ENVIRONMENT

ABSTRACT: The U.S. environmental industry is growing slowly, but steadily. It is an industry that is only now learning how to go beyond the regulations imposed by the EPA. Like so many other industries, it is improving itself through privatization and the accompanying consolidation, competition, and market forces. The global market is beckoning U.S. industry with environmental challenges the world over, but like any other industry, it generally is looking for a profit and so pursues smart business opportunities versus benevolent crusades.

Col Abdulla Al-Mureikhi, Qatar Air Force
LTC Rodney Alston USA
Lt Col William Bierbaum USAF
Mr. Larry Brady, US Agency for International Development
COL Robert Brewster USA
Lt Col John Decknick USAF
COL Donald Hyde USA
CDR John Kroft USN
John Mazur, Dept. of Air Force
Steven McGann, Dept. of State
Lt Col John Simmons USMC
LTC John Taylor USA
CDR Matthew Weingart USN
Ms Joan White, Defense Contract Management Agency
CDR Kevin Wilson USN

Dr. Gregory Foster, faculty
Dr. Steven Myers, faculty
COL Mark Steenberg USA, faculty
Ms. Jan Wiley, faculty

PLACES VISITED

Domestic
Bechtel Corporation, San Francisco, CA
Sierra Club, San Francisco, CA
Pacific Industrial and Business Association, San Francisco, CA
Lawrence Berkeley National Laboratory, San Francisco, CA
Alameda Center for Environmental Technologies, Alameda, CA
Chevron Texaco Energy Research and Technology Company, Richmond, CA
The Natural Step, San Francisco, CA
International Boundary and Water Commission, San Diego, CA
Point Loma Water Treatment Plant, San Diego, CA
San Diego Supercomputer Center, LaJolla, CA
Scripps Institute of Oceanography, LaJolla, CA
Naval Facilities Engineering Command, Southwest Division, San Diego, CA
Resource Trends, San Diego, CA
NOAA HQ, Washington, DC
Blackwater National Wildlife Refuge, Cambridge, MD
Philip Merrill Environmental Center, Annapolis, MD
EPA Chesapeake Bay Program Office, Annapolis, MD
NOAA Chesapeake Bay Office, Annapolis, MD
Horn Point Environmental Lab Water Monitoring, Cambridge, MD

International
US Embassy, Wellington, New Zealand
The Living Earth Compost Plant, Wellington, New Zealand
Ministry for the Environment, Wellington, New Zealand
World Wildlife Foundation, Wellington, New Zealand
Karori Nature Reserve, Wellington, New Zealand
Ministry of Defense, Wellington, New Zealand
Trentham Military Base (Joint Forces Command), Trentham, New Zealand
Kapiti Island Nature and Marine Reserves, New Zealand
Department of Defence, Environmental Stewardship, Canberra, Australia
Environment Australia, Canberra, Australia
Majura Field Firing and Training Range, Canberra, Australia
Collex Ltd., Sydney, Australia
New South Wales Planning, Sydney, Australia
Cooperative Research Center (University of NSW), Sydney, Australia
Waste Services of NSW, Sydney, Australia
Sydney Harbour Foreshore Authority, Sydney, Australia
Sydney Water Services, Sydney, Australia

INTRODUCTION: The purpose of this study is to share a brief synopsis of the state of the environmental industry followed by short discussions on topics with strong impacts on the industry such as regional issues, global warming, treaties, and international standards. We have given a finer definition for each of the 14 industry segments below, and reported on each distinct portion. This industry touches all other industries as they generate waste, pollution, use natural resources, or help sustain the human population. Our greatest challenge has been defining the edges of the industry.

THE INDUSTRY DEFINED: The environmental industry has been defined by the Environmental Business International (EBI), Inc as: "All revenue generation associated with environmental protection, assessment, compliance with environmental regulations, pollution control, waste management, remediation of contaminated property and the provision and delivery of environmental resources."[1] This definition has been widely adopted and is currently used by the U.S. Department of Commerce and others. We have used both this definition and the 14 industry segments defined by EBI to divide the industry into reportable units. Those 14 industry segments are grouped into the three broader categories of services, equipment, and resources and we have used the three categories to frame the discussions except where there are wide overlaps such as in water.

CURRENT CONDITION: The environmental industry represents total revenues of $213 billion (3% GNP) generated by 30,000 private sector companies and more than 80,000 public sector entities in the U.S., and employs 1.4 million Americans. The global market is $600 billion. Since 1991 the industry has suffered through regulatory uncertainty that has not improved. Though one might think the Clinton-Gore years were good for the environment, uncertainty led to policy postponements and cancellations. The industry is also recession prone. Today, environmental companies must base their businesses more and more on economic drivers instead of regulations. Those who wish to enter the market must provide enduring long-term/resource-oriented solutions to environmental unsustainability problems if they wish to make a return on their investment and gain long-term competitive advantage. However, companies shouldn't throw out the compliance business baby with the regulatory bathwater. Pollution control, waste management and cleanup driven regulation still represents the majority of revenues. But, demand is replacing these services with pollution prevention and resource recovery investments not wholly dependent on regulations. For example, water treatment equipment for discharge is losing market share to water treatment and purification equipment for reuse. The changing administrations, inconsistent regulations enforcement, lag time between policy and market demand and sensitivity of the client's ability to pay indicates a very modest outlook. Annual growth has been between 2-4% since 1991. However, defined niches (desalinization) promise double-digit growth, though there are decidedly much less opportunities. Part of the problem is that most companies are compliance based and are not prepared to tackle the new market. The greatest hope lies in coalescing the functions of producing sustainable power and squeezing more efficiency out of existing methods and materials. The best opportunities lie in the clean energy segments that grew 16% in 2001. Solar, wind, and fuel cells posted a 30% growth. Low levels of enforcement should mean a less adversarial relationship. Companies will cooperate with the EPA instead of avoiding contact. The industry can count on there being no rollback of protection standards – the public won't

stand for it. Overseas, the U.S. industry is facing growing challenges. Shrinking from 27% of the revenue in the early 1990 to single digits today, the industry faces increased international competition and consolidation. Many U.S. companies have come home as a result of such competition and unfavorable conditions as governments foster relationships with resident companies. Further, companies are learning that industries are producing less waste and initiatives are shifting from assessments to solutions and from pollution control to pollution prevention. Finally, industry goes where the money is… not necessarily where the problems are.

CHALLENGES: Environmental issues mean nothing if basic needs, food, shelter, etc are not being met. Therefore, one can argue that it makes best sense to help poorer countries to develop their economies, better their living conditions, and create wealth. Only when we have enough wealth, can we afford the luxury of caring about the environment. The industry needs smart regulations – based on data not emotions. The challenge for the industry lies in the fact that most companies are compliance based, not market based…and they need to change their mind-set. Companies must realize that collection of pollution and waste is becoming a thing of the past while methods that integrate destruction or recycling into the process are the way of the future. Industry needs to shift to partnering with government as other countries have done while focusing on emerging technologies and information that will make them more competitive nationally as well as globally.

OUTLOOK: The projected outlook for the industry is basically flat. Modest growth is anticipated throughout the industry in all areas except in clean energies areas that are expected to continue their 15-16% growth. The reasons for such modest growth vary by segment, as noted in the discussions below, but generally follow our overall economy. When economies are good, more money goes towards the environment, as the economy turns down, folks shift their attention to more basic demands and recapturing wealth. We can anticipate greater consolidation, as companies look for advantages and efficiencies, and we expect companies to return to their core competencies to ensure stability. We also expect companies to look for global opportunities, but as stated above, the industry follows the money, not necessarily the need.

GOVERNMENT: GOALS AND ROLE: The environmental industry was born out of the establishment of the EPA and its regulations. Today's industry continues to react to those regulations…and the industry does best when given clear guidance. As noted above, when the government shows indecision on environmental regulations, the industry is strongly affected, as they are largely unable to chart their future path. Smart regulations, based on data, are key contributors for industry. Government also spends a great deal of money on the industry… Super Fund site cleanups, Clean Water Act, Safe Drinking Water Act fuel the industry and as cities' infrastructures age and are in need of replacement, it will be government footing the bill. Government may or may not seek harmony with other nations on international treaties – such treaties can have sweeping impacts on the industry as we discuss in our treaty section. Basic government philosophy on the economic impact of the environmental industry is a constant difficulty for the industry as administrations change. President Bush has signaled his intentions by not

signing the Kyoto Treaty, but rather by pushing his own Clear Skies initiative. Industry is dependent on government and extremely watchful of any new programs or regulations.

Industry Segment Discussions: <u>SERVICES</u>

Analytical Services: The analytical services segment comprises those business that provide laboratory testing and analysis of environmental samples. Over 90% of these businesses are very small companies with less than $1 million in annual revenue. There are approximately 555 companies throughout the U.S., driven primarily by the market's desire for timely, locally available analyses. Exported services amount to only about $50 million. Growth in analytical services has been flat since ending a period of decline in the mid-1990s, and is projected to remain so or perhaps decline even more over the next several years[2]. Approximately 18% of this segment is based on government business. Analytical services comprise the smallest segment of the environmental services sector, earning total revenue of approximately $1.3 billion in 2002.[3]

Water Utilities, Wastewater Treatment Works & Water Equipment/Chemicals: According to Bjorn Lomborg in his book, The Skeptical Environmentalist, although the world's population quadrupled since 1940, there are sufficient water sources to support the world's needs.[4] The Earth's surface is 71% water. Of this 71%, the oceans make up 97.2% and the polar caps 2.15%. The remaining .65% supports human needs -- .62% of this is groundwater.[5] Landmass precipitation accounts for some 113,000km3 (cubic kilometers) of water. After evaporation and runoff, approximately 41,000km3 is left. To give this number a little meaning, this amount will cover the surface of the planet in 12 inches of water. Lomborg estimates that after subtracting inaccessible areas, 12,500km3 of water is available for human use. This calculates out to be 5700 liters of water per person per day.[6] Incredibly, Lomborg estimates that we only use 17% of the Earth's available water. Why then is water such an issue? Essentially the problem stems from allocation and misuse. Population increases and the unequal distribution of global precipitation mean some populations have an overabundance while others don't have enough. Moreover, many areas of the world depend on river systems that are used by several countries. "Water is the most important resource for any economy and for life."[7] Many see water as part of the "taken for granted" community infrastructure. Today, scarcity and our disruption of the natural processes that create clean and usable water are presenting business opportunities in water utilities and sewage treatment.

The water industry is evolving from a linear structure to a circular model -- this is quite natural since water is a renewable resource. The industry is made up of five interacting groups: water utilities, water users, wastewater treatment facilities, water service providers and water equipment companies[8]. "As the markets increasingly become price driven, the main user groups are becoming providers as both the water users and the treatment works sell water back into the system."[9] Water utilities are therefore becoming "middle men." "The industry is naturally evolving from conservation to resource efficiency and privatization. As resource industries evolve, users become resource managers and eventually resource sellers/re-sellers."[10] Water and wastewater treatment have increased faster than inflation since 1986…and water is still subsidized. Some 58,000-community water systems service 226 million people in the U.S.[11] (The rest have individual systems.) Six percent provide 80% of the water used.[12] This

constitutes a $29.9 billion market of which only 18% is generated by private owned utilities.[13]

There are four broad classes of water users: residential, commercial, industrial and agriculture -- agriculture and thermoelectric are the largest users. Water utility markets are being affected by increasing user fees, on-site recycling/reuse and privatization of water treatment and delivery.[14] Higher prices are spawning water resource management at the facility rather than within the community. Mounting pressure to maintain water quality without increasing taxes or fees is encouraging privatization -- only 18% of water utilities and less then 5% of sewage treatment works are private.[15]

Water reuse is clearly a growth industry, but must overcome some obstacles. Many have staked claims to water sources. Reclaimed resources find it hard to compete with these virgin resources. Virgin resources should be used as a base for pricing in order to regulate natural capital resource efficiency, productivity and environmental protection.[16] Another issue involves potable/non-potable water. In the U.S., people drink a gallon of water a day but use 1,200 gallons. Therefore, there is plenty of market room for non-potable water. Reuse brings up transport issues. The need for separate piping etc. would be greatly reduced if water reuse occurred at the point of generation.[17] Moreover, all water that comes from initial use in the home or business should be considered a resource. "Orphan" or disconnected communities are opening markets for small-decentralized reuse systems.[18]

The driving force behind wastewater treatment is regulation. The majority of the revenues from this market come from industrial manufacturers and water/wastewater utilities. Water delivery and publicly owned treatment works (POTW) combine to create an $87 billion market -- the latter represents 32% of revenues in the U.S. water industry. There are some 16,000 POTW facilities in the U.S. -- 3% of these handle 66% of the nation's wastewater. Most of the revenues come from user charges. Like the other facets of the water industry, the increasing need for advanced and tertiary treatment and economic and social factors are providing opportunities for private companies.

All of the changing dynamics in the water industry explained above are creating lucrative markets. These markets are essentially in agriculture, industrial in-process, municipal water delivery, landfill leachate, thermoelectric utilities, industrial effluent, municipal effluent and storm water, and groundwater remediation.[19] Three trends are emerging: growth in technology from physical to chemical and biological that is creating a whole system that integrates all three into an efficient and inclusive process; emergence of water/wastewater treatment packaged system companies that provide total solutions; and a shift toward buying decisions created by the increasingly competitive markets.[20] All three trends are focusing the role of the independent consulting engineer as a systems integrator.[21] The service portion is sandwiched between the technology and customer layers and finds itself in ever-increasing competition with the technology companies, package system providers and the emerging total solution providers.[22]

Federal and state governments need to regulate water systems and regional/state use. The market should be allowed to work within this framework to establish water's market value and to provide incentives for new technologies and conservation. Value occurs when needs are satisfied. Brands will develop and succeed based on quality, reputation and service. The World Bank cites that the poorest countries use 90% of their water for irrigation, but only pay 35% of the water's worth.[23] According to Lomborg, a

single desalinization plant in the Sahara powered by a large array of solar panels could provide the world's freshwater needs.[24] Until things get so bad that we are forced to pursue such a project, public administration and market forces will help conserve, protect and sustain water sources -- water allocations will be decided according to a value derived by supply and demand. Market forces are already taking hold in the U.S. and are spawning new technologies and efficiencies through the lure of making a profit.

Solid Waste Management: Solid waste is defined as any non-hazardous waste sent off its generation site for landfilling, energy recovery, recycling, or composting. The solid waste management sector of the environmental industry includes the collection, transportation, processing, and disposal functions. Solid waste management is the largest and most mature segment of the environmental industry and generates approximately $40 billion in revenue per year[25].

The health of the solid waste sector of the environmental industry closely parallels the growth of the population and the gross national product (GNP), for as either increase or decrease so does the volume of solid wastes generated. Current trends in the solid waste industry sector include: consolidation of waste industry companies (20 companies controlled 30% of the industry in 1994 while in 2001, 6 firms controlled 46% of the industry); the sector now consists of publicly traded firms (47%), municipal governments (30%), and small private companies (23%); fewer and larger landfills which results in the creation of transfer sites for separation and compaction prior to movement to larger, generally more distant land fills combined with bioreactor processing (accelerated waste degradation), increased composting of green wastes (reduces volume of waste in land fill), and better product stewardship (producers taking responsibility for products at the end of their useful life and processing back into new products)[26].

Hazardous Waste Management: The Hazardous Waste Management sector is unstable, as overcapacity and declining waste volumes have resulted in stiff competition that has encouraged an increase in merger and acquisition activities among the larger companies. Consolidation and ownership changes have lessened pricing fluctuations, but problems persist. The hazardous waste management industry requires reframing (outsourcing, resource recovery, and reducing cost structures) to contend with the challenges.

According to Environmental Information LTD, there are 294 commercial hazardous waste facilities operating in North America. They include: 25 land fills, 18 incinerators, 20 boiler and industrial furnaces, 37 stabilization facilities, 77 fuel blenders, 71 aqueous waste treatment facilities, 40 solvent recovery plants and six deep well injection facilities. These businesses operate in an atmosphere of increased waste minimization, more lenient clean-up standards, few regulations and poor regulatory enforcement. Total revenues in 2001 were approximately $4.8 billion[27]

The overcapacity plaguing the industry is a product of high facility closure costs and post closure care that prevents companies from taking excess capacity off line. It will take the cooperation of state and federal governments, waste generators and the hazardous waste management industry to resolve the overcapacity problem. A definitive solution to excess capacity is the only way to move toward market stability and enable strong industry growth.

Remediation and Industrial Services: The Remediation/Industrial Services (RIS) of the environmental industry represents physical or "hands on" environmental cleanup, maintenance work at contaminated sites, buildings or operating facilities.[28] There are three main areas of RIS; Industrial services, Abatement Services, and Site Remediation. Industrial Services (IS) involve primarily facility services like refinery turnaround, cleaning, repair, and maintenance of above ground storage tanks as well as other cleaning services for containers and manufacturing facilitates or other commercial sites such as airports. IS accounted for approximately $5.2 billion worth of services in 2002.[29] Abatement services are those contracted for cleaning buildings and is usually focused on asbestos clean up.[30] This was worth approximately $2.23 billion in 2002. This area is on a steady decline as the required cleanup of asbestos declines. Finally, Site Remediation involves remediation construction work performed at containment sites and was worth approximately $3.97 billion in 2002. Site Remediation (SR) activity varies and is highly dependant on the Superfund program. As an example, SR had $6.3 billion in revenue in the year 2000. The overall market is estimated at $55 billion with the US government providing the lions share of clean up money for this particular industry.[31]

Consulting and Engineering: The consulting and engineering (C&E) segment includes all those business that provide consulting, engineering, design, assessment, and project management functions for environmental projects. The consulting element of this segment is where most of the industry's expertise in regulatory issues, permitting, compliance, and systems integration resides. Total C&E revenue was $18.4 billion in 2001[32]. Approximately $2.30 billion of these services were exported, reflecting U.S. strength in environmental engineering technology, standards, and expertise.

The C&E segment has been negatively impacted by the current economic recession, but is probably suffering even more from systemic issues within the environmental industry. After double-digit growth in the 1980s (driven by proliferating regulations and environmental sensitivities), the segment went through a difficult period of adjustment and consolidation in the early 1990s, actually experiencing negative growth in 1996 before beginning a slight rebound. The environmentally specific knowledge and skills that C&E companies formerly provided have become institutionalized as core competencies throughout the engineering disciplines, so less of this work is currently performed by an identifiable sector.

One significant trend affecting the C&E segment has been the move toward design-build or design-build-operate contracts, especially for municipal projects such as wastewater treatment plants. Recognition of this opportunity has driven a recent spike in mergers and acquisitions, as companies structure themselves to fill this niche. Companies with revenues of more than $100 million now have over 50% of the market share, compared to approximately 33% in 1990.

EQUIPMENT

Environmental Instrumentation and Information Systems: The environmental instrumentation segment detects, monitors, and measures the presence of hazardous chemicals in all types of media.[33] These media include water, air, and soil. In the past, the market had been centered on fixed facility laboratory instrumentation; however, current consumer demand for "cheaper and faster" instrumentation has created a market

for field/onsite and in-line/process control systems.[34] Accordingly today's environmental consumers want instruments that provide greater productivity and flexibility, lower operating costs, minimum downtime, and more automation.[35]

Environmental instrumentation accounts for $2.5 billion in an $11 billion analytical market. Although the market is relatively mature and currently "flat" in the more developed countries, opportunities do exist in emissions-source testing, water-quality analysis, and dioxin testing especially in the North American, European, and Japanese markets.[36] In fact, these three regions account for more than 90% of the market for all analytical laboratory equipment combined.[37]

The real market growth in this sector can be found in developing countries. Countries such as China and India have stimulated double-digit growth for analytical laboratory instruments.[38] This growth is mirrored in other developing countries in the Pacific Rim, Middle East, Latin America, and Eastern Europe as they attempt to improve their water infrastructure as well. Information technology and systems support ($1.3B revenue) are slowly replacing the historical emphasis on domestic capital sales.[39]

Air Pollution Control (APC) Equipment: "The APC equipment segment of the environmental industry is comprised of companies selling equipment, supplies, materials, and maintenance for air pollution control systems." [40] There are three major components to APC: mobile air pollution control systems, equipment & instruments, and the services/monitoring equipment with revenues at approximately $20 billion dollars[41].

The largest revenue generator for air quality equipment is clearly presented by the mobile source[42]. Approximately $16 billion has been spent on the mobile source market of the APC, of which approximately $14.5 billion dollars has been spent on equipment. In 2005 to 2010, the supply market is expected to decline significantly as low/zero emission vehicles are introduced.

The most important industrial driver in air pollution control is the Clean Air Act (CAA)[43]. "The CAA created a mechanism by which air quality standards and emissions limitations are set and enforced by both federal and state agencies. With the passage of the 1990 CAA Amendments (CAAA), the law was expanded and revised[44]

Process and Prevention Technology (PPT): PPT is "any technology or process that improves the environmental and economic efficiency of a manufacturing process and can include improved process and can include improved computer control systems to lower raw material usage and waste." PPT is a small environmental segment today ($1.3B[45]) with great growth potential. However, it has not fully evolved into an identifiable segment of the environmental industry. PPT is an environmental segment that provides the strongest link for sustained development in manufacturing and service industries, as its aim is to reduce pollution at the source. It is difficult to identify the PPT segment because it is not regulation driven and the technologies and processes used cannot always be considered as pollution controls.

The difficulty of capturing the PPT environmental segment through cost-benefits and measures is compounded by the broad spectrum it covers. For example, the PPT segment can include employee training, environmental information systems, environmental accounting, resource and recovery, and automation. Also, improved production processes may be bundled in a company's proprietary manufacturing processes or product design and have dual purposes. Moreover, software functions

providing a manufacturing process or service with more efficient use of resources can lead to energy and raw material savings and pollution reductions.

RESOURCES

Resource Recovery: The resource recovery segment of the industry is that whose revenues are generated from the sale of recovered materials.[46] Resource recovery efforts in steel, non-ferrous metals, plastics, tires, paper, old corrugated cardboard, aluminum, glass and construction and demolition are tied to production rates within their market sectors. Volatility within the market, along with reduced production, negatively affects the resource recovery market sector.

Tariffs were implemented to help the steel industry survive cheap import steel, and correspondingly helped the resource recovery efforts in ferrous materials. In addition, China, Europe and other Asian countries have helped the United States resource recovery market niche with a growing appetite for our scrap. Furthermore, the US recycling effort was propped up by public sector support, and is slowly being absorbed by the private sector and the competitive market. As a result, divestiture, consolidation, and even bankruptcies, are helping prepare the market for long-term sustainment. Continued emphasis by the market in increasing the efficiency of recycling efforts, along with improvements in technology for resource recovery, is needed to keep the market viable in the long term. According to EBI, "more investment is needed to close the loop between solid waste and commodity materials."[47] Revenues in 2001 were $13.7B[48].

Environmental Energy Sources: A modest portion of the industry, revenues in 2001 were $10B[49]. Rather than cleaning up existing pollution or providing pollution control equipment and services for industries the best solution would be to prevent pollution before it happens through the use of environmental energy sources and mechanisms. Energy sources that do not add to pollution, do not deplete finite resources or are naturally replenishable may be categorized into the following groups[50]: Solar power: electricity, heat and energy generated through solar thermal and photovoltaic cells, fully renewable and non-polluting; Wind power: electrical or mechanical power generated through wind turbines; Geothermal Energy: Near-surface heat energy converted to electricity through thermal conduction and intrusion into the crust of molten magma; Mini-Hydropower: Electric power generated by small hydropower systems; Fuel cells: Devices that convert chemical energy (usually hydrogen) into usable electricity and heat without combustion and its associated pollution; Landfill Gas: Energy recovered from gases, mainly methane, emitted and collected from landfills as waste decomposes; Biomass Power: Electricity generated from biological materials (agricultural, wood and municipal solid waste), generally from burning.

SELECTED TOPICS

Financing of Environmental Energy Sources: Price is the factor that most affects the development and construction of environmental energy sources. Until the gap between the cost of conventional fuels and environmental energy sources is lessened, pollution from use of the former will continue and the only way for this gap to decrease is through lower construction costs of the new facilities or higher costs for the traditional resources.

Laws, with associated penalties, limiting the use of traditional energy sources could serve to increase the traditional costs. Tax incentives, such as tax credits or special allowances, would tend to decrease construction and development costs of new energy sources. Both of these strategies could be employed by local, state and national governments to encourage use of environmental energy sources.

Beyond tax incentives, special subsidies and grants may be given for this purpose. A number of international organizations, such as UNDP, GEF, USAID and the World Bank, have funds earmarked for environmental energy development.

Environmental Treaties: The US utilizes a number of environmental treaties as tools in its foreign policy arsenal. The Kyoto Protocol has gained media attention, especially since the US did not ratify it. There are many reasons for this non-ratification. In 1997, the US Senate adopted the Byrd-Hagel Resolution that urged the administration to not sign any agreement that would harm the US economy or include commitments from developing countries. In 2001 President Bush announced the US would not ratify the Kyoto Protocol as it would harm the economy and contained no commitments for 80% of the world. Although the Kyoto protocol has been ratified by 74 countries, collectively they represent only 36% of the carbon dioxide emissions of the Convention's Annex I Parties but, the Kyoto Protocol will enter into force only once 55 Parties of the Annex that account for 55% of the total carbon dioxide emissions have ratified the treaty.[51]

Global Warming: There are many data points that could lead to a conclusion that global warming is a detrimental phenomenon. Although the data is not in question, the linkages to man's effects are. Some data points: Greenhouse gas emissions constitute an environmental threat[52]; Sea ice shrinkage rates will drop by 20 percent by 2050, and the Arctic may be almost ice free during the summer months[53]; The tropopause, the zone separating the turbulent lower section of the atmosphere from the more stable stratosphere, has heightened over the last 20 years[54]; A huge amount of fresh water has diluted the salty North Atlantic, most of which, is coming from melting Arctic glaciers. This affects the Gulf Stream, which carries as much water as 75 Amazon Rivers, and transports 1 billion megawatts of heat[55]; and the hole in the ozone layer has ballooned over Antarctica to 3 times that of the US, but by September of 02, it shrank by nearly half then split into two[56]. In the end, for each indicator above, there are debated conclusions.

International Standards Organization (ISO) 14001 -- Training and Implementation: ISO 14001 addresses environmental management systems, environmental auditing, labeling, performance evaluation, and life cycle assessment in an effort to standardize organizational environmental management in any type of commercial or government operation. ISO 14001 provides a flexible tool for environmental improvement for organizations of any size, with any type of operations, in any part of the world

Over 110 of the world's nations are registered in ISO 14001. Organizations in Europe and Asia have been the most aggressive in pursuing ISO 14001 registration. Of the almost 41,000 registrations reported as of June 2002: 47% were in Europe, 41% were in the Asia-Pacific region, 8% were in North America, 2% were in South America, 1% were in Africa, and 1% were in north and west Asia (Russia and the Middle East).[57]

Global Highlights[58]: Some of the challenges facing the different regions are:

AFRICA: Increasingly, African countries are facing water stress, scarcity, and land degradation. The expansion of agriculture into marginal areas and clearance of natural habitats has been a major driving force behind land degradation. ASIA and PACIFIC: Overpopulation, poverty and lack of enforcement of policy measures have compounded environmental problems throughout the region. Discharge of sewage/wastes has heavily polluted freshwater while sedimentation in rivers and reservoirs caused by large-scale deforestation has also increased damage. Air pollution levels in some cities are among the highest in the world. EUROPE: The environmental situation is mixed with improvements to air pollution, but degradation to freshwater, coastal, and marine areas continue. While Western Europe's problems are lessening, many of the Central and Eastern European countries have growing problems as they struggle economically. LATIN AMERICA AND THE CARIBBEAN: With rising populations and lack of planning, environmental degradation has increased over the last 30 years. The natural forest degradation and risk to the reefs has garnered international attention. With populations clustered in cities, the air pollution, water contamination and inadequate waste disposal are causing severe health impacts. NORTH AMERICA: North America is a major consumer of the world's natural resources and a major producer of its wastes. Its per capita impact on the global environment is larger than that of any other region. Resource conservation has been less successful than pollution abatement. WEST ASIA: Freshwater scarcity is the main challenge for this region. Water deficits are being met through exploitation of groundwater resources – conservation policies are being enacted. Land degradation is a keen issue while hazardous waste production is among the highest in the world due to the types of industry in the region. POLAR REGIONS: Major environmental issues include the depletion of the ozone layer, the long-range transport of air pollutants, warming associated with global climate change, decline of several species and pollution of major rivers.

International Business: "Revenues generated outside the United States are now 8.1% of the environmental industry total – a noticeable gain from 6.7% in 1994. All told, exports were responsible for 40% of the $7.5 billion in environmental industry growth in 1995. This is indicative of the promise of international markets, as U.S. companies have only scratched the surface of many markets worldwide."[59] Environmental problems and challenges can be opportunities for savvy environmental firms to profit.

"In the prominent water, wastewater and solid waste segments – which together represent more than half the global market – the U.S. environmental industry has lost ground through the outright acquisition of its leading companies (French firm Vivendi's purchase of U.S. Filter in water) or the divestiture of international assets (sales of foreign operations by BFI and Waste Management in solid waste)."[60] Of interest, "In France, private management of the water and wastewater infrastructure has resulted in its having two of the three largest environmental companies in the world"[61].

Conclusion: It's economics. The industry, and the environment as a whole, is driven by economics. Industry goes where there is money, whether the expenditure is motivated by regulations or a "green" mentality. The relationship between government and the industry is shifting with greater privatization and an increasing interest in teaming. The industry is growing generally at a modest rate with some areas, clean technologies for one, showing real growth… indicative that the U.S. populous is showing increasing

interest in such technologies. The developed world's environment is improving – with economic improvement, some believe the developing world's environment will improve as well. At that time, the U.S. industry can capitalize on an expanded market.

Hydrogen Fuel Abstract

In his January 2003 State of the Union Address, President George W. Bush announced a significant increase in federal funding to support research into the development of hydrogen fueled automobiles. We of the Environment Industry Study group are intrigued by the role environmental considerations played in motivating this major government undertaking, and believe that because of the way the proposed initiative cuts across issues of United States security, economic strength, and technological leadership, and because it envisions creating a potentially massive industry sector through a unique government-industry partnership, it merits our group's survey and analysis. This analysis is provided as an appendix to this report.

APPENDIX
THE FREEDOM*CAR* INITIATIVE: VISION AND REALITY

THE VISION

> "Tonight I am proposing $1.2 billion in research funding so that America can lead the world in developing clean, hydrogen-powered automobiles. A simple chemical reaction between hydrogen and oxygen generates energy which can be used to power a car producing only water, not exhaust fumes. With a new national commitment, our scientists and engineers will overcome obstacles to taking these cars from laboratory to showroom so that the first car driven by a child born today could be powered by hydrogen, and pollution-free. Join me in this important innovation to make our air significantly cleaner, and our country much less dependent on foreign sources of energy." *President George W. Bush, State of the Union Address, January 28, 2003*

To many Americans, this announcement of greatly increased federal support for research into hydrogen-fueled automobiles was one of the most memorable proposals of President Bush's second State of the Union Address. In visionary-sounding rhetoric reminiscent of President John F. Kennedy's call for Americans to "go to the moon", the President raised the hopeful prospect of zero-emission personal transportation, offering a counter to the growing fears and apprehensions of a public bombarded by warnings of unbreathable air, escalating energy prices, dangerous dependence on foreign oil, and global climate change.

It is precisely because the President's proposal – labeled "FreedomCAR" (C-A-R standing for Cooperative Automotive Research) by the administration – cuts across so many areas of national concern, impacting the automotive, energy, and environment industries, with potentially significant consequences for national security and global economics, and because it represents a potentially unique prototype for the federal government leading creation of what may become one of the nation's largest commercial industries, that we have chosen to investigate it in this paper. In the following pages, we

will make a brief examination of the programmatic aspects of the proposal, its technological foundation, its environmental implications, its intersection with national security, and some of the key issues, obstacles, and opportunities along the road to a potential future hydrogen energy based economy.

THE PRESIDENT'S PROPOSAL

The recent hydrogen energy call to action is not the first from this President, although it has been the most publicized. The Bush administration's National Energy Policy, released during the first months of his term, stated that "in the long run, alternative energy technologies such as hydrogen show great promise". The administration's FreedomCAR initiative is, in general intent, the direct successor to the Clinton administration's Partnership for a New Generation of Vehicles (PNGV), with the somewhat controversially distinction that FreedomCAR shifts federal automotive research emphasis away from the PNGV focus on diesel-electric hybrid vehicles and high fuel mileage research in favor of hydrogen powered vehicles. The recent hydrogen fuel initiative, dubbed Freedom Fuel, has further refocused the FreedomCAR effort to address not only development of hydrogen fuel cells, but also the associated isolation, storage, and distribution systems required to move the U.S. away from a hydrocarbon-based and toward a hydrogen-based transportation sector.

The proposed $1.2 billion Freedom Fuel initiative, coupled with $500 million already appropriated for the FreedomCAR program, would result in a total of $1.7 billion spread over the next five years to develop hydrogen fuel cells, a hydrogen delivery infrastructure, and other advanced automotive technologies[62]. This proposed new federal funding would only comprise part of that being spent worldwide on hydrogen research. The U.S. private sector, especially the auto industry, has been investing substantially in recent years, as have foreign governments (primarily the European Union and Japan) and foreign private industry. However, hydrogen advocates have long maintained that without U.S. government leadership and funding to overcome economic start-up barriers, establish standardization, and, most importantly, develop common infrastructure, the vision of a hydrogen-based transportation structure could never be translated into commercial reality.

The President has articulated three specific goals for the Freedom Fuel program[63]:

- Lower the cost of hydrogen.
- Create effective hydrogen storage.
- Create affordable hydrogen fuel cells.

The President also maintains that the success of the Freedom Fuel initiative and the associated FreedomCAR will achieve the following strategic benefits for the U.S.[64]:

- Enhance America's security by reducing dependence on foreign oil.
- Ensure America's energy independence.
- Improve air quality and dramatically reduce greenhouse gas emissions.

THE TECHNOLOGY

The basic theory behind hydrogen fuel cells has been known since the early nineteenth century. Today, there are several fuel cell designs, differing in their power demand capabilities, operating temperatures, and cell membrane and catalytic materials.

Fuel cell designs such as phosphoric acid (PAFC), proton exchange membrane (PEM), molten carbonate (MCFC), solid oxide (SOFC), direct methanol (DMFC), zinc-air (ZAFC), and protonic ceramic (PCFC) are either functioning commercially or showing promise in the laboratory. Some system designs include an integrated fuel reformer that can produce hydrogen from any hydrocarbon fuel (such as natural gas, methanol, or gasoline), while yielding much lower emissions than the cleanest fuel combustion processes. Although there are no fuel cell designs that are currently cost-competitive with conventional combustion engines for automotive applications, the FreedomCAR vision is that further development and economies of scale will eventually solve this problem. From an overview perspective of an eventual hydrogen economy, it is ultimately unimportant which designs are adopted in the marketplace: they will simply be the "black boxes" that take in hydrogen and produce useful power without environmentally harmful byproducts.

The much more critical question to the vision of the hydrogen economy is how the free hydrogen (H_2) itself will be obtained. There is very little free diatomic hydrogen available on earth: seventy percent of hydrogen is bound with oxygen to form water (H_2O), and most of the remainder is bound with carbon or other elements. This propensity for hydrogen to bind makes it necessary to separate the hydrogen from the other elements of a compound using methodologies commonly called *isolation*. These methods vary in their expense, efficiency, and environmental biproducts. There are several methods of hydrogen isolation:

- Natural Gas Steam Reforming. Natural gas (CH_4) is treated with high temperature steam, breaking it down into its constituent parts and releasing the hydrogen. This is currently the most prevalent method, and the most economical for producing hydrogen in large commercial quantities.
- Biomass Gasification and Pyrolysis. Using agricultural residues and wastes, or biomass (any organic material) specifically grown for energy uses, hydrogen can be produced via pyrolysis (or gasification): the process of converting a solid or liquid into a gas through chemical decomposition.
- Water Electrolysis. This method introduces electricity into water to separate it into hydrogen and oxygen. Electrolysis provides only a small percentage of the world's hydrogen, mostly for applications requiring small volumes at high purity. It is very energy intensive and cannot compete economically with other large-scale methods of hydrogen production.
- Reversible Fuel Cells/Electrolyzers. Operating a proton exchange membrane (PEM) fuel cell in reverse as an electrolyzer is possible, but optimum operating conditions for the power production mode and for the hydrogen production mode are significantly different. Design issues for the reversible fuel cell system include thermal management, humidification, catalyst type, and loading.
- Partial Oxidation/Ceramic Membrane Reactor. Scientists are developing a ceramic membrane reactor for the simultaneous separation of oxygen from air and the partial oxidation of methane. If successful, this process could result in improved hydrogen production compared to conventional hydrogen reformers.
- Photo-Biological. Certain photosynthetic microbes produce hydrogen in their metabolic activities using light energy. The idea is to use the bacteria to split seawater to extract hydrogen. However, these bacteria are most effective

in an anaerobic, or oxygen free environment. Genetic engineering research shows the potential for making the organisms oxygen tolerant, increasing possibilities for their practical use in hydrogen production.

- Photo-Electrolysis. Multi-junction cell technology developed by the photo-voltaic industry is being used for photo-electrochemical (PEC) light harvesting systems that generate sufficient voltage to split water and are stable in a water/electrolyte environment.

The critical issue for all of these isolation methodologies is that those which can produce hydrogen in large volumes require considerable energy input (and are therefore indirect polluters through the initial – usually fossil fuel – source of the energy), while those processes which are "clean" cannot yet operate at a scale to be commercially practicable. This is the major technological challenge which Freedom Fuel must overcome to realize the vision of being truly "pollution-free": otherwise, hydrogen-based transportation will simply relocate fossil fuel consumption and greenhouse gas emission from the individual automobile to the hydrogen isolation plant, but do nothing to eliminate it.

THE DEPARTMENT OF ENERGY PLAN

The Department of Energy (DOE) is the agency responsible for implementation of the FreedomCAR initiative. DOE's vision for hydrogen energy had been in place for some time prior to the President's State of the Union Address. That vision is contained in the department's *National Vision of America's Transition to a Hydrogen Economy – To 2030 and Beyond* published in February 2002, and the November 2002 *National Hydrogen Energy Roadmap.* These two documents provide strategic guidance for continued research and development – now at a more rapid pace with the President's proposed funding increase – into commercialization of hydrogen energy.

As a result of the National Energy Policy produced by Vice President Richard Cheney's Energy Task Force in May 2001, DOE Secretary Spencer Abraham directed that a plan be developed to move the U.S. toward a future hydrogen economy. In November 2001, fifty-three senior executives from the energy and transportation industries, universities, state and federal government agencies, and National Laboratories gathered in Washington, DC for the National Hydrogen Vision Meeting, which resulted in publication of the *National Vision of America's Transition to a Hydrogen Economy – To 2030 and Beyond* (NVATHE). The intent of NVATHE was to identify: (1) a common vision of a future hydrogen economy, (2) the time frame for transition to a hydrogen economy, and (3) the key milestones to reach the future hydrogen economy.[65] The NVATHE is intended to provide various constituent groups (such as industry, policy makers, and researchers) a foundation upon which to coordinate future actions related to hydrogen energy development. The vision of the document is to enhance the conversion of the U.S. economy from one based on hydrocarbon fossil fuels to hydrogen as the primary energy resource. A summary of the major findings from the National Hydrogen Vision Meeting and contained in the NVATHE are as follows[66]:

- Hydrogen has the potential to solve two major U.S. energy challenges:
  - dependence on petroleum imports
  - pollution and greenhouse gas emissions

- Hydrogen could play an increasingly important role in America's energy future.
- The transition toward a so-called "hydrogen economy" has already begun.
- The "technology readiness" of hydrogen energy systems needs to be accelerated.
- Co-development of hydrogen utilization devices and a distribution system is required.

The NVATHE provided the foundation for the next step in the process, the *National Hydrogen Energy Roadmap*. As stated in its introduction: "This Roadmap is neither a government research and development plan nor an industrial commercialization plan. Rather it explores the wide range of activities required to realize hydrogen's potential in solving U.S. energy, security, and environmental needs"[67]. Most importantly, the document provides a methodology for coordination of both public and private sector efforts for the long-range development of all aspects of hydrogen energy as a key renewable resource for the future. Specifically, it lays out a plan for resolving the remaining challenges in each of the following segments of an overall hydrogen energy system[68]:

- Production. Government-industry coordination on hydrogen production systems is required to lower overall costs, improve efficiency, and provide means for sequestering carbon dioxide produced in the hydrogen extraction process (an essential development if the hydrogen economy is to be greenhouse gas free).
- Delivery. A greatly expanded distribution infrastructure will be needed to support the expected development of hydrogen production, storage, conversion, and applications.
- Storage. Hydrogen storage is a key enabling technology and the current technologies must be improved to satisfy the requirements.
- Conversion. Cost effective hydrogen conversion technologies to produce useful forms of electric and thermal energy will expedite the development and use of fuel cells, reciprocating engines, turbines, and process heaters.
- Applications. Consumer applications for hydrogen energy must be developed in the fields of transportation, electric power generation, and portable electronic devices such as mobile phones and laptop computers.
- Education and Outreach. Programs must be implemented to educate consumers to shift their choices in energy markets, technology development, and public policy.
- Codes and Standards. Uniform codes and standards for the design, manufacture, and operation of hydrogen energy systems, products, and services can dramatically speed the development process from laboratory to the marketplace.

In short, DOE and other conference participants believed strongly in the viability of hydrogen as a renewable energy source, and through the NVATHE and the Roadmap developed a methodology for coordinating the elements of a hydrogen energy system. Recently, DOE has also been coordinating its efforts with the National Hydrogen Association (NHA), a private sector clearing house and discussion forum dedicated to creating a shared hydrogen energy vision for various stakeholders. The NHA had

published the *National Hydrogen Association Near-Term Hydrogen Implementation Plan 1999 – 2005*[69] and *Strategic Planning for the Hydrogen Economy: The Hydrogen Commercialization Plan*[70], providing blueprints for hydrogen energy implementation into the economy and a long-term commercialization plan. These two documents parallel DOE's efforts to a degree, but also specifically address actions and initiatives that must be undertaken by the private sector to move forward in the development of a hydrogen economy.

BARRIERS TO A HYDROGEN ECONOMY

Commercialization of hydrogen fuel cells for automotive applications, as proposed by FreedomCAR, possesses great potential. However, there are a number of key challenges to overcome before this vision can succeed in the marketplace. The first and greatest challenge will be reducing cost, which currently prices the technology out of the consumer market. In order to compete in the automotive sector, fuel cell technologies will have to be mass-produced at a cost low enough to enter the broad market competition of the automotive industry. In addition to the per-unit cost of the of the fuel cell power units, there will be expensive capital investments required to establish production lines. In order for hydrogen powered cars to become truly cost competitive in the marketplace, there will have to be sufficient demand to achieve economies of scale comparable to those for traditional technologies. Normally, market requirements drive capital investment, but for the hydrogen fuel cell industry the producer (likely, with assistance from the government) will have to initially drive the market until there is a large enough demand to make efficient use of production resources.

In addition, fuel cell technology is not yet advanced enough to meet the size and weight requirements of automotive applications, nor is there an established infrastructure for distributing hydrogen fuel and supplying it at locations where there will be market demand. Until these challenges are rectified, automotive fuel cell technology will be difficult to adopt.

Finally, there will be difficult issues of intellectual property rights and industrial competitiveness to address if the "cooperative" research proposed by FreedomCAR is to bear fruit. As stated earlier, private industry has spent hundreds of millions of dollars on research and development, and will expect some proprietary right to realize return on this investment. The private sector's advanced research, if combined with government research and funding, could bring about the commercialization of the technology more quickly. However, if government research and development duplicates private sector research because of concerns about intellectual property rights, national resources will have been poorly employed. DOE will have to address numerous policy and legislative issues if the program is to be genuinely synergistic rather than counterproductive, and respectful of the competitive concerns of industry participants.

ENABLERS FOR A HYDROGEN ECONOMY

There are many things the government can do to greatly assist the commercialization of automotive hydrogen fuel cells. First, the government must partner with private industry for technology development, as FreedomCAR envisions and the NVATHE describes. In this effort DOE leadership will be challenged to ensure that

public money is not needlessly spent on duplicating or subsidizing private sector research, where the means and market drivers already exist for industry to fund the effort. Most critically, the government will have to take the lead in developing infrastructure for hydrogen isolation, storage, and distribution. The economics of developing and initially operating this infrastructure make it highly unlikely – even impossible – that it would ever be achieved by any private venture.

In addition, the government will have to become an early adopter of the technology by leading the way in acquiring hydrogen fuel cell vehicles. Since the federal government is currently one of the largest users of energy, its adoption of fuel cells will provide a ready and guaranteed market that will help entice investors to provide capital for the production of fuel cells. This will help create a demand for a new industry and also offer a key opportunity for public education and acceptance of fuel cell technology.

An education and outreach program established by the government to increase public awareness of the advantages of fuel cell technology would be an important step toward building confidence in the hydrogen fuel technology. It would be important for this education program to provide awareness of the true social, security, and environmental costs of continuing with our current hydrocarbon-based economy.

Finally, and perhaps most difficultly, the government will need to change key regulations, laws, and incentives to encourage (or force) consumers to change their buying habits. Americans' infatuation with cars is legendary. Without regulations to change the existing automotive industry practices, automobile companies will continue building vehicles that provide high performance and features such as 4-wheel drive and excess power instead of focusing on fuel economy and environmental efficiency. Tax incentives will have to be enacted to subsidize portions of the hydrogen fuel industry, especially for initial capital costs. Codes and standards may have to be modified to allow some variance in materials that may be used, to facilitate economical transition of hydrogen fuel cells into the market.

THE ARGUMENTS

When the President first announced Freedom Fuel in his State of the Union Address, commentators initially responded favorably, noting that "environmental groups welcomed Bush's proposal" and that "fuel cells R&D already [had]… strong bipartisan support on Capitol Hill"[71]. The CEO of the Alliance of Automobile Manufacturers issued a statement "commend[ing] President Bush's dedication to forging a government-industry partnership to develop fuel cells"[72]. There was broad acknowledgment that "the world's petroleum-based economy will probably eventually yield to a hydrogen-based economy"[73,74], and approval of the President's goal of placing America at the front of this trend. Yet despite the general popularity and fundamental appeal of the vision of a hydrogen economy, there have also been expressions of doubt and skepticism.

The Political Debate

As is invariably the case with any major government program – especially one encumbered with the politics of the environment and energy – many discussions of the FreedomCAR proposal are heavily colored by politics, often making even analyses that purport to be "purely technical" suspect. More than one former booster has become a

skeptic, solely a result of the issue crossing over from being a Democratic proposal (championed by former Vice President Al Gore, among others) to a Republican one[75]. In fact, the Clinton administration's much-touted PNGV "supercar" initiative – which essentially consumed $1.6 billion while producing no tangible product – was criticized by opponents as a political "smoke screen" for inaction on conventional automobile fuel standards using virtually identical language to that being levied against FreedomCAR today[76]. Referring to Clinton and Gore, one critic stated that "by resorting to discussion of speculative fantastic leaps to distract attention from bad energy policy in the present, Bush has simply taken his cue from two previous masters of petroleum-waste inaction"[77].

Considering the politicization of the issue, it is no surprise that while Republican House Science Committee Chairman Representative Sherwood Boehlert (R-NY) hailed the President's proposal as "exactly the kind of investment we need to make in our energy future"[78], many Democrats charged that it was no more than an attempt by the environmentally weak Bush administration to deflect criticism from other shortcomings. "It's just the latest installment of the president's drill today, drill tomorrow" agenda, stated Senator John Kerry (D-MA)[79]. "Those are nice crumbs… words are cheap, actions are more telling" said Representative Peter DeFazio (D-OR)[80]. Representative Dennis Kucinich (D-OH) even went so far as to propose – not particularly constructively – that if the President were serious about making the country independent of foreign oil, the administration should take the hundreds of billions of dollars it may spend on a war and invest it in hydrogen powered automobiles[81].

One Democrat who "applauded" the spirit of President Bush's proposal was Senator Byron Dorgan (D-ND) – while arguing that the Freedom Fuel initiative does not go nearly far enough. Dorgan subsequently introduced legislation calling for an "Apollo-like project" for hydrogen fuel development investing $6.5 billion over 10 years. Co-sponsored by Senators Joe Lieberman (D-CT), Hillary Clinton (D-NY), Daniel Akaka (D-HI), and others, and endorsed by the Union of Concerned Scientists and the Natural Resources Defense Council, the bill is currently pending in the Senate[82].

The ultimate Washington reality of the debate was accurately summarized in *USA Today*: "Hydrogen is political. Good idea or bad, too little money or too much, the president's critics will fight it."[83]

The Environmental Realities

The Freedom Fuel promise of zero-emission transportation is especially vulnerable to one key argument: hydrogen is not a fuel. In a sense, it is merely a means of transporting energy, which is "stored" in the hydrogen when its bonds to other atoms are broken during the extraction process. The real source of the energy is in an input to the isolation process, which is what has led some to term both electric and hydrogen automobiles "elsewhere emission" vehicles[84]. In the words of one study, "while operating a vehicle powered by a hydrogen fuel cell may cause no polluting emissions, generating the hydrogen in an environmentally inefficient manner could largely cancel out this advantage"[85].

Of all the hydrogen extraction technologies, that which is generally agreed to be most environmentally efficient (and also economical) is natural gas reforming, in which hydrogen is removed from natural gas by heat, usually provided by steam. This process is estimated to have the potential of producing life-cycle emissions of less than 70

kilograms of carbon dioxide per 1000 kilometers of travel (compared with 248 kilograms for a conventional internal combustion engine)[86]. The question of how to heat this steam, however, becomes highly contentious. If the heat comes from coal, the overall output of global warming gas could either double[87], be cut in half[88], or drop to essentially zero (if carbon sequestration is perfected[89]), depending on whose estimate is believed. While a nuclear reactor provides an excellent technical solution with no greenhouse gas output, one observer has noted that producing "our miracle zero-emission hydrogen... from fossil fuels via an intermediate stop at a nuclear reactor [is] not exactly what the Sierra Club had in mind"[90]. As discussed earlier, other hydrogen production options (electrolysis using solar power or other "green" electricity sources, fusion reactors, hydrogen-making microorganisms, etc.) are either outside current technological reality or not yet economically feasible[91,92].

This hard technical truth – that usable hydrogen is not environmentally "free", and probably never will be – is generally seen as the central flaw in the President's vision. In the words of the Sierra Club's director for global warming, pursuing a cleaner environment by shifting emissions from an automobile tailpipe to an isolation plant smokestack is "like trying to lose weight by running to McDonald's"[93].

The Necessity

The final family of arguments against the Freedom Fuel initiative relate to whether such an "alternative" energy technology is really necessary in the first place, or if fossil fuels have been unfairly demonized by the environmental community in contradiction of scientific and economic reality. One study asserts that "resource economists are almost uniformly of the opinion that fossil fuels will remain affordable for any foreseeable future"[94], citing the fact that "world oil reserves today are more than 15 times greater than they were when record keeping began in 1948"[95], and concluding that "fossil fuels are not being depleted and will probably continue to grow even more plentiful for decades to come"[96]. Many groups make the related argument that we are nowhere near reaching the attainable limits of pollution from conventional combustion or hybrid technologies (a car built in 2004 will run 99 percent cleaner than one built in 1960[97], and most believe more gains can be achieved), and that we should be placing our near-term focus here, on efficient fossil fuel propulsion, rather than investing in the distant – and perhaps superfluous – promise of hydrogen[98,99,100].

THE PROGRESS:

The hydrogen economy is not entirely a dream of the future. Already today, there are a number of functioning fuel cells in commercial use proving the technology's viability, even if many market barriers to widespread adoption still remain.

For example, DOE recently entered into a partnership with the City of Las Vegas and the company CIW Plug Power to build the world's first hydrogen and electricity co-production facility in Las Vegas. This facility will serve as a learning demonstration of hydrogen as a safe, clean, energy source for vehicle refueling[101]. DOE has also been partnering with industry to build personal mobility vehicles or "scooters" for the elderly and hydrogen powered wheelchairs. Underground mine locomotives using PEM fuel cells are undergoing safety risk assessment and advanced testing at Reno, Nevada. This

project, a joint venture between Vehicle Projects LLC, Fuel Cell Propulsion, and Sandia National Labs, could produce an economically feasible alternative to underground trains. The California Fuel Cell Transit Authorities will begin evaluating up to twenty buses using hydrogen fuel beginning in 2004.

In March 2003, General Motors unveiled a $4 million prototype of a hydrogen fueled vehicle in Washington, DC. Ford is set to unveil its prototype in June 2003, while BMW has refitted ten of its Model 745 sedans with hybrid engines that burn either gas or hydrogen. Japan's Toyota and Nissan rolled out multimillion-dollar hydrogen hybrids in December 2002.

While the transportation sector is seemingly leading the way, other hydrogen applications are occurring as spin-offs. A small company, CH Technologies, has demonstrated a hydrogen device that can power a toy train, a radio, or a lamp off a small fuel cell the size of a can of soda. Such micro fuel cells could power computers, personal assistants, or radios, completely revolutionizing the $6 billion battery industry and potentially eliminating a significant source of toxic waste in landfills. Hydrogen fuel cells for underwater robots, communication systems, medical systems, power plants, home appliances, and future space systems are all being investigated or discussed.

The Department of Defense (DOD) has also shown interest in some of the unique capabilities offered by hydrogen fuel cells. General Motors is in discussion with DOD to produce a reforming gas-to-hydrogen fuel cell system, in response to the desire of military logisticians to be freed from heavy, transport-intensive, high-consumption fossil fuel. Also, hydrogen engines are more efficient, very quiet, have lower weights, and provide low heat signatures, making them attractive for some specialized military mission requirements. DOD is also looking into hydrogen fuel cells as replacements for electrical generators, or the batteries that are critical to so many pieces of military equipment.

CONCLUSION: In the final analysis, there is no question that hydrogen fuel research will go forward, government sponsorship or not. There is no sector – automotive, energy, scientific, environmental, or political – that is of monolithic opinion either for or against hydrogen fuel. Most generally agree there is merit to the concept, while differing on the level of effort that should be expended toward its development, relative to other opportunities. Ultimately, the safest prediction to make may be that the market will do its own job of selecting the best, most economical, most convenient personal transportation technology in the long run, just as it did when the combustion engine supplanted the horse at the turn of the last century[102]. We should never shrink from having a vision, though, and this is one of enduring attraction and power. It was the vision spoken of by scientist Cyrus Harding in Jules Verne's fictional *The Mysterious Island*[103], written in 1874.

"Yes, my friends, I believe that water will one day be employed as fuel, that hydrogen and oxygen which constitute it, used singly or together, will furnish an inexhaustible source of heat and light, of an intensity of which coal is not capable. Some day the coalrooms of steamers and the tenders of locomotives will, instead of coal, be stored with these two condensed gases, which will burn in the furnaces with enormous calorific power. There is, therefore, nothing to fear... I believe... that when the deposits of coal are exhausted we shall heat and warm ourselves with water. Water will be the coal of the future." "I should like to see that," observed the sailor.

"THE FREEDOM*CAR* INITIATIVE" AUTHORS

Colonel Donald Hyde, U.S. Army
Lieutenant Colonel Abdulla Al-Meraikhi, Qatar Air Force
Lieutenant Colonel Rodney Alston, U.S. Army
Lieutenant Colonel William Bierbaum, U.S. Air Force
Mr. Larry Brady, U.S. Agency for International Development
Lieutenant Colonel John Decknick, U.S. Air Force
Commander John Kroft, U.S. Navy
Mr. John Mazur, U.S. Department of the Air Force
Lieutenant Colonel John Simmons, U.S. Marine Corps
Lieutenant Colonel John Taylor, U.S. Army
Commander Matthew Weingart, U.S. Navy

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