plus the marginal improvement in the feebate. The extra incentive of the feebate can be used to correct the market limitation described above. A feebate rate equivalent to an extra $1 per gallon of gasoline consumed over the life of a vehicle would have more leverage on new vehicle fuel economy than a $2 per gallon tax on gasoline.

[2] Certainly the federal excise taxes on motor fuels can be seen as a technology-neutral incentive to increase fuel economy, although their primary intent is to serve as a user fee to fund the highway system. By taxing the energy for transportation motor fuel taxes are effectively a tax on the amount of physical work done by transportation vehicles since, for constant energy efficiency, work done is directly related to energy use.

Feebates differ from fuel economy standards in that as long as they are in effect they provide a continuing incentive to develop and apply new technology to improve fuel economy. Fuel economy standards must be periodically raised to stimulate continuous improvement. History indicates that this can be a significant problem. As Figure 5 shows, U.S. fuel economy standards were not significantly increased for more than two decades.

Unlike fuel economy standards, feebates also create an economic incentive for consumers to choose more efficient, lower GHG emitting vehicles. The strength and nature of the market signal, however, depends on precisely how the feebate benchmark is defined. A single benchmark for all light-duty vehicles will not only encourage consumers to select the more lower emitting vehicles within a size class but will also shift sales from larger to smaller vehicle classes. If the benchmark is defined as a footprint function, like the one used in the reformed CAFE system, there could be no incentive to choose smaller vehicles.

It is not yet clear, however, how best to use feebates as a complement or replacement for fuel economy or GHG standards. In theory, standards guarantee performance but not cost, while fiscal policies can assure cost but not performance. If we were omniscient, we could accomplish the same result with either policy. However, because there is very limited experience with feebate systems, it is not clear how much of the potential of technology to increase fuel economy or reduce GHG emissions would be traded-off by consumers and manufacturers for increased horsepower or size, or other energy-consuming features. These are trade-offs that fuel economy standards do not allow. More real-world experience with feebate systems will be accumulated in the next few years as the impacts of feebate-like systems implemented by France, the Netherlands, Spain and Sweden become known (Fulton, 2009). In addition, the Universities of California at Davis and Berkeley are conducting a comprehensive assessment of alternative feebate systems for California for the state's Air Resources Board. The study should provide useful insights about these and other practical issues.

The centerpiece of any climate policy should be establishing a meaningful way to price GHG emissions. It is well known that this can be done via a carbon tax or a carbon cap-and-trade system. There are pluses and minuses for either approach. I do not have a strong preference, however, if pressed I would give the edge to carbon cap-and-trade. Cap-and-trade will undoubtedly be more complex to administer but has the advantage that long term targets can be set, and long-term thinking is needed if we are to successfully cope with climate change. Transportation fuels should definitely be included in any carbon cap-and-trade system. Pricing carbon is not a replacement for efficiency standards but a useful complementary policy. A price on carbon will encourage energy companies to seek out ways to reduce the carbon content of the energy they supply to the transportation sector. It will also tend to increase the price of fuel, offsetting to a degree the small amount of increased driving that would otherwise be induced by increased vehicle efficiency (Small and Van Dender, 2007). Pricing carbon, however, is no panacea for transportation's energy problems. \$50/tonCO_2 amounts to approximately \$0.50 per gallon of gasoline. Given the tendency of the market to undervalue future fuel savings, this is not nearly enough to stimulate the kinds of changes needed in our transportation system.[3]

[3] This does not reflect the value of reducing oil dependence, which would justify a higher levy on petroleum fuels. However, as noted above, the nation's oil dependence problem is not an externality in the technical sense. Imposing a tax on oil, though helpful, is not a sufficient solution to the problem (Greene, 2009).

How Large Should Incentives Be?

Incentives can be designed to reduce GHG emissions, reduce oil dependence, correct the fuel economy market limitation caused by uncertainty and loss aversion, or any combination of the three. To date, the subject of an optimal feebate rate has not been rigorously analyzed in this broad context. Rates established in past policies provide at least a few reference points. Feebate rates that follow from different carbon prices, oil security premiums and market corrections are then presented.

The U.S. gas-guzzler tax is specified in terms of dollar penalties per half MPG step below 22.5 MPG. Translated to gallons per mile, the average rate per 0.01 gallons per mile is approximately \$1,800 (Figure 8). In terms of dollars per gram of CO_2 per mile, this amounts to approximately \$20.

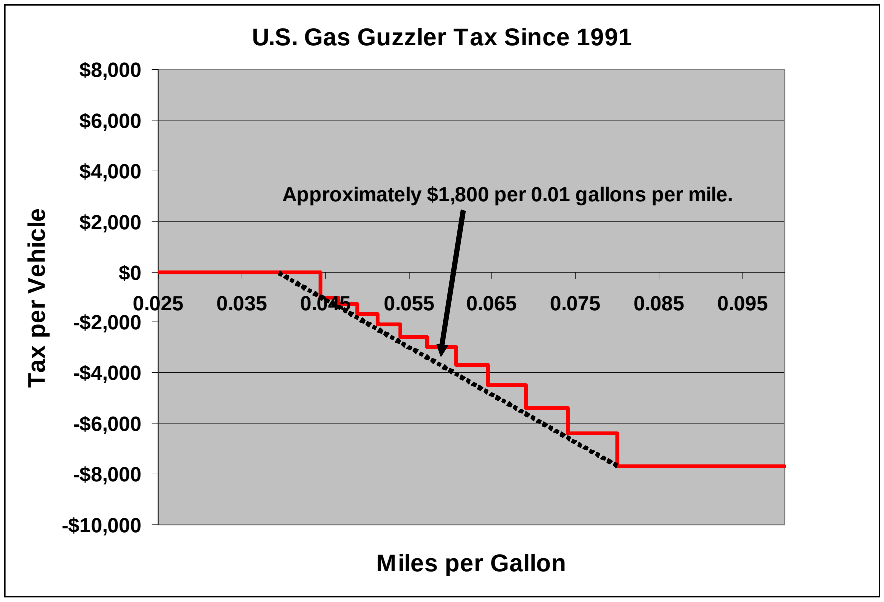

Figure 8. U.S. Gas-Guzzler Tax as an Fuel Efficiency Incentive Rate.

France's Bonus/Malus system corresponds to a rate of approximately \$1,500 per 0.01 gallons per mile, or approximately \$17 per gCO_2/mi (Figure 9). This rate does not apply to the final step for vehicles below 60gCO_2/km. The intention of the French government in setting a much higher incentive for the lowest emitting vehicles was to provide a strong incentive for developing advanced technologies such as PHEVs, EVs and FCVs. As noted above, such additional incentives are likely to be necessary during the early phase of a transition to a fundamentally different energy source for motor vehicles, such as hydrogen or electricity. Modifying a feebate rate curve to provide a greater incentive for advanced, near-zero-emission technologies is one approach to addressing the early barriers to a fundamentally different source of energy for transportation.

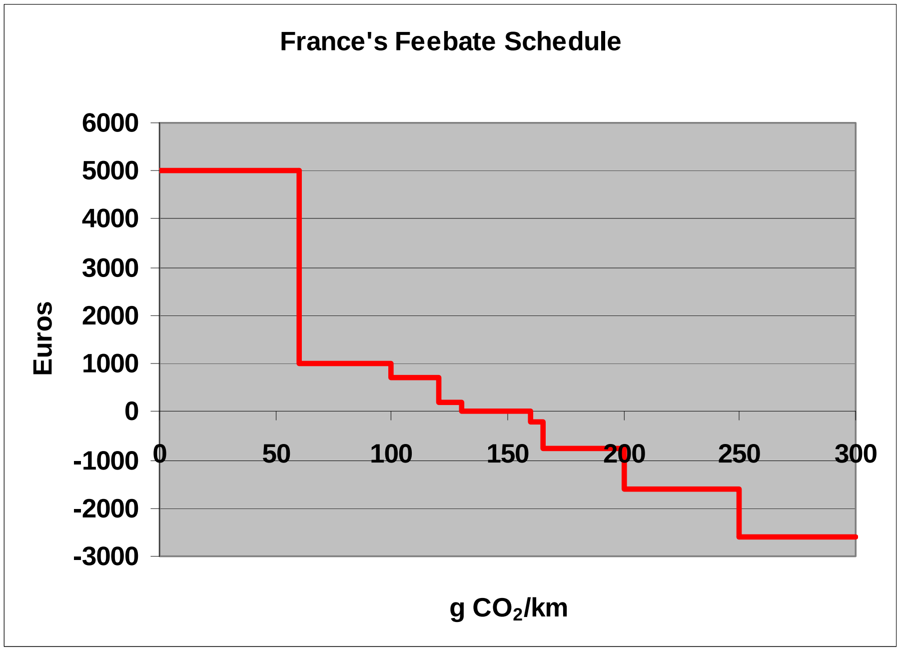

Figure 9. France's Bonus/Malus GHG Incentive System.

While existing feebate-like systems provide useful reference points, it is more valuable for policy-making purposes to relate alternative feebate rates to equivalent carbon prices or oil consumption premiums. Table 1 shows a series of feebate rates from $1,500 per 0.01 gallon per mile to $2,500 per 0.01 gallon per mile and their equivalents in terms of carbon prices and per gallon surcharges on gasoline. Key assumptions used in the calculations are provided in a footnote to the table. A feebate rate of $500 per 0.01 gallon per mile equates to a charge of $0.47 per gallon of gasoline consumed over the life of the vehicle. If interpreted as a tax on CO_2 emissions, it equates to $5.69 per g$CO_2$/mile or $53 per metric ton of CO_2. Because the feebate system has 2.5 times the leverage on vehicle fuel economy as a gasoline tax, a gas tax of $1.18 per gallon would be needed to equal the impact of the $500 feebate rate.

The numbers in Table 1 assume that the full weight of the feebate is attributed to either an equivalent gasoline tax or a carbon price. More appropriately it should be shared between these objectives. Thus a $2,000 feebate rate could be interpreted as a $1/gal. gasoline tax and $100/t$CO_2$ carbon price. However, neither calculation reflects the role of the feebate system in overcoming the problem of uncertainty and loss aversion. Given the undervaluing of future fuel savings by 2.5, a feebate equivalent to $1.20/gal. would be needed just to overcome the uncertainty/loss-aversion effect. This may explain why the United States and France chose feebate rates in the vicinity of $1,500-$2,000 per 0.01 gallon per mile.

Table 1. Alternative Feebate Rates and Their Equivalencies in Terms of Externality Costs, Oil Consumption Premiums and Correcting the Uncertainty Loss-Aversion Problem

Feebate Rate $/0.01gal/mi	Equivalent $ per Lifetime PV Gal. $/gal	Feebate Rate $/gCO_2$/mi	Equivalent Carbon Price $/tCO_2$	Gasoline Tax of Equal Impact $/gallon
$500	$0.47	$5.69	$53	$1.18
$1,000	$0.93	$11.38	$106	$2.36
$1,500	$1.40	$17.07	$159	$3.54
$2,000	$1.87	$22.76	$212	$4.72
$2,500	$2.33	$28.45	$266	$5.90

Assumes vehicle is driven 15,000 miles per year when new, declining at 4% per year, over a lifetime of 14 years. Future dollars are discounted at 7%/year.

Concluding Observations

The market's response to the problems of GHG emissions and oil dependence is not only hindered by the market failures of externalities and monopoly power but by the inherent uncertainty of future fuel savings and consumers' loss-averse behavior. As a consequence, fiscal incentives for increasing the energy efficiency of motor vehicles and reducing their GHG emissions can be especially effective policy tools. Technology neutral incentives have the dual advantages of allowing the greatest scope for innovation and harnessing market forces to select the most economically efficient solutions. As long as the incentives are in place they will provide a continuing incentive for firms to develop and implement, and for consumers to choose more energy efficient and lower emission vehicle technologies. Most, if not all of the existing incentives for energy efficient, low-emission vehicles technologies could be replaced by a consistent, economically efficient, technology neutral incentive system, such as feebates. What remains unclear at this point is how a comprehensive system of fiscal incentives should relate to a regulatory system targeting the same energy goals.

Feebate rates on the order of $1,000 to $2,000 per 0.01 gallons per mile and carbon prices in the vicinity of $50 per ton of CO_2 would very like be sufficient to stimulate research, development and implementation of advanced technologies and fuels that are not disruptive of the predominant petroleum fuel and internal combustion engine transportation system. Such economic incentives would probably not be adequate to initiate a sustainable transition to radically different energy sources for transportation, such as hydrogen or electricity. Hydrogen, in particular, will require a completely new energy supply infrastructure as well as entirely new propulsion systems for vehicles. Studies of what may be required for a transition to hydrogen vehicles (NRC, 2008; Greene et al., 2008) have concluded that even when the technological hurdles have been overcome, initiating a sustainable transition may require on the order of $50 billion in subsidies to achieve learning-by-doing and economies of scale in vehicle production, and to provide sufficient fuel availability and diversity of vehicle choice to overcome the inertia of the petroleum-fueled, internal combustion engine system. During this early transition phase, which could easily last a decade, additional incentives especially for vehicles, are likely to be required. Such incentives could be provided as a special case or by modifying a feebate schedule to provide extra, temporary incentives for the lowest emission vehicles.

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