The Present And Future Of Hydrogen Fuel Cell Electric Vehicles

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Mention zero-emission vehicles and most people think of battery electric cars. But there is another option: Fuel Cell Electric Vehicles – FCEVs – powered by hydrogen. Why don't we see more of them on the road? What are the hurdles hydrogen fuel cell electric vehicles need to overcome before we'll be able to find them at a local dealership?

The Hyundai Tucson Fuel Cell Electric Vehicle will give you the range and convenience of a gasoline-powered car with zero emissions.

Hydrogen fuel cells have already proven to be a viable technology for a variety of applications. Large stationary fuel cells are providing both primary and backup power at some facilities for Apple, Google, Walmart, and others. Many telecommunications providers use fuel cells to power cell phone towers. When Hurricane Sandy struck the Northeastern US in 2012, some hospitals, emergency shelters, and other buildings were able to keep the lights on and services operating because local utility companies had the foresight to install backup and standby power systems based on fuel cells. Increasingly, hydrogen fuel cells are powering forklifts and other material handling equipment for Walmart, IKEA, and Fed-EX. Some municipalities already operate fleets of fuel cell buses.

But what about automobiles? How long will it be before we have the option of buying a car powered by a hydrogen fuel cell?

In fact, some drivers are already behind the wheel of fuel cell electric cars. Audi, Daimler, Honda, Hyundai, and Toyota all have fuel cell models. However, often the initial release of these vehicles is rather limited. The average consumer isn't likely to see one in their local showroom any time soon. But they are coming.

The fuel cell was invented way back in the early 19th century and auto manufacturers have been tinkering with them since the 1960s. So why the delay in getting hydrogen fuel cell electric vehicles on the road? It can not be because the technology doesn't make sense in an automotive context.

Consider the growing popularity of battery-powered electric cars. With well over a billion vehicles on the world's roads in 2017, electric cars accounted for a mere 1.9 million of those. While the ratio is climbing – Argonne National Laboratory predicts that by 2030, electric cars will comprise 58% of the global light vehicle market – the vast majority of these will be battery-powered. In contrast, a December 2017 report by Washington, DC-based market research firm Information Trends put total sales of fuel cell cars at just over 6,000; more than half of those are in California. Clearly, hydrogen-powered vehicles have some catching up to do.

Yet, while battery-powered electric cars satisfy the zero-emission criteria, they still suffer from limited range – typically about 300 miles – and long recharge times – 30 minutes or more with the fastest level 3 chargers. Here, fuel cell electric vehicles have a clear advantage. Morry Markowitz, President of the Fuel Cell and Hydrogen Energy Association in the US, comments, "Fuel cell electric vehicles have great potential. They're the only zero-emission vehicle available right now and for the foreseeable future that totally replicates the current driver's experience of being able to drive 300 to 400 miles on a tank and then refuel in 3 to 5 minutes."

Admittedly, several factors put hydrogen fuel cell electric vehicles behind the alternatives – conventional gasoline powered cars and battery electric cars. But are those factors genuine obstacles? And if they are, how can they be overcome?

THE HYDROGEN FEAR FACTOR

One obstacle for many is the hydrogen fear factor, the belief that hydrogen as a fuel is inherently dangerous. Part of this likely stems from the Hindenburg disaster of 1937. Although most drivers today don't remember the incident directly, it still casts a pall over the hydrogen fuel industry, much as the sinking of the Titanic does over the cruise industry.

While attempting to dock in New Jersey after an uneventful trans-Atlantic flight, the 2-year-old hydrogen-filled German airship burst into flames and collapsed to the ground, killing 36 people. Theories as to what caused the accident are still being debated, but the shocking headlines made many people wary of hydrogen's use in consumer products. A number of similar passenger airships were in operation at the time, built in Germany, the UK, the US, and France. Unfortunately, several of those also met an untimely end when their hydrogen ignited.

So, perhaps hydrogen wasn't the best choice of fuel for an airship, but should that limit its use in autos? Not according to Markowitz. "I would say that the vehicles will be as safe or safer than current gasoline powered vehicles," he says. There are at least two factors contributing to this safety.

"The robustness of the tanks are incredible today," explains Markowitz. "That's thanks to new materials such as carbon fiber and other engineering techniques. In addition to that, hydrogen does not pool like gasoline, but in fact dissipates in the air because it's lighter than air."

Aren't compressed hydrogen tanks likely to explode in the event of a collision? "Actually, I would not even take odds that the tank would rupture as a possibility," Markowitz states. "It could be very, very slight, but if that's the case, the hydrogen itself would dissipate. But the tanks are being built to such high tolerances that you'd be surprised at the tests they're going through."

The tests Markowitz mentioned include standard automobile collision tests, as well as extreme stress tests such as burning the compressed hydrogen tanks in bonfires, dropping them from heights, crushing them, and shooting them with rifles.

Solution: Education. Consumers need to be shown that they can entrust their family's safety to hydrogen-powered fuel cell vehicles.

Lack of Understanding About Fuel Cells

People tend to distrust that which they do not understand. And it's fair to say that most drivers don't understand how fuel cells work, if they're aware of them at all.

When cars with internal combustion engines first started to rumble off the assembly line, many horse and buggy drivers greeted them with suspicion and disdain. They didn't understand how they worked. Today, most people likely know at least something about expanding gases, spark plugs, pistons, and crankshafts.

As for battery-powered electric vehicles … Most people carry battery-powered devices around in their pockets. Even if they don't understand how they work, they're comfortable with them.

Solution: More education. It's not necessary to turn every consumer into a physicist, but marketing that clearly explains the benefits of fuel cell technology will help to win over drivers reluctant to try something new.

Fuel Cell Basics

Fuel cells produce electricity through a chemical reaction. While there are many types of fuel cells, utilizing different components and even different fuels, they all consist primarily of four components:

- Two electrodes, a negative anode and a positive cathode
- An electrolyte that separates the two electrodes
- A fuel that supplies the electrons and protons for the reaction
- A catalyst that drives the reaction

The type most commonly used in vehicles – PEM fuel cells – use a proton exchange membrane or a polymer electrolyte membrane as the electrolyte and hydrogen as the fuel. In this type of system, hydrogen, made of up of one proton and one electron, enters the cell and meets a catalyst, typically platinum, which splits the protons and electrons. The electrons travel through the anode to an external circuit, and back to the cell through the cathode. The protons, meanwhile, travel through the electrolyte – the proton exchange membrane – toward the cathode, where they meet another catalyst, such as nickel, and recombine with the electrons and with oxygen to form water vapor.

Since each cell produces only a slight current, many cells are combined into a fuel cell stack.

The process can be written as:

Hydrogen + Oxygen = Electricity + Heat + Water Vapor

In fuel cell vehicles, the hydrogen would come from compressed tanks, while the oxygen is taken from the air. The result is a clean, quiet, and efficient production of electricity.

An Immature Hydrogen Infrastructure

Gasoline-fueled cars can be filled up at just about any service station on any street corner. Battery electric cars can be charged over-night in your garage, at one of the growing number of rapid charge stations coming online across the map, or anywhere you can find an outlet and someone willing to let you use it. But where do you fill a hydrogen-powered car?

The California Fuel Cell Partnership listed 35 strategically placed retail hydrogen fueling stations in the state as of May, 2018, with 29 more on the way. Stations are also beginning to appear in other regions, particularly parts of Europe and Japan. But that's hardly encouraging for the rest of the US, or for other countries with consumers eager to make the switch.

Once you find a station, will it be easy to fill up? “The actual process of filling the tank is very little different from what you do right now,” explains Markowitz. “You go to a dispenser unit at a filling station. Instead of having a fluid nozzle, you have a compressed gas nozzle you attach to your car. You hit a couple of buttons and the vehicle fills up in 3 to 5 minutes.”

Commenting on the safety aspect, Markowitz notes, “The vehicles and the stations themselves will meet or exceed safety standards that have been established over the past 50, 60 years. That ensures the safety of these vehicles and of the stations themselves.”

Solution: Time. As the number of hydrogen fuel cell electric vehicles increases, demand for stations at which to fuel them will increase and infrastructure will grow. As the infrastructure grows, more drivers will be willing to switch to FCEVs.

Hydrogen: How Much? How Pure?

Markowitz highlights two issues related to infrastructure. “The major issues facing us today are being able to meter the fuel and to make sure that the hydrogen is pure enough so it performs as expected by the fuel cell vehicle manufacturer.”

Measuring the amount of gasoline you pump into your car is relatively easy and uses well-established technology and widely recognized standards. Measuring the amount of hydrogen you pump into your car is somewhat more difficult, given the high pressures involved, variable temperatures, and the range of tank requirements. But progress is being made.

Governments and manufacturers are working to establish reliable systems and standards that satisfy the high degree of accuracy and safety necessary for retail operations. Already, the Society of Automotive Engineers (SAE), the leading publisher of automotive industry standards, has issued J2601: Fueling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles. This is a globally-accepted standard for hydrogen station interoperability and design.

Every gasoline-powered car has a fuel filter to prevent contaminants from damaging the engine and reducing performance. In hydrogen FCEVs, the purity of the hydrogen fuel is even more critical. Slight impurities – on the order of parts-per-million to parts-per-billion – from compounds such as carbon monoxide and carbon dioxide, ammonia, and even water, can wreak havoc with a fuel cell, resulting in catalyst poisoning, destroying the fuel cell completely. To counter this, manufacturers are looking at ways of producing cleaner hydrogen and of making fuel cells more resilient.

Solution: Research and development. As technologies to measure and purify hydrogen improve, wider adoption will follow.

CLEAN HYDROGEN PRODUCTION

Hydrogen is the most abundant element in the universe. But it's not an energy source. We can't drill for hydrogen as we do oil. We can't mine hydrogen as we do coal. Instead, hydrogen is an energy carrier that must be extracted from other sources.

Most – about 95% – of the hydrogen in use in industry and transportation today comes from steam reforming of natural gas, producing carbon dioxide and hydrogen. Natural gas may have a green-sounding name, but it's a fossil fuel just like oil and coal. Its primary component, methane, is a potent greenhouse gas, and burning natural gas releases carbon dioxide, another greenhouse gas.

Clearly, extracting hydrogen from natural gas is not a green alternative. However, hydrogen can also be produced from a variety of renewable sources, including biomass, landfill gas, and even sewage, as well as from the electrolysis of water. Of course, the energy to do this has to come from somewhere, but that somewhere can be other renewable sources, like wind and solar.

Markowitz notes, "One of the biggest potentials that we have is converting renewable energy to a more stable electrical or electric stationary mix by creating hydrogen through electrolysis using excess wind or solar and having the hydrogen become the storage mechanism, which then can be used to either provide electricity and maintain a stable grid, or be used as a transportation fuel."

Energy storage is one of the key factors in the successful implementation of renewable energy, which are often variable and unpredictable. On a bright, sunny day, if our solar photovoltaic array produces more power than we need, or if the winds are blowing and our wind farm is delivering excess power, we don't have to let it go to waste. Instead, we can use the excess to produce hydrogen. Then, whenever it's needed – when the sun isn't shining or the wind isn't blowing – that hydrogen can be turned back into electricity and fed to the grid through stationary fuel cells. Or it can be pumped into tanks and used to power fuel cell electric vehicles.

INEFFICIENCIES IN THE HYDROGEN FUEL CELL PRODUCTION CHAIN

Critics of hydrogen fuel cell electric vehicles often cite the inefficiencies of the hydrogen production chain. The argument goes like this:

- Producing hydrogen costs energy
- Compressing the hydrogen for storage costs energy

- Transporting the hydrogen to fueling stations costs energy
- Converting hydrogen to electricity in a fuel cell costs energy
- Converting electricity to kinetic energy in a motor costs energy

All of this is true. But should these inefficiencies be considered a show-stopper for hydrogen fuel cell vehicles? Not at all. Every energy system has some inefficiencies; no system is 100% efficient. Consider the inefficiencies inherent in the systems leading to conventional gas-powered cars:

- Locating dwindling oil reserves costs energy
- Pumping oil out of the ground or extracting it from tar sands costs energy
- Refining that oil into gasoline costs energy
- Transporting the gasoline to service stations costs energy
- Converting gasoline into kinetic energy in an internal combustion engine costs energy

Yet, we accept those costs, despite the additional costs of damage to the environment and pollution-related health issues, as well as the political instability that results as governments fight over oil-producing regions.

At least hydrogen fuel cell electric vehicles have the advantage of being emission-free. And hydrogen, unlike fossil-fuel crude oil, can be made from renewable sources, such as excess solar and wind power.

Solution: More research and development. If the advantages of hydrogen fuel cell electric vehicles do not yet outweigh the disadvantages, rather than simply dismiss the technology as being impractical, we need to work harder to improve it.

The High Cost of Fuel Cells

Markowitz notes a related obstacle to be overcome before we see the wider adoption of fuel cell vehicles. “I think that the largest initial hurdle will be cost. As with any transformational technology, getting costs down to the point where they’re competitive with the incumbent technology is the biggest hurdle that any industry faces.” But he is optimistic. “We are well on the road to doing that right now. Companies have developed technologies and engineering solutions that have reduced the cost of platinum and other high cost metals, and more importantly have made the fuel cell stack itself much more efficient, lowering the cost of the stack. That is being done through reduction in size and through greater efficiencies within the mechanism of the fuel cell itself. A good example is what Toyota has done with it’s new fuel cell car, where it’s dropped the cost of the fuel cell stack by 95%.”

The 2018 Toyota Mirai has a sticker price of $58,365 USD. That may seem steep, but the price includes hydrogen fuel for three years or $15,000. We can expect that prices will come down, just as they have for battery electric cars which, a few years ago, were typically twice the price of a comparable gasoline-powered vehicle, but which are now almost on par. Rebates and incentives, designed to help governments meet their carbon reduction targets, will no doubt accelerate development and adoption of FCEVs.

Solution: Still more research and development, combined with wider commercialization. As fuel cell and hydrogen technology improves, and as manufacturers ramp up production in response to competition, the cost will come down.

Hydrogen Fuel Cell Electric Vehicles: Soon

Will you be driving home today in a car powered by hydrogen? Probably not, unless you happen to have snagged one of the few vehicles manufacturers are leasing as part of their pilot tests. Of course, the same was true of battery electric cars a few years ago. Today, it's likely your local dealer either has electric cars in stock or can order one for you. In the not too distant future, the same will be true of hydrogen-powered fuel cell electric vehicles.

Yes, there are obstacles, but they are by no means insurmountable. They are, in general, the same obstacles that face any emerging technology. And the solutions are the same: R&D, consumer education, marketing, and, if you're fortunate, government support in the form of tax breaks and other incentives for both manufacturers and consumers.

So when will hydrogen fuel cell electric vehicles become the norm? As Bogart said in Casablanca, "Maybe not today, maybe not tomorrow, but soon …" One thing is certain, hydrogen fuel cells and cars will make a beautiful friendship.

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