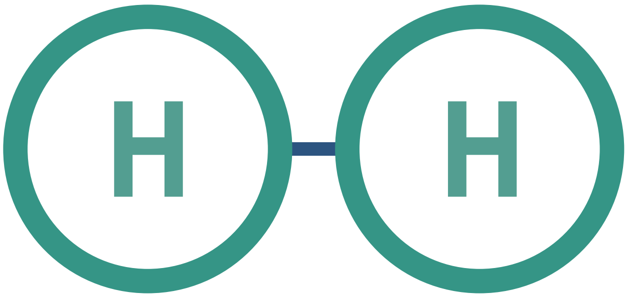
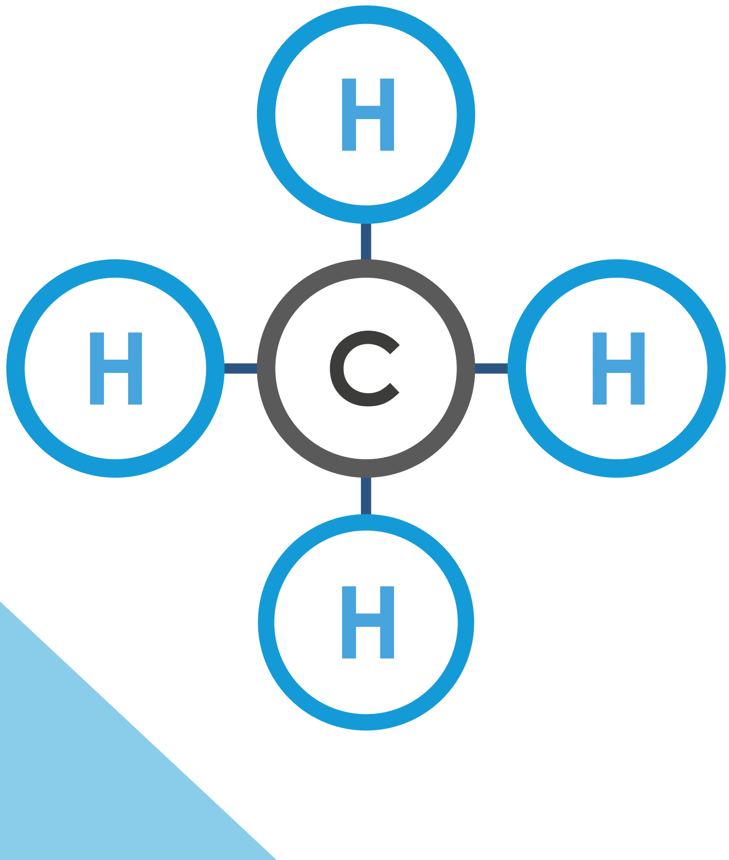
Hydrogen

A decarbonisation route for heat in buildings?





LETI

Is hydrogen a decarbonisation route for heat in buildings?

Summary

Hydrogen fuel is often touted as a viable solution to assist in meeting our UK net zero carbon targets. LETI have therefore sought to investigate this further and examine to what extent Hydrogen is likely to be used, either in part or full to accompany decarbonisation of the electricity grid.

This document acts as a primer for those seeking clarity on the likelihood of hydrogen becoming a means of heat delivery for buildings via the pre-existing gas pipe network. It is based on an extensive published document review from a broad range of viewpoints. A summary of our key findings is provided below, with extended research presented on the following pages.

When considered holistically, it seems unlikely that zero carbon hydrogen supplied via a re-purposed gas mains network will be available, for the vast majority of buildings, for the foreseeable future.

→ **Which hydrogen** – 'Green' hydrogen from renewable power electrolysis is truly zero emissions. However, the UK gas supply industry[1] advocates 'Blue' hydrogen[2] manufactured from methane with carbon capture of its high emissions using yet to be proven at scale carbon capture and storage technology.

→ **Efficiency** – Hydrogen conversion, delivery and combustion has between a third and one sixth the efficiency of the alternatives[3] (figure 1). Where it does have a clear benefit, for energy storage, this is more efficiently done centrally to serve peak electricity power generation without needing a general gas grid switch over.

→ **Implementation** – The lack of tangible benefits or engagement with the millions of building occupier/owners casts serious doubts on the practicality of a gas switch over. There is a noticeable lack of proposals to guarantee and accept liabilities for in-building gas pipework switch over. Meanwhile the hydrogen dosing of natural gas appears to be as much a technological dead-end as biodiesel dosing of automotive fuel proved to be.

→ **Costs** – Funding for a second national energy grid upgrade, incorporating new infrastructure technology unproven at scale is a major delivery risk. Along with a required 150%[4] increase in primary energy generation this appears highly questionable. Funding this from government or investors seems unlikely when viewed alongside the alternative of rapidly falling renewable electricity costs (such as windfarms)[5]. Expecting consumers to pay will unduly penalise those in society least able to pay.

When blue hydrogen, supplied via the gas network, is compared to the use of heat pumps there is a stark difference in efficiencies. Begging the question - why consider or pursue hydrogen for the heating of UK homes? We should be considering more effective way to decarbonise our buildings?

Of note, we have found that the public discourse on hydrogen appears severely unbalanced, with gas supply industry in particular "over-selling 'green-gas' to policy makers in order to protect their interests"[6].

LETI concludes it is unlikely that zero carbon hydrogen supplied via a re-purposed gas mains network will be available for the vast majority of buildings, for the foreseeable future.

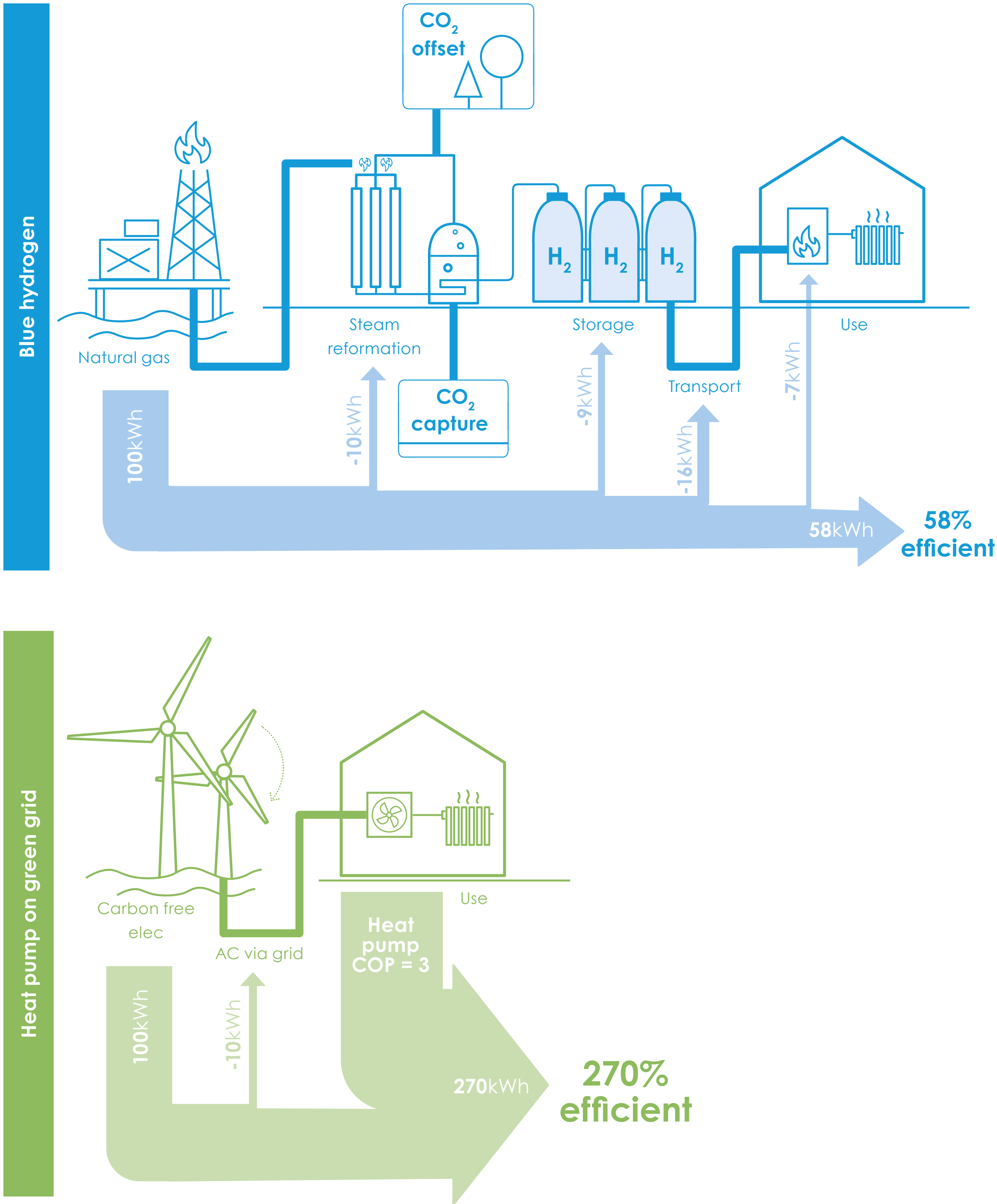


Figure 1 - The difference between blue hydrogen and heat pumps on a green grid (useable heat output compared with energy sourced for input to the grid).

Data source - Prof David Cebon[7]

Heat

Decarbonising heat, particularly with peaks at about four times the current electrical grid capacity[8], is a challenge. Whilst a switch to all-electric heat pumps can address much of this, it is by no means a fully resolved route forward[9]. As an alternative, the gas supply industry is advocating repurposing of the (otherwise obsolete) natural gas network to supply hydrogen for heat[10].

The Committee on Climate Change (CCC) has suggested that hydrogen might be available for peak demand using hybrid heat pumps (HHP)[11]. While HHPs were originally envisaged as combined units[12], practicalities now suggest separate boilers and air source heat pumps with integrated controls[13] would be required. There is currently no clarity on the route to market for these.

Previous ideas of domestic gas fuel cells seem to have fallen away, not least because their output does not match domestic heat to electricity ratios[14]. Although not specifically referred by the CCC, there seems to be an increasing push towards replacement domestic boilers that can be converted on-site from natural gas to hydrogen gas[15].

Blue Hydrogen

The gas supply industry[16] is advocating 'Blue' hydrogen manufactured by massively scaling up the process of natural gas steam reformation (figure 2). This process does however emit CO_2 as well as having upstream methane greenhouse gas (GHG) leakages[17]. Large-scale carbon capture and storage (CCS) technology is proposed to capture some 90% of these CO_2 emissions[18]. Additional bio-sequestration or similar would also be required to remove the remaining 10% of CO_2 for 'Blue' hydrogen to become zero carbon[19] (figure 3). There are significant uncertainties in developing, up-scaling and deploying these technologies. In addition, large volume storage of hydrogen for the winter peak demands would be required. Long term storage of captured carbon dioxide would also need to be developed. It seems likely that for the period until CCS is proven and implemented at scale, significant GHGs would be emitted before blue hydrogen can be delivered.

Green Hydrogen

'Green' hydrogen is created using renewable electricity with an electrolysis process and hence without the consequential CO_2 emissions[20] (figure 4). Interestingly, Germany's new hydrogen national strategy[21] has decided not to consider 'Blue' hydrogen for either the short term or the long term, instead focusing on 'Green' hydrogen. It also acknowledges they expect to become dependent on hydrogen imports because of insufficient indigenous renewable energy sources. They have therefore concluded that hydrogen should be focused on uses where portability, storage and intensity of energy is critical and where there are therefore few alternatives (e.g. high temperature industry, heavy and long distance transport etc.).

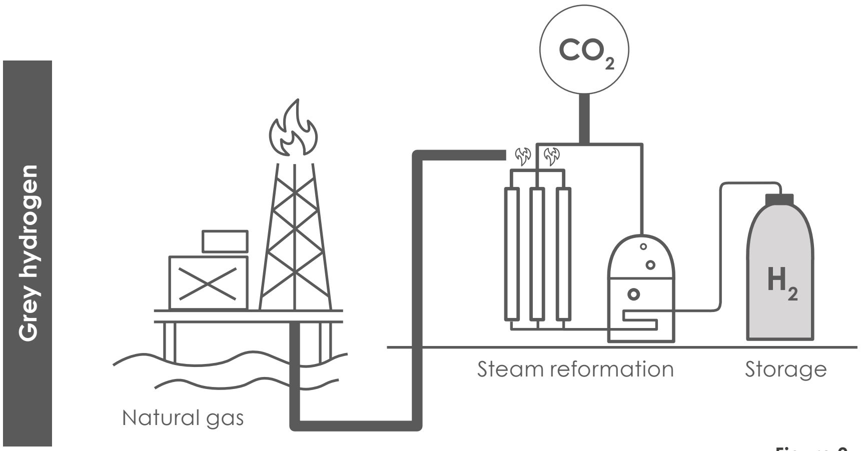


Figure 2 - Grey hydrogen, how hydrogen is currently made

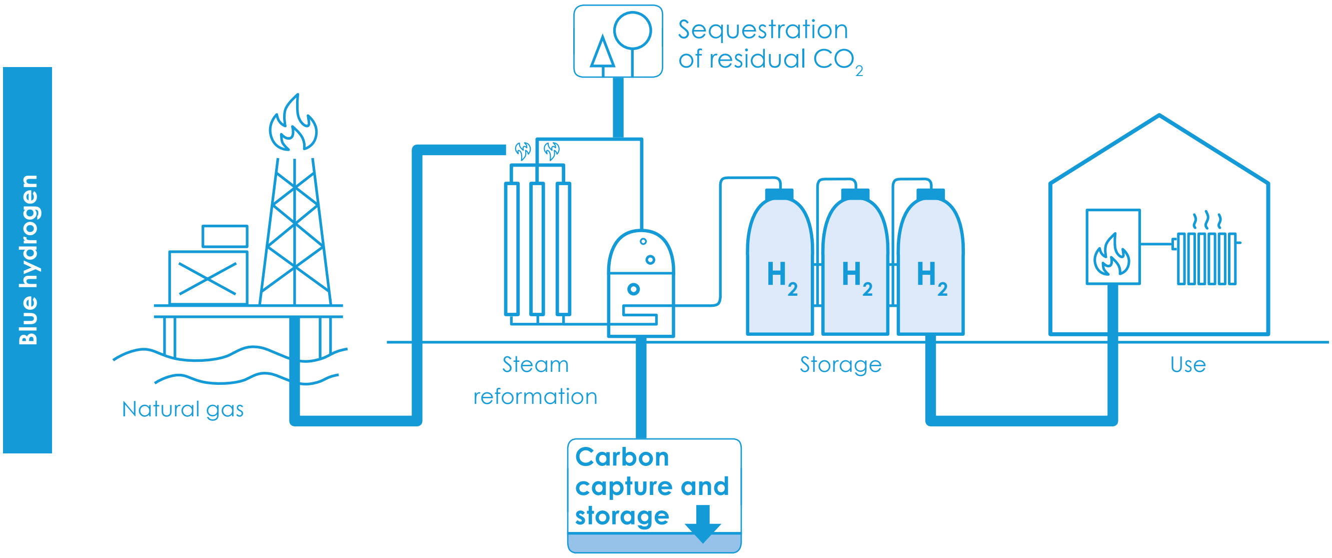


Figure 3 - Blue hydrogen, as advocated by the gas supply industry

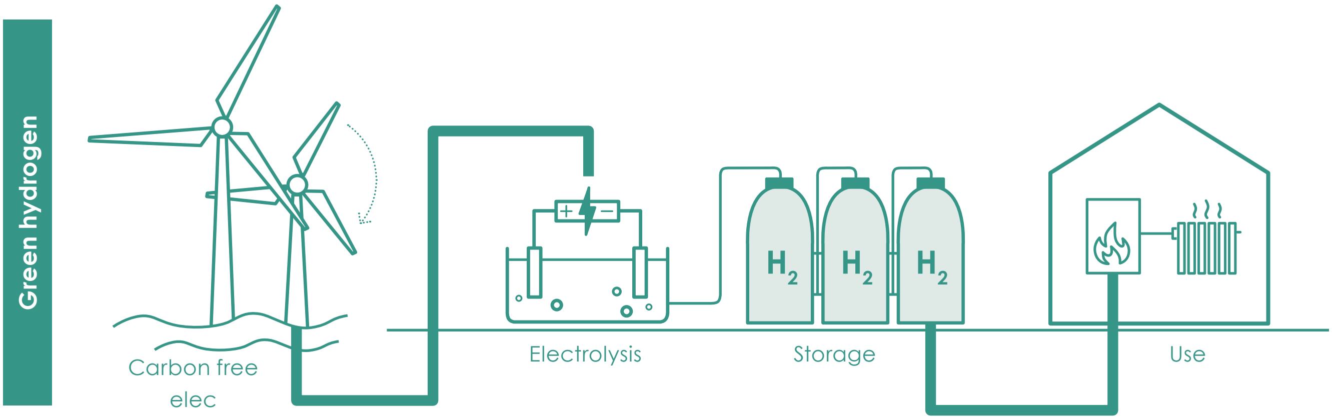


Figure 4 - Green hydrogen, made from renewable energy

Implementation

Hydrogen trials are currently being conducted[22] to address gas grid switch over issues. A switch over is expected to involve replacing primary distribution steel mains, additional pumping, reuse of polyethylene local distribution, new end-use appliances, and selective component replacement, as well as proving of the re-purposed system. However, what appears to be unresolved is the issue of who accepts liability for re-purposing of pre-existing (largely concealed) pipework inside most dwellings and other buildings.

The proposal to dilute natural gas with 20% hydrogen for the start of a route to zero carbon seems to be a technological dead-end similar to biodiesel dosing of diesel. Looking ahead further on switching the gas grid entirely to 'Green' hydrogen would need some 50% additional renewable electricity annually[23], due to its relatively poor overall delivery efficiency. How this might be achieved is currently unresolved, raising the potential of permanent investment lock-in to the GHG emissions of a 'Blue' hydrogen road map.

Hydrogen as an energy delivery vector (carrier) is relatively inefficient compared with using renewable electricity with heat pumps[24], as illustrated in figures 5 and 6. Hydrogen could provide useful renewable energy storage until needed for winter peaks. However, this can be more efficiently implemented using re-purposed combined cycle gas turbine (CCGT) power-stations without needing wider gas grid conversion[25].

The gas supply industry quotes the 1970s natural gas grid switch over as a precedent[26]. This was carried out at no cost to the consumer[27] and switched to a significantly cheaper new fuel[28]. It triggered extensive consumer complaints[29] and call backs that were largely unreported at the time (in the absence of social media). The current smart meter changeover track record does not bode any better in this regard[30].

The building side of a gas grid switch over is in the hands of millions of building occupier owners, for whom energy is not a core business. Therefore, decisions by them to permit a switch over, or not, are likely to be made using non-energy/carbon rationale (e.g. cost, amenity, expectations and disruption). However, the new manufactured hydrogen is expected to cost more than natural gas, particularly if the cost of building pipework and appliance conversion is amortised within it[31]. Issues like responsibility for disruption, redecoration and liability for re-purposing dwelling pipework are unresolved. Plainly there will be a significant communication and education challenge before the public would support a switch over from natural gas[32]. As has been illustrated by the Green Deal, lack of appropriate alignment with these building stakeholders can bring a national programme to a halt[33].

There does, however, seem to be a sounder logic of fewer high-intensity gas users connecting to a smaller network. This scenario would include:

- Peak CCGT power stations
- High temperature industry
- Long-haul aviation and heavy lift haulage
- Distribution to local consumer networks in the immediate vicinity [34].

A key feature for these scenarios would be diluting the investment cost within a wider service offering, before reaching consumers.

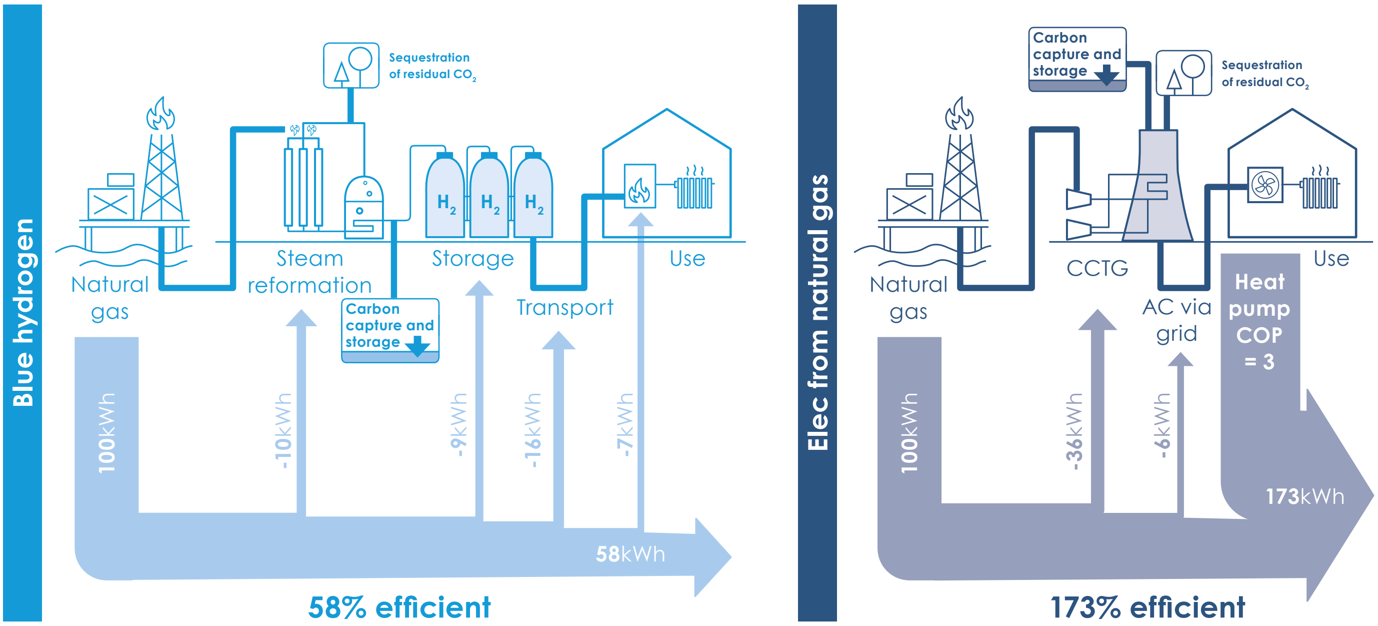


Figure 5 - The difference between blue hydrogen and electricity from natural gas supplying a heat pump

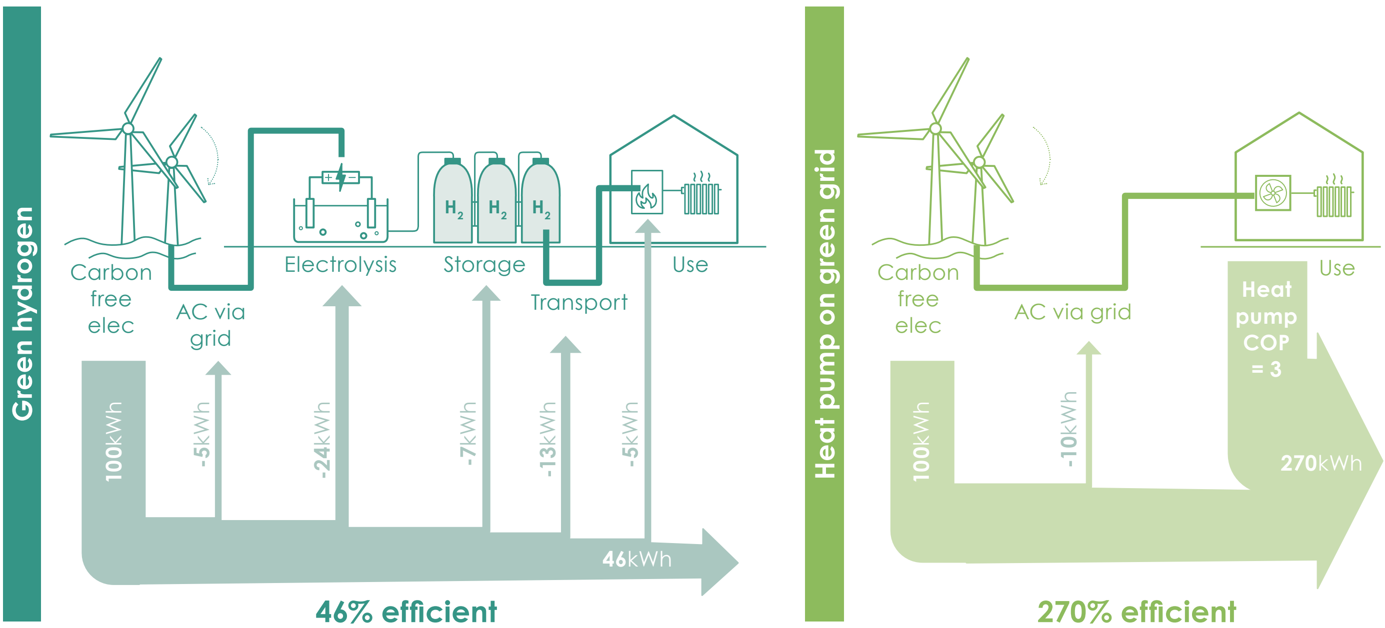


Figure 6 - The difference between green hydrogen and a heat pump supplied by a green grid

Data source - Prof David Cebon[7]

Timescale and finance

The proposed timescale for implementing Blue hydrogen with its CCS[35] does not align with LETI recommended rates of building decarbonisation[36]. If 'Blue' hydrogen remains the gas supply industries proposed end state, there is a significant risk that re-purposing the gas grid using new unproven technology at scale could prove less feasible than previously thought. By that time, the required scale of carbon offsetting is unlikely to be available at reasonable cost[37]. This would leave little time to implement alternatives, and in the midst of a climate emergency we should be leaving little to chance.

The cost of gas grid conversion is said to be of a similar magnitude to an all-electric switch over[38]. That said, paying for both conversions serving similar purposes would appear to be a poor investment. The hydrogen conversion costs also appear to be far more dependent on revenue from year-round large-scale adoption and high consumption of hydrogen[39], apparently at odds with the CCC suggestions for it serving just peak demands[40].

Unlike an all-electric switch over, there are significant hydrogen cost uncertainties, like the yet to be proven CCS[41]. This makes it a fundamentally different investment proposition. For the electrical switch over, private investment largely funds new wind power generation based on falling capital costs with relatively low operating costs, providing proven investment returns[42]. On the other hand, hydrogen manufacture operating costs will be inherently higher than natural gas[43], generate less capital return to investors and at a higher investment risk level given the unproven technology and up-scaling needed. Consequently, a gas switch over is likely to require significantly more taxpayer funding from already stretched public budgets. Simply passing this scale of costs directly through to consumers is unlikely to be acceptable because it includes those in society least able to afford it.

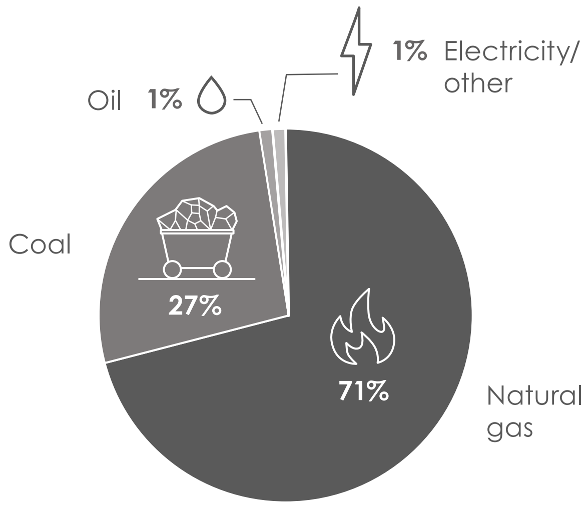


Figure 7 - Current global dedicated hydrogen production, energy input by source. Total current global hydrogen production is 44% of UK current gas demand.

Data source - IEA (2019)

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The views expressed in this document do not necessary represent the views of the organisations to which contributors have affiliations.

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This is a climate emergency

We are in a climate emergency, and urgently need to reduce carbon emissions. Here in the UK, 49% of annual carbon emissions are attributable to buildings. Over the next 40 years, the world is expected to build 230 billion square metres of new construction – adding the equivalent of Paris to the planet every single week – so we must act now to meet the challenge of building net zero developments.

The London Energy Transformation Initiative have developed this short guide to provide information for the built environment - setting out a definitive journey, beyond climate emergency declarations, into a net zero carbon future.

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