Environmental Issues of United States

During the Industrial Revolution, climate and environment have started changing mainly due to agricultural and industrial practices. Through population growth, fossil fuel burning, and deforestation, there has been mixture of gases in the atmosphere that affect human life. Gases are released in the atmosphere mostly as a result of human activities. The levels of carbon dioxide, methane, nitrous oxide, and ozone have significantly increased in the past ten years.

The United States' energy policy has historically stimulated the development of a fuel-intensive economy based on natural resource extraction and processing. The United States remains the largest energy consumer in the world, and also the world's largest emitter of energy-related carbon dioxide. Most industrialized countries rely much less heavily on coal, which is highly carbon intensive, to meet their domestic energy needs than does the United States.

Motor vehicles represent the single largest man-made source of air pollution in the United States. In recent years, the shift from cars towards larger vehicles is the reason for a reversal of years in fuel efficiency improvements. Fuel efficiency technology improvements have not been sufficient to compensate for the increasing popularity of fuel-inefficient vehicles. These vehicles produce, on average, one-third more carbon dioxide per mile than the average passenger car.

In 2001, the United States consumed 24% of total world primary energy consumption. The United States emitted 1,883 million metric tons of carbon in that year, accounting for around 24% of world energy-related carbon emissions.

In February 2003, the U.S. Department of Energy launched President Bush's "Climate Vision" program is intended to help meet the President's goal of reducing U.S. greenhouse gas intensity (the amount of carbon emitted per dollar of economic output) by 18% between 2002 and 2012. The program involves various Federal agencies working with industrial partners to reduce greenhouse gas emissions over the next decade.

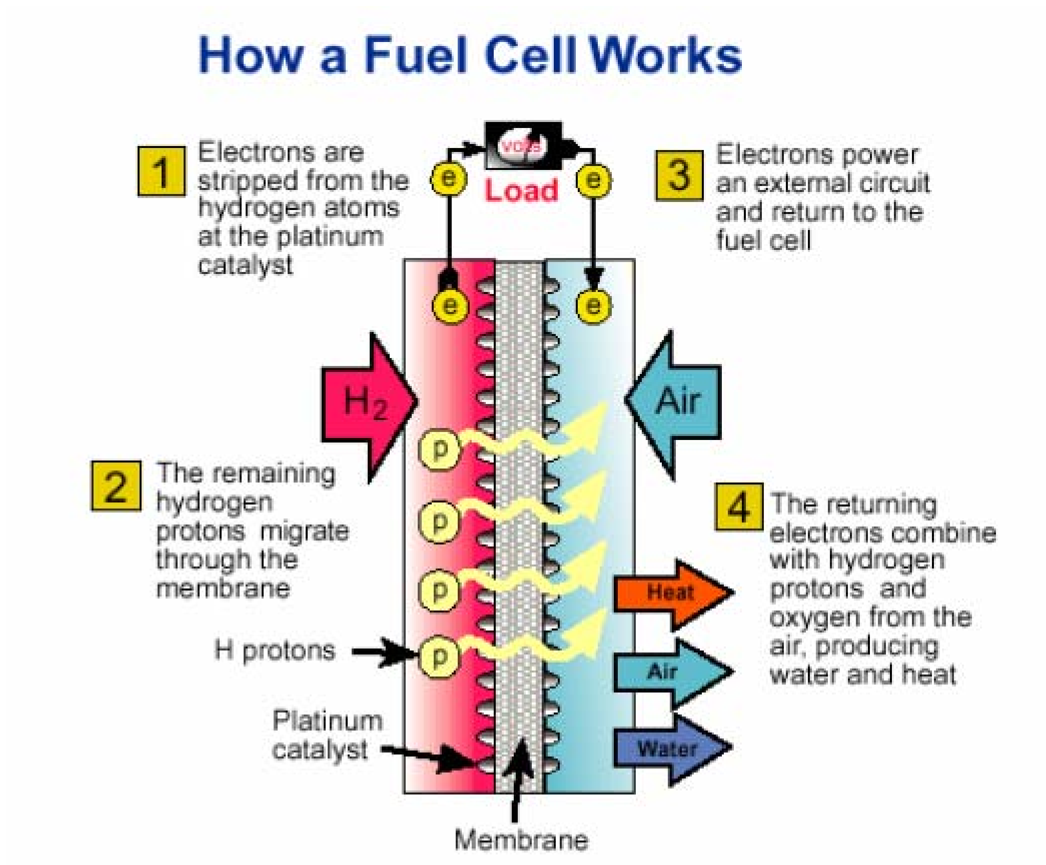
In his January 2003, President Bush announced a $1.2 billion hydrogen fuel initiative aimed at developing technologies to produce, store, and distribute hydrogen as a fuel for power generation and transportation. Also, the Bush Administration has initiated a program called "FreedomCAR" (Cooperative Automotive Research) which aims to develop hydrogen fuel cell technology, hydrogen infrastructure, and advanced automotive technologies such as hydrogen-powered fuel cell vehicles.

According to the United States Energy Information Agency's (EIA) "Annual Energy Outlook 2003" (AEO 2003), U.S. energy consumption is expected to increase at an average annual rate of 1.5% through 2025. Total carbon emissions also are expected to grow at a 1.5% annual rate, reaching 2,237 million metric tons by 2025.

Introduction to Hydrogen Energy

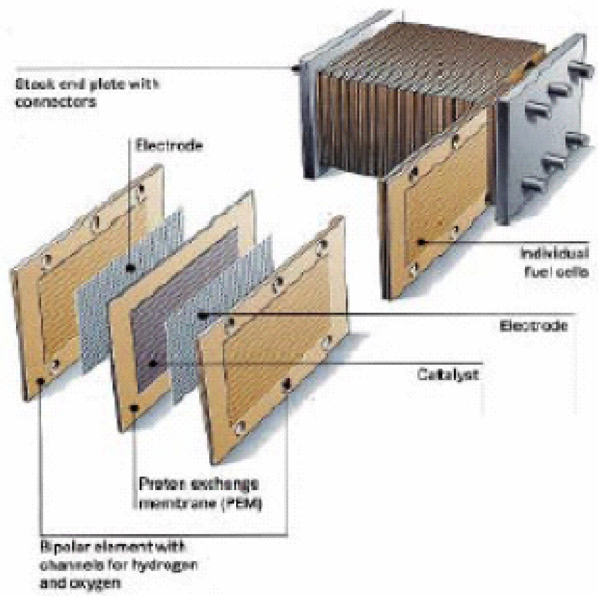
Hydrogen is the simplest element, it consist of one proton and one electron. Hydrogen is never found alone. It is always combined with other elements such as oxygen and carbon. It is found in water, biomass and organic compounds such as natural gas, methanol, and propane.

Hydrogen has high electrochemical reactivity and it is very attractive for the use in the fuel cells. A fuel cell is electrochemical device that converts fuel's chemical energy directly to electrical energy with high efficiency. Electricity is created though separation process.



Hydrogen fuel is fed into the "anode" of the fuel cell. Oxygen enters the fuel cell through the "cathode". Hydrogen atom splits into a proton and an electron, which take different paths to the cathode. The proton passes through the membrane (platinum electrolyte). The electrons create a separate current that can be utilized before they return to the cathode to be reunited with the hydrogen and oxygen in a molecule of water.

Figure 2: Fuel Cell 'Stack' to produce current and voltage output to match an application



The voltage from a single cell is approximately 0.7 volts, enough to power a light bulb. In order in generate more power fuel cells can be stacked in series in order to satisfy operating voltage.

Fuel cells are similar to batteries in operation and constituents. The key difference is that while batteries store energy, fuel cells produce electricity continuously as long as fuel and air are supplied.

Hydrogen is produced from hydrogen rich materials (methanol, ethanol, natural gas, petroleum distillates, and coal) though reformation process. There are several kinds of reformation methods. The most common method of reformation is steam-reforming or electrolytic processes. Ninety-five percent of all hydrogen is produced through steam reforming of natural gas. Down side is that steam-reforming is an endothermic process which means that energy, natural gas, is consumed. Thirty percent more natural gas is required for the medium scale production. On a large scale production the efficiency increases to over to over 85%.

Steam reforming of natural gas is currently the least expensive method of producing hydrogen, and used for about half of the world's production of hydrogen. A large steam reformer which produces 100,000 tons of hydrogen a year can supply roughly one million fuel cell cars with an annual average driving range of 16,000 km.

In steam reforming of natural gas, 7.05 kg CO_2 are produced per kilogram hydrogen. The emissions of NOX, SOX which are more dangerous than CO2 are cut to zero.

	Production	Storage	Cost est./ gal. eq	Safety	Distribution Infrastructure	Environmental Attributes
RFG	Large existing production operation Uses imported feedstock No energy security or trade balance benefits	Conventional storage tanks	$.05-.15 more than gasoline	Low flashpoint Narrow flammability limits Potentially carcinogenic when inhaled	Existing infrastructure and distribution system	Reduction in greenhouse gases Much lower reactive hydrocarbon and sulfur oxide emissions than gasoline
M 100	Abundant domestic/imported natural gas feedstock Can be manufactured renewably from domestic biomass - not currently being done	Requires special storage because fuel can be corrosive to rubber, plastic and some metals	$.90	Toxic and can be absorbed through the skin No visible flame Adequate training required to operate safely	Infrastructure needs to be expanded	High greenhouse gas emissions when manufactured from coal Zero emissions when made renewably
E 100	Made from domestic renewable resources: corn, wood, rice, straw, waste, switchgrass. Many technologies still experimental Production from feedstocks are energy intensive	Requires special storage because fuel can be corrosive to rubber, plastic and some metals	$1.10-$1.15	Wide flammability limit Adequate training required to operate safely Less toxic than methanol and gasoline	Nearly no infrastructure currently available Food/fuel competition at high productions levels	Zero carbon dioxide emissions as a fuel Significant emissions in production
H_2	Domestic manufacturing: Steam reforming of coal, natural gas or methane Renewable solar	Compressed gas cylinders Cryogenic fuel tanks Metal hydrides Carbon nanofibers Currently storage systems are heavy and bulky	$.79-$1.91	Low flammability limit Disperses quickly when released Nearly invisible flame Odorless and colorless Non-toxic Adequate training required to operate safely	Needs new infrastructure	High emissions when manufactured from electrolysis Lower emissions from natural gas Zero emissions when manufactured renewably
CNG	Abundant domestic/imported feedstock Can be made from coal	CNG needs to be compressed during refueling and requires special nozzles to avoid evaporative emissions Stored in compressed gas cylinders	$.85	Low flashpoint Non-carcinogenic Dissipates into the air in open areas High thermal efficiency Adequate training required to operate safely	Limited infrastructure	Non-renewable Possible increase in nitrogen oxide emissions

Hydrogen can be derived from renewable energy resources such as water and at the same time provide a clean and abundant energy source, capable of meeting zero emission effect. The only emission that is created is water and heat. Hydrogen made from renewable energy resources can have potential of having continuous cycle of energy production. The waste product, water, can be electrolyzed to make more hydrogen. Power from solar cells or wind turbines can be used for electrolysis. There are other renewable methods for deriving hydrogen. Biophotolysis is a biological method that derives hydrogen using the natural photosynthetic activity of bacteria and green algae.

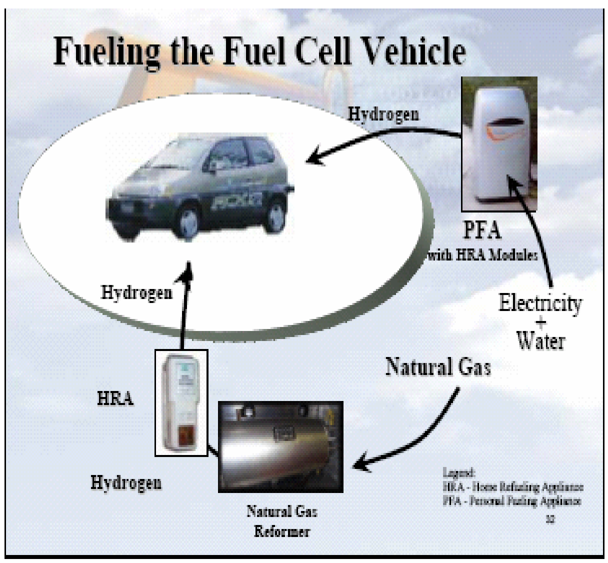
Fuel Cell Applications

♦ Transportation

The majority of fuel cell vehicles is used in fleet vehicles, such as buses, light duty vehicles and local governments world wide.

Car manufacturers also have recognized that their future fuel will most likely be hydrogen. Ford chairman Bill Ford Jr. has been the most outspoken on the desirability of a hydrogen economy. In a speech in 2000, he declared that fuel cells will end the 100-year reign of combustion engines in the near future.

The latest fuel cell cars include DaimlerChrysler's F-Cell A-class, of which they want to test 60 models in day-to-day operation. DaimlerChrysler intends to invest a further US$ 1 billion into their fuel cell development program before the end of 2004. General Motors unveiled its concept vehicle as a base for multiple technologies including fuel cell applications in 2002. Furthermore they have equipped an OPEL Zafira compact van with fuel cells, following its earlier HydroGen3 test vehicle. Ford has developed a fuel cell powered Focus and the Asian carmakers Honda (FCX), Nissan (X-Trail FCV) and Toyota (FCHV-5, Fine-S) have their own vehicle test programs well underway. Vehicles from Honda and Toyota have been leased onto American and Japanese roads. However, some motor companies are still putting effort into hydrogen ICE (internal combustion engine) powered cars due to the fact that they don't believe in a rapid changeover from petrol-powered to fuel cell-powered vehicles. The latest models are Ford's Model U and BMW's seven series. Even though both companies are examining the use of fuel cells as well, BMW is investigating fuel cells primarily as Auxiliary Power Units (APU).



The GTI hydrogen fueling system under development is a publicly accessible fast-fill station capable of delivering 40 to 60 kilograms of hydrogen per day to vehicles with onboard storage systems operating at 350 bar. The fueling system will consist of a reformer, gas purifier, compressor, storage, and a dispenser. This system could also be configured for private fast-fill or time-fill service.

♦ **Stationary Power Systems**

More than 10 000 fuel cell systems have been installed all over the world - in hospitals, financial institutions, hotels, office buildings, homes, schools, utility power plants, and an airport terminal, providing primary power or backup.

Few milliseconds without electricity can cause significant problems for many institutions. The National Power Laboratory estimates that typical computer location experiences 289 disturbances a year which can result in millions of dollars of lost revenues. Heat from the fuel cell can provide energy for space heating, increasing the overall efficiency of the fuel cell system.

Fuel cells currently operate at landfills and wastewater treatment plants across the country, proving a valid technology for reducing emissions and generating power from the methane gas they produce.

♦ **Portable Power**

There is substantial R&D involved in designing miniature fuel cells for telecommunication devices. Once available on the market, such fuel cells will allow consumers to talk for up to a month on a cell phone without recharging. Same things apply to laptops and palm pilot. Other applications for micro fuel cells include portable power tools and low power remote devices such as hearing aids and alarm systems. These miniature fuel cells generally run on methanol, an inexpensive wood alcohol also used in windshield wiper fluid.

Environmental benefits of Hydrogen Energy

In the future, hydrogen and electricity are the only energy carriers that can be completely pollution free. Electricity has already proved its value but is not a useful form of energy in remote areas or in transport, primarily due to difficulties of storage. Hydrogen is also difficult to store and transport but over long term it becomes more efficient to use than electricity.

ASA has used liquid hydrogen since the 1970s to propel the space shuttle and other rockets into orbit. Hydrogen fuel cells power the shuttle's electrical systems, producing a clean byproduct—pure water, which the crew drinks.

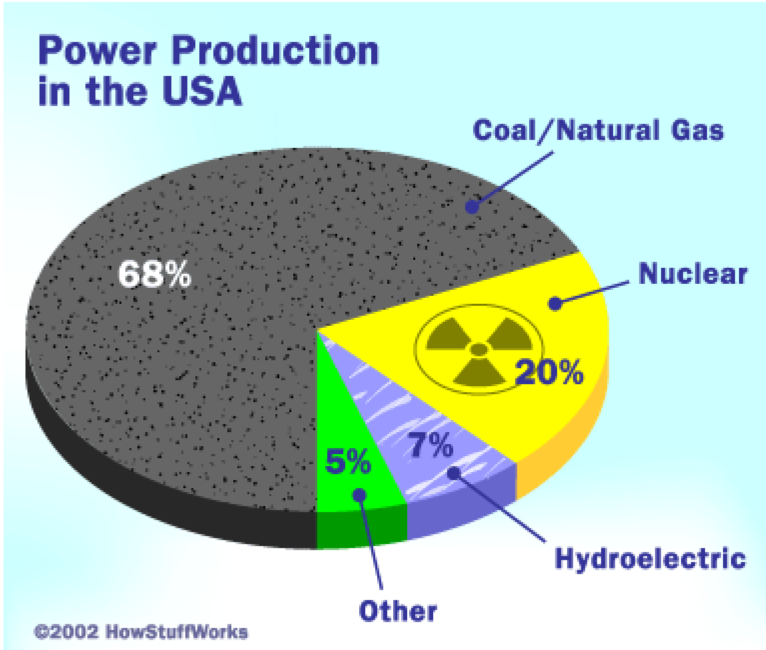
The U.S. Department of Energy projects that if 10% of automobiles nationwide were powered by fuel cells, regulated air pollutants would be cut by one million tons per year and 60 million tons of the greenhouse gas carbon dioxide would be eliminated. DOE projects that the same number of fuel cell cars would cut oil imports by 800,000 barrels a day which about 13 percent of total imports.

On the stationary side, fuel cells are ideal for power generation, either connected to the electric grid to provide supplemental power and backup assurance for critical areas, or installed as a grid-independent generator for on-site service in areas that are inaccessible by power lines. Since fuel cells operate silently, they reduce noise pollution as well as air pollution and the waste heat from a fuel cell can be used to provide hot water.

The use of FCVs in this manner may be particularly attractive since many automobile companies are currently developing FCVs as replacements to conventional internal combustion engine vehicles. Rapid EV and FCV market penetration is expected in California due to the 5 pressure of the Zero-Emission Vehicle (ZEV) Mandate, promulgated by the California Air Resources Board and also adopted by New York, Massachusetts, and Vermont. This mandate requires manufacturers to include low-emission and zero-emission vehicles among the vehicles that they deliver to the California market, and in increasing numbers beginning in 2003.

Economic Benefits of Hydrogen Energy

As a comprehensive energy policy, it can reduce demand for petroleum and at the same time provide better air quality. United States imports more than 50 percent of its oil which equals more than 10 million barrels a day. Dependence on foreign oil is a challenge to economic security, because dependence can lead to price shocks and fuel shortages. U.S. energy dependence is higher today than it was during the "oil shock" of the 1970s, and oil imports are projected to increase. Passenger vehicles alone consume 8 million barrels of oil every single day, equivalent to 80 percent of oil imports.



- If just 20 percent of cars used fuel cells, oil imports can be cut by 1.5 million barrels every day.
- If every new vehicle sold in the U.S. next year was equipped with a 60-kW fuel cell, we would double the amount of the country's available electricity supply.
- 10,000 fuel cell vehicles running on non-petroleum fuel would reduce oil. consumption by 6.98 million gallons per year.

The current market for fuel cells is about $218 million and will rise to $2.4 billion by 2004, reaching $7 billion by 2009. That's a jump from a generating capacity of 75 megawatts today to 15,000 megawatts.

The studies estimate the 2004 markets for fuel cells to break down as follows:

- $850 million - electric power generation
- $750 million - motor vehicles

- $200 million - portable electronic equipment
- $200 million - military/aerospace
- $400 million - other

Department of Energy explains that most of the hydrogen produced today is consumed on site, such as at an oil refinery. Cost estimates of hydrogen are: $0.32/lb if it is consumed on site, $1.00-1.40/lb for delivered liquid hydrogen, and $1.00–$2.00/lb for hydrogen produced by electrolysis.

In large-scale building systems, fuel cells can reduce facility energy service costs by 20% to 40 %. When not in use, Fuel Cell vehicles can be used for primary or emergency backup power of office buildings by supplying energy to the main grid.

Fuel cell vehicles could act as generators. Dodge has recently unveiled a prototype truck called the "Contractor Special" that is designed for this purpose. The potential for producing electrical power from vehicles is enormous. DOE calculated that the generating capacity of an electrified U.S. motor vehicle fleet would be approximately 14 times the entire capacity of all of the stationary power plants in the country.

Under the current rules of the ZEV (Zero-Emission-Vehicles) Mandate, which have recently been revised and have grown more complex since the mandate was enacted, 100,000 ZEVs may be on California streets by 2006. Under the revised ZEV regulation, the exact number of ZEVs and other clean vehicles that each major manufacturer will have to produce will vary depending on the strategy that each manufacturer chooses to adopt.

Distribution systems for the natural gas already exist in some parts of the USA in the form of a limited pipeline network (about 700 miles of pipeline) and direct deliveries via surface transportation.

Technically, hydrogen pipelines are not so different to natural gas pipelines installment and maintenance. The price is an issue. Argonne National Laboratory estimates the costs of hydrogen pipelines to range from US$300,000 to US$1.4 million per mile depending on the size, specific functions of the pipeline and building environment. Compared to the already high US$200,000 to US$800,000 for a natural gas pipeline this is a lot of money. Transporting liquefied hydrogen on the road is not much cheaper. This is mainly due to the limited capacities of today's hydrogen transportation vehicles. The largest vehicles can transport around 3,600 kg of hydrogen, while petrol/gasoline tankers can carry up to 30,000 kg fuel.

Similar restrictions exist for large-scale storage of the fuel. One option could be the underground storage of gaseous hydrogen, which is similar natural gas storage. Another option would be storage in a liquefied form, which is probably the most expensive solution mainly because it must be kept at -253ºC.

Mass production of Fuel Cell Vehicles requires effective distribution of hydrogen and network of hydrogen fueling stations.

Many of them have already been in use world wide but the establishment of a hydrogen fueling station for commercial use requires considerable capital investment, well-organized operating and maintenance costs. The economic performance of a hydrogen fueling station is heavily dependent on its configuration and utilization. Station configuration depends on initial capital investment but also influences operating and maintenance costs. Because of the wide variety of possible configurations, it is difficult to identify which station characteristics have the greatest effect on the economic performance of an installation, and therefore capability as an investment.

Investors may also have quite different investment evaluation criteria and constraints. All types of fueling station investors will not evaluate their investment decision in the same way. Some users may evaluate capital projects using an internal rate of return or net present value (NPV) measure. Others may use cash payback, accounting rate of return, return on investment, or impact on profit or contribution. All investors are aware of the role of possible tax effects, incentives, and evaluation methods when deciding among several alternatives. Several financial evaluation methods and incentive structures are included in the economic model.

Some of the subsystems, such as piping and fittings, instrumentation and control, and a priority/sequence panel are expected to be largely similar to those used in compressed natural gas (CNG) fueling stations and initial and recurring cost estimates are derived from data collected by CNG fueling stations.

Hydrogen financial modeling has been formed of private equity investments, public equity investments, and fund components and processed by various, large and, long-term investors. Despite the social and environmental benefit returns on equity are still at risk. Public responsiveness will have a tremendous effect in the car industry. Group of researchers from The California Institute of Technology expressed concerns in an article published in The Science Journal saying that hydrogen is so small that it is bound to leak from storage and transport containers. Hydrogen leakage can have negative environmental consequences on the ozone layer and could be highly explosive. In order to prevent leakage liquid has to be stored at extremely low temperatures and any storage container must be well insulated and utilize materials that would not crack from thermal stresses.

Global Perspective on Hydrogen Energy

Various government and industry projects have been in action world wide. Other than United States, European Union, Canada, UK, Japan, Canada, Australia have working on constructing a safe, efficient and economic infrastructure for hydrogen production, storage, transport and distribution. Commercial fuel cells powered by hydrogen are being introduced into the market for home, office and industrial use. The major auto makers have spent more than $2 billion on development of hydrogen cars, buses and trucks; the first mass-produced vehicles are projected on the road in three years.

U.S. and European officials are continuously working on the hydrogen economy, a concept that within two decades would replace dirty power plants and combustion engines with clean burning fuel cells. Energy Secretary Spencer Abraham called for an international effort that would produce hydrogen with energy provided from a host of sources that include not just fossil fuels and nuclear energy but also from wind, solar and biomass.

Policy makers globally discuss the issues of fuel shortages and geo-political games that could cut into oil and gas supplies, they are pressed to look for innovative solutions. Once the fuel cells achieve economies of scale, massive effects on the power business are inevitable.

Fuell cells are "perhaps the most significant game-changing endeavor the energy sector will see in our lifetime," Abraham said in speech this week Brussels, Belgium. "We intend that all our hydrogen eventually be produced using emissions-free technologies,". Natural gas is the most common fuel source used today to make the hydrogen that is consumed by fuel cells to produce electricity. The European Union (EU), which has set a goal of producing 22 percent of its electricity from renewable energy by 2010, has expressed concern that U.S. efforts would focus on creating hydrogen from natural gas and coal while neglecting green power sources. But the administration says that nearly half of its $39 million allocation toward hydrogen research in fiscal year 2004 goes to renewable technologies. By comparison, natural gas gets $12 million and coal and nuclear combined get $9 million.

In the U.S., hydrogen-based fuel cell technology got a boost after President Bush touted it during his State of the Union Address last January. Through a public-private partnership, the technology could become a mainstream facet of our lives by 2020, he said, noting that his administration would commit $1.2 billion over five years. The 5th EU Research Framework program (1998-2002) devoted E120 million to hydrogen and fuel cell research. In the 6th EU Research Framework program (2003-2006), research on energy and transport will be undertaken under thematic priority "Sustainable Development, Global Change and Ecosystems" for which the total budget of E 2120 million.

The will does exist to make the hydrogen economy a reality. Every major automaker is investing in fuel cells not to mention the major fuel cell makers: Ballard, Fuel Cell Energy, Siemens-Westinghouse and International Fuel Cells. As soon as people are aware of the advantages of fuel cells and are used to traveling on fuel cell buses and taxis, the door to an individual transport solution is wide open.

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