Title
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Although the Bush plan for a new generation of vehicles has merit, more will be needed to accelerate commercialization.

On January 9, 2002, Department of Energy (DOE) Secretary Spencer Abraham announced a new public-private cooperative research program with the three major domestic automakers. According to a press release, the program would " promote the development of hydrogen as a primary fuel for cars and trucks, as part of our effort to reduce American dependence on foreign oil … [and] … fund research into advanced, efficient fuel cell technology, which uses hydrogen to power automobiles." Called FreedomCAR (with CAR standing for cooperative automotive research), the program replaces the Partnership for a New Generation of Vehicles (PNGV), which was launched by the Clinton administration with great fanfare in 1993.

The reaction to FreedomCAR, as reflected in press headlines, was largely skeptical. "Fuelish Decision," said the *Boston Globe*. "Fuel Cell Fantasy," stated the *San Francisco Chronicle*. A *Wall Street Journal* editorial asserted that fuel cells were expensive baubles that wouldn't be plausible without vast subsidies. *Automotive News*, the main automotive trade magazine, expressed caution, stating that, "FreedomCAR needs firm milestones… Otherwise it will be little more than a transparent political sham."

DOE has since released a tentative set of proposed performance goals for vehicle subsystems and components, which were immediately endorsed by the three automakers. Nonetheless, skepticism about the program continues, which is not surprising given the Bush administration's ambivalence toward energy conservation and tighter fuel economy standards. Yet viewed strictly as an updating of PNGV, FreedomCAR is a fruitful redirection of federal R&D policy and a positive, albeit first step toward the hydrogen economy. However, for FreedomCAR to become an effective partnership and succeed in accelerating the commercialization of socially beneficial advanced technology, additional steps will need to be taken.

What was PNGV?

The goal of PNGV was to develop vehicles with triple the fuel economy of current vehicles [to about 80 miles per gallon (mpg) for a family sedan], while still

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meeting safety and emission requirements and not increasing cost. It was in part an attempt to ease the historical tensions arising from the adversarial regulatory relationship between the automotive industry and federal government. It would "replace lawyers with engineers" and focus on technology rather than regulation to improve fuel economy. It also reflected the government's recognition that the nation's low fuel prices resulted in an absence of market forces needed to "pull" fuel-efficient technology into the marketplace. As the technical head of the government's side of the partnership said in a 1998 Rand report: "It is fair to say that the primary motivation of the industry was to avoid federally mandated fuel efficiency and emissions standards."

PNGV was managed by an elaborate federation of committees from the three car companies and seven federal agencies. The government's initial role was to identify key technology projects already being supported by one of the participating agencies. Industry teams determined which projects would be useful and whether additional or new research was needed. Throughout the process, technical decisions were made by industry engineers in collaboration with government scientists.

PNGV was high-profile. It engaged leaders at the highest levels and was championed by Vice President Gore. It was also subjected to extraordinary scrutiny, with a standing National Research Council (NRC) committee conducting detailed annual reviews.

The lofty rhetoric about and intense interest in PNGV did not, however, result in increased federal funding of advanced vehicle R&D. PNGV's budget has always been controversial, with critics dubbing it "corporate welfare." The ambitious program was realized by moving existing federal programs and funds under the PNGV umbrella. Funding for the PNGV partnership remained relatively steady at about $130 million to $150 million per year (or $220 million to $280 million if a variety of related federal programs not directly tied to PNGV goals are included).

From the start, the corporate welfare criticism was largely unfounded and became less so over time. Initially, about one-third of PNGV funding went to the automakers. That was largely carried over from already existing programs, and most of it was passed through to suppliers and other contractors. In any case, the amount steadily dropped to less than 1 percent by 2001. Although definitive data are not available, in the latter years of the program, more than half of the funding went to the national energy labs, and most of the rest went to a variety of government contractors, automotive suppliers, and nonautomotive technology companies, with universities receiving well under 5 percent. The automakers also provided substantial matching funds, though a major portion of this spending was in proprietary product programs.

The relevant issue with regard to automakers should not have been corporate welfare but how the research was prioritized and funds were spent. The three automakers played a central role for several reasons: As the final vehicle assembler and ultimate technology user, they had the best insight and judgment about research priorities, the greater expertise and staff resources to assess development priorities to meet consumer preferences, and the ability and resources to lobby Congress on behalf of the PNGV program.

Another issue with PNGV was the use of a specific product as the goal. In general, it is wise to direct a program's activities toward a specific tangible goal, and a prototype often fulfills that role. But in the case of PNGV, the goal for 2004 of building an 80-mpg production prototype that would cost no more to build than a conventional car was flawed. One problem is that government and industry managers were so focused on meeting the affordability goal that they felt obligated to pick technology— small advanced diesel engines combined with electric power trains—that was similar to existing technology and not the most promising in terms of societal benefits. Diesel engines have inherently high air pollutant emissions, and it is unknown whether they can meet U.S. environmental standards. In addition, neither advanced diesel nor hybrid electric engines are longer-term technologies. Honda and Toyota are already commercializing early versions of these technologies: Toyota began selling hybrid electric cars in Japan in 1997, and both Toyota and Honda began selling them in the United States in 2000. More fundamentally, as the final NRC committee review of the program so succinctly stated, "It is inappropriate to include the process of building production prototypes in a precompetitive, cooperative industry-government program. The timing and construction of such a vehicle is too intimately tied to the proprietary aspects of each company's core business to have this work scheduled and conducted as part of a joint, public activity."

Even the interim goal of hand-built concept prototypes by 2001 was questionable. Indeed, the goal of public-private partnerships with automakers should not be prototype vehicles. Automakers have garages full of innovative prototypes. What is needed is accelerated commercialization of socially beneficial technology.

Still, in some ways, PNGV was a success. Milestones were achieved on schedule; communication between industry and government reportedly improved; new technologies were developed, and some were used to improve the efficiency of conventional vehicle subsystems and components; the program disciplined federal advanced technology R&D efforts; scientific and technological know-how was transferred from the national labs; and apprehensive foreign competitors responded to the program with aggressive efforts of their own, which in turn sparked an acceleration of the U.S. efforts.

From a societal perspective, this boomerang effect may have been most important, because the foreign automakers feared that this partnership between the richest country and three of the largest automakers in the world would create the technology that would dominate in the future. New alliances (the European Car of Tomorrow Task Force and the Japan Clean Air Program) were formed. Toyota and Honda accelerated the commercialization of hybrid electric cars. Daimler Benz launched an aggressive fuel cell program. Ford reacted in turn by buying into the Daimler-Ballard fuel cell alliance and announcing plans to market hybrid electric vehicles in 2003. General Motors followed by dramatically expanding its internal fuel cell program, creating technology partnerships with Toyota, and buying into a number of small hydrogen and fuel cell companies. Struggling Chrysler, with its minimal advanced R&D capability, merged with Daimler Benz.

Energy companies must be brought into the partnership, because of their key role in the transition to fuel cell vehicles.

Why fuel cells and hydrogen?

Fuel cells provide the potential for far greater energy and environmental benefits than diesel-electric hybrids. Hydrogen fuel cell vehicles emit no air pollutants or greenhouse gases and would likely be more than twice as energy-efficient as internal combustion engine vehicles. When hydrogen is made from natural gas, as most of it will be for the foreseeable future, air pollution and greenhouse gases are generated at the conversion site (a fuel station or large, remote, centralized fuel-processing plant), but in amounts far less than those produced by comparable internal combustion engine vehicles.

Fuel cell vehicles are close to commercialization, but no major company has initiated mass production. In 1997, Daimler Benz announced that it would produce more than 100,000 fuel cell vehicles per year by 2004, and other automakers chimed in with similar forecasts. That initial enthusiasm quickly waned. Now, in 2002, several companies plan to place up to 100 fuel cell buses in commercial service around the world by the end of 2003 (none in the United States); Toyota has announced plans to sell fuel cell cars in Japan for $75,000, also in 2003, as has Honda; and a variety of automakers plan to place hundreds of fuel cell cars in test fleets in the United States, mostly in California, in that same time frame. The new conventional wisdom is that by 2010, fuel cell vehicles will progress to where hybrid electric cars are today, selling 1,000 to 2,000 per month in the United States, and that sales in the hundreds of thousands would begin two to three years later.

Two energy scenarios released in the fall of 2001 by Shell International suggest the wide range of possible futures. In one scenario, Shell posited that 50 percent of new vehicles would be powered by fuel cells in 2025 in the industrialized countries. In the second scenario, hybrid electric and internal combustion vehicles would dominate, with fuel cells limited to market niches.

Three key factors are slowing commercialization: low fuel prices, uncertainty over fuel choice, and the time and resources needed to reduce costs. Costs are expected to drop close to those of internal combustion engines eventually, but considerable R&D and engineering is still needed. Current fuel cell system designs are far from optimal. Consider that internal combustion engines, even after a century of intense development, are still receiving a large amount of research support to improve their efficiency, performance, and emissions (far more, even now, than is being invested in fuel cell development). Fuel cells are at the very bottom of the learning curve.

The fuel issue may be more problematic. Hydrogen is technically and environmentally the best choice, but it will take time and money to build a fuel supply system. Investments in hydrogen and hydrogen fuel cell vehicles by energy suppliers and automakers are slowed by the chicken-and-egg dilemma. Alternatively, methanol, gasoline, or gasoline-like fuels can be used, simplifying the fuel supply challenge, but the cost, complexity, energy, and environmental performance of vehicles would be degraded. As late as mid-2001, the conventional wisdom in industry was that gasoline or gasoline-like fuels would be used initially, followed later by hydrogen. Now, in the wake of the FreedomCAR announcement, a direct transition to hydrogen is gaining appeal.

More R&D funding must go to universities to train the engineers and scientists who will design future generations of vehicles.

Is FreedomCAR good policy?

Although FreedomCAR is an overdue corrective action, it is hardly a major departure. For one thing, fuel cell R&D was already gaining a greater share of PNGV funding (from about 15 percent of the DOE PNGV funds in the mid-1990s to about 30 percent in 2001), as automakers increasingly kept their knowledge about hybrid vehicle technology proprietary. Moreover, it appears that no major overhaul will take place as PNGV is turned into FreedomCAR. The program structure and the management team will remain essentially the same. Funding for fuel cell research will be increased slightly and funding for internal combustion engine research decreased slightly. The plan to produce production prototypes in 2004 has been abandoned.

Perhaps of greater concern is automaker reluctance to expand industry engagement to energy companies. This will likely limit the overall effectiveness of the program, because uncertainty about hydrogen supply and distribution is arguably the single biggest factor slowing the transition to fuel cell vehicles. Other automakers, including the Japanese, should also be engaged, because they also are ultimate users of the technology. But perhaps the best use of limited government R&D funds may be to target 1) small innovative technology companies and larger technology companies that are not already major automotive suppliers; and 2) universities, because of their expertise in basic research, but equally because they will train the industry engineers and scientists who will design and build these vehicles in the future.

Finally, FreedomCAR does nothing, at least in the short run, to deal with the issues of fuel consumption and emissions. Fuel cell vehicles are not likely to gain significant sales before 2010, and perhaps even later. Given the reality of slow vehicle turnover, this means that fuel cells would not begin to make a dent in fuel consumption until at least 2015. Thus, if oil consumption and carbon dioxide emissions are to be restrained, more immediate policy action will be needed. If little or nothing is done in these areas, the Bush administration will continue to face the justifiable criticism that FreedomCAR is a means of short-circuiting the strengthening of the corporate average fuel economy standards.

Government's role

Fuel cells and hydrogen show huge promise. They may indeed prove to be the Holy Grail, eventually taking vehicles out of the environmental equation, as industry insiders like to say. In a narrow programmatic sense, FreedomCAR is unequivocally positive as an updating and refashioning of the existing R&D partnerships and programs. Still, for a variety of reasons, including low fuel prices, industry still does not have a strong enough incentive to invest in the development and commercialization of this advanced, socially beneficial technology. Government will continue to have an important role to play.

The recommendations set forth below are premised on the understanding that government R&D is most effective when it targets technologies that are far from commercialization and have potentially large societal benefits, when funding is directed at more basic research, when the relevant industries are fragmented and have low R&D budgets; and when there is some mechanism or process for facilitating the conversion of basic research into commercial products. A strategy to promote sustainable cars and fuels must contain the following elements:

Advanced vehicle research, development, and education

- Basic research directed at universities and national labs, especially focused on materials research and key subsystem technologies that will also have application to a wide range of other electric-drive vehicle technologies.
- Leveraged funding of innovative technology companies.
- Funding to universities to begin training the necessary cohort of engineers and scientists. This might merit creation of a second FreedomEDUCATION partnership (building on DOE's small Graduate Automotive Technology Education centers program).

Hydrogen distribution

- Assistance in creating a hydrogen fuel distribution system (with respect to safety rules, initial fuel stations, standardization protocol, pipeline rules, and so forth), requiring some R&D funding but in more of a facilitating role.
- Funding to assist the development and demonstration of key technologies, such as solid hydrogen storage, and demonstration of distributed hydrogen concepts, such as electrolysis and vehicle-to-grid connections.

This activity might merit a third FreedomFUEL partnership.

Incentives and regulation

- Incentives and rules that direct automakers and energy suppliers toward cleaner, more efficient vehicles and fuels.
- Incentives to consumers to buy socially beneficial vehicles and fuels.

These three sets of strategies must all be pursued to ensure a successful and timely transition to socially beneficial vehicle and fuel technology. The last set of initiatives is particularly critical, not just to ensure a timely transition to fuel cells and hydrogen but also to accelerate the commercialization and adoption of already existing socially beneficial technologies, including hybrid electric vehicle technologies.