Fuel Cells and Hydrogen: The Path Forward

A Comprehensive Strategy For Federal Investment In Fuel Cell Technology And Fuel Infrastructure

January 2003

Author's Note

This document was developed to

- Provide a baseline of information for policy makers, companies and others interested in advancing the commercialization of fuel cells.
- Underscore the need for a coherent, multi-year commitment by the public sector.
- Give specific policy initiatives an overall programmatic context.
- Stimulate discussion, debate and, ultimately, enactment of a comprehensive fuel cell policy.

The document was compiled by Robert Rose of the Breakthrough Technologies Institute, Inc., in Washington, D.C., from internal sources and from the contributions of many individuals and companies in the fuel cell and hydrogen industry. No endorsements were implied by these contributions, but it is our hope that interested organizations will endorse this plan and use the outline to give context to their own policy goals.

The document owes a particular debt to an ad hoc coalition of fuel cell advocates from throughout North America. The group has been meeting since 2000 to share information and, where possible, coordinate members' activities.

More than 30 individuals reviewed drafts of the document. Any errors that remain are the responsibility of the author.

Copies of the full text of the report, along with background information and supporting materials, may be found at **www.fuelcellpath.org.**

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Introduction

This paper proposes a comprehensive national strategy to advance the commercialization of fuel cell technology through research and development, technology validation, early market support and infrastructure deployment. Full commercial status for fuel cells in vehicles and power generation is achievable only with the active and sustained support of government at all levels. The effort is justified by the unique combination of public benefits fuel cells offer: high efficiency, unparalleled environmental characteristics, enhanced energy security, improved reliability, and flexibility in installation, siting, operation and fuel choice.

Capturing these benefits for our society will require active public-private partnerships in all stages of development and demonstration and in preparing markets through financial incentives, infrastructure investment and removal of regulatory and economic barriers.

Fuel cells have been called the "microchip of the hydrogen age," the key to abundant energy from secure, renewable sources. There is a worldwide consensus on the strategic and economic importance of fuel cells, reflected in a dramatic increase in public and private investment since 1995.

- The Defense Department has identified fuel cells as a "critical technology" whose development is vital to the nation's long-term defense.

- Governments in Canada, Europe and Japan are investing heavily in fuel cell research, development and demonstration, providing market entry support and investing in fueling infrastructure for vehicles.

- Japan's fuel cell research program has tripled since 1995, reaching $220 million in 2002, a larger budget than the U.S. Department of Energy's for fuel cells.

- The European Commission provides up to $70 million per year to support fuel cell and hydrogen research and demonstration activities. This includes a 30-bus demonstration program in 10 major cities.

- Individual countries in Europe and Asia have programs focused on this industry. Germany and Britain are particularly aggressive in Europe. China has accelerated its development effort.

- Elsewhere, Iceland and Singapore, among others, are committed to the introduction of hydrogen and fuel cell powered products in the power generation and the transportation sectors.

- The World Bank is financing fuel cell bus demonstrations in five developing nations and is considering a parallel program for power generation.

In the United States, bipartisan support for fuel cells is also growing. President Bush has referred to fuel cells as the "wave of the future" and called for a "focused effort to bring fuel cells to market". Democratic leaders in Congress have issued a similar call.

Fuel cells are commercially available today in some markets, such as telecommunications and backup power systems, where their unique benefits bring special value, but in most cases these early products require government incentives to make them affordable. Full commercialization on an accelerated timetable will require collaboration between government and private industry, including a substantial public investment in research and development, demonstration and pilot programs, early commercial purchases, incentives for early adopters, and removal of market barriers. We believe, however, that the public investment in fuel cells need be no larger than traditional levels of support for other domestic energy technologies, and may be more cost effective. We have no doubt the public benefit will far outweigh the cost.

Perhaps the most encouraging evidence to date of the commercial potential of fuel cells is the enormous investment the private sector has committed to the technology since 1995. Estimates of annual spending range from $1 billion to $3 billion. Fuel cell employment worldwide may have reached 13,500. As a result, *the federal government need not shoulder the burden of commercialization alone.* There is a robust private effort already under way.

The U.S. government has been a major force in the progress of fuel cells toward commercialization. The NASA space program was the initial commercial use of fuel cells. A number of other federal agencies have funded initiatives consistent with their mission, including the Departments of Defense, Transportation, Commerce and Energy and the Environmental Protection Agency. DOD has been the single largest purchaser of fuel cell cogeneration units, and has supported private purchases most years since 1994. The tax code includes incentives for the purchase of fuel cell vehicles and infrastructure, and significant new tax incentives are pending in Congress.

Unfinished Agenda. A great deal more is needed if fuel cells are to achieve their commercial potential, and yield their benefit to society. This paper provides a guide to the agenda ahead.

Fuel cells are a family of technologies. Each one has unique technical issues and approaches to commercialization. A comprehensive national strategy for fuel cells should address the unique requirements of the portable, stationary and transportation markets and also take advantage of the common elements that can be identified among the various applications.

This undertaking will require careful consideration of shared infrastructure requirements, the design of research, development and demonstration (RD&D) efforts that offer generic benefits, and strategies that reflect the market entry sequence for the various fuel cell products. It will also require investment in advanced feedstock and hydrogen carrier fuels and in improving technologies to make, store and transport hydrogen.

Education, training and customer acceptance are an important part of the effort, beginning in schools and extending to vocational and professional education and to the public.

Program Summary

Federal support for fuel cells should concentrate on six areas.

Research and Development. Federal investment is vital in pre-competitive research in materials, low-cost manufacturing processes, testing and evaluation.

- R&D programs should complement and not duplicate private research efforts.
- Pathways toward fuel cell cost reduction and reliability improvements should have highest priority.
- Fuel infrastructure should be a high priority as well.
- Significant research is necessary in hydrogen production, storage and delivery.

Demonstration and Pilot Fleets. Fuel cells have been demonstrated in many applications and have achieved a level of commercial sales in small, high-value markets, generally with the benefit of government incentives. Technology validation is required in many important and untried applications.

- Pilot fleet testing – the next step for fuel cells in many key markets – needs to be encouraged, financed and evaluated.
- Commercialization is a process; federal support is valuable in each step of the process.

Purchases. The federal government should become an early adopter of fuel cells, choosing the technology to supply an increasing share of the enormous federal power requirements, and to make up an increasing share of its vehicle purchases.

- The special characteristics of fuel cells make them desirable products for defense and non-defense electricity generation, micro-applications, emergency response, and high-efficiency passenger and specialty vehicles.
- Government deployment of fuel cells lends invaluable credibility that stimulates public acceptance of the technology.

Market Entry Support. Federal programs are critical to helping move fuel cell products from their demonstration stage to commercial use.

- Market entry support programs should include financial support such as tax incentives for early purchasers, per-kilowatt production incentives such as the wind power purchase subsidy program, and expansion of the successful fuel cell "buy down" program for local, state and federal governments and tax-exempt entities.
- Market support also should include non-financial incentives and consistent, uniform treatment of fuel cell power and other advanced and renewable power generation technologies.

Removing Barriers to Commercialization. Fuel cell commercialization will require market preparation as well as market entry support.

- This includes uniform national and international interconnection standards, prompt development and adoption of supportive, harmonized codes, standards and recommended practices, uniform international codes, and education of code officials and state and local regulators.
- Government can also play a role in assuring non-discriminatory practices in siting and using fuel cell power plants and vehicles.

Education and Outreach. The fuel cell industry seeks a comprehensive, multi-year cooperative education program covering fuel cells and hydrogen.

- The program should include outreach to decision makers and interested individuals in related professions, communication to code officials and general public education.
- Education programs should target students at all levels.
- Mid-career education should include training for specify-build-install-repair professions and trades.

Cost. We propose an investment of approximately $5.5 billion over 10 years, with resources moving from research, development and demonstration and toward purchases and market entry support as development of the technology allows, recognizing that various fuel cell technologies are at different stages of development. This investment is well within the traditional range of federal support for energy technology development.

Recommended Federal Investment in Fuel Cell Development and Commercialization ($ Millions)

Program	10-year Total
Research and Development	$ 2,330
Demonstrations/Purchase	
Vehicle Demonstrations	$ 495
Purchases for Federal Buildings	$ 650
Other Purchases	$ 180
Market Entry Support	
Tax Incentives	$ 500
Buy-Down Program	$ 175
Investment in Infrastructure	$ 950
Removal of Barriers	$ 105
Public Education	$ 60
Subtotal	$ 5,445
Management	$ 105
Program Total	**$ 5,550**

Checklist Of Action Items For Policy Makers

Research And Development: *10 Years* -- $2.3 Billion

- ❑ Cost Reduction
- ❑ Durability
- ❑ Efficiency
- ❑ System Materials, Components And Integration
- ❑ Fuels, Fuel Quality And Fuel Processing
- ❑ Hydrogen Production, Distribution And Storage

Pilot Fleets And Purchases: *10 Years -- $1.3 Billion*

For Power Generation

- ❑ 200 MW By 2005
- ❑ 200 MW Annually 2006 And Beyond
- ❑ Plan For Using Fuel Cells In Federal (And Federally Subsidized) Buildings

For Vehicles

- ❑ *Phase 1, 2004-2007*
  - ➢ 500 Passenger Vehicles
  - ➢ 500 DOD Vehicles
  - ➢ 100 Transit Buses
  - ➢ 100 School Buses
  - ➢ 20 Fueling Stations Demonstrating A Range Of Fuels And Fueling Strategies

- ❑ *Phase II, 2008-2011*
  - ➢ 5,000 Passenger Vehicles Annually Or 50% Of Federal Civilian Fleet Purchases
  - ➢ DOD Target Set By Secretary Of Defense
  - ➢ 1,000 Transit Buses Or 50% Of Federally Subsidized Purchases Annually
  - ➢ Mobile Equipment And Specialty Vehicles, Target Set By Cabinet Secretaries
  - ➢ Additional Fueling Stations To Meet Needs Of The Program

For Portable Power

- ❑ 1 MW In 2003
- ❑ 5 MW In 2004
- ❑ 25 MW In 2005
- ❑ DOE-Set Goals Post 2005

Market Entry Support: 10 Years -- $675 Million

Tax Incentives

- *Passenger Vehicle Incentives*
  - $4,000 Credit For New Cars And Light Trucks.
  - Additional Credit Up To $4,000 Based On Vehicle Efficiency.

- *Passenger Trucks.*
  - Tax Credit For 50% Of Incremental Cost
  - Additional 50% Based On Emissions, Efficiency And Fuel Choice
    - Overall Per-Vehicle Cap

- *Heavy Trucks And Buses*
  - Capital Grant Program

- *Fuel Infrastructure*
  - Credit Of 50 Percent Of The Cost Of A Station Up To $150,000.
  - 50 Percent May Be Expensed In The Year Installed.
  - Fuel Tax Credit 2003 To 2012

- *Business And Residential Property*
  - Credit Of One-Third The Cost Up To $1,000 Per Kilowatt.

- *Combined Heat And Power.*
  - Additional 10% Tax Credit For A Residence, Business Or Commercial Property That Utilizes A Fuel Cell For Both Heat And Power.

- *Portable Power*
  - Credit Of One-Third The Cost Up To $1,000 per kilowatt, 2003-2007
  - For Business, 50 Percent Of Infrastructure Cost Expensed In Year Installed.

Buy-Down Program

- $1,000/Kilowatt To The Installer Of Fuel Cells
- $18 Million In FY 2004
- Peak At $35 Million In 2006

Non-Financial Incentives

- Fair And Uniform Treatment For Fuel Cell Power
- Emission Control And Trading Programs
- Zero-Sulfur Fuel
- DOD Product Standardization

Invest In Infrastructure: 10 Years -- $950 Million

- ❑ Multiple-Pathway Approach
- ❑ Regional Fuel Cell Vehicle Refueling Corridors
- ❑ "Power Parks"
- ❑ Demonstration Communities For Fuel Infrastructure
- ❑ Utilize Existing Or Extended Pipeline Corridors
- ❑ "Multiple Use" Installations Including Power Generation And Vehicle Fueling
- ❑ Hydrogen And Hydrogen Carrier Fuels Remain In The Mix

Remove Barriers: 8 Years -- $105 Million

- ❑ "Plug And Play" Interconnection
- ❑ Distribution System Modeling
- ❑ Uniform Codes, Standards And Regulations
- ❑ Assure Rights Of DG Installers
  - ➢ Right To System Information
  - ➢ Right To Backup Power

Education And Outreach: 10 Years -- $60 Million

- ❑ Comprehensive, Multi-Year Cooperative Education Program
- ❑ Decision Makers
- ❑ Code Officials
- ❑ Students
- ❑ Schools And Universities
- ❑ Specify-Build-Install-Repair Professions And Trades.
- ❑ Media
- ❑ General Public
- ❑ International Code Bodies

Coordinated Federal Management: 10 Years -- $105 Million

- ❑ Formal And Continuing Consultation With Industry
- ❑ Choose A Lead National Laboratory
- ❑ Coordinating Role For White House

Program Costs

We propose an investment of approximately $5.5 billion over 10 years, with resources moving from research, development and demonstration and toward purchases and market entry support as development of the technology allows, recognizing that various fuel cell technologies are at different stages of development.

This investment is well within the traditional range of support for energy technology development. A recent Congressional Research Service Issue Brief (IB10041) estimated that federal research support for energy technologies totaled $84.0 billion between FY 1973 and FY 1999, including $19.7 billion for renewable energy and efficiency technologies.[1] In the same period, we estimate the federal investment in fuel cell research at less than $1 billion.

- The societal benefits of fuel cell commercialization are not precisely calculable but the benefits of energy security and clean air are easily in the hundreds of billions of dollars.

- Price Waterhouse-Coopers recently estimated the market for fuel cells could be as large as $1.7 trillion ($2.6 trillion Canadian) by 2020.

- The U.S. Department of Energy estimates fuel cell development could add 750,000 jobs to the U.S. economy by 2030.

Recommended Federal Investment in
Fuel Cell Development and Commercialization
10-Year Budget, ($ Millions)

Program	10-year Total	FY 03	FY 04	FY 05	FY 06	FY 07	FY 08	FY 09	FY 10	FY11	FY 12
Research and Development	2,330	150	250	300	400	400	300	200	110	110	110
Demonstrations/Purchase											
Vehicle Demonstrations	495	18	66	115	125	56	40	40	20	10	5
Purchases for Federal Buildings	650	50	100	100	75	75	50	50	50	50	50
Other Purchases	180	10	25	25	25	25	25	15	15	10	5
Market Entry Support											
Tax Incentives	500										
Buy-Down Program	175	18	25	25	35	22	15	15	10	5	5
Investment in Infrastructure	950	20	30	80	100	150	200	150	100	70	50
Removal of Barriers	105	10	20	20	20	15	10	5	5	0	0
Public Education	60	2	5	9	8	10	8	7	5	3	3
Subtotal	5,445	273	521	674	788	753	648	487	315	258	228
Management	105	10	10	18	18	18	10	6	5	5	5
Program Total	**5,550**	**288**	**531**	**692**	**806**	**771**	**658**	**489**	**320**	**263**	**233**

[1] Study totals are expressed in constant dollars.

About Fuel Cells

A fuel cell is an electrochemical device that combines fuel and an oxidant to produce electricity. The fuel is typically hydrogen and oxygen the oxidant, with water and heat as the by-product. A fuel cell is similar in structure to a battery but it does not run down, nor does it require recharging – as long as fuel is supplied, it will continue to operate. The conversion of the fuel (hydrogen) to energy takes place *without combustion*; therefore the process is highly efficient, clean and quiet.

A fuel cell consists of two electrodes separated by an electrolyte. In most cases, hydrogen fuel is fed into the anode of the fuel cell. Oxygen (air) enters the fuel cell at the cathode. Hydrogen, the simplest element, is made up of two protons and two electrons. Encouraged by a catalyst, the protons and electrons break apart. The protons pass through the electrolyte. The electrons must take the long way around, creating a separate current that can be utilized before they return to the cathode, to be reunited with the proton and oxygen to form water. Individual cells are "stacked" together to generate useful quantities of power.

Fuel cells are a family of technologies. Five major types, characterized by their electrolytes, are being developed: Proton Exchange Membrane (PEMFC), Alkaline (AFC), Phosphoric Acid (PAFC), Molten Carbonate (MCFC) and Solid Oxide (SOFC). A Direct Methanol Fuel Cells (DMFC) is a type of PEMFC that uses methanol without a separate reforming step. Metal-air devices are also considered to be fuel cells by the U.S. Fuel Cell Council. With significant exceptions, higher temperature systems (MCFC, SOFC, PAFC) tend to be best suited to larger applications, while low temperature systems (PEMFC, DMFC, AFC) are currently best suited to smaller applications and cyclical applications. Today's test fleet of fuel cell cars, trucks and buses is powered by PEMFC, but other family members are also being readied for vehicle applications.

All fuel cells are modular. Units ranging in size from a few watts to approximately 250 kW can be used as building blocks for larger systems. Fuel cells can be made to suit a staggering variety of power needs.

- Stationary electricity generation applications, including power for base load, back up or peak shaving needs of residential building, commercial buildings or other commercial applications such as backup systems for telecommunications.

- Transportation applications, ranging from cars, trucks and buses, to industrial equipment, off-road utility vehicles, airport ground service equipment, golf carts, and even locomotives and boats.

- Portable applications, including portable generators and power for small electronic devices such as laptop computers, cellular telephones, and video cameras.

Fuel cells are fuel flexible. The hydrogen fed to the fuel cell can be stored as a compressed or liquefied gas, within a hydride or other solid material, or may be obtained by "reforming" hydrocarbon and alcohol fuels such as natural gas, propane, methanol, ethanol, synthetic fuels, and gasoline.

Benefits of Fuel Cells

No other energy generating technology holds the combination of benefits that fuel cells offer. Benefits include high efficiency; unmatched environmental performance; high quality power; fuel flexibility; quiet operation; simplicity (no moving parts); modularity/scalability, which lead to high reliability, flexible siting and ease of maintenance; and adaptability to specialized application. Unlike solar and wind technologies, fuel cells operate continuously regardless of time of day or weather conditions and can be sited in any terrain.

Customers can tailor their fuel cell power plant to meet their unique needs for grid independent, grid connected or grid parallel power. When the fuel cell is sited near the point of use, its waste heat can be captured for useful purposes. Fuel cells can be and have been sited nearly anywhere, on a farm or inside a skyscraper, and in operating environments that range from the desert of California to the frigid climate of Alaska.

Fuel cells enable us to think about power generation in unusual ways. A fuel cell car, for example, is also a clean, efficient power-generating unit on wheels.

This section outlines some of the major advantages of fuel cells, and highlights their special benefits in selected applications.

Energy Security

Security of Supply. Because they are efficient, modular and fuel flexible, fuel cells can enable a transition to a secure, renewable energy future, based on the use of hydrogen.

- A fuel cell system that includes a "fuel reformer" can utilize the hydrogen from any hydrocarbon or alcohol fuel – natural gas, ethanol, methanol, propane, and even gasoline or diesel. Hydrogen can also be produced from electricity from conventional, nuclear or renewable sources.

- Hydrogen can be extracted from novel feedstocks such as landfill gas or anaerobic digester gas from wastewater treatment plants, from biomass technologies, or from hydrogen compounds containing no carbon, such as ammonia or borohydride.

- A process called electrolysis uses an electric current to extract hydrogen from water. Fuel cells, in combination with solar or wind power, or any renewable source of electricity offer the promise of a totally zero-emission energy system that requires no fossil fuel and is not limited by variations in sunlight or wind flow. This hydrogen can supply energy for power needs *and* for transportation.

Physical Security. Because of their distributed nature, fuel cells allow the country to move away from reliance on central station power generation, and long-distance, high voltage power grids, which are the most likely terrorist targets in any attempt to cripple our energy infrastructure.

High Reliability. Fuel cells can be configured to provide backup power to a grid-connected customer, should the grid fail. They can be configured to provide completely grid-independent power. Or they can use the grid as the backup system. Modular installation (the installation of several identical units to provide a desired quantity of electricity) provides extremely high reliability -- in specialized applications, fuel cells can achieve up to 99.9999% reliability, less than one minute of down time in a six year period.

High Quality Power. Fuel cells offer high quality power, crucial to an economy that depends on increasingly sensitive computers, medical equipment and machines.

High Efficiency

Because they make energy electrochemically, and do not burn a fuel, fuel cells are fundamentally more efficient than combustion systems.

Power generation

- Fuel cell power generation systems in operation today achieve 40 percent fuel-to-electricity efficiency utilizing hydrocarbon fuels.
- Systems fueled by hydrogen consistently provide 50 percent efficiency. Even more efficient systems are under development.
- In combination with a turbine, electrical efficiencies can exceed 60 percent.
- When waste heat is put to use for heating and cooling, overall system efficiencies exceed 85 percent.

Transportation

The U.S. passed a grim milestone in year 2000, according to the Energy Information Administration: net oil imports surpassed 10 million barrels per day. We burned 8.25 million barrels per day in our cars and trucks. (U.S. drivers consumed 155 *billion* gallons of motor fuel in 1998.)

- Fuel cells can help the United States move away from the current dependence on petroleum by providing more efficient vehicles in the short term, and ultimately by allowing a transition to renewable energy.
- Fuel cell passenger vehicles are expected to be up to three times more efficient than internal combustion engines.

Environmental Benefits

Air pollution continues to be a primary health concern in America. Exposure to ozone, particulate, or airborne toxic chemicals has substantial health consequences. Scientists are now linking air pollution directly to heart disease, asthma and cancer. Recent health studies suggest polluted urban air is a comparable health threat to passive smoking. Fuel cells can reduce pollution today and offer the promise of eliminating pollution tomorrow.

Power Generation. Fuel cells offer excellent environmental performance compared to power generation technologies that rely on combustion.

- Based on measured data,[2] a fuel cell power plant may create less than one ounce of pollution per 1,000 kilowatt-hours of electricity produced – compared to the 25 pounds of pollutants for conventional combustion generating systems.

- Fuel cell power plants are so low in emissions that some areas of the United States have exempted them from air permit requirements. As we move toward use of renewable fuels in fuel cells, producing electricity will become a zero emission process.

Motor Vehicles. Fuel cell vehicles are the least polluting of all vehicles that consume fuel directly.

- Fuel cell vehicles operating on hydrogen stored on-board the vehicle produce zero pollution in the conventional sense. Neither conventional pollutants nor green house gases are emitted. The only byproducts are water and heat.

- Systems that rely on a reformer on board to convert a liquid fuel to hydrogen produce small amounts of emissions, but would still reduce smog-forming pollution by up to 90 percent compared to traditional combustion engines, depending on the choice of fuel.

- The simple reaction that takes place inside the fuel cell is highly efficient. Even if the hydrogen is produced from fossil fuels, fuel-cell vehicles can reduce emissions of carbon dioxide, a global warming concern, by more than half.

- Tests performed on a fuel cell bus, fueled by methanol, showed zero emissions of particulate matter and hydrocarbons, and near-zero emissions of carbon monoxide and nitrous oxides – levels far below the 1998 emission standard for buses.

Fuel cells used as auxiliary power units (APUs) to power air conditioners and accessories in over-the-road trucks could reduce emissions by up to 45% from long haul vehicles, and deliver economic benefits to the truck owner in lower fuel use and less wear and tear. APUs

[2] Reported by United Technologies Fuel Cells. See www.utcfuelcells.com/news/archive/test_053001.shtml

for heavy-duty vehicles could spur the development of a fueling infrastructure for fuel cell powered vehicles by stimulating demand at major fuel stations nationwide.

International Benefits

Fuel cells are entering the market at a time when countries face growing pressure to adopt alternative energy technologies on a large scale. The challenge for the fuel cell industry is to ensure that it is ready with competitively priced performance-proven products as demand grows.

- More nations are focused on sustainable energy strategies. Fuel cells offer an opportunity for countries to move toward greater sustainability in resource consumption.

- Fuel cell efficiencies yield substantial reductions in emissions of climate change gases and promise an end to the exclusive reliance on carbon fuels for energy.

Operating Flexibility

On-site power. Fuel cell systems can ease the strain on the existing centralized power grid, and reduce inefficiencies due to transmission losses.

- Their ability to be used in combined heat and power applications increases efficiencies over central station power significantly, thereby reducing greenhouse gas emissions. The potential total efficiency of these Combined Heat and Power (CHP) systems can exceed 85 percent.

- Utilizing the technology in peak shaving applications also leads to efficiencies.

- Use of fuel cells in homes during time of peak electric demand can save home owners money and greatly reduce the reliance on older, higher polluting and less efficient power plants that are used only at times of peak demand.

- The modularity of fuel cells allows for incremental buildup of capacity where there is minimal funding available for the up-front capital costs of multi-megawatt sized or centralized power plants.

Portable Power

Power generation. Portable power applications cover a wide range of market segments including small generators and battery replacements. Fuel cells are an excellent source of power for emergency and recreational uses where access to the electric grid is not available. Domestic generator-type products are currently nearing commercialization. Portable devices offer great potential as back-up power supplies.

Battery replacement/alternative. Fuel cell power sources are also being developed for portable electronic devices. In these applications, the fuel cell would provide a much longer operating life than a battery would, in a package of lighter or equal weight per unit of power output. The fuel cell would not require "recharging;" a liquid, solid, or gaseous fuel canister could be replaced in a moment. Fuel cells also have an environmental advantage over batteries, since certain kinds of batteries require special disposal treatment. Fuel cells provide a much higher power density, packing more power in a smaller space.

The engineering and materials challenges related to micro fuel cell applications are substantial and will require innovative solutions to bring them to commercialization. If these technologies can be commercialized, then the portable and micro application market could be the fastest to develop. There is a huge potential market.

Portable fuel cells carry environmental benefits comparable to fuel cells in other applications to the extent they replace combustion systems in homes, in business, or in recreation.

- *Productivity.* Fuel cells carry productivity benefits in an increasingly mobile economy.
    - Allied Business Intelligence's report on "Portable Fuel Cell Markets" says portable fuel cells are being developed to respond to the "poor performance of rechargeable batteries by quadrupling the run time before refueling is necessary."
    - Developers expect a fuel cell powered cell phone to have up to 200-hours of talk time. Recharging fuel cell powered electronic devices could be as simple as inserting a small methanol fuel cartridge or hydrogen container.

Military Applications

Fuel cells help the military reduce the cost of battlefield logistics, provide a source of energy for the modern soldier, save money and reduce pollution at military installations and on board ships and terrestrial vehicles, and most importantly, save lives and materiel by reducing telltale heat and noise.

Fuel cells may provide life-saving power for the soldier of the future, who will be carrying enough electronic equipment to require one kilowatt or more of electric power.

A recent Defense Science Board report entitled "More Capable Warfighting Through Reduced Fuel Burden" concluded, "over 70 percent of the tonnage required to position today's US Army into battle is fuel." The report also found that significant war-fighting, logistics and cost benefits occur when weapons systems are made more fuel efficient.

Stationary fuel cells are helping the military address peak electric power needs while complying with the presidential directive to reduce energy use at Federal facilities by 20%. Stationary fuel cells for military applications can provide back up or standby power for special operations and activities and can provide power in remote areas.

Research and Development

Current Program

The federal government has invested in fuel cell research and development beginning with NASA's interest in the early 1960s. The benefits of this investment are apparent in the wide range of successful proof-of-concept demonstrations, in the commercial progress of several systems, and in the explosion of interest and investment in fuel cells. Key component suppliers have become research partners, and hundreds of potential suppliers are evaluating fuel cells as potential markets for their products.

Measurable achievements attributable wholly or largely to federal research support include:

- Significant component and system cost reduction for fuel cells and hydrogen.
- Proof-of-concept demonstrations in a variety of specific applications.
- Proof-of-concept research and demonstration of novel or emerging fuel cell technologies.
- Demonstration of fuel cells' feasibility in motor vehicle applications.
- Development and testing of integrated systems for transportation and power generation.
- Advancements in the understanding of how fuel cells work, and in other areas of fuel cell science.
- Integration of fuel cells systems and hydrogen infrastructure development.

A great deal more needs to be done.

- Public and private research programs have already achieved a factor of 10 or greater reduction in projected component and system costs, but additional cost reductions of even greater magnitude are needed for full commercialization.

- Fundamental research and testing are still needed to increase system reliability and durability.

- Improved system efficiencies will yield direct benefits to the customer and society, for hydrogen production and storage and for fuel cell systems.

- Advances are needed in hydrogen production, delivery and storage technology and infrastructure options.

- Other key research areas include advanced materials, catalyst utilization, system design and integration, manufacturing, recyclability, and sustainable design.

A Comprehensive, Government-Wide Fuel Cell RD&D Effort

The U.S. Government should undertake a comprehensive, cost-shared fuel cell and infrastructure research and development program. The program should aim to optimize fuel cell systems and infrastructure and break through barriers in system operations, materials, manufacturing processes and cost. Careful planning and coordination will yield a pre-competitive research program that focuses on priority needs.

Most importantly, the research program should recognize the interrelated nature of fuel cell stack and system development and related infrastructure.

Various fuel cell technologies have different characteristics that make them suitable for a broad array of applications. Government policies should be technology neutral. Appropriate cost and performance goals should be established for the various applications that reflect aggressive but realistic objectives.

Interrelated Research

While fuel cell systems are often unique at present, a significant number of research and development outcomes will assist commercialization in two or even several fuel cell applications. Knowledge gained in one research area can and will be applied in other product areas in power generation and in transportation. New materials, designs and manufacturing techniques that yield cost reduction in one product area can be adapted to other areas and adopted by a supplier base supporting a variety of fuel cell applications. Research that might yield real benefit for fuel cells in a variety of product applications includes:

- Miniaturization of system components.
- Optimization of system components (radiators, compressors etc.).
- High temperature / high durability membranes.
- Improvements in reformer response times and efficiency.
- Novel materials and improved materials utilization for membranes and other stack components and reformers.
- Recycling.
- Advances in balance-of-system components and component utilization.
- Design-for-manufacture techniques and system integration innovations.
- Low-volume, low-cost and high-volume low-cost manufacturing techniques.
- Advances in catalyst utilization and novel catalyst materials.
- Improved system electronics.
- Low cost interface equipment.
- Low cost/non-invasive product testing and evaluation.
- High-efficiency hydrogen production systems and purification technology.
- Fuel quality specifications.
- Improved fuel formulas and next-generation liquid fuels.
- Improved hydrogen storage tanks, materials, and components.
- Improved sensors, pumps, and safety equipment.
- New desulfurization technology.

Recommended Program

The federal government should develop and implement a comprehensive, 10-year research effort beginning in 2003, to address commercialization issues in the following key areas:

- Cost reduction.
- Materials choice and utilization.
- Recycling.
- Design and manufacturing.
- System integration.
- Balance of system components.
- Fuels, fuel quality and fuel processing.
- Hydrogen production, distribution and storage.
- System performance enhancements (durability, efficiency).
- Testing, evaluation, characterization, product standardization.

The DOE FreedomCAR program offers a sound foundation for vehicle-related fuel cell research and public-private model for research in other applications.

FY 2003 DOE R&D funding levels of approximately $150 million should increase incrementally to $400 million in 2006 and 2007, declining to $110 million in 2012 as more resources are invested in demonstrations and purchases.

Pre-competitive research should be a continuing priority of the federal government. DOE should dedicate a lead national laboratory for fuel cell research.

Congress should examine whether intellectual property provisions of current law may be modified, consistent with the public interest, to address industry concerns about cooperative research.

Federal programs should be technology neutral and driven by aggressive yet realistic cost and performance goals based on the application.

Demonstrations, Pilot Fleets and Purchases

The demonstration of fuel cells is critical to market acceptance as well as to validation of the technology. Demonstrations of pre-commercial fuel cell products in real life situations will validate product reliability and output, "ruggedize" the product, develop the data necessary for commercialization, and help manufacturers make the necessary alterations to ensure commercial success.

Demonstrations in many cases will necessitate the installation of fueling infrastructure, and will provide a necessary proving ground for hydrogen production, storage and delivery technologies.

Demonstrations also raise consumer and public awareness of fuel cell technology, fuel cell products and hydrogen and other advanced fuels.

Comprehensive Program. Demonstrations should cover the widest variety of products including micro-power, portable power, power generation and transportation sectors. Many of these demonstrations could include public access to the site, and to some of the data developed during the project lifespan.

Standardization. To facilitate these demonstrations and pilot fleet purchases, the Department of Defense should establish, where practical, standardized electrical demand for discrete product requirements to avoid countless customized products for military applications and commensurate higher costs for fuel cell systems.

In addition, the government should establish uniform, low sulfur fuel specifications for all branches of the military to increase the deployment of FC system availability for military applications.

Public Buildings

We support a cost-shared program to purchase, operate, and evaluate fuel cells to meet the power needs of federal buildings.

- The federal government is the largest energy consumer in the US with more than $8 billion in energy purchases in 1999. The federal government controls 500 buildings and consumes 1.5% of the nation's electricity. Federal buildings spend $3.4 billion and consume 336 trillion BTUs annually.

- On May 3, 2001, President Bush directed all heads of executive departments to "take appropriate actions to conserve energy use at their facilities to the maximum extent consistent with the effective discharge of public responsibilities." Fuel cells in the co-generation mode have achieved energy efficiency levels of 87%; they can help federal building managers reduce their overall energy consumption.

- The President's FY'03 budget for the Department of Energy (DOE) includes a goal of increasing distributed energy resources (DER) to 7 percent in 2005, and a doubling of combined heat and power equipment installation by 2010, based on 1998 capacity. Fuel cells can help the federal government meet these goals.

- The FY'03 DOE budget request notes that a key strategy for deployment of DER is to promote and install such equipment at federal facilities.

- The most powerful incentive for fuel cell companies in the private sector is the prospect of commercial sales. By becoming an "early adopter," government will accelerate commercialization, and also enjoy the benefits of clean, secure, efficient fuel cell power.

- Fuel cell use in federal buildings can bring substantial public benefits beyond energy efficiency, assured power for fire and life-safety systems and critical loads, and reduced air emissions and noise pollution.

Recommended Program

We propose a three-year program of advanced pilot installations, and an evaluation of an ambitious federal purchase program beginning in 2006.

- Between 2003 and 2005, the federal government should purchase a total of 200 MW of fuel cell power generation units for base load, cogeneration, backup and/or emergency generation with preference given to units sited on federally owned, leased or operated facilities.

- A minimum 200 MW should be purchased annually in 2006 and beyond.

    - Non-federal public buildings should also be eligible sites for federally purchased units.

    - Privately held buildings should also be eligible sites for federally purchased units with adequate public interest justification. Examples include federally subsidized housing and homes eligible for home weatherization assistance.

Fuel Cell Vehicle Fleets

Federal Fleet

We support a cost-shared program to purchase, operate, and evaluate fuel cell vehicles in integrated service in federal fleets with the goal of demonstrating commercial viability in a range of climates, duty cycles, and operating environments. The Secretary of Energy should lead a cooperative effort among federal agency fleet operators and private-sector fuel cell vehicle companies.

Recommended Program

The program should include the following components:

- Geographically diverse locations to ensure a wide range of climates, duty cycles, and operating environments, and public access to the refueling infrastructure.
- Diverse regulatory regimes, to ensure that all possible access barriers are identified and addressed.
- An infrastructure integrated with stationary and portable fuel cells where feasible.
- A mix of passenger vehicles, buses and specialty vehicles.
- Extended operation in regular duty cycles; data collected in consultation with suppliers.
- Training and technical support from DOE and other agencies as appropriate.

Bus Fleets. Pilot fleet demonstrations should also be conducted along the same lines for transit buses, in consultation with the Department of Transportation, and for school buses, in consultation with DOT and the Department of Education.

Civilian Fleets. After 2007, the federal government should meet 50 percent of its civilian vehicle fleet needs with fuel cell vehicles. Current alternative fuel fleet programs should be evaluated to assure the fuel cell program meets concerns of agency fleet operators. The program should provide sufficient financial support to cover any vehicle cost premium.

Military Vehicles. A comparable program should be established at the Department of Defense for pilot fleet demonstrations at defense installations. This program should include passenger vehicles, trucks and other heavy-duty vehicles and auxiliary power units.

Fuel Infrastructure. The federal government should explore infrastructure costs, health, safety and environmental impacts, and proceed to establish a national fueling network for fuel cell vehicles based on the use of hydrogen and/or hydrogen carrier fuels.

Goals and Projections. Numerical goals should be established.

- *Phase 1, 2004-2007*
  - 500 passenger vehicles.
  - 500 DOD vehicles.
  - 100 transit buses.
  - 100 school buses.
  - 20 fueling stations demonstrating a range of fuels and fueling strategies.

- *Phase II, 2008-2011*
  - 5,000 passenger vehicles annually or 50% of fleet.
  - Target set by Secretary of Defense.
  - 1,000 transit buses or 50% of federally subsidized purchases annually.
  - 50% of federally subsidized purchases annually.
  - Mobile equipment and specialty vehicles, target set by Cabinet secretaries.
  - Additional fueling stations to meet program requirements.

Portable Systems

Recommended Program

In cooperation with federal housing and emergency management agencies and other interested agencies, the Secretary of Energy should undertake a program to purchase fuel cells with less than 75 kW rated electrical output, beginning in 2003.

- Minimum purchase goals should be 1 MW in 2003, 5 MW in 2004 and 25 MW in 2005, with the Secretary to recommend post-2005 goals.

Market Entry Support

A growing number of fuel cell manufacturers and other interested parties are bringing new fuel cell products to market; others have announced commercialization schedules over the next several years. Federal support for market introduction is key to assuring a successful commercial launch of the technology, providing a bridge between relatively expensive advanced pilot programs and cost-competitive commercial offerings.

Federal support for advanced energy technologies is customary, continuing and successful. The best recent evidence of its effectiveness is wind power, which has taken advantage of market support programs to achieve significant market share.

Federal support should expand upon the existing modest support programs and utilize both direct support and tax incentives.

Recommended Program

Tax Incentives

Congress is considering a range of tax incentives to support fuel cells. We believe a comprehensive program must include support for purchase, installation, and operation of fuel cells in the full range of applications. Short-term tax incentives would reduce incremental costs for early-adopters, helping the industry to build production capacities to economies of scale.

Transportation. Congress should enact a comprehensive tax credit program for fuel cell vehicles, beginning in 2005, and continuing through 2011. The program should incorporate consumer based tax incentives for all classes of fuel cell vehicles, installation of alternative fuel infrastructure, and retail distribution of alternative fuels including hydrogen.[3]

Passenger Vehicle Incentives. Congress should enact a credit system for vehicle purchases.

- We propose to continue the existing $4,000 credit for new cars and light trucks.
- We support an additional credit of up to $4,000 for fuel cell vehicles based on the vehicle's efficiency.

Incentives for passenger trucks. Congress should enact a credit system for new fuel cell trucks beginning in 2005, and continuing through 2011.

- We support a graduated program to provide a tax credit for 50% of the incremental cost of a fuel cell vehicle, with additional 50% possible based on achieving emissions and efficiency targets and fuel choice. Eligible costs would be limited to $5,000 to $40,000, depending on vehicle weight.

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3 The Clear Act incentives passed by the U.S. Senate in 2001 embody such a program.

Incentives for heavy trucks and buses. Congress should enact an additional incentive for fuel cell trucks over 26,000 pounds and buses that seat at least 20, to assure that the support programs for light and heavy programs are comparable.

- *Incentives for fuel infrastructure.* Congress should enact a tax credit for installation of fuel-cell fuel infrastructure at any outlet accessible to the public.

    - The program should include a direct credit of 50 percent of the cost of the station up to $150,000.
    - The program should allow 50 percent of the cost of the fueling infrastructure to be expensed in the year installed.
    - Fuel for fuel cell vehicles should be subject to a 30¢ per gasoline gallon equivalent credit in 2003, 40¢/gallon in 2004 and 50¢/gallon in 2005 to 2012.

Electric Power Generation

Stationary Power

Congress should enact a tax credit program designed to stimulate the use of fuel cells for power generation, beginning in 2003 and continuing to 2007 for the installation of fuel cell systems that provide power to business and residential property.

Business and Residential Property. Congress should enact a tax credit for purchasers of fuel cell systems that provide power to business and residential property of one-third the cost of the equipment or $1,000 per kilowatt, whichever is less.

- *Combined heat and power.* Congress should enact an additional 10% tax credit for a residence, business or commercial property that utilizes a fuel cell for both heat and power.

- The investment tax credit for fuel cell purchasers should be eligible for transfer to a non-tax paying entity to ensure parity between public and private purchasers of fuel cell systems.

Portable Power

Congress should enact a tax credit program designed to stimulate the use of fuel cells to replace conventional combustion systems in portable applications.

- *Business and Residential Purchases.* Congress should enact a tax credit of one-third the cost up to $1,000 per kilowatt for fuel cell systems of any size that provide power to business or residential property, beginning in 2003 and continuing through 2007.

    - For businesses, the program should allow 50 percent of the cost of the fueling infrastructure to be expensed in the year installed.

Buy-Down Program

The Departments of Defense (DoD) and Energy (DOE) have cooperatively supported the development and commercialization of domestic stationary fuel cell systems since FY 1995, when Congress appropriated funds for the Climate Change Fuel Cell Program (H.R. 103-747). Funds have been dedicated to this program in all but one year between FY1995 and FY2002.

The Buy-Down Program grants funds to fuel cell power plant buyers to reduce the high initial cost of early production systems, providing up to $1,000 per kilowatt of power plant capacity not to exceed one-third of total program costs, inclusive of capital cost, installation and pre-commercial operation. Award criteria are rigorous.

As intended by Congress, this program has significantly aided commercialization of the first generation of fuel cell systems by supporting the purchase of 26 megawatts of fuel cell power. Demand for buy-down dollars is increasing. More than a dozen U.S. fuel cell manufacturers will field products that qualify for program grants. The number of applications has far exceeded the number of approved projects in past years.

Recommended Program

An inclusive Buy-Down program should be continued and expanded to $18 million annually in 2003 increasing to $35 million in 2006 before declining gradually in 2007 to 2012.

Continuing this effective initiative will benefit the nation by accelerating deployment of fuel cells and addressing energy security and reliability concerns. Assuming tax incentives are enacted, the Buy-Down Program will provide a comparable level of support to governments and other non-taxpayers seeking the benefits of fuel cells.

Investment in Infrastructure

Development of a hydrogen infrastructure is an enormous task with an enormous benefit.

- The potentially high "first cost" of investment of hydrogen fueling infrastructure has been identified as a major hurdle for the launch and market penetration of direct hydrogen fuel cell technologies such as PEM.

- There is a poor match between the scale of current commercial hydrogen production technologies such as natural gas reformation and the needs of the fuel infrastructure in the early stages of market penetration.

- Small-scale hydrogen production is expensive and bulky, and storage technologies for small scale uses need development and optimization.

Recommended Program

- The Department of Energy should increase its investment in government-industry cooperative programs to develop small-scale hydrogen generators that would be better matched with the needs of small fleets of fuel cell vehicles or small numbers of stationary fuel cells.

- DOE should adopt a multiple-pathway approach to hydrogen infrastructure development including

    - Regional fuel cell vehicle refueling corridors, "power parks" or demonstration communities for fuel infrastructure.

    - Installation of stationary fuel cells and hydrogen fuel stations along existing or extended pipeline corridors to take maximum advantage of existing infrastructure.

    - "Multiple use" installations that utilize fuel cells for power generation while also offering hydrogen fueling capability may allow gradual buildup of hydrogen fueling infrastructure at low cost. The use of hydrogen carrier fuels offers both short-term and long-term options for serving fuel cell vehicles that could reduce investment costs, but also offers other challenges.

- The demonstrations, and pilot fleet purchases by the government, including fuel infrastructure, and favorable tax treatments of the investments required, mentioned elsewhere in this document, would help the commercialization and spur the build-out of the necessary fuel infrastructure.

- Favorable fuel tax treatment for hydrogen fuel made from hydrocarbon sources, can be justified on the basis that it would reduce carbon dioxide emissions on a life cycle basis.

Removal of Regulatory and Economic Barriers

Interconnection

The nation's electric power system has been pieced together over many decades as public and privately owned energy suppliers gradually developed the ability to work in reasonable harmony, supervised by state and federal government agencies. The system is designed to accommodate the construction and safe operation of large-scale energy generating facilities in a highly regulated environment. Interconnection requirements and financial terms designed for central power stations can pose a substantial barrier to smaller systems including fuel cells (and most other renewable energy systems).

In order for the benefits of distributed generation to be realized, approaches must be found that will economically benefit parties on both sides of the meter. Connection requirements that might be judged reasonable for a 150 MW systems, for example, may make a 250 kW system uneconomical, to say nothing of their impact on a 2.5 kW system. Such requirements may or may not be consciously designed to block distributed systems, but that is the practical effect.

While many states have recognized the issue and some have tried to address the concerns of distributed energy, there is no consistency in their responses.

Recommended Program

We seek federal endorsement of harmonized interconnection regulations across the various states and internationally. The fuel cell industry seeks to find such solutions through the following national response.

- *"Rules of the road"* for connection that treat these technologies essentially as just another appliance for purposes of connecting to the electric grid. For example, there must be provisions for fair and equitable treatment by utilities, which includes standardized and short, simplified interconnection applications.

- *Uniform National Technical Standards* for fuel cell systems of all sizes. States should be directed to adopt a uniform technical interconnection standard that is fair, equitable and non-discriminatory. The Institute of Electrical and Electronics Engineers (IEEE) 1547 work product should provide the basis for states in this area.

- *Distribution System Models*. The impacts and the benefits of DG on the distribution network are not well understood. DOE should fund development of computer models for the simulation of small generators on low and medium voltage distribution systems. These models will allow a utility, DG owner, manufacturer or third party to identify, at low cost, the sizing, characteristics and location where DG is both economical and safe.

Uniform Codes, Standards and Recommended Practices

Fuel cell commercialization will require modification of a long list of private and governmental product standards, safety codes, and best practices recommendations governing the design, installation and use of fuel cells. This work is well under way but is laborious and new code activities seem to spring up to take the place of those that are completed.

This work must be done on an accelerated timetable or codes and standards will become a barrier to commercial success.

Once done, the revisions must be introduced to code officials, integrated into national, state and local codes, and publicized among insurers, designers, installers, specifying engineers and other code users.

Harmonization of standards at the international level would give substantial additional impetus to commercialization activities.

Recommended Program

The federal government should:

- Make it clear to governmental and nongovernmental bodies that prompt completion of code and standard modifications and harmonization of international standards is in the U.S. national interest.

- Support code bodies financially as appropriate.

- Take the lead in supporting adoption of codes and standards by those entities with relevant jurisdiction and responsibility.

- Lead an education program aimed at those who must implement or be aware of modifications in and requirements of codes, standards and recommended practices.

- Aggressively pursue international harmonization of codes, standards and best practices to prevent the erection of technical trade barriers.

Rights of DG Users

Users of distributed generation technologies need a transparent, accessible system.

Recommended Program

We seek the following, which will benefit all DG technologies:

- *Right to System Information.* Distribution system wires owners should be required to make technical information required for system studies available to qualified third parties.
    - The intent is to allow the costs and results of studies to remain free of business interest bias, while stimulating innovation and lowering cost through competition.
- *Right to Backup Power.* Congress should assure that distributed systems have a right to backup power from the grid.
    - Backup power must be available at a fair, equitable and non-discriminatory price.
    - Backup customers with small units (250 kW or less) who are unable to participate in wholesale power markets should be exempt from demand charges, customer charges or any form of fixed charges that exceed the fixed charges paid by comparable full service customers in the same class.
    - Small (250 kW or less) distributed generation customers should be exempt from exit fees.

Regulatory Incentives

Regulatory incentives are a powerful tool to stimulate market interest and innovation as well as to achieve social purposes. Fuel cells are recognized in some jurisdictions today for their unmatched environmental characteristics. Fuel cells can meet stringent standards already on the books, and thus help regulatory agencies achieve their public mandates. Agencies reviewing existing requirements can and should look to the performance of fuel cells as a technology benchmark.

Recommended Program

Properly designed, programs that would support fuel cell commercialization include the following.

- *Electric Power Generation*
    - Federal, state and local regulators should look to fuel cells' emission performance in setting their technology-based requirements.
    - Carefully drawn emission trading programs would also benefit fuel cells and other high efficiency, low emission systems.
- *Transportation*
    - Fuel cell vehicles will meet the most stringent motor vehicle emission controls established by the Environmental Protection Agency and should help the agency establish technology-based requirements for non-road engines, airport vehicles and other vehicles whose control requirements are under review. .
    - Fuel cell vehicles utilizing liquid fuels need sulfur-free fuels for maximum performance. EPA and the states should adopt near-zero fuel sulfur limits and other fuel quality requirements.

Institutional Structure

This effort requires a management structure to provide leadership and to coordinate the interests of the government. The Department of Energy has taken steps to streamline the decision making structure and improve management of fuel cell programs in its jurisdiction. We applaud these steps.

Recommended Program

We recommend the following additional steps:

- Formal and continuing consultations with industry participants including fuel cell developers, automobile companies, distributed generation companies, fuel cell suppliers, energy providers and others as appropriate.

- Coordinating Role for White House: The President, through his Science Advisor or via another coordinating body of his choosing, should establish a committee, Interagency Group or other mechanism to facilitate interagency cooperation, assure that the federal fuel cell program is meeting its objectives, and promote technology transfer between defense and civilian agency programs.

    - This effort should involve at least the following departments and agencies:
        - DOE
        - DOD
        - Commerce
        - EPA
        - NASA
        - DOT/FTA
        - White House Science Advisor
        - National Security Council

Public Education/Awareness

Background. A consensus is forming on the need for a comprehensive education program covering fuel cells and hydrogen and hydrogen carrier fuels. Some examples of this interest (just from the last few months) include the following.

- The recently released evaluation by CENTRA technology, Inc., of U.S. global competitiveness in fuel cells concludes that U.S. world leadership is "rapidly eroding." The report recommends three responses: code and standard development, financial incentives and "information and education, which will raise public confidence in the use of fuel cell technology and encourage its commercialization."

- The Department of Energy brought together a cross section of experts whose deliberations yielded a vision statement, called *A National Vision Of America's Transition To A Hydrogen Economy – To 2030 And Beyond.* It called for a comprehensive planning exercise that would, among other goals, address "Education of the general public and private decision makers about the potential benefits from the expanded use of hydrogen."

Barriers to commercialization that could be addressed by education include:

- (Non-financial) – Unfamiliarity with fuel cell vehicles, distributed energy technologies and hydrogen infrastructure and utilization; unreasonable or inappropriate interconnection requirements; restrictive or silent codes, standards and recommended practices.

- (Financial) – Insufficient capital for commercialization; unreasonable connection fees; pricing practices and tariff structures; current business models and practices.

Recommended Program

The fuel cell industry seeks a multi-year cooperative effort to address the education issues comprehensively, by

- Providing coordination and support for efforts already in the field by companies, nonprofit organizations, universities, and government agencies at all levels.
- Comprehensively identifying education and outreach targets among key audiences.
- Developing information and outreach programs targeted to the target audiences.
- Comprehensive media education, including daily press, specialty press, opinion leaders (editorial writers, columnists).
- A comprehensive effort to connect college and universities with the industry so post-secondary institutions will understand and teach needed skills.
- Outreach to audiences outside the U.S. on issues of code and standard development, technology transfer and international development.