Hydrogen for heat?

Eight critical questions for the UK Hydrogen Strategy

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Eight critical questions

As we await the publication of the UK government's Hydrogen Strategy, and its much-delayed Heat and Buildings Strategy, Regen asks eight critical questions that need to be addressed before a decision can be taken as to whether hydrogen is to become a widespread fuel for domestic heating.

Hydrogen has become a very hot topic in the net zero transition, with proponents pushing its merits, while detractors have highlighted its limitations.

Our view is that hydrogen has a key role to play, especially to decarbonise areas of industry and transportation (including marine and aviation). We also believe that green hydrogen, made by electrolysis of renewable electricity, would fit well in a net zero energy system and could provide an important multi vector balancing demand for very low-cost renewable energy. These should be priority areas for the UK’s Hydrogen Strategy.

We are concerned that the debate about the use of hydrogen for widespread domestic heating has become entrenched on both sides, with a huge amount of hype based on partial and incomplete analysis.

Regen’s current view is that hydrogen is unlikely to become a ubiquitous heating fuel in the manner of natural gas for reasons of cost, carbon emissions, distribution and storage logistics, the challenges of conversion and security of supply. However, we acknowledge that other heating solutions, including full electrification, are also extremely difficult to implement, and that there may well be other options for more discrete hydrogen clusters and targeted hydrogen heating solutions at a local and regional level.

It is also the case that, right now, there is still some uncertainty about the role that hydrogen could play, and it is too early to categorically rule hydrogen in, or out, as a future heating fuel. To make that decision we would suggest that there are eight critical questions, or challenges, that need to be addressed.

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Eight critical questions

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- What will be the final cost of hydrogen fuel for domestic customers?
- Can homes be safely converted to hydrogen?
- How much hydrogen energy can be delivered through the existing gas networks?
- How effective, and costly, will blue hydrogen CCS be?
- How much production and storage capacity will be needed to meet peak demand?
- How will the transition of the gas network be executed?
- How secure will the long-term supply of natural gas be?
- How will consumer choice be respected and what are the implications?

1 What will be the final retail price of hydrogen fuel for domestic customers?

Regen's view

Even if production costs fall, hydrogen is likely to remain a high-cost fuel for domestic heating, especially when the full costs of feedstocks, storage, logistics, distribution and seasonal market factors are considered.

Without subsidy, we would expect future retail prices to remain above 10-12p per kWh. A full cost, and market price, analysis is urgently needed.

The question of hydrogen cost has largely focused on the potential to reduce production costs, with an ambitious industry target to achieve $2 per kg of H2 or circa 4.5p per kWh by 2030.

While achieving this level of production cost reduction would be a great achievement, there is a much broader fuel price challenge which must consider:

- The volatility and projection of feedstock costs (inc. natural gas/LNG)
- The cost of seasonal and logistical storage
- Increased network distribution costs (see question three)
- The full costs of blue hydrogen carbon transportation and storage
- Winter merit order and seasonal peak demand effects
- Costs of reliance on H2 imports during winter periods
- Retail costs and margins, including asset returns and risk premiums
- The implications of hydrogen market oligopoly structures and super profits
- International cost implications for feedstock (natural gas) supply and hydrogen trading

Without a long-term subsidy it is difficult to see how hydrogen retail prices for domestic heating could be less than 10-12p per kWh, and they could be significantly higher especially during winter periods.

At this price point, circa three times current gas prices, there would likely be a flight to other forms of low carbon heating, further increasing the fixed costs per kWh of hydrogen supply.

2 How effective, and costly, will blue hydrogen carbon capture and storage be?

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Regen's view

Blue hydrogen needs to have a carbon capture rate of over 95% to be compatible with net zero.

A rush to subsidise production capacity could allow far less efficient manufacturers to dominate the market, crowding out investment in green hydrogen and blue hydrogen innovation.

Carbon capture efficiency, and secure long-term carbon storage, must be key criteria for production subsidies. Only fully low carbon hydrogen, with capture rates above 90%, should be supported.

There is a push to provide support to increase blue hydrogen production capacity, manufactured by reformation of natural gas. However, the carbon intensity of blue hydrogen is still very high. More efficient carbon capture processes could be developed in the future, but these are likely to be much more costly.

The Climate Change Committee has suggested that true blue low carbon hydrogen needs to achieve a carbon capture efficiency of 95% or more. Across Europe, the industry is lobbying for the threshold of blue hydrogen to be set initially at only 60% carbon capture. That would produce a fuel with a carbon intensity of circa 112 g CO_2e per kWh, better than grey hydrogen (279g) and natural gas (188g), but still much higher than a true low carbon fuel.

Type of Hydrogen	Carbon Capture Rate	Carbon intensity gCO^2e / kWh
Grey hydrogen	0%	279
Blue/grey hydrogen	60%	112
Bluish hydrogen	75%	70
Blue hydrogen	95%	14

Add in the additional carbon and methane emissions associated with carbon transportation and storage, hydrogen storage and distribution, LNG production, increased network losses, and reduced boiler efficiency, and the carbon savings of a blue/grey hydrogen become minimal.

3 Without major investment, how much hydrogen energy could be delivered through the existing gas networks? And how many customers could be served?

Regen's view

The debate is often presented as 'hydrogen versus electrification', but in fact both energy networks will require significant investment to meet the heat demand of UK consumers.

Adding to the complexity, it is likely that heating solutions will be highly regionalised. This calls into question the idea of a ubiquitous hydrogen network .

There is a common belief that hydrogen could become a direct replacement for natural gas, and that the existing gas network could provide the same ubiquitous heating fuel for circa 85% of UK households. In reality, it is highly unlikely that all existing gas consumers could be supplied with 100% hydrogen heating via existing network assets. Even high hydrogen scenarios require a significant proportion of consumers to opt for electrification or hybrid heating solutions.

In part, the reason for this is that hydrogen has a much lower energy density by volume than natural gas.

Comparison of energy densities – hydrogen and natural gas

Gross Energy (Higher Heat Value)	Hydrogen	Natural Gas	ratio H2 : NG
Energy per volume (kWh/M^3 @ atm)	3.3	11.0	1.0 : 3.4

Although this is partly offset by a lower viscosity, it is nevertheless true that a hydrogen energy system would need to operate at higher pressure and much higher flow rates to deliver the same amount of unit energy compared to natural gas. This means more investment in network capacity and control systems, more energy used in pushing molecules around the network, more losses in the network and significantly more logistical and seasonal storage.

The key challenge for hydrogen, as it is with electricity, is to meet the peak winter day heat demand. We need to understand at the transmission network level, at a regional level and across the lower pressure distribution networks, how much energy could be delivered, and the cost implications of network upgrades.

4 How much hydrogen production and storage capacity would be needed to meet winter daily and seasonal demand?

Regen's view

As a manufactured fuel, with a lower energy density, hydrogen heating will require significantly more seasonal and logistical storage.

The full costs of hydrogen storage need to be understood, including the working capital cost of holding large amounts of high value hydrogen, losses and operational costs.

Who would own and operate hydrogen storage, and how the market would be regulated to avoid oligopolistic behaviours, needs to be considered.

The UK gas network is very good at meeting daily demand from "line-pack" gas stored within the transmission and distribution network, topped up by daily injections from UKCS landings and European pipelines. On a typical cold day this, "just in time", network can deliver over 400 million cubic metres of natural gas carrying the equivalent of over 5 TWh of energy. Natural gas storage, which has reduced significantly with the development of gas interconnectors, is primarily used for the purpose of price arbitrage and to provide a strategic reserve, not daily logistical supply.

Hydrogen presents a very different challenge. Peak daily demand could be met directly from production capacity, but this would imply very high levels of under-utilised capacity. Or it could be met from production augmented by far higher levels of hydrogen storage. Either approach has cost and security implications.

Storage requirements would be:

- seasonal - large-scale, to smooth production supply/demand over the year
- logistical - local and regional storage needed to maintain intra-day balances
- cluster based - in the absence of a national network

Scenario analysis has not adequately modelled the whole system requirements, and cost implications, for hydrogen storage for heat, alongside other hydrogen markets.

5 How secure will the long-term supply of natural gas be? And where will it come from?

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Regen's view

Blue hydrogen would commit the UK to secure access to natural gas into the second half of the 21st century.

There is no long term source of natural gas that offers security of supply, sustainability and avoids the risk of extreme price volatility.

It would be folly to base the UK's long term heating strategy on natural gas. Green hydrogen, via electrolysis, could offer a far more sustainable energy future.

Widespread use of hydrogen for heating would require a massive expansion of blue hydrogen capacity, locking the UK into a long term dependency on imported natural gas as a feedstock energy source.

Production from the UK continental shelf is in steep decline and we have for some years become a significant net importer of natural gas. By 2040, UK gas production is expected to fall to 111 TWh, a tenth of it's peak output in 2000.

The 2021 System Transformation Future Energy Scenario, which is a moderately high hydrogen scenario for heating, requires 49 bcm (540 TWh) of natural gas per year by 2040 with an 85% import dependency. By 2050, the projected import dependency has risen to 98%.

Options for future fossil gas supplies are problematic:

- Imports from continental Europe will be heavily dependent on Russian gas, raising significant security and environmental risks (e.g. methane emissions).
- LNG imports could widen the supply pool but are subject to increasing demand competition from Asia, and carry higher costs and GHG emissions.
- Fracking has all but been ruled out in the UK and would entail phenomenal costs and environmental issues.

We are already seeing the price volatility risk of natural gas markets and the impact this has on energy bills.

6 What is the reality of safely converting UK homes, appliances, mains connections, metering and internal pipework for hydrogen?

Regen's view

Trials are underway and are likely to show that homes can safely be converted to hydrogen. But the cost, complexity, and disruption to do this is likely to be much higher, and more variable, than is currently acknowledged.

Industry analysis has tended to focus on the cost of making boilers hydrogen ready, and the ongoing conversion of the gas mains network with hydrogen compatible PE pipework. The positive narrative here is that hydrogen ready boilers are in fact cheap and could be deployed relatively easily with minimal customer impact.

In fact, there is a lot more to safe domestic hydrogen conversion including, for example, the inspection and possible need to replace; gas meters, the last yards from mains to meter pipework as well as internal meter to appliance pipework and joints. Works could range from a simple inspection to the need for significant street and on-property ground works.

While trials and further studies are planned, including the development of the first hydrogen village, we don't yet have a full understanding of the complexity and safety of hydrogen conversion. Initial desk based studies[1] have produced a wide range of costs estimates.

As well as the cost and safety implications, the logistics of carrying out these inspections and upgrades could add significantly to the transition challenge.

[1]https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/760508/hydrogen-logistics.pdf

7 What would the network transition strategy to hydrogen look like, and how would this be executed?

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Regen's view

Conversion pathways for hydrogen heating must address the key question of maintaining security of supply for both new hydrogen and existing gas consumers.

The "market", and individual consumer choice, is not going to deliver a hydrogen conversion.

It is difficult to see how this can be achieved at a nationwide level without significant additional network investment, especially at the transmission network.

Unlike the roll-out of natural gas, the conversion to widespread hydrogen heating is likely to be far more difficult and take far longer, both for individual consumers and for the networks, than has been presented. A number of different hydrogen conversion pathways have been suggested. For example:

1. By strategic design – a city or a region makes a strategic decision to go for hydrogen and begins a process of network and consumer conversion, for example, as envisaged by the Leeds 21 project.
2. By cluster development – starting within hydrogen clusters anchored by industrial and transportation demand customers and major production sites. Hydrogen supply could then "spill out" to nearby distribution networks and consumers. Eventually clusters could be linked by national networks.
3. By blending – starting with a 20% by volume blend, to build up production capacity, parts of the network could then take the step to 100% hydrogen.

However, none of the pathways described to date have offered a complete and credible (costed and time-scaled) analysis of how hydrogen conversion would be achieved, and especially how different clusters or regions would come together to create a national hydrogen network.

Conversion pathways have also not shown how hydrogen conversion can be achieved using existing network assets, while at the same time maintaining security of supply for new hydrogen and existing gas customers.

8 How would consumer choice be respected? What would be the implications if many consumers choose a different solution?

Regen's view

Energy policy makers and strategists are ignoring the fact that heating and energy efficiency choices will be made by 24 million household decision makers.

Neither the conversion to hydrogen or electrification will be easy to implement. Consumers need to be brought along the journey, and that starts with being very honest and transparent about the merits and costs of different heating solutions.

It's time for a much more honest debate.

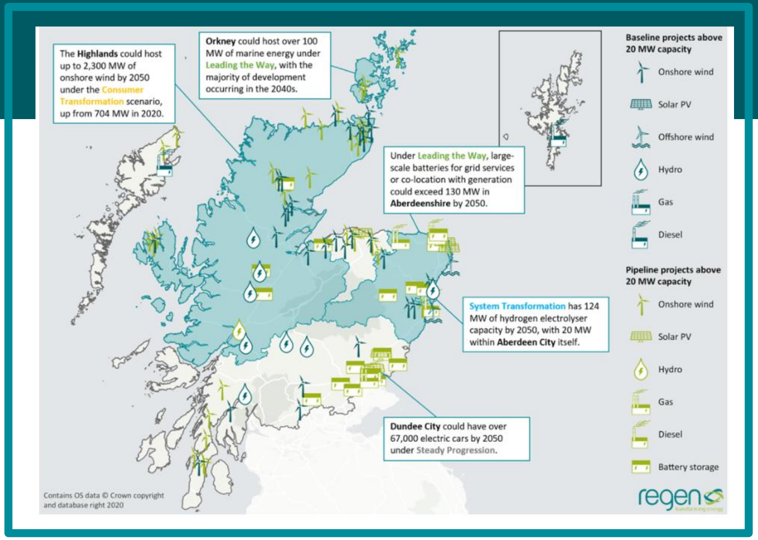
Hydrogen has been pitched as a consumer-friendly option because "it causes less disruption" and is "just like gas". In reality, the switch to hydrogen is not straight forward and, presented with the full facts of hydrogen fuel usage and cost, many consumers may rationally opt for a different solution.

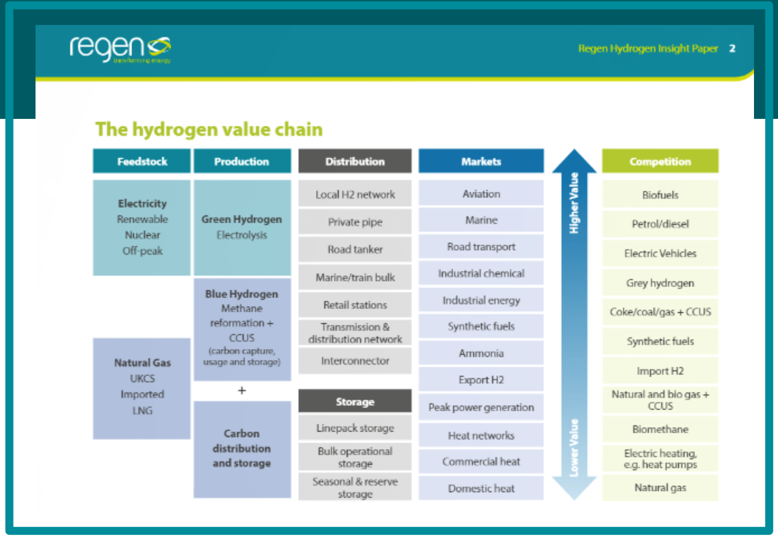
The roll-out to natural gas worked because there was a very clear and overwhelming customer benefit, and natural gas wasn't competing against other alternatives. If hydrogen does transpire to be three times the cost of natural gas, then a high proportion of those that can convert to heat pumps or other solutions will do so. This flight from hydrogen could undermine the infrastructure cost case for a hydrogen transition.

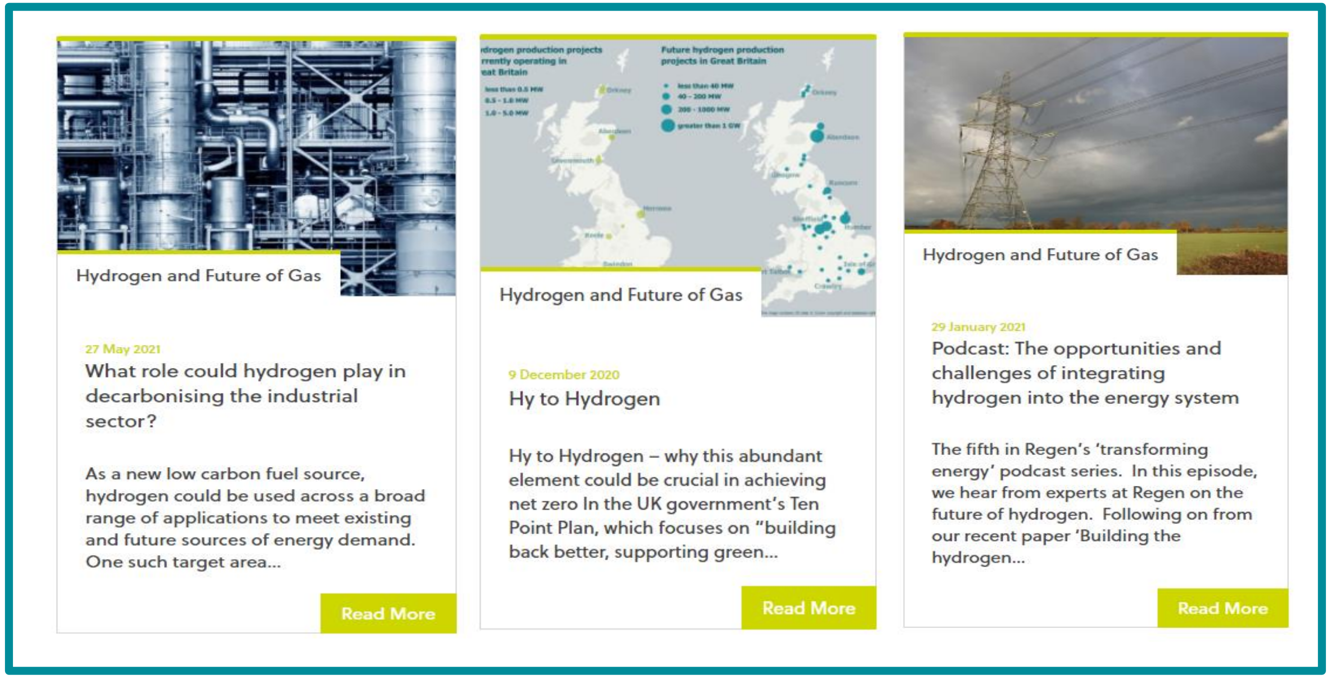
This has significant implications for the UK's future heating strategy. Does the UK try to implement a strong "top down" heating strategy, dictating to consumers their heating solution, perhaps on a regional basis? Any prescriptive approach would be difficult to implement and would require very high levels of subsidy support.

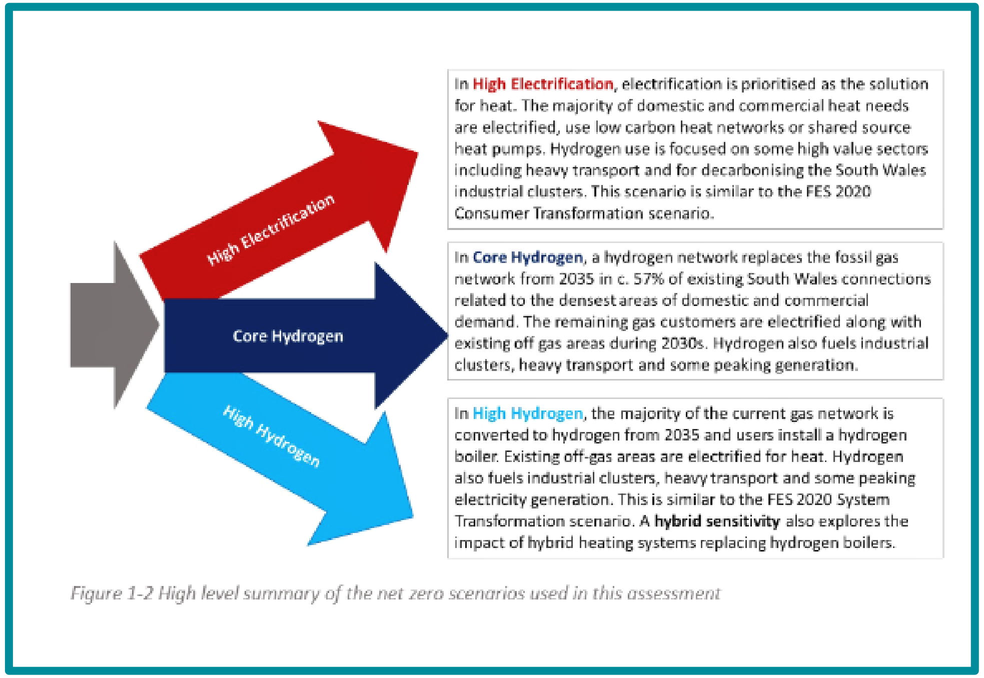
Or allow individual consumers to make their own heating solution choice and risk widespread desertion from hydrogen and rapidly increasing fixed costs per unit of energy delivered.

Regen's recent work in the hydrogen space









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