Fighting climate change with membrane-based cement technology

June 12 2015

The cement industry is one of the largest sources worldwide of carbon emissions, accounting for around five per cent of global emissions. New technologies being developed by the Norwegian University of Science and Technology may help substantially lower these emissions.

Membrane-based technology developed at the Norwegian University of Science and Technology (NTNU) is one of four technologies that may be used in a full-scale CO2 capture project – in a cement factory.

Gassnova, Norway's state-funded effort to develop carbon capture and storage (CCS) technologies for commercial use, has identified Norcem's cement plant in Brevik and Yara's ammonia plant in Porsgrunn as the most promising candidates for a full-scale CCS demonstration project in Norway. The decision was submitted to Norway's Ministry of Petroleum and Energy (OED) as part of a pre-feasibility study on 4 May.

"We've shown that membrane technology works, and are hoping it will be included in the next test phase in Brevik," says May-Britt Hägg, a professor in NTNU's Department of Chemical Engineering. "If we succeed here, we'll have a prototype that will be of interest to both power stations and industry," she adds.

Norcem's cement factory in Brevik is the fourth largest point source of emissions in Norway, releasing nearly 800,000 tonnes of CO2 annually. Yara in Porsgrunn is in fifth place, with roughly 560,000 tonnes. A waste incineration plant at Klemetsrud in Oslo may also be considered

for CCS, Gassnova says.

A Combined Heat and Power (CHP) plant at Mongstad, a gas processing facility at Kårstø, and Hammerfest LNG in northern Norway are not being considered for CCS at the moment, according to the OED summary of Gassnova recommendations. The pre-feasibility study has not yet been made publicly available.

The government will review the recommendations and inform Parliament for Norway's 2016 State budget, the OED wrote in a news release. The Ministry also noted that it would be "very difficult" to get a full-scale demonstration plant up and running by 2020.

Carbon capture from cement production

The technologies being tested as part of the project are:

- Amines (Aker Solutions)
- Membranes (NTNU, SINTEF, DNV GL, Air Products)
- Regenerating calcium cycle (Alstom)
- Solid sorbents (Research Triangle Institute, USA)

Norcem is the host and facilitator for the project. The research is funded by CLIMIT (65 per cent) and the partners' own financing (35 per cent).

The carbon captured in the test facilities is being released for the time being. An infrastructure for transporting and storing captured carbon is a prerequisite for Norcem to eventually be able to capture CO2 on a large scale.

If the government follows Gassnova's recommendations, the first full-scale plant for post-combustion CO2 capture in Norway would end up at Norcem in Brevik. In fact, it may well become the world's first cement

plant with CCS. CCS projects that are currently planned for other countries do not now include any cement factories.

The cement industry is one of the largest sources worldwide of carbon emissions, accounting for around five per cent of global emissions. Two thirds of these CO2 emissions are released during the chemical process of burning limestone for cement production and can only be cut by extracting the CO2 from the emissions in one form or another. The international cement industry is following the test runs in Brevik with great interest. The Heidelberg Cement Group and ECRA (European Cement Research Academy) trade organization are partners in the project.

Amine technology is farthest along

Aker Solutions' amine technology is clearly the most mature and proven technology of the four being tested. In a newsletter from the Research Council of Norway's CLIMIT programme earlier this year, Liv Bjerge, the Norcem CO2 Capture Project Manager, said that amine technology is probably the only realistic choice for a full-scale facility to be completed by 2020.

"However, in the longer run, we certainly have several technologies. We are very excited about membrane-based technology," she said.

Membrane technology has clear advantages. The flue gas can be cleaned without the use of amines or other chemicals. It also takes less space than the absorber unit that is used in amine technology.

Norwegian patent

The membrane-based technology has been developed and patented by May-Britt Hägg and her colleagues at NTNU. It consists, roughly

speaking, of a super thin-film polyvinylamine membrane that is placed on a porous support structure, resulting in a composite membrane.

The method of separation is called facilitated transport. Using the amine groups in the polymer structure of the membrane, CO2 is converted to bicarbonate by the water vapour that is also contained in the exhaust gas. The bicarbonate is quickly transported through the membrane, while the other substances in the flue gas are retained.

"So we're using an 'agent', a fixed carrier in the membrane, that helps to convert the gas we want to remove. In simplified terms, this is the same process that occurs in our lungs when we breathe, where an enzyme converts CO2 into bicarbonate," says Hägg.

The membrane has previously been tested in a coal-fired power plant in Portugal, with good results. But the temperature of the flue gas from cement production can be higher, and more variable, than in a coal-fired power plants.

"During the first test phase in Brevik we struggled with the rig. We spent a lot of time on modifying the construction design, and we didn't run the technology continuously over time. But when the temperature control functioned properly, we got good measurements. The membrane withstood the flue gases, and separated them way it was supposed to," says Hägg.

Partnering with Norwegian membrane manufacturer

The technology is now in an application round to participate in the Phase II test programme in Brevik. The membrane consortium for Phase II will consist of NTNU, SINTEF, DNV GL and the international membrane company Air Products. Air Products has a Norwegian branch in Kristiansand that produces nitrogen membrane separators. These are

advanced hollow fibre membranes that separate the nitrogen from the air, with uses that include protecting installations at sea that are vulnerable to explosion.

"This partnership means that we're bringing a professional membrane manufacturer on board, and adding another element of Norwegian industry to our team. Their hollow fibre membrane will be coated with our membrane, so that it will separate out CO2 instead of nitrogen," said Hägg.

The hollow fibre membranes provide a large surface-to-volume ratio, and require less space than amine absorbers. The membranes are made up of modules, which make them easier to adapt to various needs.

Two hollow fibre membranes may soon be tested in a sidestream in Brevik. The testing will last through 2016. Then summaries and reports will be submitted, and Norcem will decide which CCS technology they want to implement.

"It's true that amine technology is currently the only technology mature enough for a 2020 implementation date. But we can also envision combinations and technologies that are more adapted to individual emissions," says Hägg.

New membrane test rig in Trondheim

NTNU and SINTEF are also in the process of building a membrane rig, which is scheduled to be installed in the SINTEF test facility at Tiller in Trondheim this autumn.

"Here the advantage is that we can run different test series in controlled conditions, based on various combinations of gases, and thereby simulate different types of emission sources. We have the opportunity to

demonstrate the technology on alternative emissions sources, and to continually optimize the membrane on two fine rigs. We'll keep on testing until we have documented results. And at some point we hope an industrial actor will be interested in buying or licensing the technology," says Hägg.

Provided by Norwegian University of Science and Technology