Policy Statement

Renewable Hydrogen

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Under the Auspices of the Policy Committee

American Solar Energy Society

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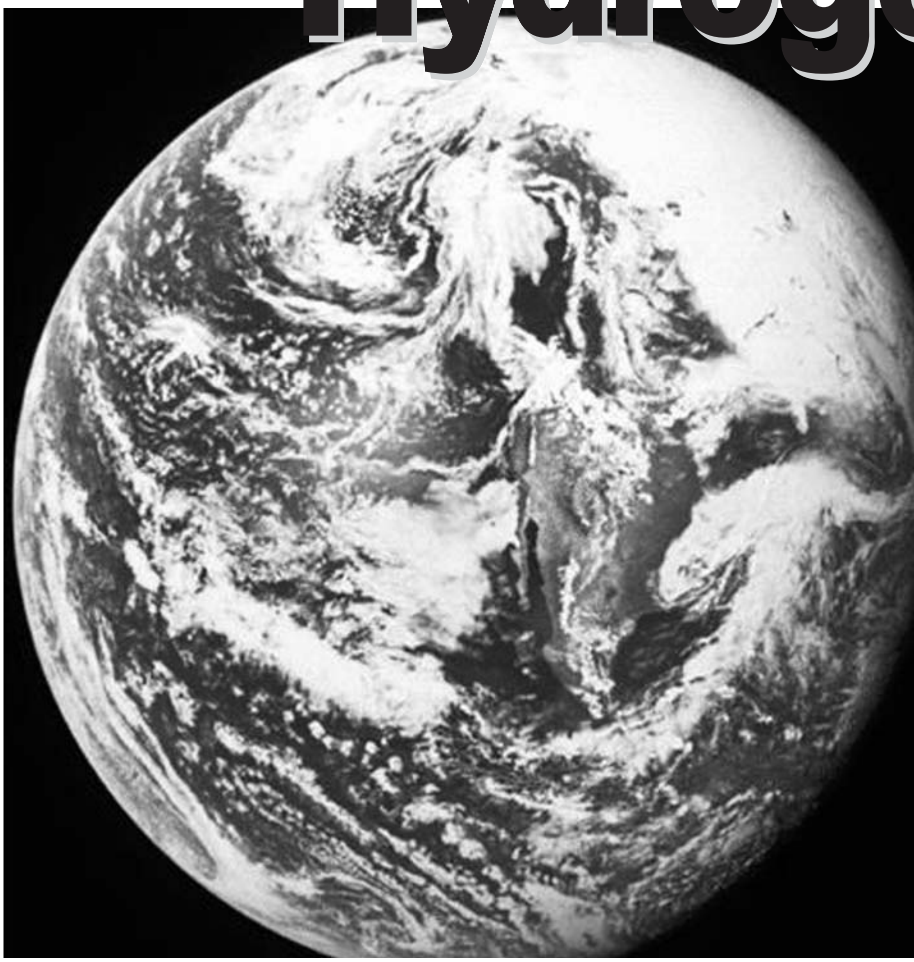
Policy Statement *on* Renewable Hydrogen



NREL/NASA

The ultimate answer to the nation's energy challenge lies in its availing itself of a multiplicity of sustainable energy options, including increased energy efficiency, solar, wind, biomass, geothermal ***and*** renewably derived hydrogen. More specifically, sustainable energy solutions must immediately become the cornerstone of a national energy policy—**NOW**—in order to avoid the looming energy crisis that will inevitably result from continued dependence on fossil and nuclear fuels.

The nation is in need of a national energy policy capable of solving the problems associated with fossil and nuclear energy sources, including reliance upon interruptible foreign sources, environmental degradation, vulnerability to terrorist attack and negative health affects. The course outlined by the Administration and the inability of Congressional leaders to enact a sustainable energy plan means that the nation is at risk and will remain so until a fundamental shift towards sustainability is made.

This policy statement is published in an effort to provide public decision-makers and sustainable energy advocates with a better understanding of the role that should be played by renewable energy technologies both in their own right as power sources, and as part of a possible transition to a hydrogen economy.

Summary

Hydrogen is only as clean as the energy sources and feed stocks used to produce it. Because more energy is needed to create hydrogen than can be derived from it, it cannot be thought of as *sustainable* unless renewable energy sources are used to make it.

Reducing reliance on fossil and nuclear energy sources will free the nation from costly foreign involvement and improve the health and well being of its citizens. It will do this by significantly reducing greenhouse gas emissions and the amounts of other poisons attributable to fossil and nuclear energy sources in the air, land and water. The American Solar Energy Society (ASES) believes that there are no magic amulets when it comes to the nation's energy supply. Although hydrogen derived from renewable energy sources offers ***an*** answer to the nation's energy problems, it is not ***the*** answer.

Introduction

This policy paper is principally based upon the Renewable Hydrogen Forum conducted in April 2003 by the American Solar Energy Society at the World Resources Institute in Washington, D.C. The Forum brought together many of the top scientists, researchers, business leaders and economists involved in hydrogen and renewable energy to define more clearly for public policymakers and sustainable energy advocates the:

- Current and projected potential for renewable hydrogen;
- Benefits to society of a sustainable energy economy that includes hydrogen derived from renewable energy sources and
- Research and development efforts needed to maximize the contribution of renewable energy technologies to a hydrogen economy.

The complicated nature of the issues, as well as the variety of ideas presented, led to a wide range of perspectives and opinions. Although opinions differed on some issues, such as the economics of various renewable technologies, there was no disagreement concerning **the need to use clean energy sources for the production of hydrogen,** or the necessity and practicality of moving up the transition timetable.

The Forum was organized both to educate the energy community and to reflect ASES' concerns over the Administration's proposed hydrogen roadmap. Although ASES applauds the efforts of President Bush and the U.S. Department of Energy to point the nation towards an energy future with reduced reliance on foreign energy sources and fewer harmful emissions from fossil fuels, the Society differs with the Administration's policy proposals on several key points.

First, ASES believes finding new sources of energy that are available domestically and do not carry with them the environmental/political consequences of coal, petroleum, nuclear and natural gas is key to the nation's near-term prosperity, health and security. ASES recognizes a transition from the current fossil fuel standard cannot occur overnight. However, allowing fossil and nuclear resources to play a large and integral role in a hydrogen economy serves only to maintain dependence on energy sources known to be harmful or unsustainable.

Second, the Society is convinced that there are better uses for petroleum and natural gas than as fuels for transportation and electric generation. Natural gas and petroleum are much more important to the nation as chemical and medicinal feed stocks and for the manufacture of carbon fiber.


NREL/Warren Gretz

Hydrogen program research team: John Turner, Ashish Bansal, and Oscar Khaselev. The splitting of water using a semiconductor immersed into an aqueous solution has been termed the Holy Grail of photoelectrochemistry. The promise of this device is that it shows us it is possible to take two of our most abundant natural resources, sunlight and water, and with high efficiency, directly generate an energy carrier, hydrogen, that is non-polluting and totally recyclable.

The highest value of 100 gallons of petroleum is not as a transportation fuel. 100 gallons of oil can be made into $3500 worth of CDs, TVs, corrective lenses, medical components, computers, carpeting, clothing, transportation components, and thousands of other things far more valuable than burning it as gasoline or diesel fuel. Continuing to use these resources for lesser economic purposes defeats the strength of the private marketplace and results in a wide-scale escalation of energy and product prices—ultimately weakening economic growth.

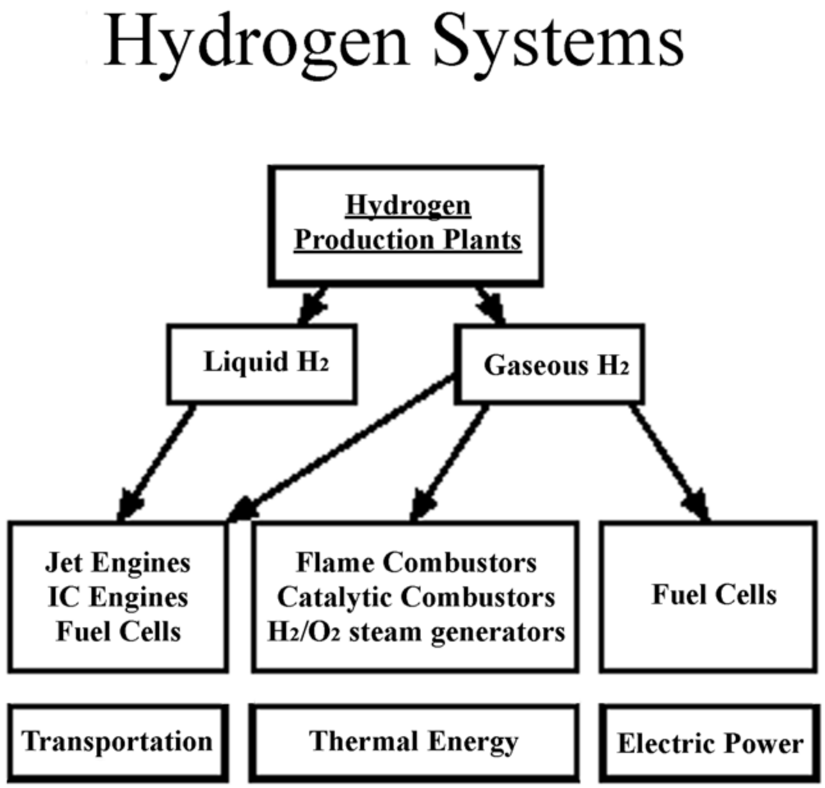
"We subsidize every segment of the nuclear industry but get less economical production of electricity and a continuing cost penalty over the next 1,000 centuries for providing expensive security against terrorists or natural events such as earthquakes that might cause releases of these radioactive poisons. If equivalent subsidies had been provided to renewable energy developments in solar, wind, wave, hydro and biomass technologies," the nation would now be on a sustainable energy standard. (McAlister, 52)

Third, it is ASES' judgment—based upon the testimony of leading experts—that President Bush's proposed road map envisions too long a journey. Waiting 30 or more years for the nation to free itself from dependence on foreign and domestic fossil fuels means the loss of millions more lives due to pollution and politics, including respiratory diseases and military action in the Middle East and elsewhere. The technology needed to make America a sustainable energy nation exists today. What is lacking is the political will to use it on a large enough scale to realize recognized economic, environmental, security and health benefits. The nation must not wait 30 or more years to solve its current and future energy problems.

Making the hydrogen economy contingent upon the perfection of carbon sequestration technology—in order to offset the environmental damage of "clean coal"—complicates and delays the process unnecessarily. Further, it is quite possible that carbon sequestration may never be successful. It is even more likely that carbon sequestration will prove as problematic politically as nuclear waste storage.

The less coal the nation uses, the less the need for carbon sequestration. The benefits of carbon sequestration can be better realized by using biomass resources that are available today and by developing a healthy dependence on other renewable energy sources like solar and wind.

Fourth, the Administration is too reliant upon the willingness of automakers, fossil energy companies—coal, petroleum and natural gas—and the nuclear industry to voluntarily embrace clean energy alternatives. While recognizing that a cultural change of such magnitude cannot be suddenly mandated without the risk of severe economic consequences, ASES looks to the historic opposition of traditional energy interests to any transition as evidence of endemic intransigence. The nation cannot afford to wait.



D. Yogi Goswami (see *note pg 16)

Twenty-five years of experience with the development and deployment of emerging clean energy technologies has provided the policy expertise needed to create and enact a national energy program capable of balancing mandates and incentives. A national renewable energy standard—requiring power producers to include increasing amounts of electricity generated from domestically available clean energy sources—is only one example.

Since the ASES Forum, the National Academy of Science's (NAS) Board on Energy and Environmental Sciences (BEES) has issued its report on "The Hydrogen Economy and Opportunities, Costs, Barriers and R&D Needs." The NAS report confirms much of what was said at the ASES Forum about the technology and provided recommendations and comments on the Administration's hydrogen roadmap. The Academy confirmed the direction of the U.S. Department of Energy's hydrogen programs, but it cautioned that "…DOE should keep a balanced portfolio of R&D efforts and continue to explore supply-and-demand alternatives that do not depend upon hydrogen." (ES-2)

This paper provides an overview of the key policy and technology issues associated with hydrogen production and utilization, as well as highlighting the role renewable energy technologies should play in a rapid transition to a sustainable energy economy and the nation's ultimate energy independence. The paper concludes with a series of specific recommendations. For more information, readers are encouraged to access and download the Forum summary at *http://www.ases.org*. Additional sources of information are also listed at the end of this document.

Overview

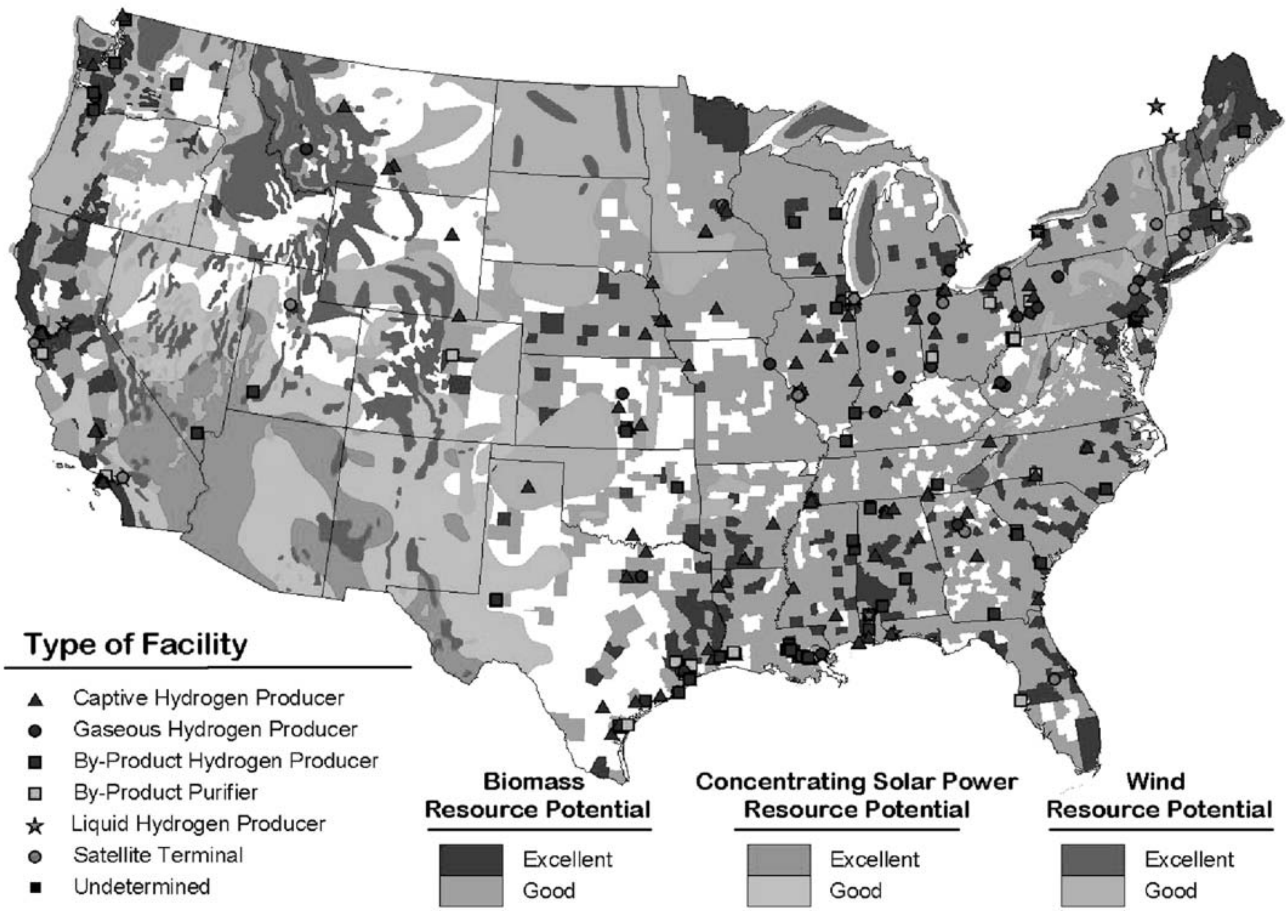
Hydrogen is the only universal fuel that can run everything—space ships, a Coleman stove, existing appliances in homes and the family automobile. The capability is not new. Rudolph Erren, a German engineer working in the 1930s, developed a simple fuel injection system for internal combustion engines costing a few hundred dollars a vehicle. One could flip a switch to go back and forth from gasoline to hydrogen. New technologies like fuel cells represent a significant advancement. Fuel cells for powering buildings, autos and trucks and laptop computers and other consumer electronics will play an increasingly larger role in the energy sector.

Today, natural gas reforming produces most of the hydrogen in the world. Ninety-five percent of the hydrogen in the U.S. and about 50 percent in the world is produced using this process. Reformation is the least expensive way of producing hydrogen and the most amenable to very large-scale production plants. (Hock, 22)

Hydrogen production, as part of an integrated petroleum refinery, is the next most common method in use—accounting for about 30 percent of world production. Coal gasification accounts for around 18 percent of worldwide hydrogen production. Next is electrolysis, which is approximately 4 percent of current worldwide production. This method depends upon the availability of low cost electricity to be cost-effective. (Hock, 22)

Hydrogen can also be produced from biomass, using thermal processes like gasification and pyrolysis. Biomass-to-hydrogen processes also result in byproducts that improve their economics. Looking toward the future, advanced biological processes, intermittent renewables, photovoltaics, wind and concentrating solar power (CSP) will provide the energy needed for electrolysis. High temperature systems using solar thermal, geothermal, biomass and nuclear energy are also on the horizon. Finally, there is direct water splitting—often referred to as the Holy Grail of hydrogen production. Although simple in principle, it is a long way off. (Hock, 22)

Wind powered electrolysis is likely to be the first economical renewable



NREL/ABT Associates

Hydrogen facilities and good to excellent renewable energy resources hydrogen production system simply because the cost of electricity from wind is currently the lowest of all the renewable technologies. Between wind, solar and biomass, the nation is well covered geographically with the energy needed to produce hydrogen economically using renewable resources. Areas of inadequate solar radiation are often high in wind or biomass resources. (Hock, 23)

Tremendous progress has been made in reducing the cost of making electricity from renewable sources. Making hydrogen from renewable energy through the intermediate step of making electricity, however, requires further breakthroughs in order to be competitive in the marketplace. As reported by the National Academy of Science Committee, "Basically, these technology pathways for hydrogen production make electricity, which is converted to hydrogen, which is later converted by a fuel cell back to electricity. These steps add costs and energy losses that are particularly significant when the hydrogen competes as a commodity transportation fuel, leading the committee to believe most current approaches—except possibly that of wind energy—need to be redirected. The committee believes that the required cost reductions can be achieved only by targeted fundamental and exploratory research on hydrogen production by photobiological, photochemical, and thin-film solar processes." (NAS, ES-3)

Another major challenge of today's industrial hydrogen, as well as tomorrow's, is the high cost of distributing it to dispersed locations. The challenge will be particularly severe in the early years, when demand is dispersed. (NAS, ES-3) It is for these reasons that a National Academy of Science report states:


NREL/Warren Gretz

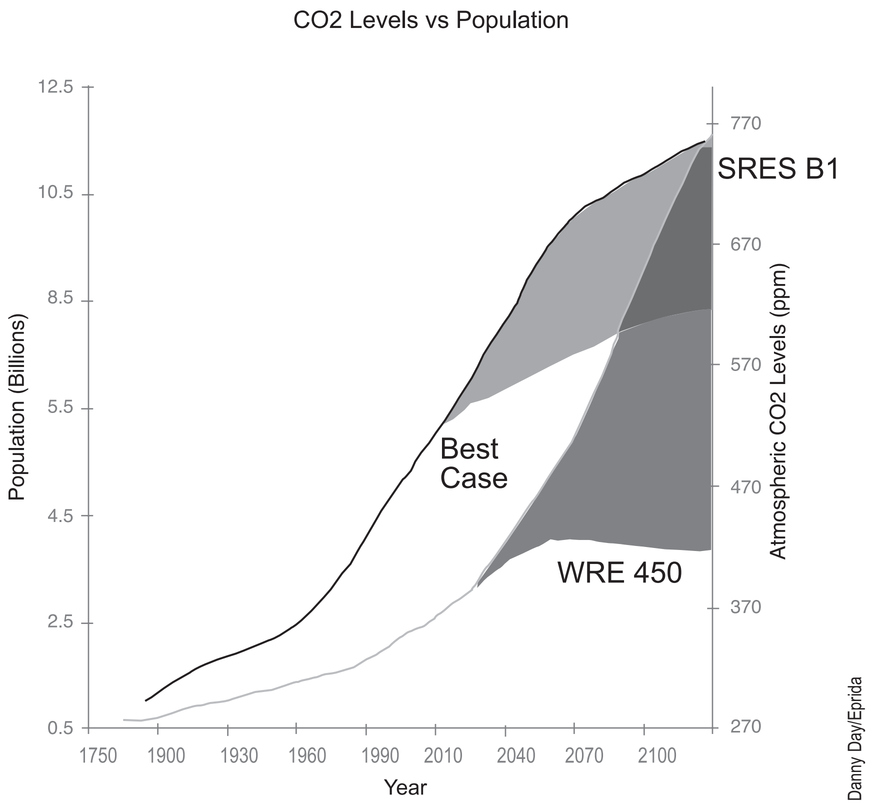
Air pollution hovers over traffic in Denver, Colorado

> *"The committee believes that the transition to a hydrogen economy will best be accomplished initially through distributed production of hydrogen, because distributed generation avoids many of the substantial infrastructure barriers faced by centralized generation… During this transition period, distributed renewable energy might provide electricity onsite to hydrogen production systems, particularly in areas of the country where electricity costs from wind and solar are particularly low." (ES-4)*

Section I. Economy, Environment and Security—the Need for a New Energy Model

Lester Brown asks, "Is the environment part of the economy? Or is the economy part of the environment? If we accept the idea that the economy is part of the environment, then it follows that the design of the economy must be compatible with it. Right now it is not. It is a highly stressed relationship and becoming increasingly so each year, as the economy expands. One reads about the stresses in the daily newspapers—collapsing fisheries, shrinking forests, expanding deserts, falling water tables, rising CO_2 levels, rising temperature, melting ice, eroding soil, disappearing species. These are all manifestations of the stress between the global economy and the earth's ecosystem." (Brown, 33)

Is hydrogen a national security issue or an environmental issue? According to the Assistant Secretary of Energy for Energy Efficiency and Renewable Energy, "In fact it's both, and you don't have to look beyond the words of the President himself to answer that question. The environmental benefits of hydrogen are very much on the mind of the President. He also has dis-



cussed the energy security aspects of the energy issue, and changing dependence on foreign sources of energy. In addition, [the Administration recognizes] the U.S. currently has a large amount of energy coming from gas, coal and petroleum—the energy sources that concern us (the Administration) because of their emissions."[1] (Garman, 29)

What would happen if China were to use gasoline at the same rate that we do? According to Lester Brown "China would need 80 million barrels of oil a day. The world is currently producing only 76 million and probably will never produce more than we are now. If paper consumption in China were raised to the U.S. level, China would need more paper than the world produces. *The bottom line is that the western industrial economic model is not going to work for China.*" (emphasis added)

"If it doesn't work for China, then it's not going to work for India, which now also has over a billion people. *And it won't work for the other two billion people in developing countries either. In the long run, in an increasingly integrated global economy, it will not work for us either. That's the bottom line. That's the context of the issues that are being dealt with in this Forum.*" (Brown, 33) (emphasis added)

The consequence of what Brown is saying is that no matter how hard the U.S. tries, energy independence is not possible as long as fossil fuels—particularly petroleum—remain the cornerstone of the domestic energy economy. Neither the U.S. nor the world has sufficient reserves of petroleum to meet the needs of developed and developing nations for the next thirty years.

"Now one of the big questions is: How do we get from here to there? That's economics, that's engineering and a whole range of other issues. The nation must think in terms of restructuring the energy economy to get the market to tell the truth, because right now the market does not tell the truth. When we buy a gallon of gasoline, we pay for the cost of getting the oil out of the ground, getting it to a refinery, refining it into gasoline, and getting the gasoline to the local service station. We do not pay the cost of the air pollution impacts like respiratory illnesses. We don't pay the cost of damage from acid rain. We don't pay the cost of climate disruption. *We've got to think about how to get the market to tell the truth.* (emphasis added) Capitalism may collapse, because it does not allow the market to tell the truth." (Brown, 33, 34)

"We also need to think about restructuring the [existing system of] subsidies. The World Bank says $210 billion of subsidies go to fossil fuel use. Imagine what would happen to solar cells and wind and geothermal if we shifted that $210 billion to renewables. We'd really begin to pick up the pace. *If you think about it, it makes no sense at all to subsidize fossil fuels.*" (Brown, 34) (emphasis added)

If the nation gets its energy at home from sustainable sources, $100 billion per year is saved from being sent overseas. Add to this the monies now being spent to "secure" the Middle East, the $100 billion or so that is traceable to the health cost of current air pollution levels, additional costs for environmental damage due to water and land pollution. Also add some valuation of the possible cost to the U.S. economy of a sudden interruption of fuel supply and the true cost of fossil supports, and the case for investing heavily in renewable energy and energy efficiency is incontrovertible. (Scott, 10)

Monies no longer sent abroad as payment for oil, foreign aid or the defense of oil rich nations could be used to fire the engine of the domestic economy and to pay for such desired public programs as universal health coverage. The annual $100 billion savings in overseas payments alone would more than pay for the transition to a renewable energy economy. It could provide the $87.5 billion needed in support of the Iraq war and its reconstruction.

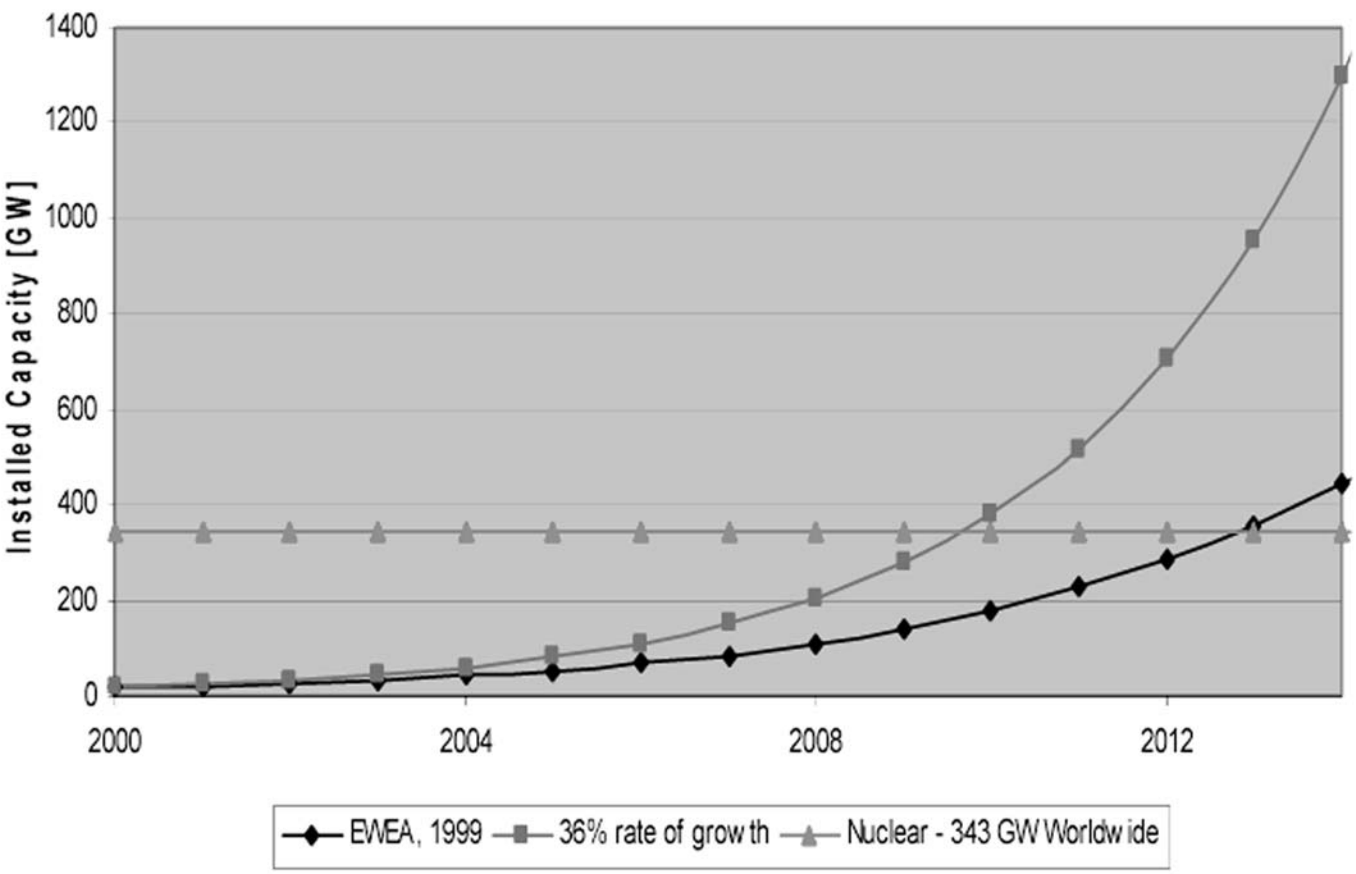
Part of the problem is that “hydrogen doesn’t make any economic sense in the next twenty or thirty years without increasing the price of competing fuels or subsidizing hydrogen—possibly both.” Reducing subsidies for fossil and nuclear fuels would introduce the element of truth that Lester Brown finds lacking in the market. According to Henry Kelly “a colossal increase in the demand for energy services will occur because of the real possibility of a doubling world population and the fact that the per capita consumption worldwide is increasing by a factor of two or three. The overwhelming problem is personal vehicles.” (Kelly, 40, 41)

Without an historic change in the energy practices of both developed and developing nations, an energy/environment crisis of epic proportion looms over the world during the next 20 – 30 years. Shifting the focus of subsidies from fossil and nuclear towards renewables and hydrogen now will allow a stable and measured transition to occur later. Waiting will not.

When the Administration rolled out its hydrogen vision in 2002 and its strategy in 2003, the source of the hydrogen was perceived primarily to be natural gas. The developing natural gas shortage however, has precluded this source from being the primary one.

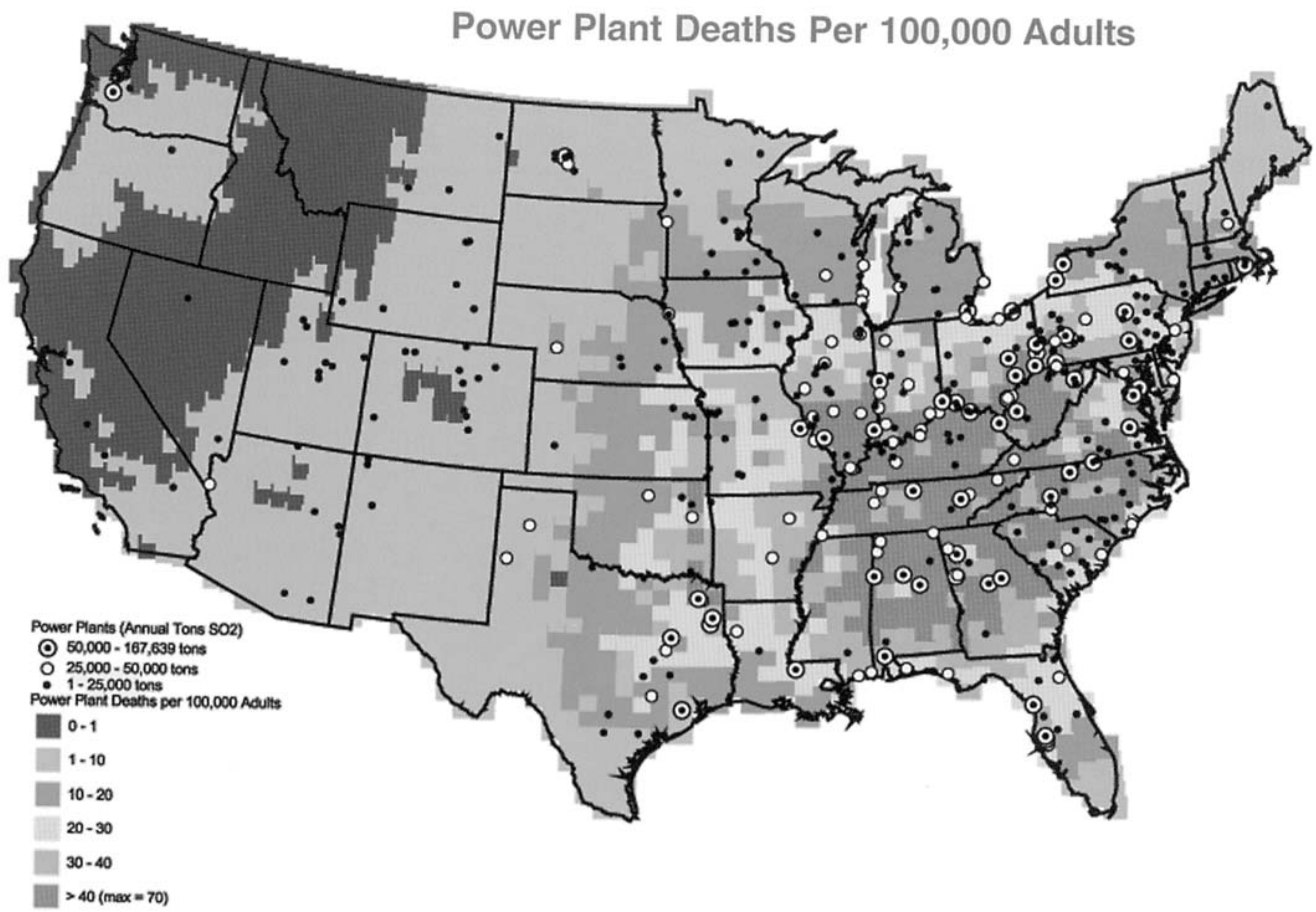
Other technologies have come forward. Nuclear, coal, natural gas and renewables are all trying to position themselves to serve as the primary energy resource to produce the required hydrogen. Among these resources, renewables possess some special attributes that should make them the best choice. (Kazmerski, 8)

For example, renewable energy sources are becoming cost effective. This is resulting in worldwide growth of the wind electricity generation capacity at near 40 percent per year. As suggested by this figure, continued strong growth will result in renew-



Paul B. Scott, ISE Research

Projected Worldwide Wind Generation Capacity—Worldwide wind generation capacity may exceed nuclear in 9 years.



NREL/ABT Associates

Nationwide correlation of power plant emissions and related annual mortality

ables becoming a major participant in electrical power generation in the coming decade. (Scott, 10)

By combining renewables and hydrogen, it is possible to avoid the intermittency problems of solar and wind technology, while providing fuels that can power vehicles and generate electricity. Renewable hydrogen, in concert with renewable energy technology, makes the proverbial "total package."

The currently higher price of sustainable energy resources is not an inherent attribute of clean energy technologies. Rather, it is a function of their being still in the early stages of commercialization and development, **AND** the level of subsidies paid to the fossil and nuclear energy industries. Removing subsidies from fossil and nuclear fuels—even without increasing those for renewables and hydrogen—would begin to equalize the prices of sustainable and non-sustainable energy resources. Technological improvements such as those experienced by the wind and PV industries will further serve to decrease the cost of emerging clean energy alternatives.

In any event, the health and security benefits of energy independence are so large as to outweigh the problem of their currently higher price in the existing scheme of things. *The real issue is not the price of existing and emerging sustainable energy; it is the true cost of fossil and nuclear fuels.* The price of domestically available clean energy is coming down, while that for natural gas, petroleum, "clean coal" and nuclear is going up. This is a trend that will not be abated by drilling in the Arctic, importing liquid natural gas (LNG), or guarding nuclear reactors from terrorist attack.

Section II. Human Health Needs

Energy sources that emit air pollution have costs not always reflected in market prices. For example, in the case of coal, if the cost due to the estimated 15,000 premature deaths from chronic obstructed pulmonary disease attributed to coal were added to the price, the cost of electricity from coal would increase by several pennies on a kilowatt-hour basis. (Garman, 30) The addition of several pennies per kWh would make wind, photovoltaics and biomass energy competitive with oil, natural gas, coal and nuclear energy, without the need of any federal subsidy.

According to the Harvard School of Public Health, air pollution from just two Massachusetts coal-fired power plants contributes to particulate matter, sulfur dioxide, nitrogen dioxide and ozone exposure over a large region. Using a sophisticated model of how particulate matter and its precursors are dispersed in the atmosphere, the study's authors, Jonathan Levy and John D. Spengler have calculated the consequences of exposing the 32 million residents living in New England, eastern New York and New Jersey and the negative impact of these older coal plants that are exempt from current clean air standards. "Their report estimated that current emissions from the Salem Harbor and Brayton Point power plants can be linked to more than 43,000 asthma attacks and nearly 300,000 incidents of upper respiratory symptoms per year in the region." The study suggests that on an annual basis, 159 premature deaths be attributed to pollution from these two plants.

According to the study, health risks are greatest for people living closer to the plants. Twenty percent of the total health impact occurs among the eight percent of the population that lives within 30 miles of the facilities.

The researchers also analyzed the potential health benefits of reducing current emissions to the lower levels that would be reached by using the best available control technology required for newer power plants since the 1977 Clean Air Act and required by the U.S. Environmental Protection Agency as retrofit on some older plants. An estimated 124 premature deaths would be averted per year, along with 34,000 fewer asthma attacks and 230,000 fewer incidents of upper respiratory problems.[2]

Years of exposure to the high concentrations of tiny particles of soot and dust from cars, power plants and factories in some metropolitan areas of the U.S. significantly increases residents' risk of dying from lung cancer and heart disease, according to a study financed largely by the National Institute of Environmental Health Sciences. The study was conducted by scientists at Brigham Young University, Provo, Utah, the University of Ottawa, Ontario, the American Cancer Society and New York University School of Medicine, Tuxedo, N.Y.[3]

Arden Pope, professor of economics at Brigham Young University in Provo, Utah, the study's co-leader, said, "We found that the risk of dying from lung cancer as well as heart disease in the most polluted cities was comparable to the risk associated with nonsmokers being exposed to second-hand smoke over a long period of time."

The study evaluated the effects of air pollution on human health over a 16-year period. Previous studies have linked soot in the air to many respiratory ailments and even death, but the new findings "provide the strongest evidence to date that long-term exposure to fine particulate air pollution common to many metropolitan areas is an important risk factor for cardiopulmonary mortality," as well as lung cancer deaths.

The findings of the study's researchers corroborate what pathologists like Tony Delucia, MD know to be the case. Dr. DeLucia is the immediate past chairman of the board of the American Lung Association. The Association was an active partner in the 2003 Renewable Hydrogen Forum. According to Dr. DeLucia, environment plays a major role in determining the health of an individual. Although not as determinative as lifestyle, environment is as important as genetics and more important than the frequency and quality of healthcare.

Factors determining health and individual mortality

Lifestyle	51%
Genetics	20%
Environment	19%
Healthcare	10%

Source: DeLucia presentation ASES H_2 Forum

The health impacts of ozone include:

- Swollen and reddened living tissue.
- Coughing.
- Shortness of breath.
- Increased asthma.
- Increased susceptibility to infection.

Increasingly, reliance on fossil fuels for power generation and as a transportation fuel is leading to a higher frequency of smog alerts. It is no longer unusual to hear media warnings about air quality in metropolitan areas like Washington, D.C. Those that suffer the most from ozone and other air pollutants include the unborn, children, the elderly, asthmatics, people with heart disease and diabetes and people who exercise or work outdoors. Air pollution from fossil fuels diminishes the productivity of the growing number who are susceptible. When considered in relationship to other health trends in the U.S.—obesity and diabetes related to weight and diet—air pollution may be seen as an expediter of today's major health problems.

Section III. Key Technical Issues

Determining the feasibility of hydrogen technology involves a careful look at the entire system. Looking only at production means overlooking other core issues like resource availability, demand, upstream energy consumption, and delivery costs. Co-product opportunities such as carbon fibers and grid interaction are also important considerations, as they can add significant cost benefits. Taking a systems approach provides a much more solid foundation for determining the most cost-effective options for building out the hydrogen production, delivery and end-use infrastructure. (Mann, 48) A successful transition to hydrogen is a very integrated process that must involve plans for production, delivery and end use. (Kartha, 48)

Technical innovation—as well as enlightened public policy—is needed to lower the capital costs, improve processes for purification and separation of hydrogen, increase production efficiency and make sound judgments concerning the best feed stocks, their availability and location. Distributed generation versus centralized production of electricity and fuels is another major consideration. It still has not been determined whether it is more cost effective to deliver electricity or fuel. Similarly, codes and standards for transporting and handling must also be drafted and implemented. Hydrogen is a safer fuel than gasoline and others, but without the right materials and designs safety can become a problem. (Goswami, 7)

Technical and policy decisions for hydrogen should not be made in a vacuum. Recent blackouts in the eastern U.S., the ravages of a particularly violent hurricane season and homeland security concerns are causing Congress and the Administration to consider significant investment and changes in transmission systems.

Extant electric lines could carry only an insignificant fraction of the potential renewable production. About 400 new 36-inch gaseous hydrogen (GH_2) pipelines or about 900 of the largest possible new electric lines would be needed to get all of the potential production to market. (Leighty, 16)

As Congress considers passage of national energy legislation and other responses to recent events, it should understand that large investment in the status quo does little to prepare the nation for the required transition to a sustainable energy economy. If new pipe and transmission lines must be built, ASES encourages Congress and the Administration to make investment decisions that reflect the future and not the past. Building out the nation's energy infrastructure without an accommodation for renewable hydrogen and centralized and decentralized renewable energy systems is unwise and places the nation at great risk.

Section IV. The Role of Renewables in the Hydrogen Economy

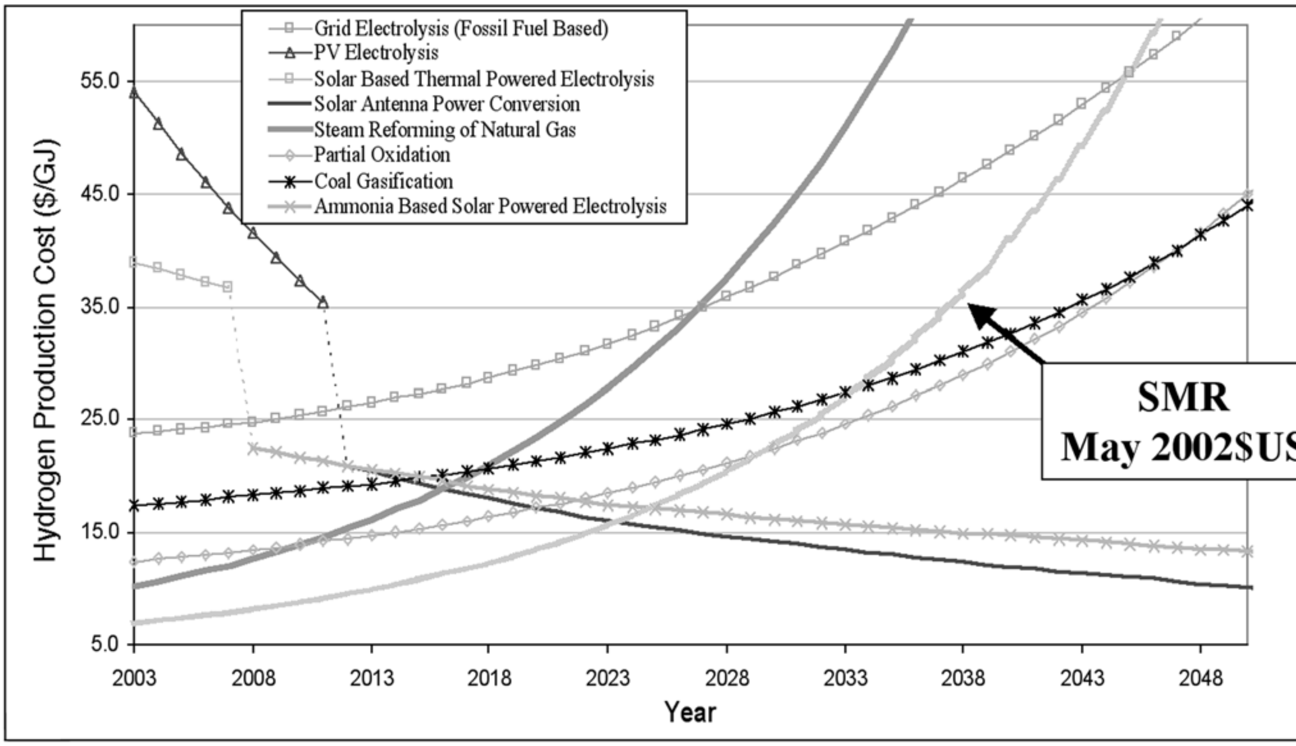
Processes using solar energy technologies can be used to decarbonize fossil fuels via cracking, reforming, or gasification prior to use for power generation. These are high-temperature highly endothermic processes.

Using solar energy for process heat offers a three-fold advantage—the discharge of pollutants is avoided, the gaseous products are not contaminated and the calorific value of the fuel is up-graded by adding solar energy in an amount equal to the enthalpy change of the reaction.

These processes offer viable and efficient routes for hydrogen production and CO_2 avoidance. The mix of fossil fuels and solar energy creates a link between today's fossil-fuel-based technology and tomorrow's renewable energy technologies. It also builds bridges between pres-

Hydrogen Production Technologies

Steam reformation (SMR)
Thermal cracking
Partial Oxidation (POX)
Coal gasification
Biomass gasification (BG)
Electrolysis
Solar photovoltaic
Solar thermal power
Wind
Photochemical
Photo-electrochemical
Thermochemical
Nuclear
Biological production
Thermal decomposition



D. Yogi Goswami

Economics of hydrogen production processes (February 2003 $US)

ent and future energy economies because of the potential for clean, domestically available energy technologies to become the nation's primary energy sources. The transition from fossil fuels to solar hydrogen can occur smoothly. (Steinfeld, 27)

Any new hydrogen production technology will be compared against steam methane reformation when it comes to commercial investment. The economics of some of the alternatives are compared in the figure above.

As shown in this figure, the costs based on fossil fuels are going up and the costs based on renewable energy production are coming down. In fact, the cost for steam methane reformation has gone up within the last year.[4] Although not explicitly included, wind would be part of the mix right now. This analysis does not consider any environmental penalty for fossil fuels. It can be reasonably argued, however, that the environmental cost per gigajoule when using coal as a feedstock is $15, for petroleum around $13/GJ and approximately $9/GJ in the case of natural gas. (Goswami, 7)

Wind and Solar Driven Electrolysis

The promise of wind and PV/electrolysis stems from their versatility in providing both fuel and power. Wind, solar and biomass technologies can provide power when those resources are available. Excess power generated at these times can be used to produce hydrogen via electrolysis. When the wind is not blowing and the sun is not shining, stored hydrogen can be used to run electrical generators, while vehicles are able to run on wind- or PV-generated hydrogen. (Scott, 11)

Biomass

Both the U.S. and the world have significant biomass capability. Biomass complements wind and solar resources, since there is little overlap in regions where a resource is highest. (Overend, 13) The pulp and paper industry has a long history of producing energy from biomass. Biomass harvested to produce pulp and paper simultaneously produces black liquor. Black liquor is an energy form as well as a chemical recovery system in the pulp and paper industry. Today, post-consumer biomass materials—in the form of municipal solid waste, landfill gas and industry waste—represent a very rich resource which is already fully concentrated and does not need to be harvested. (Overend, 13)

Current biomass-to-hydrogen technology is based on gasification and


NREL/Courtesy of Mendota Hills Wind Farm


NREL/Dave Parsons


NREL/Dave Parsons


NREL/Ray Bleez

Wind power, solar power towers, parabolic troughs and biomass are among the renewable technologies that can be used to produce hydrogen.

pyrolysis. Gasification is a very flexible technology being developed in various biomass and bioenergy programs around the world. In terms of economics, the costs to produce hydrogen via biomass pyrolysis can be brought down to the range of $1.50 per gasoline gallon equivalent.

By about 2020 the hydrogen potentials from biomass are estimated to be 29 teragrams of hydrogen from approximately seven exajoules of biomass. This is equivalent to 40 percent (+/-) of today's vehicle fleet. In terms of harmful emissions, gas savings translate to about 84 million metric tons of carbon equivalent fuel. High yielding energy crops would reduce the cost of biomass and the amount necessary by about 25 percent. The nation would be able to access more marginal land with adapted crops; biomass offers American farmers an opportunity to add another cash crop to their operation. New cash crops help to preserve the family farm and an agricultural way of life. Particularly important is the fact that U.S. biomass crops would be fairly immune to cheaper imports, as transportation costs would be prohibitive.

Hydrogen can also be produced from biomass, using thermal processes like gasification and pyrolysis. Biomass-to-hydrogen processes produce byproducts, which can significantly improve the economics of these systems.

Concentrating Solar Power

Concentrating solar power (CSP) is yet another proven renewable power producer. The main CSP technologies are power towers, parabolic troughs, concentrating PV and roof-integrated systems. CSP is a solar power technology particularly compatible with the current centralized grid system. Significant cost reduction will result through economies of scale. CSP is successful in some commercial settings and has a decade's operational history—producing 354 MWe. (Cohen, 12) Like all renewable energy technologies, its price can be reduced through economies of scale.

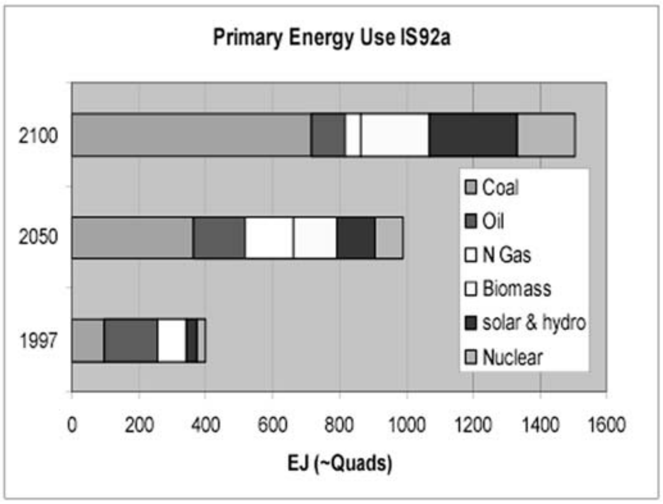
Comparisons

Of all the currently available renewable energy technologies, wind electrolysis is likely to be the first economical renewable hydrogen production system, simply because the cost of energy from wind right now is most often the lowest of the renewable technologies. (Hock, 23) Like biomass, wind offers farmers another cash crop. Rental incomes from wind machine sites are unaffected by agricultural commodity prices or nature's inconsistencies. Between wind, solar and biomass resources, the country is well covered. (See NREL renewable resource map on page 5)

It is important to recognize that "one size does not fit all" in the case of renewables. Different regions have different attributes. ASES believes that diversity both in resources such as wind, solar and biomass, and in distribution systems such as pipeline, central grid or decentralized, will provide maximum opportunity for the operation of market forces and serve to strengthen national energy policy. Diversity is important for maintaining the health of economic and environmental systems, as well as in reducing targets of terrorist opportunity.

Section V. Environmental Consequences of a Renewable Hydrogen Economy

Under any scenario a renewable hydrogen economy will be better for



Henry Kelly - Federation of American Scientists

the health, safety and economy of the U.S. than continued reliance on fossil and nuclear energy sources. Bluntly, fossil and nuclear energy sources are bad for the health and welfare of the nation—whether used directly or as a source of hydrogen.

It is useful to ask and answer the question: How much of different resources would be needed to supply hydrogen in large amounts? According to Susan Hock, Director of the Electric and Hydrogen Technologies Center at the National Renewable Energy Laboratory (NREL), "If we want to fuel about half of our current light duty vehicle fleet with hydrogen, that's about 100 million vehicles—and we assume we're using fuel cells, which are twice as efficient as current engines—we will need 40 million tons of hydrogen a year to fuel those cars.

"Now, to produce 40 million tons of hydrogen, it will either take 95 million tons of natural gas, which would be about a 20 percent increase over our current consumption; 340 million tons of coal, which is about a 30 percent increase over current consumption; 400 – 800 million tons of biomass, which is roughly equal to the residue and waste and some dedicated crops that are currently available; the wind capacity just from North Dakota; or 3,750 square miles of solar panels." (Hock, 24)

Producing hydrogen from biomass, rather than coal, offers the opportunity to sequester carbon while simultaneously producing energy. There is also the opportunity to produce metals, steam, aluminum, glass and all of our building materials. Every pound of biomass used represents CO_2 that has come out of the atmosphere and been converted into a useful product or component. (Day, 12)

For roughly every million BTUs of hydrogen produced from biomass, somewhere between 91 kilograms – 150 kilograms of carbon dioxide will be sequestered, depending on the type of biomass used and fertilizer made. (Day, 12) With biomass, there is no need to develop new, expensive and unproven carbon sequestration methodologies such as injection in the earth. Nature has already developed the technology, and it is available today.

It must be noted that carbon sequestration is an unknown quantity. Although theoretically possible, it is unclear whether carbon can be pumped into the earth and safely stored for a hundred or more years. Finding out if sequestration is possible will prove costly in terms of dollars—costs that will not be reflected in the prices of fossil fuels but paid by taxpayers.

As important as the technical feasibility is the issue of public acceptance. The not-in-my-backyard (NIMBY) syndrome that has dictated the debate and indecision in the case of nuclear waste is likely to be exhibited again in the case of carbon sequestration. The fact is that few, if any, people want to live around concentrated levels of harmful pollutants. The best answer to pollution is to avoid its production in the first place.

All renewable technologies bring with them significant environmental improvement over the nation's existing energy strategy. It is estimated that 100 percent of America's current electricity needs could be supplied with solar electric systems built on the estimated 5 million acres of abandoned industrial sites in our nation's cities or the rooftops of buildings already constructed.[5] When combined with a storage system, or in tandem with renewably derived hydrogen fuel, "solar" systems can meet all of the nation's energy demands 24/365.

Questions have been raised concerning the impact a renewable hydrogen economy would have on other natural resources such as water and land. Assuming 12,000 miles per year and 60 miles per kilogram of hydrogen, a fuel cell car will need between 3 – 4 gallons of water per day. These are life cycle calculations so they include upstream water usage for manufacturing the plant or the wind turbine, as well as the water usage during the hydrogen production phase. (Mann, 43)

Wind electrolysis uses more water than steam methane reforming, partly because steam methane reforming produces half of its hydrogen from the feedstock itself. Water is the source of hydrogen in the case of wind electrolysis. Based on the amount of water that is reported to be available throughout the world, the percentage that might be used for hydrogen production can be estimated.

In the U.S., four gallons of water per day, per car, represents about one-half of one percent of the available water supply. Even in very water stressed regions of the world, like North Africa, four gallons amount to less than one percent of the water used in the regions.

It is also important to recognize that water is used in current transportation and energy systems. To make a gallon of gasoline from crude oil in a refinery takes 18 gallons of water. (Braun, 50) In power plant systems, about a half a gallon of water per kilowatt-hour is used.

A transition to renewable hydrogen, therefore, would actually use less water than the amount used in today's energy systems. Water systems throughout the world are already showing signs of stress. *The value of a transition to an energy economy based on renewable hydrogen is increased by the benefits of water conservation.* (Mann, 43)

NREL/GM Desert Proving Ground

The U.S. Department of Energy has teamed up with other sponsors to challenge more than 200 of the best and brightest students from 15 universities in the United States and Canada to re-engineer full-size SUVs to meet the needs of the future, producing green, efficient transportation that has the performance, utility, and affordability that customers expect. Virginia Tech engineering students competing in FutureTruck 2000 equipped their Chevy Suburban with hydrogen fuel cell power.

Section V. Specific ASES Recommendations

On the basis of the presentations at the Renewable Hydrogen Forum and the experience of ASES members, the following recommendations represent the minimum steps needed to change the nation from one that is dependent upon foreign energy supplies and reliant upon fossil and nuclear fuels to one that is reliant upon domestically available clean energy technologies and hydrogen produced from them.

> *Enact a national energy policy that is premised upon the need for domestically available clean energy technologies—including energy efficiency—and improves the nation's security, environment and health.*

> *Launch a major systems-based renewable hydrogen initiative that neither gambles on the perfection of "clean coal" and carbon sequestration technologies nor encourages expansion of the use of natural gas and nuclear power.*

Key elements of the proposed initiative would include:

> *Recognizing the existence of global climate change, the leadership role that the U.S. must play in the clean-up of the world's environment and the need to become reliant on domestically available renewable energy resources within the next 20 years;*

> *Enacting a national "no exemptions" standard for power plants to clean our air and improve our health;*

> *Enacting a national Renewable Energy Standard requiring power producers to generate an increasing percentage of power using domestically available renewable energy technologies and resources;*

> *Expanding and expediting fuel cell research;*

> *Increasing auto and truck fuel efficiency standards and decreasing emission levels;*

> *Supporting consumer education;*

> *Directing the National Renewable Energy Laboratory (NREL) to devise a national profile of the*

key renewable hydrogen resources in each part of the country, estimate their near-term hydrogen production capacities and devise a plan for their earliest possible deployment;

Reducing subsidy levels for fossil and nuclear energy sources;

Increasing research funds and incentive levels for both renewable hydrogen and hydrogen's clean energy alternatives, such as advanced extended-range electric batteries and biofuels for next-generation hybrid electric vehicles;

Identifying and investing in energy infrastructures that support renewable hydrogen and other renewable energy technologies and system including hydrogen pipelines, electric transmission lines, decentralized networks, non-discriminatory grid interconnection rules and,

Promoting good science. The scientific process used to evaluate the various hydrogen production options must be conducted in a fair, open and competent manner and all data, assessments, methodology and findings must be made public.

Section VI. Conclusion

Hydrogen offers a bright new energy era for the U.S. and the world. Although plentiful, hydrogen does not exist on its own in nature, but in combination with other elements such as water (H_2O). The energy sources used to crack hydrogen from its attachments including renewables, coal or nuclear, and the feed stocks used as its source such as biomass, natural gas or coal, determine whether hydrogen is a clean or dirty energy source.

The American Solar Energy Society does not believe that the transition to a renewable hydrogen economy needs to wait for the development of fuel cells, carbon sequestration methodologies to reduce fossil fuel emissions, or the acquiescence of automakers to the need for less polluting vehicles. The know-how needed to immediately begin the transition to a sustainable energy economy is here today.

By combining hydrogen with renewable energy technology it is possible to avoid problems like intermittency and to free up fossil resources to fulfill their higher economic purpose—chemical feedstock for medicines, for instance. Renouncing reliance upon oil, natural gas, coal and nuclear energy sources will result in a cleaner environment and a healthier society. As importantly, reducing the need for foreign petroleum and natural gas supplies will reduce the nation's need to become politically involved in the Middle East and elsewhere.

The nation has the technology to make the journey to energy independence in years instead of decades. In conducting the Renewable Hydrogen Forum and making the above recommendations, ASES hopes to provide the information needed to re-assess the Administration's hydrogen roadmap and to shorten the time when the U.S. is truly free of dependence upon energy sources that have proven themselves too costly to support.

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Notes & Footnotes

All parenthetical notations throughout this document refer to the author and page number of the final published report on the Renewable Hydrogen Forum. This document is available in its entirety at *www.ases.org*.

1 (pg 6) ASES Renewable Hydrogen Report, p. 29

2 (pg 10) HSPH press release, Thursday, May 4, 2000

3 (pg 10) National Institute of Environmental Health Sciences, *http://www.niehs.nih.gov/*
Brigham Young University, *www.byu.edu/*
University of Ottawa, *www.uottawa.ca/*
American Cancer Society, *www.cancer.org/*
New York University School of Medicine, *www.med.nyu.edu/*

4 (pg 12) This analysis assumes that new developments in solar thermal power and photovoltaics will continue to reduce their costs.

5 (pg 14) NREL, January 2003, "Myths About Solar Energy," Better Building Series. DOE/GO-102003-1671

*Figure, page 4 Sherif, S., T. Veriziglo, and F. Barbir, 1999, "Hydrogen Energy Systems," pp. 370-402, Wiley Encyclopedia of Electrical and Electronics Engineering, vol. 9, J. G. Webster, (Editor), John Wiley & Sons, New York.

Additional Information

www.ases.org
The American Solar Energy Society's web site features the complete text of this and other ASES Policy Statements as well as other links and information of interest to sustainable energy enthusiasts.