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# HYDROGEN as a fuel source

Hydrogen can power vehicles, generate heat, or be converted into electricity – but its use is not problem free.

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**The UK has** committed to net zero greenhouse gas emissions by 2050 and the Government is looking at solutions to power the transition from the UK's reliance on carbon emitting fossil fuels. Hydrogen is a major development area to provide energy for a variety of uses, including domestic use.

Hydrogen is the most abundant element on earth and is a constituent of water and hydrocarbons such as natural gas (methane). It has one of the highest energy densities by mass of any fuel. It has the potential to contribute to the transition away from fossil fuels, both as an alternative fuel for combustion appliances and engines, and as a medium for storing energy. However, its place is seen as a transition fuel, not as a renewable energy source or zero carbon option. Although hydrogen is not a carbon dioxide ($CO_2$) emitter at the point of use, it is classed as a low carbon option as in the UK currently, most methods of production generate carbon.

## Hydrogen generation

At present, most hydrogen is produced by reacting natural gas with steam. However, this generates $CO_2$ as

**Grey Hydrogen**
Produced from steam methane reforming or coal gasification from fossil fuels. Carbon dioxide produced is emitted into the atmosphere.

**Blue Hydrogen**
Produced from steam methane reforming or coal gasification from fossil fuels, where the $CO_2$ from the process is captured via carbon capture and storage.

**Green Hydrogen**
Produced through electrolysis of water using renewable electricity. This requires water as a feedstock and produces oxygen as a by-product.


**There are practical and safety issues to address before widespread adoption of hydrogen.**

a byproduct and if released into the atmosphere the hydrogen is referred to as 'grey hydrogen' (see diagram). Grey hydrogen accounts for over 96% of the hydrogen produced in the UK[1]. If this process is combined with carbon capture and storage, the hydrogen is referred to as 'blue hydrogen'.

The alternative method for generating hydrogen, which will become the primary method of production in the future, is through a process called electrolysis. This involves using electricity to split water into hydrogen and oxygen using a device known as an electrolyser. If the electricity is derived from renewable energy sources such as solar panels or wind turbines, no $CO_2$ is produced, and the hydrogen is referred to as 'green hydrogen'.

Hydrogen can be generated at scale and delivered to premises via pipe networks similar to the existing natural gas infrastructure, or at individual premises using small-scale electrolysers. For example, units utilised during trials at residential premises are similar in size to a heat pump. However, scaling up in time to meet Net Zero targets requires huge and swift infrastructure changes, with government commitment and resource[1].

## Hydrogen processing and storage

Hydrogen can be used directly as a fuel like natural gas, which is particularly beneficial for industrial and heating processes that are difficult to electrify. One advantage of hydrogen as a fuel is that it does not produce toxic carbon monoxide as a by-product. Rather than burning hydrogen, the stored energy can be converted back into electricity using a fuel cell. Fuel cells work like a battery and consist of a negative electrode (anode) and positive electrode (cathode) sandwiched around an electrolyte. Hydrogen is supplied to the anode and air is fed to the cathode. Chemical reactions within the fuel cell produce electricity and heat with water as the only by-product.

Energy storage is critical for balancing supply and demand in power networks, especially with the increasing adoption of renewable energy sources like solar power. These sources are intermittent and variable, requiring storage solutions to ensure a reliable energy supply. Hydrogen can contribute to the solution, as surplus electricity can be used to generate hydrogen, which can then be stored and later converted back into electricity or used directly as a fuel.

Large scale storage can be provided by underground repositories. For example, the Kueper Gas Storage Project in Cheshire, is exploring the possibility of using underground caverns currently used to hold natural gas to store hydrogen[2]. Small volumes of hydrogen can be stored locally either under pressure in gas cylinders, or at low pressure in containers filled with metal powders that absorb and release hydrogen (metal hydrides). The disadvantage of using hydrogen to store energy compared to technologies such as battery energy storage systems is that the process of generating and then recovering the energy from hydrogen as electricity is only around 30 to 35% efficient[3].

# 96%

**Currently more than 96% of the UK's hydrogen production capacity produces grey hydrogen, which is carbon intensive and not aligned with achieving net zero. There is a significant gap between current levels of low-carbon hydrogen production and the projected levels needed to meet the UK's carbon budgets and achieve the target of net zero emissions by 2050[1].**


Hydrogen fuel pump at UK's first Hydrogen filling station, Swindon.

## Adoption of Hydrogen in the UK

To date, the adoption of hydrogen in the UK has mainly been confined to trial projects. Regarding commercial applications, in 2021 Pilkington UK carried out a pilot programme at their St Helens plant, which involved operating the glass manufacturing process using hydrogen instead of natural gas[4]. This was successful and in July 2024 they submitted a bid for government support to construct a dedicated hydrogen plant for the site by 2027. In the transport sector, UK bus manufacturer Wrightbus, manufacture hydrogen fuel cell powered single and double decker buses with fleets currently operating in five cities across the UK and Ireland[5]. One advantage of using hydrogen as a fuel compared to fully electric vehicles is that refuelling can be completed quickly. Although a significant drawback is that it requires specialist hydrogen refuelling infrastructure.

In the residential sector, a ten-month hydrogen trial was carried out in Winlaton near Gateshead in 2021. This involved supplying approximately 600 houses, a school, several small businesses, and a church with a gas blend comprising 80% methane and 20% hydrogen. Plans for two further trials in England were abandoned in early 2024 for a variety of reasons. However, another pilot scheme is planned for 300 homes in Scotland where 100% green hydrogen will be delivered via a dedicated gas network. In this trial in Fife, the homes will be equipped with hydrogenspecific heating and cooking appliances[6].

Hydrogen has different physical and combustion properties from natural gas, including a lower density and higher flame speed.

## Potential hazards associated with hydrogen

Hydrogen has different physical and combustion properties from natural gas, including a lower density and higher flame speed. As a result, combustion appliances designed for use with natural gas can only operate on natural gas and hydrogen mixtures with up to around 20% hydrogen by volume. To operate on pure hydrogen, combustion appliances will either need to be replaced, or components such as burners and combustion sensors would need to be changed. If gas appliances become widely available for hydrogen, there is the potential risk of equipment being used with an incompatible fuel source. Therefore, appliances will need to be designed with this in mind, to prevent misfuelling leading to potentially dangerous failure scenarios.

Hydrogen gas molecules are much smaller than methane which means that joints and seals that are adequate for natural gas may allow hydrogen to escape. Hydrogen is less dense than natural gas, so to deliver energy at the same rate, pipework will either need to be operated at higher pressures or flow rates than natural gas. This will also increase the likelihood of escapes of gas.

If fuel gases such as hydrogen escape and accumulate in a confined space such as a building, they can mix with air to form a flammable atmosphere. If this is ignited, this will lead to an explosion. Flammable atmospheres will only form in a certain range of concentrations, if the concentration of gas is

Prime Minister Sir Keir Starmer visits a manufacturing facility in Chester. The Government pledged nearly £22 billion funding to develop projects to capture and store carbon emissions from energy, industry and hydrogen production.

too low the gas and air mixture is too lean to present a risk of an explosion. Likewise, if the concentration of gas is too high the mixture is too rich to present a risk of an explosion.

Hydrogen can form a flammable atmosphere over a much wider range of concentrations than natural gas (4-75.6% by volume compared to 5-15% by volume). Furthermore, hydrogen has a significantly lower minimum ignition energy than natural gas (0.02mJ compared to 0.29mJ), which means it can be ignited by a much weaker ignition source. Therefore, there is a greater likelihood that any escape of hydrogen will lead to formation of a flammable atmosphere and an explosion.

Similar to natural gas, hydrogen is colourless and odourless, so cannot be detected by sight or smell. Odorants are added to natural gas to enable leaks to be detected by smell well before they reach a dangerous concentration. A similar odorant could be added to hydrogen to aid leak detection if it is delivered through the gas network and the end use is for combustion appliances. However, there are challenges with this approach where hydrogen is generated and stored locally, or where the intended use is generation of electricity using fuel cells. This is because it may not be practical to dose the odorant at the appropriate concentration for small volumes of hydrogen. Furthermore, odorants currently used for natural gas are based on sulphur compounds which are detrimental to the operation of fuel cells. Either different compounds would need to be used, which would not have the familiar odour associated with gas, or electronic detectors would need to be installed. The disadvantage with the latter is that unlike odorants these would require regular maintenance and testing to ensure they remained effective.

Hydrogen has potential to contribute to the transition from fossil fuels as a fuel for industrial and heating processes and as an energy storage medium. However, there are practical and safety issues to address before widespread adoption of hydrogen. Appliances designed for operation with natural gas will need to be replaced or modified to use gas mixtures with high concentrations of hydrogen. There is also greater risk of leaks associated with hydrogen. This is because gas supply systems will need to be operated at higher flow rates or pressures and hydrogen gas molecules are much smaller than those of natural gas. Any escape of hydrogen is more likely to lead to an explosion compared to natural gas, as it can form a flammable atmosphere over a large range of concentrations than natural gas and it is easier to ignite.

**Appliances designed for operation with natural gas will need to be replaced or modified to use gas mixtures with high concentrations of hydrogen.**



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