

INTRODUCTION

I am concerned that there is widespread misunderstanding about hydrogen, particularly about what it can and can't do for us. I listen to claims that hydrogen will “replace” petroleum, and I worry that we've lost sight of the significance of having vast reserves of energy resources. It's important to understand the difference between a fuel and an energy resource. Hydrogen is merely a fuel – a commodity that allows us to store energy so that it can be moved to another location, or used at another time. It cannot substitute for an energy resource, which already contains stored energy that can be extracted and used. In a fully developed hydrogen economy we will still be fully dependent on our energy resources. And while hydrogen may allow additional flexibility in our selection of energy resources to meet our transportation needs, it cannot change the fact that our supply of energy resources is being seriously degraded, and that this degradation has serious implications for our future.

Equally tragic, I believe, is our readiness to pass up large-scale deployment of the host of available technologies that could immediately begin easing the problem of energy resource degradation. Conservation and energy efficiency have enormous potential, and many renewable technologies also hold promise. Instead we've put our faith in hydrogen when in fact, hydrogen may not provide any relief at all.

The key to our solving the energy problem is in understanding the often overlooked variable of energy and resource *quality*. I've done my best to explain quality's importance in my responses below. Thanks for considering my views, and I hope you enjoy the discussion!

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1) Hydrogen has been called an energy carrier, rather than an energy source. Can you articulate the difference and what that difference means in terms of energy return on investment as compared to existing sources.

The carrier/source discussion is problematic because all fuels are really carriers, and most of what we think of as “sources” are actually carrying energy from the sun. So explaining why hydrogen is not petroleum in terms of sources and carriers is confusing. Yet the difference between petroleum, a resource that can be extracted and then used to do work, and hydrogen, which we must work to produce, is very important.

To understand the major difference between hydrogen and petroleum, consider how the petroleum industry operates. An oil company first has to build drill-rigs, and transport them to the oilfield. These activities consume energy. Then they drill some wells, pump some oil, and ship it to a refinery. This consumes still more energy. Refining the oil

requires an enormous expenditure of energy, and so does trucking the finished fuel products to market. Where does the oil industry get all that energy? From the fuels they make, of course! The total amount of energy they consume is only a fraction of the energy they produce. Even though it consumes energy, the petroleum industry produces energy in *excess* of what it uses. We therefore say that the petroleum industry is a *net producer* of energy. It's a good thing too, because the net-energy (excess product) they produce is what goes into our gas tanks.

Unlike the petroleum industry, the hydrogen industry is not a net producer of energy. Hydrogen must be manufactured, but making hydrogen is entirely different from making gasoline. Here on Earth all of the hydrogen atoms are bonded to something, and breaking them loose requires an input of energy. The energy invested in tearing hydrogen atoms loose is the *very same* energy you get back when you later use the hydrogen as a fuel. So hydrogen is simply a storage medium, much like a battery. In the real world, storing energy always incurs a penalty, so the amount of energy you can get back from hydrogen is actually *less* than the energy you put into making it.

It's worth reiterating the major difference between hydrogen and petroleum: Processing petroleum into gasoline provides us with a net *gain* of energy, while processing water into hydrogen results in a net *loss* of energy. This fact by itself does not make hydrogen production a useless endeavor, it just points out the fallacy of contending that hydrogen can replace energy resources like petroleum.

2) How safe to humans and the environment is hydrogen as a fuel when compared to gasoline, propane, natural gas, coal and nuclear energies in both the short-term and the long-term and which of these sources do you think will be used to create hydrogen?

How safe is hydrogen? Well, the gas itself may be relatively safe for the environment, but given hydrogen's propensity to mislead us into believing it's the solution to our energy problems, I think it's quite dangerous. The misperception that hydrogen can relieve the most critical energy problem we face – the degradation of energy resources – is keeping us from deploying existing, proven technologies that could immediately begin addressing this problem.

Earlier I said that the petroleum industry consumes only a fraction of the energy it produces. The size of that fraction dictates what is known as *resource quality*. The higher the resource quality, the less the energy needed to make a unit of fuel. The oil discovered in the early 1900's, when a single "gusher" well could produce tens-of-thousands of barrels per day, was very high quality. But that oil is long gone. Today we comb the deep oceans for tiny pockets of oil, or we talk of digging up tar sands. Although plentiful, these are much lower-*quality* resources, meaning that far more effort is required to extract and produce the same amount of net energy.

The abundance of high-quality energy resources enabled the unprecedented economic and population growth of the past hundred years. As the quality of our energy resources continues to decline, the task of maintaining our current level of economic activity becomes increasingly difficult. Reliance on high-quality resources has placed us in a precarious position economically, environmentally, and geopolitically. There are no known substitutes for high-quality oil and gas resources. Certainly hydrogen is not one – it isn't even an energy resource. Unless we stop pouring enormous effort into hydrogen in lieu of pursuing energy efficiency and other available technologies to address this crisis, we may discover just how dangerous the reliance on hydrogen really is.

### 3) How convenient and affordable will hydrogen and hydrogen vehicles and applications become to the average consumer?

This is a tough question, because you're asking me to predict the future of consumer purchasing power. Our economy is currently in peril because the high-quality energy resources that keep it running are in steep decline, and instead of seriously addressing the problem we are entertaining misguided hopes for future travel technologies. If we continue this behavior long enough to actually produce a marketable hydrogen car, and maintain our economy in the meantime by invading and occupying oil-rich countries, I think Halliburton executives will be able to purchase hydrogen cars by the tanker-load. As a bonus they'll have control of all the oil resources they'll need to make the hydrogen!

### 4) Does hydrogen have a place in the world's future energy supply and will it emerge in time to avoid the worst impacts of global warming? If so, how?

Hydrogen will never be part of the world's energy "supply", because hydrogen is not an energy resource, it's just a storage medium. (Do batteries have a place in our energy supply?) Our future supply-mix will gradually shift toward renewables as declining quality makes the fossil sources impractical (from a net-energy standpoint) to exploit. But my guess is that the problem of declining resource quality is being terribly underestimated, and the economic and geopolitical problems it is causing are going to get worse quickly. With all the encumbrances of an ailing economy, will we continue to pursue hydrogen – an energy storage technology that necessitates a total rebuild of our transportation infrastructure? Even if it made sense to do so, I doubt we will be financially capable of it.

As for global warming, the depletion of fossil fuels, rather than the emergence of hydrogen, will eventually re-stabilize the climate. The interim before stability returns is of course the concern. Currently, the pollution from fossil-fuel combustion is shading the planet, offsetting some of the heating from the greenhouse gases we've emitted. If we stopped polluting today, this "protective" layer of pollution would clear very quickly, but the carbon we've already released would continue being absorbed into the atmosphere for decades. We are therefore already committed to some additional warming, and we don't know the full extent of the impacts it will have. Nonetheless, we are far better off

addressing this problem sooner rather than later. Again, deploying existing technologies including energy efficiency and high-quality renewable energy is the answer. Waiting for hydrogen, even if it were a solution, makes no sense at all.

5) Given the future increased energy needs of the planet, no matter what fuel we substitute for oil, in order to create sustainability our attitudes about energy consumption will have to change. What are some of the key shifts you feel need to happen?

Sometimes I get the feeling that we are spending too much time looking for new, high-tech ways to allow us to maintain our lifestyle, and not enough time contemplating a lifestyle that would be less destructive. I have a feeling that the sustainable way of life may involve more than super-insulated buildings and fuel-efficient cars. We are part of the earth's natural systems, and if we plan to stay for the long term we may need to rediscover nature's rules, and learn to live by them.

What makes holding on to a destructive lifestyle so appealing? And why is acknowledging that we are a part of nature so difficult? My guess is that in the persistent struggle between love and fear, we have given fear the upper hand. This fear has us working to control our environment, but that is something we surely cannot control. We live in the natural environment, governed by laws we cannot change. Letting go of the need to control our environment requires courage – foremost the courage to love and respect ourselves, our living planet, and one another.

- *Mark Sardella*