A hydrogen fuel revolution is coming – here's why we might not want it

Hydrogen is widely touted as a green fuel for everything from cars and planes to heating homes. But all too often it has a dirty secret

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If hydrogen fuel is the future, it has been for quite some time. In his 1875 novel The Mysterious Island, Jules Verne imagined the element replacing coal as a fuel, split out of water to "furnish an inexhaustible source of heat and light". Similar noises were made in the 1970s oil crisis, when hydrogen was touted as an alternative fuel for cars. And then there was US president George W. Bush in 2003, latching on to a new enthusiasm for hydrogen vehicles during the first wave of real concern about climate change. "We can make a fundamental difference for the future of our children," he said.

Now hydrogen is back – again. From the US to Australia, and the European Union to China, the past year has seen an almost daily torrent of multibillion-dollar government funding pledges, tests of new technologies from trains and planes to domestic boilers, industry statements and analyses, and championing by leaders such as UK prime minister Boris Johnson. "We're finding it hard to keep up with," says Simon Bennett at the International Energy Agency.

"The idea of a hydrogen economy is not new," says Martin Tengler at analysts Bloomberg New Energy Finance. "Now we're in another hype cycle. The question is: is it different, or not?"

Tengler is one of many who thinks it is. Meanwhile, another question hangs much heavier than hydrogen in the air: is it really a clean, green fuel to help combat climate change? Or does the significant lobbying of fossil-fuel interests for a hydrogen economy indicate other priorities?

Hydrogen is the lightest element in the universe and the most abundant. On paper, it has a lot going for it as a fuel. Although it rarely exists on its own on Earth, it can be produced using clean electricity to split essentially inexhaustible water, producing only oxygen as a by-product.

"Is hydrogen a clean, green fuel – or does fossil-fuel lobbying suggest a different story?"

Once made, hydrogen acts as a chemical energy carrier, rather like oil or gas, that can be piped or transported to where it is needed. It stores three times as much energy per unit of mass as conventional petrol, and when it "burns" in air – releasing that stored energy – it simply combines with oxygen to produce water again. In that sense, it is the ultimate green fuel.

Perhaps the most notorious attempt to use hydrogen to change the world ended with the fiery demise of the German airship Hindenburg in New Jersey in 1937, when the hydrogen gas used to give it buoyancy caught fire. Technology for the safe storage of hydrogen has since come on in leaps and bounds. In recent decades, the idea of creating a "hydrogen economy" has focused on developing liquid hydrogen as an alternative green fuel, mainly for cars.

One thing that is different now is how hydrogen is being touted as a way to decarbonise "hard-to-abate" sectors that are difficult to power directly with clean electricity. These range from long-distance road haulage, aviation and shipping to naturally carbon-intensive industrial processes such as steel and petrochemical production (see "Six uses for hydrogen").

Green, grey or blue?

The past two years of climate pledges by businesses and governments, from the UK to China, has made clear that even these industries will have to transform if we are to meet the overarching goal of net-zero carbon emissions by mid-century. And hydrogen figures big in that goal: the European Commission's Joint Research Centre says that between 10 and 23 per cent of the EU's final energy consumption could be covered by hydrogen in 2050; the energy company Shell puts the figure at 10 per cent globally by 2100.

Meanwhile, the rapidly falling costs of power from wind and solar farms has made the large-scale, clean production of hydrogen using clean electricity plausible. The problem is that the vast bulk of hydrogen isn't currently made that way.

Humanity already produces around 70 million tonnes of hydrogen each year, mainly for use in making ammonia fertiliser and chemicals such as methanol, and to remove impurities during oil refining. Some 96 per cent of this hydrogen is itself made directly from fossil fuels – mostly natural gas, followed by coal and then oil. This overwhelmingly uses a process known as steam reformation that releases carbon dioxide.

Only 4 per cent of hydrogen is made in the way Jules Verne envisaged, using electrolysis to split it out of water. Much of the electricity to supply even that measly share of the hydrogen market comes not from green sources, but from fossil fuel power plants. Far from being green, the hydrogen produced globally today has a carbon footprint on a par with the UK and Indonesia combined, says Tengler – about 830 million tonnes of CO2 annually.

That brings us to the strange point where transparent hydrogen gets colourful, at least linguistically. "Grey" hydrogen is so-called because it is made from fossil fuels using steam reformation. It costs about $1 a kilogram. "Blue" hydrogen typically "buries" the emissions associated with producing it using carbon capture and storage (CCS) technology – an approach which exists, albeit only on a pilot scale so far – for about $2 per kilogram at the cheapest. Finally, there is "green" hydrogen, produced by electrolysers running off renewable electricity. For the most part, this costs upwards of $4 a kilogram.

When it comes to decarbonisation, "there's no point in grey hydrogen", says Rob Gibson at National Grid ESO, which runs the UK's electricity transmission network. But a move towards large-scale green hydrogen production would be very costly, says Evangelos Gazis at Aurora Energy Research in Oxford, UK. This is where blue hydrogen comes in. "If we want to reach scale, probably [blue] will be inevitable," says Gazis. Others, such as Ralf Dickel at the Oxford Institute for Energy Studies, make the case that blue hydrogen is needed in the short term because using renewable electricity to displace coal and gas power plants achieves deeper CO2 curbs than using it to make green hydrogen.

Four of the biggest existing blue hydrogen schemes are in North America, and the UK government is funding three trial projects. Some advocates argue that such schemes will be an enabler for green hydrogen, helping to build infrastructure to tackle the fiddly question of getting hydrogen to where it is needed (see "A devil of a detail"). Others see blue hydrogen very differently. Because it still involves extracting gas, oil and coal, Friends of the Earth Europe has branded it "fossil hydrogen", a lifeline for struggling fossil fuel firms.

Certainly, the sponsors of a group such as the UK's All-Party Parliamentary Group on Hydrogen are a who's who of fossil-fuel interests, including Shell, petroleum refiner Equinor, gas network firm Cadent and gas boiler-maker Baxi. But Tengler doesn't buy the argument that such support is a cover for business-as-usual. "Just because they are fossil-fuel companies, we shouldn't exclude them from the future," he says.

There is, however, the undeniable problem that blue hydrogen doesn't capture all the CO2 released while making the gas. A first CCS stage removes between around 50 and 70 per cent. Adding a second, costly step takes that to 85 to 90 per cent, with some pioneering projects aiming for more. Equinor's H2H Saltend blue hydrogen scheme near Hull, UK, should capture 95 per cent of CO2 using an alternative to steam reformation known as autothermal reforming.

Still, for most blue hydrogen schemes, at least 10 per cent of emissions aren't captured. Tengler calculates that offsetting such carbon emissions with reforestation would require an area between the size of England and that of Spain, which is about four times as big. The scale of offsetting depends on what fossil fuel the hydrogen is extracted from and how much is being made by 2050.

He still thinks it is worth it, on the basis that using blue hydrogen still creates fewer emissions than burning coal, oil or gas. "There is that portion of emissions that just don't get captured. Does that mean we don't do it? I would say we still probably should. If there's the option of blue or nothing, then do blue," says Tengler.

Jan Rosenow at the Regulatory Assistance Project, a non-profit organisation that works to expedite a clean-energy transition, disagrees. He likens blue hydrogen to the coal industry's attempts 15 years ago to promote "clean coal" plants fitted with CCS. That never happened, because the rapidly falling cost of alternatives including renewables rendered it uneconomical.

"Offsetting carbon emissions from hydrogen might need a forest the size of Spain"

If not blue hydrogen, then what are the prospects for green hydrogen? The EU, for example, has less than 1 gigawatt of electrolyser capacity now, but in July 2020 it set ambitious targets of 6 GW by 2024 and 40 GW by 2030. Germany is working with Morocco to build a project using solar power.

A dizzying cast of big companies have entered or are planning to enter the green hydrogen fray, including oil giants Repsol and Shell and the world's biggest offshore wind farm builder, Ørsted. Spanish electricity company Iberdrola is building a solar power plant to create green hydrogen in 2021, initially for conventional uses such as making fertiliser. "When we develop enough technology and scale, we can go for other sectors like the hard-to-abate, lorries, probably planes," says Samuel Perez at Iberdrola. Analyst Rystad Energy, based in Norway, counts 60 GW of green hydrogen projects planned globally – but it expects only half will appear by 2035 due to high costs.

Closing the gap between the price of green and grey hydrogen will take time. Producing one kilogram of hydrogen requires about 50 to 55 kilowatt-hours of electricity (a medium-sized UK home uses about 8 kWh a day on average) and 9 to 10 litres of water. Up to 86 per cent of the costs of green hydrogen are for electricity to power the electrolysers. But wind and solar power costs have dropped rapidly in the past decade, and are expected to fall further.

The electrolysers themselves account for the remaining cost. They are an old technology, but one that its makers claim can be made cheaper. Graham Cooley at UK manufacturer ITM Power says a 10 megawatt electrolyser costs half as much as it did three years ago, and the price will fall further, especially because of developments in China, now a major manufacturer of these devices.

Duncan Clark at Ørsted, which is in phase two of its Gigastack project using a wind farm off the Yorkshire coast of the UK to supply green hydrogen to a nearby oil refinery, says the technology is at a "special moment", akin to where offshore wind power was a decade ago before costs dropped dramatically and installations proliferated. "Only a few things are big and interesting enough to rival offshore wind, and green hydrogen is one of them," he says.

Even so, government interventions are likely to be needed, such as subsidies to make green hydrogen cheaper and carbon taxes to make grey hydrogen more expensive. “The market in the next 10 years is likely to be policy-driven. There will be a strong reliance on public funding for projects,” says Bennett.

Carry on regardless?

Hydrogen’s success may in the end be decided by society’s willingness to pay for it. Green hydrogen will need billions, either through taxation or energy bills: Bloomberg New Energy Finance estimates that it will require $150 billion over the next decade globally to bring the cost down to a competitive level. “Someone has got to pick up the bill,” says Bennett.

Nonetheless, Bennett is optimistic that the current round of hype over hydrogen is different. This is partly because of the near-unanimity from different industries on its potential and partly because, for many hard-to-abate sectors, we have few alternatives on the table. “If we don’t have [clean] hydrogen available by 2030 or 2040, we think we’re going to be in a sticky place for some of these sectors,” says Bennett.

“There are certainly risks on being overly bullish on the future hydrogen economy,” he says. “But I think it’s a bad time to be an out-and-out sceptic because there’s clearly momentum and funding going into projects in the short term regardless.” The question today no longer seems to be if hydrogen will help us fight climate change, but a matter of whether it ends up as the star turn or just a bit player.

https://www.newscientist.com/article/mg24933200-400-a-hydrogen-fuel-revolution-is-coming-heres-why-we-might-not-want-it/#ixzz751xN2H4i