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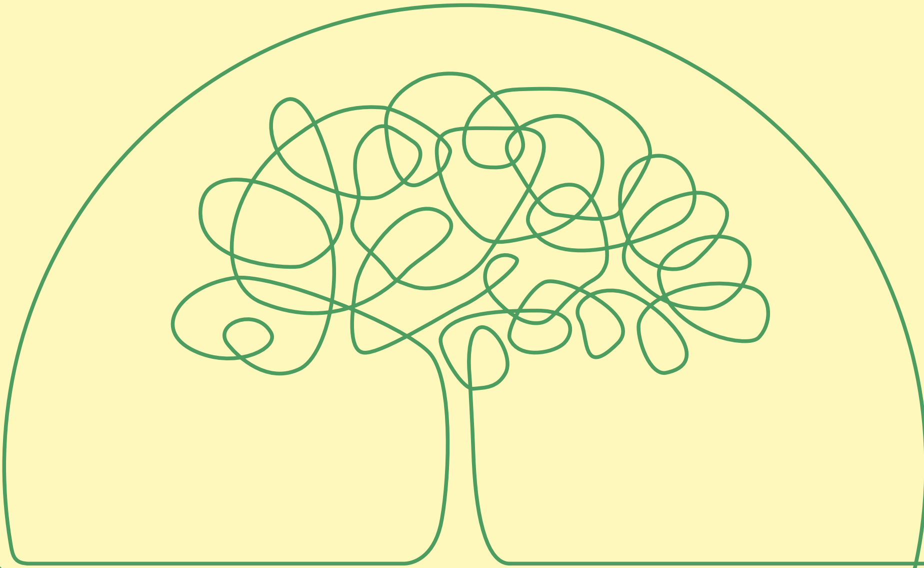

Can artificial trees help us achieve net zero?

Paul Webb
School of Chemistry

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Paul Webb – School of Chemistry
(Article written by Martin Ince)

The issue of intermittency is one of the most well-known challenges facing the transition to renewable energy. It refers to the fact that the wind does not always blow and the sun sets at night.

But Dr Paul Webb, Reader in Chemistry at the University of St Andrews, is among those developing technology that involves making use of surplus power as it arises. For him, this apparent problem is an opportunity. Many research groups around the world are working on batteries and other devices to store electricity, helping match production to demand. Another approach is to store energy in chemical form, a concept often referred to as 'Power to X'.

Asked about this mysterious term, he explains, "X could be anything. We would harness surplus renewable energy to produce an intermediate storage medium X which can be used later."

Hydrogen first

As with other St Andrews work in this area, the key to his approach is hydrogen. The first phase of development uses surplus electricity to break water into hydrogen and oxygen, making what Webb terms "a fuel with no carbon footprint." Hydrogen could be used in power stations not unlike the gas turbine plants of today, or for applications such as vehicle propulsion.
And while hydrogen is a fuel of vast promise, it is also a potential starting point for the important task of greening the world's chemical industry.

This massive industry is a vital part of both modern economies and modern life. It provides the materials for everything from pharmaceuticals and agrichemicals to transportation fuel. The problem is that it demands vast amounts of fossil fuel. According to the International Energy Agency, the chemical industry accounted for 14 per cent of global oil demand in 2018.

We cannot go without the products of the chemical industry, says Webb, and their production relies on a steady supply of carbon. To reduce emissions, the chemical industry must begin to use sources of so-called above ground carbon such as waste or biomass. But as he points out, there simply isn't a supply of biomass sufficient to meet the world's needs and there will always be concerns about responsible land use and food security. If we can mimic what plants do, by converting water and carbon dioxide directly into chemicals, we can circumvent the need to grow crops as a carbon feedstock.

The approach can be summarised as the creation of 'artificial trees'. The term, Webb admits, is a loose one. For one thing, the plant he is developing will not look like any known type of tree. But the name contains a grain of truth. He explains, "A tree harnesses energy from sunlight and uses it to convert water and carbon dioxide into chemical energy in the form of carbohydrates. We want to do the same. The only difference is that a tree uses photosynthesis, a photoelectrochemical process, whereas we use renewable energy to produce an electric current first."

A steady supply of carbon dioxide and hydrogen along with an abundance of green electricity are the essential inputs for manufacturing what Webb calls "platform chemicals," the major building blocks from which other chemicals are derived. This approach has its challenges. And Webb warns that without better technology, it will remain a pricy option. "There are certainly opportunities to improve the efficiency of carbon capture. At the moment, it costs around £8 to £10 to capture a tonne of carbon dioxide from a highly concentrated source such as a fermentation process, but as the levels of carbon dioxide fall, the cost of capture goes up. Capturing carbon dioxide from the flue gas of the University's biomass power plant, for example, will cost around £40 to £60 per tonne. For direct air carbon capture, the costs escalate to well over £300 per tonne using current technology."

The global adoption of a carbon dioxide-based chemicals platform will be dictated both by the ability to generate low-cost hydrogen from water and by a significant reduction in the energy requirements and associated costs of carbon capture. An established hydrogen economy will overcome the first obstacle but the second requires a rethink in carbon capture technology. "Our artificial tree concepts overcome this challenge by using low concentration waste streams of carbon dioxide directly as a carbon source, bypassing the need for costly carbon capture. This also allows us to harness residual heat energy from a flue gas to drive chemical reactions."

Beyond net zero?

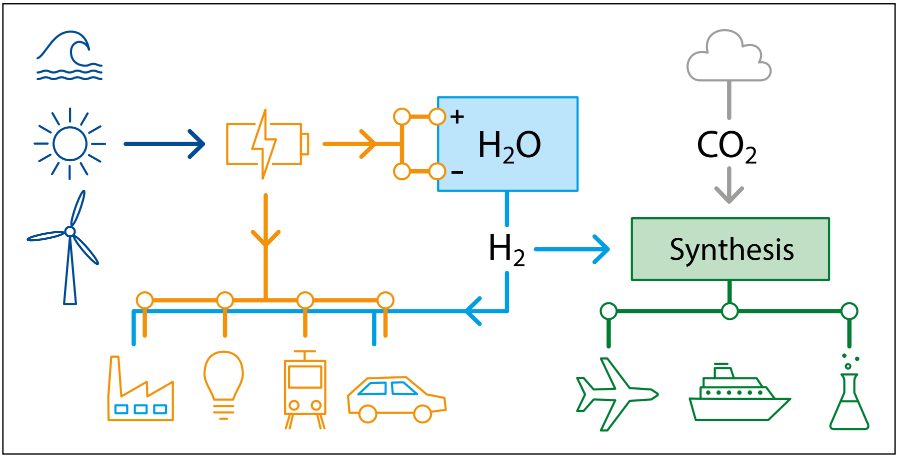
Today's global carbon politics never tires of the term 'net zero', the idea that carbon inputs and outputs must be balanced in order to avoid a catastrophic rise in global temperatures. To do this, pathways to limit global warming to internationally agreed targets will become increasingly reliant on carbon-negative processes that offset the emissions of systems more difficult to decarbonise. This can be achieved by removing carbon from the natural carbon cycle through the capture and utilisation or sequestration of biogenic carbon dioxide. Power to X provides the mechanism for developing the carbon-negative technologies that will be critical to reaching a net zero carbon future.

The application of this technology to the direct capture of carbon dioxide from air opens the possibility of decentralised chemical synthesis opportunities with global reach. When paired with new solutions for sequestering carbon, these technologies can do more than just reduce emissions – they may provide a crucial carbon sink.

Renewing Scotland

Webb is quick to point out that Scotland is the perfect place for the chemical and energy transformation that he has in mind; "there are many new wind farms, and soon the country will generate more energy than it needs." One use for all the surplus power is to export it, but other options might be preferable. Webb notes, "Scotland needs to replace North Sea jobs as oil output declines. Rather than being a net exporter of power, Scotland could utilise this energy and instead export X, high-value chemical products." He adds that this approach is in line with the Scottish Government's ambitious plans to grow the nation's chemical and life sciences sectors.

On a more local basis, he stresses that the St Andrews Eden Campus is the ideal home for this research: "It has lots of renewable energy and biogenic carbon dioxide, from the Eden Mill distillery, and from the University's own biomass power plant. Not many places have both."



Find out more
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