Energy Posture

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ABSTRACT

"The Annual Energy Outlook 2003" from the Energy Information Administration indicates an annual petroleum consumption of 38.5 quads, with 25.7 quads imported. The transportation sector uses 26 quads, or 67 percent of the total. No other sector (residential, commercial, or industrial) of our society has this level of dependence on petroleum. Electric power generation, for example, has less than 5 percent of its output dependent on petroleum. Recent energy policy has focused on hydrogen as the next-generation transportation fuel. Will this alternative stand technical scrutiny? What are the options? Do those of us laboring in the technology vineyard have a responsibility to speak out publicly on these options?

INTRODUCTION

In the Dearborn, MI, Henry Ford Museum, several hundred cars are on display—all built between the turn of the century and World War One. They represent the explosion of technology driven by the availability of gasoline. The variety is amazing: steam, electric, air-cooled, water-cooled, friction drive, belt drive, planetary transmissions, engines in the rear, engines in the front, etc. By the mid-1920s, the technology had matured. The 1926 Chevrolet was the prototype. Only the Ford Model T had a planetary transmission; only the Franklin was air-cooled. All the others held to the general configuration we see today. Subsequent innovations were incremental, except possibly the introduction of the automatic transmission in the late 1930s.

A perception at the moment is that gasoline is about to be constrained. The reasons include: dependence on petroleum imports from unstable parts of the world, carbon load on the atmosphere, and local air pollution. Just as the availability of gasoline forced the explosion of automotive technology prior to World War One, the present concern with a petroleum-focused transportation sector may well force another technological explosion.

WHAT ARE THE OPTIONS?

The replacement of gasoline with the hydrogen fuel cell seems to have the greatest public support, yet many more options are available: compressed natural gas, for example, is an excellent motor fuel. Over 100,000 vehicles in the US are now operating on this fuel, and nearly 2,000 "gas" stations are available. Many areas of the US have natural gas resources, but are too remote for the economical installation of gas pipelines. A refinery located at the gas well can convert natural gas to a very high-quality diesel fuel or methanol. The pipeline or truck transport could get these liquid fuels to market with much lower cost than transporting the gas itself. The technology of hybrid diesel vehicles is emerging. As was the case prior to World War One, there is no consensus regarding which of these transportation technologies will mature.

All of the alternatives using natural gas and natural gas-derived fuel are not major departures from current automotive design and manufacturing methods. A transition to these technologies will be limited by a modest learning curve and economies of scale constraints. But any attempt to move to a fuel cell based on hydrogen will be overwhelmed by the high costs of the learning curve and the lack of economies of scale. Let's assume that a technically satisfactory vehicle emerges from the development shop, and management decides to start a production run of 30,000 vehicles. These units will be priced out of the market. Certainly fuel cost and vehicle range will not be as good as the current competition. Will the marketplace support a vehicle on its "green" properties alone? President Clinton failed to achieve a modest Btu tax. Will the public support a massive tax on current technology and the necessary massive subsidy for hydrogen technology?

If the hydrogen vehicle will have a difficult marketplace threshold, the hydrogen infrastructure will be even more difficult. At the moment, about one trillion cubic feet of natural gas (5 percent of the total) is used each year in the manufacture of about ten million tons of hydrogen[1].

This is a large and mature industry. But natural gas is in short supply. In testimony before congress on 2/25/03, EIA administrator Guy Caruso projected the 2025 need for natural gas at 35 trillion cubic feet per year. To reach this level will include, along with increasing imports, "… drilling deep and ultra-deep offshore projects in the Gulf of Mexico; development of unconventional production sources such as tight sands, coal bed methane, and shale deposits; and construction of major new pipelines to bring gas from Alaska and Canada to the lower 48 states."

Almost no hydrogen is now generated from the electrolysis of water. It is simply too expensive. Yet, the implication from some writers on the *hydrogen economy* is this: we use renewable sources like wind and solar to generate electricity, then use the electricity to obtain hydrogen through the electrolysis of water.

To match the solar and wind resource to the generation of hydrogen, we must know the quantity of hydrogen needed. The Energy Information Administration projects 35 quads of transportation energy in the form of petroleum will be used in the year 2020. We assume the hydrogen fuel cell is so efficient that the job can be done for one-tenth (that is a long reach) the projected petroleum use. Now, 3.5 quads of hydrogen energy will be required. A cubic meter of hydrogen (standard pressure and temperature) has energy of about 10,000 Btu. To support the transportation system in 2020, we will need 350 billion cubic meters of hydrogen.

Teledyne Energy Systems[2] will furnish electrolysis plants to make hydrogen for the emerging fuel cell cars in California. This system can produce one standard cubic meter of hydrogen gas with an electric input of 5.6 kWh. The energy in 5.6 kWh is almost twice as much as the energy in the hydrogen generated. In theory, the relation should be one-to-one, but the fueling of vehicles requires that the hydrogen gas be delivered at 5000 pounds per square inch pressure. This requirement for high-pressure delivery, plus the small scale of the enterprise, drives the high electricity demand. The generation of that 5.6 kWh will require the burning of fossil fuel with an efficiency of about 35 percent. One unit of energy in the form of hydrogen will require six units of conventional energy. Not a good deal. To state this again: six units of basic fuel (coal, natural gas, etc.) can produce two units of electric energy which, in turn, can produce one unit of hydrogen energy. Some laws of physics are involved. Improvements can be made, but not by a factor of two.

The electric energy required to generate the hydrogen needed for the transportation sector in the year 2020 will be two trillion kWh [3.5 $\times 10^{15} \times 5.6 \times 10^{-4} = 2 \times 10^{12}$]. The present electric energy consumption in the US is about four trillion kWh per year and requires over a billion tons of coal, over 100 nukes, etc.

But the question at hand is this: do we need fossil fuel? Can we do it with the sun and wind? Solar collectors in the very best locations can produce about 200 kWh per year for each square meter of solar array. Wind generators, in the very best wind locations, can produce up to 1000 kWh per year for each square meter of wind disc. The very largest wind generators[3] have rotor discs 370 feet in diameter. The swept area of the rotor is 10,000 square meters—close to the area of two football fields. In the very best wind domains, this machine can generate ten million kWh per year. If we divide the kWh needed to produce the hydrogen by the kWh available from one giant wind generator we find that **two hundred thousand of these monster wind machines are needed**.

The major US wind base is in the Great Plains. Three cubic meters of hydrogen are required to produce the energy stored in one cubic meter of natural gas. Consequently, the size of hydrogen compressors, pipelines, storage tanks, etc. is simply overwhelming. Renewable resources like solar and wind are simply too dilute for significant hydrogen generation.

The three-page website from the Department of Energy (www.eren.gov/freedomfuel/) acknowledges that several sources of hydrogen generation will be investigated, including nuclear and coal.

The transmutation of 80 kilograms of mass[4] into energy in nuclear reactors will produce the two trillion kWh needed for the annual production of hydrogen. The energy required for electrolysis (the 5.6 kWh cited above to produce one cubic meter of hydrogen) decreases substantially if the water undergoing electrolysis is at a high temperature. In fact, if water (steam) is heated to 4000C, **no** electric energy is needed. Disassociation of water into hydrogen and oxygen will occur without additional energy. With present materials, however, this approach is impracticable. A nuclear reactor can play a dual role: 1) supply the heat necessary to raise the temperature of the water prior to electrolysis; then 2) supply the needed electricity for the generation of hydrogen. To mass-produce hydrogen with electricity from the present electric grid is absurd. But this may well be an appropriate initial decision.

Although coal is associated with pollution, hydrogen can be derived from coal in a very clean way. Coal retorted with oxygen and steam can produce hydrogen, along with a wide range of clean energy fuels. The dimethyl ether (DME) produced could replace present propane as a bottled gas, or could be used as a motor fuel. Electricity could be generated and process steam produced. A technology sequestering the remaining carbon dioxide would be appropriate. Local chemical plants using coal as the base could well be part of the emerging *hydrogen economy*. But look out: a useful market must be found for all the concomitant by-products. If we do not develop such markets, the manufacture of hydrogen from coal will be polluting and wasteful.

The popular literature promotes the notion that hydrogen can be generated by solar systems in Nevada or wind machines in Kansas. The problem is not only the huge size and number of the wind machines but also the cost and size of pipelines, compressors, and required storage. People touting such schemes have simply never looked at the numbers. Local generation of hydrogen from nuclear plants or coal plants will trump the wind and sun every time.

SO WHERE DOES THIS LEAVE US?

A transition to hydrogen and the fuel cell is not an overwhelming winner. The natural gas resource may be more extensive than now believed, and may form the basis for the transportation sector for some time to come. Current petroleum supplies can be stretched with extensions of current vehicle technologies such as the hybrid gasoline and diesel engine. New petroleum supplies through the hydrogenation of heavy oil and tar sands will also extend the current era.

We now stand where we stood in 1910. We see all kinds of options, but can't see the 1926 Chevrolet. But one thing contrary to public perception seems clear: If the hydrogen fuel cell is to play a role, the hydrogen will come from the steam reformation of coal or from nuclear sources—not the sunshine in Nevada and wind in Kansas. Do those of us in the technical arena have an obligation to speak out on this issue? So far, not much has been said.

References

1) "World Energy Assessment; United nations Development Programme," page 299

2) *Mechanical Engineering*, March 2002 page 16
3) *Renewable Energy World*, Sept.-Oct. 2002
4) *Megawatts and Megatons*, Garwin and Charpak page 17
5) "Hydrogen: The Fuel of the Future?" Joan M. Ogden April 2002 *Physics Today*

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