H21: Public perceptions of converting the gas network to hydrogen

Social Sciences Study

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RIIO NIC NETWORK INNOVATION COMPETITION

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01. Summary

The next decade will see fundamental changes in how people heat their homes. The global energy system is changing in response to the need to transition away from fossil-based generation towards more environmentally sustainable alternatives.

Hydrogen offers one such alternative, but currently there is limited understanding of public perceptions of hydrogen, the information that people need in order to make an informed choice about using hydrogen in their homes, and how misunderstandings could present barriers to the uptake of hydrogen technology. This is crucial to ensure the success of future policy and investment.

The H21 concept is to convert the UK gas distribution network to 100% hydrogen over time, thereby decarbonising heat and supporting decarbonisation of electric, large industrials and transport. This would be achieved using the existing UK gas grid network and technology available across the world today, whilst maintaining the benefits of gas and the gas networks in the energy mix for the long-term future. Additionally, this would maintain choice of energy for customers, i.e. they would be able to use both gas and electricity.

The H21 project is being delivered by the UK gas distribution networks Northern Gas Networks, Cadent, Wales & West Utilities and SGN. As part of the H21 project, Leeds Beckett University has been working with Northern Gas Networks to gain insight into public perceptions of hydrogen as a domestic fuel. Using innovative social science methods, the research team has explored, for the first time, public perceptions of moving the UK domestic fuel supply to 100% hydrogen. We identify what people think and feel about a potential conversion, the concerns and questions that they have, and how to address them clearly. The findings presented in this report will ensure that issues around the current perception of hydrogen are identified and addressed prior to any large-scale technology rollout.

The first stage of the project comprised a series of discovery interviews, which explored how to talk to people about hydrogen and the H21 project. We interviewed 12 participants, selected to ensure we included people with a range of experiences and domestic settings, for example people who live in urban and rural areas, those who live alone, those who live with children or a partner, those who live in their own home and those who rent. Most participants had given very little thought about where their gas and electric comes from and, other than switching supplier to get a better tariff, had very little interest in it. They had not previously considered their domestic heating as a source of carbon emissions and were surprised that there may be a need in the future to change their gas supply.

From the discovery interviews, we identified several key areas to explore in the next stage of the work.

- Beliefs about the environment
- Beliefs about inconvenience and cost
- Beliefs about safety
- Beliefs about the economic impact

↑ H21 is converting the existing UK gas network to 100% hydrogen.

An online survey was developed to evaluate attitudes and beliefs around a transition to a new gas in homes. A representative sample of over 1,000 respondents from across the UK completed the survey, enabling insight into attitudes towards a hydrogen conversion. From the data we identified five different response groupings, based on their support for an environmentally-driven change to their gas supply, and their level of support for using hydrogen in their homes.

20%

Group 1
Accepters

This group is positive about a change to their gas supply for environmental reasons and in favour of using hydrogen. People accept changes to their lives in order to reduce climate change and improve the environment, believing that climate change is a significant challenge that needs to be addressed. Effective messages for Group 1 are environmentally focused, with reassurances centred on cost and safety.

28%

Group 2
Cautious

This group is positive about a change to their gas supply but unsure about using hydrogen. They share similar attitudes to Group 1, but have less confidence in their own knowledge and understanding of climate change issues and this impacts their willingness to change. They are motivated by the environmental benefits of a hydrogen conversion but are more concerned about the likely disruption.

30%

Group 3
Disinterested

This group is unsure about a change to their gas supply and also unsure about using hydrogen. Despite believing in the importance of climate change, they are disinterested in a potential hydrogen conversion as they do not believe they understand the issue well enough. As a result, the most appealing messages for Group 3 are centred on safety, cost, and the local economy rather than environmental benefits.

10%

Group 4
Unconvinced

This group is concerned about a change to their gas supply and unsure about using hydrogen. They are concerned about climate change but lack confidence in their knowledge of the issues, which means they are unconvinced that a transition to hydrogen is the most appropriate response. They want to be reassured about cost.

12%

Group 5
Rejecters

This group hold mixed views about a change to their gas supply and are against using hydrogen. They do not accept the role of humans in climate change and are reluctant to make lifestyle changes to reduce their environmental impact. They reject the need for a hydrogen conversion and are sceptical about the need for a change. They need convincing that hydrogen is a novel, renewable energy technology and need reassurance about safety and cost.

↑ Safety testing to compare the risks of existing gas and 100% hydrogen.

The next stage of the research involved people in groups of 2-4, together with hydrogen experts, co-designing explanations of the potential hydrogen conversion. We held deliberative workshops in three locations: Leeds, Manchester and Birmingham. In each location eight members of the public (our participants) and three hydrogen experts attended two workshops, held two weeks apart. In the first we introduced the concept of a hydrogen conversion and facilitated discussion between the public and the experts. In between the two workshops, participants were given the task of interviewing a friend or family member about the conversion and sending us the audio recording of the interview. The same participants returned for the second workshop to discuss their experiences of conducting the interviews, the responses of their interviewees and to develop a set of explanations of the conversion.

We identified six themes that describe the questions and concerns that participants and their interviewees had, and how participants' views evolved from their first reaction to a more informed and reflective position.

Justifying a hydrogen conversion

Even though all our participants were in groups 2-4, and so were initially unsure about a hydrogen conversion, over the course of the two workshops they all came to the conclusion that hydrogen is an option that needs serious consideration, and promoted its benefits to others. A few were sceptical about the impact of a UK hydrogen conversion to global carbon emissions and believed that there is little point in the UK converting to hydrogen if other countries are not going to do so. Others, however, were enthused by the UK leading the world in hydrogen technologies. Participants were not engaged by explanations based on meeting government targets and instead highlighted personal responsibilities and consequences.

Where does hydrogen comes from?

Participants wanted to know where hydrogen comes from and how it is produced. They were able to grasp complex technical information about the hydrogen conversion that they can convey to others in a simple and easy-to-understand way. Few were aware of different methods of producing hydrogen and most accepted that in the short term the process of producing hydrogen would involve carbon being captured and stored, although several had concerns about whether carbon dioxide can be stored securely. A few questioned whether enough research resources were being dedicated to finding a sustainable method of producing hydrogen but most tolerated the uncertainty about when technology will be sufficiently advanced to produce hydrogen at scale using renewable technologies.

↑ Exploring public perceptions of using hydrogen in the home.

Cost

Our participants were relatively unconcerned about the estimated 7% by which their gas bill will increase should a conversion go ahead, although they were concerned that other more vulnerable people might struggle. When explaining the conversion to others, they highlighted the potential cost of not taking action. In contrast, they were concerned about the need to purchase new appliances and wanted reassurance that there would be an incentive scheme to help with the cost.

Safety

Safety was not a major concern for our participants: they assume that if their supply is converted to hydrogen then it will have been robustly tested and found to be safe. Indeed, they appreciate the safety benefit that hydrogen carries no risk of carbon monoxide poisoning. There were more concerns about how securely carbon dioxide is stored than the safety of hydrogen in their home.

Practicalities

Participants queried whether they would be able to choose to remain on a natural gas supply and some were surprised when they found out that their only choice was to switch to hydrogen or rely solely on electricity. They had questions about what they would need to do to prepare for a conversion but most assumed the impact would be minimal. They had questions about whether there would be any disruption from roads being dug up to replace pipes, how long the process would take, whether they would notice any difference in how their appliances work, and how they would find out about the conversion. Nobody asked how long their gas might be disconnected for, instead assuming that it would be hours rather than days.

Timing and certainty

There were concerns about whether a decision will be made about the conversion quickly enough to prevent irreversible environmental damage arising from climate change, and also that people would be given sufficient notice so that they can avoid purchasing expensive appliances that soon become obsolete.

Results

Our results show that with clear information, even people in these indifferent groups make an informed choice to accept a potential conversion. They are able to grasp complex technical information about the hydrogen conversion which they can convey to others in a simple and easy-to-understand way. Some remain sceptical about the contribution a UK hydrogen conversion can make to global carbon emissions, although others are enthused by the UK taking a leading role in developing hydrogen technologies.

People assume that if their supply is converted to hydrogen then it will have been robustly tested and found to be safe. Indeed, they appreciate the safety benefit that hydrogen carries no risk of carbon monoxide poisoning. There were more concerns about the safety of stored carbon dioxide than the safety of hydrogen in the home. People accept that their gas bill is likely to rise, and find the anticipated 7% acceptable but they are concerned about the cost of purchasing new appliances.

Our participants wanted a decision about a hydrogen conversion to be made and acted upon quickly, and if it is to go ahead, to receive sufficient notice so that they can avoid purchasing expensive appliances that soon become obsolete. We found that to encourage engagement with the issues it is important to help people understand key concepts such as carbon capture and storage, and with this understanding, they are able to tolerate the current uncertainties over the timescale of a conversion and how hydrogen will be produced. The results highlight the need to develop a suite of communication resources for the general public.

02. Background

The next decade will see fundamental changes in how people heat their homes. The UK Climate Change Act requires the Government to reduce greenhouse gas emissions by 100% of 1990 levels (net zero) by 2050. As domestic heating is a major source of greenhouse emissions (BEIS, 2018), there is a need to agree and implement a strategy that will remove or significantly reduce carbon emissions from domestic heating. Three strategies have been identified: increasing the energy efficiency of people's homes; changing to renewable electricity as a heating source; and converting the domestic gas supply from natural gas to hydrogen.

Programmes to increase the energy efficiency of dwellings have been underway for some time, and typically lead to a smaller-than-anticipated decrease in energy use and therefore carbon saving (Mallaburn, 2016). Whilst energy demand reduction policies have a role in meeting the requirement of the Climate Change Act, they cannot form the core strategy. Electrification of heating offers one potential solution to grid decarbonisation, with electrical supply coming from renewable sources, but there are challenges around grid capacity particularly during peak demand in winter.

An alternative to the electrification of heating is to convert the gas used for heating in homes from natural gas (methane) to hydrogen. The H21 concept is to convert the exisiting UK gas distribution network to 100% hydrogen over time, thereby decarbonising heat and supporting decarbonisation of electric, large industrials and transport. This would be achieved using the existing UK gas grid network and technology available across the world today, whilst maintaining the benefits of gas and the gas networks in the energy mix for the long-term future. Additionally, this would maintain choice of energy for customers, i.e. they would be able to use both gas and electricity.

Converting the gas supply to hydrogen also presents challenges, including generating sufficient volume of hydrogen from electrolysis, or capturing and storing the carbon released when hydrogen is produced from methane. However, the challenges of converting to hydrogen have been explored and addressed in the H21 North of England Report (2018), which proposes a nationwide conversion programme, starting in the North of England, based on:

- Converting 3.7 million meter points, which represents 17% of UK domestic meter connections;
- A 12.15GW natural gas-based hydrogen production facility delivering low carbon heat for Tyneside, Teesside, York, Hull, West Yorkshire, Manchester and Liverpool;
- Providing 8TW of inter-seasonal hydrogen storage;
- A 125 GW capacity hydrogen transmission system;
- CO_2 transport and storage infrastructure with the capacity to sequester 20Mtpa of CO_2 by 2035.

Safety tests are being carried out on the network assets as well as domestic appliances within homes. An experimental testing programme is comparing risks from a 100% hydrogen network and the existing natural gas network. Background leakage testing at the Health and Safety Executive's laboratories at Buxton consists of controlled testing of gas assets in use on the network today when used with both natural gas and 100% hydrogen. This will provide evidence for changes to background leakage levels in a 100% hydrogen network. Consequence testing at DNV GL's Spadeadam test site compares the risks from leaking hydrogen with those from leaking natural gas. Alongside this, other organisations are currently conducting tests to ensure that it is feasible to produce and store enough hydrogen, and that that the carbon can be captured and stored securely.

As well as understanding the technical and safety elements of a conversion, it's also important to explore how consumers will react to a switch to hydrogen and to understand their information needs. This will ensure that the gas distribution networks produce information that is easy to understand, relevant to the public's needs, addresses the questions and concerns that they have, and enables them to make an informed choice about whether to convert to hydrogen, or to use only electricity for their domestic energy supply.

There is some existing work on public perceptions of hydrogen as a domestic fuel. For example, Williams et al. (2018) explored people's perceptions of changing their domestic fuel source to either hydrogen or a ground source heat pump. They found that while most people were aware of the importance of reducing carbon emissions, they did not understand that this means that they may need to change their current energy supply. They had little knowledge of low-carbon energy options, and low-carbon energy is not a topic that readily engages them. Instead, their perceptions and preferences are driven by the need to minimise perceived disruption or expense. They objected to replacing their domestic appliances and to having their supply turned off during the two-week conversion process.

Scott and Powells (2019) explored public perceptions of using blended hydrogen as a domestic fuel. This work formed part of the HyDeploy project, in which Keele University (which has a private gas supply) received a blend of hydrogen (20%) and natural gas (80%). They found that public awareness of hydrogen as a domestic fuel is low, and that people do not have strong opinions about its use. Their support tends to increase once they are more aware of the potential positive environmental impacts. However, cost is a barrier, both in terms of an increase in the cost of their bills, and the cost of replacing domestic appliances. Safety concerns are also important to address although there is currently limited understanding of people's safety concerns about using hydrogen in their home.

This social sciences research explores, for the first time, public perceptions of changing the UK domestic fuel supply to 100% hydrogen. We identify what people think and feel about a potential conversion, the concerns and questions that they have, and how to clearly address them.

↑ Co-designing explanations of a hydrogen conversion.

03. Population profile of attitudes to hydrogen

3.1 Summary

This stage of the research explores the attitudes that the public has towards a potential conversion of their domestic gas supply to hydrogen.

We first conducted a series of discovery interviews to explore how to talk to people about hydrogen, and to establish the range of topics that might underpin their response to a potential hydrogen conversion. We identified several key areas to explore: the environment; inconvenience and cost; safety; and economic impact.

An online survey was developed to explore the key areas identified in the discovery interviews and over 1,000 respondents from across the UK participated. We identified five subgroups within the population, based on their attitudes towards the environment and their willingness to accept a potential change in their gas supply to hydrogen.

Group 1: Accepters (20%), accept changes to their lives that have the potential to reduce climate change and improve the environment.

Group 2: Cautious (28%), motivated by climate change but less confident in their knowledge and understanding of climate change issues.

Group 3: Disinterested (30%), disinterested in the hydrogen transition.

Group 4: Unconvinced (10%), unconvinced that a transition to hydrogen is the most appropriate response because they do not have sufficient knowledge of the issues.

Group 5: Rejecters (12%), sceptical of the role of humans in climate change and of the motivations for a hydrogen transition and reluctant to make life changes to improve the environmental.

There was broad agreement that investing in technology to support environmental wellbeing was a priority: **Messages that highlight the environmental benefits of hydrogen are well received.**

There was scepticism amongst all groups around the motivations behind environmental action and the transition to hydrogen: **It is important to be clear on motivations and benefits.**

↑ Exploring a hydrogen conversion in depth.

3.2 Methods

We used a two-stage process to identify the attitudes that the public have towards a potential conversion of their domestic gas supply to hydrogen. The first stage comprised a series of discovery interviews, which explored how to talk to people about hydrogen and the H21 project and the things that are likely to interest and concern them. This stage forms the foundation of the research and ensures that later stages explore areas that are relevant to the public and likely to differentiate their responses, rather than focusing only on those areas of interest to the researchers. The interviews covered:

- current and previous use of gas in the home
- how and why energy is valued
- thoughts on where gas and electricity come from
- imagined responses to a scenario of the current gas supply ceasing, and being replaced with an unspecified "new gas"
- and at the end of the interview, their response to this "new gas" being hydrogen

We interviewed 12 participants, selected to ensure we included people with a range of experiences and domestic settings, for example people who live in urban and rural areas, those who live alone, those who live with children or a partner, those who live in their own home and those who rent. A few had additional heating sources such as electric heaters. One had solar panels. None were aware of hydrogen as a domestic fuel, although a few had heard of hydrogen fuel cells used in vehicles. Participants were based in three different locations: Leeds, Monmouthshire, and Birmingham. These areas were selected because they encompass areas likely to be the first to be converted, should a conversion take place, areas likely to be converted later in the programme, and also cities, towns and villages.

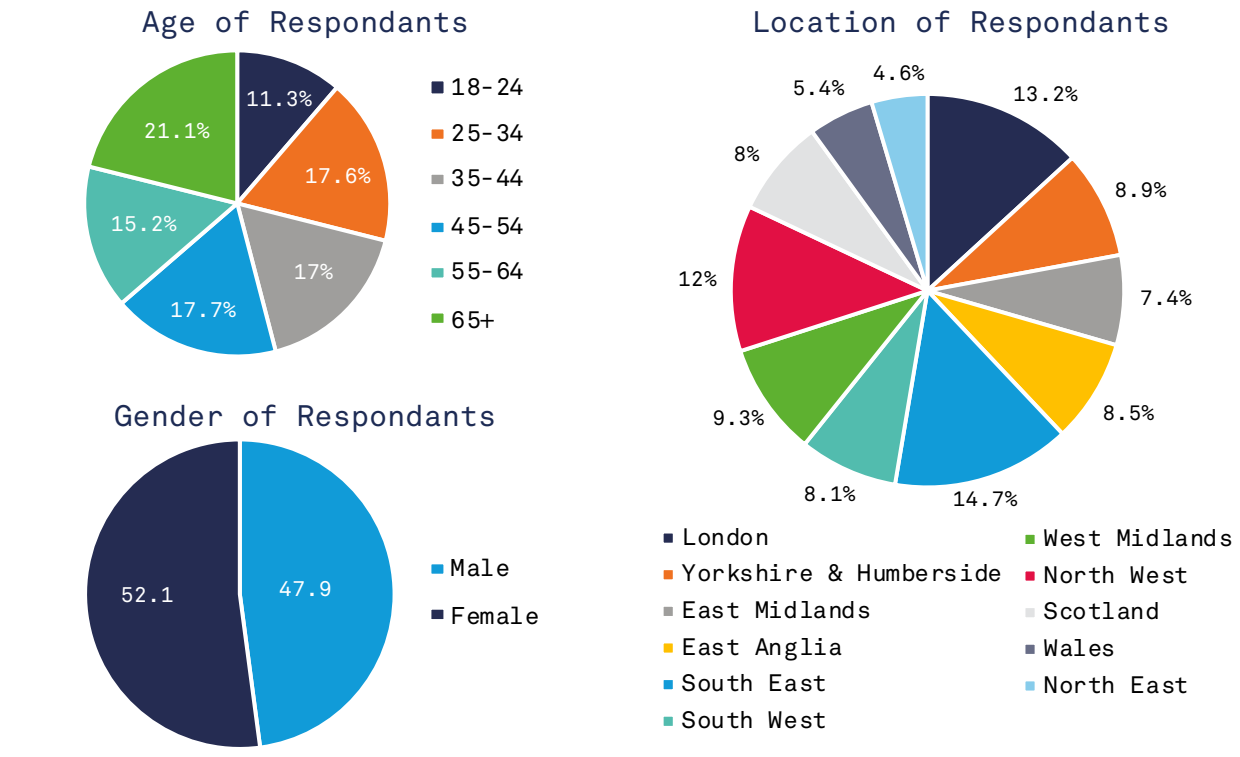
We analysed the interviews by listening and re-listening to the audio files, summarising the interviews and noting the points that might differentiate people's response to a hydrogen conversion. The results were used to inform the second stage of the project.

The second stage aimed to engage with a larger population sample and to gain more detailed insights. An online survey was developed to identify attitudes to a hydrogen conversion, and how these align with energy-related attitudes and behaviours. The survey questions were informed by the findings of the iscovery Interviews.

Data were analysed to identify a meaningful classification system that groups people based on their support for an environmentally driven change to their gas supply, and their level of support for using hydrogen in their homes. Adopting a segmentation approach such as this is useful for defining groups that have a higher propensity for behaviour change (Stanford, 2014) and enables persuasive communication to be developed, tailored towards group attitudes.

Over 1,000 respondents (n=1027), representative of the UK population in terms of age, gender and geographic location completed the survey. Respondents were recruited by a fieldwork panel agency. Demographic details of the sample are shown in Figure 1.

Figure 1: Survey sample characteristics



RESULTS

3.3 Talking to people about hydrogen

Our results from the discovery interviews showed that most participants had given very little thought about where their gas and electricity comes from, and had very little interest in it, although a few were concerned about fracking. Other than switching supplier to get a better tariff, their domestic energy supply is simply something that is there at the flick of a switch or the turn of a knob and is not something that they think about. They had not previously considered their domestic heating as a source of carbon emissions and were surprised that there may be a need to change their gas supply in the future. They had very little concern about safety of either their current supply or a future hydrogen supply. They were more concerned about getting enough notice of a future change so that they don't buy new appliances that soon become obsolete.

Following the discovery interviews, we identified several points of difference in our participants' responses which were taken forward into the next stage of the work.

↑ Hydrogen experts and the public working together to explore perceptions.

These points are summarised below.

→ Beliefs about the environment

People's beliefs about the environment, and the actions they currently take to be more environmentally friendly, are likely to influence their response to a hydrogen conversion. Greater understanding of these beliefs was therefore identified as an area to explore in the survey, with a focus on gathering data on hydrogen-specific environmental beliefs such as how hydrogen may contribute to reducing climate change and the benefits of using a non-fossil fuel in the home.

→ Beliefs about inconvenience and cost

People's beliefs about the inconvenience and cost of changing the gas network, and of changing their appliances are also likely to influence their response. We identified a need to explore their beliefs about the economic and social impact of a potential conversion on a personal level, encompassing issues such as changes to infrastructure, home appliances and day-to-day lifestyle behaviours.

→ Beliefs about safety

There was consensus amongst the Discovery Interview participants that if hydrogen is piped into their home it will be safe to use. This suggests that concerns about safety are less likely to differentiate how people respond to a hydrogen conversion. Nevertheless, it is important to include questions on perceptions of how safe hydrogen is compared with natural gas and to identify any sub-groups for whom safety is a major concern.

→ Beliefs about the economic impact

Beyond concerns around personal cost and inconvenience, participants displayed wider beliefs around the economic impact of a change in gas supply and how it may affect national priorities such as health and welfare. It is therefore important to explore beliefs around economic changes at a national level.

3.4 Population subgroups

Having established an initial understanding of how people may respond to a hydrogen conversion, the next stage aimed to engage with a larger population sample to gain more detailed insights. An online survey, informed by the finding of the discovery interviews, explored:

- General views and attitudes towards the environment
  - Environmental behaviours
  - Views on climate change
  - Awareness of domestic fuel sources
- Current gas usage and thoughts on gas supply
  - Current gas usage at home
  - Beliefs about greener energy
  - Preferences for gas versus electricity
- Reactions to a potential change to the gas supply
  - Reactions to the type of gas changing
  - Reactions to switching to hydrogen
  - Key concerns and most appealing messages

Survey respondents were told that a variety of different types of energy are being considered with the aim of reducing our use of environmentally damaging fuels in the future. They were asked to imagine that they received the following information about their gas supply.

- In the near future, the type of gas that is supplied to your home may be changed. This new type of gas is not from fracking; it is a new type of gas entirely.
- The replacement gas will be better for the environment because it will significantly reduce the amount of carbon that is released into the atmosphere.
- If the change goes ahead, it will apply to everyone across the UK, regardless of your energy supplier.
- The government will make a decision on this in the next 5-10 years.

Subgroups were formed by examining responses to two questions (see below), which gave 49 possible combinations of responses. We defined our population subgroups by identifying combinations with similar responses to the survey questions, as opposed to a priori clustering based on theoretical assumptions. This produced five different groups, shown in Figure 2.

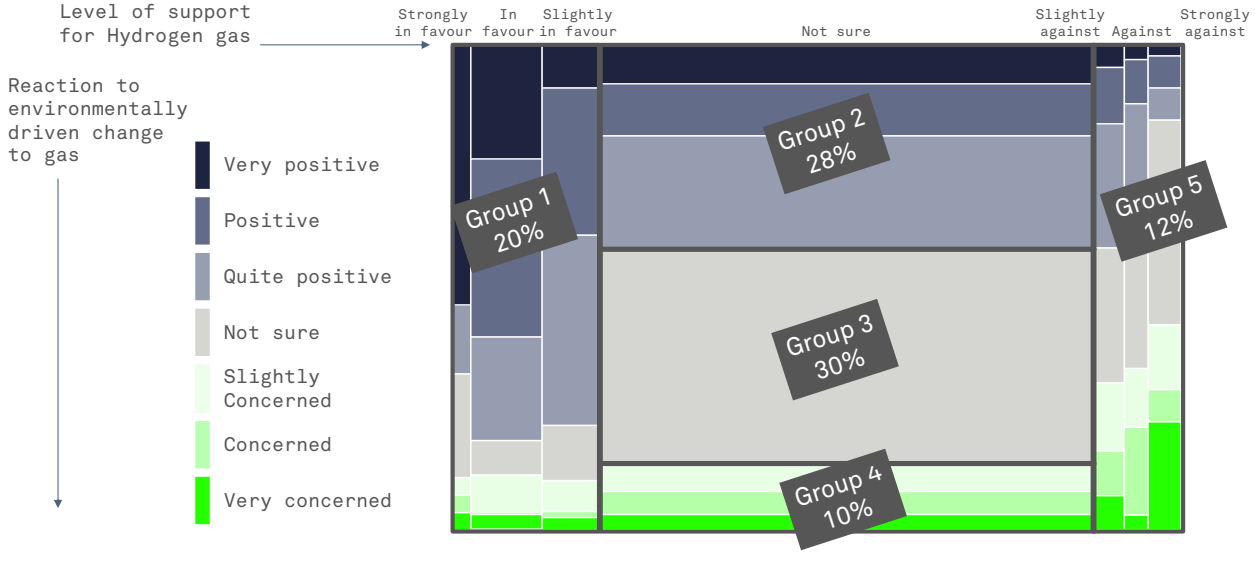
What are your feelings towards the potential change to the type of gas supplied to your home? (Q13)

Very concerned	Concerned	Slightly concerned	Not sure how I feel	Quite positive	Positive	Very positive

How do you feel about using hydrogen to run your heating/cooking? (Q19)

Strongly Against	Against	Slightly Against	Not sure how I feel	Slightly in favour	In favour	Strongly in favour

Figure 2: The percentage of the sample in each group.



The attitudes, beliefs and philosophical outlook of people in each group are described below, and their responses to the survey questions on climate change are shown in Figure 3.

↑ Safety testing assets.

→ Group 1: Accepters

Group 1 is positive about a change to their gas supply for environmental reasons and in favour of using hydrogen. They accept changes to their lives that have the potential to reduce climate change and improve the environment. There was a clear belief that climate change is a significant challenge that needs to be addressed, and this was underpinned by a confidence in their own knowledge and understanding of the issue. They regarded the hydrogen transition as an opportunity for future economic benefits to the UK that may arise from taking a leading role in hydrogen technology. Messages that drew most support were environmentally focused, with reassurances centred on cost and safety.

→ "I think it's important to embrace change especially in relation to the environment and helping to reduce one's carbon foot print"

Most appealing benefit messages	Reassurances required
1. Hydrogen is a renewable energy source, unlike natural gas	1. My bills would not be more expensive
2. Hydrogen is a sustainable energy source, unlike natural gas	2. Hydrogen is 100% as safe as the current gas
3. Hydrogen is cleaner than natural gas	3. My boiler can be converted easily

→ Group 2: Cautious

Group 2 is positive about a change to their gas supply but unsure about using hydrogen. They are motivated by climate change, with messages around the environmental benefits of the hydrogen transition being the most appealing. Unlike group 1, however, group 2 had less confidence in their own knowledge and understanding of climate change issues. They shared many of the same philosophical beliefs as group 1, with cost and safety the main assurance priority, but there was also a wider concern around the likely disruption caused by transition. This suggests group 2 may adopt a more cautious approach, requiring additional assurances and being less willing to embrace a transition to hydrogen.

→ "If it helps the environment it's a great thing although would need to know if it would affect my hob and boiler"

Most appealing benefit messages	Reassurances required
1. Hydrogen is a renewable energy source, unlike natural gas	1. My bills would not be more expensive
2. Hydrogen is safer for you, with no risk of carbon monoxide poisoning	2. Hydrogen is 100% as safe as the current gas
3. Hydrogen is a more environmentally friendly gas to use	3. My boiler would not need to be replaced

→ Group 3: Disinterested

This group is characterised by their disinterest in the hydrogen transition. Whilst believing in the importance of climate change and the need to take action to mitigate it, they did not think they understand the issue well enough to take a position either for or against hydrogen. As a result, the most appealing messages in support of hydrogen were centred on safety and cost rather than environmental benefits, which aligns more with generic everyday concerns than with energy infrastructure specifically. This disinterest suggests that messages directed towards group three will need to include a wider range of topics and be conscious that many people are not motivated by climate action or the specific benefits that hydrogen has over other sustainable alternatives.

→ "Could be a good change, change for better. But it's just uncertain at the moment. Won't know until it happens"

Most appealing benefit messages

1. Hydrogen is safer for you, with no risk of carbon monoxide poisoning
2. Hydrogen gas will be produced locally in the UK
3. Hydrogen is cleaner than the natural gas

Reassurances required

1. My bills would not be more expensive
2. Hydrogen is 100% as safe as the current gas.
3. I would not have to pay anything towards the changeover process

→ Group 4: Unconvinced

This group is concerned about a change to their gas supply and unsure about using hydrogen. While they accept the significance of climate change they are unconvinced that a transition to hydrogen is the most appropriate response because they do not have sufficient knowledge of the issues. This led to a broad range of appealing messages, encompassing environmental, safety and economic benefits. Reassurances about cost were the most important. The clear belief that climate change is a concern suggests that lack of knowledge about the environmental benefits of hydrogen, rather than indifference to climate change, are why positive environmental benefits are less impactful for group 4.

→ "I would want to know what this gas was, how it was better for the environment, where it came from, how long it would last, how much it would cost getting into all UK households."

Most appealing benefit messages

1. Hydrogen gas will be produced locally in the UK
2. Hydrogen is cleaner than the natural gas
3. Hydrogen is safer for you, with no risk of carbon monoxide poisoning

Reassurances required

1. My bills would not be more expensive
2. I would not have to pay anything towards the changeover process
3. My boiler would not need to be replaced

→ Group 5: Rejecters

This group is characterised by their rejection of the transition to hydrogen, with greater scepticism about the motivations for change. There was less willingness to accept the role of humans in climate change, and this supported a reluctance to make changes that would reduce negative environmental impacts. The most appealing messages for group 5 were about safety, and that hydrogen is a novel, renewable energy technology. The most important reassurances were about cost and safety, suggesting there would be little support from group 5 if there were perceived negative effects to themselves.

→ "Whenever they change type or style of supply, there IS ALWAYS a price increase AND they make more profit."

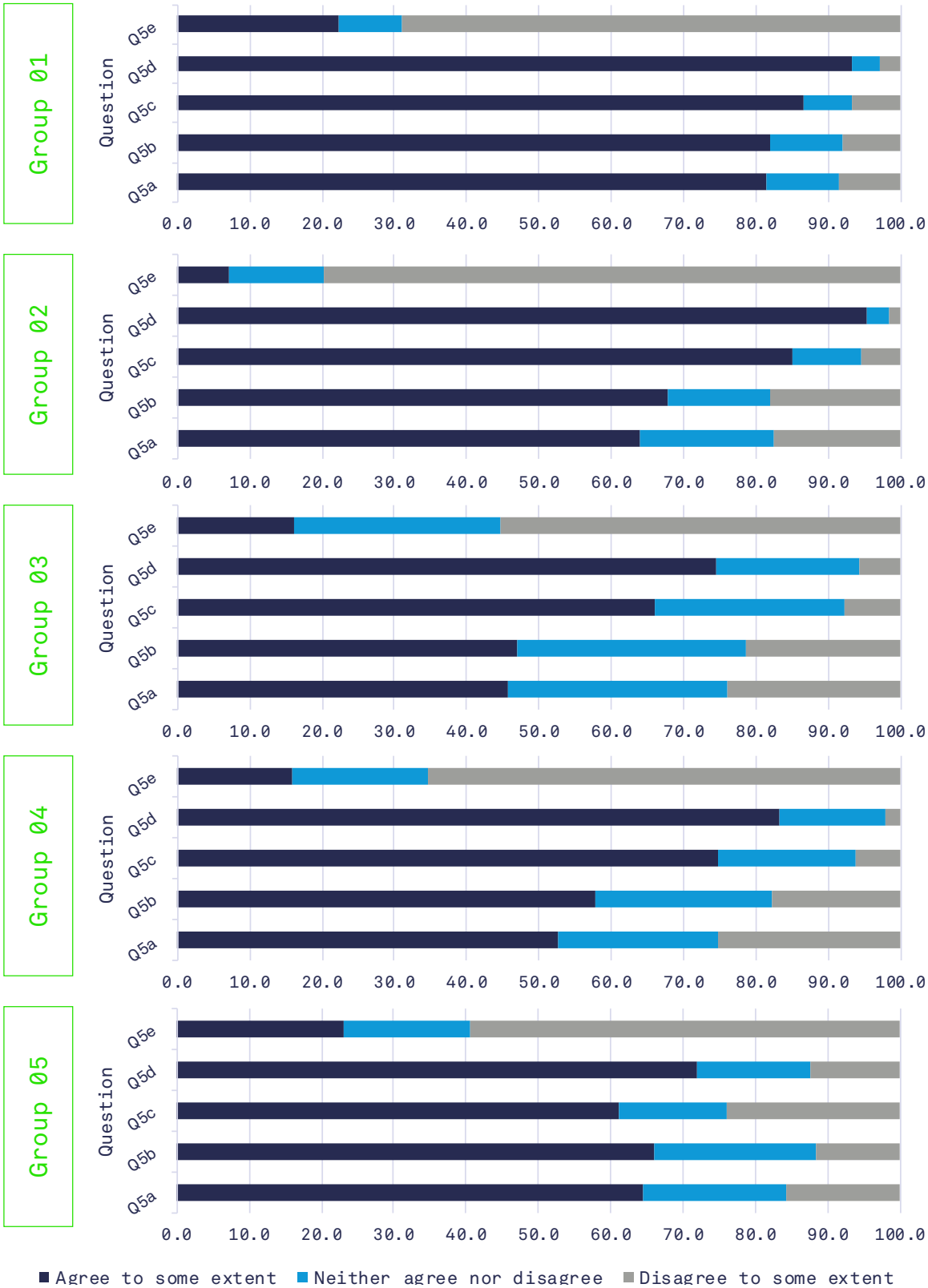
Most appealing benefit messages

1. Burning hydrogen gas produces only water, nothing else, just water
2. Hydrogen is a renewable energy source, unlike natural gas
3. Natural gas is a fossil fuel, hydrogen gas is not

Reassurances required

1. My bills would not be more expensive
2. Hydrogen is 100% as safe as the current gas
3. I would not have to pay anything towards the changeover process

Figure 3: Attitudes towards climate change held by different groups.



Q5e	I do not believe that long term climate change is actually happening
Q5d	Climate change is an extremely important issue for the planet
Q5c	Human activity is the main cause of climate change at this time
Q5b	I feel well informed about the things that can be done to help with climate change
Q5a	I feel well informed about the causes of climate change

Group perspectives

Having established the profiles of the individual groups, the next stage of the research was to examine similarities and differences between the groups. This aims to identify messages that have the potential to be effective in influencing multiple groups. Identifying differences also provides an indication of which messages may be ineffective for certain groups.

Most respondents in all five groups agreed that investing in low carbon energy technologies is a key part of investing in the environmental wellbeing of the earth (Figure 4) and that investing in the environmental wellbeing of the earth should be a top government priority (Figure 5). Groups 1 and 2 are more supportive, with group 3 less likely to have an opinion. This suggests that messages around hydrogen that highlight the potential for environmental benefits may resonate within all groups, regardless of scepticism on specific aspects. This does, however, present a challenge in framing the message to differentiate hydrogen from other renewable technologies which share the same environmental benefits.

Figure 4: Beliefs that low carbon energy technologies are important for the environmental wellbeing of the earth.

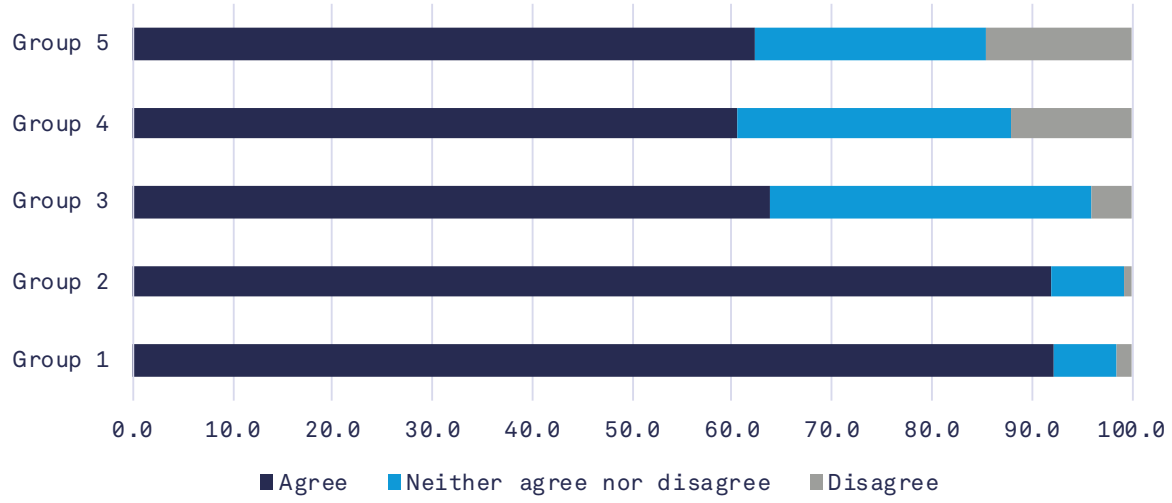
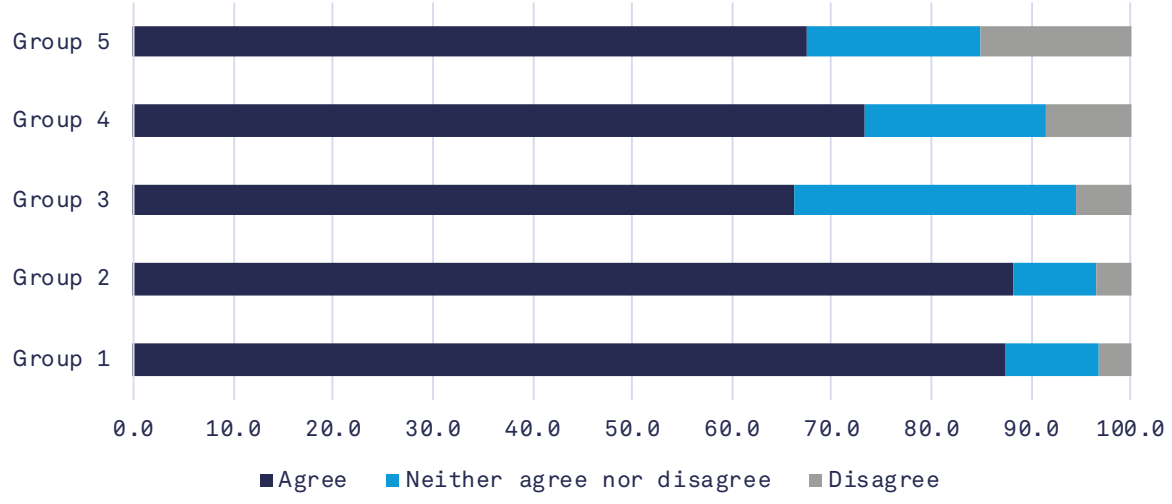


Figure 5: Beliefs that investing in the environmental wellbeing of the earth should be a top government priority.



Another area in which the groups show similar responses is beliefs about the motivations behind the transition to hydrogen (Figure 6), and believing that other national concerns should take priority over a hydrogen transition (Figure 7). As would be expected, group 3 (disinterested) shows a higher proportion of people who do not have an opinion on these topics. When framing messages around hydrogen it is therefore important to ensure there is not an either/or narrative that implies that other national priories will be overlooked if the hydrogen conversion goes ahead. Messages should also be clear around the motivation for change, why specific actions have been taken and benefits these bring.

Figure 6: Beliefs that environmental protection is not the real motivation behind the hydrogen transition.

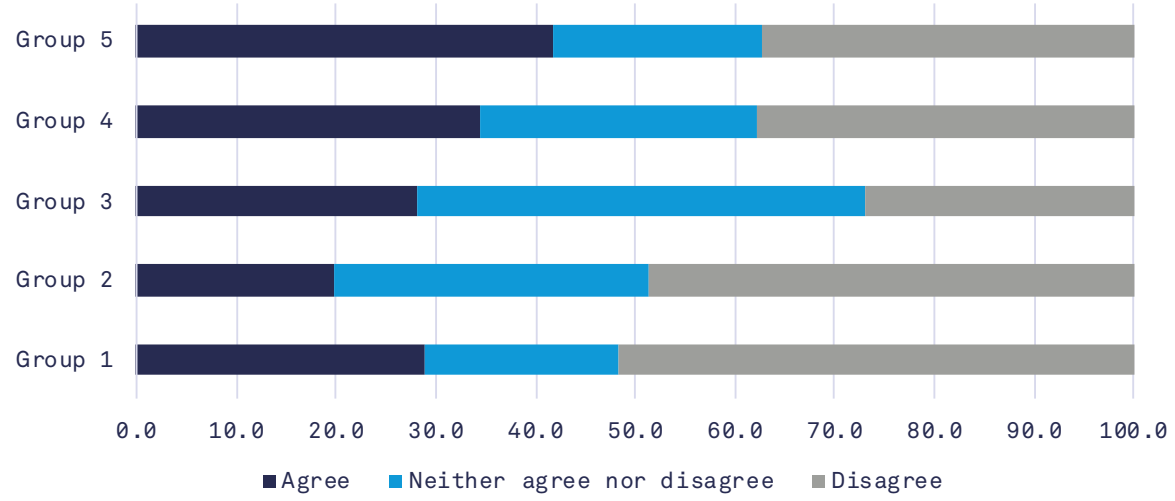
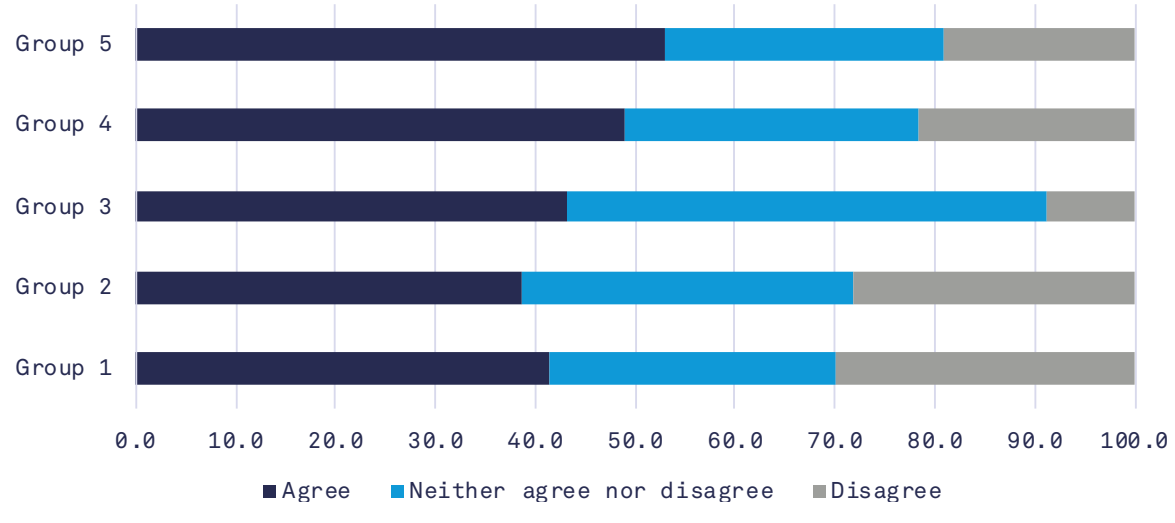


Figure 7: Beliefs that other national concerns, such as health or welfare, should take priority over the hydrogen transition.



Differences between groups emerge more clearly on beliefs about the current gas causing environmental damage (Figure 8) and whether other countries are prepared to take action to tackle climate change (Figure 9). The results show that groups 1 and 2 have a different pattern of responses to groups 3, 4 and 5. The latter – in particular group 5 - are less likely to believe that their current type of gas is causing climate change. Groups 4 and 5 are more likely to believe that there is no point in the UK taking action to tackle climate change because other countries will not do so.

Figure 8: Beliefs that the current gas does not damage the environment.

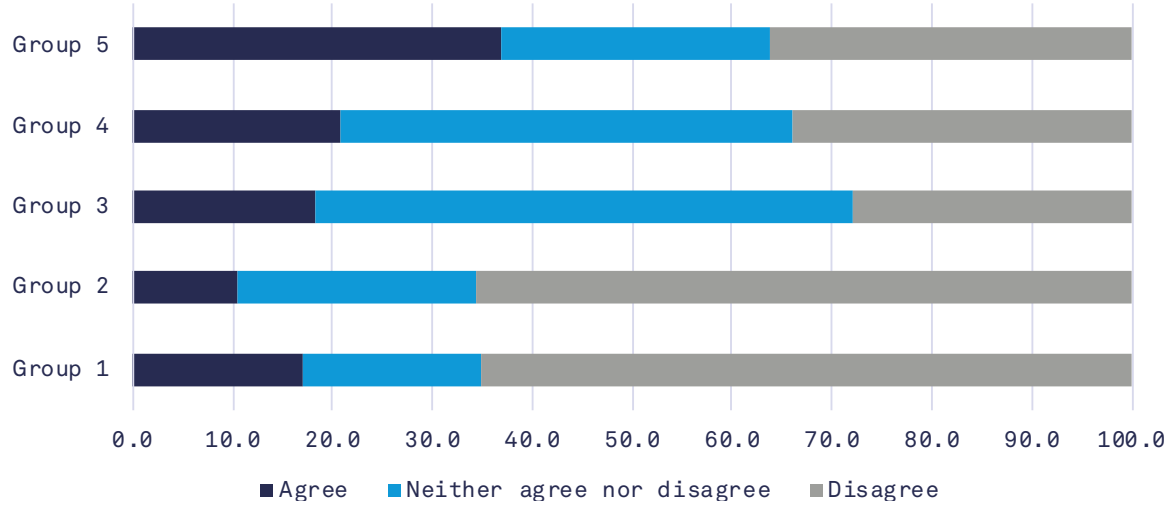
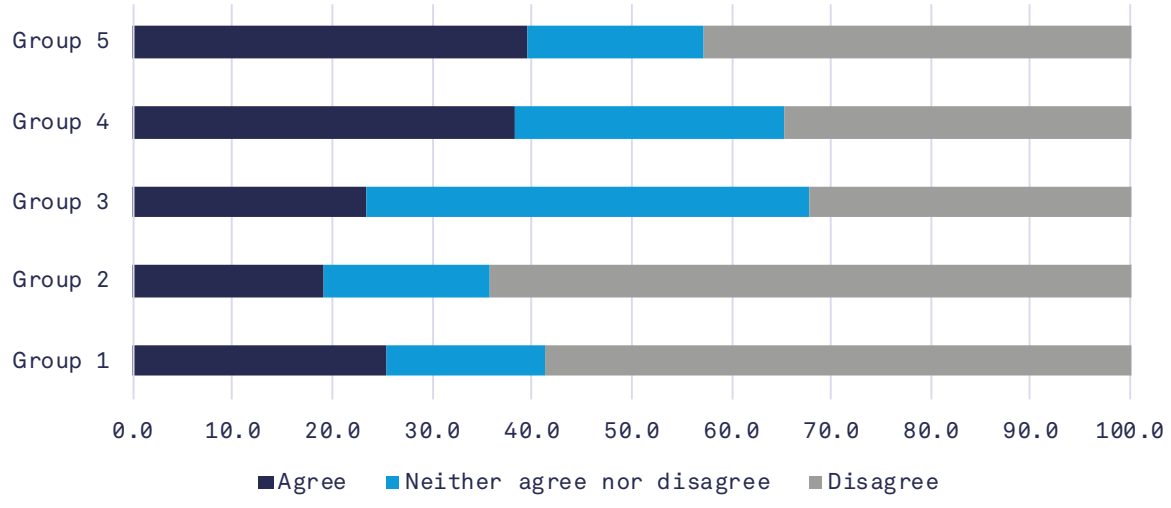


Figure 9: Beliefs that there is no point in the UK taking action because other countries will not.



04. Explaining a hydrogen conversion

4.1 Summary

It's particularly important to communicate effectively with groups 2, 3 and 4 because they form a large proportion of the population (68%) who are undecided about their response to a potential hydrogen conversion. They will be unable to make an informed choice about using hydrogen in their home if they receive information that they misunderstand or that generates unnecessary fears. In this stage of the research we worked with people in these groups to explore their response to hydrogen as a domestic fuel and, together with hydrogen experts, co-designed explanations of the hydrogen conversion.

We identified six themes that describe the questions and concerns that people had about a potential conversion.

→ Justifying a hydrogen conversion

Even though all our participants were in groups 2-4, and so were initially unsure about a hydrogen conversion, over the course of the two workshops they all came to the conclusion that hydrogen is an option that needs serious consideration, and promoted its benefits to others. A few were sceptical about the impact of a UK hydrogen conversion to global carbon emissions and believed that there is little point in the UK converting to hydrogen if other countries are not going to do so. Others, however, were enthused by the UK leading the world in hydrogen technologies. Participants were not engaged by explanations based on meeting government targets and instead highlighted personal responsibilities and consequences.

→ Where does hydrogen comes from?

Participants wanted to know where hydrogen comes from and how it is produced. They were able to grasp complex technical information about the hydrogen conversion that they can convey to others in a simple and easy-to-understand way. Few were aware of different methods of producing hydrogen and most accepted that in the short term the process of producing hydrogen would involve carbon being captured and stored, although several had concerns about whether carbon dioxide can be stored securely. A few questioned whether enough research resources were being dedicated to finding a sustainable method of producing hydrogen but most tolerated the uncertainty about when technology will be sufficiently advanced to produce hydrogen at scale using renewable technologies.

→ Cost

Our participants were relatively unconcerned about the estimated 7% by which their gas bill will increase should a conversion go ahead, although they were concerned that other more vulnerable people might struggle. When explaining the conversion to others, they highlighted the potential cost of not taking action. In contrast, they were concerned about the need to purchase new appliances and wanted reassurance that there would be an incentive scheme to help with the cost.

→ Safety

Safety was not a major concern for our participants: they assume that if their supply is converted to hydrogen then it will have been robustly tested and found to be safe. Indeed, they appreciate the safety benefit that hydrogen carries no risk of carbon monoxide poisoning. There were more concerns about how securely carbon dioxide is stored than the safety of hydrogen in their home.

→ Practicalities

Participants queried whether they would be able to choose to remain on a natural gas supply and some were surprised when they found out that their only choice was to switch to hydrogen or rely solely on electricity. They had questions about what they would need to do to prepare for a conversion but most assumed the impact would be minimal. They had questions about whether there would be any disruption from roads being dug up to replace pipes, how long the process would take, whether they would notice any difference in how their appliances work, and how they would find out about the conversion. Nobody asked how long their gas might be disconnected for, instead assuming that it would be hours rather than days.

→ Timing and certainty

There were concerns about whether a decision will be made about the conversion quickly enough to prevent irreversible environmental damage arising from climate change, and also that people would be given sufficient notice so that they can avoid purchasing expensive appliances that soon become obsolete.

The insight gained at this stage of the research was used to develop a set of explanations of the hydrogen conversion that people find relevant and easy to understand.

4.2 Methods

To find out how to explain a hydrogen conversion to people we held deliberative workshops with members of the public and hydrogen experts. The experts were members of the H21 project team and the Health and Safety Executive team conducting safety tests. Deliberative workshops are facilitated group discussions that encourage participants to explore an issue in depth, challenge each other's views, and to consider evidence on the issue so that they can reflect on it and reach an informed view. Our participants all attended two workshops. In the first we introduced the concept of a hydrogen conversion and facilitated discussion between the public and the experts. In between the two workshops participants were given the task to interview a friend or family member about the conversion and send us the audio recording of the interview. The same participants returned for the second workshop two weeks later. They discussed their experiences of conducting the interviews and the responses of their interviewees. Together with the experts, they co-designed explanations of the conversion.

The workshops took place in three different parts of the UK: Leeds, Birmingham and Manchester. These areas were selected because they are cities that would be converted at the start (Leeds), middle (Manchester) and later on (Birmingham) in the process. Each comprised eight members of the public, three hydrogen experts, and three researchers. The members of the public – our participants – were all in groups 2 (Cautious), 3 (Disinterested), and 4 (Unconvinced) as previously defined by the population grouping study. These groups were selected because they form a large proportion of the population (68%) which, for different reasons, are indifferent to the prospect of moving to a hydrogen domestic fuel supply and they are therefore the key people to communicate with. Group 1 (Accepters) and group 5 (Rejecters) were excluded from this part of the research as they already have strong views, with the Accepters already inclined to support a conversion and the Rejecters inclined to oppose it.

In the first workshop we played the start of the H21 Leeds City Gate project film (https://vimeo.com/173879655) which introduced the conversion. Participants were encouraged to ask the experts questions and to talk about their thoughts, feelings and concerns as they found out more. They were asked to take on the perspective of a persona, a technique that encourages them to contribute views without fear that others might disapprove. The personas were designed to reflect different aspects of group 2-4 characteristics and to include a range of demographics:

- Young-ish couple, living in rented accommodation, concentrating on building their careers and saving to buy their own home. Mildly positive attitude to climate change but it's not their top priority.
- Retired couple who have heard of climate change but they're not sure what to do about it and they are not motivated to make a lot of changes.
- People with young children and lots of other things to think about other than climate change and energy use.
- Person managing on a lower income who has to be careful with their money: they would struggle to pay increased bills. They don't think that environmental issues are something that particularly concerns them.

Participants then identified jargon used in the film, and with input from the experts, developed easy-to-understand explanations of the important aspects of the conversion. They talked about how they would explain the hydrogen conversion to their interviewee, and in pairs, they practiced conducting an interview. The researchers produced a summary of these explanations, which participants took with them in the form of a "crib sheet" that they could use to answer the questions their interviewees had.

After the first workshop, participants conducted an interview with a friend or family member. Participants explained the project to their interviewee, and who would have access to the interview, and the interviewees gave verbal informed consent. Participants provided a brief explanation of the potential hydrogen conversion, then answered their interviewee's questions. They were instructed not to "sell" the conversion, but simply to explain it and to explore their interviewee's views and answer their questions. Each interview lasted around ten minutes. Participants sent us the audio recording of their interview, which was analysed alongside the workshop audio recordings.

The same participants returned for the second workshop two weeks later. They discussed their experiences of conducting the interviews, how their interviewees responded, and how their experience of the interviews had changed their views on a hydrogen conversion. They reviewed the co-designed explanations and identified which explanations were important, which were good explanations and which were bad, and any explanations that were missing.

Audio recordings and notes from the sessions were analysed by identifying common themes and identifying reasons that explain different responses to a potential conversion. Our findings are shown in six sections, based on the different questions and concerns that participants and their interviewees had. Each of the sections explores how participants' views evolved, from first hearing about the conversion, to a more informed and reflective position.

4.3 Justifying a hydrogen conversion

Information on a potential hydrogen conversion was introduced gradually and participants were encouraged to ask the experts questions and to talk about their thoughts, feelings and concerns as they found out more. Very few of the participants had previously thought about how heating their homes can affect the environment. Most were initially positive about a potential conversion: once they heard about the purpose of a change to hydrogen, they concluded that there needs to be a change in how we heat our homes, and that hydrogen is an option that needs serious consideration. They were particularly struck by hydrogen only producing heat and water when burnt, unlike natural gas which produces carbon dioxide.

→ I didn't realise that gas was such a big influence to the environment and everything….You don't assume heating your house is a big thing. (DW1, Manchester)

While participants were initially supportive of the idea of a hydrogen conversion, as their discussion progressed, they had more questions about what the tangible benefits might be.

→ It sounds a bit like a no-brainer. (DW1, Leeds)

→ What are we going to achieve by changing Leeds to a hydrogen city? (DW1, Leeds)

Some participants questioned why the UK is considering making the change. They highlighted how the UK is a relatively small country and so unlikely to make a difference on a global scale. Some questioned how many countries will be willing to make changes and if there are only a few whether it is worth doing. However, several participants talked about how it is appropriate for the UK to lead the way and to set a good example to other countries.

↑ Challenging one another's views in deliberative workshops.

→ I was thinking the likes of China and Russia, who seem to flout a lot of the regulations that a lot of other countries seem to try and fall under. If countries like that continue to give out the gasses, will what we do make a difference in the long run? (DW1, Leeds)

→ What other countries are looking into it? If it's just us who are going to do it, there's no point, is there? (DW1, Birmingham)

→ I suppose it's setting a good example to other countries to hopefully follow suit. (DW1, Leeds)

The explanations that participants gave their interviewees about the hydrogen conversion showed two striking features. During the first workshop, experts were available to answer questions from participants, and they gave technical details of the potential conversion. However, there was no expectation that participants include any of this information in their own explanation. They were told to simply explain the conversion in any way they like. Despite this, their explanations included complex technical information which they managed to convey in a simple and easy-to-understand way.

The second striking point is that none of the participants gave negative or critical accounts of the conversion. They were specifically told that they were not being asked to "sell" the conversion but simply to explain what might happen and to answer any questions the person they were interviewing might have. Despite this, all the participants gave a positive account, stressing the importance of taking action and the environmental benefits that a conversion would bring. Several also highlighted that the UK has an opportunity to lead by example in using hydrogen technology to address carbon emissions.

Example explanations that people gave about the hydrogen conversion are shown below. Participants typically started their explanations by summarising why the change is happening, probably because the H21 Leeds City Gate film started with this information. They highlighted that the hydrogen conversion will help the UK meet the Climate Change Act, and explained why changing from methane to hydrogen will reduce carbon emissions. Many participants added an explanation of why it is personally relevant, e.g. because of the local weather, or protecting their children's future.

→ The UK is looking to the feasibility of converting our own current gas network to run on hydrogen. We are doing this to reduce our carbon emissions: the UK has signed an agreement to reduce our emissions by 100% by the year 2050. It will begin in the late 2020s and probably be completed in around 20, 25 years. Gas produces a lot of carbon, which is obviously damaging the environment. We've signed up to this agreement to reduce our carbon emissions, because, as you know, with all the crazy weather we've been getting. There's been a lot of denial about greenhouse gases but it does look to be affecting the whole world with adverse weather. (Interview 5, Birmingham)

→ There's a possibility that our gas will be changing, so the normal gas that we use now will be changing to hydrogen gas. The gas that we use now is methane gas, but they want to scrap that, because that contains carbon, and they want to reduce all the carbon emissions. They want to create a better atmosphere, a better environment and use less energy, and in doing so they want to use hydrogen instead, which contains no carbon at all. (Interview 2, Leeds)

→ We see climate change and global warming and stuff on the TV all the time, so this would be, if it was changing the whole gas network in the whole UK, we'd be doing our bit for climate change, and possibly the whole world would follow. (Interview 4, Leeds)

→ The plan is that we're looking at changing over from methane gas, which isn't great for the environment, to hydrogen, which is more eco-friendly. Many countries have signed up to the treaty, but Britain are at the forefront in trying to have zero net across the country into moving over to hydrogen gas. The cost will go up slightly but comparing that to the positive effect it will have on the environment, a rise is surely worth it. (Interview 1, Manchester)

↑ Developing clear explanations of a hydrogen conversion.

When they returned for the second workshop, some of the participants were even more convinced that the conversion needs to take place and that we have a responsibility to the world and to future generations to make sure these changes happen. A few described how their interviewees blamed the older generation for being reckless with the earth and its resources, and how we therefore have a responsibility to try to fix things. Speaking to other people about climate change and the steps that could be taken to tackle it had raised it as a priority issue for many participants. Several talked about how they had talked to several friends and family in addition to their research interview, and were surprised just how interested people had been.

→ For me it cemented what a good idea it is, we should be doing it, we need to be doing it for each generation. (DW2, Manchester)

→ People I talked to said something has to be done and they support it. In the past people were denying it but now they think that the world has to take action. (DW2, Birmingham)

→ My son thought it was unfair that the generation before him has caused this and his generation has to fix it. (DW2, Birmingham)

→ I reckon I could have interviewed a dozen people, just chatting to my mates in the pub they were so interested in what it was all about. (DW2, Leeds)

When reflecting about the experience of their interviews and their initial explanation, participants suggested that they had not dwelled sufficiently on the environmental benefits of a hydrogen conversion. They had talked about the need to meet government targets, but their interviewees were disinterested in targets. Instead, they were interested in making changes that would protect the planet and future generations. Participants also highlighted that there needs to be more plain-speaking information about what will happen if steps are not taken to reduce carbon emissions.

→ It doesn't tell you enough about what will happen if we don't. If we leave it until later, we can't do it. They are too scared to poke people and say we need to pull your finger out and do it. If we don't get rid of the problem this is what will happen. (DW2, Birmingham)

→ What are the benefits of carbon savings? It says about government targets but I don't think people are remotely interested in government targets. It's the world, your kids, your futures, what are you wanting to change about it? (DW2, Leeds)

4.4 Where does hydrogen come from?

Participants wanted to know where hydrogen comes from and how it is produced. Few were aware of different methods of producing hydrogen and most accepted that in the short term the process of producing hydrogen would involve carbon being captured and stored. A few questioned whether the process of removing the carbon would in itself use more energy than it saves. Several participants wanted to know about how hydrogen would be created in the long term, and if the move to electrolysis would provide an effective long-term solution. However, a few questioned whether electrolysis would require a substantial amount of energy, and whether this would be renewable. A few wondered whether enough research resources were being dedicated to finding a sustainable method of producing hydrogen but most simply accepted that research is being undertaken to find a technical solution.

→ Where will the source be? How will they produce it? How will they sustain it? (DW1, Manchester)

→ That process of subtracting the carbon, is that in effect emitting carbon to do that process? (DW1, Leeds)

→ What is the long-term plan to produce hydrogen after the natural gas conversion? (DW1, Birmingham)

→ If you could solve this electrolysis issue, would that solve the globe's power issue? (DW1, Birmingham)

A few of the participants wondered whether it would be better to move to renewable electricity rather than hydrogen, and a few specifically suggested solar panels. Others, however, highlighted the problems of capacity that had been flagged on the video they had watched.

During their interviews, most participants were asked questions about where hydrogen comes from, and they were able to describe both steam methane reformation and electrolysis production methods. Many gave detailed explanations of both methods and a summary of how new technology might change things in the future. Some participants gave more concise answers, but all managed to convey the key points about hydrogen production. Some of their interviewees asked challenging questions about the net carbon savings from both carbon capture and electrolysis methods, which our participants struggled to answer. What was striking about these explanations was that participants tolerated the uncertainty about when technology will be sufficiently advanced to produce hydrogen at scale using renewable methods.

→ At the moment, there's two ways of getting the carbon, or producing hydrogen. You can either strip the carbon molecules from the existing methane that we get from the North Sea, which there's lots of, and it is sustainable at the present time. But that carbon, once it's removed from methane, makes it hydrogen. And the carbon is taken away and stored under the sea in very safe areas. And in fact, it's from where the methane gas came in the first place. You've got huge voids under the sea, which they then fill up with the carbon. The other way is what they call electrolysis, which is where electricity is passed through water, and the resulting bubbles of hydrogen can be collected and then used as hydrogen. It's very renewable, but it's quite an expensive way of doing it. And it's not been perfected to produce large amounts yet. This is another of the things that they're looking at. (Interview 3, Leeds)

→ They're going to just separate it because it's one-part carbon, four-parts hydrogen. Separate the carbon, which is the bit that we're not okay with, pump that back into the ground in the salt caves. Obviously keep that sealed, and the hydrogen's going to go from there, straight to our home, and we'll have zero carbon in our homes. (Interview 1, Manchester)

→ The plan in the future is to do more electrolysis. At the moment the electrolysis technology isn't advanced enough now to meet the demand. So in the early stage we will use methane and capture the carbon to stop it releasing to the atmosphere. (Interview 4, Birmingham)

During the second workshop there were mixed views on how helpful it had been to talk about the chemical make-up of methane. Some participants reported that this had helped people to understand why the change would help, and others that it was unnecessary. Some of the participants had been asked questions about renewable alternatives to hydrogen that they were unable to answer, but there were mixed views on how much additional information on renewables to include in a list of FAQs on a hydrogen conversion.

4.5 Cost

All the participants assumed their gas bills would increase and many were concerned about how much the increase would be. The experts explained about the uncertainties involved in future costs, and that the current estimate is a 7% increase in their bill. Most participants were reassured by this and talked about it as being a manageable amount. Those who raised concerns tended to talk about the impact of bill increases on other people, rather than themselves. However, when they realised that in addition to the increased cost of gas their appliances would also need to be replaced, this became the focus of their costs concerns. Several asked whether would be any grants or subsidies available to help them with this cost. While many highlighted concerns about there being sufficient support for vulnerable or older people, they also expressed concerns about their own ability to pay for new appliances.

All of the participants reported that their interviewees had also asked questions about how much a conversion was going to cost. Participants recalled the 7% bill increase estimate quoted by experts and they were able to talk about how hydrogen-ready appliances will have been available, and to note that there will probably be some form of subsidy to help with the cost of replacing appliances. None of the participants complained to their interviewees about the cost, and instead found ways to justify why it is acceptable. Some of the participants talked about how increased costs should be considered alongside the costs of inaction, e.g. damage from climate change. Others highlighted how incentives may be available to help with the cost of replacing appliances, and others how there may be a scheme to help people who are struggling to pay higher bills. Examples of how our participants answered these questions are shown below.

→ At the end of the day nobody really cares except what it's going to cost them. If it's forced upon them, which this is going to be, then that's the one question they're going to ask: how much is this going to cost me? (Leeds DW1)

→ They said it's about 7% on your annual bill, roughly, and that it's something that we've got to do, we'd be happy to pay a bit extra (Birmingham, DW1)

→ I do know people who would struggle with the increases a bit. (Manchester, DW1)

→ Would there be any government initiatives to switch appliances when they come online? (Leeds DW1)

→ All of the properties will have to be changed to use the hydrogen gas: the boilers, the gas fires in your property, anything to do with gas at the moment will have to be changed. There will be a cost to you, and it's approximately, at the moment, going to be 7% extra to what you have at the moment in your property, so it's going to be 7% on top of your bills. Having said that, it's for your children, and your children's children, and their children. It's very important, if we don't do something about this climate change, then obviously we're not going to have the world as we know it at the moment. That is quite important that you bear that in mind. (Interview 1, Birmingham)

→ The plan is that when you get your new appliance, it'd be ready to run on hydrogen. But they think that there'll be some form of subsidy involved for people who haven't replaced their appliances. (Interview 4, Leeds)

→ They don't know the exact figures at this moment in time, but they've said that there's a possibility it might be around a 7% increase, compared to what we currently pay now. However, if people do struggle or are going to struggle paying that, there might be some form of incentive to help with that. (Interview 5, Manchester)

↑ Considering evidence on a hydrogen conversion.

During the second deliberative workshop some participants were a little more concerned about costs. Sometimes it was because they had recognised the potential cost of replacing every appliance in their home without the guarantee that there would be subsidies. Sometimes it was recognising how much this would cost landlords or businesses. A few participants were cynical about the government actually paying out incentives.

→ We're private landlords, we have a lot of properties and are we going to be responsible for changing all the fittings and appliances for all our tenants in 24 houses? (DW2, Birmingham)

→ I spoke to people in work and we've just spent half a million just putting in new boilers in one of our sites. They were supposed to last 20 years because they are industrial boilers and now we might be expected to change in the next 10 years and that's a huge impact. (DW2, Leeds)

→ My person mentioned that 7% increase is high when people are struggling at the moment, certain demographics of people, families with young children. If they are struggling now how will they be able to make that switch. And how much can we rely on the government? How often do they say they will do stuff and never do it? Saying there will be government incentives isn't enough for people to trust the government that has failed them for so many years in so many areas. It's a big leap for people from disadvantaged backgrounds. (DW2, Manchester)

Participants also highlighted the need to be more definite when providing information about cost, even though there may be some uncertainty. They suggested that it is better to say the cost increase will definitely be less than 10% than to say that we think it may be around 7%.

4.6 Safety

While participants talked about how it is important that hydrogen is safe to use in their homes, they were very easily reassured. A few asked about whether hydrogen is flammable or explosive, or what would happen if an unconverted appliance were run on hydrogen and a few asked whether there might be any harmful environmental effects, including effects that we may not currently be aware of. Most, however, were not at all anxious about safety. They appeared to assume that if the conversion happens, all the safety testing would have been completed. Instead, there was more interest in the safety advantage that hydrogen cannot produce carbon monoxide poisoning.

→ Isn't there a safer alternative to something as potentially volatile as hydrogen? (DW1, Birmingham)

→ I imagine there's been research in that to say that it's safe to do? (DW1, Leeds)

Some participants, however, wondered whether there could be any unanticipated negative effects that only become apparent in future years. There were also some safety concerns about how safely the carbon will be stored.

→ Is there any bad side effect to it? Is there anything that could come from hydrogen that we aren't aware of now that they say it can't damage you. (DW1, Birmingham)

→ What happens if the [CO^2] capsules are damaged? What if there was an earthquake and it damaged the capsule? (DW1, Leeds)

Some – but not all – of the interviewees asked questions about safety, and a few asked informed questions, e.g. about the risk implications of hydrogen being more flammable than methane. Participants responded to these questions by providing reassurance, rather than agreeing with or sharing their own safety concerns. They answered these questions with varying levels of technical detail, although most talked about the safety trials they had learned about from the experts. Many participants highlighted the safety benefit of no risk of carbon monoxide poisoning. A key point that they recalled is that if the conversion is to go ahead, hydrogen must be at least as safe as methane. There was no scepticism that any risks would be covered up or downplayed.

→ The studies reckon it's similar to the current gas system. There are tests going on at the moment to see how safe it is using the current gas piping. They're doing tests to see what would happen if there was a leak, etcetera. One good thing from it: there's no risk from carbon-monoxide poisoning, unlike methane, which is what we use now, the gas we use now, because no carbon is produced from the hydrogen. So that's one good benefit. There'll be no danger to people. If the risk did seem to be too great, it just wouldn't happen. (Interview 5, Birmingham)

→ It is safe. It's very light, it's a gas, and there is a possibility, as with any gas or anything, it can be explosive, but it's going to be brought to our homes safely, and it will be probably safe or safer as what we're using at the moment in the properties. (Interview 1, Birmingham)

→ The idea is that hydrogen will be used, and it will be no less safe than methane. Also, in the event of a leak of the pipes, methane is what they call a heavy gas, and it doesn't distribute very well. Hydrogen is very light and dissipates very quickly into the atmosphere. And therefore, it's technically a lot safer than methane. (Interview 3, Leeds)

When they returned for the second workshop, participants were more concerned than they had been about how securely the carbon dioxide will be stored, how often and how well it is monitored, and whether the stores could be compromised if there are ground movements, e.g. from an earthquake. They suggested more information on the safety of carbon dioxide being stored underground would be useful. They were confused about storage capacity (e.g. there is room for 70 years' worth of carbon dioxide) versus duration (the carbon dioxide can be stored safely for 70 years). They also wanted more information on safety inspections of the storage sites.

→ I explained about the cavern and that's where it can be stored, and they wanted more information about that to make sure how safe it is. (DW2, Manchester)

Participants all objected to vague answers that left a sense of uncertainty about safety. They recommended that information produced for the public avoids vague statements and uses definite terms, even if this means saying "we don't know but we are going to find out"

→ I think we'd rather hear that research is ongoing rather than "maybe" "should be" which is not what we want to hear. And like the cost – we don't really know but at the moment the best guess is about 7%. It just seems a bit namby – it's not conclusive. (DW2, Leeds)

→ You just need to say we don't know the answers just yet, that we're doing all the testing that needs doing before people are switched over and that is why it's taking so long. And you're stating that it's not definitely going to happen. You are still doing all the tests. (DW2, Manchester)

↑ Understanding the information needs of different people.

4.7 Practicalities

During the first workshop, participants had lots of questions about the practicalities of the conversion. They were keen to know when it might take place. They were reassured when told it would most likely be in the late 2020s to early 2030s for Leeds, mid 2030s for Manchester and late 2030s for Birmingham. There were questions about what they would need to do to prepare for a conversion and whether any pipes in their homes would need to be replaced but most assumed the impact would be minimal. In Birmingham, where there had recently been a programme to replace the pipes, there were a few questions about whether the conversion will require roads to be dug up again, and participants were relieved that this would probably not be necessary. One participant asked whether a hydrogen boiler is more complicated to operate. A few asked about how people will be told about the conversion.

→ If it gets the go-ahead, what year are we saying this will be complete in the cities? (DW1, Birmingham)

→ What do we need to do to be prepared? Does anything need to change in my house? (DW1, Leeds)

→ Some people close their doors in their homes and they don't go out, and they might not even watch the news. They might not know any of this is going on. So is there going to be a campaign and so on? (DW1, Leeds)

Some of the participants asked whether they would be able to choose to keep their existing gas supply, i.e. whether both hydrogen and methane would be available. One asked if it would be possible to use a mix of gas and electricity.

→ Do we have a choice? Do we have to change over? (Leeds DW1)

→ Could I, for example, use electricity as a primary source, where possible, and only use gas when needed? So, everything has to go through electric, where possible. And only use gas when there's not enough electricity? (Birmingham DW1)

Interviewees also asked questions about what will actually happen during the conversion, such as whether there will be any disruption from roads being dug up to replace pipes, how long the process will take, whether they will notice any difference in how their appliances work, and how they will find out about the conversion. Nobody asked how long their gas might be disconnected for, instead assuming that it would be hours rather than days. Participants were able to answer all of these questions. Audio recordings from the interviews indicated that participants described how the conversion would capitalise on the investment and disruption arising from the gas pipe replacement programme, and in this way positioned the conversion in a positive light.

→ No pipes will be replaced. As you know you might have seen loads of Cadent vans around. They're changing the cast iron pipes to plastic so saying that there won't be no escape [should we convert to hydrogen]. (Interview 4, Birmingham)

→ Over the last few years, the pipes are being changed anyway, because they're quite old. So some of them are iron, and they're being changed for new plastic-type, and they will be already able to carry the hydrogen. (Interview 5, Birmingham)

→ The pipes would be effectively purged of all methane one day, and the next day it would be all hydrogen. And it would be phased in over citywide. Someone described it as a bit like the changeover from analogue to digital TV. (Interview 3, Leeds)

→ They are going to have a team of people that will go out and make sure that everybody knows what's going to happen and explain it to them. And they will go knocking on the doors almost and telling people about it. (Interview 3, Leeds)

4.8 Timing and certainty

Many of the participants questioned when a decision would be made about whether the gas supply will be converted to hydrogen, and stressed that it should go ahead as soon as possible. While they recognised the value of explaining to people what is happening, they described the importance of taking decisive action rather than delaying the decision until a public consultation is undertaken.

→ Just say "Right, this is happening" Maybe this is the one thing that people would probably accept: to save our planet, this has to happen. We can't wait 20 years, 30 years to educate people. (DW1, Birmingham)

Several were concerned about the conversion taking so long that environmental changes will become irreversible before it is completed. Some were astonished that we are in the current situation in which the gas we use to heat our homes produces carbon, and questioned why this had not been addressed many years previously.

→ So, how many years before it's irreversible? That no matter what we do… (DW1, Birmingham)

→ I feel like is that it's something that should have been done ten years ago. (DW1, Manchester)

Some participants returned to the second workshop a little bit more sceptical about whether the conversion will happen. The workshops took place during the time at which the government was conducting Brexit negotiations and there were concerns that a hydrogen conversion wouldn't be given sufficient priority. There were also concerns that by the time any go-ahead is given, it will already be too late to prevent irreversible climate changes.

→ If it's such an emergency, why is it taking so long? Things will be worse in 2050! (DW2, Birmingham)

→ Mine was: "It's never going to happen, projects have come up like this before, and they never happen." But when we discussed it further, because he never stopped banging on about it later, overall he was just dubious about it. (DW2, Manchester)

→ But when will the decision be made? There is only so much talking but at some reason they need to give it the go-ahead. (DW2, Manchester)

In the second workshop, participants were asked about what the general public should be told at the moment, i.e. before a decision about a hydrogen conversion has been made. Most of the participants believed that there needs to be a conversation about the need to make changes to our domestic heating to reduce carbon emissions and climate change. Most believed this conversation needs to tell people about a potential conversion to hydrogen, as it could influence decisions about when to replace their gas appliances. They talked about how withholding information on a possible hydrogen conversion could cause unnecessary anxiety should an announcement about a confirmed conversion be made in the future. In contrast, raising this as a possibility now will mean that people become accustomed to the idea. However, some participants preferred to delay any announcement until safety tests had been completed. They were more tolerant of uncertainty around price increase and potential subsidies to replace appliances than about safety tests.

→ Getting that balance between this is what might happen, to this is definitely happening but you have only got a few years' notice. I would start the discussion now. So then in a few years time when they decide, it's not a dramatic thing for everybody. (DW2, Manchester)

→ I'd rather not know until you have the answers, certainly on the safety side of things – you want to be 100% sure on safety. (DW2, Birmingham)

4.9 Co-designed explanations

This final set of explanations address what people want to know should a conversion go ahead, so they assume the decision to convert has already been made.

→ Why are we converting to hydrogen?

The gas that we currently use to heat our homes – methane – releases carbon dioxide when we use it, and carbon emissions are causing climate change. Hydrogen doesn't contain any carbon: it only produces water and heat when we use it. By converting to hydrogen, we will protect the environment.

→ Do we have to convert to hydrogen?

You can't keep using methane when your area is converted as it will no longer be available. It doesn't matter which company currently supplies your gas as they will all change from supplying methane to supplying hydrogen. But you can choose to use electric appliances instead, if you prefer.

→ When will the conversion happen?

It will start in the late 2020s, and gradually the whole country will be converted by 2050.

→ Will it cost more?

It will cost a little more, and we expect that people's bills will rise by less than 10%.

→ What do we need to do to be prepared?

Over the next few years, hydrogen-ready appliances will be available. If you have one of those, then when your area is converted a gas engineer will visit your home and simply make some adjustments to your appliances. If you don't have hydrogen-ready appliances, you will need to replace them. There may be incentive schemes to help with the cost.

→ Will I get more information?

You will receive lots of information and lots of notice of when your home will be converted. There will be information officers and gas engineers visiting every property to make sure everybody knows what is happening and to check that the conversion will go smoothly and safely.

→ Will hydrogen use the existing gas network?

Yes, so there will be no need to dig all the roads up to replace all the pipes. Disruption will be minimised.

→ How is hydrogen produced?

Hydrogen is the most abundant gas in the universe but pure hydrogen doesn't exist in nature, it's always in other chemicals. For example, Hydrogen is in water: it is the H in H_20. At the moment there are two main ways of producing hydrogen. We can break up water into hydrogen and oxygen, and this will be the main method in the future as technology improves. At the moment, most hydrogen is made from methane gas. Methane is four hydrogen atoms and one carbon atom, so we can remove and store the carbon, leaving hydrogen.

→ Where is the carbon dioxide stored?

It's stored securely in underground rocks and caverns where the methane originally came from. Once a cavern is full of carbon dioxide it is sealed and regularly inspected to make sure it remains safe.

→ Is hydrogen safe?

There are extensive safety tests being carried out to make sure that it is at least as safe as the current gas. There are test of the pipes to make sure that there are no risks from leaks. There are also tests on homes. One of the major risks from the current gas is carbon monoxide poisoning, and hydrogen does not have this risk as it does not contain any carbon.

→ Are any other countries converting?

There is a lot of interest from other countries, and many are also planning to convert. The UK is trying to lead the world in developing hydrogen technologies and therefore protecting the environment.

05. Conclusions

This research explored how people respond to the prospect of converting their domestic gas supply from methane to hydrogen. Our results show that we can segment the public into five groups based on their reaction to a potential hydrogen conversion.

20%

Group 1
Accepters (20%)
This group is positive about a change to their gas supply and in favour of using hydrogen. They accept changes to their lives in order to reduce climate change and improve the environment. They believe that climate change is a significant challenge that needs to be addressed and they are confident in their own knowledge and understanding of the issue. They are optimistic about the economic benefits that becoming a leading hydrogen technology might bring. Effective messages for the Acceptors are environmentally focussed, with reassurances centred on cost and safety.

28%

Group 2
Cautious (28%)
This group is positive about a change to their gas supply but unsure about using hydrogen. They believe that climate change is a significant challenge but they have less confidence than group 1 in their own knowledge and understanding of climate change issues and they are less likely to have already taken action to reduce their carbon footprint. They share many of the same attitudes as group 1, and are motivated by the environmental benefits of a hydrogen conversion, but are more concerned about the likely disruption.

30%

Group 3
Disinterested (30%)
This group is unsure about a change to their gas supply and also unsure about using hydrogen. Despite believing in the importance of climate change and the need to take action to tackle it, they are disinterested in a potential hydrogen conversion, they do not believe they understand the issue well enough to take a position either for or against hydrogen. As a result, the most appealing messages are centred on safety, cost, and the local economy rather than environmental benefits.

10%

Group 4
Unconvinced (10%)
This group is concerned about a change to their gas supply and unsure about using hydrogen. They are concerned about climate change but lack confidence in their knowledge of the issues, which means they are unconvinced that a transition to hydrogen is the most appropriate response. They want to be reassured about cost.

12%

Group 5
Rejecters (12%)
This group hold mixed views about a change to their gas supply and are against using hydrogen. They do not accept the role of humans in climate change and are reluctant to make lifestyle changes to reduce the environmental impact of climate change. They reject the need for a hydrogen conversion and are sceptical about the need for a change. They need convincing that hydrogen is a novel, renewable energy technology and need reassurance about safety, cost and disruption.

We identified groups 2, 3 and 4 as core markets for future communication as the wrong messages could mean this large proportion of the public reject hydrogen as a domestic fuel based on misperceptions or unfounded fears. The next stage of the research focused on these groups to co-design, together with hydrogen experts, explanations of hydrogen conversion that will address their questions and concerns and enable them to make an informed choice about their future energy supply.

Our results show that people don't typically think about their heating as a source of carbon emissions. Even though our participants were all in groups 2-4, and so were initially indifferent to a hydrogen conversion, over the course of the two workshops, they all recognised the need for a change in domestic energy, and spoke very positively s to others about the potential benefits of a hydrogen conversion. They were able to grasp complex technical information about the hydrogen conversion which they could convey to others in a simple and easy-to-understand way. The results show that safety is not a major concern for most people: they assume that if their supply is converted to hydrogen then it will have been robustly tested and found to be safe. Indeed, they appreciate the safety benefit that hydrogen carries no risk of carbon monoxide poisoning. An emphasis on safety could therefore increase rather than decrease safety concerns. There were more concerns about the safety of stored carbon dioxide than the safety of hydrogen in the home.

Our participants were also concerned about the increased cost of gas and of purchasing new appliances, especially that there should be sufficient support for vulnerable members of society. Some were sceptical about the contribution a UK hydrogen conversion can make to global carbon emissions. Many people believed that there is little point in the UK converting to hydrogen if other countries are not going to do so. In contrast, some were enthused by the UK leading the world in hydrogen technologies. There were concerns about whether the conversion will happen quickly enough to prevent irreversible environmental damage arising from climate change, but also that people would be given sufficient notice so that they can avoid purchasing expensive appliances that may soon become obsolete. We found that it is important to help people understand key concepts such as carbon capture and storage, and with this understanding, they are able to tolerate the current uncertainties over the timescale of a conversion and how hydrogen will be produced at scale using renewable technologies.

The results highlight the need to develop a suite of communication resources for the general public. We recommend that this includes:

- A glossary of terms that explain the key concepts underpinning a hydrogen conversion and the safety testing that has been completed. This could be used in communication resources such as leaflets for the general public.
- An animation that explains the reasons for a hydrogen conversion and what it involves, including how hydrogen is produced and how the captured carbon is safely stored.
- An interactive display to demonstrate how hydrogen is stored and transported, and how the practicalities of how the conversion are achieved.

Phase 2 of the H21 project started in March 2020, and part of the project will be to produce these communication resources.

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