

Renewable Energy, Hydrogen, and Fuel-Cell Powered Cars

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Introduction

A recent report [1] by our Federal Government admitted that global warming was due mostly to industrial nations burning fossil fuels and exhausting greenhouse gases into the atmosphere, from power plants, vehicles, industrial processes, and heating. It also said if policies don't change it is just going to get worse, and to top it off they backed away from signing the Kyoto Treaty claiming that doing so would hurt our economy.

My talk challenges our government to (1) encourage industry and individuals through tax incentives to wean ourselves from fossil fuel dependence to slow atmospheric pollution and global warming, and (2) to support the Kyoto treaty. Markets exist for renewable energy that will benefit our economy. Certain political leaders obfuscate the realities here, by promoting the need for a war with Iraq. In both the case of the Gulf war in 1991, and the present war preparations the true underlying theme is about guarding our oil interests. The billions of dollars spent then, and anticipated now might better be focused on promoting renewable energy resources, taking us off a war footing and encouraging our economy to point in a new direction. At the very least our domestic energy policy should focus on ways to reduce our dependence on fossil fuels (especially oil, 94% of which is from foreign imports) by directing its major efforts in support of renewable energy resources.

Background

Corrective actions against pollution by individuals and governments alike have taken place since 178 nations gathered in Rio de Janeiro in 1992. Efforts to reduce global emissions were agreed to by most industrialized nations at the 1997 conference in Kyoto, Japan. Our government withdrew support citing potential harm to the economy, despite the fact that we are the most polluting nation on the globe.

We need ready sources of energy for heat, light, manufacturing, and transportation but continued dependence on conventional energy supplies is not healthy for our planet. The seven familiar energy sources are: (1). The fossil fuels -- Gasoline, oil, jet fuel, natural gas, wood, and coal, (2). Nuclear, (3). Hydroelectric, (4). Geothermal, (5). Wind, (6). Biomass, and (7). Solar. Not considered in this report are tidal power, and deep ocean convection but are long term future possibilities.

U.S. energy consumption, see Department of Energy [2] was 25% of world total energy (93.4 quads out of 373.9 quads consumed in 1996. 192 nations were included in their survey). A quad is one quadrillion B.T.U.'s which stands for British Thermal Unit, and is the amount of heat required to raise one pound (one pint) of water one degree Fahrenheit. There are about 252 calories in one B.T.U.

Our transportation needs took 26 quads -- gasoline, oil, and jet fuel, out of the 93.4 quads that we consumed that year, or 27 percent. Electric power generation took 23 quads; Industrial processes took 24 quads, and heating took 20.4 quads. These numbers are based on the energy equivalent in oil, even though nuclear power, hydroelectric, geothermal, wind power, biomass and solar power contributed to the total, in addition to coal, oil, and natural gas. At the present rate of consumption our use of gasoline, oil, and jet fuel will grow to 38.8 quads by 2020. This would translate to importing 28 million barrels of oil per day.

World oil consumption [3] grew 14 per cent during the 1990s. Today five thousand cubic feet of oil per second, or 12 million tons per day, or 80.3 million barrels per day, must flow out of wells to satisfy the world's needs. (Note that a barrel of oil equals 42 gallons) Burning the resultant oil, gasoline, and diesel fuel accounts for about nine and a half billion tons of carbon dioxide added to the atmosphere annually. Other contributors to the carbon dioxide build-up come from burning coal, natural gas, and wood. The yearly total of CO₂ build up from all sources is 24 billion tons.

Carbon dioxide is absorbed and processed in the photosynthesis cycle by algae in oceans, lakes and rivers, and by grasses, trees and shrubs. Not all the world wide CO₂ being added each year is used

up in these photosynthetic processes; the algae, grasses, trees and shrubs can't keep up, hence CO₂, and other pollutants accumulate in our atmosphere. Scientists now predict higher sea levels, and violent weather due to a greenhouse effect from burning these fossil fuels.

Fossil fuel based energy sources need replenishment through continual mining, drilling and oil exploration. Ironically some of the new oil discoveries in North America are in wildlife areas, which will be irreparably damaged by the traffic in drilling rigs, trucks, bulldozers, as well as the civil works required for pipelines, storage facilities, and pumping stations. Transporting crude oil always results in more oil spills. For example the tanker *Prestige*, broke up and sunk (reported November 18) off the coast of Spain and had already leaked 3000 tons of its 70,000 tons of crude oil cargo polluting beaches and killing wildlife. In Alaska the tanker *Exxon Valde* spewed thousands of tons of crude oil when it ran aground in 1989.

Nuclear energy is definitely not in our nation's, nor the world's, best interests. Although nuclear power plants don't spew out carbon dioxide from smoke stacks, they do produce lethal radioactive waste. More than 11,000 tons [3] of radioactive spent fuel will be created this year by the world's 440 commercial reactors, and in the U.S. our 131 reactor sites (in 39 states) produce 3300 tons of radioactive waste a year. Not only does this waste pose a risk in the form of accidental leakage but it could be a terrorist target. It has to be buried somewhere, and needs to be transported from various plant sites to politically acceptable waste burial grounds. Nuclear power plants require strict adherence to controls in their operation, but accidents still happen, for example we recall the Chernobyl and 3-Mile Island disasters. Incidentally it takes 2/3 of the energy output from the fission process to refine fissionable Uranium at places like Oak Ridge, Tennessee. Nuclear energy is just plain wrong for our long-term use, and must be de-emphasized and phased out.

I. Renewable Energy

Sooner or later complete dependence on renewable energy resources must take place. Viable markets do exist now offering opportunities to cut the Gordian knot that ties the world to dependence on oil and fossil fuel energy sources.

Wind farms, biomass, and solar arrays for stationary power plants, and hydrogen-fueled fuel-cells for vehicular, and portable power plants are the answers to this dilemma. In this equation certain criteria must be fulfilled:

- the energy source must not require mining or drilling;
- it must be naturally replenishable;
- it must net a positive energy output; and
- it must produce zero greenhouse gases or pollutants when consumed.

These criteria rule out coal, gasoline and oil, ethanol, natural gas and methane. It also rules out nuclear energy.

Hydroelectric power is, obviously, a non-polluting source of electric energy that fortunately already provides over one third of the total world requirement for electricity. Where the benefits of a hydro-power project outweigh the trauma to the neighboring environment, and population, building the dams and putting in the transmission lines may be the most feasible solution. A case in point is the 18.2 Gigawatt Three Gorges project in China. (Our Holland Power plant has a capacity of 150 megawatts) The government determined that the need outweighed the personal tragedies suffered by the two million families that had to be uprooted and relocated. Three Gorges project is due to be on line in 2007. Hydropower is a beneficial component in the list of renewable energy resources in many parts of the world. China with 100 GW by 2010, and Brazil with 62 GW by 2020 are major hydroelectric users[4].

Wind energy is non-polluting, and renewable. On the ascendancy, more than 5000 wind turbines are supplying electric energy into our nation-wide grid. California, with over two decades of experience using wind energy, had installed over 100 wind turbines as early as 1982 southeast of Bakersfield, California on the mountain ridges overlooking Tehachapi Pass.

Wind generation in this country has doubled [5] over the past four years. Electric co-operatives, and utilities in these states operate wind farms: California, Colorado, Minnesota, Iowa, Wisconsin, Illinois, Kansas, Nebraska, New Mexico, New York, Oregon, Texas, Washington, and Wyoming. These states are adding hundreds of megawatts of wind turbine capacity. Over 2500 megawatts is connected to the grid now.

A typical wind turbine stands over 350 feet tall, from base to blade tips; has three blades, produces power at the rate of 1500 kilowatts; and costs one-and-a-half million dollars, installed. Mounted on a swivel bearing, the turbine blades always face into the wind, like a wind vane, thus maximizing its effectiveness. Wind turbine-generators are viable in locations that have winds as low as fifteen miles per hour on average. Doing the math, a 1500 kilowatt wind turbine operating for one year could return revenues of \$919,800, at 7 cents a kilowatt-hour. Communities hosting wind turbines see them as a win-win opportunities; landowners get the benefits of rents, and the counties receive tax money.

Detractors don't like the noise, nor the visage of the tall slender towers with slowly revolving blades against what was once open country; others complain that the sweeping blades interfere with television reception, and that auto traffic is created by 'gawkers'. But on the noise scale a wind turbine creates only 45 dB (average office), a lawn mower a whopping 95 dB, a jet aircraft 145 dB, enough to permanently damage the inner ear [6] (pain threshold is 130 dB), while falling leaves produce only 15 dB.

Examples of nearby wind farms are in Kewaunee County, Wisconsin (Ron Yesney, Kewaunee County-Univ. of Wisconsin Extension), in Cerro Gordo, Iowa, and Montfort, Wisconsin. Two wind turbines are within the greater Holland area used at private rural residences.

Biomass energy in the form of methane gas is derived from decomposition of garbage, sewage, and other organic wastes such as cow manure. Between 17 and 18 gallons of manure per day is produced by a full-grown cow. A recent Chicago Tribune article reported that 650 Holstein cows at the Top Deck Farm in Westgate, Iowa [7], produce 11,500 gallons of manure a day, besides their normal milk output. The manure is loaded into concrete tanks called digesters (each 124-foot long), and it is heated to 98 degrees Fahrenheit to promote the anaerobic digestion process, producing copious quantities of methane gas. The methane is piped to gas turbine engines, which drive electric generators, and the electricity, in this example at the rate of 130 kilowatts, flows into the electric grid. Again, doing the math, the electricity at 7 cents a kilowatt-hour would yield revenues of \$80,000 (exact calculation = \$79,716) per year, if the production facility ran 24 hours a day, 365 days a year. Remember, cows produce waste around the clock. Investment costs of \$500,000 could be recovered in between 7 and 8 years at 4.5% interest. There's money to be made in manure.

It seems that many non-dairy farmers in Iowa, Wisconsin, and Minnesota have new roles as power plant operators, through the production and sale of electricity via methane from duck manure. Near Racine, Wisconsin for example, the Maple Leaf Farms harvest 40,000 gallons of manure a day from 500,000 ducks. This product is loaded into anaerobic digester tanks, and the methane gas produced is fed to gas turbine-electric generators. In a year, this farm consumes \$60,000 worth of the electricity produced, and sells \$18,000 worth left over to Wisconsin Electric Corporation.

In Michigan pig farmers, and turkey farmers should be encouraged to generate and sell electricity via the manure-to-methane-to-electricity route, as a money making venture, and as a way to clean up the environment. Finally, the sludge from all these manure-to-electricity processes becomes concentrated from the digestion process and may be sold as fertilizer to complete the cycle.

Tax incentives to help defray the capital investments in digesters, turbines, and piping are needed. Michigan should mandate the local electric power companies to generate a certain percentage of electricity from renewable sources, including power from wind farms and purchases of power from biomass facilities.

Many landfill locations use some form of recovery of the methane. Locally, the landfill mound in Zeeland produces burnable methane gas. Methane, from any source, is one of the cleaner burning fuels,

but unfortunately creates carbon dioxide, and water vapor besides the heat energy, thus contributing to greenhouse gas buildup.

Solar energy is important because it uses sunlight, a renewable and free source of energy. Solar energy produces no pollutants or greenhouse gases, and requires no well drilling or mining. Two options for making use of solar energy as a renewable are solar-to-electrical applications, and solar-to-heating applications.

Solar-to-electrical makes use of the photoelectric effect in certain semiconductors such as silicon. Silicon semiconductors are the main ingredients, in the form of chips in computers, cell-phones, and telecommunications industry. Silicon technology is well established, and cost effective. No doubt you have all noticed solar panels, like small size obliquely angled billboards, at various spots along some roadways. Most are used to provide electricity to recharge battery-operated radio signaling and telecommunications equipment. Panels contain a matrix of individual silicon photovoltaic chips called solar cells, interconnected electronically by narrow metallic films[8]. Panels collect daylight even on cloudy days, focusing it onto the chips which converts it to direct current for operating the equipment, charging batteries, or for sale to the power company. Many of the panels are fixed at the most effective angle for that latitude for capturing sunlight. In some arrangements the solar panels can move automatically to always face the sun thereby collecting the most energy all days of the year. Even so conversion efficiencies are less than 20 %; keep in mind that sunlight energy arrives at the rate of 1000 watts per square meter, so that a solar-to-electrical array of one square meter would produce electric power at a rate of less than 200 watts. To get 1000 watts electrical out, for example, the approach is to concentrate the light from an area of intercepted sunlight of more than 5 square meters, using a reflector, or lens, focusing this high intensity light onto the one square meter array of silicon cells. Costs are reduced with this approach because much less silicon is used; lenses, or reflectors are cheap. Large solar-to-electrical panels mounted in broad arrays, are in use that power buildings, some industrial processes, irrigation gates and sprinkling systems [9].

Based on the recent developments in collectors, a 1,000,000-kilowatt electric power plant to serve a city of 600,000 people would require about 8.85 square miles of area (5664 acres) for the solar collectors, and cost between \$2-billion to \$3-billion. Based on capital costs this is viable now. At 7-cents a kilowatt hour, with operation 8 hours a day, revenues should exceed \$200 million annually. Input energy is free, it is non-polluting, and maintenance would cost less than 1 cent a kilowatt-hour.

Solar-to-heating applications collect and focus the solar energy onto pipes carrying heat exchange fluids, such as water, or anti-freeze (ethylene glycol). The hot fluid is used in various industrial processes, and perhaps the earliest and most popular applications of solar-to-heating has been cooking, and heat homes, and swimming pools. Reflectors in the form of a metal trough-reflector, or lens, in north-south alignment, with the pipe located along the primary focus line are used to intensify the heat, raising the fluid temperatures into the 700 to 900 degree F. range. At least one company, Solar Hydrogen Energy Corporation, of Canada, uses the intense heat from focused solar energy to break down water to obtain oxygen and hydrogen.

Pre-historic man huddled near an open fire for warmth, and for cooking – a dispersed mode of energy application. In many ways our future energy applications could be in a dispersed mode, rather than centralized. We may generate our own hydrogen from water at home, for use in heating, cooking, and transportation

II. Hydrogen

Fuels in current use produce pollution and greenhouse gases. Nuclear energy produces radioactive wastes. Hydroelectric projects affect geography and cause population upheaval. Biomass produces greenhouse gases, wind farms and solar arrays are pollution free, but stationary. Acknowledging the growing worldwide demand for mobility we are going to need cleaner, and pollution free fuels to power cars, busses, trucks, and jet airplanes.

Hydrogen is the ideal fuel. Hydrogen burns clean, may be transported through pipelines, is storable and may be produced by a number of processes. Methods of production include

1. Formation as a byproduct of oil refining, literally as boil off;
2. Reforming, that is high temperature molecular disassociation of methane, or natural gas;
3. Superheating water in order to break down the molecules into hydrogen and oxygen;
4. Electrolytic decomposition of water into hydrogen and oxygen.

Each of these processes requires substantial amounts of input energy. Free energy from the sun is being used in both the superheat, and electrolytic processes. Fossil fuels are used in process 1, and 2.

When one kilogram of hydrogen (2.2 pounds) burns, it produces the same amount of energy as 3.2 kilograms of gasoline (one gallon). Byproducts are pure water from the hydrogen, and from gasoline: carbon dioxide, carbon monoxide, nitrous oxide, and water vapor.

Hydrogen is the cleanest burning fuel. Adopting hydrogen over other fuels would allow the planet's natural photosynthetic processes to reduce the amount of carbon dioxide in the atmosphere. Other pollutants from burning fossil fuels would decline through normal recombination process, instead of building up. Noting that the hydrogen fuel cycle returns the burned hydrogen as water, makes it the perfect renewable resource.

Adopting hydrogen as our fuel of choice would be a great stimulus to our nation's economy, as it would reduce our dependence on foreign oil imports; recall that we import 18.5 million barrels a day. It would realign our balance of payments by reducing the phenomenal outflow of our money; right now crude oil is about \$30 per barrel, and importing 18.5 million barrels a day, makes the outflow of money from the U.S. over 200 billion dollars a year.

Lest we worry about the financial impact on the foreign oil producers, the change over to hydrogen from imported oil could not take place suddenly, foreign oil exporters would have time to adapt. Ironically the largest exporters of foreign oil (Saudi Arabia, Iraq, U.A.E., Kuwait, Iran, Venezuela, Russia, Libya, and Mexico) also enjoy the greatest number of cloudless days, they receive high solar insolation, so that adapting to a solar-to-electrical economic base would seem feasible, to offset impacts of lower oil exports. The Saudi's and others could export solar-electricity instead of oil.

Using Hydrogen to power Vehicles.

Vehicle ownership has been increasing; forty years ago less than 4 per cent of the world's population owned vehicles; twenty years later 9 per cent were owners; and today 12 per cent are owners. Growth has been faster because the world's population has steadily increased over that timeframe. All these vehicles, and there are about 700 million now, have had high environmental impact.

Population is expected to grow from six billion today, to nearly 7.5 billion in twenty years. Vehicle ownership is estimated to increase faster than the population because of the growing proportion of the middle class – your typical vehicle owners. In twenty years an increase to 1.1 billion vehicles is expected. Some 75 % of automobiles are now concentrated in the U.S., Europe, and Japan. In the Scientific American article[10] they state that “more than 60 % of the increase in new vehicle sales during the next ten years will occur in eight emerging markets: China, Brazil, India, Korea, Russia, Mexico, Poland, and Thailand.”

Because of this market the big three automakers are gearing up to take major chunks of it. Furthermore continuing with fossil based fuels to supply vehicle needs will accelerate global heating. If it is bad now it will only get worse with that scenario.

Automakers therefore are thinking hydrogen.

One way to power vehicles using hydrogen is to burn hydrogen in a modified internal combustion engine (ICE) directly. Engine conversion kits consisting of a pressure reducing valve and fuel injection nozzles to modify fuel handling permit hydrogen gas to be used today. Gasoline or diesel fuel tanks have to be replaced with hydrogen storage tanks – high pressure bottles – not unlike scuba tanks, and high pressure piping.

Conversions are similar to those used by fleet vehicles such as the Skelgas Company. These vehicles are fueled with natural gas, which is mostly methane.

Another, and much more efficient way is to run cars on hydrogen is with fuel cells powering electric traction motors. The hydrogen-fuel cell-electric traction motor approach is 55% efficient, while the internal combustion engine (what we use in cars and trucks) has topped out at about 25% efficiency in converting the energy content of fuels into drive-wheel power. (The 80-mile per gallon Supercar program was shot down by the Bush administration, which may be a blessing in disguise.)

III. Fuel Cell Powered Cars

Fuel cells are based on a principle discovered by Sir William Grove in 1842. GE advanced the art and produced fuel cells in the 1960's for use in the space program (Gemini, and Apollo).

A modern day fuel cell consists of a plastic film called a polymer membrane electrolyte [11], made of perfluorosulfonic acid polymer film, sandwiched between two porous electrodes. The electrodes must be porous to let hydrogen into the fuel cell, and for water vapor to escape. Electric current (dc) is the power output. Surprisingly the membrane film keeps hydrogen gas, and oxygen gas from actually passing through from one side to the other. Electric current out of the fuel cell powers the electric motor, or other device.

The 'sandwich' from left to right: hydrogen gas port, porous **anode**, metallic **catalyst** (platinum perhaps) coating, polymer **membrane** electrolyte (PME), metallic **catalyst** coating on the other porous cathode, porous **cathode**, and air (oxygen) inlet-water vapor-outlet port. Hydrogen enters and goes through the pores, then at the catalyst coating the electrons are stripped from the hydrogen, and flow out along the metal path, but the hydrogen nuclei, protons, pass through the membrane; on the other side of the membrane they reunite with electrons returning on the metal path, forming hydrogen, which combines chemically with oxygen coming in the other port, forming water vapor, and heat. The water vapor is expelled through the outlet port. Electrons stripped from hydrogen at the **anode** completed an electric circuit through the electric motor, by returning to the **cathode** of the fuel cell.

Fuel cells may be stacked like batteries. Fuel cells produce power as long as each cell in a stack has hydrogen and oxygen. With no moving parts, fuel cells can produce energy at costs equal to existing forms of power. They are noise free, and environmentally friendly.

A typical fuel cell is shaped like a video-cassette, with fuel and exhaust pipes, and electrodes attached. Each cell produces about 1 volt; a cell consuming a feeble 1 cubic centimeter of hydrogen per second (sea level and 68 degrees F.) would produce a theoretical maximum 1.675 amperes. Higher hydrogen flow rates, and consequently higher currents are possible, so that a variety of engineering design options are available. Cells may be stacked to produce higher voltages, and manufactured with higher PME surface areas to produce higher currents. Cells also produce heat, which must be carried away, or else the inner cells in a stack could overheat. Typical exhaust temperatures can reach 175 degrees F.

The polymer membrane electrolyte, as made by Dupont is called Nafion^R (perfluorosulfonic acid). Another manufacturer is Dais-Analytic Corp. that uses novel membrane, and electrode materials, and has a proprietary stack design.

Some fuel cell manufacturers are:

General Motors Corp.

Ballard Power Systems

Dais-Analytic Corp.

Automakers are moving rapidly to have on the road affordable fuel cell vehicles by 2010, or earlier. These are: DaimlerChrysler, Ford Motor Company, General Motors Corp., Honda Motor Company Ltd., PSA Peugeot Citroen, Renault-Nissan Alliance, and Toyota Motor Corp.

When using pure hydrogen, a fuel cell powered car is a zero-emission vehicle!

Applications for non-automotive fuel cells are stand-by, or emergency power sources where the consumer cannot afford to be without electricity, such as hospitals, digital-data centers, continuous

process factories, and telecommunications companies. This is a \$10-billion dollar a year industry. GM plans to market a 75 kilowatt fuel cell system, with built-in hydrogen reformer for these applications.

Hydrogen Production and Storage

Hydrogen may be produced from natural gas, methane, or gasoline using steam reforming technology. This process still creates carbon emissions and is sometimes referred to as dirty hydrogen. Methods that will produce pure hydrogen are by heating water to superheat temperatures with solar energy; that is focus sunlight on high pressure pipes containing water, raising the temperature to the range 700 to 900 degrees F. So intense is the energy that the water molecules are broken down to hydrogen and oxygen. Solar Hydrogen Energy Corporation (SHEC), of Canada is working in this area. Another way is to generate hydrogen by electrolytic decomposition of water using solar energy photonic arrays. One company working in this area is H-Ion Solar, Inc. based in California.

Storing hydrogen for vehicular use is a tough but practical problem. To get a 300-mile range for the hydrogen powered fuel cell car, pressures in the neighborhood of 10,000 pound per square inch are necessary, otherwise the storage tanks become bulky. Bulky tanks would require SUV-sized vehicles, while such auto-makers as GM are basing their designs on a low silhouette, low center of gravity AUTOnomy-skate-board-like shaped chassis for improved ride, safety, and to get greater legroom than a conventional vehicle of the same length.

IMPCO Technologies is vigorously pursuing hydrogen fuel tank development. General Motors Corp. purchased a 25 % share in this company in mid-2002.

Another approach to storing hydrogen is to use the interstices of a compressed metallic alloy powder, such as sodium-borohydrate, which adsorbs hydrogen on the extended area of the millions of minute surfaces. One company in this business is Millenium Cell. This approach has a high degree of safety, large storage capacity, and simple rugged construction. Hydrogen release temperatures in the neighborhood of 175 degrees F are in the works.

Hydrogen distribution via pipelines to dispensing stations is very close to reality now. Infra structures to do this are in place now along the U.S. Gulf Coast, and in Europe around Rotterdam. Since the oil and chemical industries produce hydrogen for sulfur removal in the petroleum-refining process, the hydrogen flows today through hundreds of miles of pipeline in a number of countries. Annual production of hydrogen in this existing infrastructure is approximately 540 billion cubic meters of hydrogen (at 14.7 psi, and 68 degrees F.), primarily reformed from natural gas. This equates to roughly 140 million tons of petroleum a year, on an energy equivalent basis. This is nearly 10 percent of the present transportation demand. So a great deal of expertise is on hand already for piping and transporting hydrogen. In November 2002, DOE recently [12] opened a new hydrogen energy station in Las Vegas, Nevada, that will produce both electric power and hydrogen fuel. The station is the result of a public-private partnership between DOE, the city of Las Vegas, Air Products and Chemicals, Inc. (which designed and constructed the facility) and Plug Power, Inc. (which manufactured and installed the site's proton exchange membrane fuel cell). The facility can dispense hydrogen, hydrogen-enriched natural gas, and compressed natural gas.

Finally, James P. Uihlein of BP, stated before the U.S. House of Representatives Committee on Science's Energy Subcommittee (June 2002) that hydrogen's cost per mile driven is much less than conventional fuel because of the outstanding efficiency of the fuel cell engine.

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It may seem that we are already embracing renewable energy as a way of life. Don't be so sure. As long as low gasoline prices tease our love affair with great big gas slurping SUVs, power boats, Sea-Do's, and Ski-Mobiles, we will derive comfort in the status quo, and changes to correct matters will take place at a snail's pace. My concern is that by not pushing faster into using renewables, including fuel cell cars our planet may receive a diagnosis that it is too late to reverse matters in our children's children's lifetime.