

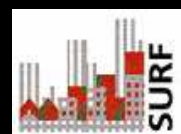


**Actors, organisations and institutions relating to the
development of hydrogen and fuel cell activities in the
UK**

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Nick Hughes
Policy Studies Institute

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Executive Summary

The penetration of hydrogen and fuel cell related technologies in the UK will be influenced by organisations and institutions at international, national and regional levels. This produces a highly inter-related and 'nested' picture, where the effectiveness of the various potential interactions between levels is crucial.

At the international level there is a diverse range of hydrogen and fuel cell related activities developing in a wide range of countries, with a variety of contexts, energy policy frameworks and motivations. Both governments and private companies periodically set relatively ambitious targets, relating to technology commercialisation. However, major and decisive action and investment is currently lacking as most actors hedge their bets by waiting to see if others will bear the risk of being first movers on an uncertain technology. The most important international sources of funding for UK actors intending to develop hydrogen and fuel cell projects come from the EU level.

At the UK national level, funding for demonstration projects is available through the DTI, the Carbon Trust, and the Energy Saving Trust. The forthcoming Energy Technologies Institute (ETI) will also be significant in this regard.

There is significant entrepreneurial activity in the UK relating to hydrogen and fuel cells, largely focussed on stationary and portable fuel cells, and the integration of hydrogen and fuel cells to renewable energy systems. This is in some contrast to the national level UK policy position, which is dominated by an automotive based vision. There is a need to address this divide, by creating policy aspirations which are open to a wider range of potential hydrogen and fuel cell development scenarios, as well as policies designed to incentivise development of automotive technologies which are unrepresented in the UK technology portfolio. Such strategic investment could have the beneficial effect of generating employment in areas of the country with available skill bases in automotive manufacturing, which have been in economic decline due to relocation of major automakers to other global markets.

In order to aid commercialisation, industry networks and communities of practice should aim to link up more explicitly with actors who might potentially be early purchasers of hydrogen and fuel cell technologies. These could include local authorities, businesses or large commercial retailers, who might provide demand for niche products for delivery fleets or stationary power and CHP applications. Institutions which might facilitate such networks include the UK Hydrogen Association, and the DCLG's local government 'Beacon Scheme'.

At the local level, motivations for the development of hydrogen and fuel cell related projects are highly specific to the region where they occur, and relate to factors including economic development concerns, the context set by other policy areas, and the region's view of itself and its aspirations. These factors will have very real effects not only on whether hydrogen and fuel cell technologies are accepted, but also on which types of hydrogen and fuel cell systems are ultimately preferred. The role of local actors and institutions is therefore crucial to the implementation of hydrogen and fuel cell projects.

High level road maps can be problematic in their tendency to homogenise the diverse nature of hydrogen and fuel cell developments. Nevertheless, many local actors express a

need for some kind of guiding vision at a higher level, to provide a framework for local activities. Whereas the national level is too removed from the specificities of regions to create a vision that is resonant with all areas, the LA level is too entrenched with other fundamental service delivery areas to be able to give real priority to futuristic technologies such as hydrogen and fuel cells. Thus the regional or RDA level, sitting between the two, is a potentially suitable locus for such a guiding vision to be created.

High level policies and road maps devised at UK national and EU level should provide an aspirational drive to encourage local and regional actors to implement hydrogen and fuel cell projects, supported by appropriate funding mechanisms, whilst remaining flexible to regional interpretations of what a hydrogen or fuel cell economy means in each local context. Key priorities, for example carbon reduction, security of supply, or economic benefits, may be set at the higher levels. Within this framework however, policies should be open to the possibility of multiple and simultaneous variations on the theme of the hydrogen economy.

Actors, organisations and institutions relating to the development of hydrogen and fuel cell activities in the UK

Introduction

The penetration of hydrogen and fuel cell related technologies in the UK can be promoted and influenced by a range of organisations and institutions at a variety of actor levels: international, national and regional. As research and development activity in the UK forms a relatively small part of the global picture, the cost and performance of technologies available to the UK will be strongly related to activities in technological development, by industrial and regulatory organisations, at the international level. The coordination of the variety of technical and socio-economic factors may require strong leadership at the national level. Nevertheless, given the importance of a geographically specific approach to consideration of implementing hydrogen technologies (see Hughes, 2006; Hodson and Marvin, 2006), consideration of institutional and social dynamics at the regional level is also crucial. This produces a highly inter-related and 'nested' picture, where the effectiveness of the various potential interactions between levels is crucial.

In the following discussion, the three actor levels, international, national, and regional, will be considered in terms of their inter-relationships, and their potential impact on the development of hydrogen and fuel cell technologies within the UK. Within these levels, a variety of operators and connections between them can be observed, and may be identified in the following ways. The term *actor* is used by High et al (2004) to describe 'an individual or organisation with a capacity for intentional behaviour (agency), and with an identity founded in a particular locality'. Thus in the context of hydrogen and fuel cell development, this could include a government department, private company, NGO, interest group, or individual (either acting alone, or from the basis of and in addition to their role within an interested organisation) which or who is in some way mobilised to exert influence on the development of hydrogen and fuel cells. Using the terminology developed by Pelling et al (2004), it can be observed that *Communities of practice* are formed within, and sometimes between, actor levels, in which actors holding 'shared values and identity', assemble to attempt to achieve shared aims. In the context of hydrogen and fuel cells, this term may be best used to describe the local and regional level interest groups who share common motivations for promoting hydrogen and fuel cell technologies in their particular region. *Networks* are relationships between actors which 'straddle the boundaries of communities of practice where members may not identify with more than a small number of others'. The distinction between networks and communities of practice as defined by Pelling et al is potentially very pertinent to hydrogen and fuel cells. While local and regional level communities of practice may share many common aims, within broader networks created by industry associations and national roadmapping processes, aims and values may be much more diverse, and consensus more elusive. *Institutions* are defined by Pelling et al (2004) as the 'rules of the game', which can be formal (legislation, guidelines) or informal (culture). Again, it shall be shown that both kinds of institution are relevant to hydrogen and fuel cell activities in the UK, but that due to the relatively small number of actors involved and the early stage of technological development, the informal kind are noticeably prevalent.

1. International Level

In this section, key international actors, policies and institutions will be listed and discussed. Their relevance in terms of their potential to influence hydrogen and fuel cell activity in the UK will be discussed.

The International Energy Agency (IEA)'s perspective on energy issues, due to the profile and expertise of the organisation, will inevitably be highly influential. The organisation has recently produced a report entitled *Prospects for Hydrogen and Fuel Cells* (IEA, 2005) containing technological characterisation and policy analysis. The report endorses the value of a broad energy portfolio, of which hydrogen should be a part, particularly with reference to the transport sector. It advises that governments should continue to fund research, development and demonstration programmes for hydrogen and fuel cells. However, in the IEA's recent set of future technology scenarios, *Energy Technology Perspectives* (IEA, 2006) hydrogen as a transport fuel only emerges in the most technologically focussed scenario, TECH Plus, and then only to meet 9% of transport demand.

According to Solomon and Bannerjee (2006) the IEA's research and demonstration projects have been supported in Germany, Switzerland, Italy, Spain, the US and Canada. The authors however express doubt that the agency's activities are likely to have a significant effect on the near term commercial viability of technologies (Solomon and Banerjee 2006).

The International Partnership for the Hydrogen Economy (IPHE) is a consortium of representatives from at least 16 countries, including the UK, with the US Department of Energy serving as the initial secretariat. It sees itself as a 'mechanism to organise and implement cooperative R&D and deployment activities' (Solomon and Banerjee 2006). It has also set a goal that participating countries' consumers should be able to buy 'a competitively priced, safe, hydrogen powered vehicles that can be conveniently refuelled, by 2020.' (Solomon and Banerjee 2006). Clearly this relatively ambitious target, if met, would have a major impact on UK hydrogen development, in some form. However, how effective the IPHE can be, and what its most effective role should be, in bringing about such changes in participating countries, needs to be established. There is an intention within the IPHE to work in greater partnership with the IEA.

The EU

In 2002, a High Level Group was set up by the EU Directorate Generals of Research, and Transport and Energy to develop the EU's strategy on hydrogen and fuel cells. This High Level Group produced a report and action plan in 2003 (EC, 2003). It outlined 5 key actions: creation of a political framework to coordinate policy measures; establishment of a strategic research agenda to guide community and national programmes; a deployment to move technology from prototype stage through to demonstration and deployment; a European Roadmap for hydrogen and fuel cells, which the report itself begins to outline; and the inauguration of a European Hydrogen and Fuel Cells Technology Partnership, to provide advice, stimulate initiatives and monitor progress.

European Hydrogen and Fuel Cells Technology Platform

The High Level Group's report argued that Europe must substantially increase its budgets to build a competitive hydrogen and fuel cell industry in the context of international competition. It warns against allowing development 'in an uncoordinated fashion, at the level of the individual Member States'. It therefore recommended the formation of a partnership to coordinate activity at the European level. According to the report, the partnership should 'include the most important and innovative companies working on hydrogen and fuel cells in Europe, and also represent a balance of expert knowledge and stakeholder interests' (EC, 2003). The resulting European Hydrogen and Fuel Cells Technology Platform (HFP) has been involved in setting up various implementation initiatives including several set up under the European Union's Sixth Framework Research Programme (FP 6). Table 1 details various hydrogen research and implementation projects funded under FP 6. FP 6 funding for hydrogen projects totalled 67.7 million, and for fuel cell projects 33.13 million (EC, 2004).

Title of project	Reference	Description
HyFleet: CUTE	http://www.global-hydrogen-bus-platform.com/	By operating 33 fuel cell buses in 9 cities around the world, to gain experience in technology development, hydrogen production and infrastructure, and to gain insights into public acceptability issues.
HyWays	http://www.hyways.de/	Development of a European Hydrogen Energy Roadmap, accounting for country specific realities.
HyChain	http://www.hychain.org/	Establishing at least 150 small-medium urban vehicles in 4 EU cities, to allow users to gain experience of them and to test refuelling logistics.
Zerio Regio	http://www.zeroregio.com/front_content.php?idcatart=186&lang=3&client=5	Development and deployment of hydrogen infrastructure for cars in two locations.
Roads 2 Hycom	http://www.roads2hy.com/about_overview.html	Mapping of extent of European research in hydrogen and fuel cells; technology assessment; develop generic profiles of 'early adopting communities'; analysing gaps, opportunities and pathways; engagement and information dissemination.
HyApproval	http://www.hyapproval.org/	Development of a handbook of approval of filling stations in Europe- standardising safety regulations.
HyLights	http://www.hylights.org/index.html	Creation of assessment framework for analysis of concluded / ongoing hydrogen transport demonstration activities, analyse gaps and identify necessary financial and legal steps in preparation of the new projects.

Table 1: Summary of selected key EU FP 6 funded Hydrogen projects

Of these projects, the two which have the strongest links to the UK will now be discussed.

HyFleet: Cute

CUTE (Clean Urban Transport for Europe) is a private-public partnership, part funded by the EC through DG TREN and FP 6. Other key partners include Daimler Chrysler, BP, Shell and Hydrogenics, as well as the various bus operating companies of the cities involved. The project has implemented the operation of 33 hydrogen fuel cell buses in 9 cities around the world. The aims were to use the demonstrations to collect findings relating to 'design, construction and operation of the necessary infrastructure', 'safety, standardisation and operating behaviour' of hydrogen production, 'ecological, technical and economic analysis of the entire life cycle', and investigations into public acceptance. (Hodson and Marvin, 2005c, p. 6; HyFleet: CUTE, 2007). The CUTE project was the catalyst for what is arguably the most advanced and most visible hydrogen / fuel cell demonstration in the UK, the operation of two hydrogen powered fuel cell public buses in London.

HyWays

HyWays is an initiative to devise a roadmap for hydrogen activity in Europe, with input from member states. Stakeholder workshops were held in each participating member state to establish for each country the most plausible hydrogen energy chains and the most favourable 'early user centres'. Using a range of modelling tools (including the MARKAL energy-economic model, and the Key Changes and Actor Mapping (KCAM) process), the project aims to develop geographically defined representations of the roll out process in each country, to contribute to an overall EU road map (EC, 2007). UK stakeholders collaboratively selected 6 key early user centres which were envisaged as being key regions for initial roll out of hydrogen technologies. These are currently defined as London, East and West Midlands, Wales, Yorkshire, North East, and Scotland (Vaughan, 2007). It might be observed that with the hydrogen debate at such a fluid and embryonic stage, concepts such as these can be highly influenced by a variety of practical and almost random issues, not least which stakeholders were able to attend a particular workshop. Such concepts can sometimes quickly achieve almost paradigmatic status within the space of a few repetitions; thus the derivation of concrete and well established concepts from relatively informal processes is a phenomenon which could have quite significant effects on the development of hydrogen and fuel cell policy.

EU Joint Technology Initiatives

In late 2006 the EU announced its intention to set up Joint Technology Initiatives (JTIs) with the intention of pooling private, national and EU resources to improve the competitiveness of the EU in technology industries, to be funded under FP 7 (HFP, 2007). A JTI on hydrogen and fuel cells has been proposed. According to the HFP, who are assimilating industry responses to the proposal, the targets of this JTI are:

- in the automotive sector, to deliver commercial hydrogen and fuel cell technologies by 2015, with a view to mass market roll out by 2020
- in the stationary and portable sectors to provide the technology base to initiate market growth from 2010-2015

The HFP has identified that funding of 250 M€ per year would be necessary to achieve this, and understands that the EU 'may' contribute 80-100 M€ per year. Public funds would have to be at least matched by private investments (HFP, 2007).

Whether such a programme, if launched, would be successful in delivering commercial applications depends also to a large extent on the success of the initiative in linking up technical research to real world applications for which there is a desire for

implementation on the ground, and ensuring a favourable policy framework can smooth the way for these technologies in the early stages.

European Regional Development fund (ERDF)

This fund was set up in 1975 to assist in the development of less prosperous areas of the EU. The funding is targeted towards two objectives, Objective 1 for the ‘structural change of regions whose development is slowed’, and Objective 2 for the ‘socio-economic change of urban, industrial and rural areas’. Funds have been accessed by medium to low level actors including local authorities (LAs), small businesses and community groups (DCLG, 2007). As shall be discussed later, the ERDF has been an important source of funding for many of the hydrogen and fuel cell related initiatives which have been implemented in the UK.

Other international policy activities

There are a range of hydrogen related policy programmes and activities being implemented globally, which, while they may not have a direct impact on the UK, might potentially have tangible effects on the state of hydrogen and fuel cell technology. Any such developments would be of relevance to the UK activities which would be likely to procure much of their required technology from global companies.

A key region of activity is the US. At the national level the US Department of Energy drives research and development through funding of around \$400m each year (DOE, 2007) and with roadmaps that give stringent commercialisation targets to be met, for example that automotive fuel cell power trains should be approaching cost competitiveness¹ with conventional engines by 2015 (DOE, 2006). Research and progress monitoring is carried out by the National Research Council and programmes such as FreedomCAR. Implementation and demonstration projects have however largely evolved at the state rather than the national level, where a variety of drivers have encouraged the use of hydrogen, in particular air quality (California), economic benefits and job creation (Michigan and Ohio), and availability of renewable resources (Hawaii) (Solomon and Banerjee 2006).

Various other countries are also taking positive steps to encourage hydrogen and fuel cells. Canada in 2003 committed CD\$ 215 million to a Technologies Partnership Programme to accelerate the deployment of hydrogen technologies. Iceland and Norway both benefit from the availability of abundant and relatively cheap renewable electricity, making renewable hydrogen production a significant possibility- Iceland has set out a goal to convert its economy entirely to hydrogen energy by 2030; Norway has announced a ten year programme worth US\$125-145, and has already launched a 580km hydrogen highway. Japan’s Ministry of Economy, Trade and Industry in partnership with major automakers, utilities and energy companies, launched in 2002 the Japan Hydrogen and Fuel Cell Demonstration Project (JHFC), under which 11 hydrogen fuelling stations are to be built in the Tokyo region, and testing has begun on a range of fuel cell cars and buses under real-life conditions. South Korea’s dependence on oil imports for its transport demand has motivated the Ministry of Science and Technology to allocate US\$843 million to 2020 towards the creation of a nuclear based hydrogen transport economy (Solomon and Banerjee 2006).

¹ A cost target of \$45 / kw. This is a revision of a previous target set in 2004 for \$30 / kw by 2015 (DOE, 2004)

Industry

The activities of private commercial enterprises are highly relevant to any institutional map of hydrogen and fuel cell activity, not least because 'overall private spending on hydrogen energy R&D dwarfs spending by governments' (Solomon and Banerjee 2006). Most major automotive companies have prototype fuel cell vehicles, although BMW favours a combustion engine vehicle carrying liquefied hydrogen. Honda, Toyota, Daimler Chrysler and GM are leaders, the last two having previously predicted low volume commercialisation by 2015, although this increasingly seems over optimistic.

The major energy companies investigating hydrogen production are BP and Shell, Shell having committed \$1 billion to hydrogen energy R&D in 2006 (Solomon and Banerjee 2006). BP is providing the hydrogen delivery infrastructure for transport demonstration projects in 10 cities around the world, including the CUTE bus project in London. BP is also constructing two major hydrogen production facilities, employing fossil fuel reforming with geological carbon sequestration, in Peterhead, Scotland, and Carson, California. In both cases the hydrogen is to be used to provide electricity at a nearby power station (BP, 2007). Shell is involved with designing and constructing hydrogen refuelling infrastructure in North America, Europe and Japan (Shell, 2007).

Other international infrastructure companies involved with providing hydrogen infrastructure include Stuart Energy Systems Corp., Linde AG, and Air Products and Chemicals Inc (Solomon and Banerjee 2006).

Fuel Cell companies span a wide range of technologies and applications. An important manufacturer of PEM fuel cells for automotive applications is Ballard, who, through its strategic alliance with Daimler Chrysler, has been central in providing the fuel cell technology for the HyFleet:CUTE programme (Ballard, 2007). Other international companies include Logan Energy and Plug Power, focussing on PEM, Molten Carbonate (MCFC) and Phosphoric Acid (PAFC) fuel cells for stationary and back up applications, and Siemens Westinghouse, which is developing SOFCs for stationary applications.

1.1 International level- key issues

Diversity of activity

Hydrogen and fuel cell related activities are developing in a wide range of countries with a variety of contexts, energy policy frameworks and motivations.

Targets and aspirations

Several governments have set relatively ambitious targets, relating to technology commercialisation, or penetration within the energy system as a whole. These government set targets sometimes produce responses from global companies, for example the US DOE commercialisation targets for 2015 have prompted several automakers to predict a commercial vehicle by the same year. However, the ambition should not always be assumed to be matched by reality, as the latest set of US DOE targets saw significant revisions from that issued three years previously.

First mover risk aversion

Thus, many actors, including governments and global companies, are demonstrating an interest in participating in a hydrogen economy should it come about. However, major and decisive action and investment is currently lacking as most actors hedge their bets by

waiting to see if others will bear the risk of being first movers on an uncertain technology. This state of affairs, if it continued, would see continued lapsed targets.

Key funding opportunities for UK actors

The most important international sources of funding for UK actors intending to develop hydrogen and fuel cell projects come from the EU level, in particular the European Regional Development Fund (ERDF) and the Joint Technologies Initiative (JTI).

2. UK National level

The 2003 Energy White Paper, *Our Energy Future*, (DTI, 2003) was a significant landmark for recent low carbon energy policy, establishing the 60% carbon reduction target by 2050, as well as priorities for security of supply, fuel poverty, and an efficiently functioning energy market. Its coverage of hydrogen, however, was minimal, leading one key central government stakeholder to comment that it was ‘not sufficient on its own in terms of hydrogen’ (Hodson and Marvin, 2005c, p. 12). Nevertheless it acknowledges that ‘on a longer term time scale, hydrogen use in transport has a major potential for decoupling transport and carbon, if current technological and cost barriers can be overcome’ (DTI, 2003, p. 70).

The Strategic Review and the DTI response

In 2005 the DTI commissioned a strategic review of the potential for hydrogen and fuel cells in the UK. The report written by E4 Tech, Eoin Lees, and Element Energy found that 6 hydrogen energy chains could offer cost effective ways of meeting key energy policy objectives- crucially these were all transport chains (E4 Tech et al, 2004). This has quickly become widely accepted cornerstone of the UK hydrogen debate, laying a very particular emphasis on discussions since- for example, during the HyWays process the UK stakeholder group has been singular amongst participating countries in its almost exclusive selection of transport related hydrogen chains. The potential impact of the conclusion of a single study, and the ease with which it has been transferred to a high level long term road map, suggests that there is a need, which is in many ways highly understandable, for a strong direction in the current vacuum of technological certainty. It is perhaps worth remembering however, that at the current relatively early stage of hydrogen technology development, the technological assumptions which inform the conclusions of particular reports, must remain open to challenge as technology develops, rather than locking policy in to a fixed and unalterable trajectory, however attractive this may be from the point of view of policy certainty.

The Strategic Review recommended a Hydrogen Coordination Unit (HCU), an industry body, and more funding (for research and development). The precise remit of the HCU is not yet clear, but it will not have a budget itself to fund projects. An industry body has since been set up, the UK Hydrogen Association (UKHA).

In 2006 the DTI launched the Hydrogen and Fuel Cell and Carbon Abatement Technologies Demonstration Scheme, under which £50 million would be available over 4 years for low carbon vehicle demonstration projects, in order to test the technologies under working conditions, gather and publish operational data, and thus to identify further R&D needs. Under the programme, £35m will be allocated to carbon abatement technologies, with the remaining £15m going specifically to fuel cell or other hydrogen technologies (DTI, 2007).

Other Initiatives

The Energy Technologies Institute (ETI) is potentially an extremely important development on the UK energy policy horizon, and one with strong relevance to fuel cells and hydrogen. The principal is a 50-50 public-private partnership, and the support of EDF, Shell, BP and E.ON UK has been secured. The goal is for funding to reach levels of £100 million per annum by 2009. Though it is not certain how much of this will

be directed towards hydrogen and fuel cells, it is nevertheless a potentially huge opportunity for the industry (DTI, 2006).

The Low Carbon Vehicle Partnership (LowCVP) is 'a partnership of automotive and fuel companies, government, academia, environment groups and other stakeholders, set up to accelerate the shift to clean low carbon vehicles and fuels in the UK' (LowCVP 2007). As such it is dedicated to the promotion of a range of technologies, and is involved with setting short term targets, for example relating to efficiency improvements in UK passenger vehicles by 2012, as much as with longer term technology advocacy. Nevertheless, the group also maintains a long term perspective, and its fuels working group is committed to providing analysis and advice on both biofuels and hydrogen, and the Innovation working group 'provides expertise' on research, development and demonstration of low carbon vehicles. One of its specific tasks is to give input to the Centre of Excellence for Low Carbon and Fuel Cell Technologies (CENEX), and it was also instrumental to CENEX's inception, as it was tasked with establishing the business case.

CENEX is an industry led public-private partnership which aims to support innovation through the creation of knowledge transfer networks. Supported by the DTI, it was formally established in 2005 following the recommendation of the Automotive Innovation and Growth Team (AIGT), which recognised while there is much specialist expertise in the areas of low carbon and fuel cell technologies within the UK, this expertise and knowledge is fragmented. It therefore recommended that greater integration would give the industry in the UK a better chance of achieving its potential. CENEX is focussed on the automotive sector, and one of its early activities is to give financial support to the deployment of a fleet of Modex (see below) electric vehicles to commercial users in Greater London. It is working with the Low Carbon and Fuel Cell Knowledge Transfer Network (see below) to disseminate the results of the trials (Cenex, 2007).

The UK Hydrogen Energy Network (H2NET) is a forum for collaboration between UK industry and academia to promote and disseminate research and discussion relating to hydrogen energy. It aims to identify research requirements and facilitate the development of academic/industrial collaborations in the UK. H2NET is supported by the DTI (H2NET, 2007).

The UK Hydrogen Association is an industry body founded in response to the recommendation for such a body by the strategic framework report (E4 Tech et al, 2004). Its members include large industrial energy and gas companies, small and medium enterprises with specialisms in hydrogen and fuel cells, academic departments and individuals. Its role is to 'galvanise across sector boundaries, provide a strong national voice on hydrogen energy', and represent the industry to the UK government, as well as at European and international fora (UKHA, 2007).

Fuel Cells UK is an industry body specifically devoted to the fuel cell industry. Similarly to the UKHA it represents the industry's priorities on research, development and demonstration to the government and other influential agencies (FCUK, 2007). Unsurprisingly, some of its membership overlaps with that of the UKHA (ie BOC, E-ON, Renew Tees Valley) however by no means all. It is not always immediately clear why a company is a member of one body and not the other- for example Intelligent Energy (FCUK only) is a fuel cell company, but also produces small hydrogen production units;

Voller Energy (UKHA only) is in fact more a fuel cell company than a hydrogen one, as most of its portable cells operate on hydrocarbon fuels (with built in reformers), not on pure hydrogen. By comparison, in Scotland, a single body represents both the fuel cell and hydrogen industries (SHFCA). FCUK is managed by Synnogy, an organisation which aims to 'facilitate cross organisational strategic thinking on 'New Energy' technologies' (Synnogy, 2007).

Fuel Cell Today is an online information network for those in the industry. It provides regular updates on the performance, cost and global market applications and demonstrations of various fuel cell technologies, by sector of use. It also provides a catalogue of organisations involved in the industry (Fuel Cell Today, 2007).

The Low Carbon and Fuel Cell Knowledge Transfer Network is designed to promote sharing of knowledge and best practice between industry and academia. The network is organised into two parallel themes of low carbon technologies and fuel cell technologies, the fuel cell side being managed by Fuel Cells UK and Fuel Cell Today. The KTN's principal partners are FCUK, FCToday, Cenex, and Foresight Vehicle, a programme run by the Society of Motor Manufacturers and Traders. The KTN programmes are a 'business support solution delivered through the [DTI's] Technology Programme', and they 'aim to stimulate innovation in the UK's key technology sectors by promoting collaboration, best practice and knowledge sharing between industry and academia'. Services provided on the website include news items, company profiles, and online conferences. The thematic divide of the network raises some uncertainty about the role of fuel cells- the low carbon theme is more explicitly focussed on transport applications than the fuel cell side, which also includes SOFCs and other non-hydrogen fuel cell applications (Low Carbon and Fuel Cell Technology KTN, 2007a).

The existence of several separate coordinating and networking umbrella groups might be said to be somewhat out of proportion to the number of individual actors. It might be observed that there is a significant amount of 'crossover' between several of these 'communities of practice' both in terms of their aims and their membership lists. The total number of actors actively engaged in hydrogen and fuel cells in the UK is still relatively small compared to other green technology industries. (By way of comparison, the UKHA lists a total of 16 members, whereas the British Wind Energy Association (BWEA) lists 316). This may have the result that the leverage of any one of these umbrella groups is less strong. Within this context, the role that 'informal institutions', such as personal contacts and 'insider' knowledge and networking have on the progression of the debate within the UK might be an issue worth further exploration.

Potential funding sources at national level

The Engineering and Physical Sciences Research Council (EPSRC) is funding a series of multi-disciplinary research consortia under its Sustainable Power Generation and Supply (SUPEGEN) programme. Thirteen consortia have so far been funded, including Fuel Cells (£2.1 million over four years) and the UK Sustainable Hydrogen Energy Consortium (UKSHEC) (£3.5 million over 4 years) (EPSRC, 2007a). The EPSRC has also recently appointed a chair in Technology Transfer, the first of its kind in the UK, which could be of strategic relevance to emerging technologies such as hydrogen and fuel cells (EPSRC, 2007b).

The Carbon Trust is an independent company funded by the government, which helps business and the private sector to cut emissions, and supports the development of low

carbon technologies. It is supported a small number of hydrogen and fuel cell projects, including some research by the Universities of Birmingham and Glamorgan into hydrogen storage and production respectively, and some research activity by Ceres Power into solid oxide fuel cells. The Carbon Trust also has also contributed £4-6 M to the Supergen programmes (Carbon Trust, 2007).

The Energy Saving Trust, which receives its funding from Defra, DfT, DTI, the Scottish Executive and private companies, is also a potential source of funding as it has grant programmes for low carbon vehicles R&D, as well as to support the installation of alternative refuelling stations (Energy Saving Trust, 2007).

Industry

As well as the global energy and technology companies with activities in the UK, discussed above, there are also a number of smaller UK based companies developing hydrogen and fuel cell products.

Intelligent Energy is manufacturer and integrator of fuel cell and hydrogen systems, including small scale hydrogen generation technologies as well as end use applications. Their most high profile application is the EnvBike, a small PEM fuel cell moped with a top speed of 50 miles per hour (Intelligent Energy, 2007). The company is optimistic that this is an optimal niche in which to launch hydrogen transportation technologies (Hughes, 2006).

Bryte Energy are trialling a year round operating hydrogen energy based system with integrated renewable energy from various sources (Bryte Energy, 2007).

ITM Power is a small Sheffield based engineering company which is making radical claims for cost reduction in PEM electrolyzers. Through the development of low cost membranes and the elimination of platinum from the system, the company claims to have reached costs of \$164 / kW, where the average cost is \$2000 / kW (ITM Power, 2007).

Wind-Hydrogen Ltd is an international company with wind farm developments operating in Australia and the UK (mainly Scotland and Wales). It plans to attach a 5MW hydrogen power plant next to its largest Scottish wind farm, Wing's Law, to smooth out intermittency of power supply, and is involved in a project which aims to implement wind hydrogen production in Teesside (Wind Hydrogen Ltd, 2007).

Modec is a manufacturer of small battery electric vans, founded in 2004, which aims to market to companies requiring relatively low distance delivery vehicles. It will begin production in March 2007. Whilst the company is currently not pursuing fuel cell or hydrogen R&D, its success is relevant for two reasons. First, for the fact that it has marketed (and taken over 130 advance orders for) vehicles which are explicitly aimed at a niche market- urban deliveries. The vehicles have a top speed limited at 50 mph, and a range of 100 miles, yet Modec has demonstrated the existence of demand for vehicles of limited performance, but which can deliver cost savings through avoidance of congestion charges and road tax (Modec, 2007). Thus Modec appears to be demonstrating the existence of the kind of niche which stakeholders have identified as the most promising entry point for hydrogen automotive technologies (Hughes, 2006). Second, it provides an encouraging example of a novel automotive technology delivering employment benefits to an area with a strong industrial skills base, but which has experienced economic

decline through company relocation. The Modec vans are to be manufactured in Coventry, where 'many of the plant's 75 new staff used to work at the Peugeot, Jaguar and Toyota plants in the city, which have since closed down' (Low Carbon and Fuel Cell Technology KTN, 2007b).

There are various manufacturers of stationary and portable applications in the UK, though the use of hydrogen as the fuel for these applications is limited (Hughes, 2006). Voller Energy specialise in portable power units providing remote energy for specialist applications such as construction, outdoor leisure activities, and military use. Its main technology is the PEM fuel cell, though it incorporates reformers in some of its products to allow for use with more readily available hydrocarbons such as butane, propane and LPG (Voller Energy, 2007). Ceres Power is a product development company spun out of a materials research group at Imperial College. The company specialises in the development of medium temperature solid oxide fuel cells (SOFCs) which can be used in stationary applications, including domestic combined heat and power (CHP), remote and auxiliary power, and uninterruptible power supplies (UPS) (Ceres Power, 2007).

On the demand side, it should be acknowledged that large businesses and corporations could become early users of relatively high cost hydrogen and fuel cell technologies. As environmental performance becomes an increasingly important part of companies' ability to attract consumers, large retailers like Tesco's and Marks and Spencer are beginning to make bold statements about their commitment towards reducing their environmental impact (Tesco, 2007; BBC, 2007). Tesco's became Modec's first customer, pre-ordering 15 electric vans for their home delivery service (Modec, 2007). It is not inconceivable therefore, that such companies could drive technology improvements and cost reductions by becoming early purchasers of hydrogen and fuel cell technologies before they come within the reach of individual consumers, for example to power their delivery fleets or to provide onsite CHP.

Connections between policy direction and industry practice

Following the DTP's response to the strategic review, and the outputs of the Hyways stakeholder engagement process, the UK policy discussion would seem to be predominantly focussed on developing hydrogen for transport applications (the scope of the strategic review did not include the use of non hydrogen fuels in fuel cells for stationary power). However, despite this focus on automotive chains, there are very few companies making automotive fuel cells or integrating them for automotive use in the UK. The principle player here is Intelligent Energy, with its Env bike. However, in marked contrast to the US, Japan and Europe, there is comparatively little UK based interest in developing the ability to manufacture hydrogen powered vehicles on a major scale, should the market opportunity arise. Just as London's demonstration buses are currently provided by Ballard and Daimler Chrysler, if policy did succeed in incentivising the development of hydrogen automotive energy chains, it would be highly likely that the UK would be creating an opportunity for large international companies, UK industry not being ready to respond. The activity from UK based companies is much more strongly focussed on fuel cells for stationary power, hydrogen production and renewable systems integration electrolysis. The direction set by the strategic review and subsequent developments is in danger of opening up a divide between policy aspirations and the existing skill set of British industry.

This potential divide invites some kind of response. One might be to continue with the hydrogen / fuel cell policy focus on automotive chains, but to devote greater attention to

developing the UK capacity to be able to respond to the potential technology demand which this implies. It might be observed that with manufacture of conventional mass produced vehicles declining in this country due to the rise of production in countries with cheaper labour markets, a shift into production of high cost specialist vehicles could be a potentially rewarding opportunity for the British manufacturing industry. The example of the state of Michigan in the US, may be instructive. In an effort to preserve its position in the car manufacturing industry in the face of global competition, it has opted to encourage the development of innovative technologies, implementing strong policies including a tax free area in Detroit for companies wishing to undertake hydrogen and fuel cell R&D (Solomon and Banerjee 2006). Though the British electric van manufacturing company Modec is working with a significantly nearer term technology, its strategy of capitalising on an existing industrial skills base in an area experiencing loss of investment, and targeting of its product to an appropriate market niche, should also be instructive for hydrogen and fuel cell policy.

Another approach, which nevertheless would not exclude combination with the above, would be to retain a broader policy approach with regard to the kind of hydrogen chains which are to be expected and promoted. The UK has several companies and demonstration projects investigating the use of hydrogen electrolyzers as a part of a system designed to regulate the variability of renewable electricity generation. Therefore to retain an awareness that with certain technology improvements, hydrogen could play a role in stationary power applications, would play more to currently existing strengths within the UK, and may have a more beneficial long term effect.

2.1 UK National Level- key issues

Funding

Funding for UK demonstration projects is available at the national level from the DTT's Hydrogen and Fuel Cell and Carbon Abatement Technologies Demonstration Scheme, which by 2009 would potentially be supplemented by the Energy Technologies Institute (ETI). Other potential funders are the Carbon Trust, the Energy Saving Trust and the Research Councils.

Alignment of UK policy aspirations and existing business activity

There is significant entrepreneurial activity in the UK from small companies largely developing stationary and portable fuel cells, and integrating hydrogen and fuel cells to renewable energy systems. This is in some contrast to the national level UK policy position, which is dominated by an automotive based vision. There is a need to address this divide, by creating policy aspirations which are open to a wider range of potential hydrogen and fuel cell development scenarios, as well as policies designed to incentivise development of automotive technologies which are unrepresented in the UK technology portfolio.

The function of the hydrogen and fuel cell communities of practice

There are various umbrella organisations which have been established to support and promote the development of hydrogen and / or fuel cells in the UK. There are significant overlaps between them, as many have similar aims, and share members, possibly leading to a lack of clarity in the industry. Most aim to link up academic and industry actors, however most remain under-represented by actors who might potentially be early purchasers of hydrogen and fuel cell technologies. Such actors could include

LA's or businesses and large retailers. Thus industry networks and communities of practice should aim to link up more explicitly with potential technology takers, enabling a shift in focus from demonstration to pre-market applications at an earlier stage.

3. Regional

The existing demonstration projects in the UK have largely sourced funding from institutions and organisations at the national and international levels. However, they have usually been driven by actors at regional and local levels, operating within specific contexts and according to specific sets of motivations. As the following exploration of policies and institutions at the regional and sub-regional levels shows, institutions at these levels are key to driving forward the roll out of ground level implementation projects.

In what follows the discussions of Teesside, Wales and London draw significantly on earlier UKSHEC working papers by Hodson and Marvin. For a more detailed exploration of actor motivations and perceptions in these contexts, see Hodson and Marvin, (2006; 2005a; 2005b; 2005c).

3.1 Teesside

Teesside is frequently proposed as being an area with significant potential to be an ‘early mover’ in the development of a hydrogen economy, due its relatively extensive existing hydrogen infrastructure, and because of the general local and professional familiarity with large industrial and chemical installations. A significant driver to thinking about the potential for a hydrogen economy in the region seems to have been a seminar organised by Tees Valley local councils in conjunction with Forum for the Future. This led in 2002 to the commissioning of a study by DEFRA and UK Steel Enterprise, carried out by Forum for the Future, which gave a strong steer towards the idea of clustering hydrogen related R&D in the Tees valley and establishing a UK centre of excellence (Hodson and Marvin, 2005a p. 10).

As well as the formal institutional capacity in the area, in terms of the physical and commercial infrastructure and processes, reference is also frequently made to more informal institutions, such as the familiarity and ‘know how’ which local actors have in dealing with such industries. As members of local authorities have a familiarity and confidence with the kind of technologies involved, in Teesside it is believed that planning applications for hydrogen infrastructures would be ‘a piece of cake’, as some very ‘slick processes’ for public consultation have been developed (Hodson and Marvin, 2005a, p. 5). The enthusiasm for the suitability of the area for hydrogen and fuel cell demonstration and deployment activities is such that local government and industry actors in Teesside have explicitly offered the region up to DTI as an ‘experimental platform’ for hydrogen demonstration projects, or as its ‘chemistry set’ (Hodson and Marvin, 2005a, p. 9).

The familiarity of local residents with chemical industries is another informal institution which is often referred to as providing a favourable context for the region. It is perceived, at least by industrial stakeholders, that local communities in general regard an industrial or chemical facility as ‘a good neighbour’ in terms of the economic benefits they bring, and that ‘you’ve basically got an educated community here that has grown up with the chemical industry’ (Hodson and Marvin, 2005a, p. 4).

One North East is the Regional Development Agency (RDA) for North East England, covering Northumberland, Tyne and Wear, Tees Valley and County Durham. Its Innovation, Industry and Science programme has drawn up a Strategy for Success, under

which were created three Centres of Excellence: the Centre of Excellence for Life Sciences (CLS), the Centre for Process Innovation (CPI), and the Centre of Excellence for New and Renewable Energy (NAREC), funded to undertake some R&D as well as to coordinate the effective commercial use of emerging research results (One North East, 2007). Of these, the CPI is most explicitly concerned with hydrogen and fuel cells, which it views as a potentially profitable area given previous and existing industrial activity and infrastructure. The CPI has also established a Fuel Cell Application Facility, to support regional companies in the commercialisation of fuel cell products (CPI, 2007).

One North East also has a Regional Economic Strategy. The Tees Valley Partnership is a sub-regional body tasked with its implementation in the Tees Valley, and also with sub regional implementation of the Northern Way, the strategy led by the three Northern RDAs: Yorkshire Forward, the North West Development Agency, and One North East (Tees Valley Partnership, 2007a). In conjunction with Redcar and Cleveland Borough Council, the Tees Valley Partnership runs a project called Renew Tees Valley, which aims to enable the area to become 'a centre of expertise and excellence in the renewable, innovative energy, and recycling / waste recovery sectors' (Tees Valley Partnership, 2007b). With the involvement of industrial stakeholders such as BOC, Johnson Matthey and Intelligent Energy, the Tees Valley Hydrogen Project, which has delivered a series of small demonstration projects, including the installation of fuel cells in a school, crematorium and urban development project (Hodson and Marvin, 2005a, p. 16; DTI, 2005). Viewed in the context of its surrounding institutional structure, it is worth noting that this project which is specifically dedicated to hydrogen is timed to run for a limited period of four years, and is nested within a number of more general sustainability and regeneration initiatives.

Industry

The post second world war industrial development of Teesside, through the expansion of the chemicals and steel industries, which were dominated by ICI and British Steel respectively, has left a large impact on the area in terms of the available industrial capacity and infrastructure. The large underground salt caverns are a by-product of chlorine manufacturing, and now offer storage potential for 600 tonnes of hydrogen. Hydrogen is already produced and used on Teesside as a feedstock for nylon, ammonia, chlorine and methanol. The three large hydrogen generation plants produce around 75,000 tonnes of hydrogen per year, distributed through 30km of hydrogen pipelines. The balance of supply and demand in the system was historically regulated by ICI. Following its sell off, there is now no single controlling influence, although Huntsman acts as an operator (Hodson and Marvin, 2005a).

There is also as a result of the presence of such industries in the area, a significant workforce skills base. Traditionally, employment in the area was dominated by the two major employers, ICI and British Steel. However, restructuring of these businesses has resulted in a significant overall decline in employment in these traditional industries. Employment is also fragmented among various other employers, including Huntsman and Shell, many of whom have their headquarters overseas.

In the Tees Valley, the industrial familiarity with hydrogen means that there is a lot of expertise in implementing demonstration projects, including safety aspects, which vary according to location, and dealing with public concerns. There is a belief among local industrial actors that evolution from existing industries is the best course for any new industrial developments (Hodson and Marvin, 2005a, p. 12).

As mentioned above, Wind hydrogen Ltd is involved in a proposed project to build hydrogen storage facilities for intermittent renewables at Teesside. It seems therefore that Teesside's existent hydrogen infrastructure is exerting an influence in attracting more than just fossil based hydrogen technologies.

Motivations

A primary motivation for the developing hydrogen and fuel cell activities in Teesside, therefore, is economic regeneration. This is evidenced by the location of the prime mover in project implementation, the Tees Valley Hydrogen Project, within a framework of the more general regeneration schemes, Renew Tees Valley, the Tees Valley Partnership, and the Regional Economic Strategy of the RDA, One North East. Stakeholders perceive that additional buy-in from both public and industry may be generated by the industrial heritage of the area, which appeals to a sense of local pride to continue to be at the forefront of industrial innovation, as well as to a more functional belief that the appropriate course for economic regeneration should be to evolve from existing or previously existing kinds of industries.

Environmental considerations, such as carbon reduction and air quality, are mentioned not infrequently, however no single actor appears to place such considerations as the primary motivation for hydrogen and fuel cell development.

3.2 Wales

One of the major institutions relating to hydrogen and fuel cells in Wales is H2Wales, a four year project which was undertaken by the University of Glamorgan, funded by the ERDF, the Welsh Assembly Government (WAG) and the University of Glamorgan. Although this project has now come to an end, its major outputs, of bringing together and galvanising a hydrogen community in Wales, and of producing a hydrogen vision and road map (Cherryman et al, 2004), remain relevant to hydrogen development in Wales. The Hydrogen Research Unit (HRU) based at the University of Glamorgan remains a key driver both in terms of developing Welsh capacity, and maintaining communication networks with London and the national and EU level institutions which operate there. The HRU continues to undertake research and demonstration projects, including development of biological hydrogen production techniques, funded by EPSRC and the Carbon Trust, and socioeconomic research funded by the ERDF (University of Glamorgan, 2007). More recently, the construction of a £1.7m Renewable Hydrogen Research and Demonstration Centre at the Baglan Bay Energy Park was announced. This project is funded by the ERDF Objective 1 and the University of Glamorgan, and will demonstrate renewable hydrogen production from solar photovoltaic cells, wind turbines and from biological processes. It is intended that the hydrogen would be used in stationary fuel cells as well as transport applications (SERC, 2007).

The significant focus on renewable hydrogen generation from the HRU demonstrates a motivation from the academic community which is strongly related to hydrogen as a future source of sustainable, low carbon energy. However, Hodson and Marvin (2005b, p. 16) interviewed local authority stakeholders for whom this view of a hydrogen economy seemed somewhat distant, and whose motivations for the development of a hydrogen economy, as in Teesside, tended to be framed in terms of the benefits for economic development.

South Wales is a traditionally industrial region, with significant hydrogen production facilities along the M4 corridor. Hydrogen is used as a feedstock in the petroleum refining, chemical manufacturing, pharmaceutical and other industries, and produced by steam methane reforming in seven small and medium sized plants in Newport, Barry, Port Talbot and Swansea. Although there are no distribution pipelines as in Teesside, the infrastructure is relatively evenly spread along the M4 corridor, which may offer the possibility of establishing sets of refuelling stations for a linear transport demonstration project (Hodson and Marvin, 2005b).

The de-industrialisation of South Wales resulting from the decline in activity in the steel making and coal sectors caused considerable job losses particularly in the 1970s and 1980s. De-industrialisation continued through the 1990s, with BP pulling out of operations in Baglan Bay. Nevertheless, there have been some important 'stayers'; steelmaking is still a large source of employment, with Corus' Port Talbot facility directly employing over 3,000 people. Other large companies in the area include BOC and Air Products (Hodson and Marvin, 2005b).

The automotive industry remains important to the area, accounting for around 22% of the manufacturing workforce. There are two major volume vehicle manufacturers operating in the area: Ford, which manufactures engines for Ford and Jaguar vehicles at its facility in Bridgend; and Toyota which manufactures engines in Deeside for its plant in Derby. In addition there are over 200 smaller component manufacturing companies in Wales (Auto Industry, 2007). These Welsh based companies, component, systems or engine suppliers, have supply chain links to many UK and foreign assemblers (Hodson and Marvin, 2005b).

Hence, in a similar vein to Teesside, the argument is to replace lost industrial activity with new but familiar processes, to create economic regeneration whilst building on existing strengths. However, it is also the case that as 15 out of 22 Welsh counties are eligible for ERDF Objective 1 funding, regeneration is also a priority in the more rural areas in the north of the country. In these areas, it is proposed that decentralised renewable and biomass hydrogen production may provide regeneration and employment opportunities (Cherryman et al, 2004).

Local authorities could have the motivation to facilitate the development of a hydrogen economy, for reasons of economic development within their locale, however it has been observed by Hodson and Marvin (2005b) that they would usually lack the resources to implement major programmes, seeing their role as 'facilitating' and 'enabling' rather than directly implementing, with funding being sought from national or EU level institutions. Importantly, it was also observed by one key LA player that national and regional strategies are important for providing 'direction [and] inspiration'. Important examples of such collaborations are the Techniums, a range of 'incubating centres' for small businesses across the country, set up in response to targets set by the WAG for increasing enterprise and innovation in Wales. Of particular relevance is the Sustainable Technologies Technium, based in Baglan Bay. This is supported by Swansea University, Neath Port Talbot County Borough Council, the WAG, the EU (ERDF Objective 1), General Energy and BP. This technium is well located in terms of its proximity to the areas where hydrogen facilities already exist, and thus could potentially provide an important focal point for its development. However, as shown by Hodson and Marvin, it should be acknowledged that local level actors do not necessarily share the broad 'hydrogen vision' of the academic community- if they viewed hydrogen and fuel cell

investment and development favourably, it would be as one possible means to local economic regeneration.

Thus, there appears to be a need from actors at the local level to have their activities supported within a framework of higher level initiatives, to provide direction and inspiration. Wales' most significant political initiative relating to hydrogen and fuel cell development is the Hydrogen Valley Initiative (H2V), set up by the Welsh Development Agency (WDA) in February 2005. This is a three year project funded under the ERDF Objective 1 scheme, housed within the WDA's Accelerate Clusters programme, itself an initiative within work on the Automotive sector, one of the WDA's identified 'key business sectors' for growth. Thus the aims of H2V are closely related to improving business conditions in the automotive sector in Wales, 'to improve the medium and long term performance of the Welsh automotive business'. However, another aim specified on the web site is somewhat wider in scope, to 'achieve a zero emission energy based economy supported by sustainable business communities'- a considerably more ambitious target (WDA, 2007).

However, as a result of the UK devolution process, the functions of the WDA have recently been absorbed by the relevant departments within the Welsh Assembly Government (WAG). In this process, there seems to be some uncertainty as to the direction of the H2V initiative- no mention of it is found on the WAG website, even though the Accelerate Clusters initiative is listed as an active project (WAG, 2007).

In other WAG documentation, the lead on hydrogen is not strong. The WAG's consultation paper on an Energy Route map, *Energy Wales*, is fairly extensive in its treatment of renewable energy in general, however its view on hydrogen is equivocal, undertaking only to 'assist in the exploration of medium to long term potential for hydrogen use in Wales' (WAG, 2005). Thus under the auspices of the WAG, there are mixed signals as to the role of hydrogen.

Therefore, it appears that the strongest enthusiasm for a Wales wide hydrogen vision is emanating primarily from academic institutions such as the HRU at the University of Glamorgan, which is achieving its aims largely through accessing EU level funding, in particular the ERDF. Motivations from this institution are related to wider environmental issues as well as economic ones, thus the wide range of potentially available renewable resources in the country become important components of the vision. At the local authority level motivations for the development of hydrogen and fuel cell technologies in Wales are more dominated by social issues such as employment and economic regeneration. Here the pre-existing hydrogen infrastructure and automotive component manufacturing capability in the South become relevant assets.

It should be acknowledged that while enthusiasm for hydrogen and fuel cell projects at local and regional levels may appear to be high, the ability to fund them is unlikely to emerge in the context of a range of other nearer term issues. It may sometimes be the case that interest in hydrogen and fuel cell development is at least in part motivated by the desire to bring in European development funding to the region in question- hydrogen and fuel cells may emerge merely as a convenient 'peg' to hang a funding application on. In this case there is a risk that demonstrations may never create a process of development which brings technology out of its 'protected space'.

In this context, local stakeholders have pointed to the need for a higher level 'guiding process', in order to provide a policy framework in which to situate local level projects. However, the political commitment at the WAG level is hard to pin down, with the status of the H2V project unclear, and no other strong guiding policy framework for hydrogen and fuel cells, for example from the Energy Route Map.

3.3 London

The roles of the Mayor of London and the London Assembly, together with the supporting staff which in combination make up the Greater London Authority (GLA), were introduced in May 2000, giving the political and institutional architecture of the city a radically different look to any other city, LA or RDA region, in the UK. The GLA raises funds through contributions from the council taxes of local boroughs, as well as through its own measures such as the congestion charge. The Mayor's office was conceived to provide a 'joined up' policy approach to London-wide issues, and sets the budgets for the following organisations, known as the 'GLA Group': The GLA itself; Transport for London (TfL); The Metropolitan Police Authority; the London Development Agency (LDA); the London Fire Brigade (GLA, 2007a). The Mayor is thus not responsible for the provision of the day to day services such as refuse collection and municipal amenities, which remain the realm of the borough councils. This combination of economic and regulatory power with a relatively narrow policy focus has allowed the post's only incumbent thus far, Ken Livingstone, the scope to mainstream certain priorities which in other institutions can struggle to emerge from the complexity of political processes.

The environment is a case in point. The Mayor's Climate Change Action Plan has set a target of 60% reduction in the city's CO₂ emissions below 1990 levels by 2025 (GLA, 2007b). According to Hodson and Marvin, the mayor was also instrumental in ensuring that a separate Energy Strategy was included in the GLA's list of statutory strategies (Hodson and Marvin, 2005c). The energy strategy is striking in how centrally it places hydrogen in its vision for 2050: 'our road transport is characterised by highly efficient, quiet, and pollution free hydrogen fuel cell vehicles... a decentralised energy system has provided the foundations for an emerging hydrogen economy' (Mayor of London, 2004). This is undoubtedly the most unequivocal political statement in favour of the hydrogen economy that has yet been made in the UK.

As well as being relevant to the Mayor's CO₂ targets, it is worth observing that hydrogen is relevant to at least two more of the statutory strategies- air quality and transport. Moreover, the pursuit of cutting edge green technologies supports the mayors aim to make 'London a leading city for sustainable energy' (Hodson and Marvin, 2005c, p.4) which fits with a general desire for London to be a world 'leader', providing a policy link between environmental and economic goals. There is also a sense that as Europe's largest city London could offer very significant demand for hydrogen, but also supply- hence London's interest in producing hydrogen from waste (LHP, 2006).

The London Hydrogen Partnership is an institution housed within the GLA and funded by the Mayors office and the LDA. It consists of a Forum of advisory stakeholders, a steering group, a secretariat, and a range of Task Groups for specific areas: Finance; Infrastructure and Renewables; Safety and Regulation; Skills, Training and Communications; Stationary Applications; Transport Applications. As its budget is not

sufficient to directly fund demonstration projects, it serves more as a networking, coordinating and goal-setting organisation. Its aims are to:

- Produce and implement the London Hydrogen Action Plan as a route map for clean energy
- Establish and maintain dialogue among all sectors / actors relevant to the hydrogen economy
- Disseminate relevant materials
- Provide a platform for funding bids and initiation of projects

(LHP, 2007)

Being housed within the GLA, the LHP's obvious partners are GLA group organisations, in particular the LDA and TfL. Through TfL, one of the LHP's most high profile goals is procurement of 9 hydrogen buses and 60 smaller hydrogen public fleet vehicles by 2010. Hodson and Marvin also found enthusiasm for greater partnerships between the LHP and the local boroughs.

Indeed, the role of the Mayor, through the LHP and TfL can be important in providing direction and leadership to actors at the local authority level can also be decisive, according to one industrial stakeholder as reported in Hodson and Marvin: '[The Mayor's] energy strategy is helpful because that drives the alignment of the sort of unitary development plans within the local boroughs, and how they are driven to implement their own strategies... the local authorities can make up their own strategies, and implement their own plans, so long as it broadly allies with the direction he's set'. Thus it seems a driving role from a regional level actor can be helpful in pushing forward plans at the grass roots level. (Hodson and Marvin, 2005c, p.9).

The interaction of various actors levels: EU, national, local

The role of international institutions in driving forward hydrogen and fuel cell demonstration projects is particularly noticeable in London, which has benefited from the implementation of the European level CUTE project. The institutional structure of this process has been described by Hodson and Marvin as the 'dropping in' of the hydrogen economy to a 'test-bed', which has been prepared by the activities of the Mayor and GLA, in particular the Energy Strategy.

This has had the interesting effect of funding and technology coordination from a supra-national level (EC, Daimler Chrysler, BP), combining with regional administrative institutions (GLA and TfL), to make an impact on public awareness at the local level.

The experience of public acceptance relating to infrastructure development has been particularly complicated. This has been most obviously characterised by the experience of a large energy company, BP, attempting to 'drop in' hydrogen infrastructure, in the form of a refuelling depot, to a local community, Hornchurch in Essex. The development provoked significant local opposition, related in part to safety concerns, as well as resentment springing from the perception that this was a project being forced down from the European level (Hodson and Marvin, 2005c, p.27). It is perhaps significant in this instance that the residents were being asked to bear the dis-benefits of the siting of the refuelling depot, without experiencing what might potentially be seen as the benefit of actually riding the buses, which operate some miles away in central London. This episode has shown some of the potential problems with a process where a

demonstration project is coordinated from a higher level, and presents a clear lesson that engagement with the local level must be crucial to this process. BP took the lesson from this process that engagement with the local community should begin much earlier, prior to submitting the planning application- a process that is well understood by industrial actors in the Tees Valley region (Hodson and Marvin, 2005c; 2005a). The experience also raised some important questions about the difficulties of formulating convincing drivers and motivations for hydrogen developments, particularly for early stage demonstrations where public benefits such as improved air quality are less tangible. In the absence of direct and obvious motivations for local communities to accept hydrogen demonstration projects, one stakeholder raised the approach of tapping into a 'feelgood factor within the community, that they're doing something for the wider benefit of society' (Hodson and Marvin, 2005c, p.30).

Relations to central government

The physical proximity of the GLA to central government departments such as the DTI, have allowed a strong degree of communication between the city and national levels of administration, with informal networks being prevalent. Some of these, including the current Mayor's association with the Labour party, have allowed the GLA to have a strong influence on national policy, according to one stakeholder (Hodson and Marvin, 2005c, p.10), who suggested that while the Mayor's Energy Strategy was being developed, it had an influence on the emerging national Energy White Paper, particularly in its treatment of regional energy initiatives. Such informal networks put London in a somewhat different position to other regions, and raise the question as to whether more effort should be made to establish formal channels for less geographically proximate regions to communicate with central government over such issues.

The role of the DTI in encouraging regional hydrogen development was discussed by London stakeholders as being to provide high level direction, whilst avoiding being overly dictatorial. The required activity was described variously as being to provide 'national recognition for hydrogen'; to 'support and encourage but not direct too much'; to establish 'some sort of guiding framework within which they can then see that their activities can play a part'; nevertheless they should avoid being too prescriptive and 'go with the flow' (Hodson and Marvin, 2005c, p. 11-12).

Industry

The benefits of such demonstration projects for industry can be to provide a rehearsal of the kind of coordination which would be required between the various business interests and policy institutions which would need to emerge simultaneously in a hydrogen economy, such as vehicles, legislative and policy framework, and infrastructure. Rehearsing this kind of coordination can be important, as many stakeholders viewed the combination of various actors, particularly public and private, as being essential to hydrogen and fuel cell development: 'industrial partners aren't willing to put money into projects unless the public sector's putting money...' (Hodson and Marvin, 2005c, p.17). Similarly, however, some policy makers seem to only have time for projects involving big players: 'You need the major manufacturers involved to bring this new technology forward' (Hodson and Marvin, 2005c, p. 22) Given the conclusions of the PSI economics workshops, however, it is not necessarily the case that this relationship should be considered solely in terms of the large industrial players, as smaller specialist companies may be ideally suited to provide products in the initial roll out process (Hughes, 2006). Mechanisms for bringing smaller scale industrial players into the process should also be considered.

Motivations

London's experience has shown that broader societal benefits (such as abating climate change and air pollution) as motivations don't necessarily play well at the local level, and that the issue of how to gain local involvement for early roll out projects may be somewhat complicated. One observation is that at least some of the resentment relating to the Hornchurch project was connected to a sense of imposition by higher actor levels (EU, BP, GLA) over local interests. The issue of what drivers will be most effective in gaining public acceptance is context specific, and in London could vary from borough to borough. Hence, despite the conviction expressed by certain actors in Hodson and Marvin (2006c) that the hydrogen economy is a 'big boys game', the involvement of all levels would still remain important.

3.4 Scotland

Regulation and policy

The Scottish Executive (SE) is the devolved government of Scotland. Policy areas in Scotland are divided between the UK Government at Westminster and the SE. In energy policy, the UK government retains responsibility for overall energy policy, however promotion of renewable energy, energy efficiency and consenting of electricity generation and transmission development, is now the responsibility of the SE (SE, 2006a, p.20). This division may be a contributing factor towards the prominence of low carbon energy policies in SE documents.

In 2003 the SE published *Securing a Renewable Future: Scotland's Renewable Energy* (SE, 2003). This document set an ambitious target of 40% of electricity produced in Scotland to come from renewable resources. It also set up the Forum for Renewable Energy Development in Scotland (FREDS), whose key role was envisaged as helping the executive to reach the 40% target. The Forum is a partnership between government, academia and industry, and is tasked with setting goals and action plans for the development of the renewables industry in Scotland.

At the request of the hydrogen and fuel cells industry, FREDS set up a dedicated Hydrogen Energy Group, again made up of representatives from government, academia and industry. Drawing on input from a consultancy report (IPA, 2005) the group produced a report in 2006 entitled *Hydrogen and Fuel Cells: Opportunities for Scotland* (SE, 2006b). The report produced the following key recommendations:

1. Support for further demonstration projects involving hydrogen use in remote or off-grid communities in Scotland.
2. Projects are funded to support unique Scottish technology that involves fuel cell design or production
3. Projects are funded to enable applications of hydrogen technologies and fuel cells, which are currently at the research or development stage, to be demonstrated commercially and value engineered for future market entry
4. An inter-university research centre to be established in Scotland to create fuel cell and hydrogen-based intellectual property for future exploitation in Scotland

For these objectives a fund of £2.5m per annum over three years is recommended (SE, 2006b).

The prominence of the recommendation of exploring the use of hydrogen in remote or off grid communities reflects an emphasis in the Scottish dialogue on using hydrogen as a regulator in electricity systems with high penetrations of variable renewables. The HEG report states that hydrogen storage mechanisms would ‘almost certainly be required to balance and integrate many diverse and intermittent sources of energy’ if the 40% renewable electricity target was met. It also portrays renewable based systems with hydrogen storage as a more sustainable and potentially more economically viable alternative to grid extension in remote areas.

This emphasis is in something of a contrast to the dialogue south of the border, where interest is almost exclusively focussed on hydrogen for road transport. In the SE’s climate change strategy *Changing Our Ways: Scotland’s Climate Change Programme* (SE, 2006a), hydrogen is mentioned under a case study of the BP Peterhead project as being part of a clean coal power system, and more broadly as part of the ‘Green jobs strategy’- however in the specific transport section, no mention of hydrogen is made at all, the focus being strongly on biofuels. The HEG report (SE, 2006b) however does recommend that hydrogen be brought under the RTFO, and suggests that in Scotland the availability of renewable electricity could allow hydrogen to make a significant contribution to transport fuel demand.

The HEG report also underlines the long term economic benefits which could be secured for Scotland, emphasising the importance of securing IP rights, and proposing that economic benefits in the order of 10,000 jobs and £500 million per annum gross value added to the economy could ultimately be the prize of strategic investment in hydrogen and fuel cell technologies.

The executive’s first material response to these recommendations came in December 2006 when the Renewable Hydrogen and Fuel Cell Support scheme was announced with a total available fund of £1.5 million. The key objectives are:

- To increase the use of renewable hydrogen and fuel cell technology in Scotland in order to promote the development of a diverse renewables supply;
- To enhance grid stability by accomodating off-grid generation from intermittent renewable sources;
- To maximise the economic benefits from renewable developments utilising renewable hydrogen or fuel cell technology

(SE, 2007)

Again the emphasis is clearly on a hydrogen system that is integrated with renewables.

Other activities

Scotland has significant pre-existing activity in industrial and energy sectors. Hydrogen is produced for industrial purposes at Mosmorrان and Grangemouth. Global companies such as Shell and BP are present in Scotland for these purposes as well as hydrocarbon extraction and refinement. BP, Shell and Scottish and Southern Energy have joined to implement a major project producing hydrogen from methane with carbon sequestration for electricity generation in Peterhead (SE, 2006b).

All Energy is an annual conference held in Aberdeen, which in part aims to build on the existing energy infrastructure and skill base in Scotland by attracting a wide range of international renewable energy companies and investors (All Energy, 2007). The 2007

conference will feature a dedicated Hydrogen parallel conference, running for the entire 2 days, showing the importance that hydrogen technologies are perceived to have.

There are a variety of smaller Scottish hydrogen and fuel cell companies trying to gain early market penetration with niche products. Such companies include Fuel Cells (Scotland) Ltd, a manufacturer of SOFC CHP units; St Andrews Fuel Cells Ltd, which was spun out from the university of St. Andrews in 2005 to exploit a patented 'roll' design for portable SOFC units; siGEN, a systems integrator for a range of applications and projects, including providing the hydrogen production and storage facilities, the stationary fuel cells and converting the fuel cell vehicle for the PURE project.

In academia, St. Andrews and Strathclyde are International Centres of Excellence in fuel cell development and integration respectively. Activities are developing at Heriot Watt, Napier, Aberdeen and RGU. (SE, 2006b, p. 12-13)

The Scottish Hydrogen and Fuel Cell Association (SHFCA) is the Scottish industry association, with a list of 45 members including small businesses and enterprises, academic and research institutes, and community based groups. The two large energy companies involved are Scottish and Southern Energy and Scottish Power. There is also representation from the LA level, with both Aberdeen City Council and Aberdeenshire Council present as members (SHFCA, 2007).

As well as the large scale BP Peterhead project, there are two smaller hydrogen demonstration projects of particular significance. The Hydrogen Office is a project being developed by a construction company called Alsherra Investments with funding from Scottish Enterprise (Scotland's main economic development agency, funded by the Scottish Executive), the Scottish Executive and the ERDF. Situated in Methil, Fife, the project is to build an office building providing incubation for small businesses, which demonstrates the use of renewables, energy efficiency and hydrogen in providing power while addressing climate and security of supply concerns. It is consistent with the more general focus on hydrogen as an intermittency regulator in Scotland that hydrogen should have such a high profile in this project (The Hydrogen Office, 2007).

Other projects aim to promote the use of hydrogen in conjunction with intermittent renewables in the more remote areas of the country. The Highland and Islands Community Energy Company is a non profit company delivering advice and funding for communities in the highlands and islands to develop their own renewable energy projects (HIE, 2007). The PURE energy centre, based in Shetland, was established by the Unst Partnership, a local economic regeneration organisation, with an equity stake by Shetland Enterprise and the Highland and Islands Community Energy Company. It is developing hydrogen based renewables systems using the abundant wind resource on the island of Unst, to create stationary power as well as to run a fuel cell vehicle (SE, 2006b). There is similar interest in the Western Isles, where a plan is being developed for a Hebridean Hydrogen Park (Hebridean Hydrogen Park, 2006).

3.5 Regional level- key issues

The effect of regional motivations on technology choice and development

Motivations for the development of hydrogen and fuel cell related projects are highly specific to the region where they occur, and relate to factors including economic

development concerns, the context set by other policy areas, and the region's view of itself and its aspirations. These factors will have very real effects not only on whether hydrogen and fuel cell technologies are accepted, but also on which types of hydrogen and fuel cell systems are ultimately preferred.

The importance of local actors and institutions

The role of local actors and institutions is always crucial to the implementation of hydrogen and fuel cell projects. Local or regional actors have been the key drivers of the most of the projects discussed above. Even where a project has been 'dropped in' from a higher level, gaining participation and acceptance at the local level remains crucial.

The need for higher level guiding visions

Despite the highly effective and autonomous behaviour of local and regional actors in undertaking hydrogen projects, often through tapping into EU level funding sources, the need for some kind of guiding vision at a higher level, to provide a framework for local activities, was expressed. The level from which this vision is driven needs to be close enough to the local level to be sensitive to its particular context and motivations, but high enough above to avoid being caught up in nearer term issues.

4. Discussion

4.1. Relevance to previous and ongoing UKSHEC work

One of the key conclusions from the UKSHEC scenario development process was that there is ‘no single, shared vision of a hydrogen economy’ (Eames and McDowall, 2006). A complementary conclusion has emerged from this review of the policy and institutional structure relating to the early stage of hydrogen development, in that there is clearly a diverse range of potential actors in the UK relating to hydrogen and fuel cells, possessing a diverse range of motivations. Sometimes motivations between actor levels may be contrasting. Motivations at local actor levels tend to be dominated by concerns relating to local economic development, encouraging investment and job creation and preservation in workforces characterised by high skill levels in industrial processes. To a certain extent air quality is a motivation for urban regions, though this remains a longer term driver. At the national level, the drive for a hydrogen economy is located within the framework of the four key energy policy goals set out in the 2003 Energy White Paper, of which the 60% carbon reduction target by 2050, and security of supply objectives seem most relevant. It is worth observing, however, that the quickest way to kick start hydrogen and fuel cell demonstrations in regions may not necessarily be compatible with strong decarbonisation- thus it is possible at some stage that local and national motivations could be in conflict.

As the UKSHEC scenarios demonstrate, the link with other policies is important. For example, some of the UKSHEC scenarios are driven by policy developments in other areas, in particular the Electricity Store scenario, where hydrogen development is indirectly driven by increasing renewable penetration. The current policy climate in Scotland shows similar characteristics to this scenario, where the target of 40% renewable energy produced in Scotland by 2020 places greater importance on the development of an effective grid balancing mechanism, for which hydrogen is being seen as a potential answer.

Even allowing for the uncertainty in projecting ahead that the multiple scenario set implies, it is often assumed that there will ultimately be a relatively uniform single future for the hydrogen economy. There is a tendency for high level visions and route maps to think in quite a uniform manner, to attempt to define ‘a’ vision. However, neither the scenario set nor this institutional mapping study rule out the possibility that even within an area as relatively small as the UK, more than one type of hydrogen economy could exist simultaneously in different regions. This is especially true as the supporting policy frameworks in the various local authority boroughs and devolved regions are significantly varied, and, depending on the extent to which the political tide turns for or against decentralisation of power, may become even more so. Thus as was observed above, a network based on smoothing out fluctuations in renewable resources currently seems far more probable in Scotland due to the strong policies promoting renewable energy which exist there. Such a system could co-exist with but be completely unconnected to one producing hydrogen from large scale SMR with CCS for transport demand in London, for example.

UKSHEC work has also emphasised the importance of a regionally sensitive approach. This has been emphasised in the public focus group and stakeholder engagement work carried out by Ricci et al (2006) in three UK regions, and also by PSI’s expert stakeholder workshops on the economics of hydrogen technologies (Hughes, 2006). This is due in

part, as has been discussed above, to the variety of motivations driving progress in different regions, as well as differences in infrastructure, demand, and resource availability. This study has complemented these findings by emphasising the importance of regional actors, as it has emerged quite clearly that the majority of successful hydrogen demonstration projects in the UK have been driven by actors at regional and local levels, including LAs, RDAs, devolved governments, and local interest groups. The obvious exception to this is the CUTE project in London, where an EU wide initiative has been ‘dropped in’ to a ‘test bed’ (Hodson and Marvin, 2005c). However, even in this case the importance of the regional aspect can not be denied, as the local transport operator, Transport for London, was a key player in the implementation, and local objections to the siting of the refuelling facility at Hornchurch in Essex, made local public engagement a key part of the process. In fact, a major conclusion from this process has been that considered local public engagement is vital from the start of such projects.

4.2. Possible areas for further research

The emergent status of the hydrogen and fuel cell industry, and the comparatively small number of actors involved in the UK, may result in a high degree of ‘informality’ in the way knowledge is shared and built up, and contacts are made. Further research might usefully explore the extent to which informal institutions and relationships are affecting the development of the hydrogen economy in the UK.

Institutions are defined by Pelling et al (2004) as the ‘rules of the game’, which can include laws, guidelines and culture, and can be formal or informal. The small number of actors involved in hydrogen and fuel cells in the UK makes the cultivation of personal relationships between those in the field much more likely, and could result in a higher than average proportion of informal institutions, where contacts are made and maintained to a certain extent on the basis of who is already ‘in the loop’. The prevalence of informal institutions can render the networks somewhat vulnerable to distortions in representation for reasons owing more to chance than anything else. A great number of organisations, interest groups, or discourses, are spearheaded by one individual. This means that contact with the individual is in practice more apparent than contact with the organisation. It means that if the key individual moves on from that organisation for any reason, the connection risks being lost. It also means that logistical issues, such as the expense and time spent travelling to the various networking meetings and workshops, exert a large strain on the ability of the broader hydrogen community to meet up and function in its entirety. This is a factor most keenly felt by stakeholders based some distance from London, where a great number of the meetings take place. The fragility of the network to such logistical issues can result in a high risk of misrepresentation when it comes to drawing up of high level roadmaps and strategies- the appearance or otherwise of a particular region or technological viewpoint in a high level roadmap can depend entirely on whether one individual was able or not to attend a workshop. The largely informal nature of institutions and relationships can mean that ideas can move swiftly from being mooted to being widely accepted.

Knowledge can be informal too; for example in Teesside it has been observed that there is a general confidence and understanding of how to gain public acceptance for industrial developments, and a culture of awareness of industrial developments which will affect the acceptance of hydrogen developments. This was a knowledge resource which was not shared and drawn upon by BP, despite being a global company, when implementing the Hornchurch development. The potential advantages of sharing this kind of

knowledge and experience suggests that there is possibly room for increased collaboration between different regional actors. Increased link up between the various regions within the UK with an interest in hydrogen and fuel cells could help to explore opportunities for knowledge transfer.

5. Conclusions

5.1 The role of high level institutions

Local and regional actors will be key to the driving forward of hydrogen and fuel cell related projects in the UK. The issue that this presents for higher level institutions is that between the various local levels, there will be significant variations in motivations, policy contexts, as well as physical and economic conditions which will lead to a variety of different hydrogen and fuel cell systems being preferred in each area. However the degree of localised detail present in high level roadmaps is unlikely to be able to account for this heterogeneity.

The efforts of higher level institutions such as DTI and EU to develop common visions inevitably simplify and smooth out the differences in regional contexts, which can risk leaving some actors feeling unrepresented. Although national level institutions are in general attuned to the possibility of hydrogen economies emerging in a regionally focussed manner, as shown by the structure of the DTI / EU HyWays process. However, they are arguably less well attuned to the degree of variety of different forms these regional representations of hydrogen economies could take. There is a risk that high level strategies can gloss over the subtleties of regional implementation. In the EU High Level Group Report (EC, 2003) there is an anxiety that deployment of a competitive hydrogen technology and fuel cell industry 'should not be left to develop in an uncoordinated fashion at the level of the individual member states'. High level road maps, by their very nature, risk being only tenuously connected to the regional demonstration projects which are the reality of an early stage roll out. This can cause resentment and disengagement at the local level.

On the other hand, and despite the high degree of entrepreneurship and ability of local actors to operate independently from central institutions, there nevertheless is a strongly articulated desire from many of them to have a lead or direction provided by a higher level institution. While this is obviously in part represented by the accessing of higher level funding mechanisms such as the EU ERDF, local actors also express the need for less tangible concepts such as 'direction' and 'inspiration' from the higher levels. Although local actors are in many cases the prime movers in implementing hydrogen demonstration projects, there nevertheless remains a clearly articulated need on behalf of many local actors to look towards higher level institutions, be it at regional or national level, for guidance and direction, in order to put their activities within a more widely supported context.

High level policies and road maps should provide an aspirational drive to encourage local and regional actors to implement projects, supported with funding, whilst remaining flexible to regional interpretations of what a hydrogen or fuel cell economy means in each local context. At the current stage of technological development, applications are highly region specific, and the pathways towards large scale up of the technology are not yet known, therefore high level institutions should not attempt to conglomerate disparate regional initiatives into a single, centralised roadmap. High level policies could set key priorities with which local projects must be in line, for example carbon reduction (or demonstrable progress towards future carbon reduction), security of supply, or benefits to the regional and UK economy. Within this however, policies should be open to the possibility of multiple and simultaneous variations on the theme of the hydrogen economy.

Additionally, high level institutions should ensure that strategic investment priorities are in line with policy aspirations. As has been observed, there is at present a disconnect between the industry focus in the UK on portables, stationary power and renewables integration, and the high level policy vision, enshrined by the HyWays process, of an automotive based hydrogen vision. Therefore, as well as increased flexibility in high level policy aspirations, strategic investments and policies should be made to incentivise hydrogen and fuel cell automotive technology development in the UK. As in the case of the Modex factory in Coventry, strategic investment in this area could have a positive effect on local economies suffering from the relocation of large manufacturers to other markets.

Although flexibility of visions will be key in early roll out stages, nevertheless high level actors such as the UK government and the EU might need to be ready to deliver more coordinated planning and support at a later stage, for example if the development of a large scale hydrogen transmission and distribution infrastructure became essential, there may be a clear case for government to fund the initial negative cash flow, before demand could repay investment. However, long term planning must also be open to major paradigm shifts in the fundamental ways in which hydrogen and fuel cell technologies are perceived and used. For example major progress in small scale electrolysis could completely bypass the need for hydrogen transmission. Therefore a high level road map should entail a commitment from a high level actor to act where necessary at crucial junctures, without tying down the many independent and often relatively small scale actors, who are currently the most effective implementers, to a single centralised vision.

5.2 The role of regional institutions

As has been discussed, a guiding vision can be crucial in driving forward local projects. Whereas the national level is too removed from the specificities of regions to create a vision that is resonant with all areas, the LA level is too entrenched with other fundamental service delivery areas to be able to give real priority to futuristic technologies such as hydrogen and fuel cells. Thus it seems that the regional or RDA level, sitting between the two, seems an ideal locus for such a guiding vision to be created. Frequently an organisation at this level is given fairly long term and strategic, yet regionally focussed responsibilities, without taking on more ground level issues. It was commonly observed by stakeholders surveyed by Hodson and Marvin that a strong vision from a regional figurehead or organisation such as the Mayor in London, or the RDA in the North East, has been helpful for local actors in providing a framework for their activities. In Wales, the dissolution of the WDA following devolution may mean that there is a gap at this key regional level, between government and local authority levels.

5.3 The role of local and private actors

Existing funding schemes from the DTI and EU support demonstration projects and technology R&D, and there are networks which aim to connect academic researchers with industrial manufacturers. However, there is perhaps a need for a more systematic approach to linking up the above actors with actors who may be the most likely early purchasers of hydrogen and fuel cell technologies. These could include local authorities, businesses or large commercial retailers, who might provide demand for niche products for delivery fleets or stationary power and CHP applications.

It may not be necessary for entirely new institutions to be brought into being for this to be achieved. The existing beacon scheme for local councils, which provides a mechanism for councils which have already made strong and innovative progress in an important area of service delivery, to receive additional and focussed funding to continue to achieve excellence in that area, could be an ideal institution. There is already a sustainable energy beacon category, for which 7 councils currently qualify. This process could suit the development of hydrogen and fuel cells, as it requires initial commitment and progress to be made at the local level, which is then rewarded with funding for the specific area, which avoids the council having to divert funds from other key service areas. It would give councils with suitable conditions and sufficient motivation a strong incentive to make progress, without facing the politically unrealistic task of imposing high standards on all councils. The beacon scheme would also provide direct mechanisms for greater sharing of experience between regions, through its 'peer support programme' (IDEA, 2007). It could also provide networks for the selected councils to engage with potential providers of hydrogen and fuel cell technologies, as relevant to their needs.

For other actors, such as retailers and businesses, an existing institution such as the UKHA could perform a similar function. If large retailers such as Tesco's and Marks and Spencer, who have expressed commitment to strong environmental performance, were able to join a network such as the UKHA, it could serve as an effective mechanism to allow manufacturers to identify very specific niche applications, which if they produced a product to match, would guarantee sales. Such relationships could do much to increase the speed of hydrogen and fuel cell commercialisation.

Finally, it must also be acknowledged that knowledge sharing on the part of actors who have implemented hydrogen and fuel cell projects, on issues including public acceptance and the relative suitability of technologies for various applications, would be of benefit for all concerned. Again, it is likely that appropriate organisations exist to facilitate this, if appropriate institutions can be devised within them.

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