'Telling it as it is': typical failings in studies of lay opinion about a Hydrogen Economy

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ABSTRACT:

Realising a future hydrogen economy is an enormous challenge for scientists, industry and institutional actors. Even if they succeed, acceptance or rejection of changes to current practice by 'the' public could make or break the project. Fortunately there are now several studies on public awareness and perception of hydrogen energy and the technologies associated with it. Our paper presents a brief review of their findings and attempts a critique of their methods and conceptualisations.

A future hydrogen economy would be a 'complex socio-technical system' not just a technology. This concept calls for appropriate methodologies, especially the need for improved qualitative research into public awareness and understanding of such complex issues as energy, and the development of a conceptual framework for gauging public attitudes to what might lie in the future.

The paper concludes with an overview of fieldwork on these topics conducted by the authors with stakeholders and members of the public in three distinct areas of the UK.

KEYWORDS : *public perception, public engagement, hydrogen energy, socio-technical system, qualitative research.*

Introduction

Realising a future hydrogen economy is fraught with enormous challenges for all the actors involved in this endeavour: scientists engaged in research and development of new or improved technologies for hydrogen production, storage and use; companies across several industrial sectors attempting to reap the benefits of a possible introduction of hydrogen as an energy vector or fuel; and governments and institutional bodies seeking to deploy hydrogen as a means to avert climate change and decrease dependence on foreign oil, without compromising economic growth and societal wealth.

Even if they succeed in making hydrogen energy economically attractive and technically viable, acceptance or rejection of changes to current practice by 'the' public could make or break the project. Hydrogen is by no means the only available route to confront the challenges posed by environmental impacts and future limited availability of fossil fuels. In fact, it is but one among a wide range of alternative fuel options, such as bio-fuels, and other energy technologies and systems are either being improved or newly developed.

For this reason, it is important to understand whether and how these issues are currently understood by those – 'the public' - who are not at present actively engaged in the development of any particular energy future, but who would eventually become 'stakeholders' once such developments are carried out. There are now several studies on public awareness and perception of hydrogen energy and the technologies associated with it [1-8], which seem to suggest a general low level of public awareness and knowledge but widespread support. Our paper aims to present a brief review of their findings but mainly to attempt a critique of their conceptualisations and assumptions, by focusing on:

1. the object of enquiry, that is, public awareness and perceptions of hydrogen as a fuel;
2. the methodology that is used;
3. the investigator's standpoint.

Public awareness and perceptions of hydrogen

Virtually all available studies (with the exception of that conducted by Glamorgan University [3]) investigate public awareness, perceptions of and attitudes towards specific hydrogen-powered technologies, in particular prototype buses that are currently being demonstrated around several cities across the globe (among them London). In these studies, 'hydrogen' is usually referred to as a fuel and is closely associated with its specific end-uses in transportation, whilst 'the public' is viewed as rather an undifferentiated group of consumers that needs to be educated to appreciate the benefits of a future hydrogen-based economy. We believe this way of framing the issue neglects important aspects, concerning both the notion of 'hydrogen' and that of 'the public', that need to be explicitly acknowledged.

Understanding hydrogen

Hydrogen is not just a fuel or a technology. It can be viewed as the core of a complex network which connects different primary energy sources to multiple and very different end-uses. Various interrelated technologies and consumer products could become part of this system, such as hydrogen refuelling stations, small residential combined heat and power (CHP) units, fuel cell cars or high-tech fuel cell-powered electronic devices. However, focusing only on some popular applications of hydrogen leads to missing the importance and significance of the whole picture of hydrogen energy systems, which also include all the facilities and infrastructures needed for hydrogen production, storage, distribution and delivery; the knowledge base, skills and human capital required to develop and deploy those technologies; the institutional, political and organisational settings in which those developments take place; and the social, cultural and symbolic meanings associated with them.

In other words, "hydrogen energy" should be regarded as a complex "socio-technical system" [9] composed of tangible technological artefacts and less tangible social, political, organisational and cultural components.

From a socio-technical system perspective, attitudes towards a future hydrogen economy cannot be considered in isolation. If hydrogen were to be introduced as an energy carrier, it would necessarily be a part of a wider energy system characterised by a multiplicity of primary energy sources, infrastructures and applications. Therefore, attitudes towards hydrogen have to be placed in the broader context of energy provision, consumption and its environmental implications.

The overall desirability of a future hydrogen economy, moreover, is far from being established, as some of the studies reviewed presuppose. Although hydrogen is receiving enthusiastic support from many leading figures in scientific and institutional arenas (e.g. [10, 11]), there are several commentators who take a more cautious and sceptical approach and highlight areas of incomplete knowledge and understanding [12-19]. The scientific community is still debating unresolved issues associated with the whole hydrogen supply chain (from production to final use); the possible alternative configurations of hydrogen systems; additional technologies that might be required (for example, CCS – carbon capture and storage) and competing options that might limit or close down the hydrogen route (electrification or bio-fuels).

What emerges from an extensive examination of expert accounts [20, 21] is that a shift to a hydrogen economy, rather than being just a question of substituting a 'clean' fuel for 'dirty' ones, would represent a complex transition to radically new energy regimes requiring decisions of a technical *and also* political, economic and social nature. Moreover, instead of a unique vision of a possible hydrogen economy, expert accounts provide an extremely complex landscape populated by diverging views of drivers, barriers and challenges shaping a wide range of possible (and rather uncertain) "hydrogen economies".

Given such a heterogeneous depiction characterised by contested assumptions and expectations, it becomes quite difficult to present 'the' public with a comprehensive and stable overview of a future hydrogen energy system. The multiplicity, diversity and uncertainty of these future technologies and products have significant consequences for the way in which 'the' public will react to them. To date, no study of public perceptions and attitudes towards hydrogen has explicitly acknowledged such complexity and uncertainties, nor have they attempted to address these issues exhaustively.

Understanding 'the public'

The other fundamental assumption that most studies make concerns 'the public', usually referred to as generic consumers, who make decisions and choices on the basis of 'information' they receive. No consideration is given as to what role is played by the source and content of such information, the ways in which information is interpreted and understood, and issues of public trust in information sources. Especially in the development and diffusion of new technologies, the public is considered as the last barrier to

overcome, once major technical and economic challenges have been dealt with (e.g. [22]). The case of hydrogen energy is no exception in this respect: the complexities, uncertainties and disputes surrounding hydrogen futures are generally masked under 'iconic', positive images giving the impression of consensus among the experts.

Moreover, the public is generally considered as a homogeneous, uninformed or ill-informed entity that needs to be educated in order to appreciate new technologies. The underpinning rationale is the belief that more information dissipates doubts, puts an end to controversies and encourages rational decision-making by the individual.

The increasing amount of social research that addresses public perceptions and understanding of various technological issues (Radioactive Waste Management, Genetically-Modified Organisms (GMOs), Nanotechnology, etc.) has led to a more sophisticated concept of 'the public' which recognises the variety, complexity and dynamic nature of public views and concerns about new technologies [23]. Alan Irwin [24] introduced the concept of 'scientific citizenship' to emphasise the role that public values and concerns about technological developments could play in policy making and risk assessments. Conventional representations of 'the public' neglect the fact that there are different types of 'publics' with distinctive understandings of scientific issues – a fact that calls for a more flexible and differentiated way of communicating and engaging with citizens.

By drawing upon empirical evidence concerning public attitudes to GMOs in the UK, Grove-White and his associates [25] give important insights into issues related to the development of new technologies in general. Technological advances and novelties are framed in substantially different ways by informed stakeholders or experts on the one hand and lay publics on the other. Technical and economic assessments of benefits, costs and risks associated with new technologies often fail to address wider concerns that emerge in public debate. Particularly relevant are concerns about the interests and motives that underlie the development of new technologies, the actors who control the content and direction of technological change, and the liability and responsibility of these actors when there are unexpected consequences or unknown effects.

Findings from their work suggest that, in some cases, people may actually become more reluctant to support new technologies after receiving more information, and that, when areas of unclear or contested knowledge are deliberately occluded to the public, this may increase public unease with new technologies, for trust in the actors involved in technological developments may be as important as factual evidence in shaping public reactions. This is particularly significant where new, disruptive technologies characterised by uncertainty are concerned, for which expert knowledge is pivotal and public awareness is low.

In the case of hydrogen energy, perceived benefits, costs and risks will certainly affect public reactions. In addition, public sensibilities towards problematic issues surrounding the future provision of energy resources, the use of fossil fuels, and their social and environmental implications may also be particularly relevant.

A question for upstream consultation is the extent to which the attitudes the public reports to specific virtual or prototype hydrogen-based technologies (such as vehicles) still hold significance in different practical contexts, where other aspects of the hydrogen system (such as stationary fuel-cells or refuelling stations) play a more prominent role. As already explained, a future hydrogen economy would necessarily comprise not only clean vehicles and smart electronic devices, but also new production facilities and infrastructures for hydrogen storage and distribution. Public reactions to those potential technological developments have not been systematically studied to date, although there are a few attempts to shed light on this area (presented by Pearson [26]).

Another question is linked to the validity of such attitudes over time. There is every possibility of change over time as the hydrogen economy unfolds. Energy shortages coupled with increased fuel prices might, in the not so distant future, have a significant impact on public perception of energy issues and mediate the process whereby people negotiate the trade-off between benefits, costs and risks of new energy technologies and their associated infrastructures.

Methodological issues

Most studies on public perceptions of hydrogen are based on questionnaire surveys, administered mainly by telephone (as in the AcceptH2 project [5-7]) or face to face [8]. The study carried out in Wales by a team of Glamorgan University [3] took instead a qualitative approach. Although quantitative approaches can indeed provide a useful snap-shot of public opinions and statistically significant data, they fail to understand the factors and drivers that shape and mediate opinions, the complex nature of public understanding of unfamiliar technologies, and the process by which such understanding is developed. Preferences are often

investigated by using the 'contingent valuation method', that is by asking people about their willingness to pay a premium for a specific good or service. This method has been criticised [27, 28] for its presumption that stated preferences would translate into actual behaviour in real-world situations, especially in cases where it might be difficult for people to assign a monetary value to something which is largely unknown.

Hydrogen as an energy carrier is at a very early stage of development and, it is argued by all studies, public awareness and knowledge of it are low. How valid are opinions based on inadequate knowledge or experience?

Findings from recent work, conducted across several cities (Berlin, London, Luxembourg and Perth) some time before and after hydrogen buses were introduced as demonstration projects, provide useful material for our discussion. Responses to ex-ante surveys [5] indicate that perceptions of hydrogen were predominantly neutral and knowledge of hydrogen and fuel cells was relatively limited. Despite this, respondents seemed rather supportive of the bus trials. They were more cautious about a large-scale introduction of hydrogen buses and demanded more information. Ex-post surveys reveal [6] that awareness levels and willingness to pay did not change significantly, whilst the amount of unconditional support for the large-scale introduction of hydrogen buses increased. Interestingly, respondents with direct experience of hydrogen buses did not seem more favourable or willing to pay more than those with no direct experience. Spontaneous associations with the word 'hydrogen' were also found not to lead to any meaningful conclusion, as no clear pattern of answers could be identified across the samples. Prior knowledge of hydrogen was found to have some influence on the acceptance in some cases, but overall it is still unclear what the drivers of public acceptance are. In sum, most studies conclude that the public seem not to have particular concerns about the safety of hydrogen when used as a fuel for transportation.

As indicated earlier, members of the public are usually only being asked to express opinions about one highly specific and selected application of hydrogen technology (fuel-cell transport). Broader issues about the wider environmental costs and benefits, or about comparisons with alternatives and other applications and their infrastructural implications are rarely, if ever, posed as issues for consideration. It is inherently difficult to ask for opinions about an as-yet undeveloped, and unknown, technology; different social groups will make their assessments in specific contexts, and their views will be conditioned by experience and use.

A wider criticism of studies which have used quantitative survey methods is that their reliability is wholly dependent on the sampling criteria, sampling frame and population parameters. Small samples are unlikely to yield reliable estimates and generalisations. Finally, however well-designed a sample survey may be, it may become un-representative if the response is low or the non-response is biased, for example by socio-economic group, age, gender or ethnicity.

The investigator's standpoint

Arguably, virtually all studies seem to have been carried out with the purpose of supporting the development of a future hydrogen economy. This raises questions about possible biases, not only concerning the promotion of hydrogen energy systems, but also in relation to the types of issue investigated. In particular, there are implications for the way in which questionnaires are designed, questions are posed and responses are interpreted. In studies addressing public perceptions of public transport running on hydrogen, eliciting public opinions and preferences becomes a way to identify possible barriers to such developments and to enact mechanisms, such as information campaigns, to tackle them. It is implicitly assumed that the predominant dimension of public reaction would be concerns over safety.

Framing the discourse on hydrogen almost exclusively in terms of the perceived safety of some applications (hydrogen buses for example) reflects a general tendency among those who actively support the introduction of new technologies. In a pamphlet published by the think-tank Demos advocating an improved approach for engaging citizens in science and technology, Wilsdon and Willis [19] argued that debates over science and technology have too often been dominated by questions of risk assessment and perception, while neglecting more fundamental questions that might be at stake in any technological development: who owns and controls it and why? What are the costs and benefits, and to whom will they accrue? They also pointed out that it is very easy to be carried away with the excitement that surrounds a new technology, which sometimes can lead to neglect of the untapped potential of the technologies we have at our disposal and to overstate the benefits of the new ones.

We have argued elsewhere [30] that indeed hydrogen has implications for public safety that should be carefully taken into account. However, these should not become the exclusive issue to be covered in debates involving the public.

A qualitative approach to exploring public understanding of hydrogen

In contradistinction to the literature to date, we have chosen to conduct our investigation by using a qualitative methodology, based on focus groups with a cross-section of the public in three different localities of the UK where hydrogen energy developments are either being planned or already in operation: they are within the regions of Teesside, South Wales and Greater London. Teesside, an area in the North-East of England characterised by a long-standing tradition in the chemical and petrochemical industries, has an established infrastructure for hydrogen production, storage and distribution. In an attempt to improve the local economy by capitalising on existing skills and facilities, regional authorities and organisations are currently developing several projects around renewable energy, recycling and hydrogen (such as the Tees Valley Hydrogen Project and the Fuel Cell Application Centre at Wilton). Similarly, a number of projects are being discussed in Wales to create a sustainable, wealthy economy through the use of hydrogen energy, such as the Hydrogen Valley Initiative and the H2 Wales project carried out by the University of Glamorgan. London is witnessing several developments directed at exploring the potential of hydrogen, especially as a means for tackling air pollution, and is part of the hydrogen bus CUTE project.

We have also carried out interviews in the same areas with a number of stakeholders, identified as representatives of institutions, organisations and private companies with an interest in the future emergence of regional or more local hydrogen economies.

Our focus on local areas in which the public has some familiarity with hydrogen energy was designed to offset the tendency of earlier studies to seek perceptions of the 'unknown'. Our use of qualitative methods was intended to reveal underlying values and beliefs that might influence how publics address hydrogen not only now but in the future. We reasoned that focus groups would be more likely to elicit these values and beliefs than individual interviews. Each discussion was framed by issues such as security of energy supply and climate change, and the benefits and costs of hydrogen energy, not only its risks. To date, nine focus groups have been carried out (2 in South Wales, 3 in Greater London, and 4 in Teesside). The meetings took between one and two hours, comprised between 8 and 13 participants, and were facilitated by members of the research team. The focus group members were recruited through existing local authority consultation panels (themselves a representative cross-section of the local population). The groups were mixed in terms of age, gender, socio-economic group and ethnicity. Qualitative analysis of these meetings is ongoing; some preliminary results from two areas are highlighted below.

During the focus groups, people were able to discuss several broad issues around energy and the environment, and were encouraged to actively frame the debate in the terms they felt most relevant to them. Information on hydrogen systems, not just applications, was provided gradually during each meeting with the aid of visual material, and people were able to ask technical questions and receive explanations.

Although qualitative studies obviously have limitations, such as the difficulty of being representative of wider populations when sampling for groups, they allow for an in-depth exploration of the process by which views are formed and understanding is developed. Group discussions offer the possibility for participants to exchange their views and build upon each other's contributions, by way of juxtaposing different perspectives and ideas, and incorporating new information provided by the researchers (see [31, 32]).

Approaches based on qualitative methods have recently been adopted in technological issues where public awareness is low. In the Tyndall Centre's investigation of public understanding of carbon capture and storage (CCS), a technology in its early stage of development, Shackley and colleagues [33] claimed that major difficulties arise when presenting, and encouraging public debate about, complex and uncertain issues that are remote from people's everyday experience and for which people have no immediate reference points.

Preliminary key findings

Preliminary findings from the groups in Teesside and South Wales indicate that public perceptions of hydrogen are neither wholly positive nor wholly negative. They are always conditional and contextual. Awareness of hydrogen as an energy carrier varied widely within and across groups, ranging from basic knowledge of what hydrogen is (part of water, a gas, etc.), to articulated understanding of its properties and uses. Perceptions of hydrogen as an energy carrier are always framed and expressed within a wider system of beliefs and values about other energy sources and technologies, and about broader environmental issues. Most participants expressed their concerns about the implications of using fossil fuels in terms of global changes in the climate and the eventual exhaustion of what are finite supplies. Most people were in favour of increased use of renewable sources and greater diffusion of energy efficient technologies and of recycling.

Concerns about hazards and risks to safety and the environment were evident, but these did not surface as major sources of objection or outright opposition to the development of hydrogen technologies. Safety issues were raised and discussed not in abstract terms, but in relation to practical contexts of use with reference to the fuels people are more familiar with, such as petrol and natural gas.

> *"How would you know if there is a leak?" (Man, TS)*
>
> *"Natural gas is the same and we have all of that" (Woman, TS)*
>
> *"Because I have worked with it and I've seen a lot of nasty accidents" (Man, SW)*
>
> *"That could happen with anything though" (Woman, SW)*

There was a recurrent belief that government and industry would carry out risk assessments and engineer proper safety systems before the introduction of the technologies.

> *"I would presume that if something got to a stage of being on the road then it would have been tested sufficiently so that it was safe" (Woman, SW)*

Focus groups all agreed that individuals' behaviour (as consumers) would be influenced by the interaction of, and 'trade-offs' between, cost, safety, 'usability', and environmental benefits. People expressed the need for detailed and reliable impartial information about this, and asked cogent questions about how environmental benefits of hydrogen would compare with other technologies, how they would be distributed and who would be responsible.

> *"It would depend where they have got the hydrogen from, wouldn't it? I mean, I wouldn't want to see, where did you say it could come from, nuclear power stations" (Woman, SW)*
>
> *"Is it cost-effective and will it relieve the pressure of global warming?" (Man, TS)*
>
> *"There are lots of uses for the hydrogen once you have got it, but where do you get it from, how do you produce it and how much does it cost to produce it?" (Man, TS)*
>
> *"Is it going to affect my pocket? This is what 99% of the people would say?" (Man, TS)*
>
> *"Is it safe? And is it easy to understand […] without having a lot of jargon surrounding it?" (Woman, TS)*

Members of the public showed very strong interest in seeing practical examples of hydrogen technologies in action, and indicated that public acceptance would largely depend on seeing demonstration projects and *real* applications in use.

People seemed in general distrustful of governments' willingness and commitment in tackling energy and environmental issues. Distrust of industry emerged as well, although this varied across different geographical contexts. Ambivalent attitudes emerged, depending on participants' direct or indirect experience (as residents, workers, etc.) of local industries, such as chemicals, steel making, coal mining and nuclear.

Most participants welcomed the idea of public engagement in such issues as energy futures and technological options, and expressed support for increased use of public consultation, although they recognised that governments would have to make decisions.

Stakeholders across the three regions expressed varied views about the prospective benefits that a local hydrogen economy could bring. These ranged from economic and social improvements, such as creation of jobs and opportunities for the local industries, to environmental benefits, including tackling global warming and improving local air quality, and security of energy supply. The risks of hydrogen as an energy carrier were discussed mainly by industrial stakeholders and framed as 'technological risks'. They had concerns about using hydrogen in a consumer environment. However, the repeated view was that all risks will be 'manageable'.

In contrast with the views of local authorities, industrial stakeholders seemed less enthusiastic about using hydrogen as a fuel and more readily tended to highlight technical and economic barriers to such development. A general view emerged emphasising the need to develop local demonstration projects to engage in communication with the public. There are different perceptions of the public across stakeholders,

in relation to what the public may think of new technologies and which information sources they trust. Some stakeholders thought that citizens would have confidence in local authorities, others were concerned that publics would not automatically trust government and scientists in giving them reliable and impartial information.

Conclusion

Our work aims to make a significant contribution to the debate about public engagement in science and technology, by taking the case of the hydrogen economy. This is an emerging field that requires the development of adequate processes and techniques in order to overcome the limitations that exploratory research studies have uncovered. In particular, the shift towards greater engagement with the public (as opposed to simple information provision and one-way communication) poses significant challenges.

In this process, more explicit recognition must be given to the possible effects of social differentiation and regional variation. Current hydrogen developments in the UK, for instance, have a regional or more local dimension that should be taken into account when exploring public awareness and attitudes. Apart from hydrogen end-uses, participants in our groups seemed interested in understanding the 'bigger picture' of whole hydrogen systems, and what the implications would be for them and in relation to the issues they were concerned or interested about. People expressed the need for more information about these developments, which might become a complex task, given that there are no unique interpretations or visions of a future hydrogen economy from the stakeholders' perspectives.

More detailed analyses, using qualitative methods and 'deliberative' forms of engagement, are essential to obtain a comprehensive understanding of lay beliefs about the hydrogen economy, how those beliefs contrast and compare with interested parties' views and agendas, and to what extent they might change in the future as the energy economy undergoes significant changes.

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