A way forward for urban transport?

Dr Peter Pearson, Director, and Tanya O'Garra, Research Associate, Imperial College Centre for Energy Policy and Technology, profile hydrogen buses…

There has been growing national and international interest in hydrogen, particularly when coupled with fuel cell technologies, in both transport applications (including buses, cars and trains) and stationary applications (electricity generation, combined heat and power, and energy storage). What are the special features of hydrogen and why has interest grown?

Hydrogen (H_2) – like electricity – is an 'energy carrier' that carries useful energy derived from primary energy sources, such as coal, natural gas, wind or biomass. Current routes for local or centralised production of hydrogen include steam reforming of natural gas (CH_4) and electrolysis of water (H_2O). Significant amounts of hydrogen are already available from ongoing production destined for a variety of industrial uses.

Hydrogen and electricity offer some of the flexibilities associated with what economists sometimes call 'general purpose technologies' – both in terms of the variety of primary energy sources, fossil fuels, renewables or nuclear, from which they can be obtained, and in terms of the relative ease of employing them in different mobile and stationary end-uses. Hydrogen's potential, in gas or liquid form, to act as a medium of energy storage is an additional advantage compared to electricity. As well as in fuel cells, hydrogen can also be used in modified internal combustion engines and in gas turbines. In fuel cell uses, hydrogen has the attractive attribute, particularly for urban transport applications, that the only emissions at the point of use are water vapour and heat. Nevertheless, since the hydrogen results from a chain of energy conversions, a proper environmental evaluation should also take into account any emissions from the upstream processes involved.

The growing interest in hydrogen has come from concerns over local – especially urban – emissions and air quality, relating to particulates and other local air pollutants, as well as noise. It has also come from concern with global emissions of greenhouse gases, including CO_2. Given the particularly rapid growth in fossil fuel use and CO_2 emissions associated with urban transport, the possibility of 'decarbonising' urban transport through hydrogen derived from non-fossil sources (and possibly fossil fuels with carbon sequestration) has become increasingly attractive. When added to the potential for enhanced security and diversity through the range of supply options, compared to a dependence on fossil fuel, particularly oil-based, transport fuels, and the potential flexibilities in end-uses and storage, the raised profile of hydrogen and fuel cell technologies is not hard to understand. Indeed, some see hydrogen as an opportunity to enhance future penetration of renewable or nuclear energy sources. For material on the UK's hydrogen strategy, see www.dti.gov.uk/energy/sepn/hydrogen.shtml; on the European Hydrogen and Fuel Cell Technology Platform, see www.hfpeurope.org/; and on the US approach, see www.hydrogen.energy.gov/.

Nevertheless, there are major issues – about both vehicles and the hydrogen refuelling infrastructures needed to support them – that would need to be addressed before hydrogen could make any major penetration into future transport systems. These challenges include issues of engineering and technology, public policy and planning, and, not least, public acceptability. Consequently, there has been growing interest in a variety of pilot projects aimed at exploring the introduction of bus and fleet vehicles in particular. They offer promising first avenues for hydrogen because fleets tend to refuel at relatively small numbers of central depots, the fleets and the infrastructure can be managed together, and fleet refuelling does not require the kind of comprehensive spatial coverage and investment necessary to support private car users. The growth of fleet refuelling infrastructures might also pave the way for the much more extensive future private vehicle refuelling systems.

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London is an appropriate location for pilot hydrogen transport applications, including buses, for several reasons. There are major urban air quality issues, there is proximity to key government decision-makers, and the Mayor and the Greater London Authority (GLA) have already expressed enthusiasm

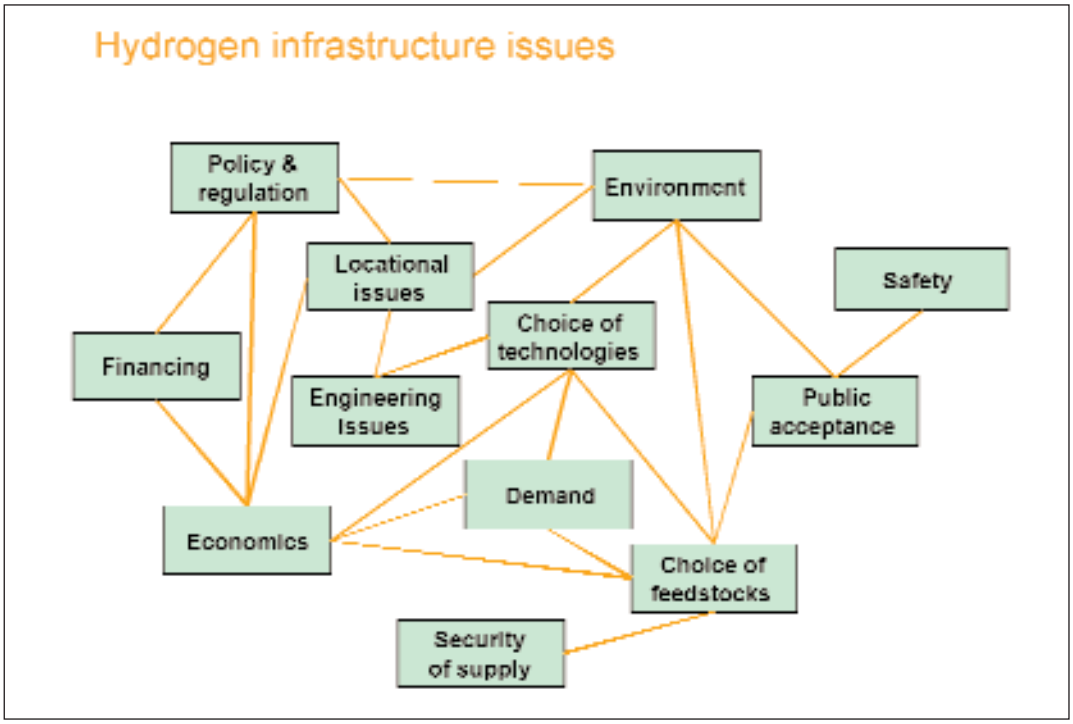

Fig. 1

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for hydrogen. They have set up the London Hydrogen Partnership, which aims 'to work towards a hydrogen economy for London and the UK' (see www.london.gov.uk/mayor/environment/energy/hydrogen.jsp), through a variety of demonstration projects, while Transport for London are managing three Citaro hydrogen fuel cell buses as part of a two year, Europe-wide trial of the technology in nine cities from 2004 to 2006 – the Clean Urban Transport for Europe (CUTE) project (see www.fuel-cell-bus-club.com).

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At the Centre for Energy Policy and Technology at Imperial College, our hydrogen and fuel cell research, led by Dr David Hart, has been exploring the issues associated with the introduction of bus and fleet vehicles in London, in a number of projects supported by the Engineering and Physical Sciences Research Council (EPSRC), the European Union (EU) and a number of industrial sponsors. Our EPSRC project, carried out in partnership with Air Products, BMW, BP, BOC and the GLA, is exploring what would be required for the development of a hydrogen fleet refuelling infrastructure in London.

The issues illustrated in fig. 1 are being explored through a variety of interlinked models and investigations, and include considerations of:

- How many hydrogen vehicles over what time scales and how the uptake of vehicles interacts with the availability of refuelling stations;
- Centralised or decentralised production of hydrogen (the latter probably more likely in the short term – but how to transit from this in the longer term);
- Which production technologies and scales; which feed stocks (probably mostly natural gas in the short term, with carbon neutral production a possibility in the longer run, and with interesting possibilities for the use of local resources of waste);
- When and how to use hydrogen as a compressed gas or as a liquid; the use of tankers or pipelines to deliver the hydrogen;
- Issues of land availability, cost and planning; and, not least, questions about economics, finance (who will finance an infrastructure, and what will be the roles of government and industry?) and public acceptability.

A number of these questions are discussed in the paper by David Joffe, David Hart and Ausilio Bauen.[1] The project will report its full results later in 2005.

Issues about the acceptability of hydrogen buses and their infrastructure – which could have major impacts on both take-up and costs – have only recently begun to be explored, despite some concerns about possible negative reactions. In 2003, we consulted experts in hydrogen, fuel cells, liquid petroleum

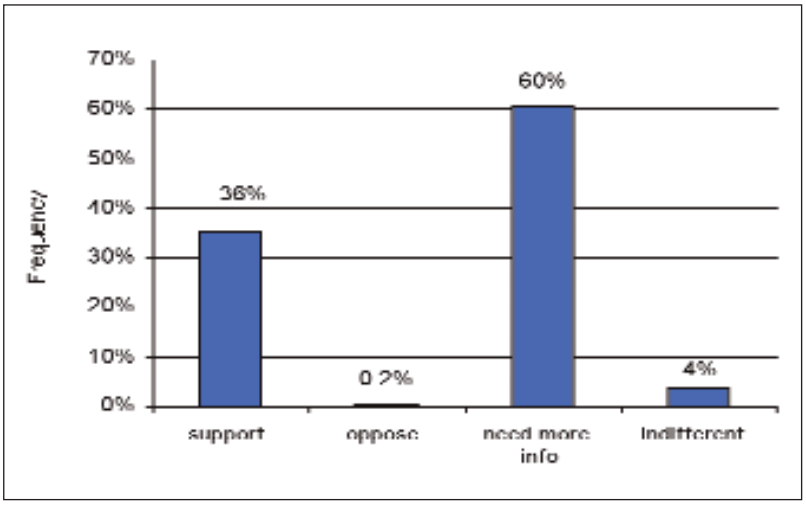

Fig. 2

gas (LPG) infrastructure, air pollution and local planning. We found that there were widely differing opinions about potential objections. Most thought safety a key issue and expected knowledge/awareness to be a key influence on hydrogen vehicle acceptability.

Existing studies report some positive relationships between knowledge and acceptance of hydrogen, while there is some indication that direct experience of hydrogen powered buses led to a relatively high acceptance of them in Munich. The few existing studies found relatively little concern with the safety of hydrogen transport, and our own survey of London taxi drivers, carried out by Susana Mourato and colleagues, suggested that they showed little concern about the likely safety of fuel cell taxis.

Another recent Imperial College study[2] focused on London and was part of a five city, EU funded project called ACCEPTH2 (see www.accepth2.com/). It involved more than 400 telephone interviews with a sample of people in Greater London. The findings suggested that public concerns with hydrogen safety were not widespread. However, there was modest awareness of hydrogen vehicles just before the introduction of the three CUTE project buses: less than half had heard of hydrogen vehicles, less than a third had heard of fuel cell vehicles, while only a fifth had heard of both. Compared with the partner cities, Londoners were least informed about hydrogen vehicles, while more than seven-10ths of Berliners had heard of them.

The answers to the questions 'how would you feel about hydrogen powered vehicles being introduced in London? Would you, in principle, support it, oppose it, need more information to make a decision or are you indifferent?' are shown in Fig. 2.

They indicate that, at the time of the survey, there was significant support and very little opposition. Prior knowledge was the main determinant of support for the introduction of hydrogen vehicles – but this may reflect the largely positive nature of the available information. Significantly, three-fifths felt they needed more information before taking a view. So, potentially, a further 60% of London's population might either oppose or support hydrogen transport, depending on the kind of information they receive and understanding they develop. This suggests a strong need to raise awareness among London's public about hydrogen and fuel cells. We found that hydrogen awareness was related to differences in gender, age, education and environmental knowledge. Consequently, in order to best reach the wider community and help them to make informed decisions about the new technology and its infrastructure, information might be best presented in different ways to different groups.

The ACCEPTH2 London study also found that London bus users were willing to pay an average of 27p on top of a 70p bus fare to support the introduction of hydrogen fuel cell buses in London. Although environmental attitude was a driver for willingness to pay small amounts, prior knowledge about hydrogen technologies was a key driver for a greater willingness to pay.

Our surveys also suggest that support for hydrogen vehicles in London tends to be higher than support for hydrogen refuelling infrastructure. At present, there seems to be only moderate opposition to hydrogen infrastructure, although this could change in either direction because so many people as yet have no clear opinions. There does, however, seem to be a significant demand for more information about hydrogen infrastructure and its implications. It is clear that further research is needed and we are currently engaged in a study of public acceptance of hydrogen refuelling stations in three London Boroughs, which is looking at how attitudes evolve over a three year period in the light of changing information and knowledge.

References:

1 Joffe D, Hart D and Bauen A (2004) 'Modelling of hydrogen infrastructure for vehicle refueling in London', Journal of Power Sources, 131, pp.13-22.

2 O'Garra T, Mourato S and Pearson P (2005) 'Analysing awareness and acceptability of hydrogen vehicles: A London case Study', International Journal of Hydrogen Energy, 30, pp.649-659.

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