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The Path toward Widespread Deployment of Hybrid-Electric Vehicles

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PREFACE

About the Author

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About WISE

The Washington Internships for Students of Engineering (WISE) program was founded in 1980. This collaborative effort among several engineering societies has become one of the premier Washington internship programs, rated as one of the top 100 internship opportunities in the country. Its goal is to groom future leaders in the engineering profession who are aware of and can contribute to the important intersections of technology and public policy. This multi-society program is supported by the American Association of Engineering Societies. Please see http://www.wise-intern.org for more information.

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Abstract:

This paper represents an independent analysis of the future potential of hybrid-electric vehicle (HEV) technology. It focuses on the ability of HEV technology to displace oil use and the public policy decisions which must be made in order to encourage the deployment of this technology. It also considers alternative technologies and debates the merits of competing approaches to advancing vehicle technology.

Encouraging the use of HEVs is an essential part of what should be an overall strategy to reduce U.S. dependence on foreign oil by fully applying our most efficient technologies to reduce our consumption. The vehicle efficiency improvements of the 1970s demonstrate that with a national will, great changes can be made to improve vehicle design. The technical feasibility of HEVs is not in question, but rather the increased cost of the technology, the perceived value of fuel efficiency, and the “leap-frog” attitude toward this technology are all barriers that are limiting the market penetration of these vehicles.

As demonstrated by the enthusiastic adoption of HEV technology to date, consumers are ready for a change. The early-adopter portion of consumers must be developed and encouraged in order to secure a greater market share by more efficient HEVs. Current government tax incentives are a good forward step. The much lauded hydrogen economy is not right around the corner and a lot of research and development needed for that transition can be obtained through continued research and development into improving HEV technology and design.

HEVs will expand efficient vehicle consumer choice and bring profits to those companies who decide to invest in producing these vehicles. We must have public policies which encourage innovation based technologies. The specific recommendations of this paper are to encourage future vehicle research and development, reform U.S. efficiency standards, reevaluate our current tax strategies and incentives, institute a “feebate” system to reward vehicle efficiency, and to encourage government fleet purchases of hybrid-electric vehicles.

The Path toward Widespread Deployment of Hybrid-Electric Vehicles

"On our present course, America 20 years from now will import nearly two of every three barrels of oil—a condition of increased dependency on foreign powers that do not always have America's interests at heart.***But it is not beyond our power to correct. America leads the world in scientific achievement, technical skill, and entrepreneurial drive. Within our country are abundant natural resources, unrivaled technology, and unlimited human creativity. With forward-looking leadership and sensible policies, we can meet our future energy demands and promote energy [efficiency]…and do so in environmentally responsible ways that set a standard for the world."

— National Energy Policy Development Group;
Reliable, Affordable, and Environmentally Sound
Energy for America's Future; 2001[1]

I. Introduction

U.S. energy, environmental, and transportation policy must reflect the fact that America currently imports more than half of the oil we consume. America's highway transportation is 97% dependent on oil, a growing portion of which is imported. The transportation sector currently accounts for 69% of U.S. oil consumption. Unless action is taken, the historical trend toward increasing dependence on foreign oil will continue.

Oil imports, a major component of the balance of trade accounts-are projected to account for more than $170 billion of our nation's trade deficit by 2020.[2] The percentage of oil imports is projected to rise to 62% by 2020.[3] The current Energy Information Administration (EIA)

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[1] United States. National Energy Policy Development Group. Reliable, Affordable, and Environmentally Sound Energy for America's Future. Washington, D.C.: GPO, 2001. p. X, VII.
[2] United States. Energy Information Association. Annual Energy Outlook 2005, Washington,I D.C.: GPO, 2005.
[3] United States. Dept. of Energy, Office of Energy Efficiency and Renewable Energy. FreedomCAR: Powering Tomorrow's Vehicles. Washington D.C.: GPO, Mar. 2003.

projections indicate that by the year 2020, the transportation sector alone will consume twice as much petroleum as the U.S. produces.[4] At the same time, the efficiency of the U.S. light duty vehicle fleet is at a 20-year low.[5]

More and more, decisions about our energy will be made by those who have America's interests less and less at heart. A growing dependence on imported oil, along with a heightened concern about the environmental impact of personal transportation, should lead the U.S. government to sponsor public policy which encourages advanced transportation concepts. One of these future technologies is the Hybrid Electric Vehicle (HEV). The development goals for this progressive technology should encourage public acceptance and widespread dissemination of this technology which has the potential to reduce emissions, obtain superior fuel economy, and remain its flexibility of using either petroleum or alternative fuels.

HEVs promise a solution to many of the problems currently facing the transportation industry. Their superior efficiency and cleaner emissions offer major improvements over conventional vehicles. They also offer additional benefits such as limiting their owner's oil dependency, decreasing air pollutants, and in some cases they have tax advantages.

Whether the U.S. adopts the public policies necessary to encourage HEV technology and thus decrease oil consumption remains to be seen. This paper will explore the most widely discussed advanced vehicle technologies, and then focus on recommendations which promote the use of HEV technology, the technology with the most promising near- and medium-term impacts for reducing or replacing oil while significantly reducing transportation greenhouse gas emissions. These recommendations are made while recognizing that multiple pathways may be required to solve the overall transportation problem.

II. Background

The concept of the electric vehicle has been around for quite sometime. The first electric delivery vehicle was manufactured in 1899. The technology has been steadily progressing and

[4] United States. Energy Information Administration. Annual Energy Outlook 2005, Washington D.C.: GPO, 2005.

[5] The Center for Energy and Climate Solutions. The Car and Fuel of the Future: A Technology and Policy Overview. Washington, D.C.: The Global Environment & Technology Foundation, Jul. 2004.

the first commercially available electric vehicle was brought to market by General Motors Corp. in 1996. Unfortunately, the first electric vehicle was an industry disappointment. In the first four years of production, GM had leased less than 800 EV-1s. The market could not bear the limitations that electric vehicles presented to them. The EV-1 only averaged 55-95 miles between lengthy 5-6 hr. recharges at a time when the average American commute time was reaching upwards of 50 minutes a day.[6] It was determined that unless electric vehicles could reach a range of 300 miles between charges, they would not be commercially viable. Ultimately most of the electric vehicle pioneers including the EV-1, Ford Ranger EV, and the Nissan Altra EV were discontinued.

The HEV is not a new concept either. The first hybrids were created about 100 years ago. These vehicles solved the fueling infrastructure problems associated with electric vehicles by running on a combination of gas and electric power. The earliest research showed hybrids to be promising technology. Later, with the additional motivation of the oil embargo and energy crisis of the 1970s Congress passed P.L. 94-413, the Electric and Hybrid Vehicle Research, Development, and Demonstration Act of 1976. This act directed the newly formed Department of Energy to pursue researching electric and hybrid vehicle technologies. The funding of this time period allowed a lot of breakthroughs to be made. Interest in hybrid vehicles eventually died out after improvements in the efficiency of traditional vehicles were made and the economics of the energy crisis decreased the Congressional demand for action.

The hybrid concept resurfaced with the release of the first hybrid-electric vehicle from a major manufacturer, the Toyota Prius. First introduced in 1997, this vehicle achieved worldwide annual sales of 12,000 by 2002 and currently enjoys a demand greater than its current production with waiting lists that are several months long. Toyota has scheduled 100,000 Prius vehicles for the 2005 U.S. market and plans to introduce additional models.

The basic components of an HEV are a small gas engine that helps propel the vehicle only at cruising speeds above 20 mph and a rechargeable battery which employs an electric motor as a generator. Instead of relying on off-grid electric power, hybrid-electric vehicles use regenerative braking technology to capture the energy usually lost in stopping the car, recovering

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[6] GMability. EV1: Lessons Learned. 10 Mar. 1998 <http://www.gm.com/company/gmability/adv_tech/300_hybrids/hyb_ev1.html>

it and storing it in the battery.[7] These vehicles operate within optimized rpm ranges over which they deliver maximum torque and have maximum efficiency. This improves the vehicle's fuel economy and cuts its emissions. A conventional internal combustion engine cannot be optimized for all of the speed and load range combinations under which it must operate. As a result its efficiency is also diminished and emissions are elevated for most of its rpm range.

There are two types of HEV configurations, parallel and series. In the parallel hybrid configuration, power is obtained from a fuel tank which supplies gasoline to the engine, but it also has a set of batteries which supply power to an electric motor. The gas engine and electric motor both connect to the transmission independently and as a result both can provide propulsion power. In the series configuration the gasoline engine turns the generator which in turn can either charge the batteries or power an electric motor that drives the transmission. In the series configuration the gasoline engine never directly powers the vehicle.

In both the series and parallel configurations braking power is used to generate battery charge and idling the vehicle can shut off its gasoline engine. A hybrid's ability to recharge itself improves its efficiency. The motor converts otherwise wasted kinetic energy created during the braking process into battery charge rather than heat. Conventional automotive drive systems based on an internal combustion engine are limited by their purely mechanical systems and are unable to recover braking energy which is lost in the form of heat. The battery system also allows the internal combustion engine to shut off when the car is decelerating or idling. Other traditionally inefficient components such as the air-conditioning unit can also be run off of the battery.

A conventional gasoline engine is typically sized to be able to accelerate onto the highway, pass other cars, or to climb a hill. This period where increased acceleration is needed accounts for only a small amount of the overall vehicle drive time. Because the engine is oversized to accommodate peak loads, most of the time it operates at less than 20% efficiency.

[7] National Energy Policy Development Group. Reliable, Affordable, and Environmentally Sound Energy for America's Future. Washington, D.C.: GPO, 2001. pg. 4.10.

To provide enough power for acceleration, a standard engine must be oversized by roughly 10x to achieve 60 mi/h at level-ground and another 3–4x to achieve 60 mi/h, at a 6% grade.[8]

A hybrid vehicle's internal combustion engine is sized for the average load, not peak load, which reduces the engine's weight/size and increases efficiency. Hybrid vehicles utilize their batteries during times of peak power demands. Because of this ability, hybrid systems allow a much smaller engine to operate at peak efficiency for a greater percentage of the overall drive time, and to get an additional boost of power from the batteries when accelerating or climbing a slope. As a result, hybrid systems boost both horsepower and acceleration.

The higher efficiency of these vehicles allows them to achieve very high fuel economy and lower emissions. For example, the hybrid Honda Insight is rated at 61 miles per gallon (mpg) city, and 70 mpg highway. A gasoline-fueled Insight achieves only 32 mpg city and 37 mpg highway.[9] Overall hybrids can achieve fuel economy gains of 40% compared to their conventional counterparts and reduce greenhouse gas emissions by 30-50%.[10] Given the enormous amount of motor fuel used each year, even a one percent improvement in vehicle fuel efficiency would save consumers about $2 billion annually. [11]

III. Transportation Alternatives

A lot of advanced vehicle technology research and development was initiated in response to the 1970s oil shocks and has since made significant progress. A discussion of the competing transportation alternatives is necessary to see why HEVs are the best near- to medium-term solution, and why we should not consider HEVs to be a leapfrog technology which should be skipped in order to conserve resources which could help speed the implementation of the hydrogen economy. The three most commonly discussed advanced propulsion technologies other than HEVs are: plug-in hybrids, fuel cell hydrogen vehicles, and alternative fuel vehicles. While

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[8] Moore, Timothy C. Ultralight Hybrid Vehicles: Principles and Design. Snowmass, CO: Hypercar Center, Rocky Mountain Institute, 1996.

[9] DeCicco, John, Jim Kliesch, and Martin Tomas, ACEEE's Green Book: The Environmental Guide to Cars & Trucks. Washington, D.C: 2000.

[10] National Association of Counties/Center for a New American Dream. Harnessing the Power of Advanced Fleet Vehicles. Feb. 2004. <http://www.newdream.org/procure/hev.pdf>

[11] United States. Energy Information Association. Annual Energy Outlook 2005, Washington, D.C.: GPO, 2005.

these technologies are promising, they must overcome technical, cost, performance and infrastructure problems

Plug-In Hybrids

Plug-in hybrids are a significant variation from traditional HEVs. These hybrids can be plugged into the power grid and run on a larger purely electric range off of their larger batteries. Because of the increased range and battery size, these vehicles cannot be charged purely using regenerative braking and must be charged by plugging the vehicle in. These vehicles have been praised for their conversion of more miles to purely electric operation. Most vehicle use is for relatively short periods of time such as commuting, followed by extended periods where the vehicle is not in use and could be charging. These vehicles would still allow extended trips to be taken, with the gasoline powered engine kicking on after the first 20 or 30 miles.

In order for plug-in hybrids to become a promising alternative fuel vehicle, several technical and economic barriers must be addressed. Cost reductions would have to be made in the batteries these vehicles use and infrastructure created to charge the vehicles. Technically, improvements in battery size and life would have to be made. The size of battery needed to make a plug-in hybrid would significantly alter vehicle weight and size. The vehicle would actually be less efficient because the battery would be so large that the overall weight would change significantly.

The California Energy commission and the California Air Resources Board, prepared a study in August of 2003 which specifically studied various alternative fuel vehicles (AFVs), including plug-in hybrids. This report entitled *Reducing California's Petroleum Dependence* studied the benefits of several different AFVs including including Fischer-Tropsch diesel made from natural gas, a mixture of 85% Ethanol and 15% gasoline (E85) for flexible fuel vehicles (FFVs), a future low-cost FFV fuel, a hybrid zero emission vehicle with a 20-mile all electric range (Hybrid-ZEV 0), and a direct hydrogen fuel cell. and showed that a plug-in hybrid with a 20 mile all electric range had the greatest positive direct net benefit in 2001 dollars over the period from 2002-2030.[12] Despite the challenges surrounding the implementation of this technology, it should be receiving as must attention as other AFVs such as hydrogen.

What about Hydrogen?

The Partnership for a New Generation of Vehicles (PNGV) was created during the Clinton administration with the goal of working with domestic automakers to make automobiles more fuel-efficient. Their goal was to create a family sized sedan that could travel 80 miles on one gallon of gas.[13] The project was later transformed in 2002 into the FreedomCAR Partnership under President George W. Bush. The FreedomCAR Partnership recognizes that the fastest growth in oil use is projected in light trucks and heavy vehicles and that we should make all vehicles more efficient across the board, not just sedans.[14] Where PNGV sought to increase fuel efficiency, FreedomCAR's mandate is to create an affordable automobile that runs on hydrogen.

Many believe that once hydrogen is introduced the complete elimination of oil use is inevitable. This transition will take time. Traditionally shifts in major fuel use, i.e. from wood to coal or coal to oil have taken 50 years with periods of overlap in between. Significant infrastructure changes such as the addition of railways and electrification have similarly also taken 40-50 years.[15] The advent of the hydrogen economy will be no different. It will take at least 50 years after the technology is mature for it to be the mainstream fuel technology with the accompanying infrastructure.

"In May 2004, both the National Academy of Sciences and the American Physical Society stated that a commercially viable hydrogen car would take 20-30 years to produce. And yet, the 2005 Senate [energy] Bill sets a goal of 100,000 hydrogen-powered cars on the road by 2010, and 2.5 million vehicles by 2020. These arbitrary numbers represent "cheerleading" at best. More likely, they will mislead the public into believing this dream is far closer to reality

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[12] California Energy Commission and California Air Resources Board (CARB), Reducing California's Petroleum Dependence, Joint Agency Report, Sacramento: CARB, Aug. 2003.

[13] United States. Congressional Research Service, The Library of Congress. Yacobucci, Brent D. CRS Report for Congress (RL30484) Advanced Vehicle Technologies: Energy, Environment, and Development Issues. Washington, D.C.: Congressional Research Service, The Library of Congress., 17 Dec. 2004.

[14] United States. Dept. of Energy, Office of Energy Efficiency and Renewable Energy. FreedomCAR & Vehicle Technologies Program - Protecting our Transportation Freedoms. Washington, D.C.: GPO, Mar. 2003.

[15] Lovings, Armory A., E. Kyle Datta, Odd-Even Bustnes, Jonathan G. Koomey, and Nathan J. Glasgow. Winning the Oil End Game: Innovation for Profits, Jobs, and Security. Snowmass, CO: Rocky Mountain Institute. 2005.get page number

than any reputable source would claim. And what about infrastructure? According to the National Petroleum News, there are nearly 169,000 service stations in the United States today. With recent estimates of conversion costs nearing $1 million per pump, infrastructure costs could reach hundreds of billions of dollars."[16]

An analysis in the May 2004 issue of *Scientific American* stated, "Fuel-cell cars, in contrast [to hybrids], are expected on about the same schedule as NASA's manned trip to Mars and have about the same level of likelihood."[17] The U.S. should invest in both efficient vehicles and hydrogen technologies. These two approaches to breaking U.S. oil dependence are not mutually exclusive. Today's hybrid-electric hybrids include a lot of the technology needed in a hydrogen fuel-cell vehicle. The technology breakthroughs we make now with HEVs are contributing towards a future hydrogen economy. Because of the technical challenges facing hydrogen: safety, storage, production costs of hydrogen, and infrastructure issues, we must continue with the adoption of super efficient vehicles to decrease our oil usage while we address these barriers.

IV. Barriers to Hybrid-Electric Vehicle Deployment

Historically most of the major barriers to advanced vehicle technologies have been technical. Issues such as energy storage, safety and liability concerns, and limited fueling options were the number one issues barring new advanced vehicle technologies from entering the market. In the case of HEVs, each of these barriers has been addressed. Energy storage is the same as a traditional vehicle with fewer complications than hydrogen or other technologies. As the vehicles have come into mainstream vehicle fleets, consumer safety and liability concerns have been alleviated as the technology has been proven reliable. There is no infrastructure or fueling problems normally associated with alternative fuel vehicles, because the only fuel required utilizes existing infrastructure.

The barriers that are currently effecting the deployment of HEVs into the market-place are harder to combat. They involve the fundamental value of the technology as perceived by the

[16] Sununu, Sen. John. "Hydrogen Cars as Snake Oil." The Hill 20 Jun. 2005: S-6.
[17] Wald, Matt. "Questions about a Hydrogen Economy." Scientific American May 2004: 66-73.

general public and the automotive industry. In particular, the efficiency of HEVs is currently undervalued by both consumers and manufacturers.

Value of Fuel Economy

The last time significant gains were made in fuel economy was when the full weight of the 1970s oil-shock began to make an impact on legislative will as well as consumer choices. During the period from 1975-1984 there was a 7.6 mpg increase in overall fuel efficiency partly as a result of the enactment of Corporate Average Fuel Economy (CAFE) standards which forced manufacturers to improve light-vehicle fuel economy by 60%. Many manufacturers opposed the CAFE legislation, but the ramifications of not having legislatively mandated fuel economy standards could have led to decreased U.S. vehicle market share. United Auto Workers President Doug Fraser noted in 1980, "If the 1975 [CAFE] legislation had not been enacted, there quite possibly could have been even greater damage inflicted on the industry and its workers by foreign imports."[18]

When asked what their energy concerns were, businesses and consumers today tend to be more concerned about the reliability of fuel availability than the level of current prices. With the typical new vehicle owner keeping their car for less than five years, full recovery of the additional cost of a fuel-efficient vehicle will not be recovered by fuel savings alone. There are signs that these attitudes are changing. When surveyed, one-fifth of U.S. light vehicle buyers said they are willing to spend $2,500 more for better fuel economy.[19] If the cost difference between hybrid-electric vehicles and their traditional counterparts could be brought down to match this acceptable cost difference, then we might see HEVs achieving significant market share.

The failure of purely electric vehicles proves that fuel efficiency is not enough to entice consumers when fuel prices are low. Only a small percentage of new vehicle buyers have spontaneously adopted hybrid-vehicle technology at today's gasoline prices, partly because fuel economy is not highly valued. The early-adopter portion of overall sales is estimated to range from 3-5% by hybrid automakers to 20% by market surveys. Hybrid sales are only expected to

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[18] DeCicco, J., R. Griffen, and S. Ertel. "Putting the Brakes on U.S. Oil Demand." Environmental Defense. 2003: 6.

[19] Steiner, E. Consumer Views on Transportation and Energy. NREL/TP-620-34468. Golden, CO: National Renewable Energy Laboratory <http://www.nrel.gov/docs/fy03osti/34468.pdf>. Aug. 2003.

reach 1.53% of the total market by 2006.[20] Most customers are slow to adopt very efficient vehicles. It also takes quite awhile for new purchases to become a major fraction of the overall fleet. It takes the U.S. vehicle fleet 14-15 years to turn over entirely.

"To the extent that the next-generation light vehicle is a truly disruptive technology that provides superior mobility services at lower cost, hence greater value, customers can broadly adopt it with astonishing speed."[21] A comprehensive 1999 review of disruptive technologies' historical adoption found that technologies which used the existing infrastructure can go from 10% to 90% capture of the capital stock within 12-15 years, implying that a fast increase in the share of HEV new-vehicle sales is possible.[22] Innovation diffusion theory suggests that getting the initial 10% market share often takes a decade or more. That is why the early adopter segment is so important to develop. The sooner that adoption starts, the sooner it will affect the entire fleet. We should be looking for ways to jumpstart early adoption by customers.

Corporate Investment in Efficiency

"Both Detroit and Washington have long assumed, from economic theory and incremental engineering tweaks, that fuel-thrifty vehicles must be unsafe, sluggish, squinchy, or unaffordable, so customers wouldn't buy them without government inducement or mandate."[23] This is a mistake that is being made to this day. The market share obtained by hybrids so far has thrown this cynicism into question. Even still, "as recently as 2004 an American automaker said that *Prius* 'has not been accepted by the American public.' Ironically, Toyota was simultaneously announcing a near-doubling of *Prius* production and considering building a U.S. plant to make more, *Prius* was flying off dealers' lots faster than any other car in America for the tenth straight month (nearly twice as fast as the runner-up), and some *Prius* dealers were extracting price premia greater than the rebates the company was paying everywhere to sell its

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[20] "Automotive Forecasting Services Hybrid Electric Vehicle Outlook." All About Hybrid Cars. San Diego, CA, J.D. Power-LMC. Feb. 2004. <http://www.allabouthybridcars.com/suv-hybrid-autos.htm>

[21] Lovings, Armory A., E. Kyle Datta, Odd-Even Bustnes, Jonathan G. Koomey, and Nathan J. Glasgow. Winning the Oil End Game: Innovation for Profits, Jobs, and Security. Snowmass, CO: Rocky Mountain Institute. 2005. pg. 149

[22] Grübler, A., N. Naki´cenovi´c, and D.G. Victor. "Dynamics of Energy Technologies and Global Change." En. Pol. 27 (1999): 247–280.

[23] Lovings, Armory A., E. Kyle Datta, Odd-Even Bustnes, Jonathan G. Koomey, and Nathan J. Glasgow. Winning the Oil End Game: Innovation for Profits, Jobs, and Security. Snowmass, CO: Rocky Mountain Institute. 2005. pg. 45

flagship products. Doubting the staying power of a successful rival is easy but imprudent, especially when it's as formidable a firm as Toyota."[24]

General Motors has recently had to backtrack on their opposition to hybrids. In January of 2004, *CNN/Money* reported: "General Motors Corp. has no plans to try to answer the success of the Toyota Prius, the critically-acclaimed gas/electric hybrid car, said Robert Lutz, GM's vice chairman of product development. It just doesn't make environmental or economic sense to try to put an expensive dual-powertrain system into less expensive cars which already get good mileage, Lutz said at the North American International Auto Show." This statement was followed two months later in March of 2004 by General Motors taking out advertisements which read: "HYBRIDS. Powered partly by engines, partly by batteries, hybrids deliver improved fuel economy with uncompromising performance…. Cars, trucks, SUVS and buses you already know and trust, with an extra boost at the fuel pump." It is good to see that the attitude of U.S. manufacturers is changing. Toyota and other foreign manufacturers lead in the hybrid arena. It would be an unnecessary risk to U.S. innovation and jobs if U.S. manufacturers fail to pursue new technologies such as hybrids.[25]

V. Policy recommendations

In order to achieve widespread deployment of HEVs fleet-wide, government intervention is necessary. Each of the following recommendations concentrates on encouraging a faster growth in the early adopter market segment. Once an initial 10% market capture is achieved by following these recommendations, HEVs could have a large enough market-share to become the dominant technology and achieve great efficiency and technology breakthroughs on the way to the hydrogen economy. Once this 10% market share is achieved, some incentives such as temporary tax incentives which are not revenue neutral could be done away with. Other recommendations which are given are proposed as more long term strategies which serve to encourage not only efficient vehicle purchases, but less overall mileage to be driven.

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[24] Lovings, Armory A., E. Kyle Datta, Odd-Even Bustnes, Jonathan G. Koomey, and Nathan J. Glasgow. Winning the Oil End Game: Innovation for Profits, Jobs, and Security. Snowmass, CO: Rocky Mountain Institute. 2005. pg. 143

[25] Isidore, Chris. "GM: Hybrid cars make no sense." CNN/Money 6 Jan. 2004 6 Jun. 2005. <http://money.cnn.com/2004/01/06/pf/autos/detroit_gm_hybrids>.

Fuel Taxes

The United States has some of the lowest tax rates on gasoline and diesel fuels in the world. Compared to Europe and Japan, U.S. fuel taxes are many times lower. (The one exception to this is aviation fuel which is virtually tax-free worldwide as a result of a complex network of treaties designed to encourage air travel.) While increasing fuel taxes might be the most economically obvious solution to encouraging fuel efficient vehicles, taxes are never popular politically and it would be difficult to propose this to our publicly elected policy makers as our only long term solution.

There are other reasons that fuel taxes are not the ultimate solution to encouraging the purchase of fuel efficient vehicles such as HEVs. Fuel costs account for only about one-eighth of the total cost of owning a vehicle. Analysis of the fleet makeup of countries that have higher fuel taxes has also not shown that there is a concrete tie between higher fuel taxes and more efficient vehicle choices. In Hawaii where gas prices are routinely 50¢ higher than the mainland, the percentage of owners buying high efficiency vehicles is no higher. This doesn’t mean that we should discount the use of fuel taxes altogether. A good reason to at least be partially increase fuel taxes is that it could encourage less overall miles to be driven once the car is purchased.

Shift Taxation from Fuel to Roads and Mileage

The more fuel efficient we make vehicles the less revenue will be garnered from fuel taxes. These taxes currently go towards funding road repairs and new transportation projects. The argument can be made that HEVs pay less for the roads that they drive on because less money is gained from fuel taxes on more efficient vehicles. The problem is not the HEVs. No sensible argument could be made in order to support having less efficient vehicles merely to ensure road maintenance does not go unfunded. Rather, we must reevaluate how such maintenance is funded.

One way to bridge the funding gap from decreased fuel tax revenues would be to institute a nationwide toll system. This toll system would be similar to successful European projects which vary toll prices depending on current congestion levels.[26] Another method of raising funds could be to institute a mileage based taxation system which would track mileage and charge drivers based on the distance traveled rather gallons of fuel consumed. This could have the effect of encouraging drivers to make fewer trips or to use public transportation. Americans currently use public transportation for only 2% of their urban trips, far behind the Western European rate of 10% or the Canadians 7%. Either way, our method of raising transportation maintenance revenue will eventually have to change as vehicles become more efficient.

Efficiency Standards

The Energy Conservation and Policy Act of 1975 required the Corporate Average Fuel Economy (CAFE) program to enforce "maximum feasible fuel economy," considering technological feasibility, economic practicality, fuel-economy effect of other standards, and the nation's need to conserve energy. The CAFE standards were not raised from 1975-2003. While the CAFE system can be credited with decreasing U.S. oil use by 7% and oil imports by 23% at a time when GDP grew by 37%, most of these gains occurred in the first decade of the CAFE system. Overall the CAFE program has had very slow effects. The 21.0 mpg light-truck standard voted on in 1975 to take effect in 1985 was just implemented in 2005, nearly 20 years after it was supposed to be implemented.

The National Highway Traffic Safety Administration (NHTSA) is now responsible for setting CAFE standards. One of the frequent criticisms of the CAFE system is that it encourages manufacturers to nudge larger passenger vehicles into the light truck category to avoid the higher CAFE standards. NHTSA has proposed a new weight-based system for determining fuel economy requirements. This would help to reclassify a lot of vehicles that are currently considered light-trucks, but are more similar to light or heavy vehicles by weight. Even if this new system is put into place, the effectiveness of CAFE standards at encouraging consumers to buy efficient vehicles can still be called into question. There is no reward for manufacturers who produce vehicles which perform better than the standard unless they have another vehicle which they sell which has less than acceptable fuel economy. The standards are also difficult to increase

[26] Perkins, S. "Recent Developments in Road Pricing Policies in Western Europe." Proc. Of ALP-NET Pricing Workshop. Berne: 12-13 Sep. 2002. OECD. <http://www1.oecd.org/cem/online/speeches/Spbern02.pdf>

as evidenced by the static standard from 1975-2003. In fact, from 1995-2000 Congress expressly forbade considering raising CAFE standards, banning the use of appropriated funds to undertake CAFE rulemaking.

Regardless of what other measures are taken to improve fuel economy, we must reform the current fuel efficiency regulatory system. Current fuel economy laws allow significant loop-holes which are unacceptable. Sport utility Vehicles (SUVs) and light tracks are allowed to have a average fuel economy of only 20.7 mpg, a standard which is 25% lower than current new car standard. There is also an upper weight-limit on which trucks are counted towards a manufacturer's average fuel economy. This has the negative effect of giving manufacturers incentive to make vehicles heavier than the 8,500 lb cut-off in order to escape having their most gas-guzzling vehicles count against their average fuel economy. These loop-holes have encouraged the efficiency of SUVs to decrease at a time when their share of overall sales is increasing faster than any other class of vehicle. Even U.S. manufacturers who are usually held to public scrutiny have back-out of their commitments to increase SUV efficiency.[27]

CAFE should treat all light vehicles the same in regards to safety regulations. We should abolish the 8,500 lb limit on what constitutes a light-vehicle that currently allows heavy passenger vehicles like the Hummer to avoid many of the existing rules. There should be a redefinition of the gas-guzzler tax which would expose all passenger vehicles to its effects and not exempt heavy cars. The quadruple tax break for business vehicles over 6,000 lbs should be reevaluated to encourage manufacturers to make vehicles lighter and with greater fuel efficiency rather than simply heavier in order to qualify for tax incentives. Currently most owners of heavy vehicles over 6,000 lbs can claim the vehicle is being used for business purposes and write off part of the cost of the vehicle regardless of whether the vehicle is actually a passenger car.

Feebates

The idea behind feebates is to give rebates for the purchase of efficient vehicles which are paid for by fees imposed on less efficient vehicles. The only way that such a program would work would be to evaluate which vehicles are the most efficient and worthy of rebates on a size

[27] Hakim, Danny. "Ford Says New S.U.V.'s Less Fuel-Efficient Than Old Ones." New York Times. 18 Jul. 2003 <http://www.nytimes.com/2003/07/18/business/18CND-FORD.html>.

basis. The top efficiency vehicles in each size class would receive a rebate paid for by the least efficient vehicles in that class. That way you wouldn't have high efficiency sedans receiving all of the rebates which would be paid for by gas guzzling SUVs. Unlike the current CAFE system which taxes vehicle manufacturers who have vehicles which don't meet the standard, this system would have savings passed directly onto the consumer as part of their purchase price.

The structure of the feebate system would have to allow for consumer choice. That is why the size based system is so essential. The size of a vehicle as measured by interior volume and footprint most closely represents how the vehicle is actually used, unlike weight class systems. Size-class feebates would apply to each vehicle in the same size-class. They would not restrict consumer choice between classes. Regardless of the size of vehicle you choose to drive you would have the choice of buying one that is more efficient with the attached rebate or one that is less efficient with the attached fee.

This would also limit the ability of vehicles to escape taxation altogether. Currently, light-trucks are exempted from the gas-guzzler tax and CAFE exempts the heaviest light-vehicles. A $1,000/0.01-gpm U.S. feebate "slope" would let new-car buyers make fuel economy decisions as if they were considering fuel use savings over the entire 14-year nominal life of the vehicle (no matter who owns it), rather than only for its first three years as they do now.[28] Feebates are so powerful that they could be used exclusively to promote advanced technology vehicles, but there are other options as well.

EPAct & Government Fleet Purchases

Every year the federal government spends billions of dollars purchasing and leasing vehicles. In 2002 alone, over $1 billion was spent by the federal government purchasing and leasing new vehicles. The overall federal fleet drove five billion miles and used a third of a billion gallons of fuel that year.[29] If the U.S. governmental fleet could be made more efficient by using government procurement programs then better technologies could be brought into production to meet this substantive demand.

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[28] United States. Dept. of Energy. Greene, D.L., J.L. Hopson, & J. Li. "Have We Run Out of Oil Yet?" Dept. of Energy, Washington, D.C. 14 Apr. 2003. <http://www-cta.ornl.gov/cta/Publications/Publications_2003.html>

[29] United States. GSA (U.S. General Services Administration). FY2002 Federal Fleet Report. Washington, DC: GSA. <http://www.gsa.gov/gsa/cm_attachments/GSA_DOCUMENT/FFR2002_R2K-g6_0Z5RDZ-i34K-pR.pdf>

The Energy Policy Act of 1992 (EPAct), P.L. 102-486 established fleet requirements for governmental agencies and utilities. Among its goals was to reduce imported oil consumption and increase air quality. The law includes requirements on state and federal government fleet purchases and the providers of alternative fuels to convert an increasing percentage of their fleet vehicles to alternative fuel vehicles. The current requirement is for 90% of new light-duty vehicle purchases made by energy providers and 75% of vehicles purchased by state agencies to be alternative fuel vehicles (AFVs).

This law was made before the public offering of some of the most efficient and cleanest vehicles, HEVs. Because of the way the program was set up, the EPACT Alternative Fuel Transportation Program (10 C.F.R Section 508) does not include HEVs in the definition of alternative fuel requirements which makes HEVs ineligible for EPAct credits because they still run on gasoline.

Many electric utilities and agencies have found it difficult to comply with the EPAct purchasing requirements. And most of the dual-fuel vehicles which were purchased in order to receive EPAct credits are currently operating on gasoline because of the limited availability or prohibitive costs of alternative fuels to run the vehicles on. These vehicles offer little or no emissions reductions or fuel savings when running on traditional gasoline fuels. In contrast, HEVs use their electric-drive for an estimated 40% of their energy needs, providing more consistent emission reductions and fuel efficiency benefits than dual-fuel AFVs. Even when an AFV is run on alternative-fuels hybrids offer superior efficiency. “As measured by British Thermal Units (Btu) per mile, the energy efficiency of HEVs is twice that of any available alternative-fuel vehicle.”[30] Most AFVs are unlikely to be cost-effective strategies for reducing gasoline consumption and emissions for the foreseeable future absent major engineering and/or science breakthroughs, according to most studies.[31]

The EPAct fleet requirements were intended to reduce oil consumption and reduce air emissions. Compliance with EPAct is becoming increasingly difficult for fleet managers.

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[30] Electric Drive Transportation Association. Updating the Fleet Requirements of the Energy Policy Act of 1992. Washington D.C.: Electric Drive Transportation Association, 2005.

[31] The Center for Energy and Climate Solutions. The Car and Fuel of the Future: A Technology and Policy Overview. Washington D.C.: National Commission on Energy Policy. Jul. 2004.

Congress should move quickly to make needed modifications to EPAct fleet requirements by recognizing HEVs as an advanced vehicle technology necessary in governmental fleets.

CLEAR Act & Tax Credits

One of the most significant pieces of recent legislation regarding HEVs was the CLEAR Act of the 108th Congress. This act established a tax credit for the purchase of new HEVs. A new passenger car or light truck would qualify for a tax credit between $250 and $4,500, depending on the fuel efficiency and drive-train design. Heavy-duty hybrid vehicles would be eligible for even larger tax credits.[32] Unfortunately, that law scheduled the clean fuel vehicle property tax deduction to be phased out from 2004-2006 with no tax incentives scheduled beyond 2006. This could significantly alter consumer demand. “By providing a meaningful, limited-term tax credit for purchases of advanced technology, vehicles, the federal government can help these technologies to penetrate the overall marketplace and achieve meaningful economy-wide reductions in petroleum consumption and air emissions.”[33]

Thankfully, the ramifications of eliminating the tax credit were realized by Congress and the tax credits of the 108th Congress were extended in the 2005 Energy Bill to 2009. This will encourage a greater number of early-adopters to take advantage of the tax savings offered by HEVs. The higher cost of hybrids can actually help American auto-manufacturers as they represent a source of increased income and jobs which will benefit Detroit and the country as a whole. If American manufacturers see the demand for hybrid vehicles and begin to fulfill that demand with American made products we have the possible future of replacing imported oil with American made hardware.

Temporary tax credits are needed in order to offset the costs of early hybrid models while consumers begin to adopt this technology. Tax credits are needed in order to help hybrids reach the point of mass commercialization. Later, once mass commercialization of a variety of models begins, the added cost of hybrid systems could drop to the point where the difference can be made up with three years of gasoline savings. The additional cost of the vehicle will be made up

32 United States. Yacobucci, Brent D. CRS Report for Congress (RL30484) Advanced Vehicle Technologies: Energy, Environment, and Development Issues. Washington D.C.: Congressional Research Service, The Library of Congress, 17 Dec. 2004.

33 Electric Drive Train Association. Electric Drive Tax Incentives Can Transform the U.S. Vehicle Fleet. Washington, D.C.: Electric Drive Train Association, 2005.

in fuel savings alone during the time that most owners have their new vehicles. At this point, temporary tax credits will no longer be needed.

VI. Recommendations and Conclusion

We must increase vehicle efficiency to decrease the transportation sector's dependency on foreign oil is. The question of what technology can best accomplish this has been analyzed and debated throughout this paper. The hybrid-electric vehicle is the best near- to medium-term pathway and the following recommendations result from this conclusion:

Reevaluate current tax strategies/incentives.

An increase in the fuel tax could encourage less overall miles to be driven on a car after it is purchased, but has a small likelihood of encouraging consumers to buy cars which are more fuel efficient. This has shown to be true in countries that do have higher fuel taxes such as the EU and Japan where annual mileage is much lower than the U.S.

Similarly, a mileage based taxation system has the potential to decrease fuel use as less miles would be driven and would even out taxation between more efficient and less efficient vehicles. Tax incentives for new hybrid buyers are also a good step towards creating an initial market share and should be continued. The 2005 Energy Bill represents a good step in this direction.

Reform standards for fuel efficiency.

The current classification system does not reflect the way vehicles are used and currently classifies far too many vehicles as light trucks which have lower fuel economy requirements. NHTSA's new weight-based system for determining fuel economy requirements is insufficient. While this would help to reclassify a lot of vehicles that are currently considered light-trucks, it doesn't completely reflect the way a vehicle is used. A size based class system, as determined by interior room and vehicle footprint is a better classification system.

No matter what classification system is used, the problem remains that the standards are also difficult to increase as evidenced by the static standard from 1975-2003. This has allowed many loop-holes to exist for far too long. The upper weight limit of 8,500 lbs on what constitute a light-truck and thus count towards a manufacturer's average fuel economy has had negative effects and must be changed. The gas-guzzler tax should also be redefined in such a way as to expose all passenger vehicles to its effects and not exempt heavy cars. The quadruple tax break for business vehicles over 6,000 lbs should be reduced or eliminated. This tax break encourages heavier vehicles which consume more petroleum.

Institute a feebate system.

A feebate system would assess a fee against the least efficient vehicles in a size class and give a rebate on the purchase price of the most efficient vehicles in the same size class. The size based class system preserves consumer choice as they can still choose a more or less efficient vehicle in any size class. The fees would not be paid exclusively by SUVs with rebates given only to small cars, but the least efficient small cars would be paying for the rebates given to the most efficient small cars. This system would eliminate the loop-hole which allows some vehicles to escape taxation altogether. Feebates would give realization to life-time fuel savings during the three year period that most people own their cars.

Redefine EPAct and encourage government fleet purchases.

EPAct fleet requirements require governmental agencies and utilities to buy alternative fuel vehicles. The current requirement is for 90% of new light-duty vehicle purchases made by energy providers and 75% of vehicles purchased by state agencies to be alternative fuel vehicles. This law was created before the first commercially viable hybrids were available and is defined in such a way that HEVs are ineligible for EPAct credits. The EPAct requirements have been hard to comply with. Most of the alternative fuel vehicles purchased under the program are running on gasoline because of the expense or non-availability of alternative fuels. These vehicles offer little or new emissions or efficiency benefits when running on gasoline. Even when running on alternative fuels, AFVs are less efficient than hybrids. EPAct fleet requirements should be changed to encourage the purchase of hybrids by government fleet managers and utilities.

Remaining Challenges

The market share captured by hybrids to date is small, but growing. The cost of hybrids is a remaining challenge to achieving significant market share. This increased cost has not proven to be less than or equal to the lifetime savings obtained by the fuel economy of these vehicles except when supplemented by tax incentives or other subsidies. If tax incentives are not maintained while the initial market segment is created, then sales of HEVs could decline significantly.

The future competitiveness of HEVs will rely on overcoming several remaining challenges, including: improving battery technology and reducing battery cost, lowering the cost of electric motors, reducing weight, and cutting overall price. Implementing each of the above policy recommendations could make hybrids less costly and more attractive to consumers. As their market share increases, investments made into researching improving technologies and reducing costs could speed HEV development and adoption.

Conclusion

The implications of following each of these proposed policy recommendations could be enough to free the U.S. from foreign oil dependence. The lessons learned from America's transition from a petroleum based economy will be shared with other developing countries which will be able to leapfrog their development past the early petroleum age and begin developing more efficient technologies immediately. The long-term effects of a petroleum based transportation industry on the environment are still a matter of great debate, but as a matter of efficiency alone, HEV technology will contribute to oil savings while reducing green-house gases. As an interim technology on the way to a hydrogen technology, HEVs will provide ample opportunity for technological breakthroughs which will later prove useful. In the meantime, their increased efficiency will decrease U.S. dependency on foreign oil and bring awareness to the capabilities of advanced technology vehicles.