The UK's Prince Charles taking the prototype hydrogen-powered Riversimple Rasa for a test drive in Wales in July. Photo: WPA Pool/Getty

COP 26 | 'Widespread use of green hydrogen in heating and cars is not only stupid — it's practically impossible'

The Recharge View | Those advocating for fuel-cell electric vehicles and H2 boilers are using misinformation to try to make money, and don't care if they slow down the fight against climate change, writes Leigh Collins

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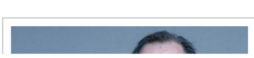
By Leigh Collins

If the slew of recent headlines and announcements are to be believed, an endless supply of green hydrogen will soon be available that will replace the fossil fuels burned in our homes, cars, trucks, buses, trains, ships, planes, steel furnaces, concrete factories and more, and will even be used to produce electricity (even though it's made using electricity in the first place).

Gas grids used to heat entire countries in winter will effortlessly switch from fossil gas to green hydrogen, with barely a mention of the logistical nightmare that would involve (*see below*), and filling stations worldwide will simply shift from petrol and diesel to compressed hydrogen, enabling fuel-cell electric vehicles (FCEVs) to travel long distances while emitting nothing more than dribbles of water.



And on top of all this, the 70-75 million tonnes of highly polluting grey hydrogen used globally each year to produce fertilisers and chemicals and refine oil will also switch to green hydrogen — despite the fact that hardly any renewable H_2 is being produced today.

In theory, we could power the entire planet with green hydrogen. In the real world, however, that would be insane. Cheaper and more efficient electric solutions will be available for many of the use cases mentioned above, requiring far less energy and therefore improving our chances of reaching net zero by 2050.

While there is definitely an argument to use hydrogen (or derivatives) for shipping, aviation and long-distance trucks, widespread use of renewable H_2 for everyday cars and the heating of buildings would be phenomenally stupid.

Heat pumps are five to six times more energy efficient than boilers burning green hydrogen, so the latter would require five to six times as many wind turbines or solar panels.

It will be a struggle just to decarbonise the power sector in time to save the planet, do we really want to try to build five to six times more wind and solar power than necessary in order to use a flammable gas in our homes?

And green hydrogen-powered cars would require between two and two-and-a-half times as much renewable energy as battery electric vehicles (BEVs).

Let's be clear, if the primary aim of those advocating for green hydrogen use in heating and cars was to save the planet, they would be advocating for heat pumps and BEVs.

"If the primary aim of those advocating for green hydrogen use in heating and cars was to save the planet, they would want heat pumps and BEVs."

They are pushing for hydrogen heating and FCEVs because they think their companies can make money from it — or in some cases, prevent them from going out of business.

After all, if you are a gas grid operator and fossil gas is phased out, how are you going to make money? The only way gas network companies can continue business-as-usual over the long term is if their pipelines are converted to run on 100% hydrogen.

So they are spending a lot of money on lobbying governments and trying to sell the idea to the public. The national press in the UK, for instance, has been swallowing the spin, with stories about "saving our boilers" and demonstration hydrogen homes — without any analysis of whether hydrogen gas networks make any sense.

Part of this marketing campaign is typical old-school fossil-fuel industry behaviour: fear, uncertainty and doubt (FUD).

Scare tactics being used include: people won't want to have their homes ripped apart to install heat pumps (actually, all they need is a small box and some pipes installed on an outer wall or rooftop — like air-conditioning units you see all over the world); heat pumps won't work in homes that aren't heavily insulated (not true); and the electricity grid will never be able to handle the amount of power needed required to heat everyone's homes (utilities and electricity grid operators disagree); and heat pumps are hugely expensive and are therefore a bad choice compared to hydrogen boilers (well, they are now, but prices will fall with economies of scale, and heat pumps are far cheaper to run, so even at higher prices, consumers would make their money back in a few years).

You will be unlikely to hear a gas distributor discuss any of the following:

1) When you convert electricity to hydrogen via water electrolysis, you automatically lose about 30% of the energy contained in that power.

2) Hydrogen has 3.4 times less calorific heating value per cubic metre than methane, meaning that 3.4 times as much H_2 is needed to produce the same amount of heat as natural gas.

3) Due to the smaller molecule size, it would take roughly three times more energy to pump hydrogen around a gas network than fossil gas. You also need energy to compress the hydrogen. So you need to use a further 22% of the energy contained in the hydrogen just to get it to people's homes. Add in a further 10% efficiency loss in the boiler, and you're left with 46% of the energy you started with.

4) By contrast, if you used electricity directly for heat, rather than converting it to hydrogen, 95% of the original energy would be useable in your home (with 5% losses in transmission and distribution) and heat pumps have an energy efficiency factor of 3.2, meaning that for every 100kWh of renewable energy put in, 320kWh of heat comes out.

5) Replacing natural gas in the gas grid with 100% hydrogen would require metal pipes on the gas network to be replaced with plastic ones that can safely handle the smaller hydrogen molecule — including those under people's floorboards and driveways.

6) Most existing valves and compressors on the gas grid would also need to be replaced or modified.

7) Highly efficient heat pumps can also be used as air conditioners, which is useful considering the planet is getting hotter. Try cooling your home with a hydrogen boiler in the summer.

8) Burning hydrogen produces large amounts of nitrous oxide, a poisonous and powerful greenhouse gas. These would need to be captured and filtered in boilers, but this would not be possible in hydrogen gas cookers or ovens where the flame is not enclosed.

9) Hydrogen flames are invisible in daylight, so that yellow flame you see in demonstrator hydrogen gas cookers, that's an additive called sodium carbonate, which produces CO_2 when it burns.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Fuel-cell electric vehicle scare tactics

Similar FUD tactics are being performed by fuel-cell electric vehicles (FCEVs) advocates. They argue that batteries will always take too long to charge, they will never be able to store enough electricity for long distances on a single charge, that the BEV charging network is too unreliable.

There are three reasons why they say that FCEVs will be a better option than BEVs:

1) FCEVs can travel longer distances on a full tank than a BEV.

2) Filling an FCEV is a lot faster than charging a BEV, taking three to five minutes.

3) People who do not have driveways or live in apartment buildings cannot install home chargers, so would rather drive an FCEV to a filling station for a quick fill-up, rather than leave their BEV for an hour or more to get a full charge.

While these three points have some validity today — although a hydrogen car travelling 400 miles may struggle to find an H_2 filling station once it reaches its destination — these advantages will be short-lived.

The best-selling FCEV today, the Toyota Mirai, (with global sales of about 11,000 from 2014-20), is said to have a maximum range of 402 miles (644km) on a full tank. But the new all-electric Mercedes EQS can go 453 miles on a single charge, and the Lucid Air Dream edition, due out next year, will have an official range of 520 miles.

And when solid-state batteries are commercialised by the end of the decade, as many predict, BEV ranges are expected to double.

Charging times are also falling quickly as new fast-charging equipment enters the market. For instance, Switzerland-based power technology giant ABB recently unveiled a new 360kW charger, which it says is "capable of fully charging any electric car in 15 minutes or less".

While there are no BEVs yet on the market that could handle such a charging speed, it seems inevitable that they will soon. The Porsche Taycan can already handle rapid charging at 270kW, and battery technology is improving all the time.

While FCEV enthusiasts will keep repeating those three so-called advantages, you will never hear them mention any of the technology's disadvantages, which are many:

1) FCEVs will always be more expensive to buy than BEVs due to the more complex technology inside (eg, the need for storage tanks, fuel cells and batteries — yes, hydrogen cars use batteries).

2) FCEVs will always be more expensive to run than BEVs if using green hydrogen, because it will require between two and two-and-a-half times as much electricity to produce that H_2., with additional costs to compress, transport and store the gas.

3) Hydrogen fuel is expensive. In California, the average price of H_2 at the pump in 2019 was $16.51 per kilogram, so a filling up a Toyota Mirai's 5kg tank would cost $82.55, which works out at $0.206 per mile. By comparison, the average per-mile fuel cost for petrol cars and BEVs in the US is $0.06 and $0.03 per mile, respectively. If the hydrogen were 100% green, it would be even more expensive (*see point 9 below*).

4) You can only fill your FCEV at a filling station, whereas you can charge your BEV at home, in the street, in car parks, etc.

5) There are about 450 public hydrogen filling pumps in the world today, compared to more than a million public BEV charging points.

6) New hydrogen pumps at filling stations cost a minimum of $2m, according to the California Fuel Cell Partnership, compared to $40,000 for an EV fast-charging point. And operating costs will be far higher, as the H_2 will need to be trucked in, and the more complex system of storage tanks, compressors, pre-cooling systems and dispensers all need to be maintained.

This means that hydrogen pumps being installed today will probably never make a profit. Even if each fill-up at a hydrogen pump generated $5 of net profit for the operator, that would require 400,000 visits to break even — which seems unlikely given that there were only about 43,000 FCEVs on the world's roads by mid-2021. By contrast, 2.65 million BEVs were sold in the first half of 2021 alone.

7) Having to truck in hydrogen effectively reduces the overall energy efficiency of the fuel, and adds greenhouse gas emissions because only petrol/diesel trucks are being used today.

8) The reliability of hydrogen fuel networks in California and South Korea — two of the world's largest markets — have been notoriously bad. In California, stations have frequently run out of fuel, leaving FCEVs stranded and unable to refuel, with customers begging Toyota to let them return their vehicles. The meagre FCEV sales in the state have suffered as a consequence, falling to just 937 units in 2020, from 2,089 in 2019. And in South Korea, a recent government report revealed that the country's 12 motorway hydrogen filling stations broke down a total of 221 times between April 2019 and August 2021. Of course, BEV drivers will also attest to frustrations with public charge points not working or already being occupied.

9) FCEVs are not really zero-emission vehicles, as claimed. Most of the hydrogen that they use is produced from unabated fossil fuels, producing nine to 18 kg of CO_2 per kilogram of H_2. In climate-minded California, the H_2 for vehicles has to be at least 33% renewable hydrogen, but that only offers about a 54% reduction in lifecycle emissions compared to a gasoline version of the same car, according to the Union of Concerned Scientists. Of course, BEVs need to be charged using renewable electricity to be zero-emissions, but anyone who purchases green power at home can achieve this, while some public charging companies — such as Gridserve in the UK — already use 100% renewable energy.

A few home truths

It's also important to consider the bigger picture of climate change when discussing the use of green hydrogen. Here are a few home truths:

1) Only 29% of the world's electricity currently comes from renewable sources — 2,800GW of hydro, wind, solar and other green energy. This needs to be as close as possible to 100% by 2050 if the world is to reach net-zero emissions.

2) The global demand for electricity is **predicted to double by 2050**.

3) Producing the 70-75 million tonnes of mainly grey hydrogen used in industry today emits **about 900 million tonnes of CO_2 per year** — more than the UK and Indonesia put together.

4) This volume of grey hydrogen should be replaced with green H_2 as quickly as possible.

5) Our priorities should therefore be decarbonising the power sector and existing hydrogen production, before unnecessarily increasing green hydrogen usage in other sectors.

6) It will be extremely difficult for the world to install enough renewable energy to decarbonise the power industry and the current hydrogen sector. *Recharge* calculates that producing 70 million tonnes of green hydrogen annually would require 2,222GW of solar, 1,176MW of onshore wind or 930GW of offshore wind — based on International Renewable Energy Agency (Irena) average capacity factors of 18%, 34% and 43%, respectively. By the end of 2020, the world had only installed 714GW of solar, 182.8GW of onshore wind and 34.4GW of offshore wind, according to Irena.

7) Using green hydrogen as an energy vector is an inefficient way to use electricity.

8)There are electric or bio-based alternatives for every use case envisioned for green hydrogen — except when it is needed for its molecular chemistry (ie, the current uses of hydrogen).

Practically impossible

So while the widespread use of green hydrogen for heating and cars does not make economic or environmental sense, it will also be practically impossible to produce the sheer volume of renewable H_2 that would be required.

Let's look at how much additional renewable energy would be needed to heat our homes with green hydrogen.

According to the European Commission, 79,038,030 tonnes of oil equivalent (919.2TWh) of natural gas were consumed in EU-27 households in 2020.

Hydrogen contains 33.3kWh of useable energy per kilogram, and let's assume each boiler has an efficiency of 90%. This means that replacing the fossil gas used for domestic heating in the EU would require about 30 million tonnes of green hydrogen a year.

If using efficient 50kWh/kg electrolysers, that would require roughly 875GW of solar, 463GW of onshore wind or 366GW of offshore wind.

By the end of 2020, the EU-27 had only installed 139.3GW of solar, 162.3MW of onshore wind and 14.5GW of offshore wind.

Densely populated Europe is, of course, struggling to build enough wind and solar farms to decarbonise its power sector by 2050, let alone install huge amounts of additional renewables to produce hydrogen for boilers.

It's a similar story for fuel-cell electric vehicles (FCEVs).

The new iteration of the world's most popular FCEV, the Toyota Mirai, can go 400 miles on a full tank, which contains 5kg of compressed hydrogen — 80 miles (128.75km) per kilogram of H_2.

Let's say the average annual driving distance per car is 12,000km, which is the European average, then a Mirai would use 93.2kg per year, requiring 4.66MWh of clean electricity.

Estimates show that there will be two billion cars on the road globally by 2050. If we imagine that 50% of those were powered by hydrogen, that would require 93.2 million tonnes of green H_2 annually — produced from 2,712GW of solar, 1,435GW of onshore wind or 1,135GW of offshore wind.

And, of course, these figures would be even higher if hydrogen-powered trucks were used to deliver the compressed gas to thousands of filling stations around the world.

Compare this to a mid-range Nissan Leaf, which has an average consumption of 17.2kWh per 100km. An average annual driving distance per car of 12,000km would equate to just over 2MWh — 57% less electricity than a Mirai. Times that by a billion EVs and you would need about 2,000TWh a year — which would require about 1,266GW of solar, 670GW of onshore wind or 530GW of offshore wind.

The unvarnished truth

Does anyone seriously believe that we could ever build the huge amounts of renewable energy required to use green hydrogen at scale for heating and cars, and still reach net zero by 2050?

And if it is impossible to build enough renewables in time, then all that hydrogen for FCEVs and boilers would have to be sourced in other ways. That means huge amounts of fossil-fuel hydrogen — either unabated grey, or blue (ie, grey H_2 with incomplete carbon capture and storage) — which would result in continued methane and CO_2 emissions that would make net-zero even harder to achieve.

(One alternative would be to build new nuclear power stations dedicated to hydrogen production, but if nuclear was easy and affordable, we would be building atomic plants to decarbonise the power sector).

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This means that anyone campaigning for widespread H_2 heating and FCEVs is actually advocating for the long-term use of fossil fuels — even if they claim that only green hydrogen should be utilised.

It is little wonder that some renewable H_2 enthusiasts are being referred to as "useful idiots for the fossil-fuel industry".

The unvarnished truth is that widespread use of hydrogen for heating and cars would be hugely expensive for the consumer — and dangerous for the planet if we have to rely on polluting fossil-fuel H_2.

It should not be seriously contemplated. Those pretending that this would somehow be a good idea — and are asking for billions of dollars of government funding to make it happen — should immediately stop.

Reaching net zero emissions by 2050 using the cheapest, most efficient methods will be extremely difficult, and require trillions of dollars.

We cannot afford to waste time and money on inefficient, foolish "solutions" that are in no-one's interests apart from those fossil-fuel companies that are too set in their ways to change their business models.

This is one of a series of special articles from *Recharge* in the run-up to COP26 in Glasgow. See the others below.

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