DIY science down on the farm

A group of retired British engineers have set themselves the task of building an environmentally friendly reactor that can circumvent conventional shortcomings in hydrogen production while producing aluminium oxide and heat. *E&T* went to see the project.
By **Ben Heubl**

AT THE GATES of a farm featuring a 'Keep Out' sign, *E&T* is greeted by a smiling cockney man wearing a T-shirt with five colourful test tubes printed on it. Alan Smith, 74, together with a team of other pensioners, runs a self-built hydrogen reactor in a former milking parlour in rural Essex.

Smith claims the little company Ecalox has engineered the world's only zero-carbon aluminium hydroxide reactor. He made it his and his colleagues' objective to establish hydrogen production from waste material both to cut carbon emissions and to help recover the value of aluminium rubbish that is often dumped and under-appreciated within the global energy value chain.

With the current interest in clean energy provision, demand for hydrogen is booming around the world. As hydrogen plays a key role in everything from fuel to fertilisers, it is perceived as a central catalyst for enabling greener energy to flourish, paving the way to a net-zero-carbon economy. Being a highly flexible energy carrier, its supporters argue that hydrogen is a powerful storage medium.

Today's production of industrial hydrogen originates mainly from steam reformation of methane in fossil fuels, primarily from natural gas, although oil and coal are also used. Professor David Book at the University of Birmingham's School of Metallurgy and Materials, explains that this is currently the cheapest way to produce hydrogen. The downside, he says, is the amount of CO_2.

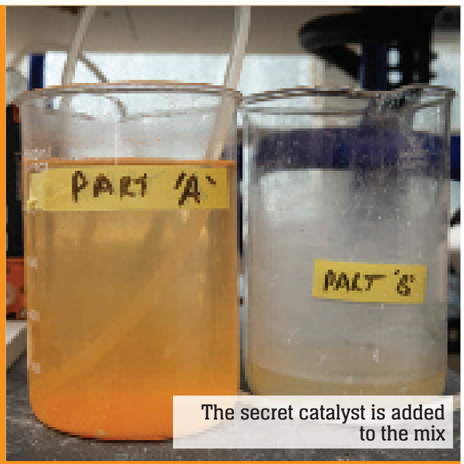
To a lesser extent, hydrogen can also be produced by electrolysis of water, according to the International Energy Agency. But affordability appears out of reach – Smith claims nobody has the price below $4/kg.

Ecalox's goal is to solve the global aluminium-recycling problem. A huge quantity of aluminium still winds up in landfill instead of fulfilling its potential as an ingredient in energy production. "Just because cans are collected, it doesn't mean they are recycled," Smith says. Only 10 or 15 per cent of the material is really being recycled globally, he estimates. In the EU rates are higher, around 60 per cent. But the smelting of the cans comes with inefficiencies, causing further issues.

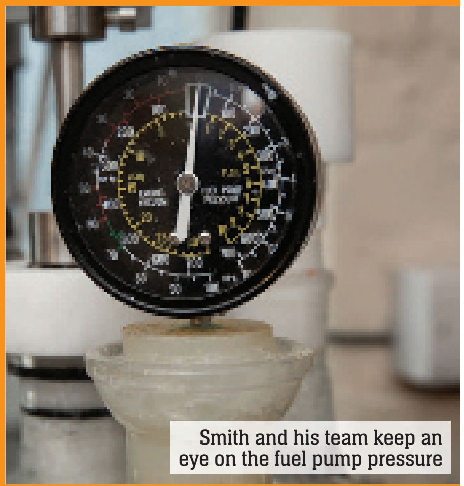
Smelting produces a hard-to-recycle salt cake – the slack from the furnace – consisting of a mixture of aluminium oxides and aluminium nitrides, metal and salts, and salt-cake recycling is not yet feasible.

PHIL ADAMS

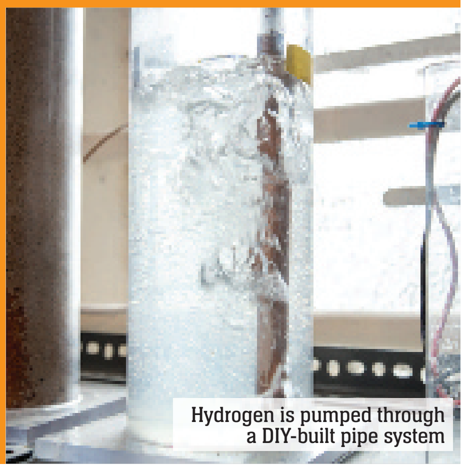
Alan Smith fills the tank of the zero-carbon aluminium hydroxide reactor with aluminium scrap



The secret catalyst is added to the mix



Smith and his team keep an eye on the fuel pump pressure



Hydrogen is pumped through a DIY-built pipe system

Due to the large surface area of shredded cans, a lot of oxides are generated in the smelting process. As recycled drinks cans contain sugar syrup, carbon ends up in the aluminium when recycled, a problem that is also an issue for Smith and his team.

After months of intense research, the engineers found a way for their reactor to deal with the carbon from the sugar syrup as well as with the denatured lacquer. At the end of each reactor cycle, which takes around four hours to complete, the end product is low-pressure hydrogen, which the Ecalox team use to fire up a small generator in the corner of the barn-based laboratory.

The key by-product is aluminium oxide. Decanted from the reactor into a bucket, it is white and odourless but needs some simple pre-treatment to increase its quality. The material looks like baby powder. Smith takes his finger, dips it into the white mass and licks it to demonstrate its harmlessness. But despite its innocuous appearance, this material packs a punch. It is the main raw material for making new aluminium and sells for more than the cost of the low-grade scrap used as the input material.

The aluminium business

While the low-grade aluminium scrap market remains very niche – the material can be hard to obtain and doesn't have a proper market price – aluminium oxide is in great demand in all sort of areas. It has applications in fillers, glass, catalysis, water purification, composite fibre, electrical insulation, body armour and paint – Smith points out three small paintings in a corner of the barn that used his aluminium oxide.

With \$500-\$600 of aluminium scrap, Smith reckons his reactor could squeeze out \$1,500 of aluminium oxide, plus all the energy it produces, he says.

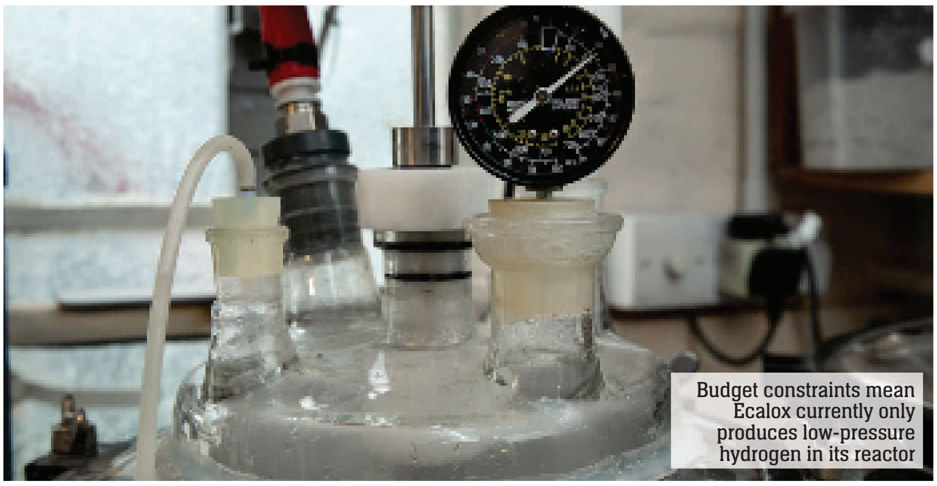
The catalyst for the hydrogen-water reactor is fully recoverable and is said to be an inexpensive material that has been kept a secret until now, though it is certainly traceable in scientific literature, Smith says.

"Because you get the aluminium and you use it to split hydrogen out in the water, you are oxidising it, so basically you burn aluminium in the reactor. Not only is it a very good raw material to make aluminium... in fact that is bauxite, the stuff they rip up tropical rainforests for, to get just that, with a CO_2 penalty of 8-15 tonnes per tonne of that [aluminium oxide]," he explains.

It would also just take 5 per cent of the energy to convert the aluminium oxide back into aluminium compared with the energy required for mining the material. "It is a very virtuous process," Smith says.

For every ton of aluminium-waste fed to the reactor tub, 4MWh of hydrogen energy is acquired from the process, Ecalox claims.

But hydrogen and aluminium oxide are not the only end products: heat is another. So much so that Smith and his team had to deploy cooling systems to lower the >



Budget constraints mean Ecalox currently only produces low-pressure hydrogen in its reactor

< reactor's temperature.

"Because you burn aluminium, you get huge amounts of heat, which is worth another 4MWh per ton," Smith explains.

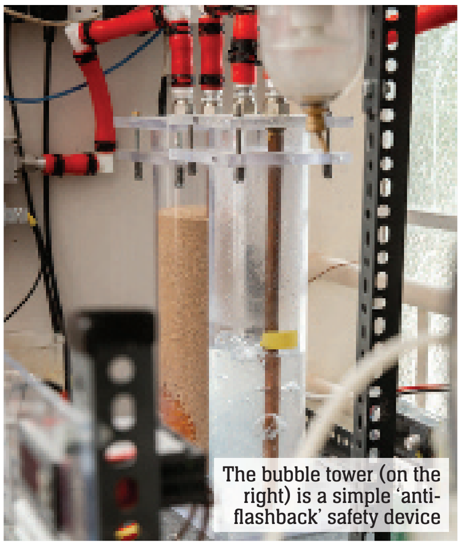
As each ton of recovered aluminium has the same energy content as a ton of gasoline, it seemed ridiculous to the team not to jump on the opportunity.

The idea of obtaining hydrogen from the reaction with water is not new; University of Birmingham's Professor Book says that the process of using water and aluminium is well studied.

Making it work

Having worked out the process to produce hydrogen and its valuable by-products, two problems remain: how to obtain large quantities of scrap aluminium, and the budget for a hydrogen storage facility.

The former would be a significant challenge – the aluminium scrap trade is very niche, Smith says, and volumes traded would be relatively low. "It is hard to get good figures. It is in the EastEnders brown envelope territory," he jokes.



The bubble tower (on the right) is a simple 'anti-flashback' safety device

The Essex milking parlour where the Ecalox team are based

The team used a market analysis by the University of Nottingham, who they are planning to collaborate with, to obtain more precise market figures. Smith adds that the university is also running a doctoral programme in hydrogen production, where he sees advantages for both parties in rolling out a low-cost alternative to carbon-intensive methods.

The first and immediate use case, Smith explains, might be in the context of a beverage packing plant. Can plants for beer and soft drinks produce enough scrap every day for the process to power the entire operation, and they could sell the aluminium hydroxide at a profit. This would make such a factory a zero-carbon operation.

Left: the input – scrap aluminium
Right: the output – aluminium oxide

The team is looking for investment to expand its operation. They have an engineering partner who will help create the first containerised commercial plants; these can be located anywhere, make few infrastructure demands and will produce hydrogen, electricity, heating or cooling.

Smith is banking on only grabbing a small part of the aluminium scrap market, for now at least. This could already be sufficient to help build a sizeable business. "If we only get a tenth of the landfilled post-consumer aluminium waste we would be able to process 50,000 tonnes a year, sell almost 100,000 tonnes of aluminium hydroxide and create a 400,000MW energy business."

In the Essex barn where Smith also built all the furniture, he and his colleagues spent much of the last year looking at the chemistry of the reactor process, tinkering with the science, refining the methods and the end product, while studying the aluminium scrap, hydroxide and oxide markets, he says.

The Ecalox team

Despite, the chemistry being "relatively trivial", Smith concedes, what no-one has done before them is to put together a whole business model and work out the chemistry that allows them to end up with a good-quality product. •