Carbon Capture Journal

CCS in the United States

Kemper County IGCC progress

2MW pilot in Kentucky begins construction

NET Power's gas power pilot

Sept / Oct 2014 Issue 41

Siemens compressors gear up for CCS

Mongstad amine testing moving on to second phase

IEA Insights: what next for CCS?

PSE's whole-chain CCS system modelling environment

Next steps for CCS in the UK and international engagement at the UKCCSRC

FLUOR®

Helping our clients reduce greenhouse gas emissions for more than 20 years

PATENTED SOLUTIONS

Econamine FG Plus[SM] is a Fluor proprietary, amine-based technology for large-scale, post-combustion CO_2 capture. This technology provides clients with a cost-effective process for the removal of CO_2 from low-pressure, oxygen-containing flue gas streams.

Proven operating experience in the removal of CO_2 from:

- High oxygen content flue gases (up to 20% by volume) and low CO_2 content flue gases (as low as 3% by volume)
- Gas turbine exhaust gas (pressure-sensitive source, only commercially proven technology to recover CO_2 from gas turbine exhaust)
- Coal flue gas

COST EFFECTIVE

The primary ingredient in the Econamine FG Plus solvent is inexpensive and readily available, worldwide. The process can be customized to fit unique site requirements and operating parameters, maximizing efficiency.

GLOBAL APPLICATIONS

Twenty-seven installations globally. Econamine FG Plus is proven on coal and based flue gases.

To find out more please visit
www.fluor.com/econamine

Carbon Capture Journal

Sept / Oct 2014 Issue 41

Carbon Capture Journal

United House, North Road, London N7 9DP
www.carboncapturejournal.com
Tel +44 (0)207 017 3405
Fax +44 (0)207 251 9179

Editor

Keith Forward
editor@carboncapturejournal.com

Publisher

Karl Jeffery
jeffery@thedigitalship.com

Subscriptions

subs@carboncapturejournal.com

Advertising & Sponsorship

Richard McIntyre
Tel +44 (0)208 150 5296
rmcintyre@onlymedia.co.uk

Carbon Capture Journal is your one stop information source for new technical developments, opinion, regulatory and research activity with carbon capture, transport and storage.

Carbon Capture Journal is delivered on print and pdf version to a total of 6000 people, all of whom have requested to receive it, including employees of power companies, oil and gas companies, government, engineering companies, consultants, educators, students, and suppliers.

Subscriptions: £250 a year for 6 issues. To subscribe, please contact Karl Jeffery on subs@carboncapturejournal.com Alternatively you can subscribe online at www.d-e-j.com/store

Front cover: Mississippi Power's Kemper County energy facility will capture at least 65% of its carbon dioxide emissions for use in enhanced oil recovery projects. The image shows a Siemens CO2 compressor which operates at 150 bar and flow rate of 63,000 m³/h

Carbon capture journal (Print) ISSN 1757-1995
Carbon capture journal (Online) ISSN 1757-2509

Kemper County IGCC project progress

Progress continues at Mississippi Power's Kemper County energy facility with the start of commercial operations of the combined cycle unit.

Mississippi Power's Kemper County energy facility will capture at least 65% of its carbon dioxide emissions for use in enhanced oil recovery projects

Putting the combined cycle unit into operation means it will be available to serve Mississippi Power customers' energy needs during the remaining summer months. Another significant milestone – the first gasifier heat up – is scheduled for later in 2014.

The combined cycle unit was originally synchronized to the grid on Oct. 5, 2013 during testing using natural gas as fuel. Over the past 11 months, critical testing was done on various components. The testing culminated with the combined cycle unit passing all applicable performance and environmental tests and being made available at full output for commercial operation.

During the course of the testing, the Kemper combined cycle unit logged more than 1,200 hours on line generating power for homes and businesses. To date, the Kemper combined cycle unit has generated enough energy to supply 23,000 homes for a year.

The project already reached two major milestones in July with the testing of the combined cycle unit and pressure testing of both gasifiers.

The gasifiers at Kemper are the core of the integrated gasification process, which will be used to convert lignite into synthesis gas. Construction progress continues with the 582-megawatt generating facility is scheduled to begin operation in the second quarter of 2015.

National and international groups visit

Visitors from across the United States and all over the world made their way to the facility to learn more about the carbon capture technology that will be on display when it begins operating later in 2014.

"This technology will capture at least 65 percent of the carbon produced in the gasification process," said Kerry Bowers, president and CEO of Southern Generation Technologies. "Coal will continue to be a major factor in energy production worldwide for decades, and there is a tremendous amount of interest in producing cleaner energy."

A delegation of officials from Shenhua Energy Company in China rang in the New Year by visiting the National Carbon Capture Center in Wilsonville, Ala., and the Kemper County energy facility.

The four-person delegation from Shenhua, accompanied by a group of professors from Princeton University, received an update on the project's status and discussed the company's Transport Integrated Gasification™ technology that will be used at the Kemper plant.

The group then toured the construction site to get a closer look at the gasifier and gas cleanup area.

Mississippi Power CEO Ed Holland addressed the group, saying how proud he was of the accomplishments at Kemper. He added his hope to strike up a partnership with the visitors.

Department of Energy staff and international energy representatives visited the Kemper facility

"We think there is a wonderful opportunity for collaboration between our countries and our companies," Holland said. "We believe this technology will be applicable around the world, and we are thrilled to have you in Kemper County."

In early March, energy experts from around the world gathered in Jackson to discuss the future of carbon capture utilization and storage (CCUS), enhanced oil recovery (EOR) and its growth in the U.S. energy industry.

At Kemper, 65 percent of the carbon dioxide emissions will be captured to be used in EOR.

"I am very excited about the projects we are seeing now like the Kemper facility," said Kenneth Nemeth, executive director of the Southern States Energy Board. "There is more than one revenue stream from a power plant. You can have CO2 as a new business model."

In his opening remarks, Gov. Phil Bryant highlighted Mississippi's commitment to being a leader in the energy sector.

"Today the U.S. produces more oil and gas than any other nation in the world and energy jobs are some of the highest paying jobs in Mississippi," Bryant said. "It is amazing the success we are having with enhanced oil recovery in Mississippi."

Following the conference in Jackson, several attendees, including members of the Navajo Nation, travelled to Kemper County for a tour of the plant and mine.

"We have more than 90 billion tons of coal reserves across the Navajo Nation, so we are looking at our options," said Johnny Naize, speaker of the Navajo Nation Council. "What we saw today was simply awesome. The construction, the amount of employment and the benefits to this county and the state will provide a bright future for Mississippi."

Bowers added that he experienced firsthand what this project is doing globally for Mississippi's reputation.

"From China to Indonesia to Europe, there's still a big interest in using coal," Bowers said.

Gasification and TRIG™

The Kemper County energy facility is an electric power plant using an integrated gasification combined cycle (IGCC) design called TRIG™ technology.

TRIG™ was developed over the last two decades at the Power Systems Development Facility (PSDF) in Wilsonville, Alabama - a research facility for the Department of Energy and Southern Company.

A unique feature of the TRIG™ technology is the high-efficiency design that sends lignite not converted to gas in the initial process back for a second round of gasification. This allows a high rate of lignite-to-gas conversion to take place at a lower temperature — and thus lower cost — than what's possible with other available gasification technologies.

TRIG™ produces gas that can be used to generate electricity while making it easier to remove emissions, such as carbon dioxide, that otherwise would end up in the atmosphere.

• TRIG™ is a superior coal-gasification method with low impacts to our environment.

• TRIG™ technology can utilize lignite, which accounts for more than half of the world's vast coal reserves. It offers a simpler and more robust method than most existing coal-gasification technologies.

• TRIG™ technology also produces more power and offers lower capital cost as well as lower operation and maintenance cost than what is possible with other available gasification technologies.

• With TRIG™ technology, the Kemper plant will turn Mississippi lignite into a clean gas while reducing emissions of sulfur dioxide, nitrogen oxides, carbon dioxide and mercury. The TRIG™ technology will reduce carbon dioxide emissions by at least 65 percent - with resulting carbon dioxide emissions equivalent to a similarly sized natural gas combined cycle power plant.

More information

www.mississippipower.com

Kentucky pilot begins construction

A two megawatt thermal post-combustion carbon dioxide capture pilot system, scheduled to begin testing at the end of 2014, is being built at Kentucky Utilities Company's E.W. Brown Generating Station near Harrodsburg.

The pilot system will serve to demonstrate improvements in the integration of carbon capture technology at an existing power plant, produce key discoveries with the goal of developing a safer, more efficient process, and test the feasibility of ideas and technologies for the integration of commercial-scale carbon capture systems.

The $19.5 million project with the University of Kentucky Center for Applied Energy Research (CAER) is made possible through a $14.5 million competitive financial assistance award from the U.S. Department of Energy's National Energy Technology Laboratory and cost-share funding from the University of Kentucky (UK), the Kentucky Department of Energy Development and Independence, the Carbon Management Research Group (CMRG) utility members, and project team members including the Electric Power Research Institute and Mitsubishi Hitachi Power Systems America.

The CMRG, comprised of government agencies, electric utilities and research organizations, seeks cost-effective technologies to reduce and manage carbon dioxide emissions from coal-fired power plants. Current utility members include LG&E and KU Energy, Duke Energy and Kentucky Power.

Construction of the two megawatt thermal post-combustion carbon dioxide capture pilot system is expected to be complete by the end of 2014, shortly followed by the testing period. Key discoveries will be determined after testing is finished in mid-2016.

"This project is the next phase in a partnership between LG&E and KU and the University of Kentucky that began back in 2006, when our company committed $1.5 million to CAER for research into the reduction of greenhouse gases," said Victor Staffieri, LG&E and KU Energy Chairman, CEO and President.

"In 2006, there were no regulations on carbon emissions, but we recognized the importance of this research for our company and our Commonwealth. That's why we continue to invest in these types of projects, which explore ways to make a difference for both our industry and future generations."

"This project reinforces coal as part of the President's "All of the Above" strategy, and underscores the viability of coal as part of America's low-carbon economy," said Julio Friedmann, Deputy Assistant Secretary for Clean Coal and Carbon Management at the U.S. Department of Energy.

Gov. Steve Beshear (fifth from right) cut the ribbon to begin construction of Kentucky's first megawatt-scale carbon capture pilot unit. Also pictured, (extreme left) Dr. Kunlei Liu, CAER Director of Research; (to right of Governor) UK President Eli Capilouto and (extreme right) Dr. Rodney Andrews, CAER Director.

How it works

The system will operate by using a few sampling ports to redirect a portion of the flue gas just before the gas enters the stack. From the sampling port, the flue gas will move into modules where its interaction with a liquid solvent will extract CO2 from the flue gas. The resulting flue gas, now carrying less than 2 percent CO2, exits the absorber and returns to the stack.

The liquid solvent carrying the removed CO2 is put through a two-stage process that boils off the carbon to produce a concentrated stream of CO2. The solvent is recycled to the absorber to process more flue gas. In commercial applications, the concentrated CO2 stream would then be compressed and piped for utilization or storage. In this "catch and release" research project, however, UK will perform detailed analyses of each process, then reintroduce the concentrated CO2 stream into the flue gas.

The system will consist of six modules connected side by side on a 2-by-3-foot grid. Each module measures about 160 square feet across and stands between 55 to 75 feet high

Background

In 2006, LG&E and KU Energy committed $1.5 million over three years to CAER to support carbon management research – including technologies to separate, capture and store carbon dioxide emitted by coal-fired power plants. In 2008, building on research initiated by LG&E and KU Energy's support, CAER created a consortium with government agencies, electric utilities and their research organizations to seek cost-effective technologies to reduce and manage carbon dioxide emissions from coal-fired power plants.

The consortium, now known as the Carbon Management Research Group, splits the cost of research of large-scale carbon dioxide capture systems, which often has shown to be too expensive and high-risk for a single utility or government agency to undertake. Each of the CMRG's previously mentioned partners contributes $200,000 a year. The Kentucky Department of Energy Development and Independence also contributes funding in the form of a one-to-one match up to $1 million annually, as approved by the Kentucky General Assembly in the biannual budget.

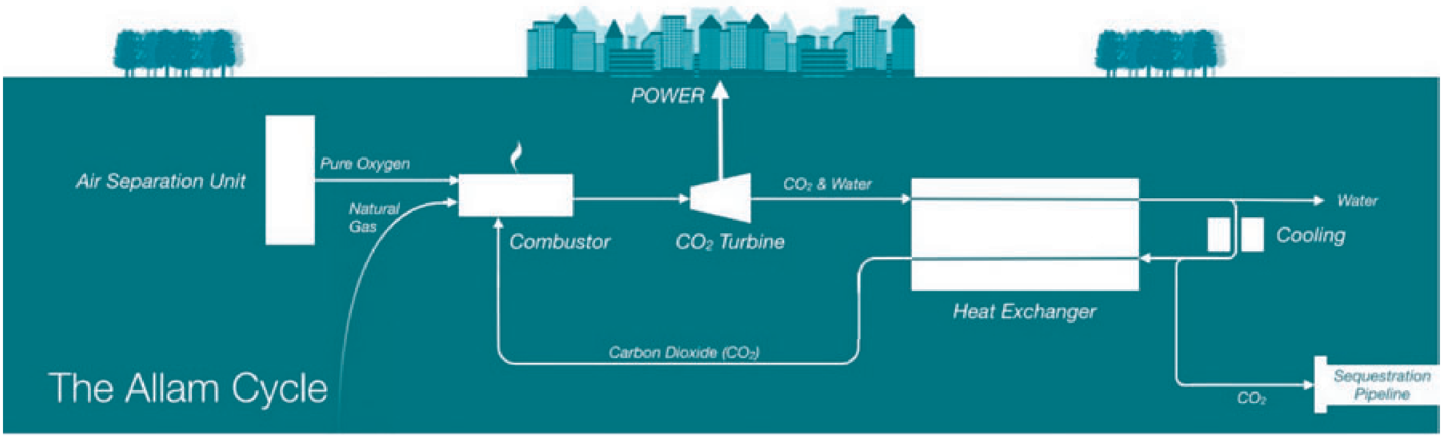
More information

www.caer.uky.edu

Efficient gas power with CO2 capture

NET Power LLC, a company based in Durham, North Carolina, is developing the best thing a carbon capture enthusiast can hope for – a way of burning gas to make electricity with just CO2 and water as the output – which is cheaper than a standard gas power plant.

By Karl Jeffery, features writer



In the Allam Cycle CO2 is used as the working fluid rather than steam

It sounds too good to be true, but apart from the fact that the first demonstration plant is still being developed, there aren't any obvious flaws in the plan.

The estimated overall efficiency is 59 per cent, including the energy required to run a pump, air separation unit and compressor, burning gas with an output of high pressure CO2, water and electricity.

The flows are completely different to a standard gas power plant, in that it uses CO2, rather than steam, as the working fluid.

In a standard thermal power station, the heat generated by burning gas is used to convert water into steam, and the steam is pushed through a turbine which generates the electricity. So steam is called the 'working fluid'. After going through the turbine, the steam is then condensed back to water in a cooling tower and goes around the process again.

In the NET Power Allam cycle, high pressure carbon dioxide is used as the working fluid, to turn the turbine and generate electricity. The input to the combustor is about 95 per cent carbon dioxide at 300 bar pressure and 750 degrees C, mixed with gas and pure oxygen (from an air separation unit). The output from the combustor is high pressure CO2 and water, now at 1150 degrees.

The output gases are then fed through a turbine, which generates the electricity. The output from the turbine is at 30 bar. After going through a turbine, the gas mixture goes through a heat exchanger, which cools the gases down to the point where water condenses out (and can be separated) but keeping the pressure high. The other side of the heat exchanger is to heat up the gases going back into the combustor.

Downstream of the heat exchanger, water is separated out in a mist separator, leaving a high-purity CO2 stream.

The pressure is now about 30 bar. The pressure needs to be increased, both for the majority of the CO2 to be recycled back to the turbine (entering at 300 bar) and to send a portion of the CO2 into a pipeline for underground storage. The CO2 is compressed to about 80 bar, and then it is further cooled until it is nearly in liquid form. This is done because it requires less energy to raise the pressure of a liquid (using a pump) than raise the pressure of a gas (using a compressor).

Altogether, NET power believes that the operational costs are lower (ie the operating efficiency is equal to or higher than a standard gas power plant) because CO2 is a more efficient working fluid than steam, because it doesn't go through the same phase changes as water. This is true even when the energy demand of the air separation unit (to create oxygen inlet stream) is taken into consideration.

The capital costs might also be lower than a combined cycle plant, because everything is at high pressure, the components do not need to be so large, and the construction is simpler, in that the entire steam portion of a typical gas plant has been removed (there is only one turbine in the system). It can be similar in capital cost to a single cycle gas turbine.

There is very little heat or energy loss in the system, and carbon capture is an inherent part of the process.

Impurities

If there is sulphur or nitrogen in the natural gas, this will be output in the water (for example as nitric acid or sulphuric acid) or, in trace quantities, in the CO2 stream. But NET Power believes that for standard natural gas, the amounts will be negligible.

"A single day of average car driving produces more NOx than a NET power plant does in an entire year if it vented its entire CO2 stream," says Walker Dimmig, Principal with 8 Rivers Capital, a company behind the project.

By using CO_2 as the working fluid, "it enables you to consider the end game of carbon capture from the beginning of the system," says Walker Dimmig. "We consider the 'problem' of CO_2 as part of the solution."

"We are enabling carbon capture to be an economic choice over existing, emitting power generation methods without requiring incentives. It looks like this will be a simple economic decision."

Development

NET Power plans to build a 50mWt demonstration plant burning natural gas. The 'FEED' design has already been finalised.

Toshiba, a partner in the project, has already developed the combustor (on a smaller scale than required for a 50mW demonstration plant) which was operated for 7 months during 2013 at high pressures. The turbine is in the design stages.

In November 2012 NET Power received a grant of £4.9m from the UK Department of Energy and Climate Change to fund research and development and manufacturing of high performance materials, as part of the UK government's £20m CCS innovation competition. Some of the grant was spent on developing turbine casings from advanced materials, by Goodwin Steel Castings.

About NET Power

NET Power is now being developed by 4 different companies.

The inventor and core developer is 8 Rivers Capital, a technology development company founded by Bill Brown and Dr Miles Palmer, who describe themselves as "two friends from MIT". Dr Palmer previously worked as a lead scientist in US technology and defence company SAIC, working on rocket propulsion, biofuels and lasers. He has a Phd in chemistry. He also spent time in the US Air Force and nearly became a NASA astronaut. He left SAIC because he wanted to develop a cleaner way to burn coal, and was interested in high pressure combustion, without using steam.

He met Rodney Allam, a Brit who had worked as head of technology development with US gas and chemicals company Air Products and Chemicals Inc. He had some ideas of ways to use CO_2 as a working fluid in power cycles, which fit together with Dr Palmer's work. The developers decided to name their process the 'Allam Cycle'.

Also involved in NET Power is Chicago Bridge and Iron (CB&I), a multinational engineering company which acquired Shaw Group in February 2013. Before the acquisition, Shaw Group had committed $50.4m of cash and in-kind services to invest in NET Power's future demonstration plant.

Developing the combustor and turbine is Toshiba, the Japanese engineering and electronics conglomerate.

Also involved is Exelon Corporation, one of the largest power companies in the US.

More information

www.netpower.com

More research needed says University of Wyoming paper

Federal efforts to reduce greenhouse gas emissions must involve increased investment in research and development of carbon capture and storage technologies, according to a paper published by the University of Wyoming's School of Energy Resources (SER) Institute for Carbon Management.

Proposed regulations from the Environmental Protection Agency aimed at restricting emissions from fossil-fueled power plants actually discourage the development of the essential and internationally needed technologies to achieve large global reductions in greenhouse gas emissions, through capture and storage of carbon dioxide from power plants and other large stationary sources of CO2, writes SER consultant L.D. Carter.

The paper notes that reports from the Intergovernmental Panel on Climate Change have concluded that strategies to achieve large global reductions in greenhouse gas emissions are only practical with effective and affordable carbon capture and storage technologies. But such technologies are not ready for commercial application at coal-fired power plants, and a move to natural gas power generation wouldn't generate sufficient CO2 emissions reductions.

A more effective approach to reducing greenhouse gas emissions would be to ramp up federal spending on carbon capture research and development, Carter argues. The paper suggests several ways to generate revenue for such research.

There also should be an aggressive effort to use existing, cost-effective technologies to reduce the release of two non-CO2 pollutants projected to significantly heat the atmosphere - black carbon and methane - the paper suggests.

History indicates that it will take at least five to 10 more years for the EPA's new standards for emissions from new and existing power plants to be finalized and litigated, Carter says.

"The five to 10 years of legal uncertainty will surely inhibit investment in the development of technological solutions," he writes. "Neither the American economy, those people genuinely concerned about climate change or the energy industry can risk waiting five to 10 years before developing needed technologies.

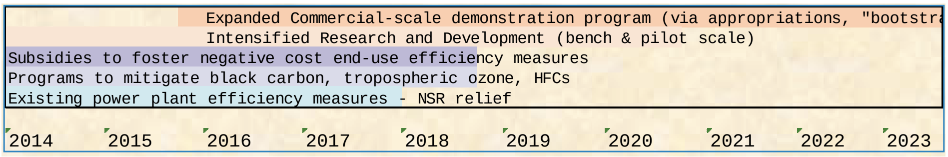


Figure 1 - Technology-driven measures

In particular, America cannot wait if reasonable commercial (carbon capture and storage) technology is to be available for deployment in the next decade."

The paper offers a menu of alternatives to address the larger issue of climate change and the narrower issue of CCS technology development. These options, expanded in the Introduction and further detailed in the overall paper, include the following:

- Near-term measures for inexpensive reduction of GHGs. These include reduction of non-CO2 GHGs like black carbon and tropospheric ozone to reduce global warming in 2050 by half, while reducing global premature mortality from indoor air pollution by millions of lives per year; cost-saving end use efficiency measures; and cost-saving power plant efficiency measures.144

- Substantial increases in federal funds for RD&D for CCS technology.

- Creative approaches to raising funds needed accelerate and expand CCS technology RD&D.

A general depiction of how these programs might be applied over time is shown above.

Conclusions

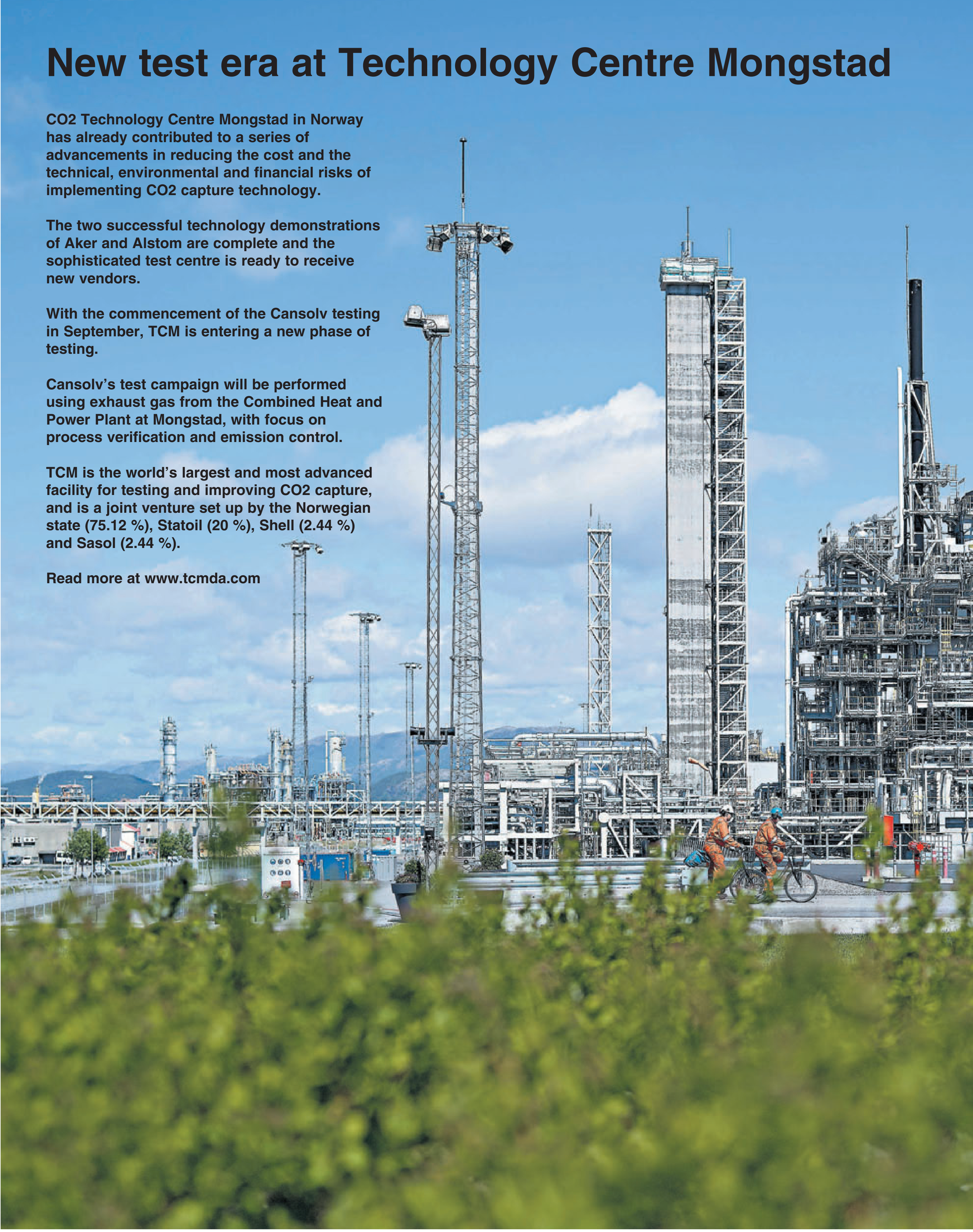
It is broadly believed that large reductions in anthropogenic GHG emissions are needed to achieve posited GHG concentration goals and cannot be achieved without viable CCS technologies. Current CCS technologies are not commercially up to the challenge. EPA has pursued a regulatory path to force the use of current technology, or sharply reduce coal use in the U.S. There is a reasonable likelihood that this strategy will be rejected by the courts as inconsistent with legal authority under the CAA. In any case, equipment vendors and others have concluded that these rules will discourage, not encourage CCS technology development. So regardless of the U.S. outcome, without U.S. leadership in CCS technology development the global outcome of this regulatory approach is inconsistent with achieving climate goals.

There are potentially attractive alternatives to the EPA regulatory approach. These include near-term emission reduction opportunities on non-CO2 GHGs that could provide almost immediate reductions in temperature increases – something that CO2 cuts cannot accomplish – and "negative" cost options to increase power plant efficiency and to reduce electricity use. Other options are oriented around approaches to foster faster development of CCS technology, and include a range of approaches to develop the needed funds for the public sector's share of these CCS development costs.

More information

Carl Bauer, interim director of UW's Institute for Carbon Management, was the contributing editor to Carter's paper, "Meeting Global Carbon Reduction Goals: A Technology Driven Climate Paradigm." The paper is available online at:

www.uwyo.edu/ser



GASSNOVA Statoil sasol

TECHNOLOGY CENTRE MONGSTAD

www.tcmda.com

Siemens compressors are gearing up for CCS

Integrally geared compressors are moving towards the high pressure and high flow rates that are necessary for CCS.

Although carbon capture and storage (CCS) is seen as an essential technology in tackling CO2 emissions from power plants and industrial plants, its commercial deployment has been slowed by its high capital costs and the energy penalty associated with capturing and compressing the CO2.

Yet in spite of slower than anticipated progress, CCS is still an important future market for compressor manufacturers.

In the US, recent proposals to set new limits for CO2 emissions from power plant could be a big driver. In June, the Environmental Protection Agency set varying limits for 49 states for the maximum weight of CO2 they can emit per megawatt-hour of electricity. These limits would have to be achieved by 2030.

If the proposal goes ahead, it is likely to have a tremendous impact on the CCS industry. Siemens is therefore continuing to invest in research and development for compressors suitable for the CCS market and other CO2 applications.

Steady progress

Due to the more favourable economic case, the first applications for CO2 compression are likely to be for enhanced oil recovery (EOR) as opposed to CCS in power plants.

In any event, the CCS market will call for compressors capable of compressing CO2 to a pressure of 160-200 bar [abs] with low energy consumption. If the gas has to be transported via pipeline (e.g. CO2 captured from a power plant and piped to a storage location), pressures of up to 300 bar are required.

Over the last few decades, compressors development has been steadily progressing towards achieving higher flows and pressures.

Siemens has more than 30 references in operation worldwide for compressors in CO2 applications. These compressors are currently handling flows (the suction flow of CO2 at the first stage) ranging from about 12,000 m3/h up to just over 83 000 m^3/h.

The Siemens compressor at Mississippi Power's Kemper County IGCC project operates at 150 bar and flow of 63,000 m^3/h

Pressure ranges from 1.8 bar up to nearly 157 bar – the highest pressure in CO2 gear-type compressor currently in operation. This compressor, with a flow of 63,500 m^3/h, is installed at the Department of Energy funded Port Arthur carbon capture project in the USA. The compressor has been in operation since 2012 and supplies a high pressure CO2 pipeline for EOR. A similar compressor operating at 150 bar and flow of 63,000 m^3/h will start operation at the Kemper County IGCC plant in the Mississippi. Here the two compressors transport the CO2 via a pipeline to the Gulf Coast for injection into offshore oil wells in the Gulf of Mexico for EOR.

Integrally geared compressors

Notably, most of Siemens' references for CO2 applications are for integrally geared compressors.

Basically, there are two types of compressors that can be used for CO2 compression – single shaft compressors such as Siemens' barrel-type compressor series STC-SV and integrally geared compressors such as Siemens' STC-GV. Integrally geared compressors were first introduced in 1948 by Demag, which was ultimately acquired by Siemens.

These geared compressors typically have 2, 3 or 4 pinions operating at different speeds around a single bull gear. By contrast, a single shaft compressor features a single shaft that carries all the impellers.

Integrally geared compressors can compress process gases to 200 bar. For higher pressures, an STC-SV and STC-GV would have to be used in tandem.

A major advantage of integrally geared compressors is that they have a much higher efficiency than single shaft machines. Thermodynamic principles dictate that more energy is required to compress a warm or hot gas compared to a cold gas. The higher efficiency of geared compressors is due to the ability to have re-cooling after each impeller.

The energy penalty between the two types of compressors for the same compression task is significant. For example two single shaft, 12-stage compressors featuring three coolers would be needed to compress gas to 160 bar at a flow rate of 110,000 kg/h. These would consume 13.1 MW of power. The same compression could be performed with an 8-stage, single casing gear-type compressor featuring 5 coolers. Here the power consumption would be 11.7 MW – an 11 per cent reduction.

Optimising components

As lowering the energy penalty of the CCS process is a key part of improving the economics of CCS, Siemens is concentrating its efforts on further developing the compression capability of its integrally geared compressors.

Although gas compression is a mature technology, compressing CO2 presents specific challenges. Carbon dioxide has a supercritical point of 74 bar. As the density of supercritical CO2 is more similar to that of a liquid than a gas, when it is at a pressure of between 74 and 160 bar it is difficult to distinguish whether it is a gas or a liquid. A compressor is used to compress a gas whereas a pump is used to compress a liquid. Operators therefore have to be careful of how they operate a CO2 compressor, as it is a compressor and not a pump.

Further, compared to other gases, CO2 has a high mole weight of 44 and strong real gas behaviour. This means there is a high increase in density per stage and consequently a strong decrease in volume flow. This calls for high power per impeller and a sharp reduction of impeller diameter for each following stage. For example, the first compressor stages of a unit for compressing CO2 up to 200 bar will have an impeller outlet diameter in the range of 1.2 m while the last impeller would have an outlet diameter of around 200 mm.

Siemens delivered compressors with a volume flow rate of 83,000 m^3/h for a coal liquefaction plant in Yinchuan, Ningxia Province, in the northwestern part of China for Shenhua Ningxia

Siemens' STC-GV family for CO2 compression can handle a flow range of 10,000-270,000 m^3/h. However, some compressor flow path components, i.e. the components in direct contact with the fluid, have been optimised for flow in the range 20,000 – 140,000 m^3/h. Conventional impellers are not well suited for compression at low range, therefore very small impellers – about 100-110 mm – are used in the low flow range.

Siemens offers two gearbox designs for these tailor-made integrally geared compressors; the selection is based on rotor dynamics and customer process requirement.

In the first design, an 8-stage compressor would have four volutes on each side of the compressor, located around a central coupling. A volute is essentially a casing located downstream of the impeller to collect the flow and guide it into a discharge nozzle and into the cooler.

The second design as it is an identical 8 stage gear type compressor but having two pinion shafts located on the upper casing split line. This arrangement can be beneficially in terms of necessary piping line run and service friendliness.

Each STC-GV comes as a packaged units consisting of 8 stages, 6 intercoolers, one aftercooler and either an electric main driver or a steam turbine drive on a frame of concrete base.

Getting bigger

Siemens' latest order will set a new benchmark for CO2 compressors. In 2009, Siemens delivered CO2 compressors with a volume flow rate of 83,000 m^3/h and five coal gasifiers, each with a thermal power rating of 500 MW, for a coal liquefaction plant in Yinchuan, Ningxia Province, which lies in the northwestern part of the People's Republic of China. The end customer is Shenhua Ningxia Coal Industry Group Co. Ltd. (SNCG), a subsidiary of the Shenhua Group, the largest coal producer in China.

In April this year China's Shenhua Ningmei Coal Group placed a follow-up order with Siemens Energy for four identical CO2 compressor trains for the coal liquefaction plant. The plant has a capacity of four million TPA (tons per annum) of liquefied coal. The CO2 compressors that Siemens will deliver to this plant are the largest ever built.

The four compressor trains each consist of one STC-GV integrally geared compressor, each of which is driven by an SST-600 condensing steam turbine via an intermediate gear. The scope of supply also includes the associated auxiliary systems. The compressors, each of which has six stages, are designed for a CO2 volume flow rate of approximately 141, 000 m^3/h, allowing these new units to compress nearly twice the volume of CO2 as the previous model.

In addition, Siemens also supplied gasification technologies and equipment for the same project. Notably, Siemens is the only manufacturer that is able to deliver the complete power plant including the CO2 capture technology and compression equipment. Having the complete system delivered by a single company allows operators to have a single interface and control system for easier plant construction and operation.

The gas in the plant is compressed from a suction pressure of 1.25 bar to 68 bar. Each compressor has a rated output of 28 MW. Part of the CO2 gas compressed by the compressor train is used, among other things, as process gas for internal transport within the plant, while the unneeded portion of the CO2 is vented. The compressor trains will be produced in Europe, while out of Huludao, China, Siemens will deliver the auxiliary systems and handle local project management and engineering.

Start-up of the compressors is scheduled for the summer of 2015 and will be a major milestone in the advance towards higher flow, higher pressure units.

Testing

The next step is to build and test a compressor that will operate at a flow rate of 200,000 m^3/h and discharge pressure up to 200 bar.

Since compressors have to be carefully tailored according to their application they have to undergo performance and mechanical testing before delivery to site. This is a key requirement for potential operators as it demonstrates that the necessary guarantees can be met.

For example, the compressors for Port Arthur and Kemper County are highly sophisticated units that have been precisely tailored to achieve high performance. Testing and confirmation of their performance was an important customer requirement.

Tests typically include performance tests to verify efficiency and power demands, as well as mechanical tests.

Prior to the delivery of the two CO2 compressors for the Kemper County IGCC project, one of the compressors was full load, full pressure tested with the job motor at Siemens' Mega Test Centre (MTC) Duisburg test facility.

Siemens has been using its MTC to carry out compressor tests at full load, full pressure with various gases and different compressor drivers (e.g. electric motors, steam turbines and gas turbines).

Testing of an 8-stage compressor for CO2 application is a complex undertaking, which is almost impossible to perform on site.

For one of the compressors installed at Kemper County each of the three process stages was put through a Class 1 test under full speed, full load and full pressure. A mechanical test of the first machine was performed before the full load test of the complete system to ensure that no mechanical complications arose during the full load test.

During the two-day testing programme, the test-bed data acquisition and evaluation system collected test data required by the customer and additional information that would be useful for Siemens' designer and development engineers.

Testing was performed with inlet guide vanes (IGVs) placed in front of the first impeller of each of the three process stages. The IGVs were placed in the various positions to determine the full operating range of the compressor. Two hot and two cold starts were also carried out during the 16-hour test run.

Since opening, the MTC has been an important tool in the testing of compressors underlining Siemens' compressor train competence. By giving compressor operators the confidence that new compressors will perform according to expectations, it will continue to be an important facility in accelerating the commercial deployment of CCS – a key tool in the battle against climate change.

More information

www.siemens.com

Integrated design and operational analysis of CCS systems

Process Systems Enterprise has developed a whole-chain CCS system modelling tool called gCCS which is now being used at the Peterhead project in the UK.

By Mark Matzopoulos, Process Systems Enterprise Ltd

Understanding the interaction between carbon capture and storage (CCS) chain components is a key consideration for those designing – and in future operating – whole-chain CCS systems such as the Peterhead project currently under development in the UK by Shell and SSE Generation Ltd.

The project is the world's first commercial-scale full-chain CCS demonstration project for gas-fired power generation. The aim of the development is to capture, compress, and transport one million tonnes per year of carbon dioxide by pipeline to the Goldeneye offshore gas reservoir beneath the North Sea for long-term storage. The Front-End Engineering Design (FEED) scope includes a grass-roots carbon capture and compression plant and modifications to the existing combined cycle gas turbine power plant.

While the gas-fired power station is currently able to respond quickly to load changes, the large-scale amine capture plant removing CO2 from the flue gas stream is governed by the typically much slower dynamics of a large-scale process operation. It is essential to be able to understand the effects of coupling the two very different types of plant on Peterhead's ability to generate electricity flexibly, and the potential impact on electricity prices.

A further complication arises from the fact that the CO2 is then compressed and piped 100 km offshore to the Goldeneye field, introducing operations with multiple dynamic timescales and the potential for faults, failures and disturbances that can also affect electricity output. The consequence of the development is that, instead of a power station that currently needs to respond solely to grid demand, the station is now connected to a complex system that can affect or disrupt operation in many different ways. All of these potential effects need to be accounted for in the design.

The implementation of the CCS chain gives rise to several sets interlinked of questions that need to be answered. There are questions on the design and operation of individual units – for example, the amine capture unit. There are related questions about integration of and interaction between adjacent units – for example the retrofit integration of the power station and amine unit. Here it is necessary to determine items such as the optimal steam take-off points and required alterations to the steam turbine that provide maximum efficiency of operation and minimised CAPEX while still retaining the required operational flexibility for both units. There are (literally) wider questions about the interaction between units across the chain – for example, how a close-in operation of the injection wells affects operation upstream all the way to the power station.

Peterhead project: modelling for flexible operation

Most of these and similar challenges apply to all CCS development projects. However, as the Peterhead project is the first such commercial-scale project of its type, there are numerous areas where – however much the individual technology has been applied or tested in other contexts – it has simply not been implemented at this scale and level of integration before. This is where high-fidelity predictive system modelling becomes an essential tool for providing reliable predictions on how integrated systems will operate in practice.

In order to quantify the dynamic behaviour of the system, Shell has commissioned a simulation project of the CCS chain from flue gas to injection, covering a wide range of scenarios. The project will involve the first commercial application of the gCCS whole-chain system modelling software specifically developed for this type of application.

The software will be used during the FEED study phase to provide insight into the behaviour of the amine-based capture unit when subject to major transient operations such as start-up and shutdown of the power plant and system trips, and the effect on operations of integrating the plant within the full system.

A key requirement is to demonstrate the ability of the proposed design to deliver effective solutions for low CO2 power production. This requires designing the process and its operating policy in such a way that there is no significant impact on the ability of the power plant to react to grid demand. It also requires quantification of the CO2 emissions associated with the various off-design operating scenarios, and if necessary adjusting the design and operation to minimise these.

The use of predictive modelling will help the project team to better understand the system behaviour under different scenarios, provide support for decisions on the system operation, and in general help to reduce technology risks and avoid unwelcome surprises when the system becomes operational.

gCCS: whole-chain CCS system modelling

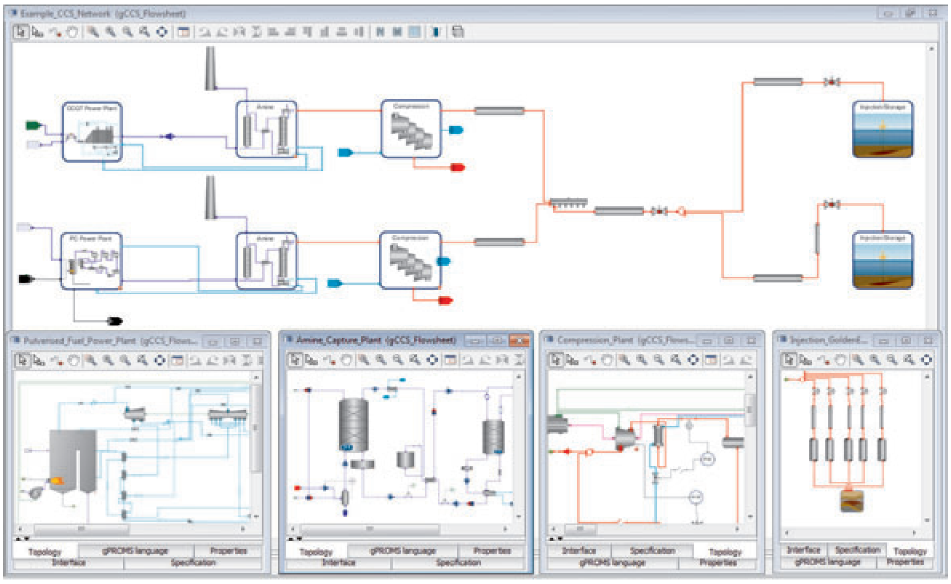
Launched in July this year, gCCS is the commercially-supported product resulting from the £3m Energy Technologies Institute (ETI) funded CCS Systems Modelling Tool-kit project. The project was established to support the future design, operation and roll-out of cost-effective CCS systems in the UK, and involved E.ON, EDF, Rolls-Royce, CO2DeepStore, PSE and E4tech.

gCCS is the world's first process modelling environment specifically designed for support of design and operating decisions – including addressing of interaction and interoperability issues – across the full CCS chain. Implemented on Process Systems Enterprise's (PSE's) gPROMS advanced process modelling platform, it covers operations from power generation through CO2 capture, compression and transport to injection. It also includes physical properties methods specially formulated for CCS analysis, such as amine operations and CO2 streams containing impurities.

Alfredo Ramos, PSE's head of Power & CCS and leader of the development, said "The Peterhead project is precisely the type of large-scale CCS application that gCCS was developed to support. For the first UK commercial use, we are very pleased to see it being used on such an important development."

Solvent-based capture plant design

Predictive modelling software such as gCCS can be used for many different types of application once a model of the basic configuration has been constructed.



Example flowsheet from the gCCS modelling environment

gCCS is particularly suited to design of solvent-based capture plants, where there are always many questions requiring answers. Apart from the typical design questions such as column diameter, number of theoretical stages, packing choices, and so on, there are a host of operational questions – for example, questions of solvent inventory for particular scenarios, optimal solvent loadings, operating policy for start-up and standby mode, and so on.

Accurate models also provide the ability to screen and rank new solvents, and determine optimal operating conditions to ensure that they achieve their full potential. Similarly, new or modified capture processes can be proven and key design decisions tested with much of the work – apart from essential validation – taking place using the model rather than via expensive pilot or demo plant operation.

Ramos says "with such developments, three things are essential. Accuracy is the first – there is no point in optimising a process design based on unreliable information. For this reason, we spent a long time getting the amine thermodynamics accurate in our rate-based solvent models. Then, robustness is essential, particularly when you are dealing with dynamic performance of a complex unit in a wide range of transient and off-design scenarios. For example, if you are ramping down the unit to idle to investigate the difference in start-up response between scenarios in which you continue to circulate amine or switch off the pumps, you need the model to be able to run through all of these numerically-demanding scenarios without failing. Finally, you need speed of solution. For large-scale optimization, or even when simply executing a number of dynamic simulation runs, you need turnaround in minutes rather than hours otherwise you cannot cover the decision space effectively. We successfully addressed all of these while prototyping the software on such a project last year, which as far as we know was the first use of a rate-based capture plant model for full start-up and shutdown analysis.

He adds, "Interestingly, the previous simulation studies showed that the process dynamics not the major inhibiting factor in achieving low CO2 power production per se. Far more important in defining capture unit performance in terms of CO2 emissions is the unit's readiness for start-up.

Analysing trip scenarios and their effects

While the interaction between power plant and capture unit is essential, the ability to model the whole system makes it possible for engineers to investigate interactions between all parts of the chain, as well as address crucial elements of design of individual components. According to Robin Irons of E.ON's CCS Innovation Centre and a key participant in the ROAD project "It is essential to have tools that enable us to look at the whole CCS system simultaneously, so that we can answer questions and make decisions based on accurate numbers".

The analysis of trip scenarios and their effect on stakeholders up and down the chain was the focus of a recent Energy Institute CCS Committee project. Recognising that safe operation of the CCS system will require close co-ordination between the different stakeholders, the project objectives were to identify and analyse potential hazards caused by typical trip, outage and shutdown scenarios.

The effects of these events on stakeholders were also analysed, and the findings used to demonstrate how the process can be safely managed in the event of a system failure. The results of this work will be formulated into a discussion document in the form of a research report, currently under development, that will seek to suggest what actions might be taken under a given a set of scenarios.

Energy Institute CCS Committee Chair Andy Brown, Progressive Energy, concluded, "the ability to quantify accurately not only the effects of trips on stakeholders, but also the time that is available for management of the consequences, provided essential information that has allowed us to gain a great insight into the management of a CCS project".

Optimal compression, transport and storage design and operation

Other individual components of the chain can also benefit from a model-based approach. One such example is the ability to apply rigorous modelling and optimisation

techniques to design of the compressor train. State-of-the-art optimisation techniques can be applied to determine the number of sections and stage configuration for maximum overall efficiency in the face of anticipated diurnal and seasonal fluctuation in compression loads. For a given compression train configuration, the same optimisation model can be used to optimise daily operation by setting optimal inter-stage pressures – or where appropriate, the optimal number of parallel trains in operation – so that the unit is always operating at the maximum possible efficiency.

It is possible to apply a similar approach to determine the optimal pipeline diameter for a given service, taking into account the need to pressurise the line – where phase considerations permit – for 'line packing'. This provides buffering capacity that can help smooth out the effect of upstream disturbances on downstream injection operation and vice versa, or alternatively allows operating companies to take advantage of low-cost electricity periods for reducing compression costs. Balanced against this is the need to deliver CO2 at the right thermodynamic condition for injection, avoiding two-phase regions. These are challenges that can only realistically be addressed by a rigorous system modelling approach.

The Peterhead project is possibly unusual in that much of the chain – from capture to injection – is the responsibility of one company, Shell. In other projects, many decisions come down to trade-offs between diverse stakeholders who may have very different natures and commercial interests, working practices, technologies and tools. The same modelling approach provides a valuable tool for quantifying the relative cost and benefits of different options and judging between often-conflicting requirements – and thus has the potential to provide a common basis for decision support.

Says PSE's Ramos, "once you have put together a model, there is almost no limit to the design and operating questions you can answer. It is like having the real thing at your fingertips, except of course it is possible to investigate things you would never be able to in real life."

More information

www.psenterprise.com

Growing international links at the UK CCS Research Centre

As Ciara O'Connor, the UKCCSRC Network and Storage Research Manager, explains, Early Career Researchers have a special role in helping the UK CCS Research Centre to work with international partners to advance CCS research.

The UK CCS Research Centre was funded by the EPSRC with a remit that includes coordinating international CCS activities and raising the UK's profile. Building on the initial Centre plans and two years of very active international experience the UKCCSRC published a detailed International Engagement Strategy in May 2014.

Prof John Kaldi, Chief Scientist, CO2CRC Ltd. and Tim Dixon, Board Member, UKCCSRC signing an MOU at the IEAGHG Summer School at the University of Texas in Austin, July 2014

Three complementary (and sometimes overlapping) types of activity are being used to deliver the UKCCSRC International Engagement vision: targeted engagement, relationship building and links to international organisations and events

Targeted Engagement Activities take advantage of overseas collaborations to progress research and other UKCCSRC objectives. These activities may be initiated by the UKCCSRC and its Members, based on perceived UK needs and overseas capabilities, or be initiated by other parties from overseas - e.g. other research organisations, industry - or from funding agencies in the UK offering travel and visit support. Where relevant, funding-related opportunities are advertised to all UKCCSRC members.

Key scientific strategic objectives for Targeted Engagement Activities are to:

• link to relevant large-scale CCS activities (which are currently very rare globally);

• gain access to useful research facilities (at all scales); or

• gain access to scientific data that are not available in the UK.

In all cases, though, the emphasis in judging which proposed Targeted Engagement Activities should be pursued is on assessing what potentially can be done through the engagement, the fit to wider UKCCSRC strategic objectives, including possibly generating additional research funding, and the value of the activity for the UKCCSRC and wider UK interests.

Relationship Building activities include ongoing dialogue and networking interactions with other leading research organisations working on CCS, likely to be supported by a formal MOU or other statement of intent once relationships have been identified and sufficiently developed (possibly through a mission to the country). Currently the UKCCSRC has MOUs in place to support research collaboration with SaskPower, Carbon Management Canada (CMC) and CO2CRC Ltd., with more being discussed.

The UKCCSRC has also made an MoU, jointly with SCCS, GEDI and CFEDI, to help set up the Guangdong CCUS Centre, witnessed by UK State Minister of Energy and Climate Change Gregory Barker, and the Governor of Guangdong province Mr ZHU Xiaodan in London in September 2013. The GDCCUSC was officially launched by Mr Xie Zhenhua, Deputy Director of NDRC, and Mr Xu Shaohua, Deputy Governor of Guangdong province, on 19th December in a ceremony just 5 minutes before the opening of the Guangdong Carbon Market (the second largest in the world).

Based in Guangzhou, China, in its first nine months the GDCCUSC has developed a demonstration programme in collaboration with China Resources Power (CRP) and China National Offshore Oil Corporation (CNOOC), held two international expert workshops, developed the Near Zero Emission Magazine, recruited an international advisory board and established a public communication programme, a manufacturing partnership and an internship programme.

A major purpose for the UKCCSRC links to overseas CCS organisations, intended to be sustained in the long term so long as the scientific justification for the relationship remains, is to facilitate or develop future Targeted Engagement Activities, including possibly many years ahead for tomorrow's UK CCS academic research community. Information exchange and benchmarking, through formal and informal processes, are also typically very valuable aspects of this type of interaction. The emphasis in this type of approach is on the current and estimated future commitment to CCS of the country involved and on the characteristics (scientific quality and relevance, but also, critically, willingness to engage) of the partner organisation(s), plus the value of the research being undertaken.

Links to major international organisations, including through meetings and workshops covering one or more relevant themes that are primarily intended to bring together a range of national or international attendees rather than linking to a specific host organisation, are also important. Benefits of attending (or organising) such meetings could include state-of-the-art surveys, dissemination of research and/or promoting awareness of the UKCCSRC, networking in support of Targeted Engagement Activities and Relationship Building, and/or supporting wider UK initiatives (e.g. RCUK or FCO-led initiatives etc.). With many key stakeholders in one place, these types of event can be a cost-effective way to communicate and network with multiple international partners.

Since early career researchers (ECRs) are often working full time on a single research project and don't have to balance teaching and other activities they have a special role in delivering targeted engagement activities. The UKCCSRC Network ECR International Exchange Fund offers a mechanism for UK based ECRs working and studying within the academic UK CCS community to link with the best CCS researchers around the world. Funds are available to support and strengthen both emerging and existing international collaborations through working visits of between one week and one month, or a longer duration where co-funding from other sources has been obtained.

The most recent call for applicants closed in June 2014. Several further rounds of funding will be available over the remaining two and half years remaining of the present phase of UKCCSRC funding, advertised in the Centre's fortnightly newsletter.

Blogs from some of the 2013 ECR International Travel Fund Awardees give a flavour of the type of exchanges so far:

UKCCSRC and CO2CRC Ltd. researchers at the CO2CRC Otway Site, Australia in November 2013

Paul Tait, University of Edinburgh, after a month at the University of Texas in Austin, USA, concluded " …. my visit …. has been hugely beneficial to my understanding of mass transfer theory and for my wetted-wall column design. I had a fantastic time in Austin and the graduate students in Professor Rochelle's group could not have been more welcoming. I made some good friends during my time there and I really hope I have the opportunity to collaborate with them, or return to Austin in the future!"

Davide Bocciardo, also at the University of Edinburgh, wrote "I had the unique opportunity to spend a month in Brazil as a visiting researcher in Fortaleza at Universidade Federal do Ceará (UFC) in the Grupo De Pesquisas Em Separações por Adsorção (Separation by Adsorption Research Group - GPSA) led by Professor Célio Loureiro Cavalcante Jr. [this included] their labs where high-pressure adsorption measurements are carried out for CO2 capture and high-pressure gas separations … I was also involved in the preparation of training material on membrane separation and CCS for Masters' and PhD students: I could introduce the UK situation and the current CCS research."

Silvia Madeddu from the University of Sheffield visited Nagoya Institute of Technology (NItech), Japan to develop an economically and energetically viable process to produce Mg(OH)2 for the sequestration of exhaust CO2 via mineral carbonation. Using the facilities there he was able to undertake carbonation experiments in a high temperature tube furnace connected to a CO2 gas cylinder to test gas-solid carbonation reactions from 200 to 700°C. On training in the use of X-ray Diffraction (XRD) and Thermogravimetry (TG)in Japanese Silvia noted that "communication was not always straightforward but it was usually very entertaining and we discovered ourselves to be unexpectedly talented with gesture!"

Alexandra Maskell, a PhD student in Carbon Storage at the University of Cambridge combined work on reservoir modelling using the TOUGHREACT modelling package at CSIRO's Earth Science and Resource Engineering group in Melbourne with a visit to the CO2CRC Otway Site as part of a UKCCSRC mission. CO2CRC Ltd. had organised a 2-day site visit to help the group of UKCCSRC researchers better understand the layout, meet with the main team in charge, and start to lay the groundwork for future collaborative work. Alexandra has also been invited back to the University of Melbourne and CSIRO by Ralf Haese, Jonathan Ennis-King and Tara LaForce for three months to continue the numerical modelling of the Green River CO2 accumulation that she started there

Building on long-term UK CCS links with Canada and a UKCCSRC mission to Canada in summer of 2012, funded by the UK Foreign and Commonwealth Office, the UKCC-

SRC and Carbon Management Canada (CMC) established a formal exchange programme for Early Career Researchers (ECRs) in 2013, with four exchanges in each direction in a first phase that is just completing. As Dr. Steve Larter, CMC's Scientific Director, said "Young researchers will be the ones to deliver breakthrough solutions to today's carbon management problems - but they won't do it working in isolation. Collaboration is a critical element in the innovation process and exchange programs like this one help our early career scientists build the relationships necessary for the development of ground-breaking, deployable technologies."

UKCCSRC member, Stella Pytharouli, from the University of Strathclyde, is also working in Canada with UKCCSRC funding, under Call 1 of its internal research programme, at the Aquistore storage project in Saskatchewan. Her work will help to three-dimensionally image hydraulically conductive features in the reservoir, caprock and overburden by monitor micro-seismic events prior to, and during, CO2 injection using a three-component nanoseismic surface array This will complement data collected by the existing geophone network at the site by the Petroleum Technology Research Centre. But as Ian Yeates from SaskPower observed, after assisting Stella on a preliminary site visit, the winters in Saskatchewan can be challenging "Two weekends ago it was -39C with a wind chill into the -50's. This weekend just past it was above 0C. Spring is here!"

Hopefully Stuart Gilfillan, a UKCCSRC member at the University of Edinburgh, will not have to deal with such challenging weather at the CO2CRC Otway Site in Australia where, in collaboration with CO2CRC Ltd., he will be studying water geochemistry to establish the fate of CO2 using noble gas tracer injection and recovery to determine residual trapping levels, and independent oxygen stable isotope measurements to quantify the amount of CO2 dissolution. These tests, one of the second round of research projects funded by the UKCCSRC, will help to calibrate downhole geophysical techniques that CO2CRC Ltd. will use.

Closer to home, the UKCCSRC and CATO2 organised a joint ECR meeting in York in March 2014. Participants started out using CATO-2's CarbonFuture XXL exercise to role-play being part of a carbon intensive company's management team having to implement a low carbon strategy. The meeting also included presentations on the CCS landscape in the Netherlands, the UK CCS policy landscape and European CCS in the Bigger Picture respectively and breakout sessions to give the ECRs a chance to discuss their research projects across Capture and System Analysis; Chemical Looping and Pre-combustion Capture; Storage and Monitoring; Storage and Public Perception.

North Sea Young CCS Researchers present Amsterdam Declaration to John Gale of the IEAGHG

In a return 'away fixture', UKCCSRC ECRs participated in the 1st North Sea Young CCS Researchers Conference, Rotterdam June 2014, hosted by CATO-2 in the Netherlands. The meeting included field excursions to the Maasvlakte E-ON power plant and pilot plant. ECRs from different CCS institutions around the North Sea (UK, the Netherlands, Norway and Germany) presented on their research projects during the meeting and also negotiated an 'Amsterdam Declaration' which was presented to John Gale, General Manager, IEAGHG at CATO-2's 7th Dutch CCS Symposium in Amsterdam.

In the Declaration, the ECRs stated the importance of CCS as a mitigation measure in dealing with climate change. They called for greater multidisciplinary and international discussion to raise public support for CCS and for Governments to help improve financial incentives for investment in CCS through the development of a financial regulation framework. The ECRs themselves, through the Declaration, committed to play their part in engaging the public on the importance of CCS and to contribute more to international CCS research collaborations and CCS networks.

Space is limited here, so additional activities supporting CCS research and development with key international partner organisations will be covered in future articles. One other event that should be noted now, however, is an upcoming networking reception at GHGT12 co-hosted by the UKCCSRC with CMC and CO2CRC Ltd. on the evening of Monday 6th October. This will bring together members of these organisations who are attending this major international conference and many of their invited international colleagues for a very efficient exchange of CCS information. Results from the last reception, at GHGT11 in Kyoto, included in the launch of an informal Gas CCS Network which will be holding its third meeting also at GHGT12, on the evening of Tuesday 7th October. So watch this space!

More information

Contact Ciara O'Connor, UKCCSRC Network and Storage Research Manager:

ciara@ukccsrc.ac.uk

www.ukccsrc.ac.uk

New testing era for Mongstad

Technology Centre Mongstad, the world's largest carbon capture testing facility in Norway, reports that its first round of testing is complete, and it has signed a milestone deal with Shell Cansolv for a new era of testing.

By Karl Jeffery, features writer

The project started in May 2012, with a budget to run for 5 years to May 2017, so is now two years in. Shell Cansolv has now signed a contract for testing of Cansolv's advanced CO2 capture process at the existing amine plant at TCM, due to start in September and to run for five months.

"The regenerable Cansolv CO2 Capture System offers a method to remove up to 90% of the CO2 from exhaust gases, and TCM is thrilled to be able to perform testing with one of the leading vendors in the CCS industry," said TCM's managing director Frank Ellingsen.

Tord Lien, the Norwegian minister of Petroleum and Energy, said the deal, "confirms that the facility represents an important contribution to the global efforts to develop cost effective CO2 capture technology."

TCM is also keen to undertake more research itself, rather than jointly with technology partners, because this way it ends up with more freedom to share the results, Mr Ellingsen says.

So far, TCM has completed a 'baseline study', to work out what separation performance might be expected using today's capture technology, and a MEA (monoethanolamine) solvent. The separation performance is measured in terms of ultimate separation, energy consumption, solvent degration, waste and leakage, among other factors.

As a 'baseline study' it is designed so that all future technology can be benchmarked over whether it offers an improvement. "Everything will be compared to MEA from now on", Mr Ellingsen says.

It has two separation units running to date – an Aker Solutions plant running amine technology, and an Alstom plant is running chilled ammonia technology.

The first year also showed that the plant could operate with 98 per cent availability.

The plant is supplied by flue gas from two separate streams - a nearby Statoil oil refinery, and a gas electric power plant. Both flue gas streams have a similar mixture of gases than would be found in the flue gas of a standard coal power plant.

The plant is scaled at about a tenth of the size it would need to be to capture CO2 from a standard coal power plant, but also about ten times the size of a typical pilot plant.

There are 3 main ambitions behind TCM: to provide a forum for technology companies to test and evaluate their technology, to provide carbon capture technology 'owners' (such as oil companies, power companies and governments) more insight into the technology, and to share knowledge in general.

> Technology Centre Mongstad, the world's largest carbon capture technology facility based near Bergen, Norway, reports that its first research phase is complete, testing CO2 separation technology from Aker and Alstom

The technology also fulfils perhaps one more important objective – giving people more confidence in carbon capture in general – since senior energy policy officials around the world still do not have the confidence in carbon capture technology to require its implementation on a wide scale.

Knowledge sharing

TCM has established a knowledge sharing network, with 5 members, in the US, Canada and Europe, including the main carbon capture projects – Saskpower (Canada), and the Mississippi Power Kemper County IGCC project (US), and delegates from South Korea.

The first meeting was held in Bergen in May 2014, "an effective knowledge sharing session," Mr Ellingsen said.

A formal partnership was signed between the governments of Norway and US too share knowledge on carbon capture, which will be led by Norway for 2 years, then led by the US for 2 years.

There will be a further physical meeting in Austin in October 2014, during the 12th Greenhouse Gas Technologies (GHGT) conference.

The centre has had visits from staff at SaskPower, which is setting up the Boundary Dam carbon capture project in Saskatchewan,, Canada, expected to be the first full scale carbon capture and storage project in the world. Representatives of Shell's "Quest" carbon capture project in Alberta have also visited.

There have been visits from staff involved in the Rotterdam ROAD project, and a collaboration with the UK's Peterhead project.

Commitment from Norway

All four political parties in Norway have signed a commitment to say they want to continue developing CCS technology, after a change of government in Autumn 2013 caused some uncertainty.

The Norwegian Minister of Energy, Tord Lien, personally attended the Carbon Sequestration Leadership Forum Ministerial meeting in November 2013 in Washington, to demonstrate his commitment to CCS.

The longer term goal is to establish a full scale carbon capture unit in 2020.

The original plan was for Mongstad to be a full scale carbon capture plant – this plan was dropped in September 2013 due to cost escalation. But it continued as a research centre.

Gradual improvement

Even if the main technology elements of carbon capture do not change, the research, and continual tweaking of the technology, should make a major contribution to reducing the cost of carbon capture over time, Mr Ellingsen says.

In a similar way, a car built 100 years ago looks more or less the same than one built today, but is much more reliable, durable and efficient to operate.

Industrial processes develop in a similar way, he says. Ammonia has been manufactured on an industrial scale since 1913. Today it is manufactured using roughly the same process, but "we do it completely differently," he says.

Through research and operations, you can "identify new opportunities which make it possible to make a step change."

Bigger picture

So how does the bigger picture look like from TCM's perspective?

"If you look at CCS today, technology research is paving the way for a fully commercial market," Mr Ellingsen says.

The first phase of testing at Technology Center Mongstad, with technology from Aker and Alstom, is complete and Shell Cansolv has just signed up to test its Carbon Capture System in a new phase

So far, the biggest driving forces for carbon capture have been enhanced oil recovery, using CO_2 injected into the ground to improve oil production, or where people wanted to produce gas fields which were high in CO_2 and needed to separate the CO_2 out, to avoid paying tax, such as Snøvhit and Sleipner in Norway.

To justify carbon capture on a standard coal power plant today, "You need government support," he says. "That's the reality."

For carbon capture to move faster, you need stronger public acceptance of the need to act to reduce CO_2 emissions – and a higher carbon price, Mr Ellingsen says.

Increased interest

TCM has also seen interest in carbon capture pick up over the past year, says Vegar Stokset, head of communications with TCM.

"Climate change again is running high on the list of what people are concerned about. There are plenty of positive signals, such as moves in the US to regulate coal power plants, moves in China to develop a carbon tax.

"There's definitely some positive signals coming out," he says.

www.tcmda.com

IEA Insights - what lies in store for CCS?

IEA Insights: CCS 2014 is a continuation of efforts by the International Energy Agency to provide strategic, economic and policy analysis on various aspects of carbon capture and storage.

CCS has suffered from a lack of attention by public and policy-makers over the past several years.

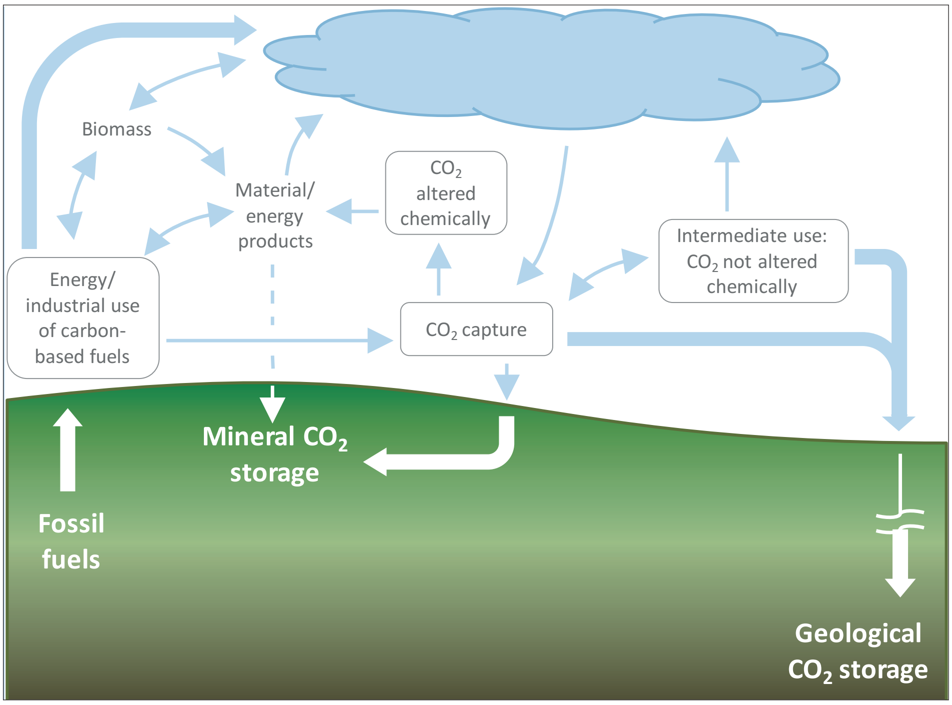
At the same time, science increasingly points to the dangers of climate change and various mitigation plans continue to emphasise the critical role of CCS to limit temperature increase. The 2013 IEA CCS Roadmap presents a set of actions that are needed between today and 2020 to lay the foundation for scaled-up CCS deployment. It is necessary to now concentrate on concrete action by both governments and industry to drive CCS forward.

It is of particular importance to boost activity in the area of CO2 storage, on various levels. Storage is critical to any project design and must be addressed up front. While storage is the last of the three steps of a CCS project, it must be developed simultaneously with capture and transport, from the very beginning. This is because reservoir characteristics and behaviour may determine the design and operation of the whole CCS chain. Also, available experience shows that it can take 5-10 years to qualify a new saline formation for CO2 storage, even when theoretical estimates are already available and look promising. To understand the emission reduction potential of carbon capture and storage (CCS), decisionmakers

need to understand the size and distribution of carbon dioxide (CO2) storage resources. Therefore high-level national and regional storage data is very important and has to be developed first. This can provide information on theoretical storage capacity and reveal

geographical areas with significant CO2 storage potential. While high-level data does not replace site-specific exploration, assessment and testing, it may help individual project proponents to make informed assessments and take decisions regarding the best potential storage sites.

Assessing national storage resources is currently done through various methodologies. It would be important to achieve a clear and widely shared definition of CO2 storage potential and an agreed method for its calculation. Moving to a uniform methodology can enable stakeholders to identify and compare different storage resources in different locations. There is also a need to enhance the cooperation between organisations that have attempted or completed CO2 storage resource assessments and those that are looking to begin assessments.



A family of processes that interact to increase or reduce total CO2 emitted

Notes: This graph does not intend to represent the complete cycle of carbon stocks and flows. Boxed text denotes processes; unboxed text denotes stocks of carbon; the cloud denotes the atmospheric stock of carbon; arrows represent flows of CO2.

The necessity of large up-front investment in securing storage capacity is also a critical aspect in the process of investing in CCS. The final investment decision for a large capture facility cannot be taken without a very high level of confidence that the resulting CO2 can actually be stored in the envisaged site or sites. Therefore, the whole investment framework and its various stages are either strongly influenced, or actually defined, by the development of the storage site.

In order to achieve mitigation targets, CCS is also critically important for industrial applications, not only for power. Many heavy industries, such as steel and cement, produce significant GHG emissions in their manufacturing processes, and CCS may be the only option to address these emissions. Policy approaches to boost CCS in these industries need to be tailor-made, as the key sectors on question all present their specific circumstances. Many energy-intensive sectors are also exposed to global competition, which makes the policy design critically important.

Recent times have also seen a re-emergence of discussion on CO2 utilisation. Utilisation is often seen as a means to provide revenue for CCS projects and hence to help CCS traverse the "valley of death" in the absence of sufficient climate-related policies and financial incentives. It is important to carefully categorise the various potential CO2 utilisation options, as not all utilisation is beneficial to climate change mitigation efforts.

The need to accelerate CCS development

The target date for the 2015 Paris UNFCC Conference of Parties (COP) for a new international agreement on climate change mitigation draws nearer. Countries are looking more deeply at their potential 'contributions' in reducing their greenhouse gas (GHG) emissions, in particular with a view to achieving the 2-degree target adopted at Cancun in 2010.

As part of this process, carbon capture and storage (CCS) moves increasingly to the forefront as a critical tool, but one that has recently engendered more scepticism and doubt than comfort. CCS investment, demonstration projects and large-scale deployment are well behind the targets envisaged by analysts, governments and industry, causing some to question its viability – and by extension, the practicability of a 2-degree GHG emissions trajectory. Despite slow progress to date, for the IEA all signs continue to point to the necessity and viability of CCS as a CO2 abatement technology, within a portfolio of other low-carbon technologies. But important challenges remain ahead.

Last year, the IEA published an update of its CCS Roadmap, setting out some of the important policy and other actions needed to confirm the practicability of CCS as a large scale CO2 abatement tool and to set it on the required corresponding deployment pathway. Questions exist regarding the amount of CO2 that can ultimately be stored, in part given concerns regarding storage capacity (a point addressed further below) and correspondingly, the amount of abatement that CCS might ultimately deliver.

But in the current phase of development, the challenges facing CCS seem to be less about achieving a large-scale mature business, but rather about creating a robust, credible track record of initial projects and establishing an early-mover business model. In order to help support industry in moving this important low-carbon technology forward, the IEA will continue to provide technical and economic analysis. Through a selection of topical articles, this publication represents a continuation of that effort.

The present is critical for the future of CCS

As the IEA Executive Director, Maria van der Hoeven, noted in her foreword to the 2013 IEA CCS Roadmap (2013), "After many years of research, development, and valuable but rather limited practical experience, we now need to shift to a higher gear in developing CCS into a true energy option, to be deployed in large scale. It is not enough to only see CCS in long-term energy scenarios as a solution that happens some time in a distant future. Instead, we must get to its true development right here and now."

The quote serves to highlight the need to move from scenarios to action. Given the past and current trends in fossil fuel use and the related CO2 emissions, the urgency of CCS deployment is only increasing. This decade is critical for moving CCS through and beyond the demonstration phase. This means that urgent action is required, beginning now, from industry and governments to develop technology and the required business models, and to implement incentive frameworks that can help drive CCS deployment in the power sector and industrial applications.

Apart from a few notable exceptions, CCS has suffered from a lack of attention by the public and policy-makers over the past years. Unless progress is made in these areas, CCS risks standing still while the energy system continues to evolve.

Seven key actions for next seven years

The 2013 Roadmap presents seven key actions to be taken in the near term in order to lay the foundation for scaled-up CCS deployment between today and 2020. They require serious dedication by governments and industry, but are realistic. They address all three elements of the CCS process:

- Introduce financial support mechanisms for demonstration and early deployment of CCS to drive private financing of projects.
- Implement policies that encourage storage exploration, characterisation and development for CCS projects.
- Develop national laws and regulations as well as provisions for multilateral finance that effectively require new-build, base-load, fossil-fuel power generation capacity to be CCSready.
- Prove capture systems at pilot scale in industrial applications where CO2 capture has not yet been demonstrated.
- Significantly increase efforts to improve understanding among the public and stakeholders of CCS technology and the importance of its deployment.
- Reduce the cost of electricity from power plants equipped with capture through continued technology development and use of highest possible efficiency power generation cycles.
- Encourage efficient development of CO2 transport infrastructure by anticipating locations of future demand centres and future volumes of CO2.

The seven key actions provide guidance to governments and policy makers – and also provide a basis for tracking progress in the development and deployment of CCS. The IEA will continue its analytic work in support of the Roadmap conclusions, and in parallel is developing a series of indicators and metrics to track progress regarding the key actions. This publication provides some additional analysis that supports these actions.

www.iea.org

What lies in store for CCS?

One of the major challenges limiting large-scale CCS operations at a global level, both in the short-term and in the longer term is the issue of storage. The publication addresses three interrelated aspects of this puzzle.

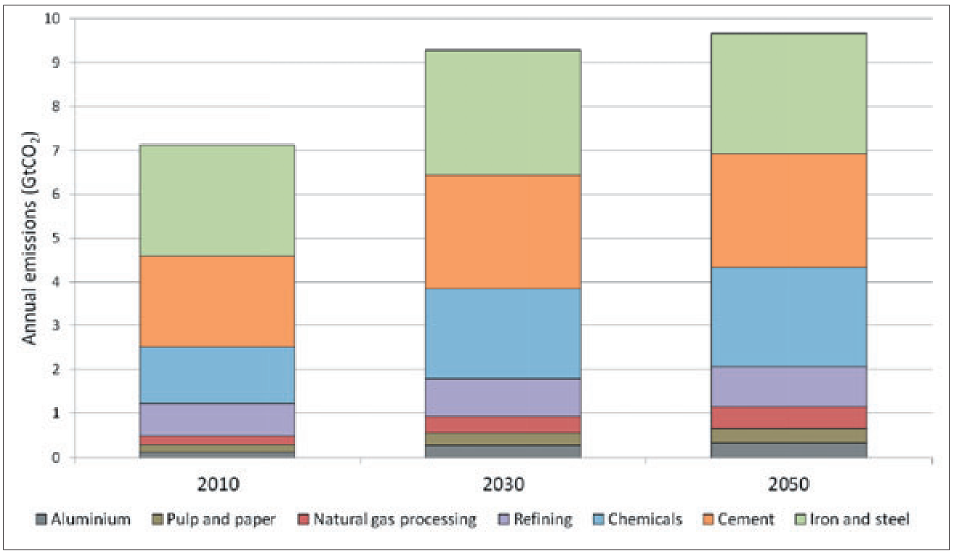
The first chapter looks at recent experience in CO2 storage activity in various parts of the world. Through case studies, it shows how progress has been made in achieving high-level storage area assessments, as well as at project level, where important practical experience has been gained in storing CO2. The chapter emphasises the fact that determining the feasibility of storing CO2 is a critical step that cannot simply be considered as the last part of a CCS project preparation process. In fact, selecting storage will actually impact the whole project design and so should be addressed right from the start. In addition to storage, the chapter also discusses transport infrastructure questions.

The second chapter proposes steps to develop a more generic and standardised storage capacity evaluation methodology that should yield more comparable assessments. Assessing storage capacity is an important element for a government, as it enables it to ascertain the role CCS could play in its future energy mix. While country- or region-level assessments may improve understanding among industry on prospective storage areas, ultimately each and every storage site requires a very detailed site-specific assessment.

Chapter three discusses some project-level key investment steps that are strongly linked to the process of finding, characterising and developing the storage site. The capital expenditure of a CCS project tends to be weighted towards the capture plant, while project technical risk is dominated by uncertain storage availability. Storage is an important aspect in the process of reaching a final investment decision for any CCS project, an area where further analysis within the financial decision-making process is needed.

CCS is about more than power: a major role for industry

While much of the discussion on CCS to date has focussed on the power sector, and notably coal, IEA analysis shows that one of the major opportunities for CCS is to reduce emissions from a variety of industrial applications, notably in the cement and steel industries that generate GHG emissions as part of the manufacturing process. While there are alternatives, albeit costly, to CCS to reduce GHG emissions from power generation, the alternatives for industry at this point are less evident. Chapter four of this publication helps to shed additional light on industrial GHG emissions and the importance of CCS in this regard. The chapter also discusses the specific policyrelated challenges facing CCS in industrial applications.



Global emissions trends by industrial sector under current policies

Note : the IEA Energy Technology Perspectives current policies scenario, or 4DS (4°C Scenario), takes into account pledges made by countries by 2012 to limit emissions. The biofuels sector is not included here as its emissions are considered as net zero emissions in GHG accounting principles. Biofuels can in some cases provide low-cost opportunities for emissions reduction through CCS. The chemicals sector includes petrochemicals.

Source : IEA (2013b)

Framework for evaluating the role of CO2 utilisation

One way to finance carbon capture and storage activities is to find ways to generate revenues that help to offset the cost of the CCS activity. This is particularly important given the reticence of governments to assume fully from its resources – or to impose fully on businesses – the "climate tax or penalty" required for CCS.

As a result, there is a lot of discussion around prospects to use CO2 to generate money, especially in North America (e.g., EOR), and increasingly elsewhere. For example, some recent analysis in China has looked into whether CO2 can help with water extraction. Unfortunately, the discussion around 'use' has suffered from a lack of clarity regarding the varying impacts on climate change mitigation generated by different types of utilisation. Not all CO2 utilisation is alike – hence the need to separate the wheat from the chaff when looking at utilisation through the climate change prism.

For the IEA, most interesting is CO2 utilisation that results in 'permanent' sequestration of the CO2. EOR is a good example of this as, under right conditions, the CO2 can be permanently stored underground. Potentially, other forms of use could result in CO2 being sequestered, for example in building or other materials with extremely long lives. These forms of uses can be characterised as "CCS-like" by resulting in the effective sequestration of CO2 over time, even if it isn't stored in the classic sense underground. At the other end of the spectrum, many forms of commercial CO2 utilisation result in the CO2

being emitted into the atmosphere within months or years – and consequently fail to generate the sequestration that is at the heart of the CCS impact. However, some cases that do not result in sequestration can generate other worthy benefits for climate change mitigation. Two are worth mentioning. First, CO2 can be used in the production process or otherwise in a manner that reduces or substitutes for related fossil fuel emissions. Second, CO2 utilisation can help to generate interest and funding for CCS related technological development or deployment, thereby indirectly supporting the CCS effort.

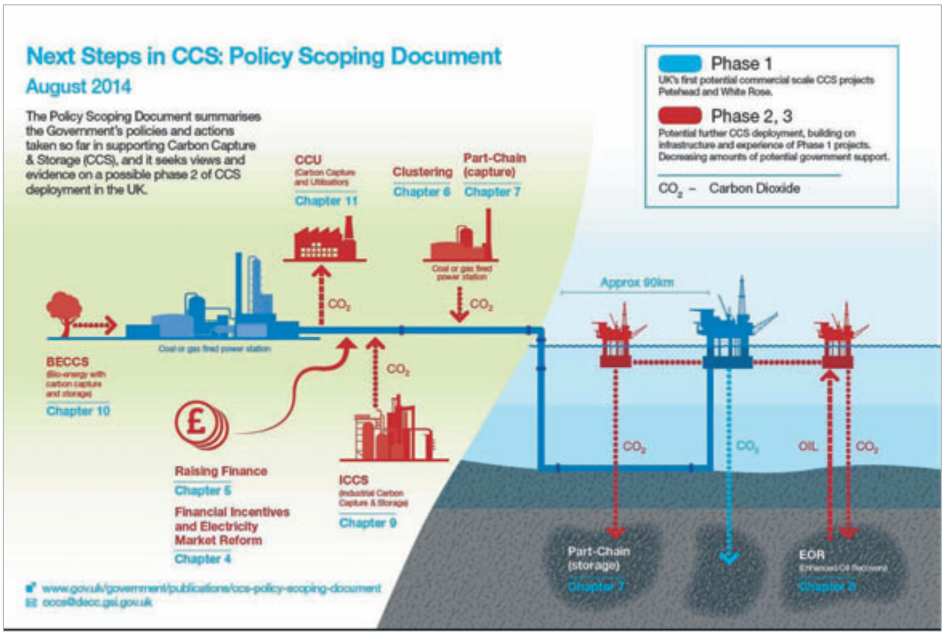
In the end, CO2 use that directly results in permanent sequestration – namely "CCS-like utilisation" – remains the potential jackpot to catalyse CCS. Given the importance of CCS for climate change mitigation, this effort to find sequestration - like uses merits continued attention.

But at the same time it is also important to understand where and when CO2 utilisation fails this important test, and whether it still can help climate change mitigation efforts. The risk to be avoided is to allow CO2 utilisation to become a distraction that will detract attention from effective sequestration efforts.

What's next for CCS policy in the UK

The UK Coalition Government has published a scoping document setting out its plans for CCS deployment. Meanwhile the UK's main opposition party has produced its own blueprint in the event of a Labour win in next May's election. The energy company Centrica has also produced a report looking at the UK's future energy choices.

The UK Government has published a scoping document that seeks views on a possible Phase 2 of CCS deployment.



'Next Steps in CCS' summarises the policies and actions the Government has taken to support Carbon Capture and Storage (CCS) deployment in the UK and seeks views and evidence on a possible Phase 2 of CCS deployment.

It reiterates the UK Government's committment to supporting the commercialisation and cost reduction of CCS and talks of the need for CCS to 'be commercial in a decade."

However the Carbon Capture and Storage Association has criticised the document for not being clear on how further CCS projects outside of the two that are part of the current demonstration competition will be funded.

"The CCS industry was anticipating a clear indication from Government on how it planned to deliver on its stated outcome of commercialising CCS in the early 2020s," said Dr Luke Warren, Chief Executive of the CCSA. "Having now reviewed this document, we are extremely disappointed that Government has not taken this opportunity to outline how CCS projects outside of the competition can be developed.

"Government's role is to clearly set out the framework that will support investment in CCS. We are very concerned that this document fails to provide the necessary certainty for investors and significantly jeopardises the Government objective of commercialising CCS in the 2020s."

"CCS presents a significant opportunity for the UK and we remain committed to working with Government to ensure that the full value of CCS in the UK is realised."

The Energy Technologies Institute welcomed the report. Andrew Green, the ETI Programme Manager for CCS, said:

"We have long argued the importance of CCS to address long term emissions reductions and provide a potentially strong economic prize to the UK. Without a national CCS infrastructure the cost of reaching UK Climate Change targets will double from a minimum of around £30bn per year in 2050 – the equivalent of an additional 2p per kWh on all UK energy use in 2050. "

"The publication of today's policy scoping document by DECC is another signpost to the work needed to turn this potential into a reality and a real benefit to the UK. The UK is a world leader in implementing CCS at scale. Our own work has shown that the UK is potentially well served in terms of carbon dioxide storage capacity and that an infrastructure to transport and store it is practical and affordable. Work is ongoing to improve capture technology and develop technologies to provide assurance that carbon dioxide is safely and securely stored. "

"With DECC's Commercialisation Programme now underway, we recognise that the focus needs to be firmly on enabling the next phase of CCS projects and the required transport and storage infrastructure, on route towards a sustainable, affordable and secure energy system in the coming decades. We welcome DECC's leadership to create a policy framework and financial support for this fledgling industry: this scoping document reflects both the complexity of developing an all-encompassing policy framework and DECC's commitment to work collaboratively with all stakeholders to make CCS a compelling economic case for the UK to implement. We look forward to contributing to the consultation and engaging with the CCS community to play our part."

The document solicits responses on a range of issues related to progressing CCS in the UK, including financing, financial incentives, enhanced oil recovery, industrial CCS, bio-CCS, carbon capture and utilisation, knowledge transfer and further CCS research and development. Responses must be received by 23rd October 2014.

UK Government funding available for CCS

From October 2014, renewable energy projects will compete for a budget of over £200 million a year, as part of the government's reforms to the electricity market.

The funding is for the first allocation round for the new Contracts for Difference, which provide long-term certainty and reduce risk for investors.

Energy and Climate Change Secretary Ed Davey said that renewable energy projects would have to bid competitively for the contracts, ensuring that new, clean electricity generation would be built at the lowest possible cost to energy consumers.

"We are signalling now that at least a further £50 million is planned for an auction round in 2015, with a total of around £1 billion potentially available later for further projects, including Carbon Capture and Storage, up to 2020-21."

Labour's CCS vision

In our efforts to decarbonise the economy, it is clear that Carbon Capture and Storage is a necessity, not an option. As well as contributing to a balanced energy mix, CCS represents perhaps the only currently viable way to decarbonise essential industrial processes.

In the next Parliament, a Labour Government will institute bold reforms designed to rebalance our economy. The decentralisation of £30bn of public funding would give local authorities greater power to direct transport, housing and infrastructure developments in their region.2 A new National Infrastructure Commission will report on the UK's long-term infrastructure needs, producing annual assessments of the Government's progress in meeting these requirements.3 A 2030 decarbonisation target for the power sector, combined with a continued commitment to the terms of the fourth carbon budget and the principles of the 2008 Climate Change Act, will cement the long-term trajectory of decarbonisation.4

It is in these contexts – decentralisation, infrastructure planning and decarbonisation – that a Labour Government would promote CCS. Regional clusters of industrial and power users, making use of shared transportation and storage infrastructure, can demonstrate that decarbonisation is not at odds with industrial activity whilst also serving to rebalance our economy.

This is not the trajectory that has been established by the Coalition Government. From the scaling back of the second CCS competition to the lack of progress on industrial applications, the Coalition's approach has been typified by dithering and delay. There is a real danger that Labour's legacy of international leadership on CCS will be squandered by the Coalition.

In order to get CCS back on track in the UK, a Labour Government will bring forward policies in line with 5 key principles:

1. Access to support (currently via the Levy Control Framework)

2. Effective financing of new infrastructure

3. Support for CCS on industrial emissions

4. Effective environmental regulation

5. Emphasis on cost reduction

There are a number of current considerations on CCS, many of which will have to be resolved during the next Parliament. These principles will guide a Labour Government's response to such challenges and ensure that the UK reaps the maximum benefit from its carbon capture and storage potential.

Centrica's UK energy choices report

The report looks at options for the UK energy market in order to meet carbon obligations in the most effective and cost efficient way. It proposes three key principles:

1. Lowest cost, least regret. Given the uncertainties, the report says affordability and adaptability must be at the heart of delivering the UK's 2050 decarbonisation target. It is important not to lock into certain technology pathways too soon only to find more cost-effective options emerge later.

This is especially true when enough lower-cost options are available to meet near term targets.

Therefore, lowest-cost measures should be prioritised to ensure decarbonisation targets are met as affordably as possible, and to minimise the risk of today's measures being overtaken by cheaper or better options in the future. Furthermore, least regret options should receive the most focus. These are the options that make economic sense in the widest set of future scenarios, given the uncertainties ahead. Their robustness to future uncertainty means we can be confident that investment won't be wasted.

Embedding a 'lowest-cost, least regret' approach in the UK's energy strategy would maintain a focus on affordability regardless of what lies in the future, while ensuring secure supplies and meeting our climate change commitments.

2. Simple and cost-effective decarbonisation targets. The existing carbon budgets framework, as set out by the Climate Change Act, is an effective way to guide the UK to achieving its climate ambitions. It provides enough certainty that the UK is on a realistic pathway to 2050, but allows flexibility about the mix of options chosen.

Other targets, such as 2030 power sector carbon intensity, renewable targets for 2030 or technology-specific targets tend to add cost and complexity by being overly prescriptive or creating conflicting priorities, and are inconsistent with a 'lowest-cost, least regret' approach.

3. Support those most impacted by the cost. Decarbonisation comes at a cost, even in a cost-effective approach. Vulnerable customers and energy-intensive industries are most likely to feel the impacts of these additional costs. Therefore, it is important that an affordable energy policy has clear The report explores the practical implications of pursuing a 'lowest-cost, least regret' approach for a number of sectors of the economy.

It finds that in power generation, the key low regret options were switching from coal to gas generation and new nuclear power. In contrast, solar PV appeared to be a high cost option, since it generates no output at times of peak demand, namely winter evenings, and therefore does not support security of supply without investment in back-up. Offshore wind has the potential to be high regret because it is an expensive option that may not be needed until the mid-2020s, or at all if Carbon Capture and Storage (CCS) technologies become economically viable.

More information

www.decc.gov.uk

Responses to Labour's plan should be sent to :

Tom.Greatrex.Mp@Parliament.uk

www.centrica.com

Developing a conceptual CCS vision for Saskatchewan

ICO2N has developed a CCS infrastructure vision for the province of Saskatchewan looking at forecasts for CO2 capture volume and enhanced oil recovery.

ICO2N launched the project in 2012, which incorporated expertise gathered from an initial workshop (Future of CCS Economic Development in Saskatchewan) held in Regina, Saskatchewan and presented conclusions in a workshop held in September of 2013.

The project was supported by IPAC CO2 and the Saskatchewan Government with assistance from the energy industry, and brought together resources from industry and government to use ICO2N's modeling capacity.

Using the ICO2N model the project prepared forecasts for CO2 capture volumes which were identified by plant type and geographical locations and prepared forecasts for enhanced oil recovery (EOR) volumes and locations. The project also assessed carbon capture opportunities and matched them with EOR demand for CO2 over time and established important inter-provincial linkages.

This unique model allows industry and government to evaluate the long term economic potential of carbon capture and EOR opportunities in the province. It can also be used to help governments understand how policy changes may be instrumental in developing carbon capture and EOR in the province.

This study shows that for reasonably high oil prices the development of EOR in Saskatchewan near Lloydmister and further development near Weyburn looks promising. ICO2N commissioned Baker Hughes to evaluate oil pools south and east of Lloydminster and near Weyburn to determine which ones should be considered for EOR. ICO2N evaluated CO2 emission data near these EOR pools and estimated potential volumes of CO2 available for use in EOR. Once groups of EOR pools were chosen, pipe infrastructure was established to provide these groups with CO2 from nearby sources.

This study suggests that close to 17 Mt/yr of CO2 could be used for EOR by 2030 near Lloydminster. This amount of CO2 may yield more than 100,000 bbl/day of heavy oil recovery based on this study. Most of this CO2 was assumed to be supplied by once through steam generators (OTSG) located north of Lloydminster.

In the Weyburn area it may be possible to capture an additional 4.5 Mt / year of CO2. However, the demand for CO2 in this area may exceed the volume of CO2 potentially available. It was assumed that most of the CO2 would be supplied by coal plants in the southeast part of the province. 6 MT/yr of CO2 volume near Regina might be available in the future, but was not included in this assessment.

An overall economic gap exists between CO2 capture costs and revenues received from the sale of CO2 for EOR. However, the selling price of CO2 for EOR will need to increase substantially to allow entities capturing CO2 to make a reasonable rate of return. However, EOR looks economically attractive for a single entity to both capture and develop EOR fields.

Carbon capture and storage represents that single largest opportunity in the energy sector to reduce greenhouse gas (GHG) emissions. CCS can provide a foundation to achieve sustainable growth of the energy sector and the Saskatchewan economy. To further this objective the ICO2N model can be used to analyse carbon capture and EOR scenarios to enhance economic and policy development.

Conclusions

This study indicates that at prevailing netbacks (the one based on $100/bbl WTI) that there may be an economic case to pursue further EOR opportunities in both the western and southeastern parts of the province. The western part of the province benefits from the opportunity to capture a large amount of CO2. However, most of this CO2 comes from OTSG sources which likely have capture costs of about $150/t. The eastern part of the province benefits from potentially lower costs sources of CO2 but the mass of CO2 available is significantly lower than the potential demand for CO2 for EOR.

Given the economic potential for EOR, this study suggests that further work should be completed. We recommend proceeding with a study of a specific case in more detail. Ideally industry participants would indicated which capture projects would be available for CO2 capture and when. EOR CO2 demand profiles could then be created to better match the CO2 supply profile. These demand profiles could be completed for a single agreed upon netback estimate.

Further work should be completed to assess how to deal with the challenging economics for the CO2 capture entities, particularly in the west. If a single entity completes both the CO2 capture and EOR, then CO2 pricing becomes a transfer price. Then the most economically attractive oil pools could be chosen to be supplied by available CO2. The economics of this case could then be evaluated.

Given that SaskPower is the ideal supplier of CO2 for further EOR projects in the southeast, further work with SaskPower would be encouraged to further improve the economic estimates for EOR in the southeast.

There are promising new technologies which may significantly decrease the cost of CO2 capture in the future. If these technologies become viable then the economics for EOR will improve significantly. It may make sense to repeat this study in the future as more information on the cost of these technologies becomes available.

More information

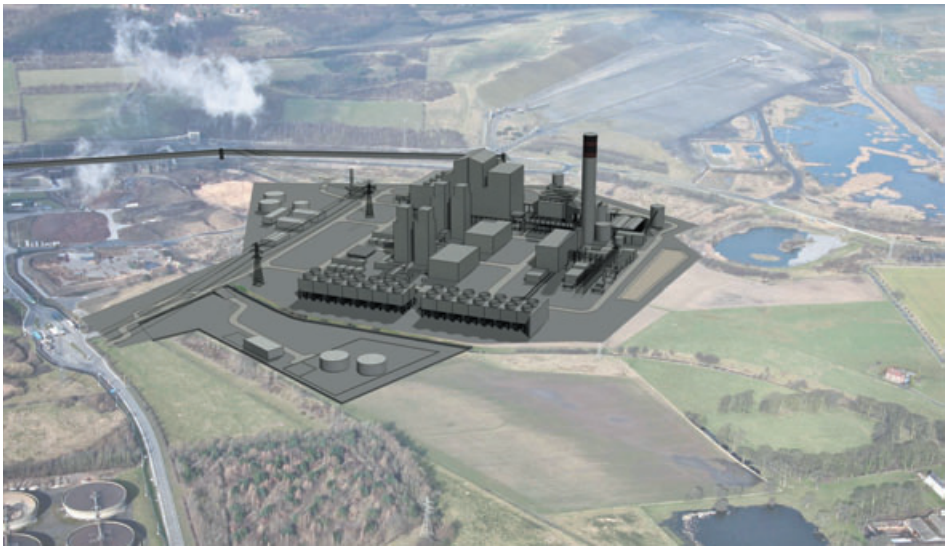
www.ico2n.com

Projects and policy news

White Rose project awarded EU funding

www.whiteroseccs.co.uk

Up to €300M has been awarded to the White Rose CCS project in the UK under the EU NER300 funding competition second call for proposals.



Developed by Capture Power Limited, a consortium between Drax, Alstom and BOC, the proposed 426MW coal power plant, located near Selby in North Yorkshire, will be equipped with CCS technology from the outset and 90% of all the CO2 produced by the plant will be captured and transported by pipeline for permanent storage beneath the North Sea.

As part of an ongoing formal consultation programme, local residents are being invited to attend public exhibitions next week to view the latest plans. Exhibitions are being held at Selby Town Hall on Tuesday, 15 July, the Junction at Goole on Wednesday, 16 July and Drax Sports and Social Club on Thursday, 17 July. The exhibitions are open from 2pm to 8pm.

Dr Luke Warren, Chief Executive of the Carbon Capture and Storage Association

“Today’s announcement of the award decision to the White Rose CCS project is great news indeed, and represents a real step forward for CCS in Europe.

White Rose is one of the two CCS competition projects in the UK and there are a number of others outside this competition also in development. It is encouraging that the European Commission is able to support the UK’s efforts to commercialise CCS.

Globally, CCS is a reality today and crucially the world’s first commercial-scale CCS project fitted to a power station – the Boundary Dam project – begins operation in Canada in September. Today’s announcement for White Rose will help to ensure that Europe can begin to catch up with those countries taking a lead on CCS.

To build on today’s announcement and maintain momentum in CCS in Europe, it is vital that CCS forms an integral part of the 2030 climate and energy package. If Europe is to remain competitive, decarbonise and ensure energy security, the use of CCS in power and industrial processes must be part of the package.”

Brad Page, Global CCS Institute CEO

“The UK’s White Rose CCS Project is planned to be the first large-scale oxyfuel project in the world with the ability to use biomass fuel for co-firing. This means that in addition to capturing nearly 90% of its carbon emissions, under the right circumstances it could reach zero or even negative emissions. This project, and several others at advanced stages of planning in the UK and mainland Europe, have the potential to reinvigorate CCS in Europe and help meet the world’s climate targets.”

Dr. Graeme Sweeney, Chairman of ZEP

“This decision sends a strong and positive signal, reaffirming the importance of CCS deployment and that we must keep pushing European projects with the continued support both at EU and Member State level. ZEP’s modelling shows that in the coming years CCS can create and secure an estimated total of 330,000 jobs across Europe. The EU’s long-term goal of reducing GHG emissions by 80-95% by 2050 cannot be met cost-effectively without CCS. Achieving our emission reduction goals while maintaining Europe’s industrial base is also essential for competitiveness, job retention and job creation in Europe."

Dr Vivian Scott, Scottish Carbon Capture and Storage

“CCS technology is crucial to reducing carbon emissions from power plant and industry across the UK, Europe and worldwide. The White Rose project will demonstrate that the technology can deliver low-carbon power from coal, and will develop a North Sea CO[2] pipeline and storage infrastructure that can be utilised by other large CO[2] emitters, such as energy-intensive industry, in the Yorkshire and Humber region.

“The NER300 programme was created to support CCS following the European Council’s resolution in 2007 to deliver ‘up to 12 CCS demonstration projects by 2015’. So far, this ambition has struggled to be realised, and only a handful of projects remain in development. We must not lose sight of these schemes – the ROAD project in the Netherlands, the Captain project in Grangemouth and Don Valley in Yorkshire – which, together with White Rose and the Peterhead project in Scotland, have the potential to initiate the development of the North Sea as a globally significant region for CO[2] storage.

“EU Member States, the EC and new European Parliament are currently negotiating Europe’s 2030 climate and energy package. But while the EC recognises the need for CCS to help achieve the target of a 40% reduction in carbon emissions by 2030, it does not suggest any specific measures to support it.

“Proposals to strengthen the emissions trading scheme are welcome, but they will not deliver a carbon price sufficient to support CCS alone. Today’s announcement must be followed through with a strong commitment by heads of government to deliver CCS projects on coal and gas power plant, and on industry, and with tailored measures in the EU2030 package.”

Brown Coal Innovation Australia funds carbon capture pilot

www.bcinnovation.com.au

Brown Coal Innovation Australia (BCIA) has awarded funding to a research and development project in Victoria, Australia.

The project, selected in BCIA's 2013/14 competitive R&D funding round, will target significantly reduced carbon emissions from brown coal power generation and also aims to slash the capital and operational costs for large-scale carbon capture plants.

BCIA has received multi-million dollar funding from the Victorian Government and the Australian Government via a relationship agreement with Australia National Low Emissions Coal R&D (ANLEC R&D). The ANLEC R&D relationship agreement provides for BCIA to manage ANLEC R&D's brown coal energy research portfolio.

BCIA has awarded $650,000 towards the research project which will combine CSIRO (Commonwealth Scientific and Industrial Research Organisation) CO2 capture innovation with that of major Japanese technology vendor IHI Corporation. The project targets a 40 per cent reduction in the energy usage of current plant post combustion capture (PCC) processes for Victorian brown coal-fired power plants. Capturing CO2 requires significant power and consequently increases energy costs. There are currently about 25 pilot-scale PCC processes operating throughout the world seeking to reduce this energy penalty.

BCIA Chief Executive, Dr Phil Gurney, said: “This research project is targeting a 40 per cent reduction in energy use of current post combustion capture (PCC) processes and will see the installation of a $1 M Japanese-built PCC pilot plant at AGL Loy Yang Power station, the first in Victoria to operate around the clock. The expected reduction in energy usage – as targeted by this project – would lead to significant savings in the cost of energy supplied to the consumer compared to implementing carbon capture using first-generation PCC plant."

“This project entails a two-year evaluation of two advanced liquid absorbents, two advanced process designs and an advanced gas/liquid contactor. The combination of these three aspects represents a significant step forward in PCC technology application for Victorian brown coal-fired power stations. Additionally, this research project is unique because it denotes a major collaboration between internationally renowned technology provider, IHI Corporation, and Australia's national research institute; CSIRO,” Dr Gurney said. “The collaboration is a world-first evaluation of a technology provider-developed PCC process in flue gases from Victorian lignite-fired power.”

Monash University PhD-student, Mai Bui, records data from CSIRO's existing post-combustion carbon capture pilot plant located at the AGL Loy Yang brown coal power station in the Latrobe Valley, Victoria; image courtesy of CSIRO

In the first year of the research program, a 0.5 tpd CO2 capture pilot plant - incorporating an advanced, low-pressure packing material - will be designed and manufactured by IHI in Japan. The plant will then be transported to Australia and re-commissioned at AGL Loy Yang Power station in Victoria's Latrobe Valley. The combination of three new technology innovations - simultaneous improvements in capture agents, equipment and process design - is expected to deliver almost a 40 per cent reduction in the absorbent energy requirement of the pilot plant compared to a standard amine process.

UK and Australia join on CCS research

www.ukccsrc.ac.uk
www.co2crc.com.au

The UK Carbon Capture and Storage Research Centre (UKCCSRC) and the Co-operative Research Centre for Greenhouse Gas Technologies (CO2CRC) will collaborate.

The two organisations signed an MoU which formalizes an already strong relationship. Last month, UKCCSRC announced £2.5 M funding for CCS research including the project Quantifying Residual and Dissolution Trapping at the CO2CRC Otway Project Injection Site, which excitingly involves collaboration with CO2CRC and provides UK researchers the opportunity to conduct research at the unique Otway subsurface research site.

In addition, last year, UKCCSRC funded an Early Career Researcher (ECR) exchange programme which saw students being funded to undertake research at Australian institutions.

This MoU brings together two of the world's leading CCS research organisations whose breadth and expertise combined is a huge boost to international collaboration on CCS research.

2Co Energy to sell Don Valley CCS project

www.2coenergy.com

2Co Energy is in negotiations to sell the project to Norwegian CCS technology company Sargas AS

2Co Chief Executive Lewis Gillies said that the company was focussed on its core business which is enhanced oil recovery (EOR) and that the development of CCS projects would make EOR a reality for the UK.

The Don Valley Power Project (DVPP) is at an advanced stage of development with some £60million already having been spent on the power plant. It also already has its planning permission, agreement for connecting to the national grid and various licences in place, including for the supply of water to the plant. National Grid Carbon will transport the captured carbon dioxide by pipeline and store it permanently in a saline formation in the southern North Sea.

The project is the only one in the UK to benefit from an EU grant awarded under the European Economic Programme for Recovery (EEPR). This €180 million grant continues to be essential in funding the project to the point where the final investment decision will be made.

In large part due to the EU funding the project is sufficiently advanced to come into operation immediately after the projects in the government's CCS Commercialisation programme. It would be the first project to follow on from Yorkshire's White Rose project benefitting from the significant cost savings to be had from using the same CO2 transport and storage infrastructure and demonstrating the cost benefits of developing a cluster of projects in the Yorkshire–Humber area.

"Sargas has CCS technology ready to be deployed at an industrial scale that is more energy efficient and, as a result, lower cost than all currently available alternatives," said Trevor Nash, Chief Executive, Sargas. "We have looked at potential CCS projects globally and have been attracted to the UK by the advanced stage of thinking on the policy support for renewable and low-carbon energy. DVPP is unique in having both EEPR funding to help the project through the development phase and the prospect of a Contract for Difference from the UK government to support the operation of the plant. It's an exciting project we will press forward with urgently."

Capturing CO2 emissions needed to meet climate targets

www.pik-potsdam.de

A study from the Postdam Institute for Climate Impact Research supports CCS as a key policy in mitigating climate change.

Technologies that are discussed controversially today may be needed to keep the future risks and costs of climate change in check, says the study, "The role of technology for achieving climate policy objectives: overview of the EMF 27 study on global technology and climate policy strategies," published in the journal Climatic Change.

It is based on the analysis of 18 computer models by an international team of scientists under the roof of the Stanford Energy Modelling Forum (EMF 27).

Combining the production of energy from fossil fuels and biomass with capturing and storing the CO2 they emit (CCS) can be key to achieving current climate policy objectives such as limiting the rise of the global mean temperature to below 2 degrees Celsius.

"Versatile technologies seem to be most important to keep costs in check," says lead author Elmar Kriegler from the Potsdam Institute for Climate Impact Research. Both bioenergy and CCS can help reduce emissions from non-electric energy use that would be hard to decarbonize otherwise.

Examples are the burning of coke in blast furnaces in the steel industry which can be equipped with CCS, and the combustion of petrol for transport which can be replaced by biofuels. "If combined, energy from biomass and CCS can even result in withdrawing CO2from the atmosphere and hence compensate remaining emissions across sectors and over time, because grasses and trees absorb CO2 before they are used to produce energy," explains Kriegler.

In contrast, the availability of individual low carbon technologies in the electricity sector was shown to be less important. This is due to the fact that the electricity sector has a number of mitigation options, like nuclear, solar, and wind power, but also gas and coal power with CCS. So the lack of one of them can more easily be compensated by the others.

Many simulations in the study could not at all achieve emissions reductions in line with the 2 degrees target without the use of bioenergy combined with CCS. Among those that could, mitigation costs on average more than doubled in scenarios without CCS. "Concerns regarding bioenergy and CCS are highly relevant, but given the potential importance of these technologies, it becomes clear that their opportunities and risks urgently need to be investigated in greater detail,"

Tees Valley CCS project hires coordinator

www.teesvalleyunlimited.gov.uk
www.pale-blu.com

Pale Blue Dot Energy has been awarded a 12 month contract to build the business case for developing an industrial CCS network on Teesside in the UK.

As project Co-ordinator, Pale Blue Dot Energy will design how the carbon will be captured from an initial four industrial plants on Teesside, determining the best location for where the carbon will be stored, and establishing how the gas will be transported to the storage site.

During the next 12 months, it also will research and draw up a compelling business case for installing the infrastructure in Teesside by commissioning and managing a range of specialists in order to provide the necessary information including costings.

Tees Valley Unlimited has been liaising with industry, including the North East Process Industry Cluster (NEPIC) and the Process Industry Carbon Capture and Storage Initiative (PICCSI), about the project, which has the potential to lower industrial emissions, enhance the competitiveness of key industries, and develop a competitive location to invest in new plants.

The scheme would be the first UK CCS network purely based on industry and has been driven by demand from companies.

Stephen Catchpole, Managing Director of TVU, the Local Enterprise Partnership for Tees Valley, said: "This is a significant step forward in our ambitions to create a low carbon industrial cluster in Tees Valley.

"CCS infrastructure will provide a vital extra reason for chemical and industrial companies to invest in Tees Valley and will help push Tees Valley ahead of the global and European game in relation to CCS."

The Tees Valley project work builds upon the significant CCS track record that the Pale Blue Dot Energy team already has from working on UK CCS projects.

Pale Blue Dot Project Manager Ian Phillips commented "Whilst Pale Blue Dot Energy has only been trading since August 2013, our team has been working on CCS power projects since 2007. We are delighted to be working on such a visionary initiative – decarbonising our industrial emissions is every bit as important as reducing emissions from power generation, and has been a much-neglected area in the low-carbon debate".

Stan Higgins, NEPIC Chief Executive Officer, said: "The development of a CCS network is crucial to helping Teesside industries meet the climate change agenda.

"In addition, it will act as a stimulus in attracting environmentally-focused companies to locate to Tees Valley, which will contribute to the area's future economic prosperity."

Linde and Solidia Technologies work on using CO2 for concrete production

The U.S. start-up Solidia Technologies has signed a partnership agreement with The Linde Group to industrialize an innovative technology that could reduce the environmental footprint of pre-cast concrete.

The collaboration will include the development, demonstration and commercialization of Solidia's CO2-based concrete curing technology. A global leader in the international gases market and engineering, Linde will work with Solidia to demonstrate the feasibility of commercial-scale production.

"Linde will bring CO2 supply and delivery expertise including engineering of application-specific equipment to contribute to this joint development. This project marks an important step in proving and enhancing our CO2 management capabilities," said Dr Andreas Opfermann, Head of Clean Energy and Innovation Management at Linde. The two companies will also collaborate to market the technology as a new solution for the pre-cast sector.

Solidia's CO2-based concrete curing technology uses Solidia Cement™ manufactured using the novel chemistry developed by Solidia. The patented technology allows lower CO2 emissions in the cement production process and involves the capture of CO2 in precast concrete manufacturing. Overall, CO2 emissions could be reduced by up to 70 percent.

The technology offers manufacturers significant cost savings compared to water-based curing of conventional cement based on faster curing times, lower energy and raw material consumption, reduced waste generation, and reduced labor requirements, says Linde.

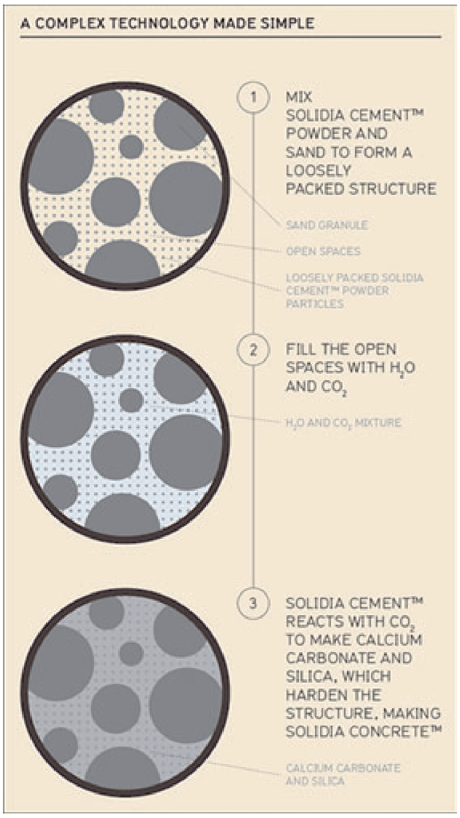
Cement production is responsible for three to five percent of total global carbon emissions, and global demand for concrete products is second only to the demand for water. Cement manufacturers have committed to reducing their carbon footprint but are often constrained by their assets and chemistry.

By helping develop a means of transforming CO2 into a valuable commodity for one of the world's largest industries, the collaboration will help speed the market and social impact, recategorizing CO2 as a catalyst for profitability and growth.

"As collaborators with a global reach and decades of technological and market knowledge, industry leaders such as Linde play a significant role driving innovation to market," said Solidia President and CEO Tom Schuler. "

"Linde's expertise in gas delivery and equipment engineering enables rapid commercialization by freeing us to focus on the development of our core technology. Likewise, our technology gives Linde access to a large, new market that would not exist without Solidia."

The Cement Sustainability Initiative of the World Business Council for Sustainable Development set 2050 CO2 reduction targets for the global cement industry. If the industry were to adopt Solidia's technologies today, it would achieve those 2050 goals by 2015



Solidia's CO2-based concrete curing technology can reduce CO2 emissions

More information

www.the-linde-group.com
www.solidiatech.com

Capture and utilisation news

FTIR gas analyser in use at UK carbon capture research centre

www.quantitech.co.uk

Quantitech has commissioned an advanced Gasmet FTIR multiparameter gas analyser at the UK Carbon Capture & Storage Research Centre (UKCCSRC) facility.

The analyser is in use at the Pilot-scale Advanced Capture Technology (PACT) facility near Sheffield, which supports both industrial and academic research.

The Gasmet DX4000 FTIR analyser was supplied and configured by Milton Keynes based Quantitech and delivered with a sampling system and heated sample lines so that hot, wet and corrosive gases can be measured.

"The FTIR gas analysis performs a vital role in our work with all carbon capture methods; enabling us to monitor CO2 levels in addition to almost any other gas from the Gasmet library of over 5,000 compounds," said PACT Business Development Manager Dr Kris Milkowski, from the University of Leeds.

In most applications we would recommend a fixed continuous emissions monitoring system (CEMS) for such applications, said Quantitech Sales Director Dominic Duggan, however, as a research site, the PACT facility requires maximum flexibility in its resources, so the portability of this system is ideal for PACT's work.

Quantitech's FTIR gas analyser is being used at the UK's Pilot-scale Advanced Capture Technology (PACT) facility

Inventys raises funds from major investors

www.inventysinc.com

Inventys Thermal Technologies closes financing from Chevron Technology Ventures, Mitsui, Roda Group & Chrysalix to advance its carbon capture technology.

Building on continued funding support from international venture capital firm, Mitsui Global Investment (MGI), and leading cleantech investor, The Roda Group, the financing also included new participation from Chevron Technology Ventures LLC (CTV), the Venture Capital arm of Chevron Corporation, and Chrysalix Energy Venture Capital, one of the longest serving cleantech venture capital firms. The funding will be used to expand manufacturing and enable the deployment of full-scale systems with leading energy and manufacturing companies in late 2016.

Inventys' gas separation system, VeloxoTherm™, is based on a proprietary low-pressure Temperature Swing Adsorption (TSA) technology resulting in a carbon capture cost of USD $15 per tonne - one third the cost of current post-combustion solutions.

"At a fraction of the size of other systems, the flexibility to integrate into new and existing combustion and chemical processes, and the unique ability to regenerate the CO2-saturated adsorbent using minimal energy, Inventys' approach enables the widespread adoption of CO2 enhanced oil recovery (EOR) and carbon capture and sequestration (CCS) while helping customers reduce their environmental footprint," the compamny said.

This financing comes after a successful in-house, full system pilot incorporating real flue gas and industrial hardware from Howden, and the announcement that former U.S. Energy Secretary, Dr. Steven Chu, has joined the Inventys Board of Directors.

"We believe we have developed the most viable carbon capture technology to leverage the abundance of man-made waste CO2 for the production of a valuable product – oil - while also sequestering CO2 from large carbon emitters," said Andre Boulet, CEO of Inventys.

"The Roda Group is a long-time supporter of Inventys recognizing early on its potential to fundamentally change the way we produce energy," confirmed Dan Miller, Managing Director of The Roda Group. "We invest in passionate, proven teams that stand to deliver products with enormous market opportunity and make a positive impact on the world. The Inventys team is just that and together, we have the ability to advance the EOR market while curbing the planet's greenhouse gas emissions."

Mantra established in the United Kingdom

www.mantraenergy.com

Mantra Venture Group Ltd. has announced the incorporation of Mantra Energy Alternatives UK Ltd. The UK subsidiary has been established to pursue specific funding and collaboration opportunities arising from previous visits to the country by Mantra's management.

"After exploring and identifying promising collaboration opportunities in the UK, we have established the subsidiary to advance them to the next level," said Patrick Dodd, VP of Corporate Development. "We are very optimistic about these opportunities, due to the novelty of our technologies and the quality of the collaborators we are working with there."

Mr. Dodd will be meeting with these collaborators when he returns to the UK in mid-September as part of the Canadian Manufacturers & Exporters' (CME's) Automotive Trade Mission. The CME mission will introduce and promote the Canadian delegation to players in the UK's auto sector, including meetings at the facilities of universities, research organizations, and automakers, and concluding with the Cenex Low Carbon Vehicle Event. Described as "the UK's premier low carbon vehicle event", the exhibition will host the sector's major players and demonstrations of the state of the art in low carbon transportation.

Mantra's ERC converts CO2 into useful products such as formic acid

"The CME mission is an excellent platform from which to promote Mantra's MRFC technology, which is very compelling for transportation applications and is patented in the UK," continued Mr. Dodd.

Mantra Venture Group Ltd. is a clean technology incubator that takes innovative emerging technologies and moves them towards commercialization. The Company, through its subsidiary Mantra Energy Alternatives, is currently developing two groundbreaking electrochemical technologies designed to make reducing greenhouse gas emissions profitable, ERC (Electro-Reduction of Carbon Dioxide) and MRFC (Mixed-Reactant Fuel Cell).

ERC is a form of "carbon capture and utilization" (CCU) that converts the polluting greenhouse gas carbon dioxide into useful, valuable products including formic acid and formate salts. By utilizing clean electricity, the process offers the potential for an industrial plant to reduce emissions while generating a salable product and a profit.

The MRFC is an unconventional fuel cell that uses a mixture of fuel and oxidant, thereby greatly reducing the complexity and cost of the fuel cell system ideal for portable applications.

Transport and storage news

U.S. DOE selects CO2 storage projects for funding

energy.gov

The U.S. Department of Energy (DOE) announced the selection of 13 projects to develop technologies and methodologies for geologic storage of carbon dioxide.

The projects selected by DOE will develop technologies, methodologies, and characterization tools to improve our ability to predict geologic storage capacity, understand geomechanical processes, and add to the safety of geologic storage.

The total value of the projects is approximately $17.6 million over three years, with $13.8 million of DOE funding and $3.8 million of non-federal cost sharing.

Managed by the NETL, the selected projects have been awarded in two areas of interest: "Geomechanical Research" and "Fractured Reservoir and Seal Behavior."

National Grid awards contract for CO2 pipeline

www.nationalgrid.com

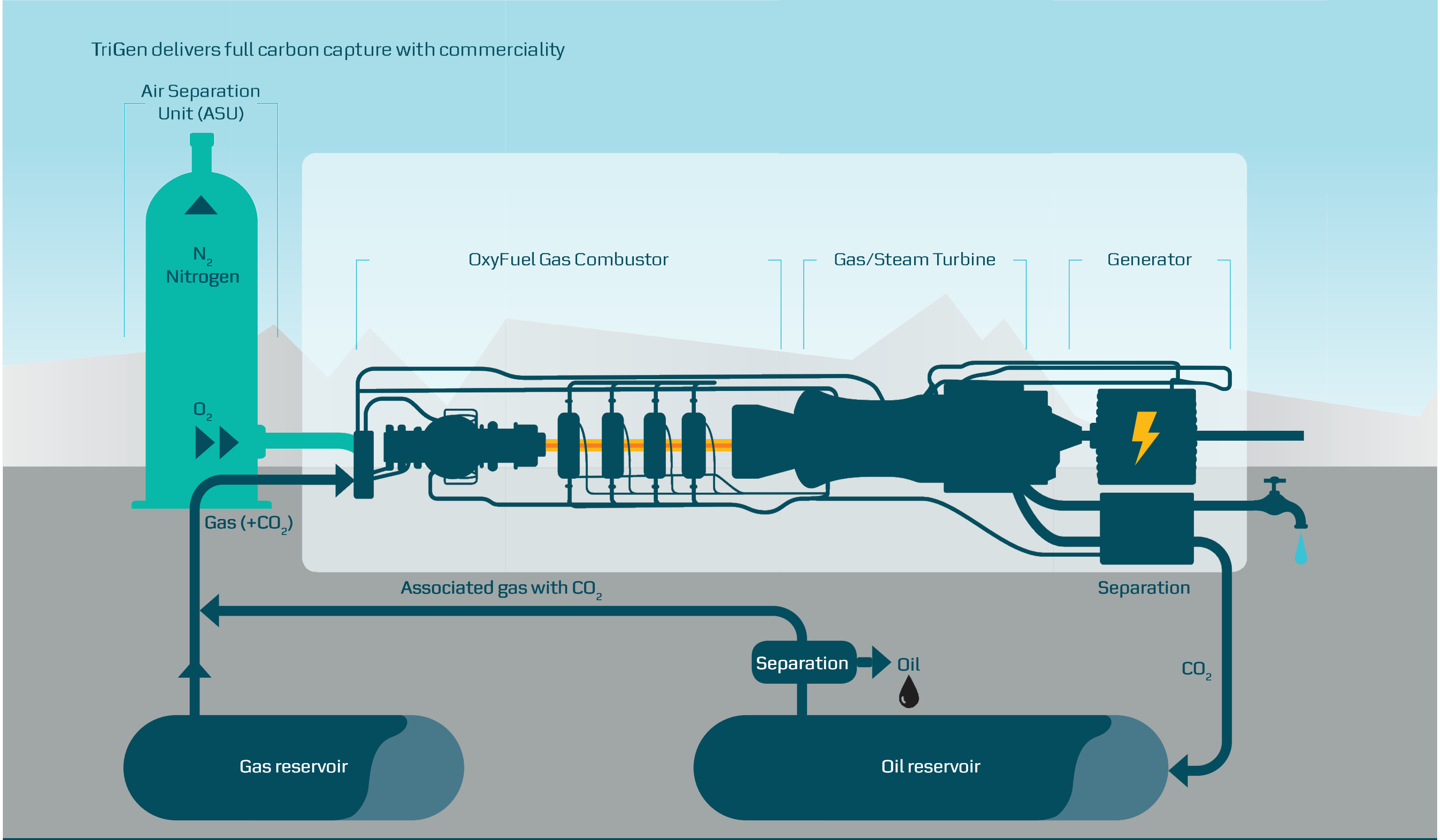
National Grid Carbon Limited (NGC) has awarded the Front End Engineering and Design contract for its carbon capture and storage pipeline to oil and gas engineering specialists Genesis.

Genesis Oil and Gas Consultants will carry out the risk evaluation and cost estimates as well as the engineering and design work associated with the transportation and storage system. This will run from Drax power station in Humberside in the UK to the storage site in the North Sea.

This follows the Government's announcement last December that the White Rose project could begin its FEED study as part of its CCS commercialisation programme. National Grid Carbon is providing the transportation and storage elements for the CCS project.

National Grid Carbon is working with Capture Power Limited, a consortium of Alstom, Drax and BOC on the White Rose project to capture carbon dioxide emissions and store them permanently in the North Sea.

The onshore and offshore pipeline infrastructure will have the capacity to transport up to 17 million tonnes of CO2 a year with the White Rose project requiring about 2 million tonnes. The CO2 would then be pumped in liquid form under high pressure into natural rock formations over a kilometre beneath the North Sea seabed for permanent storage.



The TriGen™ Oxycombustion Process by Maersk Oil

Clean power for over 100,000 homes while boosting oil recovery

Net electric power
200 MWe

Pure water
0.5 MGD

Maximize
oil recovery
7000 bbl/d

TriGen produces clean energy, pure water and 'reservoir ready' CO_2 by burning natural gas with pure oxygen. The oxygen is first obtained from an Air Separation Unit (ASU) that also produces significant quantities of nitrogen that can be used for fertilizer or reservoir pressure maintenance.

As all of the TriGen products are useful, it enables zero emission energy from fossil fuels. Maersk Oil is working on developing commercial scale power projects that enable CO_2 EOR projects and is available to discuss potential collaboration opportunities globally. A single train TriGen plant can deliver:

- Up to 200 MW clean electricity net
- 500,000 gallons/day pure water
- Up to 45 mmscfd 'reservoir ready' CO_2 which can then produce ca. 7000 bbls/d incremental oil via Enhanced Oil Recovery (EOR)

Explore more at **maerskoil.com** and **maerskoiltrigen.com**

MAERSK OIL