By Gerd Winter

Hydrogen: holy grail of energy?

It is not a fruit hanging low! Yet, the tantalising possibilities of hydrogen have kept us reaching out for it ever since it was discovered as a potential energy carrier. How close are we to realising the dream?

In 1839, Sir William Grove used electricity to first split (electrolyse) water in to its components hydrogen and oxygen, to then reverse the process, producing an electric current. The device was simple enough: two separated chambers filled with either oxygen or hydrogen and two platinum strips dipped in diluted sulphuric acid. He called it 'gas voltaic batteries' – what would, some 50 years later, become 'fuel cells'. However, hydrogen as a potential energy carrier was quickly sidelined. Instead it became the century of ready-to-use hydrocarbons: petroleum provided the ideal source of fuel for robust combustion engines. But the times of fruit hanging low may be over.

The hydrogen option has always received considerable attention when its big brother, oil, went scarce. So in the 70s, when a 'hydrogen economy', a term coined by Australian electrochemist John Bockris, seemed just around the corner. The vision was a system in which hydrogen would be used to transport energy from renewable sources over large distances and stored in large amounts.

The hydrogen option has always received considerable attention when its big brother, oil, went scarce.

Now, in 2008, we are still far from it.

Hydrogen has to be manufactured, using a primary energy source. Most of the hydrogen produced today is by heating hydrocarbon and steam in the presence of a metal-catalyst – a process also called steam reforming – which, unless captured, releases CO_2, a less desirable option in an era of climate change. The hoped for alternative would be electricity generated by renewable energy sources, but the process of electrolysis is quite inefficient. There are other considerable hurdles. Hydrogen is a highly flammable, low density gas requiring space and special safety provisions, obvious challenges for storage and efficient transport. It's usage as an economically viable fuel alternative in cars is also uncertain. Governments and multinational corperations have spent billions of dollars on the development of fuel cells, yet they are still struggling to reach market potential. "Fuel cells have been a dream since they were discovered but it is still a very expensive technology," says Dr David Rand, senior research scientist with CSIRO Energy Technology.

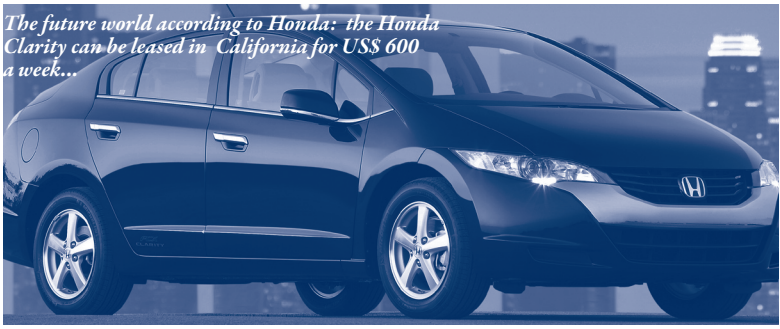
Nevertheless, the advantages of hydrogen as an energy carrier are too compelling to be overlooked: its sources (mostly water or methane) are abundant, and it can be used to power a myriad of applications, from computers and mobile phones to transport vehicles, producing only water and heat as by-products.

No wonder there are diverging views on the issue, which became apparent at the recent 17th World Hydrogen Energy Conference (WHEC2008) in Brisbane.

According to Rand, views ranged from "hydrogen romantics", who see hydrogen as the ultimate solution to energy sustainability problems, to people that point to the pretty formidable technical challenges in the whole chain from hydrogen generation, distribution, storage and utilisation to issues of safety, codes and standards. Rand's own view is that the drivers in terms of energy security, dwindling oil reserves and environmental aspects, such as urban pollution and climate change, demand "that we look at all possible options for transport fuels in the future. Hydrogen is one of those." However, he says that while it is a great idea, it's going to be hard to get there. "Every step will require a breakthrough in science and there is a limit to what can be developed in a short time."

There are significant developments, though, around the world and also in Australia (see also 'Water fuel' p21).

How to store generated energy so that electricity can be supplied 24 h a day is a pressing question plaguing the renewable energy industry. At the end of last year, Melbourne-based Solar Systems, which is also building a $450 million solar power plant in Victoria, announced a $62 million commercialisation program for its base-load solar power technology. At its core is a patented procedure that stores energy generated in sunny conditions as hydrogen, allowing an on-demand power supply in sunless periods. At room temperature the electrolysis of water is quite inefficient but this changes as water is heated to very high temperatures. Solar Systems technology captures sunlight and directs it as concentrated beams onto photovoltaic (PV) solar cells, where the energy is translated into electricity. PV cells can only use the visible part of sunlight. The considerable energy of infrared rays, part of the invisible light spectrum, is usually lost as excess heat. Solar Systems has developed filters that selectively reflect the infrared rays before the beams hit the PV cells. These rays are bundled and the thermal energy fed into a system in which water is electrolysed at around 1000 degrees Celsius. Under these conditions, 100 watts of electricity can yield 140 watts of hydrogen, which compares to only about 60 watts at room temperature. Demonstrated so far only on a small scale, John Lasich, technical director of Solar Systems, believes that once demonstrated on a commercial scale, the system could also provide hydrogen for transport vehicles, with a price tag competitive with petrol.



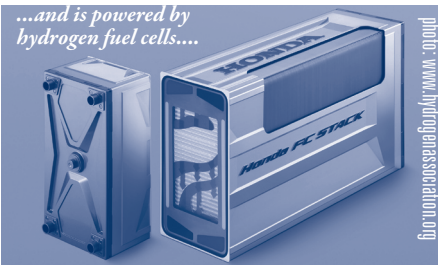
The future world according to Honda: the Honda Clarity can be leased in California for US$ 600 a week...

photo: www.hydrogenassociation.org

These developments are encouraging but address only one, although important link in the chain. Iceland, having an abundance of geothermal energy that can be used to produce hydrogen, had already committed to establishing a hydrogen economy in 1998. Yet a decade later Iceland faces very similar problems to Australia. Dr John Wright, director of the CSIRO Energy Transformed Flagship, says it is a chicken and egg situation. "They are ready to go but they do not have the (hydrogen fuelled) cars at a reasonable price yet. Neither do we in Australia, therefore there is no use for it, so nobody is building the infrastructure. And when there is no infrastructure car manufacturers are not going to make the cars needed." The promises, particularly regarding fuel cells, have not lived up to the hype. Yet there is movement, in Australia with a recent trial in Perth with buses running on fuel cells. And in June Honda released the

world's first fuel cell powered car intended for mass production. The car currently costs several hundred thousand dollars each to produce. Honda is, though, confident that within a decade the price will come down below US$ 100,000 as production increases. Meanwhile the Honda Clarity can be leased in California for US$600 a week. "20 years ago we did not have the gas infrastructure we have now and that shows how quickly this can change," says Wright. There are strong drivers on the horizon that could change the tide: rising oil prices, a price on carbon with the implementation of an emissions trading scheme in 2010 and a renewable energy target of 20% by 2020.

In the lead up to the conference, Wright says, they did some modelling and were positively surprised by the results. The modelling was based on the Honda Clarity leasing option at $600 a week, and assuming a steady price of oil at 130 US$/barrel of oil, a prize of carbon at around 70$ per ton of CO_2 and a national electricity emission intensity going down from about 1 ton of CO_2 per MWh to 150 kg per MWh by 2050. On the basis of these numbers, the CSIRO energy models predict that by 2022-24 Hydrogen fuelled cars will start being imported into Australia and by 2050 having a share of about ¼ of all kms travelled. Hydrogen would account for 8% of transport fuel consumption. This modelling is obviously dependant on highly volatile variables. Oil at US$200 dollars a barrel, not an unlikely scenario, would see fuel cell cars imported into Australia much earlier. "I think it'll come, maybe not as quickly as some people would like but it's all a balance between the competing technologies and what makes economic sense," says John Wright. Australia's role is likely to be that of a technology taker rather than maker, he says. "We are good in some niche areas, but in regard to fuel cells, the amount of work that is going on overseas just overwhelms anything that we can do."



...and is powered by hydrogen fuel cells....

photo: www.hydrogenassociation.org

The speed of the process will depend on market forces but also on the political framework. Last year a report to a Senate inquiry into alternative fuel came to a cautious assessment of Hydrogen as an alternative primary energy carrier. The final report states: "In the committee's view, hydrogen is a fuel that might be considered in the distant future, but is not a useful option to consider in Australia's current or medium term transport fuels mix." And it cites Mr Kevin Black of the Natural Gas Vehicle Group saying: " Everybody seems to be pinning their hopes on hydrogen, which is still, frankly, pie in the sky.... The greatest fear of hydrogen researchers in this country is that governments and the media will hype it up so much that people will have expectations that will never be met."

> "I think it'll come, maybe not as quickly as some people would like but it's all a balance between competing technologies and what makes economic sense," says John Wright.

Dr Gary White, research program manager at the CRC for Advanced Automotive Technology, believes the Committee was well informed. He says that Australia is uniquely positioned in that it "has cleaner fuels (natural gas, LPG) in more abundance than other countries and a lower population to take advantage of it." He says given the challenges associated with hydrogen "we can make some big steps with technology that is just about ready to go and will have much lower disruptive impact on lifestyle and business alike." The announced Toyota Camry hybrid vehicle, a project receiving Federal Government support, is an exciting development but he would also like to see a stronger penetration of LPG into the market. "There is also natural gas, which is likely to emerge in the short term as a viable alternative fuel for conventional engine technology. In the medium term, plug-in electric vehicles accessing greener energy sources represent a good solution for Australia."

Ian Lowe, emeritus professor of science, technology and society at Griffith University and president of the Australian Conservation Foundation, is sceptical about electric cars as a convincing alternative. Looking at the material requirements to equip the existing Australian vehicle fleet with batteries, he believes "the hydrogen fuel cell is the power source of the future." Natural gas and LPG could be a short term solution, with reforming natural gas to hydrogen providing a transition to hydrogen produced from renewable energy sources.

But, he says, we now need to plan a transition towards a Hydrogen economy and face up to the reality of the two main driving forces: peak oil and climate change.

The current debate in Canberra about how to ease the pain inflicted by high petrol prices indicates, he says, that both major parties have not yet accepted the reality: petrol prices will continue to rise, as was predicted 30 years ago. Low says that future oil price hikes are unlikely to be a steady increase. Instead it is likely there will be power struggles rather than equitable sharing of diminishing oil reserves and the possibility of serious interruptions in supply.

> "...the hydrogen fuel cell is the power source of the future," says Ian Lowe.

To prepare the nation will require, above all, political leadership.

In the case of Iceland there are a set of unique circumstances. As an island nation its transport system does not have to compete with anyone else allowing for independent decisions; they have a solid base in science and technology; and they have a relatively small population per unit land area. Australia shares all these characteristics, he says, except it lacks the political leadership to make long-term rational decisions.

He thinks that the Rudd Government, however, may bring about a more proactive stand, instead of leaving the lead to the market, which in terms of its push towards developing hydrogen fuel technology is well ahead of governments. It is not too surprising, he says, that forward looking elements in the oil industry, like Shell and BP, have prototype hydrogen filling stations, he says. "Whatever we are buying, they want to be selling it."

...and can be charged at a Home Refuelling Station producing hydrogen using natural gas (experimentally operating in Torrance, California, since 2003).

photo: www.hydrogenassociation.org