CCS gets some new chemistry

A new process for capturing carbon dioxide is being demonstrated at a pilot project at the Drax power station in the UK.
Junior Isles reports.

According to many industry observers, the world will not be able to achieve its climate ambitions without carbon capture and storage (CCS). Although the electricity sector is making a rapid transition away from fossil fuels, globally, coal and gas will continue to play a significant a role for decades to come. Finding a way of decarbonising existing and future fossil fired fleet is therefore crucial. Cutting carbon emissions in industry is also important and currently there are very limited options when it comes to cutting carbon dioxide emissions.

The International Energy Agency (IEA) states that CCS could reduce global CO_2 emissions by 19 per cent, and that fighting climate change could cost 70 per cent more without CCS.

But in spite of the pressing need for the technology, its commercial uptake has been very slow. A report published in May by the International Association of Oil and Gas Producers (IOGP) noted there are only 18 commercial projects in operation globally today with a total capture capacity of some 40 Mtpa CO_2.

CCS deployment has been predominantly limited by economics – several projects have seen budgeted capital costs spiral, and the technology also imposes an energy penalty on power plants, which makes the business case in power generation challenging.

But this could be set to change as a team of chemists and engineers look to implement a new carbon capture technology at the massive Drax power station in North Yorkshire, UK.

In June, C-Capture, the designer of innovative chemical processes for carbon dioxide removal, working alongside the Drax Group, secured a £5 million grant from the UK government for a two year programme of work to progress their £11 million bioenergy and carbon capture and storage (BECCS) pilot project at Drax.

The funding will be used by Leeds-based C-Capture, a company established in 2009 out of Leeds University's School of Chemistry following investment from IP Group, and Drax's Innovation team to further develop its understanding of how C-Capture's technology could be scaled up.

Explaining the origins of C–Capture and the technology, Professor Chris Rayner, an organic chemist and Founder of the group, said: "About 10 years ago, maybe longer, we started looking at ways where we could selectively get CO_2 to react in the presence of other gases – particularly things like nitrogen and oxygen, which is typically what is in flue gases – and try to develop new chemistry to do that. People have been doing CO_2 separation for many years. The original technology patented in the 1930s used amines. They capture CO_2 very well but they've been around for so long, when we set up C-Capture we thought there must be a better way to do it."

After four or five years of research and development, the company has come up with a process that allows CO_2 to be captured under much milder conditions than has been previously possible.

"The chemistry is much better in terms of performance and environmental profile but still uses very simple chemicals... and for the scale that CCS is done on, it has to be simple and really scalable," said Professor Rayner.

The technology is what Professor Rayner calls a post-combustion, solvent-based capture process.

He explained: "When you generate power, you're usually burning something... The flue gas produced will usually have anything between 5-15 per cent of CO_2, as well as quite a lot of nitrogen and some oxygen. The key thing is to selectively react the CO_2 and leave anything else unreacted."

This is achieved in a two-step process. The first stage has an absorber column, where a shower of the new amine-free solvent comes down the column while the flue gas is blown upwards. When the solvent comes into contact with the flue gas, it selectively reacts with the CO_2, leaving the remaining gases to continue upwards to exit the top of the column free of CO_2.

Solvent with CO_2 attached to it remains at the bottom of the column. This is then pumped into a stripper column that operates at a much higher temperature, around 100-120°C, compared to 20-30°C in the first. At this temperature, the bond between the solvent and the CO_2 breaks and the CO_2 comes out of the stripper column as a pure stream that can be used or sequestered. This stripper column also serves to regenerate the solvent, so that "lean" solvent is ready to capture more CO_2.

"It's a continuous process, where the solvent is pumped around the absorber and stripper, so flue gas goes into one end and a stream of CO_2 comes out of the other," said Professor Rayner.

The key thing in the process is the new class of solvent, which has quite a different reactivity compared to amines. An important aspect of the solvents is their energy requirement – a big drawback with current solvent-based post combustion capture is they require a significant amount of energy to heat up the solvent in order to release the CO_2. This parasitic load reduces the efficiency of the power station.

According to Professor Rayner, the new solvents are less reactive with air than existing amine solvents and therefore oxidise less, resulting in less degradation over time. "We think we have major benefits in terms of solvent lifetime compared with the current best technologies," he noted.

He added that the new solvents are much less corrosive than many of the amines that are currently used. This means cheaper construction materials can be used, which could in turn significantly lower the cost of building plants.

With the economics of CCS being a major stumbling block, the development of the technology comes at a crucial time.

Professor Rayner said: "Pretty much everyone says we need to decarbonise as rapidly as we can. In three of the four scenarios presented by the IPCC, we need CCS to limit warming to 2°C... if the [UK] government is to reach its net zero target by 2050, then CCS is essential. So we need to start doing things now and we need to start doing them on scale.

"Costs are an issue but there have been numerous high-level studies that show that the cost of doing nothing far outweighs the cost of deploying CCS... The costs of these things are always coming down."

"To calculate the cost of capturing a tonne of CO_2 from a very large power station is a very difficult calculation but what I can say, is that the energy penalty of our process is significantly lower when comparing our technology with others that are out there. World-leading amine processes use about 2.5 GJ per tonne of CO_2 captured. Ours is in the region of 1.5-2 GJ/t. The Drax project is trying to understand that number and firm up whether it's nearer to 1.5 or 2. Even if it's 2 GJ, that's still a major improvement compared to all the current technologies."

Since it began capturing carbon dioxide in February, proving the technology works, the team at the Drax pilot has done different upgrades on the solvent and this work will continue.

The recent government grant will help take the pilot project up from about 1 t/day of CO_2 capture to 100 t/day over the next two years. This size will provide much of the chemistry and engineering information needed to design a much larger process.

"We hope that we will have everything we need to design a very large process within a couple of years," said Professor Rayner. To give an idea of the final scale needed, he says Drax would need roughly a 10 000 t/day capture installation on its site.

The Drax pilot will be running for at least another six months before trials are shifted to Norway. Here a chemistry validation and testing programme will be conducted with research partners SINTEF and the CO_2 Technology Centre Mongstad. The pilot scale rigs at Mongstad will enable more accurate measurement of parameters such as energy consumption and emissions. In addition to being larger in scale, the Norway facility will also provide a degree of independent validation.

"As the programme begins to get finalised at Drax we will move things over to Norway, which will probably be some time towards the end of next year," said Professor Rayner. "It will happen when we think we have enough good data to operate the plant in Norway."

The goal is to have a large scale process on the Drax site in the mid 2020s. This would coincide with the government's timeframe of having CO_2 capture clusters and CO_2 transport infrastructure in place.

"There's no point building a big capture plant if you have no way of disposing of the CO_2," noted Professor Rayner. "Over the next 5-10 years, there will be lots of developments where clusters of CO_2 producers will have to come together in different locations to provide hubs, which can then take the CO_2 via pipelines to the North Sea for storage in geological features, mainly depleted oil wells."

With Drax being the UK's largest power plant, and one that has switched from coal to biomass, the world will be watching this next step closely. Notably, as it runs on biomass it will become the world's first negative emissions power station – effectively removing carbon dioxide from the atmosphere while electricity is being produced. This is important in offsetting emissions from other sectors that are very difficult to decarbonise such as aviation.

Professor Rayner summed up: "The Drax project has given us a high profile, which has helped with enquiries from outside. Now, a number of projects are under discussion around world. We also will be deploying the technology in other areas which require large scale CO_2 separation such as industrial emitters like cement, iron and steel, and hydrogen manufacture, and gas upgrading applications, such as purification of natural gas and biogas.

"Working with Caspar Schoolderman, our COO and Director of Engineering and Doug Barnes, Head of Chemistry, we've developed something that is incredibly new and important for the future... seeing something go from a very small scale in a lab up to, say, 10 000 t of CO_2 capture a day, would be awesome. And that really is just getting things started."

Professor Rayner: "we've developed something that is incredibly new and important for the future"