Briefing

What is the best use of hydrogen in the UK?

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green alliance...

Clean hydrogen can be a climate solution. It can act as a form of energy storage and can replace fossil fuel gas without the resultant carbon dioxide emissions. However, there are two critical constraints to its use: it is unlikely to be available at the same scale or low cost as fossil gas and, if it leaks from any point in a pipeline network or facility, it is also an indirect greenhouse gas.

Our analysis suggests that unless hydrogen use is restricted to very well regulated industrial clusters, with an extremely low leakage rate, hydrogen could have very limited climate benefits. It should not be seen as a panacea for decarbonisation and, where it is used, it must be carefully monitored and directed towards those sectors where there are few alternatives.

This calls into question the proposal to blend hydrogen with fossil gas in the national gas network. This may only reduce greenhouse gas emissions by around four per cent. Even with the lowest feasible leakage rates, it would be six to nine times more expensive per tonne of CO_2 abated than the current heat pump subsidy.

Hydrogen use now and in the future

Hydrogen is used in oil refineries to produce diesel and kerosene. It is a crucial ingredient in the manufacture of certain chemicals, especially ammonia, methanol and fertilisers. It is also used as rocket fuel and in cryogenic research. A limited network of hydrogen filling stations in the US and Europe has enabled a small number of hydrogen fuel cell vehicles to enter the market, but uptake remains low.

Almost all the hydrogen in use around the world today is 'grey' or 'brown' hydrogen, extracted from fossil gas or coal by separating out hydrogen and carbon atoms, a process which releases CO_2 into the atmosphere. The UK currently produces 16-25TWh of grey hydrogen a year. By comparison, the country consumes around 800TWh of fossil gas, some of which is used to create hydrogen.

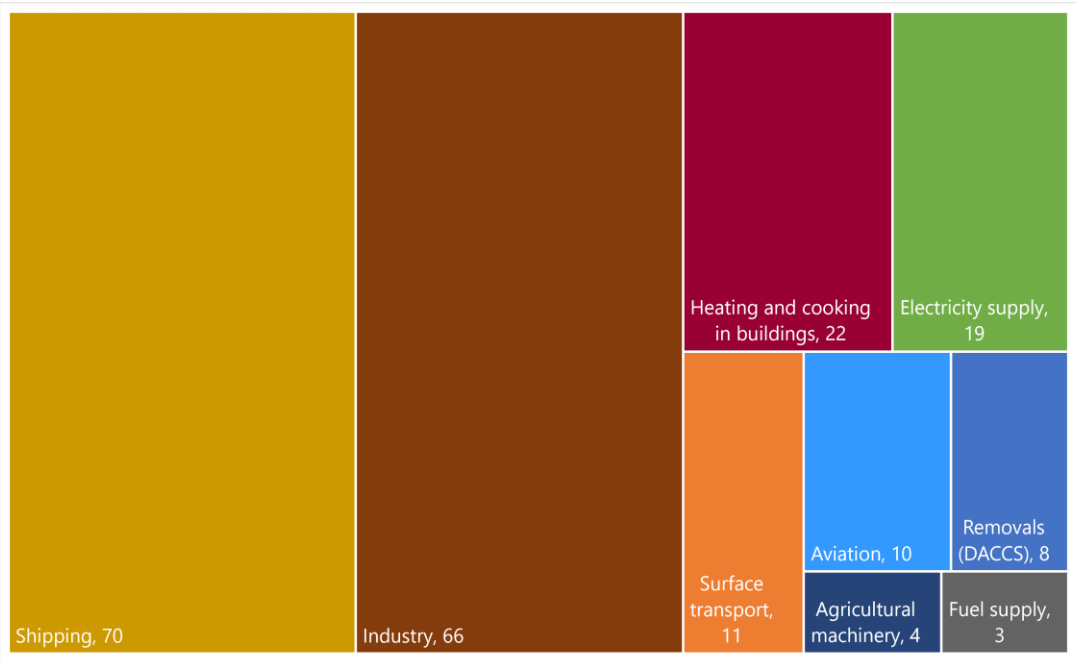
By capturing CO_2 from grey hydrogen production and storing it underground, so called 'blue' hydrogen is created. Depending on the capture rate, this can be a low carbon source of hydrogen, though this is not yet tested at scale, and methane emissions from fossil gas extraction and transportation can also be significant. But the lowest carbon source, 'green' hydrogen, can be made by splitting water into hydrogen and oxygen in an electrolyser powered with renewable energy. Similarly, using excess nuclear electricity (and potentially heat) can produce very low carbon 'pink' hydrogen.

To be considered as low carbon, green and pink hydrogen need to be generated from dedicated newly built zero carbon power sources, or to be generated only when there is more clean electricity being produced than there is demand for.

However it is made, clean hydrogen could be used to decarbonise several areas of the economy. Proponents suggest that clean hydrogen could be used widely as a fuel, a feedstock for chemicals or other fuels, or as a storage medium for clean electricity.

The illustration below shows the Climate Change Committee's projections for low carbon hydrogen demand in the UK across different economic sectors in 2050, at a total of over 200 TWh. Current hydrogen production capacity via electrolysis in the UK is around 0.03 TWh per year.

Predicted hydrogen demand in 2050 (TWh)



The risks of expanding hydrogen use

Burning hydrogen does not release carbon dioxide, but hydrogen, if released unburnt, is a short lived climate pollutant.[1] This is in part because it increases the lifetime and therefore the warming impact of methane in the atmosphere. Methane is also a short lived climate pollutant.

A government-commissioned study from 2022, as well as work by scientists at the National Oceanic and Atmospheric Administration in the US, have shown that hydrogen has a global warming potential 12 to 13 times stronger than CO_2 over a 100 year time frame. Over a 20 year time frame, it is approximately 34 to 40 times more powerful than CO_2. The Environmental Defense Fund has shown that this can cut in half the anticipated near term climate benefits of replacing fossil fuels with green hydrogen.

The scientific understanding of hydrogen's role as an indirect greenhouse gas has evolved recently, but there are still two sources of major uncertainty in its overall warming effect. First, there is limited understanding of how quickly it is absorbed by reactions with soil, which influences its global warming potential. Second, it is unclear how much hydrogen may be unintentionally leaked, or intentionally vented or purged. Furthermore, technology to detect leaks is not yet widely available, so even today's leakage rates are unknown.

However, we do know that methane leakage from fossil gas operations, transmission and end use can be on the order of a few per cent, and is often underestimated.[2] Safety tests for the Hy4Heat programme found that hydrogen tends to leak 1.2-2.8 times more quickly than methane wherever damage to pipework or incomplete seals are found. Researchers at Columbia University estimate that a scaled up hydrogen economy could experience leakage rates of three to six per cent. Certain end uses and transportation methods could experience losses of up to 20 per cent.[3]

The higher the leakage rate, the lower the climate benefits. In the context of proposals to blend hydrogen into the gas grid, the emission savings may be minimal. Even at low leakage rates, we estimate that the climate benefit of a blend of 20 per cent hydrogen and 80 per cent natural gas (by volume) in the national gas network might only cut emissions by around four per cent.

System wide hydrogen leakage rate	Total saving in net greenhouse gas emissions from hydrogen blending at 20% by volume[4]	Cost per tCO_2e[5]
0.5%	4.3%	£880-920
1%	4.2%	£900-940
2%	4.1%	£920-960
5%	3.8%	£1000-1040
10%	3.2%	£1180-1230

Detecting and minimising leaks

Unlike methane, there are no readily available tools for measuring small hydrogen leaks, though the Environmental Defense Fund and Aerodyne Research are working to commercialise a suitable instrument to do so.

Because of the warming implications of hydrogen emissions, its future must have strict leakage mitigation measures in place. For most of the sectors in which there are few low carbon alternatives to hydrogen, such as chemical feedstocks, some aspects of steel making, long term energy storage and perhaps shipping and aviation, hydrogen use could be concentrated and controlled by professionals. By contrast, using it for home heating or road transport would disperse it through a vast network of pipes and technologies, and it would be handled by the general public when using vehicles or appliances. These end uses would come with higher risks of leakage.

Government support for hydrogen

In 2021, the government published the Hydrogen Strategy, which sets out how it expects the production and use of hydrogen to develop, under market forces, to accelerate the decarbonisation of the UK economy. In March 2023, it announced 15 winners of government grants to develop hydrogen production facilities, under the first round of the £240 million Net Zero Hydrogen Fund.

At this stage, the UK is backing hydrogen as a climate solution across all sectors where there is a potential to use it. Government policy and financial support has been directed primarily at hydrogen production and there has been little consideration given to the best end uses. There have been no efforts to monitor hydrogen emissions. Given that low carbon hydrogen will be scarce, and the recent findings about the impact of hydrogen leakage on the climate, the conversation must rapidly shift to which end uses should be prioritised or avoided, and how to monitor and minimise hydrogen emissions.

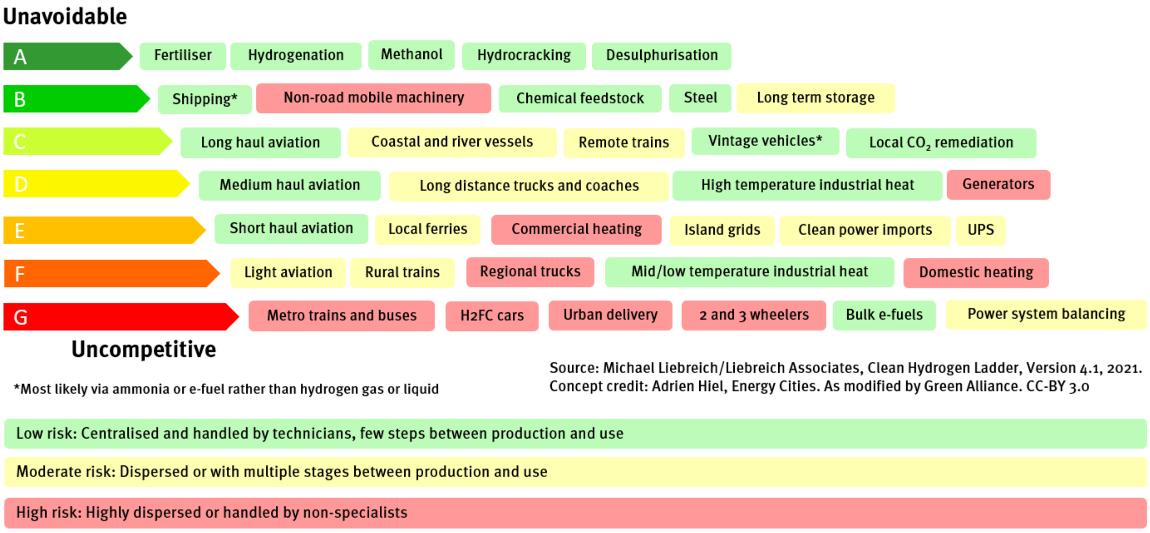
In late 2023, the government expects to decide whether it will allow blending of hydrogen in the existing gas network, up to 20 per cent by volume. This should only be considered if the government can guarantee that pipeline and household leakage will be kept below one per cent.

In 2026, the government will decide whether hydrogen could completely replace fossil gas and be used directly for home heating, based on research and trials in two village scale pilots. The climate impact of hydrogen, and the increased risk of leaks in a dispersed system, suggest that the government should rule out its use for homes. It could do this now, rather than waiting until 2026.

System design

Those interested in hydrogen as a climate solution are likely to have encountered the clean hydrogen ladder, popularised by Michael Liebreich. This is informed primarily by an economic assessment of where using hydrogen is likely to be unavoidable or where it will be extremely useful, compared to where it is less likely to be use widely, and does not reflect the risk of hydrogen leakage to the climate. The ranking is Michael Liebreich's judgement, informed by extensive research, and taking account of whether there are good alternative energy solutions or not, for each sector.

Below, we have adapted the clean hydrogen ladder, adding colours to emphasise which end uses are at higher risk of leakage than others. This is based on whether the use is likely to be centralised or dispersed, how many transport stages there might be between production and use, and whether it will be handled by trained technicians or non-specialists.



Methane

Methane is another short-lived climate pollutant with impacts directly related to hydrogen. A major expansion in the production and use of hydrogen, without extreme care to avoid leaks, can prolong the lifetime of methane in the atmosphere, increasing its warming impact.

Methane's warming impact is around 30 times that of carbon dioxide over a hundred year timescale, or around 80 times more on a 20 year timescale. Keeping global warming below 1.5°C requires a rapid reduction in methane emissions. The Global Methane Pledge, to which the UK is a signatory, seeks a 30 per cent reduction globally by 2030.

Today, methane emissions come mainly from three sectors: agriculture, energy and waste. Previous Green Alliance analysis has shown that it is straightforward for the UK to reduce methane emissions by 43 per cent by 2030. This can be achieved through low cost measures and by acting now across the three sectors. Bringing down methane emissions could decrease hydrogen's warming effects.

What should happen now

In the near term, the government's Energy Bill proposes a levy on consumer energy bills to fund the development of hydrogen infrastructure and the production of low carbon hydrogen. At a time of high energy bills, this levy is controversial, as it is unlikely that households will benefit directly from hydrogen infrastructure or production.

Actions MPs and peers can take:

- Amend the Energy Bill, so the secretary of state for energy security and net zero can only be granted the power to introduce a hydrogen levy on consumer bills if a system wide leakage rate of less than one per cent can be guaranteed.
- Ask written and oral questions of the secretary of state for energy security and net zero about how hydrogen leakage will be minimised.
- Ask the government to rule out the use of hydrogen for home heating and private vehicles.
- Ask the government to publish how it plans to reduce short lived climate pollutants.

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Endnotes

[1] Briefly, the warming potential of increased hydrogen concentrations in the atmosphere occurs via three mechanisms: 1. increased interactions between hydrogen and hydroxy radicals, which would otherwise react with methane and break it down into carbon dioxide; this leaves fewer hydroxy radicals, prolonging the

lifetime of methane and therefore increasing its warming effect; 2. higher concentrations of tropospheric ozone, which is a greenhouse gas; 3. higher concentrations of stratospheric water vapour, which increases warming. The total impact of hydrogen on global heating is a function of the residence life of hydrogen in the atmosphere, which is currently estimated at two years, and the total volume of hydrogen released unburnt into the atmosphere.

[2] S N Riddick, et al., August 2019, acp.copernicus.org/articles/19/9787/2019/ and E Saboya et al., March 2022, acp.copernicus.org/articles/22/3595/2022/acp-22-3595-2022.html

[3] Arrigoni, A. and Bravo Diaz, L., August 2022, publications.jrc.ec.europa.eu/repository/handle/JRC130362

[4] Assuming hydrogen is 12 times more potent than CO_2 over a hundred year lifetime. This also assumes the hydrogen is certified low carbon and matches the government's upper limit for emissions intensity of 20 gCO_2e/MJ (million joules)

[5] Carbon abatement costs are calculated using an estimated cost of blue hydrogen supply in 2025 (£66-85 per MWh), based on the projections from the Department for Business, Energy and Industrial Strategy (in 2021) and adjusted for higher fossil gas supply costs (expected to be £35-50 per MWh). We include additional system costs for hydrogen blending, including grid upgrades, storage costs and deblending costs for certain industrial users, as estimated in: J Bard, et al, January 2022, 'The limitations of hydrogen blending in the European gas grid', conservatively using 70 per cent of the estimated EU-wide total blending cost (which includes both system costs and production costs) of 0.66p per kWh. The blending 'premium' we calculate is a 14-19 per cent increase on wholesale and system fossil fuel gas costs. This compares appropriately to the estimates from RAP for blending which are 8-20 per cent using green hydrogen, which is likely to be more expensive than blue hydrogen, but which ignores the impact on system costs from blending. These costs can then be compared to the estimated emissions savings which result from the current £5,000 subsidy for heat pump installations offered by the government, which we estimate as £109-154 per tonne of CO_2 abated.