Hydrogen As A Potential Fuel

Conrad Heins

In a world facing the real possibility of disastrous global warming, a fuel that does not produce carbon dioxide would appear to be a real godsend. Carbon dioxide is the ubiquitous by-product of all other combustion processes and the most important greenhouse gas responsible for that warming. Hydrogen is a potentially attractive replacement for both coal and oil as a fuel source because it produces no pollutants when it is burned. Only water is formed.

$$2\,H_2 + O_2 \text{ --------->} \; 2\,H_2O$$

Although it will most likely play a role as a fuel in a renewable energy society, I believe that at the present time it is a mistake to push the use of hydrogen as a substitute for non-renewable carbon based fuels. Let me explain why.

Conservation

First and most importantly, the proposal to substitute hydrogen for other fuels is addressing the problem from the wrong end. We should be concerned far more with reducing the need for fuel, through conservation and improved energy efficiency, than with replacing a "dirty" fuel with a "clean" one. In the United States we use about twice as much energy as the Germans or Scandinavians to accomplish the same tasks, whether they be heating their homes or driving to work. We need to focus not on the supply-side but on the demand side of the energy equation.

Application

A second, related point is that by addressing the problem in terms of supply we tend to ignore how the energy is being used, We fail to ask the critical question, "Is this particular kind of energy the best answer for this particular application?" Only when this question is posed are we able to to make judicious choices, especially if we want to take into account the second law of thermodynamics efficiency considerations, which deal with energy quality as well as energy quantity, or environmental impacts.

Reaction

Third, hydrogen is a far more reactive chemical than any of the materials that are currently used as fuels. I am not talking about flammability or explosiveness, but rather hydrogen's ability to undergo chemical reactions with other compounds. It is a good reducing agent; it adds to double bonds, causing embrittlement of plastics and elastomers; and, because it is such a tiny molecule, hydrogen can even work its way between the atoms of metals such as steel, causing hardening and embrittlement.

Unrenewable

Fourth, hydrogen is not made from a renewable energy source. Virtually all of it is produced from natural gas, methane, by an endergonic reforming process that uses steam.

$$CH_4 + 2\,H_2O \text{-------------->} \; CO_2 + 4\,H_2$$

It might be argued that because part of it comes from water we are obtaining the hydrogen, at least partly, from a renewable resource. However, the energy captured in the hydrogen will always be less than the energy in the methane plus the energy required to drive the reaction. And carbon dioxide is still produced; as much, in fact, as would be formed if the methane were burned as a fuel in the first place! Why waste energy to produce an energy storage material that is far more difficult to store and handle than the fuel it is made from, especially when the starting fuel is the cleanest burning of any of today's primary energy sources.

It must be emphasized that hydrogen is made from natural gas because this is the least expensive way to make it--considerably less expensive, for example, than of using electrolysis of water using electricity at off-peak rates. It is unrealistic to assume that, at least for the near term, hydrogen would be made in any quantity from anything but methane. We are left with the likelihood that the "hydrogen economy", like today's "hydrocarbon economy", would be based on a non-renewable resource.

Solar Hydrogen

Of course, it is possible to break apart water and obtain hydrogen in other ways. The formation of hydrogen and oxygen from water using electricity is the one that is most often touted. If the electricity is provided by PV panels, we are talking about using a renewable energy resource, sunlight, to provide hydrogen in a non-polluting way. Such a proposal, when first heard, sounds attractive. However, a little further examination indicates that is not a good answer.

The biggest problem is the prodigious amount of electrical energy that would be required to replace even a portion of the hydrocarbon fuels we now use. Wilson Clark, in his classic book, Energy For Survival, makes his point very clear.

"The amounts of hydrogen that would be required in a hydrogen economy are enormous. For instance, according to Dr. Gregory, to produce enough hydrogen to fully substitute for the natural gas produced in the United States at the present time [1974] --i.e., 70 trillion cubic feet of hydrogen-- would require more than 1 million megawatts of electric power to produce. Total electric generating capacity in the United States is only 360,000 megawatts. To meet the projected hydrogen requirements for natural gas alone would call for a fourfold increase in generating capacity, which would mean building 1,000 additional 1,000-megawatt power stations! This does not provide for increased electric power demand for other purposes, nor does it take into account the generation of hydrogen for transport fuel or as an additive in chemical and industrial processes."

By way of comparison, world production of photovoltaic generating capacity was about 50 megawatts (peak sun) last year. Even if this capacity were to be increased a 100-fold and all of it used to produce hydrogen, we would still be making a fraction of 1% of what would be needed to replace the natural gas consumed in the U.S. In addition...

Storage

Why use electricity, the most versatile form of energy available, to produce a material that is not easily stored (the boiling point of hydrogen is -435° F., about 25° F. above absolute zero) or handled and that will probably be burned to produce mechanical energy in a process that will be less than 30% efficient...When the electricity might be used directly?

If energy storage is needed, why do it through such a difficult-to-store material for which large scale storage technologies do not even exist, When electricity can be stored in batteries, flywheels or pumped storage systems far more effectively.

Efficiency

If it is to be used for transportation, why select a process that will operate at no more than 30% efficiency (an internal combustion engine) when an electric motor can be used that is at least 75% efficient? And why select a fuel that is so difficult to deal with in a mobile situation? (Wilson Clark, one of the early proponents of hydrogen fuel, includes a good discussion of the hydrogen powered automobile in ENERGY FOR SURVIVAL. He points out that a Dewar flask type container for liquid hydrogen that would that would hold the energy equivalent of 15 gallons of gasoline would have to be about 37 gallons in size and would cost (1974 prices) about $1,800. The use of metals, such as magnesium, to store hydrogen as a metal hydride would require an even larger volume).

Why Photovoltaics

Finally, why photovoltaics? As pointed out earlier, photovoltaics is not a good choice for generating vast amounts of electricity. It is much more suitable for smaller scale applications where grid power is not available. Although it will probably be used to generate utility power as well, utilities have never considered using it in any other capacity than for peaking power. In addition, these systems presently produce electricity at a cost of from $.25 to $.75 per kilowatt hour (20 year life cycle cost). Even were the cost to be cut in half, which is what we expect to happen during the next decade, we are talking about a much more expensive kind of electricity than could be produced by other renewable sources, such as the LUZ concentrating solar thermal facility that is presently supplying peaking power to the Los Angeles basin at about $.08 per kilowatt hour.

If these questions are answered primarily by, "because photovoltaics is renewable and non-polluting, and the burning of hydrogen produces no pollutants", I suggest that a much more thorough analysis of the situation needs to be carried out.

Access

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