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Unfamiliar fuel: How the UK public views the infrastructure required to supply hydrogen for road transport

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ABSTRACT

In 2007, under contract to the UK Department for Transport, we engaged with the public about the *infrastructure* to supply hydrogen for transport.

We combined a quota-sample survey of 1003 across three disparate ‘travel-to-work areas’ in England with focus groups representative of them. We informed the groups ‘at arm's length’ through a purpose-made video, composed with advice from a hydrogen scientist and made by professional broadcasters.

Participants saw benefits in hydrogen energy. None rejected it on safety grounds, though many discussed the risks. The costs were considered a problem.

‘The public’ was not of one mind. Regular car drivers were unwilling to reduce their car use. Bus users, cyclists and walkers often sought improvements in air quality. Motorists knew more than others about hydrogen energy.

In discussion we seek psychological and socio-cultural explanations for these results. We conclude by drawing out implications for the future of hydrogen in transport.

Introduction

In 2013, the UK Department for Business, Innovation and Skills (BIS) published a ‘roadmap’ for developing hydrogen fuel-cell road vehicles and the refuelling points and other infrastructure they would need, anticipating as many as 1.5 mn on UK roads by 2030 [1]. It aims for the target set by the Climate Change Act (2008): to reduce UK Green House Gases (GHGs), which contribute to global warming and so threaten climate change, by 80% of 1990's level before 2050. This comes at a time when transport is playing an increasing part in those emissions [2].

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McDowall [3] argued in advance of the publication of the BIS plan that such roadmaps are too often 'one-offs': they should conform to established standards and be rigorously evaluated. Part of the evaluation should be deliberation 'upstream' of implementing new technology, conducted among engineers and scientists in the field and business and other stakeholders. Arguably it should include dialogue between members of the general public and experts in the field, for the public will be affected as consumers and citizens and might push for or else resist the new technology. According to Williams and Edge [4] two-way dialogue could 'socially shape' the technology so as to form a better fit than otherwise with the demands of everyday life.

In 2006 the UK Department of Transport (DfT) Horizons Programme commissioned the project reported here. Our remit was wider than hydrogen's end-use in vehicles. It was to engage the public with the *infrastructure* that would be required to produce, store and distribute the considerable volume of hydrogen needed to replace oil. Subsequent studies in both Germany [5] and Norway [6] have addressed this issue with the public.

Since 2000, the UK government itself has advocated engagement with the public upstream of implementing new technology [7,8]. This follows a wider trend in Europe and beyond [9] and also responds to public resistance in the UK to earlier developments, such as genetically modified crops and measles, mumps and rubella vaccination [10]. In 2000 public engagement was carried out on nanotechnology by the Royal Society and the Royal Academy of Engineering [11].

Background

How then might hydrogen provide energy, in particular fuel for transport? [12] Our principal source for the summary that follows is long-term 'visions' for hydrogen energy drawn from an interdisciplinary panel of experts and stakeholders by 'deliberative mapping', which evaluated each vision on multiple criteria [13,14].

Hydrogen is the most abundant of elements, but on Earth, unlike in the Sun, hydrogen is found in chemical compounds, such as water formed with oxygen and the several that with carbon form hydrocarbons – among them coal, natural gas and oil (all fossil fuels), and also biomass from plant life. Releasing hydrogen from these compounds to serve as energy in its own right requires other forms of energy: for instance, heat to 'coke' coal so as to release the mix of hydrogen and methane known as 'coal gas'; the heat from nuclear reactors to release hydrogen in steam; the heat in steam to reform natural gas; dark fermentation of biomass such as energy crops; and electricity to separate hydrogen from oxygen in water by electrolysis.

Hydrogen can fuel transport so long as it is converted into heat, as is petroleum in the internal combustion engine, or else into electricity to power electric motors. The latter is achieved by a hydrogen 'fuel cell', which in effect reverses the electrolysis by which hydrogen is released from oxygen in water. It leaves a residue of nothing but water.

Like both oil and electricity as sources of power in vehicles, hydrogen must be stored on board and that store has to be refilled when nearly empty. The on-board store needs to hold sufficient for a practical gap between refills. Hydrogen is gaseous at 'room' temperature and the lightest of elements. If it is to fit in a tank compact enough to sit on board a vehicle, it has to be highly pressurized, liquefied at near to absolute zero, or stored in solid state – by chemical absorption into or physical adsorption onto suitable materials.

Re-fuelling stations need to be spaced at intervals. Each might be a 'micro-generator' of hydrogen, steam-reforming natural gas fed by the national pipeline or producing hydrogen from renewable sources on-site. Otherwise it might deliver hydrogen carried by pipeline or tanker from a 'central-generator'. Like the vehicle, the re-fuelling station must store hydrogen ready for use.

Oil – in the form of petrol or diesel – is used more by far than any other fuel in transport. Electricity is in use too, but on a much smaller scale. Substituting hydrogen for oil or for electricity in transport would carry benefits, costs and risks. They have to be weighed in the balance with the benefits, costs and risks of the fuels it might replace.

The *benefits* of hydrogen as compared with petroleum are that it produces no air, land and sea pollution in use [15]; that hydrogen fuel cells make no noise; and that hydrogen-in-use produces no greenhouse gases (GHGs) [16]. The same benefits apply to electrically powered vehicles. However, electricity merely carries energy from various sources, but hydrogen can also serve as a store of energy, whether produced intermittently from such renewable sources as wind, tide/wave and the light of the Sun, or else – for the sake of efficiency – produced constantly from nuclear or geothermal power. By contrast, a secure supply of electricity relies on power stations in the national grid that can be turned on when demand exceeds supply. These are usually powered by natural gas, which contributes to global warming and pollution.

Like other fossil fuels, natural gas is not renewable. Moreover, fossil fuels are not evenly distributed in Earth's crust. Thus countries that have to import them adversely affect their balance of trade, while suppliers of fossil fuels – national or corporate – have a vested interest in maintaining others' dependence upon them. Hydrogen energy, by contrast, can be produced sustainably from whichever low carbon energy is in abundance in any locality.

Currently, the *costs* of powering transport by hydrogen are high. This is largely attributable to the fact that hydrogen technology is yet to be fully developed and gain from the economies of scale that stem from mass production. Should reserves of oil become scarcer, so the price advantage that oil has over hydrogen should diminish.

Hydrogen carries *risks* to the user, but not necessarily as great as often perceived [17–19]. It is the lightest element. This has the advantage that, should it escape into an open space, it will ascend rapidly, unlike petrol, which is liquid and, if spilled, can spread out on the ground and readily ignite. However, if hydrogen were to escape in an enclosed space – say a garage – it would probably explode. Like the risks associated with petrol, those of hydrogen must be controlled by technology and handling practices tailored to the fuel.

Hydrogen energy is by no means as familiar a fuel to the general public as oil. In the 2000s, prototype hydrogen buses