# The ifs and buts of Hydrogen

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Hydrogen may be useful, but how green can it really be? asks **Roland Kupers**.

It has been used for centuries: from lifting the balloon that Jacques Charles floated over Paris in 1783 to being an integral part of ASML's monumental chip-printing machines. Over recent decades, a grander hydrogen economy has appeared just over the horizon, but much like nuclear fusion, it has remained firmly just over the horizon. But now there is a widely-held conviction that hydrogen's day may have come, accompanied by a lavish dose of taxpayer money. The US is providing $8 bn in subsidies as part of its infrastructure bill, and others like Australia are gearing up to become hydrogen exporters.

While hydrogen could play a pivotal part in the energy transition away from fossil fuels, many of its proponents are driven more by faith than engineering and we run the risk of losing sight of several substantial downsides to hydrogen. These challenges suggest a more modest role for the smallest molecule.

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Hydrogen is devilishly hard to contain, as the molecule is so small. Bumping into larger molecules around it, it picks up disproportionate energy, boring its way through the tiniest openings, even through metals and plastics. Measurements of these emissions are rare, but they are estimated at 1-10%. For comparison, emissions of methane – a much larger molecule – in the natural gas industry are estimated at 1-3%.

It remains little-known outside academic circles, but hydrogen in the atmosphere is an indirect greenhouse gas. Historical estimates put it at six times more potent than carbon dioxide, but a recent paper states that this vastly underestimates hydrogen's climate impact. Clearly this requires more consideration, but it seems prudent to limit hydrogen application to large hubs around hard-to-decarbonise industrial facilities like steel plants, rather than consider extensive pipelines to distributed users. Today's oil and gas industry struggles mightily to keep methane from escaping, it will plausibly do a far worse job with the much smaller hydrogen molecules.

Making hydrogen effectively stores the energy from other sources that is used to make it. To characterise the origin of its source energy, hydrogen is tagged with different colours. If it is made by splitting coal or natural gas, it is called grey hydrogen. If the carbon missions from splitting those fossil fuels are captured and buried (carbon capture and storage), the hydrogen is labelled blue. Finally, truly green hydrogen would be made from renewable sources of gas or by using renewably-generated electricity to split water molecules (electrolysis). That would be climate-neutral hydrogen, with virtually no carbon dioxide emissions associated with its production. But whether green hydrogen can even exist, is debatable.

Consider an example where the output of a large wind farm is used to produce hydrogen. This might be considered green hydrogen. But when you include the entire energy system, which is dominated by fossil fuels, the story becomes complicated. Diverting the wind energy into hydrogen, necessarily means lengthening the life of a fossil fuel plant, thereby delaying its retirement. Until there is a net surplus of renewables, and when most fossil fuel generators have been retired, making green hydrogen just delays closing fossil power plants. And we are not talking about small quantities.

The IEA reports that the currently-proposed capacity for hydrogen production would, in the longer term, require 475GW of wind and solar power – about one third of the current global capacity.

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The inevitable conclusion is that green hydrogen cannot exist until there is a surplus of renewables that is no longer required to replace fossil power. This takes us well into the second half of the century. Until then hydrogen will be *de facto* grey – or possibly blue – with mostly negative climate benefits. The greenhouse gas footprint of blue hydrogen is more than 20% greater than burning natural gas or coal for heat and 60% greater than burning diesel oil for heat.

Clearly making green hydrogen requires a lot of energy. Subsequently burning hydrogen is also inefficient and leads to even further losses. For example, the electricity used in an electric car will take you three times the distance than a car powered by green hydrogen made from the same amount of electricity.

However, while making hydrogen of any hue is currently inefficient, it will get better over time. And there may well be hard-to-decarbonise sectors that justify the losses in conversion. But electric cars get smarter all the time as well, so it's a race between batteries and hydrogen.

Australia and other countries are looking to ship liquid hydrogen around the world as is currently done with liquified natural gas (LNG). But shipping liquid hydrogen would be at least five times more expensive per unit of energy as shipping LNG. This is because the energy per cubic metre in LNG is nearly four times that in hydrogen, and liquifying hydrogen needs three times the electricity required to liquify natural gas.

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A potentially more efficient way to distribute renewable energy than liquefaction and shipping hydrogen might be to harness renewable power over long distances through low-loss High Voltage DC (HVDC) power lines. China has already built over 30,000km to connect its remotest wind and solar plants in the west of the country to its vast eastern industrial heartlands. Even more ambitious projects such as connecting Australian renewables directly to Singapore or Chilean solar to China are being explored.

The inefficiency of hydrogen transport will need to outcompete long-distance power cables, which will increasingly provide a ready and more energy-efficient alternative.

Elon Musk said way back in 2017: "Everything will go fully electric, apart from (ironically) rockets. Ships are the next easiest to solve after cars." Apart from the fact that we are learning not to bet against Musk, Start-up Fleetzero is already building battery-electric cargo ships. In 2021, an Israeli company launched Alice, a nine-seat electric commuter plane and EasyJet is partnering with Wright Electric to test electric planes by 2023 for all routes under 500km. Chile's nitrate mines have taken delivery of their first heavy electric trucks, powered by cheap Andean solar power.

Such examples illustrate that the niches that hydrogen proponents tout, have a tendency to shrink or disappear as battery innovation races ahead. Cost reduction patterns are quite well understood by economists, and they are roughly driven by the size of the installed base. The economic ecosystem of batteries includes laptops and cell phones. This scale drives innovation and it is vastly larger than hydrogen's. Its much larger installed base will lead to more rapid cost reduction, and hydrogen is therefore unlikely to catch up to batteries in cost effectiveness.

And this is what we see in practice as one application after another that was once identified for hydrogen, becomes electrified.

So if green hydrogen sounds too good to be true, it probably is. The climate emergency certainly justifies a strong focus on hydrogen research. Making electrolysers more efficient and measuring hydrogen leaks much better is critically important. Hydrogen deployment in tightly-controlled and concentrated industrial hubs as pilot projects is useful. But we should be open to the possibility that green hydrogen may well remain just behind the horizon. A vast expenditure of public subsidies certainly appears premature.

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Delaying hydrogen deployment does not come at a price. For the next decades all renewable capacity will be required to replace fossil power plants, road transportation and other applications. Putting that capacity to less efficient use in making hydrogen, does not deliver any net climate benefit – and even runs the risk of being climate negative on a system-wide basis.

The recipe therefore should be to electrify everything we can immediately, and in parallel realise some focused hydrogen deployment in concentrated industrial clusters. We should also do further research with hydrogen, particularly on its emissions and warming impact.

### Roland Kupers

Roland is an advisor on Complexity, Resilience and Energy Transition and the author of A Climate Policy Revolution: What the Science of Complexity Reveals about Saving the Planet.

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