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Introduction

It is now widely agreed that it is beneficial for experts and policy-makers to involve citizens and consumers in discussion about possible scientific and technological innovations and their associated risks. Public participation in major policy decisions affecting citizens' lives, and user involvement in the design of consumer products and processes, are seen as a means of obtaining some degree of democratic legitimacy and practical knowledge of end-user preferences. However, there are difficulties in accomplishing 'upstream' public engagement, especially where anticipated innovations have potentially profound and transformative consequences for people's lifestyles. Technological innovation is a *socio-technical* process within a wider socio-technical system: technology does not simply determine cultural and social practices, but is shaped by them (Geels, 2005; Geels and Smit, 2000). But at the earliest stages of research and development (and risk assessment), consumers and citizens may be unable – or unwilling – to express firm views about possible options. In addition, debates about technologies are necessarily value-laden (as they ultimately comprise choices between conflicting goals and purposes) so they are therefore contested between different social groups and interests. This inevitably affects the nature of any engagement exercise and the search for a mythical 'public' consensus.

The discourse around public engagement superseded the previous orthodox model of one-way science (and risk) communication sometimes known as the 'Public Understanding of Science' (PUS) model. In that model, laypeople were thought to be inadequately informed or irrational about science (or risk) and therefore needed to be 'educated' by experts. The assumption that 'the public' [*sic*] has a 'knowledge deficit' has been challenged, mainly because it presumes that expert scientific knowledge is objective and superior to lay knowledge. But studies in the sociology of science and technology have illustrated that science's partial and uncertain nature, as well as its connection with certain values and interests, raise questions about its objectivity. Lay knowledge has its own particular relevance and needs to be recognised as complementary to expert knowledge.

To overcome the weaknesses of the deficit model, measures have been devised to explicitly involve the public in discussions of science and technology, and to elicit their beliefs and preferences surrounding different choices, through deliberative methods (see for example: Irwin and Wynne, 1996; Irwin, 2007; Renn, 2008; Rowe et al, 2004; Rowe and Frewer, 2004, 2005). 'Upstream' deliberative engagement implies an active role for citizens throughout the entire process of scientific research and development. In this process, citizens are not merely passive recipients of an established body of expert

knowledge which pre-empts their contribution to decisions about the desirability or feasibility of a technology. But as will be discussed further below, there are many different types of engagement, and there are important limitations on its practice.

It is not possible here to detail all the limitations which constrain attempts to engage the public in emergent technologies, but in general, several important features can be identified. First, despite the critique of the PUS and deficit model, it is still likely that the highly technical and complex nature of information available may make it difficult for citizens to make reasonable assessments about the merits and disadvantages of certain proposals. Even allowing for different methods of communication to reach a population characterised by educational, cultural and socio-economic differentiation, some proposed innovations and their attendant risks may indeed be difficult to understand. Where the science is uncertain, or is dealing with unknown risks (cf. nanotechnology) attempts to engage the public, however genuine and systematic, will be problematic (see Horlock-Jones et al, 2007a). Second, in undertaking public engagement, a major question arises about whom to engage – the whole population, or representative samples, or purposive samples of those most likely to be directly affected? Obviously this depends on the nature of the issue and its immediate relevance to different social groups, but 'the' public – or rather 'publics' – are segmented into different social groups, with different interests, which affect the saliency of the emergent technology and its perceived risks. Some may be positive about the technology, some may be hostile, some may be indifferent, and some may not even wish to be consulted (see Burningham et al, 2007) and because of this, it is difficult to design a participatory programme which accommodates these varying levels of engagement. Thirdly, it is worth emphasising that irrespective of governments' or stakeholders' desire to secure public acceptance of an emerging technology, any engagement procedure must anticipate the possibility of rejection, or only obtaining conditional and limited approval. Engagement *per se* does not necessarily result in social acceptance or endorsement – and arguably, nor should it, if it is open-ended and enables alternative options to be debated. This also raises another fundamental general question: what is the purpose of public engagement? Is the objective simply to identify the level of public awareness and then to formulate better-informed educational programmes to improve the level of citizen/consumer understanding? Is it to include citizens in developing different 'roadmaps', 'visions' or 'scenarios' as part of technological forecasting? Is it part of market research to test reaction to potentially new products or processes, or as part of technology assessment? Is it to explicitly pose alternative options, to evaluate public preferences and priorities among competing alternatives? Decision-makers must confront these questions and clarify the goals of the engagement if they are to undertake such important exercises effectively.

Having outlined some of the broader issues and questions facing those involved in these aspects of risk governance, we can now be more specific about some of the most important limits of citizen engagement in emerging technologies.

Key problems in upstream public engagement

1. *How can consumers and citizens express opinions or preferences when the technologies are still under development?*

One of the characteristics of scientific and technological innovations is that the basic research and development is slow and gradual, sometimes incremental, sometimes very rapid with 'breakthroughs'. But often information is restricted because of commercial reasons; not all of the emerging knowledge is in the public domain. Scientific information may also be tentative and provisional, even speculative, with many uncertainties. This may be appreciated by laypeople, but it may nevertheless restrict their capacity to offer realistic judgements.

One very general response to this difficulty is for stakeholders (scientists and technologists, as well as the 'marketeers') to be required, as far as possible, to indicate potential consumer uses and show the putative benefits and risks associated with practical applications. This may be done through demonstration projects and prototypes but would need to be done on a large-scale outside of the laboratory. Different technologies imply different approaches to trying to solve this problem.

2. *How can citizens/consumers engage with an emergent technology when that technology is itself characterised by heterogeneity and competition among its commercial, industrial and scientific promoters?*

It is well-known that in R & D and innovation, scientific teams and commercial firms are in competition with each other to secure more funding or investment. They may present different embryonic components of the technology, and make different claims for their effectiveness and efficiency. Ordinary laypeople cannot be expected to carry out an evaluation of such disparate claims. There is also the continuing problem of credibility and trust: whose account is believed?

Advocates and stakeholders will usually promote their own 'vision'. But consumers and citizens can expect to be shown alternatives with costs and benefits, and risks, described. Demonstration projects and prototypes may be useful, but only if they are disseminated to a wide public audience and (if possible) are available for them to try out. This is closely connected with processes influenced by Constructive Technology Assessment (Genus and Coles, 2005; Genus, 2006; Schot and Rip, 1996; Schot, 2001; van Merkerk and Smit, 2008). Clearly the use of the internet and use of virtual reality may also assist this. But the problem of trust remains unresolved: to whom can the public turn for impartial advice and information, to be able to discriminate between partial (and partisan) claims?

3. *How can citizens/consumers express views about an emerging technology when the socio-technical system in which it may operate has yet to be established?*

Any embryonic or emerging technology must be embedded in a wider socio-technical system and institutional structure – which includes not merely the cultural and social practices affecting the mode of use of the product or process but also the regulatory framework in which it operates. There is a kind of 'Catch-22' situation here. It may be difficult even for stakeholders to specify the terms and conditions under which their innovation will be used, or to anticipate all the risks and the regulatory (e.g. affecting health and safety) implications. But without such knowledge, laypeople are unable to assess the innovation from a 'whole-systems' perspective, and may simply register their own ambivalence.

The solution to this may partly lie in the use of roadmaps and scenarios in which alternative future infrastructures (and socio-technical systems) are sketched out, with their attendant options for co-ordination and regulation outlined. But if these are too abstract and 'distant' they are likely to be regarded as insufficiently realistic for laypeople to offer substantive comment.

4. *How are programmes of public engagement to be organised and co-ordinated, by whom and at what levels?*

Is public engagement primarily an activity to be undertaken by public bodies rather than the private sector, or by both? Are initiatives to be carried out at neighbourhood, municipality/city, region or national levels?

Again, depending on the technology and its stage of development, public engagement is likely to be more successful if it is done at several different spatial or territorial levels. It is also more likely to be effective if it is targeted at specific social and cultural groups, to attempt to ensure its relevance for those groups. Clearly if planned infrastructure has a particular environmental impact on only certain localities, then the necessary engagement requires even more careful adjustment. What remains unresolved is the degree of trust placed by citizens in different stakeholders and their perceived legitimacy.

5. *Organising extensive and large-scale public engagement (especially using deliberative methods) is complex, expensive and time-consuming. How is this to be financed and organised?*

For system-transforming innovations, and for emergent technologies having far-reaching effects on large sections of the population, it seems necessary that deliberation and dialogue (not mere consultation) should be carried out by the state. If this is done comprehensively and systematically, it will be expensive and time-consuming. This type of upstream public engagement is not merely 'market research', as deliberation entails presenting a variety of options to citizens, identifying diverse viewpoints, and an iterative process to attempt to construct a possible consensus. The costs of <u>failing</u> to incorporate citizens' opinions and preferences will also be high: political opposition, conflict, consumer dissatisfaction and complaints, etc.

6. *What happens if, as a result of public engagement, certain sections of the population oppose the developing technology? Will this stop, or simply delay, the innovation?*

Clearly the experience of introducing GM foods provides important lessons, and the long-standing public anxiety about nuclear power indicates that however highly advanced the technology, the perception of 'unknown-risk' and 'dread-risk' highlighted by Slovic (2000) and others will influence public reactions. Realistically, market forces and government policy will ultimately determine the direction and pace of innovation. But developments which can be shown to secure broad public support – and which demonstrate tangible public benefits – are more likely to become accepted or even endorsed. To obtain this support may take time and considerable effort, which may lead to delays. It is for stakeholders to demonstrate the necessity and urgency of their preferred innovation, and then to seek such endorsement.

To further appreciate the wider theoretical context for debate about these limits, it is important to locate the discussion within the academic literature.

Public engagement and deliberation in risk management surrounding technological innovation

The extensive and multi-disciplinary literature about the relationship between expert risk assessment and public perceptions cannot be easily summarised (see Flynn, 2007; Mythen and Walklate, 2006; Pidgeon et al, 2003; Pidgeon et al, 2006 ; Slovic, 2000; Taylor-Gooby and Zinn, 2006). This literature is diverse and characterised by methodological and theoretical pluralism – not least the debate about realist versus social constructivist approaches to risk. In parallel with this, arguments developed within the sociology of scientific knowledge (SSK) and science and technology studies (STS) have questioned the determinism implicit in some accounts of technological innovation and the secondary status given to lay actors (see Klein and Kleinmann, 2002). One dominant theme is the challenge to conventional explanations of science and technology which privilege expert views and which regard lay knowledge as mistaken or irrational (the 'deficit model'). Irwin and others have radically challenged the 'public understanding of science' (PUS) model - based on making the public better educated and informed about science so that they could understand 'the facts' and behave more rationally. This critique rejects the PUS model for disregarding the contested and uncertain nature of science, and for mistakenly treating lay knowledge as inferior or misguided (Irwin and Wynne, 1996; Irwin and Michael, 2003). Governments - faced with distrustful, sceptical and questioning publics alarmed by controversies over scientific and technological innovations such as nuclear power, genetically modified organisms, and nanotechnologies - have instead gradually adopted an alternative 'public engagement' approach (Horlick-Jones et al, 2007a; Irwin, 2007; Mohr, 2007).

Similarly, risk analysis scholars have acknowledged that citizen participation is a vital element in risk assessment and management. Renn (1999; 2008) has pioneered the

development of 'analytic-deliberative' methods, to find rigorous ways of incorporating public beliefs and opinion in decision processes. As Renn observed, a discursive and dialogic approach involving the public and experts is likely to improve mutual understanding and communication, and to enhance democratic legitimacy:
"Discursive processes need a structure that assures the integration of technical expertise, regulatory requirements, and public values. These different inputs should be combined in such a fashion that they contribute to the deliberation process the types of expertise and knowledge that can claim legitimacy within a rational decision making procedure. *It does not make sense to replace technical expertise with vague public perceptions nor is it justified to have the experts insert their own value judgements into what ought to be a democratic process*" (Renn, 1999, 3053: our emphasis).

Others have also advocated including laypeople in debates about science and technology as early as possible in the research and development process. Grove-White et al (2000) specifically criticised the 'one-way' nature of conventional information provision in science (and risk communication), and argued for greater transparency. They argued that close attention must be given, at the earliest stages of technology development, to what they termed the 'social constitution' of new technologies. Different technologies embodied different types of societal organisation and relationships. Industry, science and the public should engage in 'interactive understanding' through mutual learning, and debate alternatives. Wilsdon and Willis (2004) further argued in favour of moving public engagement 'upstream', to "ask deeper questions about the values, visions and vested interests that motivate scientific endeavour" (Wilsdon and Wills, 2004, 18). They proposed that there should be public scrutiny of issues such as the ownership, control and social purposes of any technology, "to make visible the invisible, to expose … the assumptions that usually lie hidden" (op cit, 24).

Noting that public participation (and risk assessment) usually occurs when a technology is almost ready for implementation, and attention is focused on its 'downstream' impact, Wilsdon and Willis proposed a radical shifting of engagement 'upstream' in order to shape the objectives and priorities of the innovation from its inception. Such upstream public engagement (UPE) should be 'substantive', that is, it must shape decisions, rather than coming after the event; it should 'open up' debate and the public should help decide which issues and what questions should be addressed. Wilsdon and Willis' model of UPE is also 'deliberative' and entails methods such as consensus conferences, citizens' panels and citizens' juries as ways of mediating different (and conflicting) interests. Among their suggested questions are fundamental ones such as: "Why this technology? Why not another? Who needs it? Who is controlling it? Who benefits from it? Can they be trusted? What will it mean for me and my family? Will it improve the environment?" (op cit, 28).

Some writers, having observed recent UPE exercises (such as those about GM food and nanotechnologies in the UK) are now cautious about their validity and usefulness. Various criticisms have emerged. For example, Abelson et al (2003) and Renn (2008) have questioned whether the methods most frequently used are procedurally fair and

competent, and have asked whether they had any impact on policy. Petts (2004) argued that there are still concerns that some analytic-deliberative methods are primarily about legitimating policy-making rather than forming policy. Rowe at al (2004) raised the possibility that participatory and deliberative methods might be accused of tokenism, as they did not ensure genuine empowerment of citizens. Thus Rowe and Frewer's (2005) typology of public engagement differentiated between communication, consultation and participation – with only the latter enabling citizen influence on agenda-setting, decision-making and policy-forming. It remains a matter of debate as to how far different engagement exercises ever achieve such influence. Leach et al (2005) observed that citizen involvement through deliberative processes was still predominantly based on a 'liberal' theory of citizenship, in which citizens are given a passive role. Leach and Scoones (2005) argued that deliberative forums remain framed within a scientistic discourse. Wynne (2005) has also criticised the "extravagant optimism" surrounding recent participatory exercises, and claimed that the commitment to engage the public is "something of a mirage" (Wynne, 2005, 68). Similarly, Stirling (2005) has questioned whether new participatory discourses used in the social appraisal of technology 'open up' or 'close down' public debate.

For example, in two of the most significant recent public consultation exercises in Britain, about genetically modified organisms (GM) and nanotechnologies, critical observers have raised doubts about the impact and value of the engagement process. Horlick-Jones et al (2007a; 2007b) evaluated the 'GM Nation' debate (which was intended as an experiment in engagement) and found that participants were unconvinced that their involvement would influence government policy; that their involvement had occurred too late; and that many of the procedures were not deliberative. In relation to nanotechnologies, Pidgeon and Rogers-Hayden (2007) described how this consultation was explicitly designed as upstream engagement, which they defined as:
"Dialogue and deliberation among the affected parties about a potentially controversial issue at an early stage of the research and development process and in advance of significant applications or social controversy" (Pidgeon and Rogers-Hayden, 2007, 194). However, they noted that the 'nano-jury' had considerable difficulties in 'engaging' with highly future-focused and scientifically-uncertain technologies. Similarly, Doubleday's (2007) account of the citizens' jury on nanotechnologies found that the framing of the debate in terms of risks posed by nanoparticles closed down the possibility for argument about the broader purposes of the innovation.

Other concerns about the adequacy of analytic-deliberative processes and upstream engagement exercises have also surfaced. Two major points can be highlighted. First, there are continuing concerns that there is still an asymmetrical relationship between the experts and citizens, and the agenda for debate may be pre-empted. Chilvers and Burgess (2008) refer to nuclear waste governance in the UK and public/stakeholder engagement, and highlight significant imbalances in power between those involved in 'deliberative mapping' which may undermine public trust. They suggest that issues were framed in such a way that certain questions were excluded, and technocratic discourse was dominant: for example, questions about existing nuclear waste and new nuclear

generation were treated as distinct and separate issues, when they were seen as integrated by the public. They also wondered if public engagement may be a "passing fad to justify difficult decisions during a time of increased public scrutiny" (Chilvers and Burgess, 2008, 1898). Secondly, there are doubts about how widely adopted UPE really is in government policymaking and in the private sector where environmental risks are paramount. For example, in their investigation of industrial chemical companies' 'engagement' of the public, Burningham et al (2007) found that the companies still subscribed to the deficit model, where the public's distrust was seen as (further) evidence of their irrationality. Burningham et al found little evidence of upstream engagement occurring, or even being seen as necessary or desirable, by the companies surveyed.

Thus, despite the ambitious and radical expectations surrounding UPE (see Cornwall/Demos, 2008), there are major difficulties in implementing it and continuing questions about its impact on policy. Leading writers have expressed serious doubts about its effectiveness. Irwin (2007) argues that while the *rhetoric* of dialogue and engagement may have become well-established, in its institutionalisation, it has simply become another part of the scientific governance toolkit and 'business-as-usual'. Petts (2008) has also cautioned about expecting too much from public engagement. She argues that the belief that UPE will promote greater public trust in science is over-optimistic: the deliberative processes *per se* may not engender trust but may even disturb it. Lidskog (2008) warns that in evaluating 'imperceptible' or 'invisible' risks, lay knowledge is always likely to have secondary status, and citizens' deliberative capacities are limited.

The fundamentally important issue is whether UPE can be ever be undertaken in what may appear to be highly abstract, highly uncertain, *emergent* or future technologies. Numerous writers have noted the difficulties of assessing public awareness of even relatively well-established scientific or technological topics. However, it can be argued that there are some embryonic innovations where the scientific knowledge base is still evolving which pose special problems for engaging the public. It is instructive (but unsurprising) to learn that, in the case of GM food, UPE and qualitative studies of public perceptions reveal deep-rooted ambivalence about biotechnology, given the scientific debate about GM and continuing uncertainty about its long-term effects (see Bickerstaff et al, 2008; Horlick-Jones et al, 2007a; Pidgeon et al, 2005). Similar ambivalence has also been consistently reported in studies of public attitudes towards nanotechnologies (Doubleday, 2007; Mohr, 2007; Pidgeon and Rogers-Hayden, 2007; Royal Society and RAE, 2004). Such ambivalence is not simply a reflection of a lack of knowledge or information. Rather, it signifies a reluctance by people to make unequivocal statements about these innovations, and the wider socio-technical systems in which they might be embedded, until they are directly experienced and/or shown how they might connect with their everyday lives. Moreover, as Kotchetkova et al (2008) have remarked about lay knowledge of stem cell research (using deliberative mapping techniques), people have ambivalent and complex views which cannot be simplistically reduced to acceptance or rejection. Indeed they argue that such ambivalence "should not be concealed, eliminated and dismissed" (p82).

Thus, the equivocal and provisional nature of public attitudes towards new and emerging technologies is to be expected. But that returns us to questions about the 'reach' of UPE. How far 'upstream' can public engagement go in technologies still at the experimental or laboratory stage? Fisher et al (2006) have argued that in 'technology assessment' the upstream engagement approach assumes, crudely, a linear model where expert knowledge moves from basic science to applied research, and then product development. But to have a real influence, laypeople's engagement must be incorporated upstream in the Research & Development process, and '*mid-stream*' in the techno-scientific processes that implement the R & D – as distinct from only assessing the 'downstream' impacts for the end-user. This might enable public involvement in shaping the technology before it becomes established and marketed. How far this can be achieved and demonstrated remains unclear.

To further illustrate some of the practical problems of carrying out upstream public engagement in an emergent technology, we will now consider evidence from an ongoing study of lay perceptions of, and attitudes towards, hydrogen energy technologies. Prior to examining this case-study, some brief information about hydrogen and hydrogen energy technologies is presented.

Hydrogen and hydrogen energy technologies

Only a very brief and simplified summary of hydrogen energy can be given in this paper (but see United Nations, 2006; Ricci et al, 2007a; Ricci et al, 2008). Hydrogen is an energy *carrier* not a primary energy source – although it is the most abundant element in the universe. Hydrogen is produced commercially for various industrial uses by 're-forming' natural gas (or methane from biomass) and also by electrolysis of water using electricity from any source (nuclear, solar, wind, wave). Many champions of hydrogen see it as a supplement or even an alternative for fossil fuels; they stress it is 'green' and non-polluting. Hydrogen can be used in fuel-cells – in transport (such as vehicles), in stationary applications (such as combined-heat-and-power systems for buildings) and even in portable devices (such as laptops). Radical and ambitious claims have been made about hydrogen's potential to 'democratise' energy production: Rifkin (2002) suggested that consumers in a new 'hydrogen economy' could become their own hydrogen energy producers (using their own cars and houses). Many of the advanced industrial economies have invested large sums in research and development of hydrogen. Both in the USA and Europe, demonstration projects have been introduced, such as fuel-cell buses and trials of hydrogen-refuelling stations, and many motor car manufacturers are reaching an advanced stage in producing hydrogen fuel-cell cars.

There are however, many critics and sceptics, who challenge hydrogen's 'green' credentials and question whether it is genuinely sustainable. Most hydrogen is currently reliant on fossil fuels, and to replace this poses problems in terms of the quantity (and

reliability) required from renewable energy sources. Furthermore, many commentators have identified severe safety hazards and risks with hydrogen – it is highly explosive, and the gas must be stored at extremely high pressures and at extremely low temperatures in liquid form. How hydrogen is to be produced, stored (for example, there are scientific doubts about whether new solid state storage materials such as carbon nanotubes are efficient and reliable), transported, distributed and used raises major safety (as well as economic) questions. The European Commission has identified safety, regulatory and public acceptance issues as important 'non-technical barriers' to the development of hydrogen as an energy carrier (EC, 2006). A recent report in the UK has also highlighted institutional and economic barriers to the widespread introduction of hydrogen infrastructure in transport (AEA, 2008). Industrial and scientific stakeholders have differing views about possible alternative future scenarios. Eames and McDowall (2006) and McDowall and Eames (2006) have used deliberative mapping among stakeholders and identified six separate hydrogen 'visions', with very different characteristics and interests. Ekins and Hughes (2007) have questioned whether the 'hydrogen economy' projected by its advocates is economically feasible. They show that there are different possible hydrogen economies and infrastructures, but in the short- to medium-term it is unclear whether there is sufficient market demand for it, and there are strong incumbent technologies to prevent it from developing. They also argue that massive public investment – justified in terms of public policy such as reduced carbon emissions – would be necessary to bring about a strategic transition to a hydrogen based economy.

Here then, there is an emergent or embryonic technology, surrounded by many scientific and economic uncertainties, whose proponents claim will bring important advantages and will solve some of our contemporary energy problems. But are the general public aware of it, and what are their attitudes towards it? Evidence about these important questions is relatively sparse, the methodology for investigating them is varied, and the evidence is mixed (see for example Fuhrmann and Bleischwitz, 2007; Heinz and Erdman, 2008; Roche et al, 2009; Ricci et al, 2008).

Public perceptions of hydrogen energy technologies

To illustrate some of the complexities involved in gauging laypeople's awareness of this new and emergent technology, and some of the limits of upstream engagement, we review qualitative evidence from recent and ongoing studies of hydrogen energy, conducted by the authors. The (mainly qualitative) data derive from two inter-linked projects.

The first is part of the Engineering and Physical Sciences Research Council (EPSRC) programme on sustainable energy and the UK Sustainable Hydrogen Energy Consortium ('UKSHEC', 2003 - to date: see http://www.uk-shec.org.uk and http://www.psi.org.uk/ukshec/publications.htm). Within this programme, the authors (with other colleagues) have carried out case studies in three areas of England and Wales where there are already existing hydrogen production facilities and infrastructure, or plans for developing them, and/or early stage demonstration projects using hydrogen fuel

cell vehicles and other hydrogen energy applications: Teesside (north east England), Wales, and London. Two phases of focus group meetings were carried out (in Oct-Dec 2005 and Oct-Nov 2006) with members of the public sampled from local authorities' own consultation panels. In the first phase there were nine groups, and in the second there were seven groups ; each group was mixed in gender, age and socio-economic group (group size varied between six and eight people, although there was also 1 group with only three and 1 group with thirteen members). Focus group participants were deliberately recruited on the basis that they had no direct involvement in the hydrogen industry. At the first meetings, their general awareness of environmental and energy issues was discussed, and then various types of information about hydrogen were provided. At the second set of meetings (in October-November 2006), more detailed information about hydrogen was presented and participants invited to debate alternative scenarios. These discussions were digitally audio-taped, transcribed and then thematically analysed by the research team.

More recently, a series of *Citizens Panels* were carried out in Teesside and Wales (November 2008 and April-May 2009), in which members of the public participated in two meetings with experts, questioned and challenged those experts, and debated various alternative scenarios for hydrogen energy. Members of the Panel were selected again from local authorities' own public consultation panels, which are statistically representative of the local population. In the first Teesside event, nineteen persons (eight females, eleven males) attended an all-day meeting facilitated by the research team, and from the same group, eighteen people attended the second meeting three weeks later. At the first session, following a general discussion of issues surrounding the environment and energy, participants listened to presentations by two expert scientists about hydrogen energy, questioned them, and discussed those presentations in detail in smaller 'break-out' groups. A third presentation was given by an expert stakeholder from the region about proposed hydrogen technology developments; this was followed by further questioning and discussion by the citizens' panel. At the end of the meeting, people were given a DVD about hydrogen and its applications in transport, for them to view prior to the next meeting. At this second meeting, the three experts who had attended the first event were present, together with a representative from the Health and Safety Executive, who talked specifically about the safety and regulatory concerns about hydrogen. Once again, members of the citizens' panel were able to challenge and question these experts, and they also participated in a deliberative exercise commenting on a set of six hydrogen 'visions' previously produced from an earlier stakeholder workshop (Eames and McDowall, 2005). All of the presentations, questions and discussions were digitally recorded and the transcripts have been analysed thematically.

Here, findings are summarised from the *second* meetings of the Focus Groups, and then from the Teesside Citizens' Panel only; material from the Wales Citizens' Panel will be presented at a later date.

The other project was a study carried out in 2006-2007 for the UK Department for Transport about public engagement with hydrogen infrastructure in transport (Bellaby and Upham et al, 2007).This combined a telephone survey and 12 focus groups in three

areas of England where there was *no* existing or embryonic hydrogen infrastructures: Norwich, Sheffield and Southampton. These areas were also purposively selected because they comprise different types of labour markets and have very different travel networks. A commercial company carried out the telephone questionnaire survey of a representative sample of the local populations (n = 1,003), and from this recruited four focus groups in each area. These groups contained between 8 and 10 participants and were mixed in terms of age, gender and socio-economic group. A professional facilitator convened the group discussions, and after general discussion of issues such as climate change and other environmental and energy issues, a specially commissioned DVD about hydrogen energy and its transport applications was shown, and participants invited to express their opinions. These focus group discussions were digitally audio-taped, transcribed and thematically analysed by several team members and an independent researcher.

Findings from each of these studies are now presented, first those from the 'UKSHEC' research, and then those from the Department for Transport project. As is usual in reporting focus group qualitative data, a summary or overview is given (Barbour and Kitzinger, 1999; Bloor et al, 2001).

Focus Group views on Hydrogen energy technologies

All of the groups were very aware of issues such as climate change and global warming, and the crisis over fossil fuels. Many participants expressed a concern that action should be taken by national governments to address these problems and acknowledged that significant changes in consumer behaviour (over energy use) were also required. In common with the other (very few) studies of public perceptions of hydrogen, our focus group members had very little awareness of hydrogen energy and its possible uses (see Ricci et al, 2007b; Ricci et al, 2008).

However, after being presented with various types of information about hydrogen, there was neither enthusiastic acceptance nor complete rejection – rather, people maintained a determinedly 'agnostic' view. Participants raised fundamental 'whole system' questions about how hydrogen and its associated infrastructure might work, and wanted to know more information about its relative benefits, costs and risks compared with conventional energy sources and carriers. Many of their comments made connections with, or raised questions about, how hydrogen technologies related to the local economy and environment, and their employment implications. In the area with a well-established industrial history in petro-chemicals, steel-making and coal mining (and also high levels of environmental pollution and recent unemployment) there was some acceptance that hydrogen production and distribution on a large-scale might not be problematic, and people were confident that safety issues could be dealt with. In another area where there had also been an industrial history of steel-making and coal-mining but then decline and unemployment, the local government was promoting job-creation and environmentally-sustainable regeneration, focus group members were divided about the potential impact of hydrogen on the economy and the natural environment. In London, a major concern among focus group members was current levels of air pollution and the possible advantages of hydrogen fuel-cell vehicles, but there was scepticism about whether people

were willing to bear the increased costs of new infrastructure. Very few of the focus groups cited potential safety hazards of hydrogen as an overwhelming concern; it was widely believed that risks would have been minimised to safe levels and 'engineered out' before such technologies were introduced. Cost and convenience were the over-riding concerns from a consumer perspective.

However, running through the comments and discussions were a series of questions which signalled profound uncertainty and ambivalence about hydrogen (see Flynn et al, 2008). Several participants asked basic and important questions about how the hydrogen was going to be produced, and whether, if the major source was still fossil-fuels (e.g., from natural gas steam reforming) there were any environmental advantages. They were unsure (or unconvinced) that renewable energy sources could generate sufficient hydrogen on a large-scale. They asked for much more detailed information than was currently available from official sources and identified issues which are still the subject of ongoing scientific research (and uncertainty). When they discussed possible hydrogen technologies such as fuel-cell vehicles, domestic combined-heat-and-power systems and other portable applications using hydrogen, safety issues figured more prominently. In considering the practicalities of using hydrogen-based technologies, participants acknowledged that people's everyday routines meant that they were effectively 'locked-in' to existing technologies and it would be difficult to persuade the public to change their behaviour until there were fewer uncertainties surrounding hydrogen.

Asked about their attitudes to the possibility of becoming small-scale producers of hydrogen energy (micro-generation), most of the focus group participants were cautious and sceptical about the value of hydrogen fuel-cells linked with wind-turbines and solar (photovoltaic) panels. They also raised doubts about their cost-effectiveness, their performance and reliability. Here, risks to safety and ease of operation in hydrogen-based combined-heat-and-power systems were also highlighted.

Focus group members in each of the three areas had been provided with basic information sheets about the science around hydrogen, and also 'picture-postcards' showing simplified representations of the production, distribution, storage and use of hydrogen. They had also been shown computer slide presentations of images of current demonstration projects and possible future scenarios, and were invited to comment on them. Many of the participants reported difficulty in understanding how a hydrogen fuel-cell works, and with the complexity of some of the information. Many also wished to know how the specific technologies compared in terms of cost and efficiency with other energy technologies, particularly in relation to hydrogen production by electrolysis, biomass and fossil fuels. In addition to these immediate concerns, broader questions were asked about the location of production facilities and negative externalities. Some people expressed difficulty in giving opinions about a possible future 'hydrogen economy' because they were unfamiliar with how this might operate as a system.

Towards the end of the focus group discussions, participants were asked for their views about consultation with the public about hydrogen energy. In all of the groups, people interpreted 'involvement' and 'engagement' not as dialogue but as one-way communication of information from experts and stakeholders to citizens. This may be partly explained by their unfamiliarity with more deliberative and interactive forms of consultation, and more experience of simply receiving communication through the media or completing questionnaires. Some participants expressed deep cynicism about consultation processes, and suggested that public policy about hydrogen was already a "done deal". However, a significant number of other participants suggested that most people were uninterested, unable or unwilling to become 'engaged'. This raises interesting questions about the objectives of 'upstream' engagement.

Participants emphasised that in order to involve or engage the public, the issues had to be presented to them *in ways which were relevant to their immediate everyday lives*. Several pointed out that realistic judgements about whether the hydrogen economy was desirable or needed could only be given when they could experience hydrogen energy technologies 'in action'. They also stressed that information had to be communicated by spokespersons who could be trusted; people were distrustful of 'vested interests' and many were particularly critical of business, industry and government.

Overall, in these focus groups, public perceptions of hydrogen were broadly neutral but were also highly conditional and context-driven. Most importantly, people expected to be able to see practical demonstrations of the technologies in use, and also wanted greater knowledge about the wider socio-technical system which might emerge. They were unable and unwilling to voice positive or negative opinions until they received much more information, and in particular wished to be shown how hydrogen would materially benefit them as individuals as well as bring environmental benefits.

Hydrogen and Transport Infrastructures

In the other project about hydrogen transport infrastructures, there were 12 focus groups; only a highly selective and condensed summary of findings can be given here (but see Bellaby and Upham et al, 2007). In all of the groups there was little awareness of hydrogen energy, but considerable interest in being provided with detailed information about its future uses. After being shown a DVD and other information, participants stressed that they needed to know how it might connect with their own daily routines and lifestyles. They also asked questions about how hydrogen compared with existing energy carriers and what its overall costs and benefits might be. Significantly, there was consistent opposition to using fossil fuels and nuclear power to generate hydrogen. Attitudes towards renewable energy sources were more favourable; while some supported wind power (subject to aesthetic and noise conditions) many were unaware of the possibility of biomass for hydrogen, and had varied opinions about it. People talked about the difficulty of imagining a large-scale infrastructure for the production, distribution and storage of hydrogen. The also identified the complexity of the safety and regulatory aspects of such a new system as problematic. Many asked questions about the relative costs and efficiency of hydrogen as compared with other energy sources and carriers. In the Sheffield groups, questions were specifically asked about the advantages and

disadvantages of centralised or localised production of hydrogen. Concerns were raised about safety risks in localised production, and also in using and re-fuelling hydrogen fuel-cell vehicles. In the Southampton groups, views were very mixed about the prospects of centralised versus de-centralised production of hydrogen. Questions were asked about the pressure at which hydrogen must be stored and related efficiency and safety issues. But across the groups generally, there was also widespread support for the view that the public would accept a new infrastructure if the benefits were demonstrated.

While safety concerns did not result in extensive or serious opposition to hydrogen, many participants in all the groups raised questions about potential hazards. People wanted to know how hydrogen would be handled, and in what ways their own behaviour (e.g., in using cars) might have to change.

Many people were unable or unwilling to express definite opinions about the possible configurations of hydrogen infrastructure and a possible 'hydrogen economy' without much more information from what they regarded as trustworthy sources. Their views were conditional on knowing much more about the specific technologies envisaged, and the context in which the infrastructure would be developed. Thus, for example:

> *"We don't have enough technical information about these processes really to decide whether we want to get involved with them ... In order to make a judgement ... you actually need to have quite a lot of technical information, or you have to, you either have to do that, or you have to make a much more personal decision about which scientist to trust and how much"* (Woman, Norwich, social grade ABC1).

Frequently, participants emphasised that to discuss hydrogen in isolation was unrealistic: they constantly referred to the need to consider hydrogen in relation to our current dependence on fossil fuels and doubts about the value of renewable (wind, wave, solar) energy sources. In all the focus groups, people expressed the view that if there was to be a major transition to hydrogen it would need to be justified in terms of improvements in cost and performance over existing technologies, and would also necessitate large-scale demonstration projects to convince the public of its practicality.

Regarding the value of public engagement itself, there were mixed views across the groups. Most people believed it was necessary and important for the public to be informed of potential changes in the energy infrastructure, but many also questioned the nature of the engagement process. There was widespread scepticism about whether public opinion would be influential in decision-making, and how people might know whether it had affected policy. Speaking about other major plans and technologies, which were introduced only for faults to emerge later, a man in one of the Norwich groups said; "*They usually launch it, and then mend it"*. A woman in the same group directly asked: *"Who's going to be making the decisions?"*. A person in one of the Sheffield groups was worried that major policy changes might be decided by focus groups rather than by the national electorate. In several groups cynicism was voiced about the degree to which the

public could influence policy: commercial and industrial interests were seen as having the ultimate power. Thus in one of the Southampton groups, one participant recognised that while government and official bodies might consult the public, *"They might be funding things like this* [i.e. the focus groups] *but to get feedback. But at the end of the day, they* [government] *will still let it be commercially driven, I'm sure of it"* (Man, 45+, social grade C2DE).

In summary, what the findings from all these focus groups (from both projects) indicate is that knowledge of hydrogen is limited but attitudes are agnostic. People are keen to learn more about hydrogen energy technologies, but reluctant to express explicit approval – or outright rejection – until more information is available about the relative costs, benefits and risks of such technologies as compared with existing systems. Frequently, participants asked questions about what several of them referred to as 'the bigger picture' and most people found it difficult to comprehend the large-scale and radical changes in the energy system envisaged by proponents of the 'hydrogen economy'. Many also voiced doubts about the impact of public consultation exercises, suggesting that engagement was of little consequence to policy and decisions.

Teesside Citizens' Panel deliberations

From the two meetings at which expert presentations were made, several themes emerged in people's questioning and deliberations. First, general awareness of hydrogen and its potential applications was low. People asked detailed questions about how hydrogen compared – especially in terms of efficiency and costs - with other energy sources and energy carriers. They also asked about how accessible these new technologies would be or whether the price would deter people. Secondly, practical questions were also asked about how hydrogen fuel-cell technologies would be maintained and serviced (in a domestic setting), as well as the environmental impact of hydrogen production facilities. Safety surfaced as an issue but it was not overwhelmingly important in the discussions, although questions were asked about the potential hazards of storing large quantities of gas in refuelling stations, pumping it at through pipelines, or transporting it by road tankers. Third, many of the participants favoured obtaining greater familiarity with hydrogen technologies through *demonstration projects*, although most were actually unaware of some existing local demonstration projects. Fourth, generally positive views were expressed in support of continued Research and Development, particularly where this was linked with regional economic regeneration and employment opportunities.

When debating the role played by the citizen or consumer in technological innovation, most people believed that usually there was little public input, and that public opinion was often ignored by government and was weak in relation to market forces. Having listened to the experts, and having questioned them, citizens' panel members debated the difficulties of assimilating technical information and raised the issue of how to deal with conflicting and complex science. For example, one man asked: "*Why is it when you put two people in white coats, they all have different views*?". Trust became a central concern, but there was no agreement about who might be the most trusted provider of information. Participants nevertheless urged that impartial information must be presented

which enabled them to consider different options, and which would identify advantages and disadvantages in an unbiased way. But when asked directly about the significance of public engagement, most people expressed cynical views. Some argued that certain groups would not be interested and that others would be unable to become engaged for practical reasons (the time and cost of becoming involved is a deterrent). While welcoming the chance to participate in these citizens' panel meetings, and having the opportunity to meet and discuss matters with experts, most were sceptical about how influential public engagement might be. A few even argued that important policy decisions should be largely left to the experts rather than being subject to public consultation. This group at least seemed to regard the principle of upstream public engagement as attractive but ultimately ineffectual.

Conclusions

Expecting laypeople (and experts) to imagine future technological developments and to make judgements about their desirability and feasibility is always fraught with difficulty. Involving members of the public in upstream engagement about *emerging technologies* is challenging and problematic. There are important limits on its feasibility.

Geels et al (2007) noted that it is often assumed that public reactions to technological innovations will be distributed along a *continuum* between enthusiasm and resistance. But, they argue, public perceptions and actions are much more complex and varied than this. In addition to creating new products, industries and markets, there has to be 'societal embedding' (see Geels and Smit, 2000) in the cultural practices of consumers. The new technology must fit in with people's beliefs and norms if they are to use the product. They refer to three types of societal embedding in which there is a 'hype cycle' among enthusiasts or optimists; conflicts among different social groups about the value and purposes of the new technology; and also controversy leading to stalemate. By implication, the outcomes are uncertain. Moreover, Schot and Geels (2008) argue that: "technology actors usually focus on developing, testing and optimising technology, but neglect the embedding in broader societal goals, or leave it to a later stage" (Schot and Geels, 2008, 538). They note that empirical studies of demonstration projects show that many of these are based upon a 'technology-push' approach with a very narrow concept of how users (consumers) can be included. In their multi-level perspective on transitions management, radical technological innovations must move beyond a micro-level 'niche', and become integrated in a meso-level 'socio-technical regime', which is part of a macro-level 'socio-technical landscape'. Conventionally, however, firms and governments promoting new technologies focus mainly on the technology and pay little attention to the wider context in which it might be used. Indeed, particularly relevant in this case, Harborne et al (2007, 184), examining the development of hydrogen fuel cell buses, concluded that demonstration projects are "framed purely as 'technological' rather than 'social experiments'", and that this limited their relevance in the assessment of different visions of socio-technical regimes. Thus, however genuine the commitment to engage people in technology assessment, there remain doubts about how far the advocates and

promoters of such innovations can locate them within possible futures and alternative cultural and institutional frameworks.

The case-study of hydrogen energy technologies discussed here indicates some of the important constraints on upstream public engagement where the technology is still embryonic or nascent. It is not simply the difficulty of communicating information about the basic science, or conveying differences in scientific opinion about alternative methods of production and storage, or presenting expert risk assessments of safety to an 'uninformed' public which is at issue. Rather, it is about providing citizens with a meaningful and realistic appreciation of the environmental and personal benefits, costs and risks which might result from a transition to a hydrogen economy. This necessarily entails providing a description of alternative scenarios embodying choices and consequences. But this requires a 'whole systems' perspective which is currently absent or unimagined. The process of societal embedding for hydrogen energy technologies has yet to be determined. Asking citizens or consumers to express preferences among vague and uncertain possibilities when so little is known about how the technology will be used operationally in everyday life, let alone about what kind of institutional and regulatory system is required, is unlikely to yield significant improvements in public engagement.

But this reflects a much deeper issue – even if a sophisticated set of alternative scenarios or visions could be developed (with robust cost-benefit analysis, and risk assessments etc), different stakeholders will necessarily have different interpretations of (or aspirations for) preferred 'visions'. Upstream public engagement faces the fundamental problems of any form of consultation process: how to resolve conflicts among a diverse public and fragmented producer interests; when or at what stage of the innovation to facilitate citizen participation; and what methods to use to ensure inclusiveness and efficacy (citizens' juries? citizens' panels? multi-criteria mapping?). Upstream public engagement in an emergent technology like hydrogen does not simply have to address one decision or one policy, but *multiple options* with different systemic features. Inevitably, then, upstream public engagement will continue to be a contested concept in theory and practice. It may be a democratically valuable endeavour, but its achievement is always likely to be limited and incomplete.

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