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Transportation of hydrogen from production to distribution is costly.

David W. **Keith**, Dept. of Engineering and Public Policy at Carnegie Mellon University and Alexander E. **Farrell**, with the Energy and Resources Group at the University of California Berkeley, July 18, **2003**, “Rethinking hydrogen cars” Science, Vol. 301, Issue 5631, p315

The introduction of any new transportation fuel is a rare, difficult, and uncertain venture — it demands a linked introduction of a new fuel distribution system and new vehicles, because neither is useful without the other. Although technically feasible, a hydrogen refueling infrastructure would be expensive: initial cost would likely exceed \$5000 per vehicle even if one assumes large economies of scale. The cars themselves will also likely be expensive. If hydrogen cars are ever to match the performance of current vehicles at a reasonable cost — particularly fueling convenience, range, and size — technological breakthroughs in hydrogen storage and energy conversion will be required. Like electricity, hydrogen is an energy carrier that must be produced from a primary energy source [HN3]. Today, hydrogen is produced from natural gas on a large scale and at low cost: hydrogen production consumes 2% of U.S. primary energy, and at the point of production, it costs less than gasoline per-unit of energy. Although hydrogen production is simple, as a low-heating-value, low-boiling-point gas, it is inherently expensive to transport, store [HN4], and distribute — all strong disadvantages for a transportation fuel.

Transporting Hydrogen is tough and inefficient

Jeff Wise. “The Truth About Hydrogen” Popular Mechanics. Published in the November, 2006 issue.

HURDLE 3: Distribution

Even in portable form, hydrogen is a tough substance to move from place to place. It can embrittle steel and other metals, weakening them to the point of fracture. **TRUCKING AND RAIL:** Currently, most hydrogen is transported either in liquid form by tankers or as compressed gas in cylinders by trailers. Both methods are inefficient. Trucking compressed hydrogen 150 miles, for instance, burns diesel equivalent to 11 percent of the energy the hydrogen stores. It also requires a lot of round trips: A 44-ton vehicle that can carry enough gasoline to refuel 800 cars could only carry enough hydrogen to fuel 80 vehicles.

Storage and cooling hydrogen requires a lot of energy

Jeff Wise. "The Truth About Hydrogen" Popular Mechanics. Published in the November, 2006 issue.

HURDLE 2: Storage

At room temperature and pressure, hydrogen's density is so low that it contains less than one-three-hundredth the energy in an equivalent volume of gasoline. In order to fit into a reasonably sized storage tank, hydrogen has to be somehow squeezed into a denser form.

LIQUEFACTION: Chilled to near absolute zero, hydrogen gas turns into a liquid containing one-quarter the energy in an equivalent volume of gasoline. The technology is well-proven: For decades, NASA has used liquid hydrogen to power vehicles such as the space shuttle. The cooling process requires a lot of energy, though-roughly a third of the amount held in the hydrogen. Storage tanks are bulky, heavy and expensive. **SOLID-STATE:** Certain compounds can trap hydrogen molecules at room temperature and pressure, then release them upon demand. So far, the most promising research has been conducted with a class of materials called metal hydrides. These materials are stable, but heavy: A 700-pound tank might hold a few hours' fuel. However, exotic compounds now being studied could provide a breakthrough to make hydrogen storage truly practical. "High-pressure tanks are a stopgap until we can develop materials that will allow us to do solid-state storage efficiently," says Dan O'Connell, a director of GM's hydrogen vehicle program.

A hydrogen economy is a debilitating diversion.

David **Morris**, *VP of the Institute for Local Self-Reliance*, February 24, **2003**, AlterNet., <http://www.alternet.org/story/15239/>

To understand why, we need to start with the basics. Hydrogen is the most abundant element on the planet. But it cannot be harvested directly. It must be extracted from another material. For the fossil fuel industry, not surprisingly, hydrocarbons will provide most of our future hydrogen. They already have a significant head start. Almost 50 percent of the world's commercial hydrogen now comes from natural gas. Another 20 percent is derived from coal. What does all this mean? A hydrogen economy will not be a renewable energy economy. For the next 20-50 years hydrogen will overwhelmingly be derived from fossil fuels or with nuclear energy. Renewables are poised to rapidly expand their presence. A hydrogen economy would be a potentially debilitating diversion.

Hydrogen is unsuitable with the energy market.

David **Morris**, *VP of the Institute for Local Self-Reliance*, February 24, **2003**, AlterNet., <http://www.alternet.org/story/15239/>

There is another energy-related problem with hydrogen. It is the lightest element, about eight times lighter than methane. Compacting it for storage or transport is expensive and energy intensive. A recent study by two Swiss engineers concludes, "We have to accept that [hydrogen's] ... physical properties are incompatible with the requirements of the energy market. Production, packaging, storage, transfer and delivery of the gas ... are so energy consuming that alternatives should be considered."

Hydrogen economy intensifies pollution.

David **Morris**, *VP of the Institute for Local Self-Reliance*, February 24, **2003**, AlterNet., <http://www.alternet.org/story/15239/>

Not only will a hydrogen economy do little to expand renewable energy, it will increase pollution. Making hydrogen takes energy. We are using a fuel that could be used directly to provide electricity or mechanical power or heat to instead make hydrogen, which is then used to make electricity. Back in 1993 William Hoagland, senior project coordinator at the National Renewable Energy Laboratory's hydrogen program, prophetically told Time Magazine, "I can't see why anyone would invest in additional equipment to make hydrogen rather than simply putting the electricity on the grid." Converting natural gas into hydrogen and then hydrogen into electricity increases the amount of greenhouse gases emitted.

Hydrogen not technically a fuel - you have to make it before you can use it

Jeff Wise. "The Truth About Hydrogen" Popular Mechanics. Published in the November, 2006 issue.

At first glance, hydrogen would seem an ideal substitute for these problematic fuels. Pound for pound, hydrogen contains almost three times as much energy as natural gas, and when consumed its only emission is pure, plain water. But unlike oil and gas, hydrogen is not a fuel. It is a way of storing or transporting energy. You have to make it before you can use it — generally by extracting hydrogen from fossil fuels, or by using electricity to split it from water.

And while oil and gas are easy to transport in pipelines and fuel tanks — they pack a lot of energy into a dense, stable form — hydrogen presents a host of technical and economic challenges. The lightest gas in the universe isn't easy to corral. Skeptics say that hydrogen promises to be a needlessly expensive solution for applications for which simpler, cheaper and cleaner alternatives already exist. "You have to step back and ask, 'What is the point?'" says Joseph Romm, executive director of the Center for Energy & Climate Solutions.

Production of Hydrogen relies on Fossil Fuel use

Jeff Wise. "The Truth About Hydrogen" Popular Mechanics. Published in the November, 2006 issue.

HURDLE 1: Production

The United States already uses some 10 million tons of hydrogen each year for industrial purposes, such as making fertilizer and refining petroleum. If hydrogen-powered vehicles are to become the norm, we'll need at least 10 times more. The challenge will be to produce it in an efficient and environmentally friendly way.

FOSSIL FUELS: At present, 95 percent of America's hydrogen is produced from natural gas. Through a process called steam methane reformation, high temperature and pressure break the hydrocarbon into hydrogen and carbon oxides — including carbon dioxide, which is released into the atmosphere as a greenhouse gas. Over the next 10 or 20 years, fossil fuels most likely will continue to be the main feedstock for the hydrogen economy. And there's the rub: Using dirty energy to make clean energy doesn't solve the pollution problem-it just moves it around. "As a CO2 reducer, hydrogen stinks," Romm says.

ELECTROLYSIS: Most of the remainder of today's hydrogen is made by electrically splitting water into its constituent parts, hydrogen and oxygen. This year, a PM Breakthrough Award went to GE's Richard Bourgeois for designing an electrolyzer that could drastically reduce the cost of that process. But because fossil fuels generate more than 70 percent of the nation's electrical power, hydrogen produced from the grid would still be a significant source of greenhouse gas. If solar, wind or other renewable resources generate the electricity, hydrogen could be produced without any carbon emissions at all.

Hydrogen as fuel still has a long way to go.

Paul **Rodgers**. *Belfast Telegraph* 23 **November 2006**

Using hydrogen as a fuel is not a new idea; it burns 10 times faster than petrol (think of the Hindenburg) and powers the main engines of America's space shuttles. Importantly, it can be extracted from water with electricity produced by solar, wind, wave, tide, geothermal or nuclear generators.

But it still has a long way to go before it becomes the world's main motoring fuel. Hydrogen is expensive, especially if it's made from environmentally friendly sources. The cheapest supply comes from methane, by a process that produces CO₂, although this could in the future be sequestered.

Even if the cost of making green hydrogen falls enough to match the rising price of fossil fuels, the problem of infrastructure remains. Britain has only one garage with a hydrogen pump: BP's site in Hornchurch, Essex. To refit all the UK's 9,600 filling stations would be daunting.

What's more, station owners will be reluctant to switch until they're sure which new fuel will triumph, for an internal combustion engine running on hydrogen is not the only option.

Hydrogen for electricity is roughly equal to today's power plants

Jeff Wise. "The Truth About Hydrogen" Popular Mechanics. Published in the November, 2006 issue.

HURDLE 4: Use

Once hydrogen reaches consumers, is there anything they can do with it except drive vehicles? Home energy generation is one other option. The question is whether hydrogen would be more practical than current methods. Hydrogen produced by steam reformation or by electrolysis loses energy when it is converted into electricity. The resulting efficiency is roughly equal to that of today's power plants — which pay a lot less for raw materials. Direct generation of electricity through wind and solar power will also be more efficient for most stationary applications. That leaves transportation as the most promising use for hydrogen.

Even after surpassing technical hurdles Hydrogen's huge price tag stands in the way

Jeff Wise. "The Truth About Hydrogen" Popular Mechanics. Published in the November, 2006 issue.

Once the technical hurdles are crossed, hydrogen's huge price tag may still make the technology prohibitive. A recent analysis by the Department of Energy projected that a supply network adequate for even 40 percent of the light-duty fleet could cost more than \$500 billion. And that leads to a classic chicken-and-egg problem: How do you get millions of Americans to buy hydrogen-powered vehicles before there's an infrastructure in place to refuel them? And how do you get energy companies to build that infrastructure before there's a potential customer base?

Hydrogen power still decades away.

Worlds News Digest (*December 31, 2004*) Energy: Panel Urges Conservation, New Sources; Other Developments.

http://150.147.23.35:9797/com/2facts/?MuseHost=www.2facts.com&MuseSessionID=52abe8e585890d46077e48d9ed1d2dd&MuseFirst=1&MusePath=%2Fstories%2Ftemp%2F1771temp2004337330.asp#d2004337330_2

Researchers at the Idaho National Engineering and Environmental Laboratory, a government nuclear laboratory, and at Salt Lake City, Utah-based ceramics maker Ceramtec Inc. December 2 announced the discovery of a new technique to produce hydrogen from water, which used far less energy than earlier methods. However, some experts said fuel-cell-powered cars were still decades away because of the difficulty in shipping and storing hydrogen power. Widespread use of the new hydrogen-generating technique would also require construction of a new kind of nuclear reactor that used hotter water.

BMW'S Hydrogen 7 Not as Green as it Seems

Christian Wüst. SPIEGEL ONLINE November 17, 2006, 03:04 PM
<http://www.spiegel.de/international/spiegel/0,1518,448648,00.html>

BMW is manufacturing the first series of hydrogen fueled cars. They're not as green as they seem. For a start, they're incredibly thirsty -- and they will put more strain on the environment than a heavy diesel truck.

The problem is that hydrogen is in scarce supply and producing it requires vast amounts of energy. Climate-friendly production of liquid hydrogen on a large scale presupposes a virtually unlimited supply of ecologically produced electricity -- not something likely to materialize in the near future. That's why energy experts from the Wuppertal Institute for Climate, Environment and Energy believe forcing the transition to a hydrogen-based economy within the next three to four decades is "not an ecologically sound" idea.

Storing the volatile energy source also requires energy and money. The only method that promises a reasonable storage life is liquid storage at temperatures below -253 degrees Celsius (-423 degrees Fahrenheit). The process of cooling the storage facility down to such a low temperature alone uses up to one-third of the energy contained in one fuel tank.

And so, in creating the Hydrogen 7, BMW is announcing a future of putatively clean, full-throttle driving. The new car caters to the pleasing fantasy of customers spoiled by high-horsepower engines: That they can conform to ecological standards without making any sacrifices, burning "clean" fuel to their heart's content. Advertising images display the Hydrogen 7 against a backdrop of wind turbines and solar panels.

But the image is one of deceit. Because the hydrogen dispensed at the new filling station is generated primarily from petroleum and natural gas, the new car puts about as much strain on the environment as a heavy truck with a diesel engine. Add the loss of environmental benefits involved in the production and transportation of the putatively clean fuel to the consumption of the car itself and you get an actual consumption corresponding to considerably more than 20 liters (5.3 gallons) of fossil fuel.

The environment isn't the only loser: Customers will also have to shell out a lot of money for their deceptive display of ecologically responsible driving. The current standard price for liquid hydrogen is 57 euro cents (0.73 US cents) per liter (0.3 gallons). And the price tag on a 100 kilometer (62 mile) drive in the Hydrogen 7, at a comfortable speed, is about €30 (\$38).