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The future for jet fuel: what are the options?

Fleet cars and green choices

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Hydrogen — dream fuel or simply a dream?

Is hydrogen the perfect non-carbon road fuel? Or is it too inefficient to create anything but a myth? The long-promised hydrocarbons substitute for transport fuels could still be long on promises, says ***Jon Herbert***. Unless bacteria give a helping hand.

A new hydrogen filling station, recently opened on a service area near Swindon, could become the first humble step in a revolution taking petrol and diesel off Britain's roads for ever. The M4 corridor — very aptly marking the most southern UK ice sheet tip of the last great Ice Age — is a symbolic choice for a proto "hydrogen highway" designed to put the climate-friendly fuel into daily public use.

Could nature's smallest molecule prove to be a natural stable-mate for renewable energy, or is it fated to remain a perpetual illusion?

Hydrogen and hydrogen technology pose enormous opportunities and challenges. They could theoretically replace the centralised national grid-generation and distribution of electricity, as well as fossil-based road fuels. The science suggests deep inefficiencies. But backed by a fair wind — and there's a clue — the ultimate question is: can the economics be made to stack up?

Although envisaged since the time of Jules Verne, the term hydrogen-economy was first coined in 1970. As fuel for the internal combustion engine, it has twice the efficiency of hydrocarbons.

But there is a better way yet to harness hydrogen. Fuel cells combine hydrogen with atmospheric oxygen efficiently to create an electrical current and pure water. There is no other pollution. But the demanding technology has to be perfected for the road.

Hydrogen is also attractive as a potentially native power source. It can be "made" locally — possibly in your home! No pipelines, no vulnerable imports, no politics, no tankers. Wherever you have a ready source of electricity, hydrogen can be produced — to turn back into electricity for transport traction. Too good to be true? Perhaps.

Nature's bounty

Hydrogen is often said to be abundant in nature, at a water droplet near you. But that is the start of the problem. Oceans are not full of hydrogen. Seas consist of water. Splitting water into hydrogen and oxygen via electrolysis takes energy, in large amounts and at low cost. And the process has to be sustainable.

For the reality is that hydrogen is not an energy source. It is simply an energy carrier. It must be manufactured. Energy has to be put in so that energy can be taken out. And as with all physical and chemical conversions, there are inevitable efficiency losses.

While it is efficient as a fuel, its overall manufacture and transition is quite energy inefficient, to the extent that advances in battery technology may now be giving rechargeable electric cars the edge.

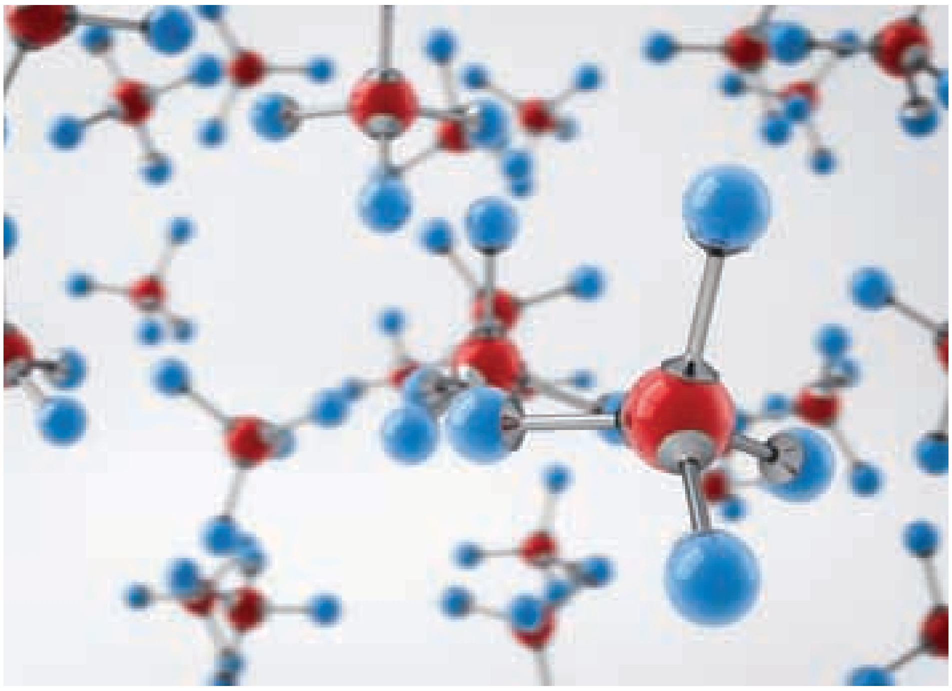
Until recently, electric battery cars have had a range of circa 60 miles, compared with some 300 miles on hydrogen. But battery advances are beginning to extend this range; battery-driven cars can also literally plug into the existing nationwide power network. Survey works shows that most electric car users will recharge their vehicles at home every two to three days.

Energy needs

If hydrogen is to have a sustainable future, where will the energy needed to make it come from?

Here, there are two scenarios, explained in more detail later. In one scenario, hydrogen can be made in bulk centrally — preferably using renewables or nuclear energy — and delivered locally by a yet to be created new distribution network. In this model, the national grid could become redundant with a hydrogen fuel cell, say in the family car, plugged into the home at night to power-up domestic accumulators that then provide all the energy the average household needs.

In a second scenario, electrical power would continue to be distributed via the existing grid and used to make hydrogen at home. In either



case, the preferred hydrogen feedstock could eventually be water.

A third interim option is to "make" hydrogen from natural gas, with the accompanying carbon emissions. Here, hydrogen can be generated on board the vehicle using a hydrocarbon reformer. As explained later, this might be the practical halfway house allowing hydrogen to become commonplace on UK roads until a truly sustainable solution is available.

For a "pure" hydrogen economy — completely independent of polluting hydrocarbons — the argument becomes more complex still. The no-carbon allure of hydrogen is that it could ultimately replace fossil-fuel use in transport completely, together with gas, oil and coal used for conventional power station firing. Renewables, and a possible future generation of nuclear stations, might provide energy for hydrogen production. But then again both could replace conventional "dirty" generating capacity themselves. So this part of the argument becomes a closed loop.

New infrastructure

However, a massive new renewable/nuclear infrastructure would to be needed to manufacture enough bulk hydrogen to replace hydrocarbons in transport.

Yet, if the conversion efficiency of creating hydrogen, distributing it and turning it into traction power for transport is as low as some calculations suggest, the scale of renewable/nuclear power generation would need to be high, at low cost.

Fears about intrinsic hydrogen economy inefficiency centre on calculations of the amount of energy needed to isolate hydrogen from water, natural gas or biomass, compress or liquefy the light gas, ship the energy carrier to the end user and convert it back into useful energy through fuel cells. It has been estimated that only some 25% of the initial energy is left available for traction. This compares with some 70% if electricity is transmitted, converted and stored in batteries for vehicles with regenerative braking. Advanced batteries now have a cycle efficiency of more than 80%.

The conundrum becomes slightly worse. As the smallest element in the periodic table, hydrogen also forms the smallest molecule. This can make it difficult to store. Leakages are expected to be high. Even more hydrogen would be needed to make up for these losses.

Given the present state of renewable development, arguments and counter-arguments for and against wind-farm developments, the potential of solar, wave and tidal power, plus setbacks in UK nuclear power station building strategy, what are the prospects for copious, inexpensive, sustainable, local energy sources that would be dedicated to creating hydrogen for transport?

On the positive side, the cost of creating a national hydrogen refuelling system may not be prohibitive. Estimates for a German network have been estimated at circa £1 billion. A less optimistic US report estimated that the Federal Government would need to invest $55 billion to put two million hydrogen vehicles on the road by 2023.

Halfway house

The successful introduction of hydrogen could come about via a halfway house in which hydrocarbons are converted as the vehicle travels via a reformer — or fuel processor — into useable hydrogen that generates electricity — hybrids. A fuel cell/electric motor combination is two to three times more efficient than an internal combustion engine, but has a low power-to-weight ratio.

Carbon emissions are still inevitable, though in a better ratio per unit of power produced when compared with internal combustion engines, which can still release nitrous oxides and other pollutants when running on hydrogen. No extensive infrastructure is needed for this route.

In the absence of mass water electrolysis, the next best option could be the steam reforming of natural gas at filling stations — again avoiding the need for a bulk hydrogen delivery infrastructure.

Alternatively, steam reforming of natural gas, oil or coal could also take place at centralised plants for distribution by pipeline, canister, tanker or novel delivery scheme. Again, the energy needed is more than the energy content of the hydrogen produced. And for fuel cells, extremely pure hydrogen is needed.

In addition, reforming is not a zero-emissions solution. Emissions in the range of 150g to 300g of carbon dioxide per mile must be expected. Tests have shown 11.9kg of CO_2 produced for every kg of hydrogen via the steam reforming route. Ideally, in-situ steam reforming coupled with yet-to-be-developed carbon capture and storage (CCS) technology might be sustainable.

Current hydrogen production

Hydrogen is already manufactured extensively for major industrial and agricultural use. Ammonia (NH_3) produced by the Haber process for fertilisers accounts for circa half and is in growing demand.

Most of the remaining half is used for hydrocracking, which converts heavy petroleum into lighter fuel fractions. Rising oil prices are encouraging energy companies to turn to poorer crude sources, such as tar sands and oil shales, and this use of hydrogen is rising even faster, currently some 4 million tonnes annually.

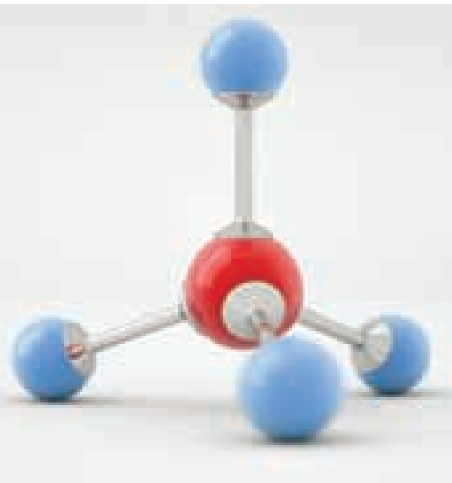
If sustainable sources of hydrogen were possible, one "green" use could be in synthetic hydrocarbon "synfuel" production. It has been estimated that some 40 million tonnes of hydrogen per year would be enough to create liquid fuels from coal that could end US dependence on oil imports.

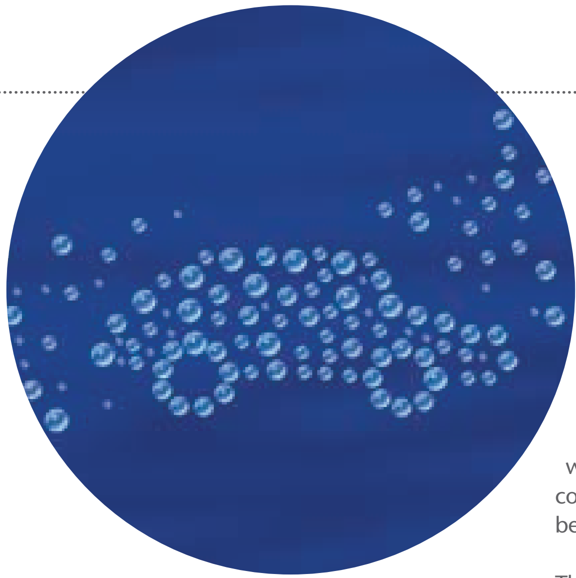
More challenges

But there are still more challenges before hydrogen can be put on the roads.

A key issue is the safe distribution, storage and vending of hydrogen to the public. Tankering petrol around the Britain's roads sounds hazardous but leads to remarkably few lethal accidents. Popping into a gas station for a hydrogen top-up has to be equally uneventful. Remember the Hindenburg?

By weight and volume, hydrogen stores less energy than hydrocarbons and is less docile to store. Liquefied hydrogen only exists under pressure.





Quo Vadis?

The early push and enthusiasm for a universal hydrogen-powered transport system has modified. The urgency the world's energy giants displayed a decade ago, when they were keen to partner technology in anticipation of becoming global hydrogen suppliers, has undergone a major rethink. Practical projects to prove the viability of garage forecourt vending technology, vehicle and engine design, distribution networks and prolonged day-to-day use have provided some answers but also uncovered some problems.

A commercial dilemma is the classic chicken-and-egg scenario. Who is going to invest billions of pounds into setting up a serious network of hydrogen service stations until they can be sure that a fleet of hydrogen-driven cars will follow? Conversely, who is going to invest in producing cars for the road on a commercial scale without a proven hydrogen distribution and vending network in place?

California is a hydrogen pioneer. Closer to home, Unst on the northern tip of Shetland has drawn international attention for its success in turning excess wind into hydrogen via the Pure project. Shetland has wind in abundance. When it blows, the local industrial estate takes power. Once local batteries are also fully charged, spare wind splits water into hydrogen that fuels local vehicles. Scotland takes hydrogen very seriously as part of its strategy to become a renewable energy hub. The Norwegian island of Utsira has similarly demonstrated a hydrogen economy at work.

A fleet of buses have piloted compressed hydrogen as a fuel in the country's capital, Reykjavik, with research that could put hydrogen power into the national fishing fleet.

Microbes to the rescue

If not hydrogen, then what? Ammonia created by bonding hydrogen with atmospheric nitrogen is seen as viable energy carrier that is easier to liquefy, transport and use as a fuel. A theoretical alternative to a hydrogen economy might be a methanol or ethanol economy making liquid fuels from carbon dioxide, including fossil-fuel burning power plants.

Focusing on an "electron economy" — the shortest and most economical way of transferring green energy to consumers — has been proposed as the most efficient way to progress without wasteful energy conversions. This would mean electricity becoming the prime energy carrier.

There is however a substantial ray of hope for hydrogen. Limitless hydrogen could be harvested from self-powering cells fuelled by bacteria, according to US research from Pennsylvania State University. The breakthrough would mean that no external source of electricity is required. Current costs are too high for commercial application. But that is the nature of progress.

The microbial fuel cell (MFC) uses bacteria occurring naturally that release electrons externally to produce electricity as they break down organic matter. Releasing protons that combine with these electrons, the microbial electrolysis cell (MEC) could be the technical advance needed to provide bulk cheap hydrogen. Add fresh water, sea water and dividing membranes in a "reverse electrodialysis" (RED) process, and the small amount of additional power needed to energise the system is intrinsic to the process.

Using alternating stacks of membranes to harvest energy created from the movement of charged atoms from saltwater to freshwater, a small voltage could be created in what would be known as a microbial reverse-electrodialysis electrolysis cell (MREC).

Practical commercialisation could be many years away. But it is a promising start. The research aim now is to produce larger-scale cells. This could end the dilemma of hydrogen being, in the researchers' words, "dogged with high production costs and environmental concerns". The real dream is to treat wastewater — a benefit in itself — and produce hydrogen without any renewable, nuclear or grid energy input.

So, as far as hydrogen is concerned, it might still be possible to have one's cake and eat it. ■

Jon Herbert has been a Director of ISYS International. He is a former communications manager and investment advisor. He has written on environmental issues for many years.