UNIVERSITY OF LEEDS

# ESTABLISHING THE UK HYDROGEN CORRIDOR: SOCIO-ECONOMIC, ENVIRONMENTAL & REGULATORY ISSUES

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**Abbreviations/Glossary of terms**

| | |
|---|---|
| BEIS | (Department for) Business, Energy and Industrial Strategy |
| CC2 | Social-economic, environmental and regulatory cross-cutting theme |
| CCC | Committee on Climate Change |
| CCS | Carbon capture and storage |
| CCUS | Carbon capture utilisation and storage |
| FCH | Fuel Cell and Hydrogen |
| FEED | Front End Engineering Design |
| H2CORE | Hydrogen Corridor bid |
| LCC | Leeds City Council |
| NGO | Non-Governmental Organisation |
| NPH | Northern Powerhouse |
| SIPF | Strength in Places Fund |
| SME | Small and medium-sized enterprise |

# 1 Introduction

To support the H2CORE Strength in Places Fund (SIPF) bid this scoping study evaluates the socio-political, community and market factors that may influence the large-scale application of hydrogen as an energy vector to decarbonisation processes within and between Leeds and Teesside. Through the triangulation of data from surveys, interviews, participant observation and document reviews, we identify key knowledge gaps and areas for further research within the social-economic, environmental and regulatory workstream (CC2) of the H2CORE bid.

The report begins with a discussion of the social acceptance framework used for this analysis and identifies key themes relevant to CC2 (section 2). Section 3 describes the scoping study methods and section 4 presents the key findings using the social acceptance framework as a heuristic to structure the analysis. Section 5 concludes with a summary of key findings in relation to the relevant SIPF bid questions.

# 2 Background and Literature

The social-economic, environmental and regulatory cross-cutting theme (CC2) aims to develop an integrative understanding of the 'social acceptance' of hydrogen technologies for the successful implementation of the Hydrogen Corridor. It is well documented how so-called 'non-technical factors' can undermine implementation of renewable energy technologies, including lack of support from key stakeholders and policy makers, and poor understanding of the roots of public attitudes which may include cultural and landscape issues (Wüstenhagen et al 2007). To assess potential implementation barriers of the Hydrogen Corridor we broadly define social acceptance to include socio-political, community and market factors that may influence the production, distribution and end-use of hydrogen as a fuel for domestic, transport and industrial use (see: Upham et al 2015 and Wüstenhagen et al 2007).

*Socio-political factors* include acceptance of technologies and policies, public support, and support by key stakeholders, policy makers and industry actors at multiple scales. *Community factors* include attitudes, perceptions and engagement strategies of local stakeholders, particularly residents and local authorities. Here the focus is often on siting decisions and implementation of renewable energy projects and associated infrastructures (see e.g. Wüstenhagen et al 2007). Key questions include how costs and benefits are shared (distributional justice), the extent to which decision making processes are fair given all relevant stakeholders opportunity to participate (procedural justice), and the extent local communities trust the information and actions of investors and actor from outside the community (ibid). An assessment of the potential environmental impacts of hydrogen activity on the local environment (e.g. air quality) is also relevant to the analysis of community acceptance. *Market factors* help explain the process of market adoption of an innovation, by exploring consumer preferences and practices, investment behaviour of firms and the broader investor community, regional expertise, skills and employment opportunities, and intra-firm interactions that may lead to renewable energy innovation (ibid). These interdependent factors are conceptualised in Figure 1.

A limitation of previous studies is that they have tended to focus on attitudes and preferences of single stakeholder groups (e.g. the public, industry or decision makers) towards specific aspects of the technology, such as fuel cell vehicles or hydrogen production methods (Hyacinth 2016). Our approach for H2CORE differs, as we will assess the social acceptance of hydrogen from a range of stakeholders at multiple scales using a whole-systems approach including the production, distribution and end-use of hydrogen as a fuel for domestic, transport and industrial use (see Figure 1). However, for this

scoping study we provide initial insight into each of these factors in order to identify key knowledge gaps and areas for further research to inform the H2CORE SIPF bid.

*Figure 1: Social Acceptance Conceptual Framework*


(Adapted from: Upham et al 2015 and Wüstenhagen et al 2007)

The H2CORE social sciences cross-cutting workstream (CC2) will engage with a variety of themes from the academic literature to develop a cohesive approach assessing the social acceptance of hydrogen. Drawing further from the socio-technical transitions literature, a coevolutionary framework underpins CC2 (see e.g. Foxon 2011). Foxon's (2011) multi-level framework explores transitions to a low carbon economy through the coevolution of ecosystems, technological systems, institutions, business strategies and user practices. This approach is apposite for CC2 as it facilitates the analysis of causal mechanisms that may influence change through the interaction of activities within systems. This approach allows us to pinpoint blockages and opportunities for the social acceptance of hydrogen both within and between systems, as well as within and between micro, meso and macro levels.

The social sciences advisory group for H2CORE gave input on the various projects that underpin CC2. To assess the *socio-political factors* that affect social acceptance of hydrogen technologies, we will evaluate the institutional context as well as public perception and opportunities for policy support and polycentric governance (CC2-P1 and P2)[1].

The dual imperatives of speed and justice are widely debated within the landscape of UK decarbonisation strategies (both regional and national). Underpinning these imperatives is the need for plurality, a multiplicity of knowledge, expertise, actors and interests to be included in these processes (see e.g. Delina et al 2018). In order to spur economies of scale and accelerate a hydrogen

[1] CC2-P1 is the coordination and synthesis project for CC2 and is titled 'Social science coordination, synthesis, dissemination and impact development is the overarching coordinating work package'; CC2-P2 has been proposed by James Van Alstine and Simone Abram and is titled 'Policy analysis and Polycentric governance for a rapid and just energy transition.'

energy transition, new energy technologies must have policy support including government targets, a cooperative private sector, and a willing public (ibid).

A key challenge is how governance processes and institutions (formal and informal rules of the game including state and non-state actors) shift to account for the multiplicity of knowledge produced about the sociotechnicality of hydrogen energy systems. To account for these alternative voices (beyond engineering, economics and the usual decision makers) we need polycentric forms of governance, where power sharing occurs between state and non-state actors at and between multiple jurisdictional scales (Delina et al 2018). H2CORE is an opportunity to create polycentric governance processes, through a working coalition, partnership and network for a rapid and just energy transition in the UK.

To inform public engagement activities and message framing, a comprehensive analysis of public perception and attitudes towards hydrogen is needed at the local, regional and national levels (CC2-P1 and P4). A wide range of research on public and stakeholder attitudes and acceptance towards fuel cell and hydrogen (FCH) technologies has been undertaken (see e.g. Hyacinth 2016). The EU-funded Hyacinth project (2016) produced a comprehensive literature review identifying key findings from 20 years of socio-psychological research on the social acceptance of FCH technologies. The key findings from this report include (Hyacinth 2016: 45):

- There are very few cross-country studies that systematically compare public attitudes towards FCH applications
- Studies have predominantly focused on transport applications with few focusing on public or other stakeholder perceptions of residential applications of hydrogen technologies
- Most of the studies are based on surveys with users and members of the general public, with more recent studies providing information on FCH to participants to minimize likelihood of collecting pseudo-opinions. Some studies do combine surveys with qualitative research.
- Studies tend to show that low levels of knowledge and interest in hydrogen among the public nonetheless correlates with relatively high levels of acceptance of FCH technologies
- No systematic comparisons were found regarding acceptance of specific FCH technologies; however, the report acknowledges public attitudes towards FCH technologies might differ depending on the application and/or the way hydrogen is produced
- On the way that different factors (from personal to context) influence attitudes and acceptance of FCH technologies, most studies investigated the role of personal and psychological factors such as knowledge, environmental attitudes or personal beliefs in the context of transport applications
- More recent research on stakeholder perceptions has predominantly focused on expert groups

It is important to note that the concept of social acceptance needs to be applied cautiously to hydrogen, given the small numbers of users of actual FCH technologies. Responses from the public are usually elicited from imagery and text rather than experience with hydrogen (Hyacinth 2016: 45).

To some extent, missing from the coevolutionary framework and previous work on decarbonisation is the analysis of power and politics as well as engagement with just energy transitions. To evaluate ***community factors*** that affect social acceptance and to address these shortcomings an 'energy citizenship' approach will be taken to engage the public for a just hydrogen energy transition (CC2-P1,

P2 and P4)[2]. Indeed, it is widely recognised that energy transitions must be 'humanized' (Delina et al 2018) and that there is a need for strong interlinkages between energy systems and social justice (Jenkins et al 2018). It is imperative that an energy justice approach (distributional justice, procedural justice and justice as recognition) underpins the resultant material and social transformations inherent in sociotechnical transitions (Jenkins et al 2018). In order for public trust and legitimacy to underpin a new 'energy citizenship', there is need for greater consideration and voice to non-traditional actors in socio-technical transitions. These include the role of users, non-users, communities, marginalised groups, and non-dominant and non-state actors in shaping energy transition processes (ibid). More broadly, this links to calls for greater explicit consideration of agency, power and politics in socio-technical transitions and energy justice research (ibid). H2CORE is an opportunity to engage and co-produce hydrogen futures with traditionally marginalised voices and publics, to embed principles of justice in hydrogen innovation and governance processes for a new 'energy citizenship' (see e.g. Chilvers and Kearnes 2016).

A key concern of various publics, as will be discussed below in section 4, is the environmental impacts of a hydrogen corridor between Teesside and Leeds. Rapid transitions to new technologies or new ways of delivering societal needs necessarily has impacts on the environment. Global impacts include land use change, habitat loss, the collapse of biodiversity and rising levels of soil, air and water pollutants.

Such widespread impacts are difficult to pin down to individual technological changes, but this is not always the case. For instance, uptake of large scale wind turbine deployment had unpredicted impacts on birds, bats or marine mammals and fish and their deployment is now carefully managed; the introduction of species for agriculture/forestry purposes that have subsequently become invasive is a common, difficult to predict, outcome of such interventions.

Although we know technological change will alter the natural environment, it is rare for the environmental impacts of transitions to be investigated at an early stage of the transformation. Doing so allows novel academic insights as well as the early development of regulatory frameworks that can then facilitate the maximisation of environmental and societal benefits. H2CORE has a unique opportunity to explore and quantify what a hydrogen transition could mean for biodiversity, ecosystem function and ecosystem services (CC2-P?)[3].

Core to the co-evolutionary and social acceptance frameworks is the evaluation of **market factors** that affect the adoption of socio-technical innovations. The social sciences advisory group for H2CORE have proposed a variety of projects. An evaluation of the consumer basis for change will be undertaken through assessing consumer preferences and practices (CC2-P4), as well as a full economic cost and benefit analysis of hydrogen considering air quality, carbon saving, jobs and consideration of how costs may vary over time (CC2-P5)[4].

[2] CC2-P4 is currently titled 'Development of consumer basis for change' and has been proposed by a number of colleagues including James Van Alstine, Fiona Fylan, and Paul Van Schaik (TU)

[3] CC2-P? is currently titled 'What would the Hydrogen Corridor mean for the environment? Assessing impacts at local, regional and global scales' and has been proposed by Martin Dallimer. The text here on environmental impacts comes from his proposal.

[4] CC2-P5 is currently titled 'Full economic cost and benefit analysis of hydrogen' and has been proposed by Andrew Brown.

Business models and strategies will also be evaluated in order to facilitate business model innovation within low carbon and circular economy supply chains (CC2-P6)[5]. Pathways to a sustainable, low carbon and circular hydrogen economy will be identified, bringing the co-evolution of industries, policy, society and environment together in a whole-system analysis (CC2-P7)[6].

# 3 Scoping study methods

This scoping study outlines our key findings structured according to relevant Cross Cutting Theme 2 (CC2) related questions in the bid document, and analysed in accordance with the adapted social acceptance conceptual framework presented in Figure 1. A mixed methods approach was adopted in order to reflect the need for timely engagement with a wide range of stakeholders (including experts as well as lay actors), and the different potential hydrogen developments under consideration (transport, domestic and industrial).

Methods employed included:

- Survey: An online survey designed to gain a better understanding of the views of different publics was developed. Questions focused on opinions and beliefs about the region developing and using hydrogen technologies, as well as the potential role of hydrogen in tackling climate change and air pollution. The survey was distributed to Leeds Citizens' Panel and via community and civic networks in Middlesbrough. There were 578 responses in total, the majority of these being from Leeds.

- Interviews: Semi structured interviews with key stakeholders (purposive sampling) identified through attendance at events or other interest in hydrogen developments (outline in appendix). A total of 30 people (industry experts, academics, NGOs and community representatives, policy and governance actors) have been interviewed to date. Twelve of these were focused primarily on issues relating to transport in Leeds. Six were focused on policy and industrial actors in Middlesbrough.

- Desk-based study of grey literature: Policy briefs, industrial and government reports, technical reports from Front End Engineering Design (FEED) studies and other hydrogen projects were reviewed, with particular consideration for non-technical, socio-economic, governance and policy issues.

- Observation and participant observation at naturally occurring events: Members of the project team attended, and where appropriate took part in (e.g. presented), events during the time frame of the research.

These methods were deemed appropriate in this context given the early days of the potential development as well as the wider complexity of the context. In addition, employing a range of methodologies increases opportunities to engage a wide range of actors and stakeholders identified as being significant in the literature.

[5] CC2-P6 is currently titled 'Business Models' and has been proposed by Anne Velenturf.

[6] CC2-P7 is currently titled 'Industrial evolution' and has been proposed by Anne Velenturf.

# 4 Key findings

Key findings are presented according to the features of the social acceptance framework where they emerged from the data as being most relevant to the Teesside-Leeds hydrogen corridor. Section 4.1 presents key socio-political and governance features. Section 4.2 summarises the data in relation to key community and environment issues, and section 4.3 considers market related issues in detail.

## 4.1 Socio-political/governance features

This section presents key socio-political and governance issues that emerge from the data. Each heading reflects a feature that is most evident following thematic coding of data from multiple data. Data sources are indicated throughout, and where appropriate, quotes or specific data from primary and secondary sources are given to illustrate key points.

**Government strategy and policy:** The Climate Change Act commits the UK to reducing carbon emissions by 80% from 1990 levels by 2050 (Climate Change Act, 2008). Heat counts for over one third of the UK's GHG emissions (BEIS 2018: 2). Addressing this challenge requires transformational change to energy (and other) systems, in power generation, as well as in transport. Document, interview and observation data are in chorus on both the likely future importance and role of hydrogen in the UK in creating such transformational change, and the need for clear policy to support the transition. Participants stressed that 'the net zero economy needs H2'. The UK Government consultation on clean growth, for example, concludes that:

> '*Widespread use of hydrogen also has the potential to deliver deep reductions in carbon emissions, consistent with our 2050 commitments.'* (BEIS, 2018, 6)

The UK Government has recognised that there is a need to develop a long-term policy framework for heat that will:

> *'…ensure that appropriate support is in place for consumers; enable the most cost-effective transition across energy industries and infrastructure; and, contend with the uncertainties arising from the multi-decade heat decarbonisation timetable. Advances in technologies may open up new solutions, and economywide developments such as the decarbonisation of transport and power generation may alter the feasibility of others.'* (BEIS, 2018, 4)

The desktop study undertaken here reveals that hydrogen has been identified in consultations and other government policy literature as being of significance in heating (domestic and business) as well as transport contexts. The Committee on Climate Change's recent Net Zero report, in its 'Further Ambition' scenario, highlights a significant role for hydrogen and CCS in the decarbonisation processes to net-zero GHG emissions by 2050:

> *'Our Further Ambition scenario reaches a 96% GHG reduction by 2050 compared to 1990 levels. A significant low-carbon hydrogen economy will be needed to help tackle the challenges of industry, peak power, peak heating, heavy goods vehicles, and shipping emissions. CCS will have a larger role, including in industry and at scale in combination with biomass. Major changes are needed to how we use and farm our land.'* (CCC, 2019, 137)

A key feature of the discourse relating to UK national government support of hydrogen and high expectations with regard to its use in decarbonisation, is that it is essential to support these expectations with a robust policy framework and a stable policy environment. Participants stressed that 2019 is a 'critical year for H2' and noted the importance of government policy on Carbon Capture

and Storage (CCS) as well as anticipation of the white paper on energy the UK Government has promised to publish in 2019. Participants at the National Summit on Hydrogen also noted international norms promoting the future of H2 such as a report published by the IEA in June 2019.

**(Lack of) Government support and uncertainty**: Energy transitions require clear government support. A key overarching theme is the prevalence of uncertainty in the whole hydrogen economy value chain. Historically, transitions to coal, gas, nuclear and latterly renewables, notably off-shore wind, have been supported by both subsidies, targets and a clear policy framework (Bolton et al 2016). The wholescale decarbonisation of heating and transport sectors will require similar national government support. The discourse relating to this area is evident across the data. For example, in a presentation at the stakeholder engagement event at the University of Leeds (04/06/19), Chris Beck (TWI) stated that wind energy is only feasible now because of early subsidies. For hydrogen to be feasible in the next 20 years, the UK needs to adopt a similar approach which requires government support. A challenge to this is that subsidies and for example, Feed in Tariffs (FiT) designed to support decarbonisation are 'being ramped down'.

The Northern Powerhouse Partnership at the National Summit drew similar conclusions on the need for coherent policy on hydrogen (and CCS). Key points from Andy Davidson's presentation suggests government support and funding for a number of smaller projects has been 'piecemeal' to date; the danger here is that hydrogen remains 'a tomorrow energy' whereas action to embed hydrogen into the energy mix is required now, even if this is imperfect it is better than to wait and see. This means that the Roadmap for hydrogen and testing (with CCS) at significant scale needs to be supported by policy.

An interesting feature of this discourse is that there is also a need to 'move away from siege mentality…' and to 'get on and do it' (observation of table discussions at Hydrogen Summit, 28/6/2019). In Scotland for example, progress has been made in hydrogen developments, in particular in transport (Aberdeen project report), without the need to develop new policy, instead new policy is now being produced which reflects learning from demonstration projects. This ties with comments below in relation to gas in domestic heating, on the need to sensibly use existing policy and regulatory frameworks (for example Ofgem) whilst in the 'fail fast' stage (Oliver Lancaster presentation, Hydrogen Summit, 27/6/2019). In this sense, rather than labouring over developing policy suited to the mid and longer term, the key is to give clear short-term messages to kick-start transformation.

Industrial actors (SMEs, existing gas and transport organisations and their representatives) in particular note the importance of clearer messaging and support from Government re intentions for hydrogen and CCS. Key challenges include lack of government support and existing institutional infrastructure. For example, rail operators may want to move to H2 but existing franchising business models do not provide the necessary incentive structures. As one interviewee noted:

> *Scattergun approach, consult on everything, don't make decisions until pushed and then final decision seems arbitrary (Interviewee CB3).*

While BEIS recently announced support for CCS research and development, i.e. proposed three CCS industrial clusters functioning by 2025, participants at the National Summit on Hydrogen stressed that government support was needed for this to move from idea to reality.

**Temporal dimension of H2:** In terms of policy at both national and regional level, there is broad agreement in the data that there is somewhat of a 'policy vacuum' (interviewee CB2) for hydrogen, and in particular in terms of hydrogen with CCS. It was noted during hydrogen events, as well as in interviews and documents that there is a growing concern that whilst there are 'warm noises' about

policy direction and support for hydrogen there is a lack of commitment which is detrimental to progress (interviewee CB2, observation at summit). Furthermore, key and timely policy decisions are needed on H2 and CCS. In order to decarbonise heating for example, hydrogen proponents believe that a clear policy decision is needed before 2023 (or even 2021), and that the already regulated gas industry is the best place to enact that policy. Put succinctly, we currently have 'short term politics, but need long term decisions' (D. Sadler at H2 network event in 2018). For a long-term sustainable solution, a global market of H2 will need to be established and regulated.

The need for timely action on policy is also discussed in terms of investors. As noted by Rachel Reeves MP, Chair of the House of Commons BEIS select committee, at the Hydrogen Summit 'the Government needs to give clearer signals to investors' in order to ensure decarbonization programmes will be supported by commercial investors. Furthermore, regulations need to encourage early adopters so that demonstration projects become feasible as was the case with the early years of development of renewable energy. A strong desire to focus on early policy decisions is evident clearly in observational data and interviews. However, the market for hydrogen is not yet clear, and so investors need alternative signals in order to take risks associated with being an early adopter. In this sense, regulations need to actively encourage early adopters so that demonstration projects become feasible as was the case with the early years of development of renewable energy. The following extracts from interviews exemplify this point:

> *'There is currently an absence of national Energy policy. It's just a system of regulation (Ofgem and others) but essentially it's left to the market. We can't leave decarbonisation to the market.'* (Interviewee AR2)

> *'Leaders need to show commitment to decarbonisation via an overarching policy.'* (Interviewee AR7)

In essence, the speed of policy development does not reflect urgency/need for change and policy to support low carbon developments now. Industry is not in position to take risks to back hydrogen without timely government support both in terms of funding for physical and clarity of policy direction (Observations from Summit, desktop review, interviewees CB2, CB3).

**Contested policy space, H2 vs electrification:** H2 versus electrification/heat pumps appears to be a highly contested policy space. It is not clear to investors or industry which way heat policy is heading. Respondents suggested that Government ultimately needs to decide on a policy direction because (i) other actors (e.g. industrial) have vested interests or (ii) lay people do not know (or care) about the technicalities. For example:

> *'It has to be government who decides...because you can't expect the average person behind the till at Tesco to understand [and fight for] hydrogen...I'm not saying they don't have the intelligence, just that they don't have the TIME, and inclination maybe, but [mainly] they don't have the time to understand hydrogen.'* (Interviewee AR1)

Furthermore, it is not clear that there is agreement on the appropriateness or need for a wholescale transition to hydrogen for domestic and industrial use. Commenting on discussions at an energy round table event in the North West, one interviewee noted that 'gas providers thought that hydrogen is very important, but reps from the electricity sector present did not' (Interviewee, CB2).

What is relevant here is that industry is unable to make decisions on hydrogen developments at scale when policy not clear. The contested policy space is impacting the market for hydrogen and vice versa. There is a tension between long term vision, social acceptability in future and what can be done now.

There is a potential to focus on transport and air pollution (see Aberdeen bus project for example) and used this to build a pathway to a hydrogen economy that would support net zero targets by 2050. This view is clearly supported by data from multiple sources, for example:

> *'to be net zero by 2050 you need action now and we need to amend regulations as well...'* participant, National Hydrogen Summit.

From events, discussion suggests that the Government wants to 'back winners' (observation 4/6/19) and is using similar mechanism for funding and development to CCS, i.e. creating competition for funding between regions.

**Scale of decision-making - local and regional governance:** Discussions at events (local and national) as well as interview and survey data point to the relevance of scale in governance and decision-making. Issues relating to devolution and importance of the role of regions are discussed. There is some concern about the potential to create what might be unnecessary competition between regions. For example, in table discussions at the National Summit, participants discussed whether the focus on creating competition for funding might lead to a 'race to the bottom' rather than an efficient use of research resources. Mark Lewis, TVCA noted that competitions for funding have 'had a bad press in Teesside' following the delays and then cancellation of the competition for CCS which impacted the region heavily. It was also noted that other countries, e.g. Germany, have nationally funded H2 programmes.

Similarly in his presentation, Oliver Lancaster (Wales and West Utilities) noted the 'need to fail fast', have many small projects and share learning across regions to support wider decision making, but then fully invest in regions to test full chain at scale. The HyNet project reports on the regional importance of hydrogen in terms of both socio-economic (jobs, economic growth) and geographical features (close to associated industry). This is also reflected in observations and interview data.

The role of combined authorities, local councils and local enterprise partnerships, among others, in driving decarbonisation policy will be a key area for further research. For example, Leeds has the West Yorkshire Combined Authority, Leeds City Region LEP, and representatives of local authorities working towards a zero carbon economy by 2036. This is being pursued through, among others, an emerging local inclusive industrial strategy and Leeds City Region's energy strategy and deliver plan (2018). The hydrogen economy is an area of interest, particularly with the NGN H21 project and hydrogen for transport.

An interesting governance question was raised at the National Summit on the role of mayoral power in Tees Valley, and its ability and willingness to push forward decarbonisation plans. Given Leeds does not have a mayor, one Leeds Councillor noted that sometimes we need to move forward despite (lack of) national government policy, highlighting that the 12 LEPs could drive the H2 economy forward.

## 4.2 Community/environment

**Public acceptance:** The importance of public acceptance of low carbon technologies and its significance for success of a project has been discussed in the literature (Upham et al 2015). For hydrogen developments, the data suggest that it is a widely held belief that consideration of publics' perceptions on and acceptance of hydrogen *'…must be at heart of [developer's] thinking'* (David Smith, CEO, Energy Networks Association). Observation data support this for example at the 2018 H2 workshop at the University of Leeds Tom Knowland, Head of Sustainable Energy & Climate Change at Leeds City Council highlighted the importance of public perception and acceptance in domestic

conversion to H2, stating that whilst there is very strong local council support for H21 *'…the project goes nowhere if we can't address public perception and acceptance'*.

In this review, interview and survey data have been informative in highlighting features of public acceptance discourse that may be of particular relevance in the case of the Teesside to Leeds corridor. For example, survey results suggest that there are moderate to high levels of acceptance of hydrogen as a means of developing a green economy locally, with caveats around the environmental impact of different types of hydrogen used (see Appendix 1). Respondents were asked about their support for using hydrogen in their home, for having hydrogen refuelling stations in their area, and for hydrogen-powered vehicles, buses and trains. Responses were scored from 0 (strongly against it) to 100 (strongly for it) and mean scores are shown below. There were support for all of these uses, with support for hydrogen buses and trains statistically higher than for other uses ($F(3) = 3.6$, $p = 0.013$).

- Heating $\overline{x}$ = 69
- Vehicles $\overline{x}$ = 75
- Buses and trains $\overline{x}$ = 80
- Refuelling stations $\overline{x}$ = 71

A key sub section of the public acceptance discourse is the notion that publics need to be better informed in order to more fully take part in decision making on hydrogen. Interview and observation data evidence this feature:

> *'The public must be educated informed and THEN involved. Then we can have rational decision making.'* (Interviewee AR6)

> *Discussion (Arcola question) on need to engage and increase understanding about hydrogen beyond events with lots of technical and policy experts and how to do this quickly.* (Summit, 26/6/19)

This point, i.e. that there is a current lack of knowledge about hydrogen, also chimes with survey data. From the open ended questions, 36% of respondents (the highest proportion) indicated they 'need to know' more about hydrogen. However, it can be contrasted with proposals (and successful testing of) 20% blend H2 in the current gas supply (Cadent Keele, 2019) without the perceived need to seek widescale public acceptance where safety testing is stringent and customers would not experience any difference in their supply or use. Similarly, other policy and industry actors commented on the limits to the need to seek public acceptance of technology when technical knowledge might be of little significance and raising public capacity to fully understand the technology will be time consuming. In this sense for example:

> *'We don't call the gas we use now 'methane' so why don't we just carry on calling it gas, or clean gas [when it's hydrogen]?'* (Interviewee, CB2)

> *'HSE testing is the important thing. Consumers don't want to know the details of how it all works, or what makes it safe, they just want to know that there are adequate checks in place to make sure that it is as safe as what we currently have.'* (Sakinder Mahmood, Future Networks Manager, Cadent, 26/6/19)

An interesting feature of the data which chimes with academic and grey literature, is that whilst there is considerable talk about the importance of getting the public acceptance piece right, there is very little actual public engagement, and strategies to engage with or better understand public perception and acceptance are as yet in their infancy despite the need to move quickly. An extension of this feature, and in keeping with temporal 'fail fast' comments noted above, is the need to quickly develop a body of 'social proof' **(**Mark Wheelden, SGN) in, for example, projects where the aim is not to do wholesale conversions to hydrogen but to integrate hydrogen in to existing infrastructures (e.g. the h100 project). For industrial actors, public acceptance issues equate closely with consumer testing and in particular safety. There is a perceived need to prove safety in order to gain (and sufficient for) public acceptance.

This perception seems to be a one-dimensional approach to public acceptance which may oversimplify sometimes place-based public perceptions on hydrogen, which disregards the significance of the wider role for public understanding of, and participation in debate and action towards, decarbonisation. In this view, publics are being asked to have a perception on, and knowledge about, a particular technology (i.e. hydrogen in this case) which is not a reasonable expectation. The extract below exemplifies this point:

> *'…public participation is about lobbying the government to create a radical agenda for change, and then it's up to them [the government] to get the experts around them to deliver it… it's not up to the public to figure this out. You know what I mean? It's just for us to say, look we want a safe future. It's quite clear what people want isn't it? A safe green future… We can't become the experts. It's up to the government to surround themselves with the experts to decide what to do with our tax and our resources.*' (Interviewee AR4)

**Public concern on Climate Change and air quality:** Contrary to observations and interview data from policy and industrial actors, survey results suggest that climate change and air quality are of greater concern than potential issues of safety. Survey data suggest high levels of support for developments that will address public concern relating to climate change, carbon reduction and air quality 'Reduce carbon emissions (2.05), help make the air in my community cleaner (2.54)'.

In addition, the importance of wider environmental impacts and future impacts was raised in interviews and survey data notably in relation to concerns about impacts of production of hydrogen and storage of CO2 produced in current hydrogen production. This point is exemplified by survey responses. We gave respondents descriptions of three different types of hydrogen (green, blue, brown see appendix) and asked whether they would prefer it to the current gas: natural gas. Responses were scored from 0 (prefer natural gas) to 100 (prefer hydrogen):

- Both green ($\overline{x}$ = 82) and blue ($\overline{x}$ = 59) hydrogen were preferred to natural gas, whereas natural gas was preferred to brown hydrogen ($\overline{x}$ = 32).

**Trust:** Gas network representatives feel they are the most trusted utility in country, noting they do not have any issue with public trust. The survey results to some extent support this, with moderate to high levels of trust for authorities and local industry but with caveat in open ended questions in survey as well as interview data that publics need more information before being able to make informed decisions.

- Respondents agreed that local industries should be set up to produce hydrogen ($\overline{x}$ = 5.6) and that local people should support hydrogen developments in our area ($\overline{x}$ = 5.3).

Interview data are less conclusive with some respondents noting that there are questions over public and stakeholder trust in 'the expert', for example, in actually delivering the promise of local green jobs. In this view there is a wider context of mistrust due to uncertainty resulting in people trying to build confidence by overstating certainty (and not being honest about risks and uncertainties) which then undermines trust when risks are revealed/become apparent as things go wrong – this is a cyclical process. There is also a perceived lack of trust in decision makers and the wider system of governance which impacts on publics and community ability to make their own decisions.

> *'I am worried that there will be a decide-announce-defend approach, this is definitely a risk'* (Interviewee AR12)

A proposed alternative is to have open conversations and, for example, citizens juries, which can be used to rebuild trust and create capacity amongst wider publics. Table discussions at the hydrogen summit touched on this point. The view was that whilst it is important to engage with wider public (NB, referred to as either 'the public' or 'consumers'), it is 'very time consuming' and 'ultimately decisions are made by very few people' (observations, 26/6/19). This clearly links with points raised above and in the literature, that public acceptance is deemed as important by policy and industrial actors, but does not necessarily happen in a democratic way that would support a just transition.

This discussion points to the need to explore opportunities for engagement with a wider variety of public. Currently where there is engagement beyond policy and industrial actors it is typically concerned with the public as consumers and as such engagement is typically consumer testing. Wider publics are informed (e.g. in newsletters, social media and local newspapers) rather than consulted.

These interesting findings in chorus suggest that there are disconnects between understanding of perceptions of different actors. Policy actors see the need for public engagement, industrial actors are more reticent, but see safety and testing as essential, whereas members of wider publics trust providers and policy makers to make technical decisions on health and safety, but want to know more about wider environmental implications of hydrogen.

## 4.3 Market

**Investment support:** Investment support is a core theme that ties closely with issues discussed in section 4.1, that there needs to be clarity on the investment decisions required to make transition to H2 viable. There is an identified need for UK central government to provide investment support for hydrogen development and to reduce financial barriers to entry where they exist. A key overarching theme here is the prevalence of uncertainty in developing a hydrogen economy.

> *'[Government] intervention is critical in the context of supporting investment in major low carbon infrastructure… which will simply not happen if 'left to the market'* (Cadent, 2018, 28)

> *'Central government need to provide support to help reduce cost barriers'* (Interviewee, AR4)

Interview and observation data suggest there are key gaps in understanding and some hesitance by key government officials to make decisions on investment. Phil Blyth at the National Workshop for example asked 'can we deliver 'decarbonisation'?' A clear emerging narrative (which connects with the narrative relating to temporal issues in 4.1) is that currently there are more questions (technical and socio-economic) than solutions, and that to a degree progress in getting answers to these questions is slow and not constructive. For example:

*'It feels like government planners just put on 'consultancy' until they get the answer they want.'* (Interviewee, AR3)

A proposition has emerged from the data that investment support is not forthcoming because the full lifecycle for hydrogen is not yet modelled and understood and there is reticence amongst key actors to avoid another 'diesel gate' for H2 and CCS development (i.e. spectacularly getting it wrong from a government policy perspective and/or being duped by the private sector). Interviewees pointed to the need for shared learning and cooperation across sectors and regions to spur the investment at scale needed for the production, transport, storage, distribution and consumption of H2.

**Market complexity and uncertainty:** Also influencing investment support is the market complexity of H2 development. For example, domestic conversion in particular is a more complex issue given the number of private companies involved as well as domestic uses and appliances. As summarised from events, key barriers to conversion to hydrogen include the number of private companies now versus when gas supply was first organised centrally; plus, connections to gas supply are now much more complex which would likely lead to more supply disruption during conversion. Furthermore, conversion of the UK gas system to transport hydrogen will need to be undertaken.

In addition, from a technical, energy efficiency perspective, hydrogen is seen by some as an inefficient way of heating. The narrative from electrification advocates is that it is more cost effective to improve the grid and use (renewable) energy directly rather than use energy to convert methane to hydrogen (Interviewee, JV1). In this sense it is difficult to promote the benefits of hydrogen to investors when the both technical and market development is so complex and likely to be costly to roll out for domestic or transport use.

These issues are affecting Government's ability and readiness to make decisions on the future of hydrogen. The tendency then to leave decision making to the market does not provide both the rapid and substantive decarbonisation actions needed to reach Net Zero by 2050. As one interviewee stressed, the market is not moving fast enough because it is locked into 'corporate boardroom type discussions.'

**Hydrogen vs alternatives:** While for advocates, hydrogen is viewed as 'the fundamental building block for the UK to meet its 2050 [carbon reduction] targets' (H21, 2018, 4), others highlighted the tension between electricity vs hydrogen for domestic heating and transport. One expert felt there needed to be a blend with electrification, another was pro-electrification for domestic heat (e.g. heat pumps), and still another expert interviewee felt that if existing building regulations were upgraded coupled with incentives for home retrofits, then home heating systems may not be necessary at all in the UK. There was broad concern that, particularly on domestic heat, big business was trying to save a legacy 'stranded asset' (domestic gas) by converting existing infrastructure over to H2, while other more potentially efficient and effective alternatives were being overlooked (e.g. updating building regs with significant retrofit investment). On transport, there was more consensus that H2 needs to be part of the equation, particularly for HGVs. Observation at hydrogen events revealed that further research should engage with the energy community beyond hydrogen and gas transmission, e.g. electricity and renewables.

**Varieties of H2 and cost:** A key concern is the cost of hydrogen given, as an industry expert pointed out, that hydrogen for rail transport is not competitive with diesel at its current cost. Interviewees highlighted the need for revised business models, e.g. for rail franchises to implement H2 trains and for H2 to be factored into new price controls (i.e. through 2021-2026 government regulations). Given the production of clean hydrogen is expensive, there is an imperative for government and industry to

bring the cost down (interview, AR10). Discussion at the Hydrogen Summit revolved around the proposition that customer acceptability hinged upon cost, and that politicians will need to have an open debate with the public on the cost of decarbonisation.

The challenge of cost and preference for green hydrogen is illustrated with survey results:

- Green hydrogen is strongly preferred ($\overline{x}$ = 82) and blue ($\overline{x}$ = 59) hydrogen is preferred to natural gas, whereas natural gas was preferred to brown hydrogen ($\overline{x}$ = 32). There was a significant difference in use preference, with green hydrogen scored significantly higher than blue or brown hydrogen ($F(2) = 40.9$, $p < 0.001$).
- Acceptance of higher cost in order to secure green energy £1.11:£1 for higher income groups versus estimates of hydrogen costs modelling

Note that estimated cost for green hydrogen are £3.30 – £4.15/kg, grey £1.35/kg i.e. *'…approximately double cost of natural gas so from an economic perspective if you're not factoring in wider benefits to the region then why not do gas and CCS?'* (Interviewee CB2). Expert and general public stakeholders highlighted the need for economic incentives to spur H2 innovation and investment particularly towards green hydrogen.

For example, in answers to open questions in the survey respondents noted that economic incentives are required to support companies in the hydrogen sector, and also subsidies to make domestic hydrogen fuel sufficiently cheap to be acceptable to the public. Some also highlighted that the public would also need financial subsidies if they are expected to replace their appliances. Respondents also stressed the need for research investment so that technologies are developed and tested.

**Regional and local economic benefits:** Discussions at the Summit and in interview data suggest there are potential regional economic benefits, noting opportunities for industrial symbiosis and regional hubs. A whole energy systems approach to develop a hydrogen economy was emphasised by presenters. Participants at events as well as interviewees highlighted the need to transfer the loss of old gas jobs to high value green jobs, which will need to happen as a joined up process with wider links between old (sunset) and new industries. The importance of localising supply chains to spur SME development was stressed as well as the importance of learning from the missed opportunity of localising growth from the offshore wind industry. Given the decline of heavy industry in the hydrogen corridor participants said that any hydrogen development must recognise the potential to regenerate the region and replace lost jobs/skills and that H2 jobs must support and enable a just transition. There was universal support for the need to raise the skills base and link to schools and colleges.

# 5 Concluding summary

Hydrogen has been proposed as a key means of decarbonisation within and between Leeds and Teesside. To support the H2CORE Strength in Places Fund (SIPF) bid, this scoping study uses a social acceptance conceptual framework to evaluate the socio-political, community and market factors that may influence the large-scale use of hydrogen as an energy vector. Through the triangulation of data from surveys, interviews, participant observation and document analysis, key and important knowledge gaps and areas for further research have been identified within the social-economic, environmental and regulatory workstream (CC2) of the H2CORE bid.

It is worth noting here, that in this analysis there are multiple, interconnected key features that would be expected for an issue with wide ranging and related implications. This interconnectedness warrants further exploration as part of future research and is noted below in summarising and

addressing the bid questions. Figure 2 below provides a summary of these key features according to their relevance in terms of socio-political, community and market related issues.

Temporal issues are particularly relevant across all three social acceptance features in this case. For socio-political/governance issues, a need to establish a policy framework which is suited to both short term decision making for example for testing of suitability of hydrogen use in different settings (transport, domestic, industrial), as well as medium to long term decision making for example investment decisions. Complexity here relates to the need to move forward with hydrogen developments in the short term if its use is to contribute to decarbonisation in line with Net Zero and Climate Change Act commitments.

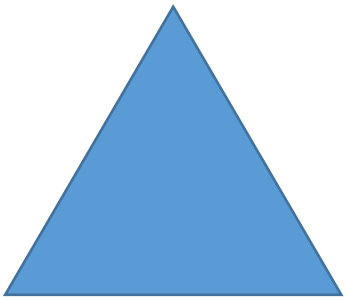
In relation to community issues, data suggest that hydrogen is seen as a potential means of reducing carbon emissions. Challenges relating to social acceptance, in particular to a need to increase knowledge and understanding of hydrogen as an energy vector in different contexts have been discussed. In keeping with social acceptance literature, this analysis suggests that public support and acceptance is important at early stages of development, however, it also adds that there are currently low levels of understanding of hydrogen and its use, together with some historical concerns about safety.

This review suggests that market (in particular economic) related issues are also cross cutting. A critical feature of the data from all sources is that clarity is needed on socio-political and governance issues in order for investors to support hydrogen developments. Cost estimates to produce green hydrogen are significantly higher than costs to produce natural gas with CCS, and there is contested policy space in terms of which energy vector, or which combination of energy vectors, will gain Government support. In this sense, for hydrogen to be economically viable, there needs to be government investment at scale; private sector investors and incumbent industry actors are not likely to risk investment without such policy and financial guarantees.

*Figure 2: Social Acceptance Framework for Teesside to Leeds Hydrogen Corridor*

**Socio-political**

- Clarity needed on national policy to support Net Zero targets and commitments under Climate Change Act
- Temporal issues – need to be able to move now and 'fail fast'
- Scalar issues - need for locally relevant policy development to support whole systems approach. Local political will exists but not clear of national support for hydrogen over other potential low carbon energy vectors. Devolution, especially of transport decision making



**Community**

- Public support for developments to improve air quality and support carbon reductions
- Current low levels of public engagement, narrow range of stakeholders engaged, and questions over trust in experts/decision-makers
- High levels of economic inequality in the region and degradation of formerly industrial region; economic development is needed

**Market**

- Potential for regional and localised green growth
- Current high levels of unemployment and low skilled employment
- Opportunity for new high skilled, green jobs in the region
- Challenge of balancing costs of green hydrogen versus who pays discourse
- Consumer acceptance testing to date positive
- Temporal issues – need clarity on government position in order to make investments

Finally, the analysis here is useful to support H2CORE's SIPF bid. Features of the thematic analysis relating to the social science-related bid questions have been summarised below.

***What is the intended significant, relative, uplift in growth and/or productivity as a result of the activities proposed?***

Thematic analysis of interviews observations and document data highlight the potential for hydrogen development to be part of a just transition to clean low carbon energy. As an energy producing area and having faced historical impacts of energy and economic decline, hydrogen development present an opportunity to create highly skilled jobs. However participants at events and interviewees stressed the need to transfer the loss of old 'high carbon' jobs to high value green jobs to enable a just transition. The importance of localising supply chains to spur SME development was stressed as well as the importance of learning from the missed opportunity of localising growth from the offshore wind industry. Finally, there was universal support for the need to raise the skills base and link to schools and colleges.

***What is the importance of this consortium to the local economy?***

Job creation, and particularly the potential for high skilled 'green' jobs in the local economy, is a significant theme emerging from our research (see for example survey results in appendices 1 and 2). The IPPR has identified up to 46,000 low carbon jobs in the north of England by 2030 that could be created in the energy sector alone (not just hydrogen). However, this needs to be balanced against risks of job losses high carbon energy sector (IPPR estimates up to 28000 jobs at risk in the coal, oil and gas industries by 2030).

***What broader societal and environmental impact will the project bring to the chosen geography? This can include impacts on areas such as quality of life, diversity, education, social inclusion, health***

Survey respondents highlighted critical features of hydrogen developments that would encourage their support, which include environmental benefits, improving local quality of life and enhancing the regional economy. Respondents were asked to rank a set of six potential benefits from hydrogen. The responses showed three clusters. The mean ranks (with lower numbers indicating greater perceived benefits) are:

- Reduce carbon emissions (2.05), help make the air in my community cleaner (2.54)
- Make the area a better place to live (3.65), create local jobs (3.69)
- Support the local economy (4.23), help the region become a centre of excellence for hydrogen (4.82)

***Is there the potential for your project to have an impact on local or national policy?***

Yes. One of the key issues facing decarbonisation strategies such as hydrogen is lack of policy certainty and ambition (document, interview and observation data). The SIP project has already stimulated discourse among major actors (e.g. the gas lobby, academics, SMEs) via the National Hydrogen Summit held in Leeds in July 2019. The BEIS select committee aims to establish a more supportive policy environment for hydrogen. Interviewees spoke of the need for a more coordinated, overarching national energy policy, especially following the Net Zero targets announcements. Some argue that this is more important than the Industrial Growth Strategy.

Development of a hydrogen economy locally will be a pilot for testing the costs/benefits etc for a clearer national hydrogen policy.

Devolution is also an issue for local governance of transport systems and potentially new technologies, which was mentioned by several interviewees. This may be restricting the autonomous development of relevant local policy. Interviewees highlighted the role of WYCA and the LEPs as important in the development of hydrogen.

***How have you built in appropriate engagement with relevant publics into the design of your project*?**

A key finding in this review is that public engagement and knowledge and capacity building is essential for social acceptance of hydrogen. The project thus far has held stakeholder scoping workshops, interviews and the two surveys: the Leeds Big Climate Conversation (hosted by Leeds City Council and Leeds Climate Commission) and the SIP scoping study survey that we sent to Leeds' Citizens Advisory Panel and through Teesside's social media channels. We have so far engaged with a mix of experts and lay citizens through these channels. Moving forward, a range of engagement strategies with a variety of publics are proposed through the various projects in each work stream.

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# Appendices

## Appendix 1– Strength in Places, hydrogen corridor survey responses July 2019: Headline findings from the Hydrogen Survey

An online survey was developed that addressed beliefs about the region developing and using hydrogen technologies and about the potential role of hydrogen in tackling climate change and air pollution. A total of 578 responses were received: 548 from Leeds and 30 from Teesside (we hope Teesside's response rate increases over next two weeks). This is a summary of responses to closed questions. The open questions from the survey will be analysed by next week.

Respondents were told that hydrogen only produces water when it is used and so can reduce carbon emissions and air pollution. They were asked a series of questions about how much they agree or disagree with using hydrogen and with tackling climate change and air pollution. Responses were scored from 1 (strongly disagree) to 7 (strongly agree). Respondents agreed that:

- Local industries should be set up to produce hydrogen ($\overline{x}$ = 5.6)
- Local people should support hydrogen developments in our area ($\overline{x}$ = 5.3)

They did not agree that

- Investing in hydrogen is a waste of money ($\overline{x}$ = 2.5)
- Hydrogen will be bad for our region ($\overline{x}$ = 2.6)

They agreed that there is a need to tackle air pollution from vehicle emissions ($\overline{x}$ = 6.4) and air pollution ($\overline{x}$ = 6.3), that it is really important to move to an energy source that creates less carbon ($\overline{x}$ = 6.3) that everybody has a responsibility to reduce climate change ($\overline{x}$ = 6.2). Both the UK government and local government were believed to have a responsibility to tackle climate change ($\overline{x}$ = 5.9 and $\overline{x}$ = 5.7 respectively). There was more uncertainty about whether hydrogen technologies will only benefit big businesses and not local people ($\overline{x}$ = 3.4) and whether they would want to live near a hydrogen production plant ($\overline{x}$ = 4.0). There was also uncertainty about whether local businesses and the national government (both $\overline{x}$ = 3.7) and local councils ($\overline{x}$ = 4.0) can be trusted to make good decisions about hydrogen technologies, However, people trusted that hydrogen technologies will only be introduced if they are safe ($\overline{x}$ = 5.1).

Respondents were asked to rank a set of six potential benefits from hydrogen. The responses showed three clusters. The mean ranks (with lower numbers indicating greater perceived benefits) are:

- Reduce carbon emissions (2.05), help make the air in my community cleaner (2.54)
- Make the area a better place to live (3.65), create local jobs (3.69)
- Support the local economy (4.23), help the region become a centre of excellence for hydrogen (4.82)

Respondents were told that we don't know how much hydrogen will cost. They were asked: For every £100 you spend on heating your home at the moment, how much would you be prepared to pay to use hydrogen? Possible responses ranged from £100 to £140. The mean response was £108, with those finding it difficult to live on their current income being prepared to pay less (£102) than those who are better off, who would pay up to £111($F(3) = 5.96$, $p = 0.001$). The amount people were prepared to pay was predicted ($R^2 = 0.16$) by their belief that it is important to move to an energy

source that produces less carbon and their household income. There were no differences based on age or gender.

Respondents were asked about their support for using hydrogen in their home, for having hydrogen refuelling stations in their area, and for hydrogen-powered vehicles, buses and trains. Responses were scored from 0 (strongly against it) to 100 (strongly for it) and mean scores are shown below. There were support for all of these uses, with support for hydrogen buses and trains statistically higher than for other uses ($F(3) = 3.6$, $p = 0.013$).

- Heating $\overline{x}$ = 69
- Vehicles $\overline{x}$ = 75
- Buses and trains $\overline{x}$ = 80
- Refuelling stations $\overline{x}$ = 71

Additional questions on perceptions of safety, environmental impact, and how worried they would feel about using hydrogen in this way were asked about two of the uses: hydrogen in the home and for refuelling stations. All of these were significant predictors of support. They explained 47% in the variance of support for using hydrogen in the home, with the strongest predictors being how it would affect the environment (standardised ß = 0.46) and how worried they would feel (standardised ß = 0.33). They explained 68% of the variance in support of hydrogen refuelling stations, with the strongest predictors being how it would affect the environment (standardised ß = 0.57) and how safe they are (standardised ß = 0.23).

We gave respondents descriptions of three different types of hydrogen (see below) and asked whether they would prefer it to the current gas: natural gas. Responses were scored from 0 (prefer natural gas) to 100 (prefer hydrogen). Both green ($\overline{x}$ = 82) and blue ($\overline{x}$ = 59) hydrogen were preferred to natural gas, whereas natural gas was preferred to brown hydrogen ($\overline{x}$ = 32). There was a significant difference in use preference, with green hydrogen scored significantly higher than blue or brown hydrogen ($F(2) = 40.9$, $p < 0.001$).

- Green hydrogen is produced from water using renewable electricity (e.g. solar, wind). This doesn't produce any carbon at all, either when hydrogen is produced or when it is used.
- Blue hydrogen is produced from natural gas. The carbon produced in the process is stored securely underground. This process is carbon neutral.
- Brown hydrogen is produced from natural gas. The carbon produced in the process is released into the atmosphere. It produces more carbon than blue or green hydrogen.

Respondents were asked whether Universities in Leeds and Teesside should apply for research funding to help the region become a national centre for hydrogen use and production. There was very strong support for the bid. Respondents answered on a scale from 0 (strongly against this funding) to 100 (strongly for this funding). The mean score was 84 (84 Leeds, 88 Teesside).

*(exact wording: Universities in Leeds and Teesside are applying for government research funding to help our region become a national centre for hydrogen production and use. This funding would be used to find out the best way to produce, distribute and use hydrogen and to help develop new technologies that could be used nationally and internationally. They hope that this will benefit our region by producing new jobs, reducing carbon dioxide emissions and improving air quality. - Do you think they should apply for this funding?)*

## Appendix 2 - Responses to open questions in Strength in Places survey July-August 2019

Respondents to the survey were asked a series of open-ended questions:

**1. Do you have any comments about using hydrogen to decarbonise our economy?**

Respondents were asked if they had any comments about using hydrogen to decarbonise the economy. They were free to answer in any way. We analysed the data using content analysis, in which responses are coded and the codes grouped into categories. Each respondents' comment could contain several codes and contribute to several different categories. We identified six categories of responses in the comments that respondents gave on this topic. These are described below and illustrated with example responses. The proportion of comments in each category is shown in Figure A6.1.

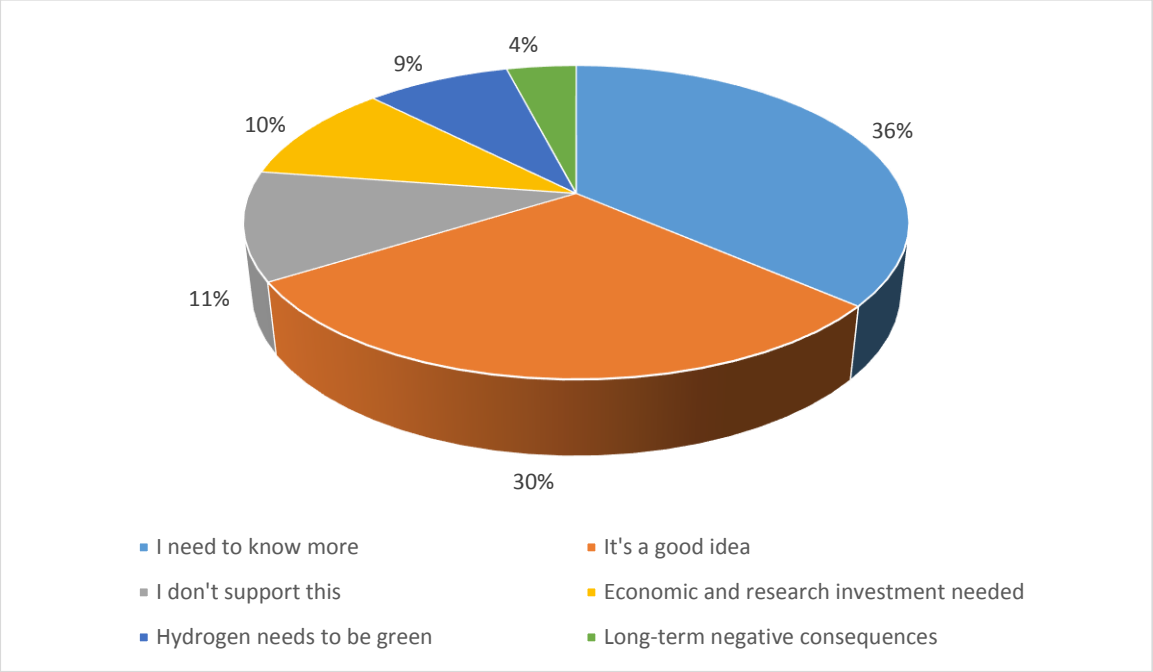


**Figure A3.1: Proportion of comments about using hydrogen to decarbonise the economy.**

**I need to know more**

Many respondents noted that they need more information about hydrogen, such as its benefits and how they compare with renewable electricity, and how "clean" hydrogen really is. Many wanted reassurance, most commonly about its safety. Several noted that there would need to be extensive safety testing and that this should be carried out independently and not by the industries that will profit from hydrogen. There were also comments about how people wanted to know more about who would own hydrogen industries and who would receive the profits, with a few noting that communities should receive the profits. People also questioned the motivation behind introducing hydrogen and wondered whether it is better for the environment or better for shareholders. Many of the comments were simply that people don't know enough about this topic and that there needs to be a public information campaign.

*A greater understanding of production & benefits would be welcomed.*

*Don't really know enough about it the environmental benefits (and risks - water vapour is a greenhouse gas after all too) but I think that's the key starting point: how is produced, what is the well-to-wheel carbon intensity, how does that compare? Next question is about the wider risks and then economics. Not just on average but who takes the risks, who gets the benefits?*

**It's a good idea**

These comments express support for hydrogen technologies, most commonly because it protects the environment. Several noted that this seems to be the best option for the future, and some that it seems a better option for transport than electric vehicles, which have problems with batteries. Many added provisos, such as it being a good idea only if it is safe, if it is not too expensive, if it does not release carbon into the atmosphere, or as long as it increases jobs in the area.

*The implementation of safe alternatives to fossil fuels and carbon emitting technologies is urgent and vital. As a resident of Tees Valley, I feel there is no ambition more important.*

*Only good if it can be guaranteed to be absolutely safe, economical to produce and as low a price as possible for the end user. It must be comparable to other energy types on all these counts, otherwise there will be no support for it.*

**I don't support this**

These responses were about not supporting the use of hydrogen. There were many reasons for this, including that hydrogen is an explosive gas and therefore not safe to use, that we should make use of current alternatives to fossil fuels (e.g. renewable electricity), that it will cost too much and people won't be able to afford to replace their appliances. Several comments were made about the UK contributing only a tiny proportion of the world's carbon emissions, and so any change to hydrogen would have a negligible impact. There were a few comments about climate change being a natural process and so no action is required. One respondent highlighted that if everybody's appliances are scrapped then there will be a huge increase in landfill waste.

*Only older people will remember the Hydrogen bomb. Hydrogen is explosive and can cause immense damage in the event of an accident.*

*Hydrogen is extremely dangerous. It is spontaneously flammable in air, above a very small mix, about 17% if I remember. It must only be used in an industrial capacity.*

*Wind and solar energy production and increasing battery storage technology should make hydrogen technology redundant. There seems little point in investment in a technology that is unlikely to be universally adopted.*

**Economic and research investment is needed**

These comments are about a need for investment in hydrogen technologies if it is to be viable. Respondents noted that economic incentives are required to support companies in the hydrogen sector, and also subsidies to make domestic hydrogen fuel sufficiently cheap to be acceptable to the

public. Some also highlighted that the public would also need financial subsidies if they are expected to replace their appliances. Respondents also stressed the need for research investment so that technologies are developed and tested. Finally, a few comments were about the need for sustained commitment to hydrogen, rather than support withdrawn and switched to a different energy source in a few years.

> *To the best of my knowledge Hydrogen is a very flammable gas & unless it is produced, processed & handled with great care can be extremely dangerous. Decarbonisation is a worthy cause, but there would need to be very stringent health & safety measures taken to bring it into general use.*

> *An excellent idea - the obvious current obstacle is viability. Until there is a specific economic incentive for hydrogen, or conversely a significant penalty for natural gas/other carbon-based fuels, the technology will not take off commercially.*

**Hydrogen needs to be green**

The comments are about the importance of green (rather than blue or brown) hydrogen being developed, although some noted that there may be a need to rely initially on blue hydrogen until there is the technology and capacity to cost-effectively produce enough green hydrogen. A few respondents highlighted that hydrogen should be only one of a range of measures to reduce carbon emissions, and that there should also be a drive to reduce consumption. A few were concerned that a switch to hydrogen would slow research into alternative solutions.

> *I like the green hydrogen approach a lot. I'm much less happy about those based on continuing fossil fuel extraction. It feels like "green washing" by the fossil fuel industry.*

> *Concerns that reliance on hydrogen will prevent transition to potentially "greener" solutions and prevent the overall reduction in consumption, manufacture etc that is probably needed.*

**There may be long-term negative consequences**

Several respondents expressed concerns about possible long-term problems to both our health and to the environment that we are not currently aware of. For example, if water is used to produce hydrogen, there could be future problems with the water supply. There were also concerns that there may be negative health implications if people are exposed to hydrogen, and whether oxygen released during hydrogen production might be harmful to health. A few noted that nuclear power had previously been promised as a safe and cheap alternative, but there are long-term problems with nuclear storage and there have been explosions at nuclear plants.

> *The long-term effect is not known. It is like nuclear energy: it was OK at first now they have a mountain of nuclear waste which they don't know what to do with and disposing of it will be very very expensive.*

> *Any steps to decarbonise our economy are desirable but I wonder what impact it will have on the country. If it converts hydrogen to water presumably this involves the absorption of oxygen from the atmosphere so what, if any problems, will this create for flora and fauna?*

**2. Do you have any concerns about our region becoming a national centre for producing, using, and distributing hydrogen?**

Many respondents had no concerns about the region becoming a national hydrogen centre. Many, however, commented that they don't know enough about the topic to have any concerns and that if this initiative goes ahead the public will need a great deal of information on hydrogen. We identified four categories in the data: the proportion of comments in each category is shown in Figure A6.2.

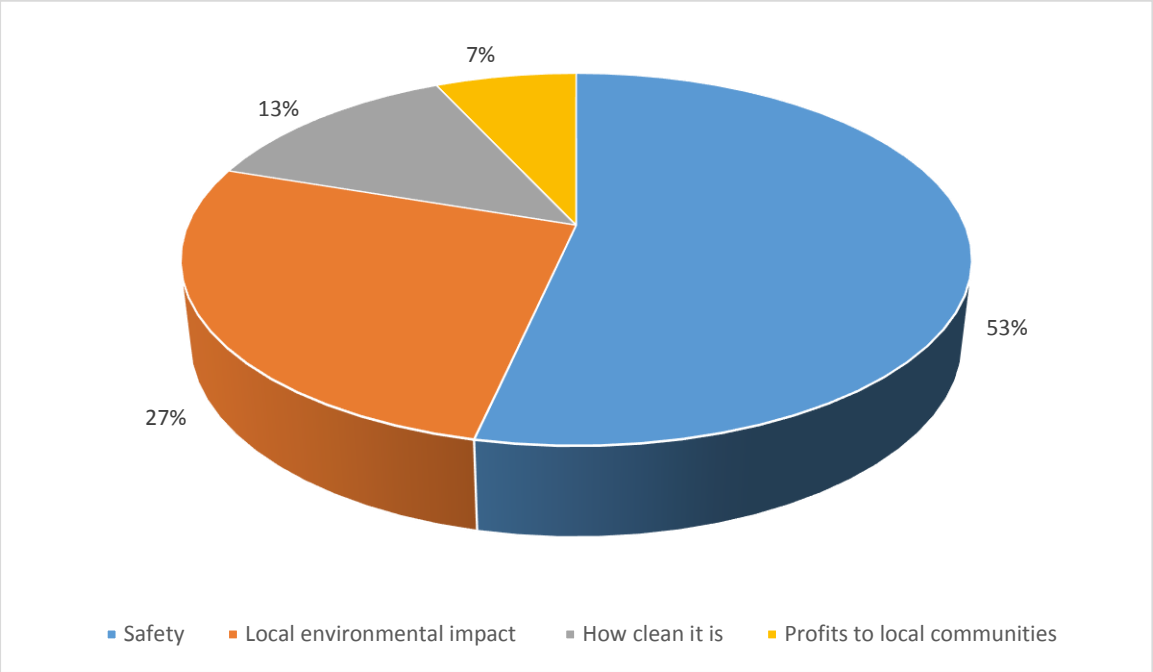


**Figure A3.2: Proportion of comments on concerns about hydrogen.**

**How safe is it?**

These concerns are about the safety of hydrogen, including when it is used and also when it is produced, stored and distributed. There were comments about the need to make sure a hydrogen industry is properly regulated, and that there is strong legislation in place to ensure safety.

> *I always thought that hydrogen was highly explosive and flammable. I'd need cast iron guarantees about the safety of the process, storage and end result before I committed to living near such a facility.*
>
> *I think Hydrogen production plants should be placed well away from any homes or other industries because it is so dangerous and highly volatile. Any production plants should be placed in the North or Irish sea or on uninhabited islands off the Scottish coast because of the risk of explosion.*
>
> *It could make living in the area more dangerous.*

**What will the local environmental impact be?**

These concerns are about the impact that hydrogen plants will have on the environment in the local area. Respondents identified that there might be increased noise, a rise in HGVs in the area, more pollution. Some were concerned that sites may be located where they live, which may make it a more unpleasant environment and adversely affect house prices. There were comments about the disruption while hydrogen plants are built and potentially roads dug up to lay new pipes. However, a few respondents noted that there are already oil plants in the local area so having hydrogen plants would not make much difference. A few respondents were concerned that we should be making the local economy more diverse rather than continuing the narrow focus on the chemical industry. A few noted that if local money is invested in the hydrogen industry it could divert money away from other areas that require improvement, such as transport.

> *It would be a great concern if hydrogen tankers are on our local roads.*
>
> *This will not help to diversify the regional economy it will embed further unsustainable chemical manufacture in the region.*
>
> *It is a concern if distribution points are centrally located, resulting in more traffic. However, if they are located on the fringes of our borders and possibly directly from the motorway network (e.g. vehicles not having to travel through suburbs to deliver/collect) and directly next to the rail network so deliveries can be made by rail. If these locations are sensibly placed then I have no concerns.*

**Will it be as clean as claimed?**

These concerns were about whether hydrogen is as good for the environment as it is claimed. Many respondents highlighted that it needs to be produced using renewable energy sources, and that it should not damage the environment. Several stressed the need for it to be green hydrogen. A few were concerned that hydrogen could be seen as a "quick fix" and so efforts would be diverted away from developing other approaches to reducing carbon emissions. This was particularly the case if blue hydrogen is used rather than green.

> *Not sure if it will be that clean to produce but if it can be achieved, I am all for it*

**Profits go to local communities**

Many of these concerns were about hydrogen businesses being set up by large corporations, and all the profits taken away from the region. Respondents suggested that businesses should be owned by local communities and profits used to benefit the local people. Several respondents were concerned that there may not be good decision making about hydrogen, with decisions based on profit rather than safety and environmental protection.

> *Patents should not be swallowed by big petrol and locked away.*
>
> *I do not trust this government to make the right decisions about major changes in producing using distributing hydrogen. They are far too interested in making money do themselves and their friends and not about what is in the best interests of our region.*

*I have no concerns as long as it is controlled by the local populations in democratic way and benefits the local population.*

**3. What benefits do you think there might be if our region becomes a national centre for producing, using, and distributing hydrogen?**

Respondents suggested a wide range of benefits arising from the region becoming a national hydrogen centre. We identified four categories in the data: the proportion of comments in each category is shown in Figure A6.3.

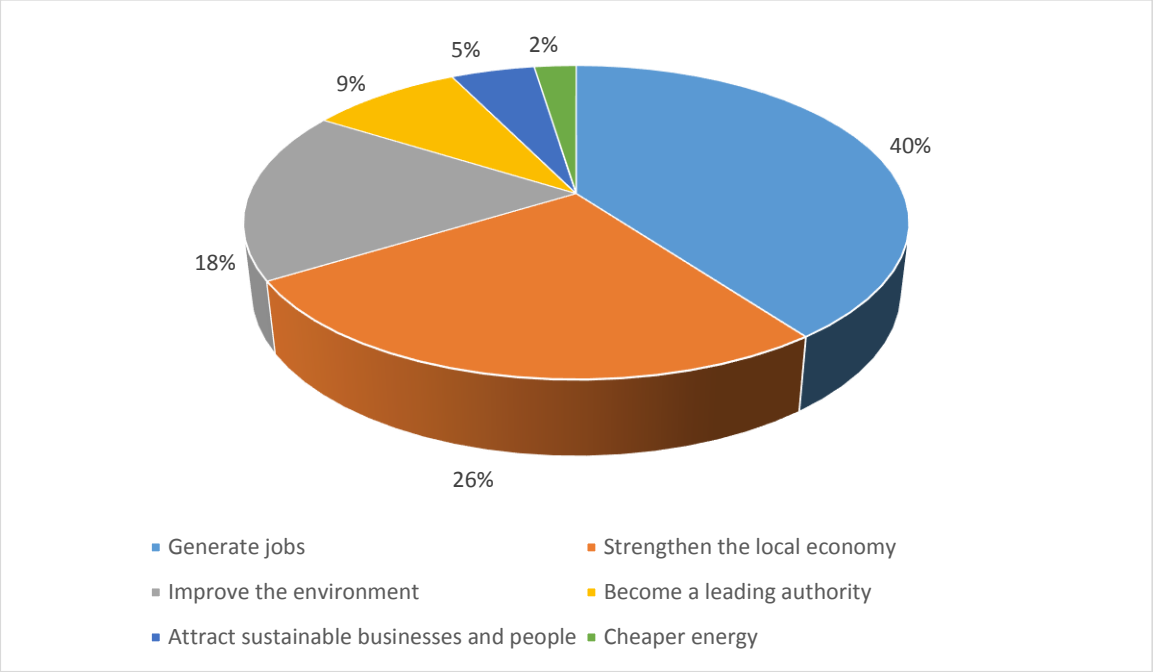


**Figure A3.3: Proportion of comments about the benefits of the region becoming a national hydrogen centre.**

**Generate jobs**

The most common response was that becoming a national centre will bring more jobs to the local area. Several highlighted that there will be highly skilled jobs in science, which will help keep local talent in the area.

*More jobs, good prospects for young people.*

*Job economy and science careers.*

**Strengthen the local economy**

These benefits were about how becoming a national centre will bring investment into the local area. Respondents noted that there would be spin-off companies set up, and there would be benefits to the supply chain, including for small businesses. The hydrogen industry was assumed to need highly

skilled people on high incomes, which would also benefit the local economy. Overall, the region would become more prosperous. A few respondents noted that if the region were a national centre it would become more important and have increased influence with government. This in turn was thought to further strengthen the local economy.

> *A region that shows foresight in any new technology usually benefits from other forms of investments, therefore the more professional we appear as a region would have a knock-on effect for other industries and attraction of new talent.*
>
> *Stimulation of the local economy through the introduction of new industries starting up in the area.*

**Improve the environment**

Many of these comments were about the region helping to reduce carbon emissions, which would have benefits both locally and globally. It was also suggested that becoming a national centre would help produce a better local environment. Many were about how it would lead to cleaner air.

> *It will lead the way towards genuine environmental improvements and "greenhouse" gas reductions. It will make the cities less dangerous and more pleasant.*
>
> *Good for reducing lung problems i.e. less hospital visits.*

**Become a leading authority**

These benefits are about how the region would become a leading and sought-after authority on hydrogen. This would benefit the region's reputation and it would become known for leading the way in sustainable energy. Other areas would look to the region for advice and guidance. There would be a highly skilled workforce

> *We could become leaders in the quest for carbon reduction.*
>
> *Naturally economic benefit and job creation but just as importantly, the benefit of branding the region as one of green technology, cleaner air and leaders in innovation.*
>
> *The brand of Leeds as a centre of technological innovation and sustainable energy is something the community can get behind in a positive way.*

**Attract sustainable businesses and people**

These benefits are about our region – as a national centre – becoming more attractive to businesses. It was suggested that businesses would be attracted by easier access to carbon-neutral energy, and by the region having a reputation for innovation and for sustainability. A few respondents noted that the region would also attract people who want to work in the sustainable energy sector, and people who support sustainability more broadly and have pro-environmental attitudes. This was believed to be helpful in making the area a better place to live.

> *Attraction of industries themselves which will rely on carbon-free energy. The survival of energy intensive industries in a post-carbon world will likely in some way depend on*

*hydrogen technology, and to have it on our doorstep will attract companies which recognise this threat.*

*More industries moving to our area to take advantage of carbon-neutral power.*

*Attracts people with the progressive attitude to sustainability and securing a safe future for my grandchildren.*

**Cheaper energy**

Several respondents suggested that if hydrogen were produced locally there would be an abundant and reliable source of cheap fuel. Some also believed that the cost of fuel would be lower than in other areas of the UK.

*Cheaper fuel in the locality.*

**4. Do you have any other comments about our region becoming a national centre for producing, using, and distributing hydrogen?**

Respondents were invited to leave additional comments about the region becoming a national centre. There were a wide range of comments, supporting the idea, expressing concerns and reservations, expressing opposition, and highlighting that they don't have enough knowledge of hydrogen to have an informed opinion. Their responses were categorised and described below. The proportion of responses in each category is shown in Figure A6.4.

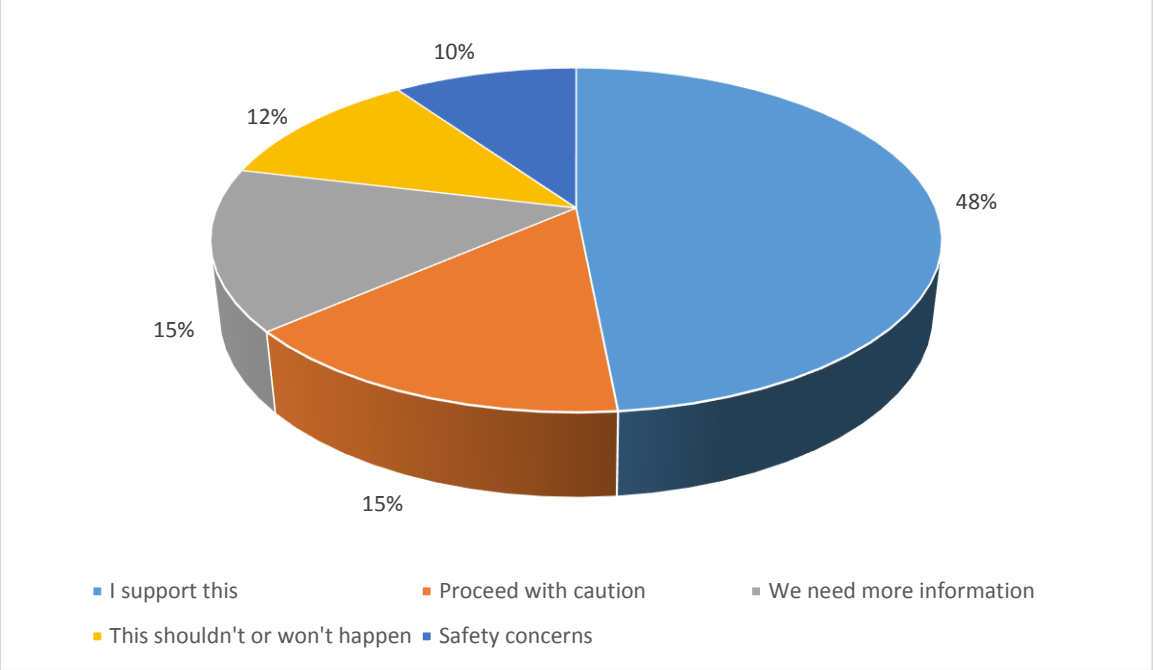


**Figure A3.4: Proportion of general comments in each category.**

**I support this**

These comments were about respondents being fully or mainly supportive of the region becoming a national centre. Most comments were that the region should "just get on with it" and about how it will benefit the region, bring jobs to the area, and build a reputation for innovation and for sustainability. Some of the comments were about how this needs to happen quickly if we are to protect the environment or to put the region at the forefront of technology.

> *I am fully supportive that our region should become a national centre as this will put our region on the map for good reasons (i.e. helping the environment and reducing the UK's carbon emissions).*
>
> *Get on with it, get there first, make it happen. Attract funding from government and investors.*
>
> *If we don't move quickly we will miss the only current opportunity to rejuvenate the Tees Valley economy, and this will lead to further decline.*
>
> *Go for it. We need a new green energy economy. This has to start somewhere, why not here?*
>
> *It would be a good thing for promoting Yorkshire around the world.*
>
> *I think it would be an honour to lead the country, and other countries. A beacon of sense and responsibility in what are worrying times. David Attenborough would certainly be a great supporter; and lots of people listen to him as the only person who is facing the realities and truth of what we are doing to our beautiful planet.*

**Proceed with caution**

These comments expressed support for the initiative, although with caveats. Respondents highlighted the importance of steps such as conducting sufficient research to be sure of the benefits and the potential negative impacts, introducing appropriate regulations and safeguards, and making safety rather than profits the top priority. Some highlighted that research into hydrogen should not mean that research into alternative renewable energy sources should cease.

> *Just make sure you check and double check the facts including associated costs of providing this product because get it wrong and it would give a negative view of our region.*
>
> *Providing the cost benefit equation works, and it's absolutely safe in all regards, the sooner the better!*
>
> *Safety must be number 1 priority, no cutting corners to save money. Mustn't be in our region simply to avoid it being in the south.*
>
> *It has to be safe and not impact the environment in other ways.*

**We need more information**

These comments were about not knowing enough about the topic to know whether or not this is a good idea, or that information for the public needs to be developed and distributed.

*I do not have enough information to comment on hydrogen technologies.*

*I don't think we have enough information on the pros and cons to make an informed decision*

*I need to understand hydrogen as energy better before I can say it would be a good thing. The government supports fracking and nuclear so they really can't be trusted to tell us what would be the best thing to use for energy.*

**I don't support this or doubt it can happen**

These comments did not support the region becoming a national centre or were about being cynical that hydrogen could be used as a safe and cost-effective fuel. There were several comments that the scale of the required infrastructure is so great that it will not happen, and that the project will, like others, over-run and over-spend. There were also a few comments expressing distrust of political leaders' motivations and ability to deliver the project.

*Do not even think about it!!!!*

*I believe the impact is limited in the UK and the impact on industry. As you eliminate one industry along with jobs and infrastructure you create new jobs and infrastructure, but will it balance the employment equation? I doubt it will.*

*I'm worried that it will steer other industries away from our region.*

*Is the infrastructure adequate to support such a large-scale project? Who will it impact on the areas surrounding the production and distribution plant?*

*It will no doubt be a project that like many previous ones, comes in way way over budget. Taxpayer beware!*

*I think it is untrustworthy as our political leaders.*

**I have concerns about safety**

These comments expressed concerns about how safe producing, using or distributing hydrogen actually is, or about long-term unintended consequences. A few respondents noted that their concerns may be alleviated as more research is done and information released.

*Concerned about safety and becoming more industrialised*

*My only concern for our region would be where would all the water come from if it was to be used in the hydrogen production.*

## Appendix 3 – Data sources

| | |
|---|---|
| JVA | James Van Alstine |
| CB | Claire Bastin |
| AR | Amy Ross |
| FF | Fiona Fylan |
| KFS | Karely Felix-Salgado |

*Table A3.1 – Interviews*

| Interview | Interest |
|---|---|
| AR1 | Academic |
| AR2 | Policy – Local/regional governance |
| AR3 | Environmental NGO |
| AR4 | Academic/community activist |
| AR5 | Environmental NGO |
| AR6 | Academic |
| AR7 | Industry |
| AR8 | Industry |
| AR9 | Trades Union |
| AR10 | Trades Union |
| AR11 | NGO |
| AR12 | Policy – national governance |
| CB1 (with JVA1) | Energy expert |
| CB2 | Policy – Local/regional governance |
| CB3 | Energy expert/Local Government |
| JVA1 | Energy expert |
| JVA2 | Academic |
| JVA3 | Academic |
| KFS1 | Policy – Local/regional governance |
| KFS2 | Industry |
| KFS3 | Industry |
| KFS4 | Industry |
| KFS5 | Industry |
| KFS6 | Business lobby |
| KFS7 | Industry |
| KFS8 | Industry |
| KFS9 | Industry |
| KFS10 | Industry |
| KFS11 | Academic |
| KFS12 | Academic |

*A3.2 – Documents reviewed*


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*Table A3.3 – Observations/events*

| **Date** | **Event** | **Host** | **Details** | **Attending researcher** |
|---|---|---|---|---|
| 19 January 2018 | Hydrogen Network Meeting | Energy Leeds | | JVA |
| 23 April 2018 | Hydrogen Network Meeting | Energy Leeds | | JVA |
| 27 February 2019 | Northern Powergrid talk | The Energy Institute and Energy Leeds | The role of electricity in unlocking the low carbon future. | JVA |
| 4 June 2019 | UK Hydrogen Corridor Workshop | University of Leeds | Research and innovation opportunities on hydrogen in the Tees-Leeds Corridor | JVA/CB/AR |
| 27-28 June 2019 | National Hydrogen Summit | University of Leeds and Leeds City Council | Day 1: Research and innovation opportunities. Day 2: Policy and implementation | JVA/CB/AR |