spotlight

The Hydrogen Fuel Cell

What is it?
Have you read about the Arcola Theatre in L&SI? It's aiming to be a carbon neutral venue, and part of that plan involves using a hydrogen fuel cell to provide 5kW of clean power.

Only 5kW?
Yes - but with low energy light sources, some creativity and a positive attitude, you can get by on it. It encourages efficiency all round.

What's so good about fuel cells?
They are very good at generating electricity - about three times as efficient as combustion-based systems. Fuel-to-electricity efficiencies of up to 60% are possible, compared with as little as 20% for a diesel generator, for example. Plus, they are virtually waste-free, they have no moving parts so they are very reliable, and they're quiet.

So this is the latest thing?
Not quite - someone had the idea in 1839, but they were first properly developed for the Apollo moon missions. There are various types, defined by the materials they employ or the fuel they use. The type used by Arcola is small, lightweight and runs at low temperature (around 60-80°C). That means it's the more likely type to be used to run your car, or your home. Another type, the Alkaline fuel cell, was developed by UTC Power for the Apollo programme. An updated version still powers NASA's Space Shuttles today, but they need very pure fuel and are hideously expensive, as you might expect. Other types of fuel cell tend to be large, heavy and hot, so they can't be used just anywhere.

How do they work?
Most fuel cells in use today combine hydrogen with oxygen, producing electricity, heat and water. Hydrogen - the fuel - is channelled into contact with an anode on one side of the fuel cell, while oxygen (drawn from the air) is channelled to a cathode on the other. At the anode, each hydrogen atom is split into a positively-charged ion (the proton) and a negatively-charged electron. A membrane between the two electrodes (called a Proton Exchange Membrane or 'PEM' in the type of fuel cell used by the Arcola) allows only the protons to pass through it to the cathode, while the electrons have to travel instead along a circuit: this creates an electrical current, which can power an electrical load. Once at the cathode, the electrons and protons recombine and join with oxygen to form water - the system's waste product.

Why doesn't the Arcola just get two fuel cells and have 10kW of power to play with?
Cost, unfortunately. The Arcola's fuel cell is supplied and sponsored by the London Hydrogen Partnership, with funding from the government, the Arts Council, Hackney Council and the Mayor of London's 'Greening London Theatre' initiative.

Component costs of fuel cells are high - requiring novel manufacturing techniques and precision engineering. Durability is another factor affecting the overall cost: membranes degrade over time, especially under repeated on/off cycles and temperature changes. The IdaTech ElectraGen system used by Arcola is rated for 10 years by the manufacturer: solar panels tend to be rated for 20 years and still struggle to be cost-effective. However, new technologies are being researched which should allow the membranes to remain stable for longer - high-temperature plastics and nano-technology are providing some promising answers, but there is still some way to go.

Where does the hydrogen come from?
Ah, the big question. The hydrogen is supplied to the Arcola as bottled gas, by BOC. Some fuel cells can use a fuel 'reformer' or processor that extracts hydrogen from hydrocarbons such as natural gas or ethanol - this is how BOC harnesses the hydrogen in the first place, at large-scale hydrogen plants.

So it uses fossil fuels?
Yes, but other technologies are being developed to make renewable hydrogen a reality. You might think of it as a weaning process - it's creating an infrastructure which will eventually enable us to shake off our dependence on fossil fuels.

Hydrogen itself is the biggest problem with the proposed "hydrogen economy": extracting it from fossil fuels has its own implications, not least the creation of carbon dioxide. Carbon capture and storage is therefore a vital area for technological development. The USA, with around 250 years' supply of coal under its feet, considers coal to be an essential future source of hydrogen, so dealing responsibly with the carbon is essential.

Ideally, hydrogen will be generated from water in a renewable manner. Electrolysing water using solar power is one option, currently in use. Photosynthesising hydrogen using blue-green algae is another option, though this is still at the lab stage. It is anticipated that one of these, or several other methods in development, will ultimately provide clean, renewable and affordable hydrogen.

But what about storing and transporting hydrogen - isn't that difficult?
Small amounts of hydrogen can easily, if somewhat expensively, be managed. There remain technical challenges to storing and transporting large amounts of hydrogen, however, and there is lots of work underway on different solutions to this. It is important to recognise that not all fuel cells run on hydrogen, many now run on methanol (you will see them being used in laptops over the next few years) or natural gas - which involve fewer specialist logistics.

So, how much for a fuel cell like the one at the Arcola?
Fuel cells are not yet mass-produced, so the cost is still higher than it could be. The Arcola's fuel cell cost around £12,000 installed (including an outdoor hydrogen storage area), although there are lower priced options available. Hydrogen retails at over £25 per cylinder - and a cylinder should last through one or two full-length shows with a 5kW peak power lighting rig. The Arcola has a special deal with BOC, but even so, it's still many times more expensive than power from the grid - at the moment.

Is hydrogen going to take off then?
It seems that it is taking off, and costs will fall accordingly, while the cost of conventional fossil fuel-derived power will only rise. What's more, efficiencies are improving all the time. There are already buses, boats, fork-lifts and submarines powered by fuel cells - and car manufacturers are taking it up in a big way. Earlier this year, Boeing test-flew a small plane using batteries and fuel cell power, while fuel cells are increasingly used as backup power systems in telecoms and IT applications.
In Japan, 2,200 home-owners already get their power and hot water from fuel cells and the Japanese government plans for 25% of homes to do so by 2020. In New York, the Freedom Tower and other buildings going up on the site of the Twin Towers will be powered by 12 state-of-the-art fuel cells delivering 4.8MW of power - at a cost of $10.6m.

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