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An exploratory study of public opinions on the use of hydrogen energy in Wales

S.J. Cherryman, S. King, F.R. Hawkes, R. Dinsdale and D.L. Hawkes

The introduction of hydrogen into the energy market is being pursued by governments around the world in an effort to abate climate change, provide security of supply and reduce air pollution. While technological aspects are well researched, the social aspects of the transition are not. The public's attitude and perception of hydrogen energy will be of great importance as we move closer to the implementation of the technologies. Using two focus groups this exploratory study aims to identify Welsh public opinions on the production and end use of hydrogen energy. Gender differences were apparent, as women were generally more accepting of hydrogen technology. The main concerns were safety (both of use and in production) and cost. Cost remained paramount, even in the light of environmental considerations. The groups' attitude to the development of hydrogen technology was supportive but with the caveat that price and safety should not be compromised.

Keywords: hydrogen, public attitude, hydrogen technology, acceptance, Wales.

1. Introduction

Concerns over the environment and security of energy supply are driving governments towards the development of a hydrogen economy. The UK Prime Minister Tony Blair (2004) said of climate change, "… unabated it will result in catastrophic consequences for our world." Emissions of carbon dioxide (CO_2) and other gases are the dominant influence on climate change. The government has adopted the Royal Commission on Environmental Pollution's suggestion that a 60 percent reduction in CO_2 emission is needed by 2050 against 1990 levels (RCEP, 2000). The UK government White Paper (DTI, 2004) has identified hydrogen as a tool for reaching these targets.

Hydrogen is a clean fuel with no CO_2 emissions and can be sustainably produced through CO_2-neutral processes. It is increasingly seen as a key solution to the energy problems of the twenty-first century, providing clean and efficient heat and power from a range of indigenous sources. Like electricity, hydrogen is an energy carrier requiring an energy input for its production. The state of hydrogen technologies and associated economics has been reviewed by Cherryman et al. (2004).

While the transition to a hydrogen economy will be global in nature, we must also realize that it will develop under the specific political framework of each country and reflect the

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cultural differences of peoples. In 1999 Wales became a devolved government through the National Assembly for Wales. Section 121 of the Government of Wales Act 1998 puts Wales in a unique position as one of the first countries legally obliged to take decisions based on sustainability. In support of this policy, guidelines on renewable energy have been developed (NAfW, 2002, 2004). The document *Energy Wales: Route Map to a Clean, Low Carbon and More Competitive Energy Future for Wales* identifies the potential to integrate hydrogen into future energy policy (NAfW, 2005).

Currently, there are two hydrogen groups in Wales (H2Wales and Hydrogen Valley) who are together working with around 90 small and medium size enterprises, non-government organizations and charities to facilitate developments in hydrogen technologies in Wales. Despite Wales's admirable desire to trail-blaze the development of sustainable solutions and carbon abatement, there has at times been a backlash from the public against developments that fall in line with this legislation and national goals, particularly wind farm projects being developed on the coast. Thus, engagement with the public is paramount in order to ameliorate concerns.

Development of niche markets for hydrogen products has begun around the world in order to fulfill specific needs within the marketplace. However, in order for hydrogen technology to bridge the gap between niche market and mass market the general public will have to want to buy the technology. This leads to a dichotomy—how can the general public want a product with little or no knowledge of its existence? It has been argued by Schulte et al. (2004) that there needs to be a campaign to raise awareness of hydrogen and hydrogen technology before products come to market in order to ameliorate public concerns. In recent years, hydrogen technology has been more visible to the public through media reports, whilst oil companies and car manufacturers have attempted to introduce the public to the new product "hydrogen" through advertisements. However, no coordinated effort has been made in the UK to provide the public with a coherent awareness campaign. It can be argued that no such effort can be made until the public view of hydrogen energy is understood.

Limited studies have been conducted on public perception and acceptance of hydrogen. The Accepth2 Public Acceptance of Hydrogen Transport Technologies European funded project has been active in making an initial assessment of public attitudes in Germany surrounding the introduction of hydrogen buses. The competitive evaluation conclusions were that both the school students and the bus passengers questioned had a high acceptance level of hydrogen and the technology, and understood the risk of explosion. It was also concluded that knowledge (technical/scientific) of hydrogen or of the technology does not influence the acceptability of hydrogen and there is a general interest in learning more. There was a small gender difference with males being very slightly more accepting than the females of the groups were. Learning in school had a positive effect on acceptance; it is also suggested that demonstration of the technology could aid acceptance by the general public (LBST, 1998).

The Accepth2 report (LBST, 2003) gives analysis and comparison of eight studies carried out in German cities, which include the technical, political and social dimensions of hydrogen. These conclude that there was an overall positive response to hydrogen vehicles. High environmental awareness seemed to influence the attitude of the groups more than their technical knowledge did. The main concerns centered on vehicle and fuel cost, performance and consumption, and that trust and knowledge are needed in order to penetrate the mass market. However, there were conflicts within the studies reviewed as gender was seen in some as having no noticeable effect whilst others saw men having a higher level of acceptance than women did.

In the United States, a study by Hart (2005) indicated that the majority of respondents were in favor of the government making funding commitments to the transition to hydrogen.

Interestingly, 50 percent of Americans knew that hydrogen produced no emissions (at the point of use).

To date in the UK, only three studies have been published in relation to public understanding/perception or awareness of hydrogen. These were carried out in London. Mourato et al. (2004) found that environmental considerations affected London's black cab drivers' long-term purchasing decisions. Schulte et al. (2004) showed that one of the easiest ways to influence perception of hydrogen is through product exposure, thus engendering a trust in the technology. The study by O'Garra et al. (2005) is the first to be statistically valid; all other studies having been conducted using convenient subject groups. That study found that few respondents knew of hydrogen as a transport fuel and that safety concerns were low. The majority of people with prior knowledge supported the introduction of hydrogen vehicles. The study also established that gender had a large influence on the acceptability of the technology with men being more supportive than the women questioned. The study concludes that there is a need for more information to be made available to the public. It is clear that there is a significant challenge to confront in terms of public information provision and public acceptance before the widespread adoption of hydrogen energy can take place (Goltzov and Veziroglu, 2001).

So far within Wales, no work has been carried out on the public acceptance or awareness of hydrogen technology. The work reported here forms part of a study on the implications of a move towards the hydrogen economy in Wales (Cherryman et al., 2004). It is a first step towards establishing social attitudes to the use of hydrogen energy in Wales and towards the development of an appropriate awareness program.

2. The study

This work was carried out as part of a European Union (EU)-supported project—"A sustainable energy supply for Wales: towards the hydrogen economy" (www.h2wales.org.uk). The study was undertaken to understand public perception of hydrogen fuel and to determine the level of acceptability of hydrogen fuel technologies. This work was also carried out with the intention to use these data to inform future quantitative studies in the area.

Owing to the exploratory nature of this study and the relatively small amount of research that has been undertaken in this subject it was decided to use grounded theory in order to find the emergent theory, and potentially validate the quantitative work that has been carried out.

The study was carried out in October 2004 in two 2-hour slots involving 18 individuals:

Group 1: nine men aged 25–55, mixed social grade (see Table 1);
Group 2: nine women aged 25–55, mixed social grade (see Table 2).

Table 1. Age and social grade of participating men

Age	Social Grade
34	E
25-55	D
29	D
42	D
25-55	C1
25	C1
25-55	B
25-55	B
25-55	B

Table 2. Age and social grade of participating women

Age (years)	Social grade
45	D
25–55	C2
55	C2
38	C1
25–55	C1
25	C1
48	C1
25–55	C1
25–55	B

The participants lived in South East Wales, a mostly urban and peri urban region with 60 percent of Wales's 3 million population. Participants were recruited using a market research recruitment firm; a structured questionnaire was developed and distributed to the recruitment firm to ensure a spread of participants. Members of environmental groups, the energy industry and the media were excluded from the study as being more likely to hold strong views that may not be typical of the lay public. Participants were paid £60 by the recruitment firm to participate in the study. The venue, a mid-range hotel, was chosen to be neutral and non-threatening. The groups were separated by gender as it has been noted that women can feel intimidated by men in group situations, and can feel reluctant to discuss technological/scientific subjects. In addition, it may be expected that men and women have different priorities and concerns in relation to technical and scientific issues as discussed in *Science and the Public* (Office of Science and Technology and the Wellcome Trust, 2000) and *Eurobarometer 55.2* (2001). This gender grouping, together with the socioeconomic and age ranges, provides a broad view of perception among the population in South East Wales.

In the first sessions, the groups were led by a facilitator, who provided the Office of Science and Technology briefing notes on the hydrogen economy with some basic information (Postnote, 2002) as well as some more general information from the University of Glamorgan.

The facilitator stimulated the group with some general questions and the group was then allowed to continue to talk with the facilitator probing on relevant issues as they were raised, until the arguments were exhausted. This method allowed the study to draw out the complex picture associated with the image and perception of hydrogen and hydrogen technology. The end of the first session was used to gather questions to be answered by an expert at the second sessions.

The second session was structured around answering the questions raised by the group the previous week, which the expert did, aided by a selection of photographs. The expert was a university Research Fellow working in the Hydrogen Research Unit at the local university, and was introduced to the group as an expert brought in to answer their questions. The session format allowed participants to ask new questions, raise new issues and reflect on and debate the information provided and previous discussions in their own way.

3. The groups' understanding of science and the environment

At the beginning of the second session, the participants completed a self-assessment questionnaire to provide information on their attitudes to science and the environment. The questions were taken from *Science and the Public: a Review of Science Communication and*

Public Attitudes to Science in Britain (Office of Science and Technology and the Wellcome Trust, 2000).

Through the questionnaire, it was found that participants were generally supportive of science. None agreed with the statement "I am not interested in science and I don't see why I should be" and only one woman disagreed that "science and technology are making our lives healthier, easier and more comfortable." There was also considerable trust in the regulation of science, with only one woman agreeing "the speed of development in science and technology cannot be properly controlled by the Government." This broadly mirrors the findings from the Office of Science and Technology and the Wellcome Trust (2000). In hindsight it is the researchers' opinion that this questionnaire should have been carried out at the beginning of the first session as opposed to the beginning of the second session.

4. Session 1: the groups' understanding of hydrogen

At the beginning of the first session, the participants' understanding of hydrogen was ascertained. In general, the women were less concerned than the men were at the mention of the word "hydrogen," although for at least some individuals in both groups the word "hydrogen" conjured up images of explosions. For the women, this was a response to gases in general, for the men, it related to the hydrogen bomb and the *Hindenburg* accident. One of the women was a hairdresser and she associated hydrogen with hydrogen peroxide.

Everyone was aware that water is made up of hydrogen and oxygen (H_2O). The men, however, appeared to know more about hydrogen as a chemical, or at least they were more prepared to proffer information than the women were. One man had heard of fuel cells in relation to hydrogen and one of the women had seen something in a newspaper about hydrogen being used as a fuel for transport.

Using a mock headline in a local paper announcing hydrogen-fueled buses in Cardiff, the capital city of Wales, elicited knowledge from some about noise levels. Some were aware that cars and buses running on hydrogen (fuel cells) would be quieter than standard vehicles. In general, participants did not expect hydrogen-powered buses to look any different from "normal" buses. While they did not see why such a bus would need to look any different, they also felt that the manufacturers would not want them to look any different. Moreover, several participants in both groups knew people who had converted their cars to run on liquid petroleum (LP) gas, and these did not look any different.

There was also some awareness that hydrogen-powered buses would be cleaner in environmental terms because hydrogen is a clean fuel and that the only emission would be water/steam.

> It is a clean fuel.
>
> The only emission is water and there is an abundant supply of hydrogen. (Men)

However, there were instances where a little knowledge led to more confusion than clarity. For example, one man knew that water is H_2O, which led him to ask: "If there is more hydrogen in the air won't that combine with the oxygen and produce water?"

This, plus the fact that water is the main emission, stimulated a discussion about the impact of emissions on the local climate and whether it would rain more. Importantly, there was some confusion with helium, which probably stems from the similarity of the (unfamiliar) words and the use of both gases in airships.

Supply

The wider context against which discussions took place should be borne in mind. Just before the first sessions, there had been coverage in the media of the Venezuelan presidential vote and concerns about the future supply of oil from Venezuela. Obviously, the situation in Iraq was well known and the rising price of oil was featuring on national news. Several aspects of power and fuel supply were identified by the groups. Firstly, there was the issue of the security of supply of oil and the level of world reserves. Secondly, there were issues related to consumers being able to access retail outlets for hydrogen.

Participants were aware of problems in the supply of petrol and the women highlighted our dependence on petrol as a society by citing the problems caused by the "fuel crisis" (blockades of petrol refineries by protesters against tax increases) in the UK in the autumn of 2000. Participants had a general knowledge that petrol would not last forever and that other sources of fuel are needed but were unsure of the timescales involved. The men raised the question of who would supply hydrogen to the consumer. Their first thoughts were gas companies such as British Gas, whom they assumed would monopolize the market. Once participants were aware that the big oil companies, such as BP and Shell, are involved in the development of hydrogen as a fuel source they realized how little they knew about the supply of oil. The involvement of these "big concerns" in the research reassured them. Weaning people off their cars was seen to be very difficult to achieve, so finding alternative fuel sources was thought to be very important. "… the car is so convenient, so many people just jump in the car for the slightest thing" (Woman).

If hydrogen is to be used as a major fuel source, consumers must have easy access to reliable sources or they will not use it. "… the availability is an important factor" (Woman). As mentioned above, some participants knew people who had converted their cars to LP gas, especially taxi drivers. This was now a more feasible option as not only was it cheaper, but: "You can get it [LP gas] at Asda [supermarket] now" (Woman).

Safety

There were two main views on safety. Firstly, there were those who believed that before anything was put on the market it would be heavily tested and therefore safe.

> Working in the bus industry before, I know the testing the buses go through is rigorous, compared to a car it's another 50% again, if they have managed to get it into a bus it is going to be safe, because they do put them though rigorous testing. (Man)

> As long as we were told it was safe and we knew how to manage it, and knew the do's and don'ts. I am sure those of us who do have our heads screwed on, they are going to be responsible. (Woman)

Secondly, there were those who were concerned about flammability and explosions, no matter what testing occurred, and the latter was cited in association with the hydrogen bomb. "I don't think you can get away from the bomb because when you talk about hydrogen people will think of the hydrogen bomb" (Man).

Perhaps because of the awareness that hydrogen is "highly" flammable, there was greater concern in the men's group about safety than in the women's group. The men's group also raised the question of what would happen if there were a crash where there was an escape of hydrogen and how this would affect the atmosphere. There was, however, an appreciation that

an accidental release of any type of fuel has implications. "Well you have got the issue of what happens when it goes into the environment and the crash issues but you have that with diesel and petrol cars now" (Man).

Those who were less concerned about safety cited strong parallels with the dangers inherent in using petrol.

> I was just thinking if they had had a discussion group about a combustion engine run on petrol, what would it be like, how dangerous it would be and how it could explode, they would probably be saying very similar things to what we are saying now. (Man)

> If you have a pot of petrol on the table you would be very nervous about it. When it's in your car and you get it from the pump you don't really think about it. (Woman)

Some of the men were concerned about moving hydrogen around but others again identified parallels with existing technologies. "Gas cylinders get transported around on the backs of lorries and they are under pressure, so I don't think I'd be that concerned" (Woman). While some of the men considered the impact of accidents during transportation, the women assumed that the fire brigade would be trained to deal with accidents.

While the *Hindenburg* disaster sounded a note of caution for some of the men, the women's view was: "I think we've advanced a bit since then" (Woman).

In conclusion, some participants believed: "I think I will be for it definitely because I don't think the Government will let it go ahead if it wasn't as safe as petrol" (Man). On the other hand: "Well they [the Government] sponsored nuclear power development. I don't have that same faith in the Government" (Man). But then again: "I don't think anything like that happens if it wasn't safe, because there are so many pressure groups" (Man).

Cost

Cost was the primary consideration for participants when considering whether they would choose hydrogen as a fuel source personally. This was not only the cost of the hydrogen itself but also the cost of buying or converting machinery (such as cars or heating boilers) to run on hydrogen. Even for those more environmentally aware, cost was ultimately more important than the impact on the environment.

> I think it's more an issue with cost … I think if you went out to the streets and asked 2000 people, 70% of them would think of more of the cost than the environment. You are only thinking in the short term. (Woman)

Grants for conversion of appliances, homes and cars were suggested by the group, if the government wants to get people to switch to hydrogen. However, there was skepticism that once most people had converted, initially low prices for hydrogen would rise as a result of increased taxes.

> They will probably make it cheaper and give people tax breaks for doing it. (Man)

> They will wait till we are all addicted to it and put the taxes up. (Woman)

> I mean, give it a couple of years and the government will get their claws into it and then it's not going to be cheap. (Man)

With respect to public transport, participants said that they would not use a hydrogen bus if it were more expensive than a standard bus, unless it was raining.

Environment

The women believed recent changes in the local weather conditions, such as the exceptionally hot summer of 2003 and heavy rainfall in 2004, to be demonstrations of global climate change, as the following discussion illustrates.

> We are so advanced in things more than before, but we are still using petrol, which is giving off things that are causing problems but by the time our children are having children I wonder what state we are going to be in. I hope we can find something that is better for the environment.
>
> Something that is renewable, our fear is we are seeing it in perhaps the weather changes and what we were supposed to see in perhaps 20 years time we are seeing now with the rain, we don't know how much that has got to do with the ozone.
>
> But it is a fear for my children I think.
>
> You seem to every day pick up a paper and see more situations classed as natural disasters but we don't know if that is why.

Women also recognized that there could be benefits from a fuel that does not produce noxious fumes. "I think the pollution side if they could prove it's better 'cos these days pollution is a big thing, with people who suffer from asthma."

The men saw the environmental issues as: "There are environmental issues with producing petrol and there will be with this [hydrogen] too, the difference is it's going to be a different set of environmental issues."

The women were aware that everyone should "do their bit" with recycling and fuel conservation but they were also aware that this was difficult. It required some level of effort (such as taking things for recycling), some institutional changes (more facilities and incentives for recycling) and might even produce conflict with children (by, for example, limiting the number of televisions in a household). Hence, they believed that: "Just putting it [hydrogen fuel] forward as an environmental thing isn't enough."

Despite this environmental awareness, cost remained the major obstacle in these participants' willingness to take up the technology.

Hydrogen and Wales

At the end of the first session, participants were informed by the facilitator about current hydrogen projects in Wales. All were surprised, none was aware that hydrogen is being produced and used in Wales. Neither was there awareness that bus trials are taking place in a number of cities around the world, including London. Participants were asked how they felt about Wales being at the forefront of the development of hydrogen technology. Even those who were more concerned about safety issues thought, "it would be great." Participants thought that it would be good for tourism and for jobs.

> It would be exciting if Wales could produce it, whatever the method, so we could be self-sufficient, it would be a real boost for the economy. (Woman)
>
> It will bring in more jobs, good politically, could raise the intellectual level of the country, could put us on the map. (Man)
>
> It [hydrogen] will be good because we could produce it ourselves. (Woman)

5. Submitted questions

At the end of the first session, the facilitator identified a number of questions drawn out from the discussions. These were relayed to the expert to enable her to prepare answers for the next session. The questions participants wanted the expert to respond to fell into groups: there were some technical questions about hydrogen as an element and the difference between using hydrogen to power internal combustion engines and the use of fuel cells; questions about the environmental impact of making and using hydrogen as a fuel source; questions about transport and questions about the cost. Specific questions posed to the expert included: how hot is the steam from a fuel cell car? How big are fuel cells? Both groups wanted to know what happened when fuel cells run out and how fuel cells are disposed of or recharged.

The expert gathered a selection of pictures and information to answer the concerns of the discussion group.

6. Session 2

Emissions

The heat of the steam emitted from hydrogen-powered engines was queried with the expert but participants were reassured when they learned from the expert that the steam would be "at the same temperature as the steam coming out of a kettle but the actual temperature of the exhausts at the moment is a lot hotter than that." Moreover, the hydrogen-fueled buses have their exhausts on the roof so that the steam rises and this could be seen in the picture of the London bus passed to the participants.

Production methods

Although during the first session production methods were examined and information provided (Postnote, 2002), during the second session the issue was investigated further. Once the production methods were explained by the expert participants recognized that pollution would be removed from the point of use to the point of production. But the group did not have enough understanding of the processes involved to distinguish between the type of pollution produced by renewable and non-renewable methods, as can be demonstrated by the comment: "It just seems to transfer the problem to the place where it's being produced" (Woman).

The most favored method of production was the biological methods involving algae and bacteria as these were thought to produce the lowest levels of pollutants. Participants, especially the women, thought that this line of research should be pursued.

> They use penicillin that came from mould in the first place. Although it sounds terrible, the end product is worth it. (Woman)

> We have to move on, so we have to realize that more money has to go into research. (Woman)

Production methods that are carbon neutral were more attractive to participants than those that relied on conventional fossil fuel electricity production. There were some concerns about whether sufficient trees could be grown quickly enough, as not everyone immediately grasped the concept of coppicing. "As long as for the wood they are burning they can reproduce it, they need to make sure the on-going tree planting continues to outweigh …" (Woman).

There were also concerns that: "You still have the burning though" (Woman). The participants did not seem to be aware that CO_2 from biomass is part of the normal carbon cycle, unlike fossil fuel burning which will take millions of years to recapture the carbon.

Sequestering the carbon dioxide produced during hydrogen production was thought to be an option to be considered because scientists may develop a way of dealing with it in the future. "We would hope the brains would move on and find another way forward" (Woman).

Using renewable energy methods, such as wind farms, to produce hydrogen was also seen to be a good way forward.

The expert wanted to explore how participants felt about using nuclear power to produce hydrogen. Participants were not happy with a nuclear power option. Not only was it seen as unsafe, it was seen as an old technology. "Are we really moving forward if we are using nuclear?" (Woman). Another woman felt that she did not know enough about nuclear power to comment and that she did not want to know more about nuclear power because "it would scare most people." Nuclear power was not seen as environmentally friendly, unlike the renewable energy and biological production methods that had been described.

With respect to the location of production plants, participants said that if there was a proposal to locate a site near to their home they would want to know about emissions, safety, etc. just as with any other production plant. The women in particular saw nothing different about a hydrogen production plant from other industrial development. Some of the men, on the other hand, were concerned about the scale of the production plants, the sources of energy the plants would require and local pollution problems emanating from the plants. Questions were asked about whether the production of water as a by-product would mean that the local atmosphere would be damper than it might otherwise be. "But what about the by-products from the factories that make the stuff?" (Man).

One man was concerned about what would happen to the oxygen left over from removing hydrogen from water. The expert reassured him that when used to produce energy hydrogen would recombine with oxygen, thereby keeping a cycle going.

One participant, however, considered that: "The by-product is water and it's the worst of all the greenhouse gases" (Man).

On learning that industry already produces hydrogen, and that initial production would center on existing sites using existing methods, participants appeared reassured about safety and pollution during production.

Storage

Learning that hydrogen does not have a "shelf life" and can therefore act as an energy store was another point in its favor. This was especially true in the context of using wind power to produce energy that could be stored for periods when there was no wind.

Usage

Some participants were surprised to learn that there are buses running using hydrogen fuel and that the car industry has long-term research projects in the area. Some assumed that performance would be like traditional electric cars, little different from milk floats. Performance is important to women as well as to men. The women said that they would expect the same performance or car manufacturers would "never have entertained the idea."

We asked participants what they consider when buying a car, as a way of eliciting how the use of hydrogen rather than petrol might feature in their decision-making process. Cost (value for money, purchase and running costs) and reliability were the two most important

factors. Nothing that needs regular charging or has distance limits would sell to these groups. "Basically they [cars] have to last and they have to work" (Man). These participants acknowledged that some people would consider environmental performance but not the majority.

Questions were asked about noise levels of hydrogen-powered vehicles. Once it was explained that if hydrogen fuel were used to power an internal combustion engine noise levels would be the same as at present but with fuel cell technology noise levels would be reduced, participants had no further concerns. The expert who attended the second session raised safety concerns that had been voiced elsewhere about pedestrians being at risk if they could not hear vehicles coming. Participants realized this could be an issue but had not thought of it.

The women assumed that the change over to hydrogen power would be a gradual process, led by "those who always have to have the latest thing" and that people would have time to see that the fuel is safe and efficient before using it.

> The first thing I thought of is the explosion side of it but if people are using it and not afraid of using it … It's like anything new. (Woman)

They thought that using public services, such as buses, to generate publicity would help to inform people about hydrogen and enable them to get used to it. They also believed that financial incentives would be needed to encourage and support people to move to hydrogen energy sources. Hence, they identified the need for a lead from government. They suggested tax reductions on cars and fuel and grants for converting domestic boilers. Again, they found parallels in moving people on to condensing boilers, the introduction of natural gas and the switching of television from analogue to digital in the UK. They also suggested putting hydrogen-powered boilers into new homes and making new cars run on hydrogen.

Participants identified some groups, such as the elderly, for whom change might be threatening or difficult. Moreover, they believed that educating children about hydrogen would be a good way of disseminating information and reassuring people, as children can be used to educate their parents.

In contrast, there was some suspicion from the men about the current focus on public transport. Questions were raised about whether this was a way to force cars off the road. In a similar vein, there were also concerns about forcing people to buy more expensive hydrogen-fueled cars, rather than having their existing car converted and that only newer cars would be able to be converted. The involvement of commercial car manufacturers served to reassure these men that new products would be cost competitive. They were sure that car manufacturers would not invest in developing products using a technology that is too expensive for consumers to purchase. However, they were seen as having a stake in making existing cars obsolete. The men recognized that hydrogen fuel will not solve congestion problems and this left some room for suspicion that the government would still use the tax system to pressurize people off the road.

There was some belief that: "We will get forced in to it anyway and won't have much of a say in it" (Man).

In contrast with the women, some of the men had little understanding of the government's role in ensuring appropriate regulations are in place and that the UK attracts inward investment from international companies seeking to locate production plants. They tended to see the technology as being market led, driven by the private sector. Indeed, support from national politicians reassured some of the men but not others because politicians were seen to "jump on bandwagons" or disagree with each other "because that's what they're supposed to do." Some felt that the scientific community needed to speak out in favor of hydrogen but others were skeptical of their involvement.

> Why trust them so much? It was trumpeted that nuclear power was safe and battery powered cars would save the day but they ran into problems. They do that with all sorts of technologies. (Man)

Some men believed that persuading people to use hydrogen fuel will come down to "the specifications" for the cars and their value for money. However, the expert was warned that vested interests from somewhere would oppose a hydrogen economy: "Someone will set up a group to say they don't like it" (Man).

Participants were not given information about other forms of alternative energy. Nevertheless, wind power and bio fuels were raised by the participants. The men felt that another technology might come along and replace hydrogen in the not too distant future.

7. Discussion

Although this study was not statistically validated or structured, it has provided insight into the public attitude to hydrogen in Wales, and provides exploratory findings that can be used as a base for future work. The idea that Wales could become self-sufficient and a leader in this field aroused national pride. It will be interesting to discover if the findings of this study are transferable to the rest of Wales, including rural and more bilingual areas. In particular, the rural/urban divide needs to be explored given the recognition that pollution could merely be displaced from the point of use (towns and cities) to the point of production (more rural areas).

Gender differences were apparent. Some of the men who took part in this project were very negative. Nevertheless, both the men and women said that they thought that men would want to "pull things apart and try to look for reasons [to dismiss a technology]" and that "women are more accepting [of technology]." Women also thought "men don't seem to accept change quite so easily." This directly contradicts the Schulte et al. (2004) and LBST (2003) studies that found that men were more accepting of hydrogen and hydrogen technology and the wider literature which shows that women are more technologically risk averse (Siegrist and Gutscher, 2005). It should also be borne in mind that the men in our group had more knowledge of hydrogen as a chemical and Shaw (2002) found that the better educated are more skeptical of scientific developments. It is unclear whether the gender differences here are a novel finding or arise from the small sample size.

The two main concerns were found to be safety (both of use and in production) and cost. With respect to safety, the existence of tried and tested technologies was reassuring; the women more often identified parallel situations (such as the transition from town gas to natural gas in the UK) that had gone well and this reassured them about hydrogen. Indeed, the men who were less concerned than the rest of their group about safety also referred to previous and current situations (such as the introduction of LP gas vehicles) to reassure others in their group. However, unless the technology is cost effective, in fact more cost effective than current technologies, participants would be reluctant to shift to hydrogen technology. Cost remains paramount, even in light of environmental considerations. Hence, environmental arguments alone seem unlikely to change fuel usage behavior, based on these findings. Participants did find the environmental argument to be reassuring and something that makes hydrogen worthy of consideration but not compelling. Indeed, biological and renewable energy sources were seen as the most desirable ways forward for hydrogen production.

It was viewed by some, that:

> Most things work on a proof of a track record. So once the tests have been done and they have proved themselves, I think most people are going to go for it, it's all down to the way it's marketed. (Man)

One of the women pointed out that the time for reflection between the two sessions, separately from the extra information presented in the second session, had enabled a different perspective. Any information strategy must therefore realize initial reactions may be hostile. As one participant said, "it's like with anything, people need time to get used to it."

Any project that sets out to engage the public with hydrogen fuel must provide information about the cost, safety and production of the fuel. In addition, all dialogue/communication activities to engage with the public must use illustrations, since visuals made a clear impact on views in the group sessions. On the basis of the initial focus group research, the biggest issues as to the future of hydrogen fuel are mainly related to production, safety at the point of use, cost and performance against the alternatives. However, some participants were skeptical of politicians, while others were skeptical of scientists; hence it is recommended that any event includes a spread of experts.

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