Hydrogen for domestic heating: a preliminary analysis from National Energy Action (NEA)[1]

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1. Introduction

In 2019, the UK amended the Climate Change Act to commit to achieving net zero by 2050, effectively ending its contribution to global emissions. Beyond the decarbonisation of key sectors of the economy, including energy and energy generation, one of the foremost challenges associated with this commitment is the decarbonisation of domestic homes. Space and water heating accounts for approximately four fifths of domestic carbon emissions,[2] and it is therefore clear that emissions from domestic homes will need to be eliminated in the coming three decades for Net Zero to be reached.[3]

The vast majority of scenarios[4] for meeting this challenge pivot on two requirements:

1) A significant proportion of existing UK homes will require substantial improvements to the thermal efficiency of their building fabric.
2) A significant proportion of existing UK homes will need to transition away from fossil fuel based systems, such as natural gas boilers, to zero- or low-carbon alternatives.

The decarbonisation of domestic heating intersects with the challenge of eradicating fuel poverty across the UK. Different definitions of fuel poverty exist, but it is commonly understood as an inability to access adequate energy services that are required for good health and wellbeing. The official definition used in England is the Low Income Low Energy Efficiency (LILEE) indicator. Under this indicator, a household is considered to be fuel poor if:

- they are living in a property with a fuel poverty energy efficiency rating of band D or below, and
- when they spend the required amount to heat their home, they are left with a residual income below the official poverty line[5]

The latest fuel poverty strategy for England, 'Sustainable Warmth', links the LILEE indicator to a fuel poverty target for 2030, which is to ensure that all fuel poor households reach EPC C by that year. It

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[1] National Energy Action (NEA) works across England, Wales and Northern Ireland to ensure that everyone in the United Kingdom can afford to live in a warm, safe home. To achieve this vital mission, NEA provides access to energy and debt advice, delivers training, supports local and national energy efficiency policies and co-ordinates wider services which can help change lives. Our key partners across the UK nations include local and national governments, regulators, industry and the third sector to deliver practical support to improve the quality of life for those in or at risk of fuel poverty. We are working with others to achieve a fair transition to net zero for fuel poor households.
[2] Eurostat (2020) Energy consumption in households.
[3] Committee on Climate Change (2019) Net Zero – The UK's contribution to stopping global warming.
[4] See the scenarios presented in Committee on Climate Change (2020) The Sixth Carbon Budget: The UK's path to Net Zero. This report primarily focuses on the 'Balanced Net Zero Pathway', but also assesses several alternative scenarios for reaching Net Zero by 2050.
[5] BEIS (2022) Annual fuel poverty statistics report 2022 (2020 data).

also emphasises that decarbonising heating in fuel poor homes will be a key part of meeting this target.[6] Research by NEA has shown that a range of technologies exist for the decarbonisation of fuel poor homes; primarily heat pumps, but also alternative systems such as district heating and, in rarer circumstances, other electric technologies such as high retention storage heaters.[7] Much of NEA's current research and evaluation work focuses on understanding the benefits, challenges, and risks of decarbonising fuel poor homes with these technologies.

In the medium-term, hydrogen for heating is one area that could potentially decarbonise fuel poor homes' heating. When burned in the home (e.g. on a hob or in a boiler), hydrogen emits no carbon emissions, and it is therefore possible that the currently existing natural gas grid could be repurposed to transport hydrogen to gas customers across the country.[8] Various analyses produced by government, industry, and academia have highlighted that this could begin by 'blending' hydrogen into the existing gas network up to a volume of 20%, which could serve as a stepping stone to stimulating the hydrogen industry and preparing the ground for a full conversation of the network to hydrogen.[9] The UK government is currently exploring these possibilities, and is supporting a number of hydrogen trials that aim to gather evidence on the technical, social, and economic feasibility of a hydrogen transition.[10] The UK government plans to use this evidence to make decisions regarding hydrogen blending in 2023 and the future of the gas network in 2026.[11] If a decision is favourable, large-scale conversion could take place in the 2030s.[12]

The intention of this paper is to summarise NEA's emerging view on several challenges and risks that will need to be considered if a transition to hydrogen is to work effectively for fuel poor homes. Ultimately, the paper pivots around the assertion that if a hydrogen transition does take place at some point in the future, it will be necessary to support households living in fuel poverty with broader forms of energy-related advice and wider support that can improve their situations. This is based on a broader premise that any upgrade of domestic heating systems should be an opportunity to improve the health and lives of vulnerable households.

2. Safety

Given the hydrogen's innate properties (highly inflammable, colourless, odourless, and burning without a visible flame) converting an existing gas network to transport hydrogen presents notable safety challenges. Previous research into the possible use of hydrogen for home heating has highlighted safety as one of the main concerns consumers will have. Nationally representative survey research by Newcastle University into public perceptions of blended hydrogen found that 44% of respondents would be worried about the possibilities of gas leaks, explosions, and fires, and the level of initial concerns that their respondents had was significantly associated with their overall support for using hydrogen in the home.[13] A separate research project by the same authors highlighted that some of the specific properties of hydrogen (e.g. flammability, ignition energy and

[6] BEIS (2021) Sustainable Warmth: Protecting Vulnerable Households in England.
[7] NEA and Energy Action Scotland (2021) Fuel Poverty Monitor 2021.
[8] For an early analysis of this proposition, see: Dodds, P. and Demoullin, S. (2013) Conversion of the UK gas system to transport hydrogen, *International Journal of Hydrogen Energy* 38 (18): 7189-7200. For a more recent industry perspective on conversion, see: Energy Networks Association (2021) Britain's Hydrogen Network Plan.
[9] See Isaac, T. (2019) HyDeploy: The UK's First Hydrogen Blending Deployment Project, *Clean Energy* 3 (2): 114-125.
[10] BEIS (2021) UK hydrogen strategy.
[11] BEIS (2021) UK hydrogen strategy, p.52.
[12] BEIS (2021) UK hydrogen strategy, p.63.
[13] Scott, M. and Powells, G. (2019) Blended Hydrogen: The UK Public's Perspective.

temperature, flame speed, detonation level, and speed of diffusion in the event of leak) were perceived by consumers as posing an additional safety risk in the home, especially by families with young children.[14] Similarly, research by Leeds Beckett University noted that some, but not all, of their research participants asked questions about safety, including informed questions about (e.g.) the risk implications of hydrogen being more flammable than methane.[15] Beyond the UK, research about the use of hydrogen for domestic heat in Australia found safety was the most important determining factor shaping participants' willingness to live in a hydrogen home.[16] The question asked by one focus group participant in this research is indicative of the kinds of questions some consumers will have about hydrogen:

> *"And obviously, hydrogen's quite dangerous. Is it like, as dangerous as other – like, as having gas at the moment? Or is it going to be like, more dangerous because it's more flammable and the higher percentage we get up, is it going to get more dangerous?"*[17]

Safety concerns will arguably be even more important in fuel poor homes. Fuel poor homes may be more likely to have old and aging gas infrastructures (e.g., pipework runs), which may require considerable remedial work to be able to safely transport hydrogen and older, often more inefficient or unsafe heating systems.[18] The *risk of harm* may also be more acute in fuel poor homes; research has consistently shown that fuel poor homes are more likely to contain occupants with long-term health conditions or disabilities, and it will therefore be important that safety risks are minimised for people that might be at more risk if (e.g.) a fault causes supply to cease for a number of days after conversion. Finally, although it is the intention of industry that 'hydrogen ready' boilers[19] will increasingly replace natural gas boilers in homes over the next decade, fuel poor homes may be less likely to service and replace their boilers at the recommended times (e.g. at the end of their life expectancy), and may therefore require replacement appliances at the point of conversion. In addition, fuel poor homes may require further support with the maintenance and servicing of hydrogen appliances in the years following conversion to minimise possible risks and ensure they are functioning safely and effectively. Research by NEA for the Gas Safety Trust found that 'factors which cause or expose households to the risk of fuel poverty – low-income, poor-quality housing and the age and health of occupants – can impact on the heating and servicing behaviours of households to elevate CO risk in homes.'[20] While CO is not a risk with hydrogen, the same behaviours and fuel poverty related coping strategies could lead to safety concerns where households are unaware of the need or are unable to afford to service their hydrogen appliances.

It is worth noting that, in purely technical terms, the risks of using hydrogen will likely be broadly similar to the risks associated with natural gas use, and that there are even advantages of hydrogen, such as the elimination of carbon monoxide risk.[21] However, the highest safety standards must not only be proven (e.g. with oversight and approval from Ofgem and the Health and Safety Executive),

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[14] Scott, M. and Powells, G. (2020) Sensing hydrogen transitions in homes through social practices: cooking, heating, and the decomposition of demand, *International Journal of Hydrogen Energy* 45 (7): 3870-3882.
[15] Fylan, F; Fletcher, M. and Christmas, S. (2020) H21: Public perceptions of converting the gas network to hydrogen.
[16] Lambert, V. and Ashworth, P. (2018) The Australian public's perception of hydrogen for energy.
[17] Lambert, V. and Ashworth, P. (2018) The Australian public's perception of hydrogen for energy, p.33.
[18] NEA (2017) Understanding carbon monoxide risk in households vulnerable to fuel poverty.
[19] See for example British Gas (2022) Hydrogen boilers: everything you need to know.
[20] NEA (2017) Understanding carbon monoxide risk in households vulnerable to fuel poverty
[21] At the same time, the extent that hydrogen may emit harmful levels of NOx is currently disputed, with further evidence required. See Wright, M.L. and Lewis, A.C. (2022) Emissions of NOx from blending of hydrogen and natural gas in space heating boilers, *Elementa: Science of the Anthropocene* 10 (1): 00114.

but also demonstrated to the wider public, so that they can have confidence in hydrogen if their existing natural gas systems are converted to use it.

3. Cost

Low income is one of the core drivers of fuel poverty, along with high fuel costs and poor energy efficiency of homes. NEA considers that any future conversion to hydrogen must be free at the point of access for fuel poor homes (i.e. not involve any capital expenditure, installation costs, new appliance costs, or ancillary costs). Just as importantly, NEA considers that one of the key challenges facing hydrogen is the possible unit cost of hydrogen for households.

Consumer research has consistently highlighted that cost is a key issue facing hydrogen. Research by Leeds Beckett University has demonstrated that consumers would be concerned about the dual costs of energy bill increases and appliance replacements if they were converted to hydrogen, and this research also highlighted that consumers in the 'able to pay' bracket were concerned about the detrimental impact of increased costs on fuel poor, vulnerable, and older consumers.[22] Furthermore, research undertaken by Newcastle University found that any increased cost would be a significant barrier to consumers' willingness to take part in a blended hydrogen trial.[23] This research found that 41.2% of a nationally representative sample valued hydrogen but were not willing or able to pay more for it, and that 43.7% of respondents agreed with the statement 'I fear that hydrogen would be too expensive', compared to 13.3% that disagreed.[24] Internationally, a small amount of academic research has also shown that there is a very limited willingness to pay more for different hydrogen technologies (e.g. hydrogen buses) among national publics.[25]

Research and analysis by industry has also drawn attention to the possible costs of hydrogen, both in terms of the system costs of transitioning the energy system to incorporate hydrogen as a heating fuel, and in terms of the possible unit cost of hydrogen to the home. In its section on home heating, a recent report by Cadent has noted that "whilst no-one knows what hydrogen will cost when it is deployed, it is reasonable to believe that it will be more expensive than fossil gas today."[26] The report later states that, although the installation of a hydrogen boiler is expected to cost roughly the same as the installation of a natural gas boiler, "the cost of the hydrogen fuel itself is expected to be higher and, like renewable electricity, will require subsidy to protect the customer as production scales enabling prices to fall."[27]

It is possible that as processes of hydrogen production and distribution are scaled and refined, these predicted costs will reduce. However, modelling analyses of the future energy system tend to point to the system costs of converting the gas network to hydrogen, especially when compared with alternative scenarios such as high market penetration of heat pumps.[28] This is important because if

[22] Fylan, F; Fletcher, M. and Christmas, S. (2020) H21: Public perceptions of converting the gas network to hydrogen.
[23] Scott, M. and Powells, G. (2019) Blended Hydrogen: The UK Public's Perspective.
[24] Scott, M. and Powells, G. (2019) Blended Hydrogen: The UK Public's Perspective.
[25] See the summaries of research and references on willingness to pay for hydrogen in Scott, M. and Powells, G. (2020) Sensing hydrogen transitions in homes through social practices: cooking, heating, and the decomposition of demand, *International Journal of Hydrogen Energy* 45 (7): 3870-3882 and in Scott M. and Powells, G. (2020) Towards a new social science research agenda for hydrogen transitions: Social practices, energy justice, and place attachment, *Energy Research and Social Sciences* 61: 101346.
[26] Cadent (2021) Our Green Print: Future Heat for Everyone, p.19.
[27] Cadent (2021) Our Green Print: Future Heat for Everyone, p.26.
[28] See for example IICT (2020) Hydrogen for heating? Decarbonization options for households in the United Kingdom to 2050.

there are any additional costs of using hydrogen, regardless of when it is deployed, they will feed through into increased (or deepened) levels of fuel poverty, either through increases in energy bills through the wholesale cost of hydrogen or through higher mutualised levies to pay for the costs of converting the network in its entirety. A key consideration for policymakers, industry, and academia is therefore to work with consumer groups to assess how the costs and benefits of hydrogen might (or might not) be fairly and equitably distributed across society, and determine the distributional impacts of a transition to hydrogen both generally, and on fuel poverty. The minimum expectation in this regard should be that the transition to hydrogen does not result in additional running costs for fuel poor households, which could be achieved through a combination of progressive funding models, innovative tariff structures, and the broader rollout of energy efficiency measures and standards.

4. Fuel poor schemes

Across the UK, there are currently several government and industry funded schemes that directly aim to address fuel poverty. NEA considers that any transition to hydrogen will need to be accompanied by a parallel transition in support for fuel poor households. Moreover, NEA considers that one of the largest opportunities of hydrogen is in the devising of a transition and conversion model that will link in with broader energy-related and fuel poverty support. This will require moving a step beyond the current government focus on consumer protection and exploring possible mechanisms through which fuel poor homes can be identified and provided with the necessary support throughout the process of their hydrogen conversion. This could take place in a minimum of three ways.

Firstly, a delivery model could be devised that offers additional services to homes identified as fuel poor to ensure that converting their gas supply decarbonises their heating and tackles fuel poverty simultaneously. Such an approach, for example, could focus on identifying homes that have an EPC rating of D or below early in their engagement process and facilitating the upgrading of insulation alongside their conversion, either through links to relevant energy efficiency programmes that are in place at the point of hydrogen conversion (e.g. future iterations of the Energy Company Obligation, the main energy efficiency programme operating across England, Wales, and Scotland ECO, the Social Housing Decarbonisation Fund, or the Home Upgrade Grant), or through a bespoke mechanism built into the hydrogen conversion delivery model. Where appropriate, the hydrogen transition delivery model could also include provision for detailed energy-related advice and support (e.g. income maximisation services, tariff switching support, energy efficiency advice, etc.) before, during, or after their conversion takes place. In such an approach, hydrogen conversion would take place as one part of a wider ‘whole house’ decarbonisation and fuel poverty alleviation model, with commensurate funding and involvement from key actors at local government, housing association, third sector, and industry levels.

Secondly and at a minimum, customer engagement processes surrounding hydrogen conversions (e.g. doorknocking, community events, information campaigns) should be equipped and have mechanisms for conveying information about relevant support schemes (and their accreditation and official endorsements) and, where necessary, providing direct referrals into relevant support schemes. This could include referrals to relevant energy efficiency programmes (as listed in the previous paragraph), and to any local, regional, or national fuel poverty support schemes (e.g. local authority single point of contact health and housing services, energy advice organisations). All actors involved in promoting and engaging with the public on hydrogen conversions should have the necessary training to be able to identify vulnerable people and make referrals into these schemes as necessary, including resident liaison officers and gas engineers.

Thirdly, one area that requires more explanation is the future of fuel poverty support delivered directly through the gas networks. At present, the Fuel Poor Network Extension Scheme (FPNES) is delivered by gas networks to connect fuel poor households to the gas network, often in tandem with funding from ECO or alternative sources to install first time central heating systems. The benefits of this scheme for fuel poor households over recent years has been demonstrated by NEA,[29] however the requirement to phase out the burning of fossil fuels in homes places a question mark over the future of FPNES. It also poses difficult questions about the role of Gas Distribution Networks delivering fuel poverty support in the future if a decision over the gas network is not due until 2026 and conversion does not begin until the early 2030s. Either way, NEA believes that consideration needs to be given to how funding currently delivered through FPNES is maintained and, looking further forward, how the fuel poverty support programmes of the future can be designed if a hydrogen conversion is designed to take place in the 2030s.

5. Communication and engagement

Hydrogen conversion will require an information campaign and public engagement of the kind not seen since the transition from 'town gas' to natural gas in the 1980s.[30] Previous research on public perceptions of hydrogen has demonstrated that knowledge and awareness of hydrogen among the UK population is consistently low. For example, research undertaken for the CCC in 2018 found that just over half (51%) of survey respondents had never heard of hydrogen fuel boilers,[31] and in survey research undertaken by Newcastle University, 64.4% of respondents answered only one or none of three knowledge questions on hydrogen correctly, suggesting that a majority of respondents "felt that they did not know enough about hydrogen to give an opinion on whether or not it should be accepted as a fuel for UK homes."[32] International research also suggests that segments of the population more likely to know about the potential of hydrogen as a heating technology tend to be those working in the trade (e.g. heating engineers) and those with backgrounds in STEM subjects.[33] It is therefore clear that any conversion to hydrogen will require a concerted effort at the local, regional, and national levels.

This is important because there is little evidence that public information campaigns effectively engage with fuel poor households. Instead, research tends to show that advice on energy needs to be provided by trusted, independent, often local actors in a range of different spaces and places; face-to-face inside the home, at community events, and through different mediums (e.g. radio, local newspapers).[34] This is particularly the case for households that are typically excluded from beneficially accessing the energy market due to the intersection of the structure and design of the market with their personal and household characteristics. For example, research has shown that

[29] NEA (2021) Working in partnership to influence the continuation of the Fuel Poor Network Extension Scheme: A Briefing for the GB GDNs prepared by National Energy Action.
[30] Arapostathis, S; Laczay, S. and Pearson, P.J.G. (2019) Steering the 'C-Day': Insights from the rapid, planned transition of the UK's natural gas conversion programme, *Environmental Innovations and Societal Transitions* 31: 122-139.
[31] Madano and Element Energy (2018) Public acceptability of hydrogen in the home, p.8.
[32] Scott, M. and Powells, G. (2019) Blended Hydrogen: The UK Public's Perspective, p.2.
[33] See for example Alanne, K. (2018) A survey of Finnish energy engineering students' knowledge and perception of hydrogen technology, *International Journal of Hydrogen Energy* 43 (22): 10205- 10214.
[34] NEA and Energy Action Scotland (2021) Fuel Poverty Monitor 2021, p.46-49.

digitally excluded households and other groups with specific communication needs and requirements will need engagement that is tailored, accessible, and trustworthy.[35]

Successful strategies for could encompass what could be termed 'multi-modal' communications, encompassing community events, doorknocking, postal, local radio, local media, and online as one strategy, as well as the involvement of trusted community partners to build trust with residents where necessary. Smart Energy GB, for example, worked with multiple community partners in their 'In Communities' programme.[36] Their strategy involved identifying key groups of vulnerable consumers that might face specific barriers to uptake or adoption of smart meters, and then funding and working with community organisations to reach the identified groups. Such an approach would require key actors in hydrogen conversions (e.g. Gas Distribution Networks, industry, government) to work closely with charities and groups that support consumers with specific needs (e.g. older people, visually impaired, sight impaired, those who speak English as an additional language) to ensure that all relevant information (e.g. customer information packs, options for participation) about the conversion is provided in a suitably accessible manner, such as through translations where appropriate. If this is not done, there is a risk that these consumers will be unwittingly excluded from processes of engagement, replicating the injustices and exclusions of the energy market as it exists presently and minimising the possibility that they will benefit from their conversion.

6. The 'customer journey'

Research by Citizens Advice and other organisations has highlighted the importance of the 'customer journey' for domestic heating transitions, including hydrogen. Citizens Advice highlight a range of challenges that may be associated with the customer journey to hydrogen conversion, spanning pre-installation, immediately prior to installation, installation itself (including the time spent off supply by the occupants of the home), and post-installation.[37] These challenges include the need to replace existing appliances with hydrogen compatible boilers, hobs, ovens, and gas fires; the possible need replace external pipework where necessary; the need for new meters to be developed and installed in parallel to conversion; and the development of new and universally accessible billing methodologies; and possible post-installation services that may be required, such as maintenance, repair, and servicing.

These challenges are important for all households but are vital to resolve for fuel poor and vulnerable homes. Without the upfront capital to convert these appliances, there is a definite risk of the poorest households forgoing the utility these products provide as a direct consequence of a decision (the move to hydrogen) that is likely to have been out of their own influence. In turn this could sour attitudes towards a hydrogen rollout and could make public acceptance far more challenging, especially when combined with reasonable safety concerns.

In response, NEA believes that the following additional parts of the customer journey will require further research and analysis in the coming years:

- **Time off supply**. Fuel poor and vulnerable households are often most at risk of coming to harm through exposure to cold temperatures in and outside of the home, and at present it is unclear how long people will be off supply while their hydrogen conversion takes place.

[35] See Chambers, J; Robinson, C. and Scott, M. (forthcoming) Digitalisation without detriment: A research agenda for digital inclusion in the future energy system, *People, Place and Policy*.
[36] Smart Energy GB (nd) Smart Energy GB In Communities.
[37] Citizens Advice (2020) Hydrogen for homes: Discussion paper with questions about how hydrogen might work for homes in Great Britain.

There is therefore a need to ensure that fuel poor and vulnerable homes have access to adequate energy services while their conversion is taking place, including heating, cooking, washing, and showering/bathing facilities that are suitable to their needs and do not cause unnecessary stress or detriment. Planning the temporary provision of these energy services within the wider customer journey and conversion process requires considerable research and development.

- **Social practices**. Social practices are defined as socially shared activities that are undertaken by people in society. They include, for example, activities such as smoking and running, as well as more essential daily activities such as commuting, doing laundry, and heating the home. Research has suggested that hydrogen conversions may cause disruption to deeply embedded social practices of heating and especially cooking, especially (e.g.) if flame speed and diameter or new home infrastructures are different to those which the occupants of the home were previously used to.[38] More work is needed, ideally alongside industry trials, to understand how 'gas energised' social practices of heating, cooking, and using hot water may change as a result of hydrogen conversions in the home, and how any changes that might be considered unnecessary or disruptive can be mediated and minimised through advice, support, and handholding throughout the conversion process.
- **Tenure**. The customer journey will inevitably be different for different homes depending on if they are owner occupier, or in the private or social rented sectors. Owner occupiers typically enjoy full autonomy over decisions relating to their home. However, in the social rented sector housing associations will be key actors in facilitating and shaping hydrogen conversions, and the respective roles and preferences of tenant and private landlord will need to be negotiated for hydrogen conversions to take place successfully in private rented sector homes.
- **Capital and ongoing revenue**. Research is needed to fully understand what the full upfront cost of converting homes to hydrogen and changing appliances will be, and this should include exploring any variances in running costs.[39] In addition, beyond upfront costs, it will be necessary to understand what variance in ongoing costs fuel poor homes might face due to their additional usage, given they disproportionately live in the least efficient homes, and highly variable costs associated with system charges for households compared to Gas Distribution Network Operator's roles in maintaining the existing methane distribution networks.

In conclusion, NEA believes that one of the key priorities for considering hydrogen as an alternative heating fuel should be how it can be harnessed to bring about wider societal benefits and how it can be an opportunity to improve the health and lives of fuel poor households. This will require moving a step beyond a necessary focus on consumer protection to explore possible ways that fuel poor and vulnerable households can be supported throughout the conversion period and indeed, the longer-term net zero transition period. This would require devising a delivery model that places fuel poverty and vulnerability at its core, and which can be further refined over time as hydrogen and other low- and zero-carbon technologies, and society's responses to them, advance.

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[38] Scott, M. and Powells, G. (2020) Sensing hydrogen transitions in homes through social practices: cooking, heating, and the decomposition of demand, *International Journal of Hydrogen Energy* 45 (7): 3870-3882.
[39] For example, a recent review suggests a possible £3,000-£4,000 cost of converting a property to 100% hydrogen, and also notes that limited evidence exists on maintenance cost. However, this review does not comment on possible variances in costs for fuel poor homes. See Castek, R. and Harkin, S. (2021) Evidence review for hydrogen for heat in buildings.

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