Capturing the **forgotten source of CO2**

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Engineers Sofiane Zalouk and Johan Rey both work on improving the sustainability of industrial boilers. Here they describe how they have developed a carbon capture system designed specifically for intermediate emitters.

To start with, please could you describe the inspiration for this project?

The fast industrial deployment of technologies for carbon capture and storage (CCS) will be necessary if we want to make a significant impact on CO2 emissions at the planetary scale. Nearly all the CCS pilot-scale projects in progress in various countries address the problem of high tonnage emissions, in particular from facilities like thermal power plants, iron and steel plants and cement factories. These rely upon first generation technologies that use amine scrubbing to collect CO2 post-combustion.

The problem of emissions from sectors producing between 25,000 and 100,000 CO2 tonnes per year, which represents a significant proportion of the total tonnage, have yet to be approached at the pilot scale. The project CO2 EnergiCapt aims to fill this gap by developing the first pilot CCS project dedicated to heat production units for district heating, as an initial target.

Why is carbon capture technology going to be so important in the future?

Carbon dioxide capture could play an important role in reducing greenhouse gas emissions. The greenhouse gas making the largest contribution from human activities is carbon dioxide. It is released by burning fossil fuels; for example from combustion and by certain industrial and resource extraction processes. Emissions of CO2 due to fossil fuel combustion are virtually certain to be the dominant influence on the trends in atmospheric CO2 concentration during the 21st century.

Why has no one attempted to solve carbon capture for mid-range emitters before?

The emitters that generate large centralised amounts of CO2 are today the priority, in particular electric power plants. For example, the primary source of greenhouse gas emissions in the United States is electricity production, which was responsible for 31% of greenhouse gas emissions in 2013. Approximately 67% of our electricity comes from burning fossil fuels, mostly coal and natural gas. But solutions also need to be found to address the intermediate emitters, which together account for a substantial amount. These emitters represented 21% of greenhouse gas emissions in 2013.

Have the results from your demonstration project been promising?

The results are actually very promising. Firstly, we reached a CO2 capture efficiency of 85% and this could easily be raised to 90%, because our system features independent gas and solvent streams. Increasing the solvent stream used to capture the CO2 or decreasing the gas stream from the source of emissions is quiet easy and can both drive efficiency up to 90% or more as long as you have enough solvent and a powerful enough pump.

The real technological bottleneck mostly concerns the liquid to gas ratio, the membrane's behaviour when interacting with the flue gas, the membrane's thermal behaviour and the steadiness of the capture. Since the start of the project, many interesting and promising results have been gathered on these topics.

What have been the main technical challenges you have had to overcome while developing the solution?

The main technical challenge was the design of the absorption unit since the feasibility of absorption from real flue gas using a hollow fibre membrane contactor was still unproven at the beginning of the project. Then, the choice of the membrane-solvent pairing and the design and implementation of the pilot were obviously also some of the most critical parts.

What is the next step for the project?

The project will end at the end of the year so there are several next steps intended after that. First, next year we will start a Power-To-Gas project called JUPITER 1000 in France for a period of five years. In this project, Leroux & Lotz Technologies is responsible for building a CCS unit using the EnergiCapt process to collect CO2 and convert it into methane via a methanation reaction.

At the same time, we are very interested in testing our technology on different flue gases like those from coal boilers or biomass boilers, as well as those from different industries like the cement industry or power plants. We are looking for partners to do so, but we are also likely to test our process on our own boilers since we are boiler manufacturer.

The reduced footprint of our membrane technology makes our process very suitable for industries with limited space, for instance oil platforms. We are therefore very interested in applying our process in different area like natural gas extraction, de-acidification and enhanced oil recovery.

Novel approach to CO2 capture slashes footprint and energy costs

Traditional methods of carbon capture are both bulky and energy intensive, which limits its adoption by medium scale emitters. Now Leroux & Lotz Technologies have developed a system that uses a new capture method and improved energy integration to tackle both problems at once.

A PRESSING PROBLEM

There is an overwhelming consensus among scientists that CO2 released due to human activity is directly causing the most rapid increase in global temperatures in history. But despite this stark warning, emission levels continue to rise across the globe.

While carbon-free alternatives exist for power generation, fuelling vehicles and heating our homes, they have yet to reach a point where they are cost competitive with fossil fuels. As a result, convincing politicians and business leaders to abandon the energy source our industrialised society was built on is likely to be a long and bumpy road.

But while eliminating CO2 emissions from fossil fuels may be too ambitious a goal in the medium term, carbon capture and storage (CCS) technologies have in recent years emerged as a potential stop gap. These systems are designed to remove CO2 from the exhaust flue gasses produced by emitters before storing it deep underground.

The oil and gas industry has been using the process to store waste CO2 separated from extracted natural gas for years and there are several pilot projects to remove CO2 from industrial emissions currently under development. These projects are almost exclusively concerned with the largest emitters of CO2 such as fossil fuel power plants, the steel industry and cement factories.

But according to the US Energy Information Administration, intermediate emitters producing between 25,000 and 100,000 tonnes of CO2 per year are responsible for up to 21% of greenhouse gas emissions. This is what prompted French industrial boiler company Leroux & Lotz Technologies (L&LT) to launch their "CO2 EnergiCapt" project in 2011. Funded at 30% by the French National Research Agency (ANR - France) with the remainder coming from L&LT, the scheme is designed to address the need for carbon capture technology tailored to smaller CO2 emitters.

photo credits: Leroux & Lotz Technologies

TAILORING THE SOLUTION

Most current CCS technology is both large and energy hungry. While this is less of a problem for large facilities like power stations, for smaller emitters such as district heating plants or the agri-food industry, these limitations make the use of CCS unfeasible. As a result, R&D research manager Sofiane Zalouk and R&D engineer Johan Rey came up with an entirely novel system that helps to address both problems.

Traditional CCS solutions rely on absorption columns, where solvents that absorb the CO2 are fed in at the top and exhaust gasses are fed in at the bottom. CO2 is removed from the fumes by the solvent, which becomes saturated with CO2 and collects at the bottom, while the treated exhaust now low in CO2 escapes from the top.

These systems have a very large footprint though, so instead Zalouk and Rey decided to use hollow fibre membranes – a form of semi-permeable barrier used to separate gasses and liquids – to create much more compact "contactors". The membranes were fashioned into cylindrical tubes, with the solvent running through the centre of the tube while the exhaust gasses pass over its exterior.

"This brings many advantages," says Rey. "Firstly it decreases the footprint as the contactors offer very high specific surface, which makes the unit a lot smaller than an absorption column. Secondly there is no contact between the flue gas and the solvent, which both decreases pollution of the flue gas and solvent degradation. It also increases the system flexibility as the streams of flue gas and solvent are independent."

In 2013 a demonstrator was set up at a district heating plant in Paris run by CPCU, to test the design on the flue gasses emitted by a 140 MWth gas boiler. The first step in the process involved a flue gas condenser that cooled down the fumes to remove moisture to avoid condensation in the contactor that can reduce capture efficiency, as well as recover condensation energy. After being condensed the gasses then passed to the contactor, which contained a solvent consisting of 70% water and 30% ethanolamine, a chemical commonly used to absorb CO_2. After this the solvent passed to a desorption column where the CO_2 was stripped from the solvent.

PROMISING RESULTS

While the small-scale prototype only treated 0.2% of the gas emitted, tests using a gas analyser showed that the system was capable of a capture efficiency of 90% - comparable to traditional CCS methods. According to Zalouk, the tests also gave the engineers valuable data on the correct ratio of solvent to gas, the membrane's interaction with real flue gas and how the contactors respond to different temperatures.

"The project has also given us invaluable experience in designing and operating the demonstrator, which is very important for us since our trade is to design, integrate and set up," he adds. "By the end of the year, we will also get data on the energy cost of the process and its impact on the plants, and will be able to scale up all our results."

As well as introducing a novel method for capturing CO_2, the engineers also worked on improving the energy integration of the process to address the other major limitation of CCS technology – energy costs. This involves making the most efficient use of all energy sources available in the process or on site.

Rey says the design of energy integration measures is specific for each case and depends on heat sinks available on site. The aim is to build a kind of synergy between the factory and the capture unit while limiting the impact on the existing process, for instance on the boiler's efficiency. But with their demonstrator the engineers were able to use the flue gas condenser to preheat the solvent before the desorption unit, which reduced the energy required to desorb the CO_2. They also used the sites cold water network instead of a refrigeration unit to cool the solvent before the absorption unit, which is operating at low temperature (20-30°C), and to cool at the desorption unit outlet the CO_2 was stripped from the solvent in order to condensate steam and maximize the CO_2 purity until 98%w.

SCALABLE AND VERSATILE

While the project run by L&LT does not address the question of what to do with the CO_2 once it has been captured, the company has since 2015 become involved in a French project called Jupiter 1000, which will combine captured CO_2 and hydrogen from water to create methane gas. L&LT will use its EnergiCapt process to provide the CO_2 required for the process. "Methanation is a very interesting way to use and convert CO_2 since the CH_4 produced is an energy source which can be directly injected in the natural gas network, or easily kept as stock." says Rey. "manifold ways exist for CO_2 from capture technologies, for example: oil recovery, refrigerant, Bio-transformation into fuel.." complements Zalouk.

The demonstrator project finishes at the end of 2015, but the researchers are confident they will be able to find further test beds for their solution. "This technology is mainly modular thanks to the membrane contactor, which mean scaling up or scaling down is very easy," says Zalouk. "The fact that it can be retrofitted is also very important because the technology is then suitable for all the industries and CO_2 emitters we talk about.

"With the high compactness of the technology thanks to the membrane contactors, the ability to retrofit makes the installation and the integration of the unit as simple as possible, without requiring any modifications on the boiler or the process. The capture unit can be considered as a kind of "black box" that can be plugged on to any flue gas outlet as a filter."

Lastly, a special acknowledgement. This work has been supported by French Research National Agency (ANR) through Efficacité énergétique et réduction des émissions de CO_2 dans les systèmes industriels program (project CO_2-EnergiCapt n°ANR-10-EESI-03).

Researcher Profile

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Johan Rey is a process engineer and R&D Engineer in the Industry Business Unit of Leroux & Lotz Technologies. He primarily works on CO_2 capture and conversion by power to gas. In 2011he received his a M.Sc degree in Process and Electrical Engineering at Université Claude Bernard Lyon and in 2013 he received his M.Eng in Process Engineering at UTC – Compiegne whilst undertaking an internship at Leroux & Lotz Technologies.

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FUNDING
Leroux & Lotz Technologies
French National Research Agency (Agence Nationale de la recherché-ANR)