FROM WASTE TO ENERGY

Carbon capture, utilisation and storage (CCUS) is a key technology in the quest for net zero. **Naser Odeh** and **Josh Dalby** tell *RQ* how biochar, a by-product of some biomass pyrolysis, can help improve the quality and sustainability of the food on our plates.

RQ: What exactly is CCUS?

Naser Odeh: CCUS refers to a combination of technologies where carbon dioxide (CO_2) is first removed from the flue gases of power generation and industrial processes or directly from the atmosphere.

It's then either utilised in other processes onsite or compressed and transported by dedicated pipeline, by road or by ship to a location where it can be used in industry (known as carbon capture and utilisation, CCU) or injected for permanent storage in oil and gas fields or geological saline aquifers (carbon capture with permanent storage, CCS).

The various elements of the CCS chain (CO_2 capture, transport and storage) are well-established and have been successfully demonstrated in industry for decades – but individually. For example, CO_2 removal is an essential process in natural gas sweetening and in the chemical sectors for the production of hydrogen and ammonia. Also, CO_2 injection for enhanced oil recovery is a well-established process in the oil and gas industry.

On the utilisation side, CO_2 is used in the food and drink and pharmaceutical industries, for urea manufacturing, in greenhouses and much more. Also, a wide range of emerging applications are being developed – some of which are intended for permanent storage of the carbon, such as concrete curing and aggregates, while others such as synthetic fuels and e-kerosene are aimed at displacing fossil-based fuels.

The combination of CO_2 removal from the atmosphere (known as direct air capture, DAC) or from the biomass process (for example, combustion or gasification) with carbon capture and permanent storage (BECCS) has the potential of achieving negative emissions – which, according to the Climate Change Committee's sixth Carbon Budget, are essential if the UK is to meet net zero by 2050.

Such methods are known as greenhouse gas removal (GGR) technologies, which also include carbon capture via biochar from biomass pyrolysis as well as nature-based methods such as afforestation.

RQ: Why does CCUS offer such great potential in helping to meet net zero?

NO: The pathways to limit global warming to well below 2°C and preferably to 1.5°C compared to pre-industrial levels all include

CCUS. There are hard-to-abate sectors where CCUS provides the only decarbonisation route or the most economically viable solution. CO_2 removal from the atmosphere through DAC combined with permanent storage of the CO_2 is seen as necessary to balance residual greenhouse gas emissions in 2050 from the agricultural and construction industries.

In addition, modelling by the Intergovernmental Panel on Climate Change clearly shows that BECCS is necessary for temperature rise to be limited to 1.5°C. This highlights the important role that CCUS in general and greenhouse gas removal technologies such as DAC and BECCS can play and why demonstration programmes need to be established and accelerated through the 2020s.

RQ: Ricardo is leading a consortium that is designing a community-scale greenhouse gas removal system that produces biochar as one of its outputs. How can projects like this play a significant role in cutting emissions?
NO: Large-scale DAC and BECCS demonstrations are currently in planning in the UK and across the world. There is also a need to start thinking about small-scale decentralised GGR systems. Ricardo is collaborating with Bluebox Energy to make this a reality.

Bluebox Energy has been developing ultra-low carbon combined heat and power (cogeneration) solutions for business parks, communities, industrial and farming processes since 2014. We've been collaborating with Bluebox since June 2020 to develop a GGR cogeneration system which removes carbon dioxide through two different mechanisms, first through capturing almost half of the carbon in the biochar produced from biomass pyrolysis and also capturing the majority of the remaining carbon in the flue gas via a BECCS system.

Both biochar and BECCS are recognised as GGR technologies and so this solution has the potential to deliver significant negative emissions.

Locating such systems in the vicinity of the biofuel, which can either be waste wood resulting from forestry or another sustainable biomass source, significantly reduces life cycle emissions and improves the case for negative emissions.

What's more, the carbon dioxide can be collected from site and distributed for various applications in industry, so the deployment of such community-scale systems provides significant flexibility and eliminates reliance on complex and expensive CO_2 transport and storage infrastructure.

The Ricardo-Bluebox consortium has finalised the design of this biomass pyrolysis-based cogeneration system with funding from the Department for Business, Energy and Industrial Strategy. We are now in the process of securing additional funding to build a system prototype and demonstrate its performance.

"SUSTAINABLE AGRICULTURAL PRODUCTION, SOIL CARBON MANAGEMENT AND CLIMATE CHANGE MITIGATION ARE INEXTRICABLY LINKED" JOSH DALBY, RICARDO

RQ: How does this community-scale GGR system work?
Josh Dalby: The technology uses sustainably sourced waste wood from timber production. Pyrolysis turns this biomass feedstock into biochar and syngas. Recent studies show that the carbon trapped in biochar can potentially stay for hundreds to thousands of years.

The hydrogen-rich syngas is burnt in a combustor, supplying heat to drive the hot air turbine. The turbine generates electricity and large amounts of clean hot air which is used to

TERMS OF ENGAGEMENT

AFFORESTATION: planting new forests across land without trees. As a forest grows, it naturally removes CO_2 from the atmosphere and stores it in its trees.

BECCS: bioenergy with carbon capture and storage, a greenhouse or carbon dioxide removal technology which applies carbon capture technology to biomass-based energy production in order to capture CO_2 and store it.

BIOCHAR: a black, carbon-rich material similar to charcoal made by burning biomass using pyrolysis.

BIOMASS: organic material used as fuel to produce heat or electricity.

PYROLYSIS: a controlled process by which a high temperature is used to decompose organic materials in the absence of oxygen.

SYNGAS: short for 'synthesis gas': a mixture of carbon monoxide, carbon dioxide and hydrogen. A bi-product of the pyrolysis process.

power the advanced CO_2 capture system.

What makes our solution unique is its ability to generate enough energy from its renewable and dependable biomass fuel source to be energy positive and capture so much CO_2. This means that as well as the removal of the CO_2 from the flue gas and its capture and storage as a commercial product, the technology will also supply local homes and businesses with renewable heat and electricity.

RQ: What can the biochar be used for?

JD: There are several existing and emerging applications for biochar. It can be used by farmers, anaerobic digester operators and wastewater treatment sites.

Soils rich in carbon have greater physical and chemical properties for supporting plant growth. Over time, however, as a result of both natural processes and cultivation, these soil carbon pools become depleted. Adding biochar is a way to sustain the soil carbon pools and maintain productivity.

The biochar creates a layer in the soil which acts in a similar way to a domestic charcoal water filter. It holds chemicals and nutrients and prevents them leaching through to deeper levels and watercourses while improving their availability to plants. At the same time it provides an environment for microscopic organisms, bringing further improvements in soil health. This means it is much in demand in organic farming.

More productive soils also lead to greater production of biomass which, in turn, means a greater amount of CO_2 being sequestered from the atmosphere. In this way, sustainable agricultural production, soil carbon management and climate change mitigation are inextricably linked.

As well as improving the fertility of soil, biochar is also used as a supplement to animal feed in livestock farming as it supresses methane emissions generated in the digestive process. This means that in regions such as Europe and North America, where meat consumption is still high, the demand for biochar is likely to continue to increase substantially.

Analysts have predicted that the global biochar market could reach $3.1 billion by 2025 and expand at a compound annual growth rate of around 14 per cent in the next decade.

RQ: You mentioned that the system runs on waste wood. Where is that sourced from?

JD: This is one of the key strengths of our technology. Many existing biomass systems are powered by wood pellets, which require additional processing steps before they are suitable for use. These wood pellets are typically sourced from sustainable forestry operations with most UK distributors sourcing from either within the country or from abroad.

A key factor in ensuring the maximum amount of carbon capture is to minimise the life cycle or upstream emissions associated with the production and delivery of the feedstock. Because our technology can use unprocessed waste wood, it opens up opportunities for local sourcing. As well as sustainable forestry operations, nearby sawmills and furniture factories could provide enough woodchip to be suitable for our system. Community-scale systems such as this can be located near the biomass source, thus reducing life cycle impacts and upstream emissions.

Negative emissions technologies can generate revenue streams for industry and local communities

RQ: When might we see this technology deployed?

JD: We have identified a site for our first demonstrator plant and our ambition is to have it running in mid-2023.

Then, by focusing on smaller community-scale applications, we can deploy quickly and widely. We can operate close to the source of waste, minimising GHG emissions related to the transportation of the raw materials. And each community can benefit from the by-products.

RQ: Could the UK be at the forefront of community-scale carbon capture technology on a global stage?

NO: In terms of GGR technologies, the focus worldwide is currently on deployment on large stationary stations including power plants and industrial sites.

We propose that deployment on community-scale systems also has a key role to play in CO_2 removal from the atmosphere, thus helping achieve net zero targets while also developing the CO_2 and biochar markets and providing communities with heat and electricity.

However, such community-scale systems are still expensive and so support is needed in the early stages to reduce costs, overcome the technical challenges and develop the supply chain. This will help the UK become a leader in a technology that can be exported worldwide, with the significant emission savings making an important contribution to net zero targets.

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To find out more about Ricardo's CCUS work visit: ee.ricardo.com/energy/carbon-capture-utilisation-and-storage