The Green Machine Challenge:
A Concept for Promoting Ultra-Efficient Vehicles

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SUMMARY

Higher fuel efficiency is important for addressing many economic, security, and environmental problems associated with the transportation energy consumption, which is 97% petroleum based in United States. Cars and light trucks account for 60% of U.S. transportation energy use and for many years, public and private research efforts have worked toward the development of vehicles of greatly improved efficiency. The Partnership for a New Generation of Vehicles (PNGV), a U.S. government and industry collaborative research and development venture announced in 1993, is refocusing such efforts on a set of ambitious goals, including the development of prototypes having three times the fuel economy of today's cars. To date, however, technologies for substantially improving vehicle efficiency have failed to progress beyond the research and development stage and into mass production. Programs for directly influencing vehicle efficiency in the marketplace have been limited to incremental improvements in vehicle efficiency or oriented toward promotion of alternative fuels without specific regard to efficiency. This paper explores the potential role for a market creation program to help commercialize cars and light trucks having fuel efficiencies which are substantially rather than incrementally higher than those of recent conventional vehicles.

The "Green Machine Challenge" is a working title for a potential program to stimulate market introduction of ultra-efficient cars and light trucks. Ultra-efficient vehicles would have fuel efficiencies substantially higher than current mass-market vehicles while maintaining contemporary standards for size, affordability, range, performance, and other vehicle amenities. This concept has been discussed in some form for a number of years and it could operate similarly to the market creation programs for alternatively fueled vehicles which have been set up in recent years. A Green Machine Challenge might entail a variety of program elements, such as strategic procurement of advanced vehicles by government fleets, voluntary purchase commitments by private fleets or individuals, a national competition, financial incentives for manufacturers or consumers, and marketing and consumer information. Thus, such a program could involve some combination of elements oriented to demonstrating sufficient market demand and encouraging manufacturers to make the investments needed for initial production runs of ultra-efficient vehicles.

As a prelude to a larger report on the subject, this paper sketches possible elements of a Green Machine Challenge and identifies the issues which need to be examined in order to develop a workable market creation program plan. The paper provides background information, discusses the policy context for developing a Green Machine Challenge, traces U.S. light vehicle fuel economy policies and trends, and reviews related policies for light vehicle emissions control and fuel supply diversity. A framework for planning market transformation policies is presented and used to explore the potential role for a program to create demand for efficient vehicles as part of a comprehensive strategy for transforming the market to address energy-related policy goals. Further policy analysis and planning are needed to identify the feasibility and likely effectiveness of a Green Machine Challenge. Issues which need additional study include an assessment of the size of potential target markets for the program, estimation of technology availability and achievable efficiency targets, examination of interactions with and coordination with other policies affecting light duty vehicles, development of program design recommendations, estimation of program costs and benefits, and identifying potential funding mechanisms.

INTRODUCTION

Transportation energy use has been a serious policy concern in the United States since 1973, when Middle East conflict resulted in an oil embargo. The past two decades have brought progress in resolving some of the political difficulties that caused the first energy crisis. Nevertheless, the U.S. transportation sector remains 97% dependent on petroleum, of which the import share is now nearly 50% and still growing (Davis and Strang 1993; EIA 1994a,b). The resulting economic costs and security risks continue to motivate control of motor vehicle fuel consumption. Reducing motor fuel consumption also reduces air pollution, particularly "upstream" emissions during fuel production and distribution and non-tailpipe vehicle emissions (DeLuchi et al. 1992). More recently, there has been a heightened awareness of the need to control rising emissions of carbon dioxide and other greenhouse gases. The Clinton Administration issued a Climate Change Action Plan (CCAP 1993) which commits the nation to returning greenhouse gas emissions to the 1990 level by 2000 and to establishing a declining emissions trend thereafter. Although transportation accounts for one-third of U.S. greenhouse gas emissions and is one of the more rapidly growing sources, transportation sector actions yield only 12% of the reductions identified in the Climate Plan. The need to develop additional policies was acknowledged and the Plan called for a one-year study of options for returning U.S. car and light truck emissions to their 1990 level by some future year.

In late September 1993, just two weeks before the Climate Plan was announced, the Administration joined with the major U.S. automakers in announcing a historic initiative called the Partnership for a New Generation of Vehicles (PNGV--prior to formalization, it was colloquially known as the Clean Car Initiative). This joint research and development venture expresses the growing consensus that a fundamentally new vehicle technology will be needed for the 21st century if the United States (and the world) is to successfully address concerns related to motor vehicle fuel consumption, including air pollution, oil import dependence, and greenhouse gas emissions. There is also a desire to strengthen the domestic job-providing abilities of the automobile industry, a core part of the U.S. economy. The PNGV is a joint agreement for public/private research and development efforts involving the Departments of Commerce, Defense, and Energy, as well as the national laboratories with the "Big Three" automakers (Chrysler, Ford, General Motors) and other technology firms. The Partnership has three broad goals: (1) improved automotive manufacturing methods, (2) technologies for near-term efficiency and environmental improvements, and (3) prototypes of a "new generation" vehicle having a fuel economy three times that of today's vehicles while maintaining contemporary standards of comfort, utility and affordability (PNGV 1994). The PNGV is strictly a research and development (R&D) program, focusing on technology availability rather than market establishment or commercialization.

Improving vehicle efficiency is one mechanism for addressing societal concerns regarding the U.S. transportation system. Controlling travel demand, improving vehicle emissions controls, and alternative fuels are others. The realization that greatly improved vehicle energy efficiency is important for achieving deep cuts in greenhouse gas emissions has reenforced the need to move beyond incremental refinements of existing automotive technology. At present, however, there are no U.S. policies to substantially encourage either incremental or leap-forward efficiency improvements in production vehicles. In particular, there is no policy mechanism for ensuring that advanced technologies move into commercialization (through incorporation into production vehicles and sales in the mass market) in ways that deliver widespread energy savings and environmental benefits. Technology development may not be sufficient to insure commercialization, particularly when the

purpose of the technologies is to meet non-market goals. Without sufficient initial consumer demand, it may be difficult for manufacturers to justify introduction of new technologies because of the higher costs involved before economies of scale are achieved.

Studies have not been undertaken regarding the need for, or desirability of, policy mechanisms for ensuring commercialization of ultra-efficient vehicles. A variety of studies have addressed the feasibility, benefits, and costs of strengthened fuel economy standards. A number of studies have analyzed other market mechanisms, such as fuel taxes and vehicle price incentives, for improving vehicle efficiency and reducing transportation energy use. However, issues regarding potential non-technological barriers to full commercialization of ultra-efficient, new generation vehicles have received limited attention. This paper provides a preliminary discussion from a project intended to remedy this gap in policy analysis. It presents the concept of a special program, which might entail a variety of elements, for spurring commercialization of ultra-efficient vehicles; "Green Machine Challenge" is the working name for this concept. (It should not be confused with existing programs, such as the Natural Gas Vehicle Challenge or Hybrid Electric Vehicle Challenge, which are student engineering design competitions currently sponsored by the U.S. DOE and the automotive industry.) While yet to be precisely defined, the term "ultra-efficient" refers to vehicles having fuel efficiencies substantially higher than current mass-market vehicles while maintaining contemporary standards for size, affordability, range, performance, and other vehicle amenities.

THE GREEN MACHINE CHALLENGE

The concept of a Green Machine Challenge is to provide the automotive industry with a special, initial market creation incentive to commercialize cars and light trucks offering a major step forward in energy efficiency. Such a program would attempt to induce sales volumes sufficient to achieve economies of scale for new technologies and would also help condition the market by increasing public awareness of new technologies and their benefits. The objective is to encourage application of advanced technologies to meet non-market goals, such as reducing petroleum use, air pollution and greenhouse gas emissions, without sacrificing other attributes which consumers find desirable. In this paper, without presuming any particular environmental or energy-use targets, we refer to such vehicles as being "ultra-efficient." Programs of this form have been previously proposed by Shamansky (1982), DeCicco (1991), and the Sustainable Energy Blueprint (1992). Interest in pursuing such an approach for efficient vehicles is most recently stimulated by the success, in another sector, of the Super-Efficient Refrigerator Program (SERP), which accelerated the commercialization of a full-size refrigerator which exceeds the 1993 efficiency standards by 30 percent (Feist et al. 1994).

By way of example, a Green Machine Challenge might seek to obtain up-front commitments for the purchase of a substantial number of ultra-efficient vehicles over a 3-4 year period beginning 4-5 years from inception of the program. Qualifying vehicles would meet a specification related to substantially improving energy efficiency per vehicle mile or cutting the per-mile energy use by a specified amount (e.g., one-half of the average of today's similarly sized new vehicles); alternatively, the specification might be expressed in terms of equivalent greenhouse gas emissions per mile. The specifications might also include very low tailpipe emissions (e.g., California ULEV levels[1]), high

[1] The Ultra-Low Emission Vehicle (ULEV) standard is the most stringent non-zero emissions standard proposed for light duty vehicle criteria pollutants; it specifies initial certification levels at 0.04 g/mi of reactive organic gases (hydrocarbons), 1.7 g/mi of carbon monoxide, and 0.2 g/mi nitrogen oxides, along with stringent emissions control durability requirements (CARB 1990).

safety standards (e.g., meeting a dynamic impact test), an acceptable price (e.g., within the current real price range for vehicles of the same class), and designated levels of performance, recyclability, reliability, and domestic content. Separate requirements could be set for several major vehicle types, e.g., a full-size (6 person) passenger car, a compact (4 person) car, a passenger van or wagon seating up to 9 persons, and a full-size pickup truck; these classes have had the largest shares of the U.S. market in recent years. The types of program goals just mentioned are purely illustrative. Identifying appropriate and workable specifications for a Green Machine Challenge is a task which this study begins to address and which would have to be completed by developing an informed consensus among potential program sponsors and participants.

The commercialization incentives provided by a Green Machine Challenge could involve a number of elements. One likely element is the creation of an initial market for ultra-efficient vehicles by means of aggregated purchase commitments involving vehicle fleet operators (public and private) and individual consumers. Participants would agree to purchasing a specified number of ultra-efficient vehicles within a set time period. Thus, state and local governments, rental car companies, commercial fleet leasing agencies, and businesses operating their own vehicle fleets could also be invited to participate in the Challenge, as would private individuals interested in acquiring a "Green Machine." Questions to be answered include what volume of purchase commitments is needed to justify serious attention by automakers and how this volume compares to the pool that might be generated by potential participants on the demand side. Similar participants are involved in current efforts to promote alternatively fueled vehicles, so another key question is how to coordinate programs involving different objectives but focussing on similar target markets and commercialization mechanisms. There would also be the question of how the administer the Challenge, since a coordinating entity would be needed to develop specifications, gather purchase commitments, and evaluate vehicles. In the case of the super-efficient refrigerator, a nonprofit corporation was established to provide an independent governing structure for the program (Feist et al. 1994).

Another element of a Green Machine Challenge program could be subsidies for initial sales of the qualifying vehicles. Such incentives could take the form of cash rebates or tax benefits for purchasers; they could be vehicle subsidies, tax incentives, or a cash award for automakers; or a combination of buyer and seller incentives. A financial incentive, consisting of both prize money for manufacturers and subsidies for initial sales, was part of the Super-Efficient Refrigerator Program. Vehicle subidies in the form of tax credits and deductions are an aspect of current state and Federal programs to create markets for alternatively fueled vehicles. Clearly, questions arise regarding the size of incentives needed, how best to deliver them, what sources could be used to finance such subsidies, and the equity of the transfers entailed.

We qualify our discussion by noting what some might see as a limitation in our working definition of an ultra-efficient vehicle. Some analysts have envisioned "green" vehicles that depart substantially from today's dominant market classes in terms of size, range, and performance. Examples are various neighborhood electric vehicles (MacKenzie 1994; Sperling 1995) and commuter cars (Sobey 1993; Riley 1994). Riley, for example, proposes that consumers are likely to value other characteristics which can find expression in such vehicles but which are not being tapped by current mass-production designs. Undoubtedly, substantial engineering research and development could go into making such vehicles attractive, while relatively less engineering effort would need to go into reducing fuel use per mile, which is more easily obtained in vehicles of smaller size or lesser performance. Reasons that such designs may be reasonable are the low occupancy, range, and performance needs that characterize a substantial portion of actual driving. However, without passing judgement on the merits

of such approaches, a more narrow view of efficiency improvement is adopted here. We assume vehicle utility attributes (size, range, acceleration and speed performance) similar to those of vehicles that dominate the U.S. market today. This assumption puts the engineering burden squarely on achieving fundamental improvements in vehicle energy efficiency through reduction of drivetrain losses and reduction of tractive loads at fixed utility. Clearly, if technological advances can yield substantial fuel economy improvements in full-size, full-function vehicles, even greater fuel economy levels can be achieved in smaller vehicles should these come to play a major role in the transportation sector.

POLICY CONTEXT

Public concerns--expressed through government action, in contrast to consumer wishes expressed in the showroom--started influencing automobile marketing with the 1958 passage of the Monroney Act, which required a sales sticker on every new car to disclose its suggested retail price and standard equipment along with optional items and their prices. The information required on new vehicle sales stickers (termed "Monroneys" in the trade) has expanded over the years, most recently with the requirements for national origin of parts and assembly enacted in 1993. Public concerns have had a determining role in shaping automobile technology since the establishment of regulatory standards, first for emissions in 1965, next for safety in 1966, and then for fuel economy in 1975. Regulation has undoubtedly improved the design of U.S. vehicles in terms of emissions, safety, and fuel economy, although there is disagreement about the relative costs and benefits of various regulations to date. For fuel efficiency, retrospective evaluations indicate that the improvements were primarily technologically based and were cost-effective (DOE 1989; Greene 1990a), although others have claimed adverse impacts from the standards (Crandall et al. 1986). Relative to 1977 fuel usage rates, light vehicle fuel savings now amount to at least 50 billion gallons annually, a majority of which is attributable to fuel economy regulation (Greene 1990b; DeCicco 1995).

In addition to consumer protection, public health, traffic safety, and energy security, greenhouse gas emissions have been added to the list of public concerns which motivate policy development regarding automobiles. Improving fuel efficiency directly addresses the concerns of energy security, pollution reduction, and climate protection:

* U.S. cars and light trucks consume about 12.3 Quads (6.4 Mbd) of petroleum fuel, mostly gasoline, accounting for 35% of national petroleum consumption (Davis and Strang 1993). During the early nineties, the United States has imported over 40% of the oil it has consumed, a fraction that is expected to reach 60% over the next two decades (EIA 1994a).

* Hydrocarbon (HC) vapors are a form of regulated air pollution which are partly proportional to light vehicle gasoline use. Hydrocarbon emissions are a major cause of health-threatening ozone smogs and include benzene and other directly toxic or carcinogenic compounds. Transportation sector fuel consumption results in at least six million tons per year of HC emissions (EPA 1993), of which perhaps one-third is due to evaporative emissions. DeLuchi et al. (1992) find that a substantial portion of evaporative emissions are proportional to the quantity of fuel consumed.

* Gasoline is a fossil fuel and directly contains about 5.4 lbs of carbon per gallon. Fuel use by U.S. light vehicles contributes about 320 MTc/yr (million metric tons per year, carbon mass basis) of greenhouse-gas emissions, since gasoline use entails total carbon-equivalent emissions of 7.2 lb/gal (26 MTc/Quad) when counting the direct carbon content plus the additional emissions of carbon dioxide and other greenhouse gases associated with extraction, production, distribution, and consumption (DeLuchi 1991).

Investing in cost-effective levels of vehicle efficiency improvement also benefits general economic welfare in the United States, since the fuel cost savings are respent on other goods and services throughout the economy entailing greater domestic employment than the capital and import intensive petroleum sector (Geller et al. 1992).

Table 1 summarizes vehicle technology changes according to the public concerns they address and the Federal laws now in place that can effect such changes. Vehicle efficiency improvement is clearly a way to address most of the public concerns related to motor vehicle fuel consumption. (Note that we are not considering all of the public concerns related to motor vehicle use, such as traffic congestion and accessibility, which are beyond the scope of this study.) The Energy Policy and Conservation Act (EPCA 1975) established fuel economy standards, the role of which is briefly described below. The major Federal policies subsequently put in place to address vehicle technology do not include provisions directed toward changing fuel efficiency actually achieved in the light vehicle market.

Current Fuel Economy Policy

The 1973 oil embargo set in motion a technological transformation which was reenforced by Corporate Average Fuel Economy (CAFE) standards established in 1975 and the 1979 oil price shock. The U.S. car fleet has now almost wholly converted to front-wheel drive, unit-body construction, and there have been steady improvements in engine technology, aerodynamics, and other design refinements which improve fuel efficiency. After ten to twelve years, the light vehicle stock is mostly replaced, especially in terms of usage, so the effects of this transformation are now complete. The average EPA-rated fuel economy for new light vehicles (cars plus light trucks) has been within 0.9 mpg of 25 mpg for the past thirteen years (Murrell et al. 1993). For criteria emissions and safety, standards have been strengthened periodically by means of legislative and administrative actions. In spite of attempts over the years, this type of policy pressure has not been established for continuing fuel economy improvement. Moreover, light trucks have been more leniently regulated than cars (for emissions and safety as well as fuel economy). Light trucks' share of the personal transportation market has greatly increased since the 1970s, so that they now account for nearly half of the lifetime fuel use of the new light duty fleet.

Table 1. Automotive Technology Changes vs. Public Goals and Policies

	Vehicle Technology Changes		
	emissions control	alternative fuels	efficiency improvement
Public Concerns			
Energy Security		X	X
Criteria Pollutant Reduction	X	X	X
Domestic Economic Welfare		X	X
Climate Protection		?	X
Public Policies			
EPCA (1975)			X
AMFA (1988)	X	X	
CAAA (1990)	X	X	
EPACT (1992)	X	X	

The gas-guzzler tax was a second policy oriented to improving automobile efficiency. This Federal excise tax on certain new cars was enacted in 1978 and first took effect in 1980. Vehicles with fuel economy below a gradually increasing threshold were subjected to a substantial tax. The threshold fuel economy, below which cars are subject to the tax, reached 22.5 mpg in 1986 and has since stayed constant, although gas-guzzler tax rates were doubled as of January 1991. Manufacturers tended to improve their least efficient models' fuel economy to avoid this tax (Ledbetter and Ross 1991). However, the gas guzzler tax applies to less than 10% of the car fleet and not at all to light trucks, so it provides little or no pressure for ongoing fuel economy improvement. Moreover, there is no indication that current market forces will pull new fleet fuel economy above the present levels, which hover just above the level set by CAFE standards. A prognosis of essentially flat fuel economy is confirmed by the industry's own statements in recent hearings on fuel economy standards.

In addition to policies designed to influence market outcome regarding transportation energy use, the United States has had, at least implicitly, a "technology policy" for motor vehicle energy consumption and fuels. Vehicle and fuels research and development programs have been part of DOE activities since the founding of the department. Related research and development (R&D) efforts have been sponsored by the Department of Defense, the Environmental Protection Agency, and the Department of Commerce. To date, none of the DOE-sponsored transportation R&D products have been transferred to the U.S. light vehicle market. The technology-based efficiency improvements have resulted from the industry's own private R&D efforts. Part of this shortcoming may be due to shifting goals and funding levels over the years. It is interesting to note that DOE's hybrid-electric vehicle research, which was active in the early 1980s but then largely terminated until its recent revival, involved work with Volkswagen. Volkswagen continued their own development efforts in Germany and subsequently placed into service a test fleet of several hundred hybrid vehicles (related to a VW Golf design; see Seiffert and Walzer 1991) while such efforts had all but disappeared in the United States. Recently, the PNGV has signaled a substantially higher level of commitment and focus to vehicle efficiency R&D by both government and industry in the United States. As noted earlier, however, the PNGV is strictly an R&D program, with no specific objectives for implementing efficiency improvements in production vehicles. However, it is hoped that the close partnership with industry will facilitate more effective technology transfer than has been achieved by government-sponsored light vehicle efficiency R&D programs to date.

Fuel Use Growth and Alternatives

Over the past two decades, population growth, an expanding work force, road building, and ongoing suburbanization contributed to a doubling of Vehicle Miles of Travel (VMT). Over the next twenty years, VMT is expected to increase by roughly 2% per year, implying close to another 50% increase in personal vehicle travel (UCS et al. 1991). The transportation conformity provisions mandated by the Clean Air Act Amendments (CAAA) of 1990 and the new flexibilities in the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 offer hope that future development patterns and infrastructure spending will support a shift to alternative travel modes, at least in urban areas. New development, however, alters only a small fraction of the settlement patterns already laid down. Travel demand's geographic determinants will only be transformed over rather long time scales, 30-40 years or more. The nationwide effect of these new approaches to transportation planning is uncertain. However, they are expected to avoid only a portion of VMT growth rather than achieve a leveling off. The VMT reduction actions identified in CCAP (1993) are estimated to cut 6.6 MTc/yr, or about 2%, from transportation sector greenhouse gas emissions in 2000.

The fuel economy improvements achieved over the past two decades were sufficient to temporarily control gasoline consumption in spite of steadily rising VMT (Davis and Strang 1993). Because new vehicle fuel economy has stagnated since the early 1980s and the average light vehicle lasts twelve years, the United States has essentially finished reaping the benefits of the fuel economy improvements set in motion during the 1970s. As a result, light vehicle gasoline consumption and its contribution to greenhouse gas emissions are again starting to rise in step with VMT. EIA (1994a) estimated car and light truck fuel consumption at 12.7 Quads/yr in 1990 (6.4 Mbd), implying 320 MTc/yr of greenhouse gas emissions. There is a diversity of views about the near- and mid-term growth rates, with projections of additional light vehicle carbon emissions ranging from 70 MTc/yr (EIA 1994a) to 130 MTc/yr (DeCicco 1995) by 2010. Nevertheless, there is little doubt that substantial growth will occur in the absence of policy change. Thus, the United States cannot avoid turning to technological changes, either improved efficiency or a shift to lower-carbon fuels, to control transportation sector greenhouse gas emissions (and oil imports). Technology change is even more important to achieve substantial cuts over the long-term.

Alternative (non-petroleum) fuels and feedstocks are an important way to address the energy security concerns and environmental concerns associated with car and light truck gasoline use (Sperling 1989). To the extent they are produced and distributed using lower-carbon or renewable (no net fossil carbon) feedstocks, alternative fuels also reduce greenhouse gas emissions (DeLuchi 1991). Research and development (R&D) efforts for various alternative fuel and vehicle designs have been underway for many years. Such efforts have been a major focus of the U.S. DOE Office of Transportation Technology (OTT) programs. AMFA (1988) articulated a Federal role in promoting alternative fuels and established credits towards meeting CAFE standards for manufacturers supplying alternatively (including flexibly) fueled vehicles. CAAA (1990) provided additional impetus, for "clean fuels," although it left open ways to meet the environmental objectives through a combination of reformulated gasoline and better vehicle emissions control technologies. EPACT (1992) provides more concerted incentives, including various tax subsidies, for non-petroleum alternative fuels. Some of the relevant provisions of these Federal actions are further discussed below.

Encouraging alternative fuel vehicles (AFVs, including electric vehicles) will require large investments in new fuel supply infrastructure. In addition to fuel-specific technology changes, AFVs will need to improve efficiency to achieve acceptable range (Bleviss 1989) and to substantially reduce greenhouse gas emissions. EPACT, as well as various States' legislation to promote alternative fuels, will result in increasing AFV sales over the coming years. EIA (1994a) projects that AFVs could increase to over 10% of new light vehicle sales by 2010. Because of lags in stock turnover and alternative fuel limitations (e.g., some AFVs would be flexibly fueled and use gasoline some of the time), only about 5% of petroleum fuel energy use would be displaced by alternative fuels in 2010. Since most alternative fuels being promoted by existing policies are still fossil-based, light vehicle greenhouse gas emissions will be reduced by no more than 2% by 2010 through the alternative fuel vehicle programs now in place (EIA 1994a). However, alternative fuels can be expected to make larger contributions to greenhouse gas emissions reduction if there are concerted efforts to favor renewable rather than fossil feedstocks and if AFVs are made significantly more energy-efficient than today's gasoline vehicles.

Fuel Economy Policy Needs

At this junction, measures to improve the fuel efficiency of the roughly 15 million new cars and light trucks sold in the United States each year are essentially absent from the policies in place to address transportation energy use. This issue has nagged policy makers for some time. Attempts to plan for a post-1985 round of CAFE standards increases were discussed in 1979-80, when the Iranian revolution and resulting oil price shock lent a sense of urgency to the issue (U.S. Senate 1980). In 1982, then-Representative Robert Shamansky of Ohio introduced the Automobile Research Competition Act. This proposal relied on manufacturer incentives by offering a prize of about $140 million to the manufacturer that could develop a vehicle achieving at least 80 mpg and that sold at least 100,000 vehicles per year for at least three years. The program would have also set specifications for payload capacity, acceleration, safety and emissions. The Shamansky bill was not enacted but provides precedent for the Green Machine Challenge concept discussed here.

Bills to strengthen CAFE standards were introduced during the 100th-102nd Congresses. Notable among these was a bill (sponsored by Richard Bryan and Slade Gorton in the Senate and Leon Panetta in the House) which called for a 40% improvement in new car and light truck fuel economy by 2001. Similar measures, proposing somewhat lower or higher rates of incremental fuel economy improvement, were considered during deliberations leading to the CAAA (1990) and EPACT (1992) but all were unsuccessful. A number of fee and rebate ("feebate") proposals were also introduced during this period but none advanced very far in the legislative process. Substantive measures to improve car and light truck fuel economy were excluded from the National Energy Strategy (NES 1991), leaving a well recognized gap in U.S. energy policy. During Congressional hearings on the NES, DOE officials acknowledged that there "may be unmet CAFE needs" for the petroleum-displacement objectives of the National Energy Strategy (Stuntz 1991).

The Climate Change Action Plan (CCAP 1993) also excluded actions for improving vehicle efficiency, other than a provision for efficiency labeling of aftermarket tires, which will have a small effect. However, the CCAP does call for a one-year study to better address the issue. This Federal Advisory Committee effort will identify sets of policies to cost-effectively return car and light truck greenhouse gas emissions to their 1990 level by some future years, with no upturns thereafter (Federal Register 1994). A broad spectrum of policies, regulatory and non-regulatory, for addressing car and light truck greenhouse gas emissions will be on the table during this process. Policy options for increasing vehicle efficiency include:

* Regulatory approaches, such as stronger and reformed CAFE standards or binding caps in fleetwide greenhouse gas emissions.

* Broad-based market incentives, such as higher fuel taxes, which could be carbon-based and involve offsets of other taxes, or pay-at-the-pump insurance.

* Vehicle-based market incentives, such as an expanded gas guzzler tax, feebates, and efficiency or emissions-based registration fees.

* Market creation programs for efficient vehicles.

* Public awareness programs providing information about vehicle efficiency, component efficiency, and benefits of more careful driving and vehicle maintenance.

* Research and development (R&D) for efficient vehicle technologies.

So far, the only new policies being implemented are the last two, namely the public information on tire efficiency and expanded R&D on vehicle efficiency.

The most significant recent policy development related to vehicle efficiency has been the R&D program to be coordinated by the PNGV. Clearly, the development of market-ready vehicles of tripled fuel economy could make a dramatic difference in addressing the public concerns related to light vehicle fuel consumption. The development of additional cost-effective technologies for near-term efficiency improvement and emissions control can also deliver public benefits if incorporated into production vehicles. However, given the restriction of the PNGV to pre-competitive (and therefore pre-market) R&D, one cannot project, in either magnitude or timing, the fleetwide efficiency improvements that might result from the program.

MARKET TRANSFORMATION STRATEGIES

Examining the principles of market transformation provides a conceptual framework for analyzing strategies for influencing the light vehicle market. In the context of energy use, market transformation is the process by which new technologies enter the market and achieve substantial market penetration (Geller and Nadel 1994). Clearly, when non-market goals are involved, market forces will not suffice to produce ideal outcomes. Moreover, there are barriers which prevent even energy-saving, lifecycle cost-effective technologies from achieving significant market penetration. These barriers include lack of awareness or information, limited product availability, perceived risks, different parties making investments and paying operating costs, energy price distortions, and limited access to capital (Gordon 1991; Hirst and Brown 1990; Reddy 1991; and Stern and Aronson 1984). Therefore, the market does not yield a socially-optimal level of energy efficiency. Policy interventions are needed to overcome barriers to cost-effective energy-efficiency improvements.

Policy Approaches for Market Transformation

Policies to advance market transformation include both "technology push" policies to help develop and bring innovative concepts to market and "technology pull" policies to accelerate market penetration of available but under-utilized technologies. The distinction is that "push" policies are mainly oriented to influence the supply side of the market (manufacturers) while "pull" policies are mainly focussed on the demand side. Such technology policies are an important way to improve environmental quality while providing economic benefits (Ross and Socolow 1991).

Table 2 lists the types of market transformation policies relevant to improving vehicle efficiency. "Technology push" policies include support for research and development, demonstration projects, and financial incentives to manufacturers for commercializing new technologies. Technology-based economic development programs, such as state or regional consortia, can draw on these mechanisms along with public backing in the hope of not only bringing new technology to market, but also creating local jobs. When a technology serves a market need, market demand takes over once the product is brought to market at an acceptable price. Semi-conductors are an example of such a technology. When technologies do not meet a market demand, however, "technology pull" interventions are needed. Peformance standards require that products in the market meet certain test requirements, in this case, for energy efficiency; the emissions and CAFE standards are examples. So are sales mandates requiring manufacturers to produce and sell certain technologies, though mandates might be considered a "push" on manufacturers, who are given the responsibility of creating enough demand

to satisfy the mandate. Strategic procurement refers to mandated government purchases of vehicles meeting the desirable specifications. Procurement can be coordinated among Federal, state, and local governments to provide a greater degree of purchase aggregation and market influence. Mandatory procurement can be extended to certain private buyers as well. Voluntary purchase commitments involve non-mandatory coordinated procurement efforts, which can involve governments, private firms, and private individuals. Consumer incentives can take the form of cash rebates, tax credits or deductions, or other special privileges for buyers of the new technology. Finally, marketing and consumer information efforts, such as advertising, special events, or other promotional programs, can increase public awareness and pique buyer interest.

Table 2. Market Transformation Tools

Technology Push	Technology Pull
Research	Performance Standards
Technology Development	Sales Mandates
Demonstration	Strategic Procurement
Manufacturer Incentives	Voluntary Commitments
Economic Development Programs	Consumer Incentives
	Marketing and Consumer Information

Geller and Nadel (1994) provide examples of market transformation in several end-use markets, including refrigerators, housing in the Pacific Northwest, and light-duty vehicles. In general, complementary policies can yield desired market transformations. For example, the average new 1993 refrigerator consumed roughly 40% as much energy as a 1972 model. These efficiency gains were driven by minimum efficiency standards and utility rebate programs. In the transportation sector, however, the market transformation that occurred since the early 1970s involved the external forces of the 1973 and 1979 oil crises plus the resulting gasoline shortages and dramatic price hikes, in addition to the policy tools of CAFE standards and the gas guzzler tax. Although the Federal government carried out research and development programs related to efficient vehicle technologies, these are not known to have influenced the light duty vehicle market during the transformation of the past two decades.

Commercialization Incentives for Efficient Electric Equipment

A number of programs designed to commercialize ultra-efficient residential and commercial sector end-use technologies by assuring a substantial initial market have been established. A program to bring to market super-efficient refrigerators led to the commercialization of a model that consumes

30% less energy than previously available models (L'Ecuyer et al. 1992; Treece 1993; Feist et al. 1994). Efforts to establish initially assured markets for ultra-efficient residential air conditioners, clothes washers, commercial air conditioners and heat-pump water heaters are under way through the Consortium for Energy Efficiency (CEE 1993, 1994).

For refrigerators, the Super-Efficient Refrigerator Program (dubbed the "Golden Carrot") coordinated utility incentives to stimulate the development and subsequent commercialization of an advanced design leading to superior efficiency levels. The manufacturer producing the winning refrigerator received a $30 million prize, paid as units are delivered into the service areas of the sponsoring utilities. The next set of "Golden Carrots" for heat-pump water heaters, residential clothes washers, and commercial air-conditioners do not provide a cash prize, but do involve coordinated incentive programs. Utilities announce future eligibility levels for incentive programs, thereby demonstrating to manufacturers that if they commercialize ultra-efficient products, there will be a market for them (CEE 1994). Capital expenditures and limited sales during initial production result in negative cash-flow during early phases of commercialization of a new product. Therefore, programs which assure larger initial markets can make early commercialization more feasible. Coordinated utility incentives and strategic bulk purchases can both serve this purpose. If the "Golden Carrot" involves a prize, manufacturers can pass on all or part of the prize to consumers as lower prices to increase the number of units demanded thus allowing even larger initial production runs further lowering per unit costs.

Three other important attributes of the "Golden Carrot" programs that aid the market transformation process are legitimacy, publicity, and likely impact on regulatory standards. By bringing together a variety of key stakeholders including energy-providers, government agencies, and environmental groups, these programs legitimate the efficiency goals. A high profile for the program, or the publicity that surrounds a competition, can enhance public awareness of efficient technologies and designs, helping to bolster consumer receptivity and interest. Finally, because of the regulatory regime enacted in the National Appliance Energy Conservation Act (NAECA), Federal standards can be tightened if it can be shown that higher efficiency standards are technically feasible and economically justified (L'Ecuyer et al. 1992). If any one manufacturer commercializes a more efficient model, others will be at a disadvantage in meeting the next round of government efficiency standards if they have not begun their own efforts to improve efficiency. While commercialization programs such as the "Golden Carrot" help with the initial phase of market transformation, insuring that improved technologies reach the whole market involves the broader market pull of efficiency standards or widely applicable financial incentives.

Market Transformation Strategies for AFVs

Two recent Federal laws include provisions intended to spur transformation of the light duty transportation market toward alternatively fueled vehicles (AFVs). The Clean Air Act Amendments (CAAA 1990) envisions vehicles that are less-polluting and the Energy Policy Act (EPACT 1992) foresees a national light vehicle fleet fueled by substantially non-petroleum fuels. Both include fleet procurement requirements which will create an initial market demand intended to spur development and help commercialization of AFV technologies. The types of programs in effect are listed in Table 3, using the categories presented earlier. Since fuel availability is a major barrier for AFVs, there are also incentives for alternative fuel supply infrastructure (which we do not consider here).

The CAAA relies on tighter emissions control standards and more effective certification testing to achieve reduced air pollution from vehicle emissions. The emissions standards are designed to prompt industry-wide application of gasoline vehicle emissions control technologies that are available or near commercialization. Two CAAA prescriptive mandates require the use of cleaner vehicles. Although intended to spur commercialization of non-petroleum fueled vehicles, the specifications are fuel neutral. The first is the market-pull approach of the CAAA fleet provisions. This program phases in requirements for operators of centrally fueled fleets in certain non-attainment areas to acquire vehicles meeting more stringent emissions standards. When fully phased in, this fleet program is intended to affect 250,000 vehicles per year.

The other mandate is the supply-side approach of the California Pilot Program. Administered by U.S. EPA, the intent of this program is that manufacturers must sell minimum numbers of vehicles in California meeting Phase 1 emissions standards beginning in 1996 and more stringent Phase 2 standards beginning in 2001 (Waxman et al. 1991). As implemented, this program imposes increasingly tighter fleet average emissions standards, based on various levels of California Low Emissions Vehicles (LEVs--see CARB 1990); the Phase 1 requirements are essentially met by a TLEV and the Phase 2 requirements by a LEV. California's own emissions standards effectively require that LEVs be marketed in California by 1998 and that vehicles meeting the most stringent, ULEV, standard are marketed by 2001. Some aspects of the California standards are likely to be adopted by a number of states in the Northeast and Mid-Atlantic region.

In addition, California has imposed a state mandate that 2% of major manufacturers' vehicles be Zero Emissions Vehicles (ZEVs) starting in 1998. The only available technology that meets the ZEV standard is the rechargeable battery electric drivetrain. New York and Massachusetts also wish to complement their LEV programs with a ZEV mandate. It is hoped that this mandate will spur development of more advanced technologies such as fuel cells which would enable electric vehicles to become more fully competitive with conventional vehicles. Moreover, a regional consortium called CALSTART has been formed with the goal of advancing electric vehicle technologies while developing a new industry drawing on underutilized defense-related manufacturing skills, particularly in Southern California.

In the view of the CAAA authors, "ultimately, clean-fuel vehicles must penetrate the passenger-car market to achieve major reductions in air pollution" (Waxman et al. 1991). The CAAA anticipated that many of the vehicles introduced to meet the legislation's requirements would be AFVs. The authors chose fleet acquisition mandates as a route to encourage clean-fuel vehicle development because central refueling facilities would ease the transition to new fuels, fleets would be able to provide regular professional maintenance for early models and fleet operators would be more likely to benefit from the advantages of switching to cheaper alternative fuels than the average consumer since fleet vehicles are driven twice as many miles per year as the average vehicle (Waxman et al. 1991). In principle, the fleet requirements are meant to bring technologies into the market in advance of broader requirements that the technologies be applied throughout the market. Fleets would provide an initial market demand for AFVs in 1998, helping to ease manufacturers toward production mandates three years later.

However, except for the ZEV mandate, it is presently unclear whether there will be much transformation of the general market once the fleet requirements are satisfied. Vehicles using very low sulfur reformulated gasoline are expected to meet the ULEV standards, as recently demonstrated by Honda in a version of the Accord. As a result of such progress in gasoline vehicle emissions

Table 3. Market Transformation Programs for Alternatively Fueled Vehicles	
Technology Push	**Technology Pull**
Research, Development, and Demonstration (RD&D) Federal and State programs Gas and Electric industry programs	Performance Standards Clean Air Act requirements California LEV program
Manufacturer Incentives CAFE credits	Strategic Procurement EPACT government purchases Various state fleet purchases
Manufacturer Requirements California Pilot Program ZEV mandate	Voluntary Commitments Clean Cities program
Technology-Based Economic Development CALSTART	Consumer Incentives EPACT incentives
	Marketing and Consumer Information Clean Cities program Various state and utility programs

control, the transition toward AFVs anticipated by the CAAA may be largely unnecessary beyond what is required by the ZEV mandate. Thus, there is a risk that some of the fleet efforts for AFVs could be a "dead-end," since the remaining clean air incentives are not sufficiently compelling to extend AFVs into the general market.

The vehicle provisions of EPACT (1992) strictly specify non-petroleum alternative fuels and are intended to "stimulate the development of alternative fuel vehicles that could be used in the general vehicle fleet, while encouraging the establishment of a fuel distribution infrastructure that will make alternative fuels available to the general public" (Stuntz 1991). Affecting approximately twice as many fleets as the CAAA, EPACT uses fleet mandates to attempt a more definite market transformation to AFVs. In addition to establishing a robust initial demand, the Federal program to create a market for AFVs relies on early Federal acquisition of AFVs beginning in 1993 to demonstrate their feasibility. DOE's Clean Cities program is intended to coordinate bulk purchases, provide legitimacy and generate publicity to enhance EPACT's measures to create an initial AFV market (Federal Fleet Conversion Task Force 1993). The Federal government has also sponsored AFV demonstrations under the authority of the Alternative Motor Fuels Act (AMFA 1988).

Unlike the CAAA (1990), however, EPACT (1992) does not include supply-side requirements to bring AFVs to market, although it does provide AFV incentives. It is expected that manufacturers would respond by "gradually shifting light duty vehicle production to fuel flexible or dual-fueled vehicles" (Stuntz 1991). By 2010, these vehicles are expected to displace 2 Mbd oil per day, 9.5% of projected 2010 consumption. This displacement implies AFV market penetration of at least one-fifth of the vehicle stock by 2010 and probably much higher since flexible and dual fuel vehicles will not always run on alternative fuels. Sales would need to ramp up to at least 20% in 2010, potentially much higher if significant levels are not achieved earlier. For this market transformation scenario to play out, alternative fuels must be substantially cheaper than gasoline and be sufficiently available. Also, either AFV technology costs must compete with gasoline vehicles or extensive subsidies must be maintained to offset incremental AFV costs relative to conventional gasoline vehicles. EPACT provides a set of subsidies for both AFV incremental costs and for alternative fuel supply infrastructure (EIA 1994c, U.S. Senate 1992).

Possible Elements of a Green Machine Challenge

A comprehensive strategy to transform the light vehicle market toward higher fuel efficiency would involve most elements of Table 2, including measures targeting both the supply and demand sides of the market. Support for research and development can help push new technologies, but absent sufficient market pull, technology development alone is unlikely to be sufficient to ensure extensive use in the marketplace. The rapid improvement of light vehicle fuel economy between 1973 and 1987 and the subsequent maintenance of the achieved new fleet average fuel economy in spite of increases in average vehicle weight and performance indicate that regulatory standards are an effective policy for assuring applications of efficiency improving technologies. This assessment is confirmed by statistical analysis (Greene 1990b). Given the success of CAFE standards, it might be argued that strengthened standards are sufficient. However, other considerations suggest that it might be desirable to complement standards with other measures. It is politically difficult to raise the standards when the availability of cost-effective, efficiency-improving design changes are disputed by manufacturers. Also, the standard-setting process is limited in the extent to which it can assume the use of technologies not yet fully demonstrated, for which reliable cost information is unavailable. (Cost data are needed to evaluate the "economic practicality" considerations that must be addressed when setting regulatory standards.) Finally, if the efficiency levels involve leap-forward technologies, such as those foreseen in the PNGV, market risks are greater, resulting in a cost "hump" that acts as a barrier to initial commercialization.

A market creation program for vehicles having greatly improved efficiency can help overcome such barriers and lay the groundwork for more broadly-based market incentives. This is the role played by the "Golden Carrot" programs for refrigerators and other electricity end-use equipment. The EPACT (1992) fleet requirements play a similar role for AFVs. A notable difference between the Super-Efficient Refrigerator Program and the EPACT AFV incentives is that the refrigerator program included an "on-books" cash prize for a winning design judged according to specified performance criteria. Some combination of similar mechanisms could be used in a Green Machine Challenge. A key element in the refrigerator "Golden Carrot" was that the program was carefully designed to illicit a response from the manufacturers that substantially advanced the technology. Goals must be ambitious enough to pull technology, but not so high that manufacturers find them unrealistic, which would result in a failure to respond to the challenge.

Potential elements of a Green Machine Challenge can be examined within the framework of the generic market transformation tools of Table 2. A program could involve market push in the form of manufacturer incentives, perhaps including lump-sum cash awards. Market pull elements could involve coordinated procurement, consumer incentives, consumer information, advertising, and other forms of publicity. Coordinated bulk purchases of vehicles would help to assure large enough initial markets to bring down per unit costs and to encourage manufacturers to commercialize market ready technologies. Manufacturer incentives or consumer rebates would strengthen this incentive. Finally, publicity generated by the program could stimulate consumer interest and create an increased incentive for manufacturers to achieve the Challenge goals. As is the case for any policy option, successful implementation depends on details which influence the effectiveness, cost, equity, and side-effects of the program.

Examining the general principles of market transformation and the examples of programs already underway for AFVs allows us to sketch some ideas about designing a market creation program for ultra-efficient vehicles. Table 4 lists the types of mechanisms that could be used for a Green Machine Challenge and briefly identifies the options and some questions that need to be answered. Some of the issues are cross-cutting, since the supply (manufacturer) and demand (consumer) sides of the market are mutually influencing. Thus, developing a program containing only market pull (demand-side) elements would still involve consideration of the supply-side issues, particularly the overarching issue of what production volume must be targeted to insure creation of a market that remains viable after the program runs its course. The objectives of this paper are limited to raising the issues, so a full elaboration of the questions arising in Table 4 is not attempted. However, we can report on preliminary thinking and analysis about a few of the likely elements of a Green Machine Challenge program.

Public and private fleets become a focus of market creation efforts because multiple purchases can be addressed through a single point of contact. Initial interviews were conducted with fleet managers to learn their reactions to participation in a voluntary "challenge" program. Our initial results and the questioning approach are included in the appendix; full findings will be presented in the project report which will follow this concept paper. We selected a mix of fleets which included a variety of sizes, purposes and both public and private ownership. We also spoke with leasing companies, car rental companies and representatives of the fleet managers' trade association. In addition, we drew on survey work on the role of fuel economy in public fleet managers' purchase decisions (Skinner and Cohen 1994).

Although reactions were mixed, managers of larger fleets (both public and private) were generally interested in promoting efficiency improvements. Several indicated that they would be conditionally interested in participating in a Green Machine Challenge. Some municipal fleets were open to developing a letter of commitment for future purchase of efficient vehicles meeting certain specifications; others indicated that their budgeting process would not allow such future commitments. A number of views were expressed about the current AFV efforts, including an apparent lack of coordination among various government programs and sometimes even within programs of a given agency. The variety of governmental programs having different goals provides an opening for fuel suppliers to use program provisions favorable to their interests as an opportunity to pressure fleet operators to "hook up" when the achievement of broader public goals is unclear. Fleet operators tend to be positive about market aggregation, but want to be sure that such a program would be large enough to make a difference in terms of cost savings and quality assurance. Fleet association representatives were more comfortable with approaches that set performance criteria which had to be

Table 4. Potential Elements of a Green Machine Challenge

Manufacturer Incentives

Competition -- What type of award; what volume of production should be rewarded; what time frame should be allowed; should there be multiple winners or let one "winner take all."
Rebates -- How large; should they be limited to a certain number of vehicles; how can they be financed; how should vehicle origin (domestic vs. import) concerns be addressed.
Regulatory incentives -- Extra CAFE credits or emissions credits.

Strategic (mandatory) Procurement

Government fleet purchases -- What volume of purchases is needed; how many potential purchases are left after EPACT AFV commitments and how to coordinate with AFV programs.
Private fleet purchases -- Are mandatory requirements appropriate in this case; what number is reasonable; can there be credits toward EPACT requirements.

Voluntary Purchase Commitments

Governments, private fleets, individuals -- How can commitments be coordinated; what level of up-front commitment is meaningful; technical and warranty support.

Consumer Incentives

Rebates or tax incentives -- How large; how can they be financed; how long should they stay in effect.
Special use privileges, etc. -- Are special parking or roadway access privileges useful; what conflicts arise with other policy objectives; is special warranty or maintenance support needed.

Marketing and Consumer Information

What should be the extent of public sector marketing vs. manufacturer marketing efforts.

met by vehicle suppliers, such as those specified by the South Coast Air Quality Management District. Generally, there was sense that fleet operators were happy to do their fair share of the effort to transform the vehicle market, but wished to be convinced that a program will lead to change in the overall vehicle market; fleet operators are not comfortable with programs that begin and end with fleets.

A promotional program for ultra-efficient vehicles can complement efforts to ultimately switch to alternative fuels, since efficiency improvements will be necessary for consumer acceptance of AFVs. Many efficiency improvements are equally applicable to AFVs and petroleum-fueled vehicles (Bleviss 1989; DeCicco 1992). As noted earlier, efficiency improvements are essential for AFVs to have range comparable with conventional petroleum fueled vehicles without sacrificing interior volume to fuel storage. A potential point of conflict between a coordinated procurement program for ultra-efficient vehicles and AFV programs is that many fleet vehicles will be covered by the EPACT requirements by 2001. Fleet operators may be hesitant to participate in a program if they are already attempting to comply with AFV mandates. At least two potential resolutions of this potential conflict merit further investigation. First, the Challenge may need to include separate AFV specifications. Participants could specify that they were committing to purchase ultra-efficient AFVs only. Alternatively, ultra-efficient gasoline vehicles could be allowed to earn credits toward EPACT compliance for comparable amounts of petroleum displacement. Such a measure would require legislative approval. Identifying other ways to insure that an efficient vehicle program is coordinated with and complementary to existing AFV programs will be addressed in the subsequent phase of this study.

The need for several years of lead time before vehicles of substantially improved efficiency can be put into production poses a dilemma for advanced vehicle market creation programs. A fairly large pool of potential buyers would have to be established in order to motivate manufacturers to invest in a new, more efficient design, but then the buyers would have to wait several years before the vehicles become available. Thus, the situation for improved efficiency is different than that for most alternative fuels (other than electricity). Alternative combustion fuel use need not require fundamental changes in vehicle design; many AFVs are obtained by aftermarket conversions of gasoline vehicles. Such conversion is even done for electric vehicles, but with a high cost and a performance compromise. Optimized AFV designs would require more lead time. However, except in the case of electric vehicles, for which the strategy includes the California ZEV mandate, it is unclear whether current AFV market transformation strategies are sufficient to bring into production designs which are optimized to the extent of today's gasoline vehicles.

A way out of this dilemma might be a staged design for the Challenge, so that it initially involves modest efficiency improvements. Subsequent stages could progressively raise the expected level of technology improvement by requiring a substantial "step-forward" in efficiency. A range of estimates are available about what might constitute such a step based on conventional vehicle technology refinements (Greene and Duleep 1993; DeCicco and Ross 1994). Over a longer time frame, the stages could ultimately lead to a "leap-forward" level, such as the tripled fuel economy targeted by the PNGV. This approach is consistent with an evolutionary paradigm for new vehicle technology development, in contrast to a more discontinuous, breakthrough-premised paradigm. The timing of stages is suggested by the typical ownership period of new vehicles, 4-5 years, which is similar to the time needed for design and tooling-up of new vehicle production.

One way to engage potential participants in the near-term would be agreements for purchases of vehicles currently available that are among the most efficient in their class. Examples of such "Best-in-Class" levels were estimated by Murrell et al. (1993), and range up to 25% more fuel efficient (best dozen in weight class relative to an average 1993 passenger car). Such purchases would provide immediate energy savings and emissions reduction benefits. The efficiency improvements realized in Best-in-Class vehicles would be necessarily modest compared to likely targets for ultra-efficient vehicles, but could induce manufacturers to market modest design refinements which would also be

applicable in more highly evolved efficient vehicles. Thus, a Best-in-Class component in a Green Machine Challenge would enable more widespread program participation and provide opportunities for interested buyers to participate during interim years, before the first stage of "step-forward" efficient vehicles became available.

FURTHER ANALYSIS NEEDS

This paper has discussed the policy context and a conceptual framework for developing a market creation program for ultra-efficient vehicles in the United States. Such a "Green Machine Challenge" could aid the commercialization of new technologies such as those being researched and developed by the PNGV. A possible structure for such a program was noted, but further analysis and elaboration is needed in order to more thoroughly examine the need for and feasibility of a Green Machine Challenge, identify workable program designs and options for implementation, and estimate program costs, benefits, and impacts. More specifically, the following is a list of issues to be addressed and methodologies to be used in the next phase of study:

Further analysis of the need for market-pull policies to complement the PNGV. This question will be addressed by analyzing light duty vehicle market trends, reviewing projections of market evolution and assessing market barriers to commercialization of new technology. A review will be undertaken of analogous work on barriers to equipment manufacturers' incorporation of energy-saving technologies in the buildings and industrial sectors; such studies provide a rationale for the range of technology transformation policies being pursued to achieve efficiency improvements in those sectors. Further study is needed regarding the non-technological barriers to fully commercializing efficient technologies in light-duty vehicles. Identifying these barriers would help in determining how a market creation program for ultra-efficient vehicles should be designed. Available consumer survey data, studies of manufacturer product planning, and econometric analyses of vehicle choice will be reviewed to better characterize these potential barriers. A baseline scenario will be developed to estimate likely rates of new technology penetration assuming that PNGV-derived technologies become available at the prototype stage but that there are no other new policies to provide market incentives for greater vehicle efficiency. A standard stock model will be used to estimate the energy and greenhouse gas emissions impacts of the scenario.

Assess potential target markets for a Green Machine Challenge. This analysis would involve reviewing primary sources reporting fleet composition and studies of vehicle fleets such as those done in support of alternative fuels programs; compiling results from surveys and studies of the needs of fleet purchasers and other possible participants in an advanced vehicle procurement program. Conduct a limited, exploratory survey of fleet managers regarding vehicle needs, purchase considerations, and their reaction to ultra-efficient vehicle purchasing; work through fleet manager associations and existing fleet vehicle market aggregation programs. As noted above, initial conversations with several fleet managers indicate that a number of barriers will need to be overcome. A goal of further investigations would be to determine if enough interest exists among fleet managers to drive a voluntary procurement program and to determine exactly what sort of fleets (size, location, vehicle uses, type of business, etc.) should be targeted for participation. Also, a review of vehicle market research will help determine the possible extent of individual consumer participation in a Challenge, with and without additional financial incentives.

Estimate technology availability. In order to identify technology targets for vehicles targeted by a challenge, there will need to be a literature review examining research and development program goals as well as the current status of available efficient vehicle technologies, near-commercial technologies, and technologies under development. This would involve studying program documents and reports on PNGV efforts and obtain updates from individuals involved in the PNGV from both government and industry. This analysis would also involve compiling information on relevant technology and vehicle prototypes; synthesizing the information to determine intermediate technology levels leading toward long-term goals; and estimating potential timetables for market availability of efficient technologies and applicability by vehicle class.

Assess interactions with and coordination with other policies affecting light duty vehicles. This analysis would involve reviewing studies of the impacts and limitations of other policies related to vehicle efficiency, both existing and under consideration, including fuel economy regulations, market incentives such as feebates, and fuel tax increases. One or two scenarios involving such policies would be developed as alternative baselines with which to compare the impacts of a Green Machine Challenge. Interactions with other vehicle policies must also be carefully examined, especially those relating to emissions control and alternative fuels. This analysis would involve reviewing the current and projected scope of participation in alternative fuel vehicle procurement and incentive programs; identifying areas of overlap and potential conflict or synergism with potential advanced vehicle program participants. Results of this analysis should include suggestions for coordination with alternative fuel vehicle programs. Planned Federal and state programs addressing vehicle emissions and safety should also be reviewed, so that an assessment can be made of the feasibility of such vehicle improvements while simultaneously pursuing substantial increases in efficiency; these results should be factored into targets for the market creation program.

Identify preliminary vehicle specifications. This analysis would examine market trends and the vehicle needs of potential buyers, in order to select the car and light truck classes on which a market creation program should focus, and then identify efficiency targets, which might be staged, for each class. These classes should be prioritized by weighing their significance in the overall light duty market (the ultimate object of market transformation efforts) against the considerations of technology applicability and relevance for the initial target markets. Efficiency specifications for each class must be high enough to require a true technology advance, but not so high that manufacturers do not respond to the challenge. An analysis of achievable efficiency levels is necessary to determine MPG targets. The methodology for this analysis would have several parts: first, a best-in-class analysis to determine the range of available improvements; next, an investigation of near-commercial technologies and technologies under development to determine initial step-forward MPG targets; and finally, drawing on the aforementioned review of PNGV efforts and prototypes to estimate the availability of more advanced technology levels.

Develop program design recommendations. Finally, the next phase of the study will identify one or more possible structures for a Green Machine Challenge, choosing a combination of program elements most likely to be effective and suggesting their scope, timing and duration, and means of coordination with other vehicle policies. An analysis of auto industry product development and production investment decision-making will help determine program elements that will generate a response. Relevant points for investigation include the number of vehicles a Challenge should include, the number of years purchases should be spread over and whether or not commercialization or consumer incentives are necessary. There should be a discussion of the type of organization that could manage the market creation program, considering, for example, the need for an advisory board composed of

representatives of public fleets, private fleets, government agencies, environmental groups, and others. Other supporting analyses should also provide estimates of program costs and who would pay them; benefits (direct and indirect/social); relation to other public policy goals (energy security, air quality, climate, job creation).

In summary, given the history of successful market transformations for light vehicles between 1973 and the present, as well as the successful market pull programs in several other product markets, a Green Machine Challenge is a promising mechanism for establishing initial markets for both incrementally more efficient vehicles and next-generation, ultra-efficient vehicles. Further efforts in the next phase of this study will provide a more complete assessment of the feasibility, costs, and impacts of such a program and develop more specific recommendations for designing a Green Machine Challenge.

APPENDIX: Information Sources and Preliminary Findings on Vehicle Fleets

The information gathering approach being used in this study will rely primarily on a review of existing reports and press covering vehicle fleets, particularly regarding various alternative fuels programs now underway. The trade periodicals Automotive Fleet and the North American Fleet Association's (NAFA) Fleet Executive and a 1992 Oak Ridge National Lab (ORNL) report provide good background on fleet characteristics. An EPA docket (A-91-25 and IV-B-01) was opened in preparation of rulemaking for the Clean Fleets provisions of the CAAA(1990) (56 Federal Register 50196). Two Federal reports, "Alternatives to Traditional Transportation Fuels" (EIA 1994c) and GSA's Federal Motor Vehicle Report (GSA 1991) provide information on AFVs acquired to date by fleets. These sources, however, are inadequate for determining the likelihood that fleets would participate in a voluntary coordinated procurement program.

We conducted a limited survey of public and private fleet managers. In addition, we drew on research by the International Council for Local Environmental Initiatives (Skinner and Cohen 1994) and spoke with U.S. EPA staff who had worked with fleets in conjunction with the Clean Fuel Fleets program, DOE staff who had dealt with fleets through the Clean Cities program, and staff at the NAFA. The questions used when interviewing fleet managers and Some of our early findings are given below. A more thorough survey is necessary to determine the feasibility and likely participants in a challenge program. We contacted fleet staff from the following organizations: API Security, Culver City, CA; Arlington County, VA; Fairfax County, VA; Federal Express; King County, WA; Lease Plan International, Atlanta, GA; State of New Jersey; New York Port Authority; Oklahoma City, OK; San Antonio, TX; and Sprint Long Distance Services.

Questions used to guide interviews of fleet managers

We have started to develop a sample set of questions for eliciting fleet managers' reactions to requests for voluntary participation in a Green Machine Challenge. We hope to get a sense of whether they would participate in such a program and what commitments they might be willing to make. Here is the telephone interview pattern developed from our initial survey work:

The program that we are developing aims to encourage the auto manufacturers to bring to market vehicles of greatly improved fuel-economy. I'm interested in the role that fuel economy plays in fleet procurement decisions. How would you characterize the role that fuel economy plays in your procurement decisions?

What factors are more important?

Potential follow-ups: Many models have more powerful versions which have lower fuel economy ratings than the base model, for example, 6 vs. 8 cylinders available in the Chrysler LH series. When purchasing a particular model, do you sometimes purchase the more powerful, less-fuel efficient model?

If vehicles equivalent in size, reliability, warranty and safety to the current vehicles you procure but much more fuel-efficient were made available on the market, how likely would you be to procure these more-efficient vehicles?

How much more fuel efficient would they have to be to affect your decision? 5%? 10%?

If at all likely, Would you be willing to pay somewhat more for such vehicles?

How much more?

If unlikely, Why not?

Because fuel efficiency plays a relatively minor role in peoples' choice of which vehicle to buy, it is not certain that auto makers will make the investments needed to actually bring very fuel-efficient vehicles to market even if they are technically feasible.

One way to convey to manufacturers that producing a more efficient vehicle would be worthwhile is by combining the influence of vehicle buyers who are interested in more efficient vehicles. These vehicle buyers would issue a challenge to the manufacturers--something along the lines of, "if you build a vehicle which meets a predetermined set of specifications and gets triple today's fuel economy, we will pledge to buy 'X' number of such vehicles as long as its cost is within certain parameters."

Do you think that you might be participate in such a voluntary program?

If no: Why not?

Do you think that other fleet managers might be interested in such a program?

Is your fleet likely to be affected by government requirements that certain fleets acquire alternative-fuel vehicles?

If yes: Have you started to acquire AFVs?

If yes: How would you characterize your experience with AFVs?

Do you know the average fuel economy of your current fleet?

Do you keep track of how much fuel they are using?

Do you expect your costs to go up or down when using AFVs?

Thanks. I really appreciate your help.

Could you refer me to any other fleet managers in order to ask them the same sort of questions?

Preliminary results from initial contacts

1. Larger fleets (over 50 vehicles) are more likely to include fuel economy in purchase decisions than smaller fleets. In general, they use some form of life-cycle costing and are less likely to let manufacturer or dealer loyalty affect their purchase or lease decision.

2. Several public fleet managers were concerned that a challenge could result in single- source RFPs.

3. A concern for several fleet mangers, especially private fleets, was committing to capital expenditures several years in advance when they are unsure of what their needs will be in that year.

4. Public managers were more comfortable with the idea of coordinated procurement to affect production than private managers. This may be because they are more likely to have already begun to acquire AFVs.

5. Leasing companies may be an excellent source of information on fleet managers' preferences. They deal with a variety of fleet types. In general, leasing companies buy vehicles for a client after the client has chosen which vehicles it wishes to lease. Manufacturers's sales efforts are targeted at lessees, not the leasing companies. NAFA should be another good source.

6. The two rental car companies contacted refused to answer any questions citing competitive pressures. The only information gleaned was that the mix of vehicles they purchase for any one store depends upon local conditions. Since rental car companies do not incur fuel costs, they may not be likely candidates for participation.

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