Carbon Capture Journal

CCS in the UK

UK restarts CCS ambitions with Clean Growth Strategy

£129 billion net economic benefit of CCS to UK

Econic turning waste CO2 into plastics

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Testing CO2 monitoring at CMC's Field Research Station in Canada

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- Climeworks combines CO2 direct air capture with geological storage
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OGCI and Shell CEO talk carbon capture at Offshore Europe

There were some discussions about carbon capture at Offshore Europe, the oil and gas trade show in Aberdeen on September 5-8 – including some thoughts from Shell's CEO Ben van Beurden, and an update from Gerard Moutet, Executive Board Chair of the Oil and Gas Climate Initiative, a group of 10 oil major CEOs.

By Karl Jeffery

Ben van Beurden, CEO of Shell, said he had two regrets about carbon, speaking in the plenary session of Offshore Europe.

He regretted that "we haven't been harder hitting on the price of carbon," although saying that "we have been pushing for a carbon price for decades."

Currently, without a carbon price, "it doesn't make commercial sense to do it [CCS]", he said.

The oil industry needs a price of carbon because "we need parameters that compel and motivate us to invest in these things."

"Don't expect us to inflict self-harm. Do expect us to put our money where our mouth is when conditions are there," he said.

"Ultimately, if you look at climate change, it is all possible and viable, and it is not going to tank the world economy."

He also admitted that it may have been a mistake for oil companies to promote CCS as a solution for power generation (rather than for industry) – because in gas and power, it relies on Shell's customers (who buy gas to burn in power stations) to do it.

CO_2 emissions from industries of all kinds are as large as CO_2 emissions from power generation, and this includes plants which oil companies run, such as petrochemical plants.

For now, governments appear to think that reducing CO_2 is "all about renewables," he said.

"We were involved in a CCS project in Scotland pulled at the 11th hour due to different priorities in the [UK government] Treasury."

"Without CCS there is no hope to meet the Paris commitments. It is not going to happen automatically. At some point people will wake up. CCS will come back and we have to be ready for it."

The cost of CCS will drop once it gets installed. The cost of CCS "has to go through the same cost curve as renewables," he said.

Also in the Offshore Europe plenary session, BP's CEO Bob Dudley said that if the industry is going to be able to promote gas as a "natural transition fuel" (between coal and renewables), it needs to get away from criticism about methane leaks, with methane being a major greenhouse gas. "It is the Achilles Heel of a natural low carbon fuel," he said.

BP is part of an industry wide scheme to find out what the methane leaks actually are, and to eliminate flaring.

OGCI

The latest developments and thinking of the Oil and Gas Climate Initiative (OGCI), an organisation of 10 oil majors, was presented with by Gerard Moutet, executive board chair of OGCI, with a lunchtime talk at Offshore Europe in Aberdeen in September, one of the world's largest oil and gas events.

Mr Moutet is formerly VP Climate Energy with Total (2009- 2015), and before that general manager of Total Norway and VP for fields geosciences with Total headquarters.

OGCI has committed to spend $1bn on reducing greenhouse gas emissions, and set up an investment body, with a CEO and London office, to work out how to spend it.

The members are BP, China National Petroleum Corporation (CNPC), ENI, PEMEX, Reliance, REPSOL, Saudi Aramco, Shell, Statoil and Total.

OGCI has identified carbon capture and storage, measuring and reducing methane emissions, and transport efficiency, as methods it could reduce greenhouse gas emissions, based on the impact of the method and the amount of influence the industry has over introduction of the technology.

The organisation is mainly looking for technological investments it can make.

OGCI does not have any plans to lobby, for example for a carbon tax or carbon price. And also, there is not a consensus among the members about which such regulation would be best. "We have to focus on the subject where all the companies are at ease to do it," he said.

Mr Moutet describes Carbon Capture Utilisation and Storage (CCUS) as a "very important but difficult subject", mentioning the many CO_2 studies which show that keeping temperature rise under 2 degrees will be much more expensive if CCUS is not used.

"Let's be realistic, it is not moving as fast as it should be," he said. "It should happen faster. I don't have a magic bullet - if I had it, it would happen."

The main problem with CCS is "there's no business model", Mr Moutet said. Oil and gas companies are "process organisations", and there is no rational basis to do it. However history has shown that when there is a rational basis to do it, as we saw with the Sleipner project in Norway – the Norwegian government put a price on CO_2 emissions and the industry did carbon capture.

More information

Read the full report on the CCJ website.

www.oilandgasclimateinitiative.com

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Front cover:

The $7 million Field Research Station, built by CMC Research Institutes and operated by its Containment and Monitoring Institute, will play a pivotal role advancing the commercialization of carbon storage and helping industry better understand the movement of fluids underground

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UK restarts CCS ambitions with Clean Growth Strategy

The UK Government has released its long anticipated Clean Growth Strategy which sets out how the UK can meet its climate goals while benefitting from low carbon technologies. Measures include funding for R&D and international collaboration, marking a fresh approach and reaffirmed commitment to CCUS in the UK.

The plan was widely welcomed as a new approach to CCUS in the UK, but needs more detail on how the strategy will be delivered, and a clear indication as to whether the UK is going to take a lead in implementing CCUS globally.

The report says that there is a broad international consensus that carbon capture, usage and storage (CCUS) has a vital future role in reducing emissions. This could be across a wide range of activities such as producing lower-emission power, decarbonising industry where fossil fuels are used and/or industrial processes as well as providing a decarbonised production method for hydrogen which can be used in heating and transport.

This makes CCUS a potentially large global economic opportunity for the UK. The International Energy Agency estimates there will be a global CCUS market worth over £100 billion - with even a modest share of this global market, UK GVA could increase to between £5 billion and £9 billion per year by 2030.

However, the current technology is expensive and there are only 21 large-scale plants operating, or in construction, across the world – of which 16 rely on revenue from providing carbon dioxide for enhanced oil recovery.

The Clean Growth Strategy is underpinned by three commitments: to reduce emissions in the most cost-effective way: to maximise innovation to develop world leading technologies and to seek the maximum possible benefits from investment for improving the productivity of the UK economy.

"While we have explored ways to deploy CCUS at scale in the UK since 2007, the lack of a technological breakthrough to reduce the cost of CCUS and the cost structures and risk sharing that potential large-scale projects have demanded has been too high a price for consumers and taxpayers. It is clear from the relative lack of deployment of the technology that other governments have reached a similar conclusion."

"However, we have continued to invest in innovation and technology development both in the UK and overseas. To date we have invested over £130 million in R&D and innovation support to develop CCUS in the UK, supporting the development of technologies including NET Power's Allam cycle, Carbon Clean Solutions and C-Capture."

"We are also one of the leaders in providing aid support to CCUS internationally through our support to CCUS pilot projects in countries with a fossil fuel-intensive energy sector, such as Mexico, South Africa, and Indonesia."

Investing in cutting edge technology to achieve global cost reductions in CCUS

The Government provided £7.5 million for the early development support to the UK invented Allam cycle technology used by NET Power. This technology has the potential to capture 100 per cent of the carbon dioxide emitted at a cost similar to that of an unabated Combined Cycle Gas Turbine (CCGT).

"This early support from the Government in a cutting edge technology has been critical to developing the technology and for the 8 Rivers NET Power project to reach demonstration scale. In March 2016, construction began on the NET Power pilot project, a 50 MWth first-of-its-kind natural gas-fired power plant located in Texas and the plant is expected to start operations in late 2017."

"The pilot project also includes significant UK content with two UK companies – Goodwins Steel Castings Ltd and Heatric involved in the project. We now see a new opportunity for the UK to become the global technology leader for CCUS, working internationally with industry and governments to bring about global cost reductions."

"We will do this through re-affirming our commitment to deploying CCUS in the UK subject to cost reduction. We will build on the success of the Offshore Wind Cost Reduction Taskforce and convene a CCUS Cost Challenge Taskforce to deliver a plan to re-

Key measures

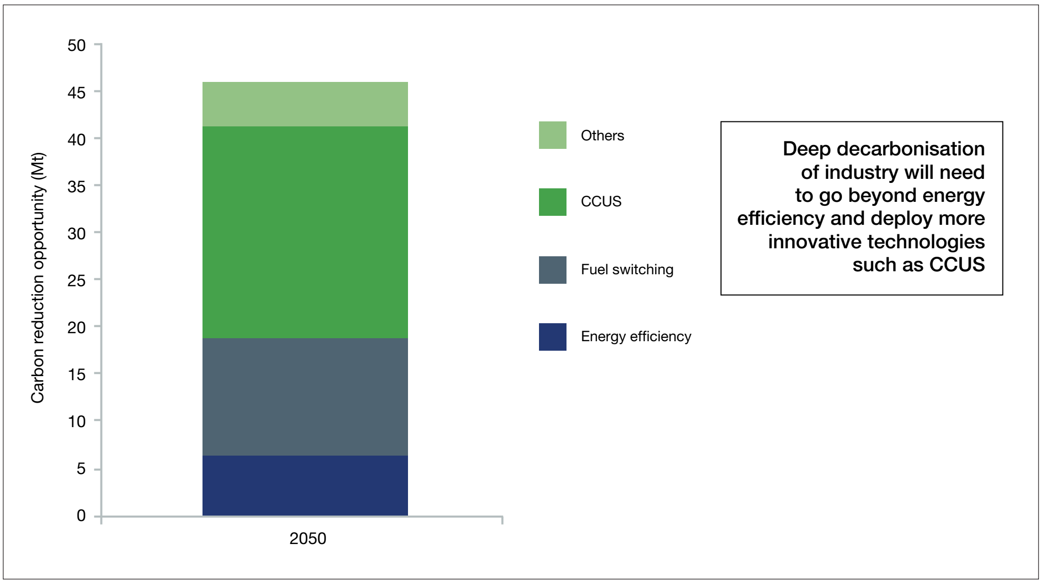
The strategy includes several measures for CCUS, specifically:

- Up to £20 million in a Carbon Capture and Utilisation demonstration programme plus up to £100m for industry collaborations
- A new CCUS Council to look at the option of deploying CCUS at scale in power and industry
- A CCUS Cost Challenge Taskforce to deliver a plan to reduce the cost of deploying CCUS, with the ambition to deploy at scale from 2030 if costs come down
- Lead an international working group and organise a Global Carbon Capture Usage and Storage Conference in 2018 with international partners

duce the cost of deploying CCUS. This will then underpin a deployment pathway for CCUS in 2018, setting out the steps needed to meet our ambition of deploying CCUS at scale during the 2030s, subject to costs coming down sufficiently."

"This will include looking at the options for permanent storage of carbon dioxide domestically as well as elsewhere via international shipping."

"Following the advice from the Parliamentary Advisory Group on CCUS the Government will review the delivery and investment models for CCUS in the UK to understand how the barriers to deployment can be reduced, and how the private and public sectors can work together to deliver the Government's ambition for CCUS."



Carbon reduction opportunities across industry (2050). Source: 2050 Roadmaps Cross-Sector Summary report (2015). This illustrates the technical potential for emissions savings in the report's 'MAX TECH' pathway

"We will work with the ongoing initiatives in Teesside, Merseyside, South Wales and Grangemouth to test the potential for development of CCUS industrial decarbonisation clusters. We will set up a new Ministerial-led CCUS Council with industry to review our progress and priorities. Through the CCUS Council we will also monitor costs and deployment potential with the option of revising our deployment path accordingly."

International collaboration

The Government also plans to convene and lead a new international working group to drive down the cost and accelerate deployment of CCUS. This will include:

• Participating in Mission Innovation and its Carbon Capture Challenge and working closely with private-sector led initiatives such as the Oil and Gas Climate Initiative;

• Developing closer collaborative working with countries such as Norway, the United States, Canada and Australia including joint working on innovation and carbon dioxide transport and storage solutions and working multi-laterally through the Carbon Sequestration Leadership Forum and North Sea Basin Task Force;

• Continuing to be a global leader in CCUS investments through the UK's £60 million international CCS programme which has been running since 2012, by investing a further £10 million in the programme. This will further strengthen international action on CCUS and draw on UK technical and commercial expertise; and

• Organising an international Global Carbon Capture Usage and Storage Conference in 2018 with international partners.

Innovation

The Government also plans to spend up to £100 million from the BEIS Energy Innovation Programme to support Industry and CCUS innovation and deployment in the UK including £20 million of funding available for a carbon capture and utilisation demonstration programme to invest in new innovative technologies that capture and utilise carbon dioxide.

The programme will support next generation capture technologies, with an aim to lower the cost of capture compared to the current best performing technologies; and small-scale industrial capture demonstrations to reduce the risks associated with carbon capture on an industrial site.

"We also intend to support the application of CCUS in low carbon hydrogen production; develop our understanding of the role of GGR technologies, including bio-energy with carbon capture and storage; and support innovations that reduce the cost of transporting and storing carbon dioxide."

The Government intends to set out further detail in 2018.

Investing in supporting new UK CCUS technologies and companies

The Government has provided over £4 million to support Carbon Clean Solutions Ltd, a UK headquartered company. This has supported the research, development and deployment of their novel carbon capture solvent technologies contributing to cost reductions in both the capital and operating costs of the technologies.

In early 2017, building on this early support from the UK Government, Carbon Clean Solutions launched an innovative carbon capture and utilisation project in India. In March 2017 Carbon Clean Solutions signed a partnership agreement with the global resource management company, Veolia, for a large-scale rollout of Carbon Clean Solution's carbon capture technology in a number of industrial processes.

More information

Download the Clean Growth Strategy from:

www.gov.uk

UK's Clean Growth Strategy shows welcome ambition but lacks firm commitment to CCS

Scottish Carbon Capture & Storage welcomed the report but said it fell short of the Government commitment needed to support CCS.

The UK Government has released its Clean Growth Strategy, which demonstrates a welcome recognition that investing in low-carbon technologies to help achieve international commitments on emissions reduction can bring benefits to the country's economy and jobs.

As a strong proponent of deploying full-scale carbon capture and storage (CCS) technology in the UK, Scottish Carbon Capture & Storage (SCCS) is encouraged by the Government's ambition to show international leadership in carbon capture usage and storage (CCUS), with up to £100 million of investment for innovation and the setting up of a new CCUS council.

However, we are concerned that this ambition is tempered by a series of caveats, which fall short of the clear government commitment that is needed to support the deployment of carbon capture and storage (CCS); that the funding proposed may not be sufficient to cover the demonstration projects needed to reduce the costs of the technology; and that the timescales suggested in the strategy may not be realistic. It is not clear that the Clean Growth Strategy's policies represent a sufficient move forward from our current position on CCS delivery in the UK.

The government's own advisory body, the Committee on Climate Change, has stated that the fifth carbon budget (2028-32) will be very difficult to hit without CCS. Studies show the essential contribution of CCSto cost-effective UK decarbonisation and point to the heavy costs that will be imposed on UK consumers by a failure to enact an effective CCS policy.

A recent study by Summit Power shows that the development of a UK CCS industry – focused on an East Coast network – could provide a total economic and societal benefit of £163 billion in the period to 2060, including £54 bn of domestic economic activity with over 225,000 associated jobs and £9 bn of positive balance of trade.

The Clean Growth Strategy itself states that driving down carbon emissions from our own activities "could provide a real national economic boost", with the UK low-carbon economy growing by an estimated 11% per year between 2015 and 2030. CCS is an integral part of that growth but it needs sufficient and timely investment. We are extremely concerned that the strategy will be found lacking, and that the opportunity for new jobs and economic growth could be lost as a result.

The government's ambition to have the option to deploy CCS at scale during the 2030s is welcomed, but it will require a stronger funding commitment to deliver the demonstration projects that will bring learning and cost reduction. The UK has an immense carbon dioxide (CO2) storage capacity, and existing oil and gas infrastructure that could be repurposed to transport CO2 (Peter A. Brownsort, Vivian Scott, R. Stuart Haszeldine.

Reducing costs of carbon capture and storage by shared reuse of existing pipeline – Case study of a CO2 capture cluster for industry and power in Scotland. International Journal of Greenhouse Gas Control. 52: 130-138. (2016)); however, there is no mention in the strategy of infrastructure development. Decisions on the value of preserving useful on or offshore transport infrastructure, such as oil and gas pipelines, need to be made quickly so we can avoid unnecessary costs in the future.

We have previously expressed our concerns about the potential impacts of outsourcing the UK's CO2 storage requirements to other countries, such as Norway. This would be a short-sighted solution, which would relinquish the opportunity to use the UK's own resources to develop our own CO2 storage industry. The UK should not give up the opportunity to generate revenue from the sale of CO2 storage services to other European states, or surrender any control of costs and availability of storage. With significant benefits to the UK economy at stake, we urge the government to avoid such a course of action and instead focus on supporting the development of CO2 storage in the UK.

There is no recognition in the strategy of the Lord Oxburgh report recommendation to create a CCS Delivery Company. This would manage construction and risk for early projects, deliver a transport and storage infrastructure that could be privatised when established, and could cut the cost of meeting UK climate targets by billions each year.

The cost of CCS is currently a significant barrier to its deployment, and we welcome the government's proposal to establish a CCUS Cost Reduction Task Force, which we hope will look in more detail at how a CCS Delivery Company could be set up and include this in its CCUS deployment pathway. We would welcome the opportunity to provide expertise to this task force and the CCUS Council.

The UK Government's position on CCS is positive but remains modestly funded and lacking in decisive action. Without an unambiguous and immediate commitment, the UK will lose its potential to be a global leader in the technology. We observe the intentions of other North Sea nations, such as Norway and the Netherlands, to operate CCS at scale in the 2020s and call upon the UK Government to match that ambition.

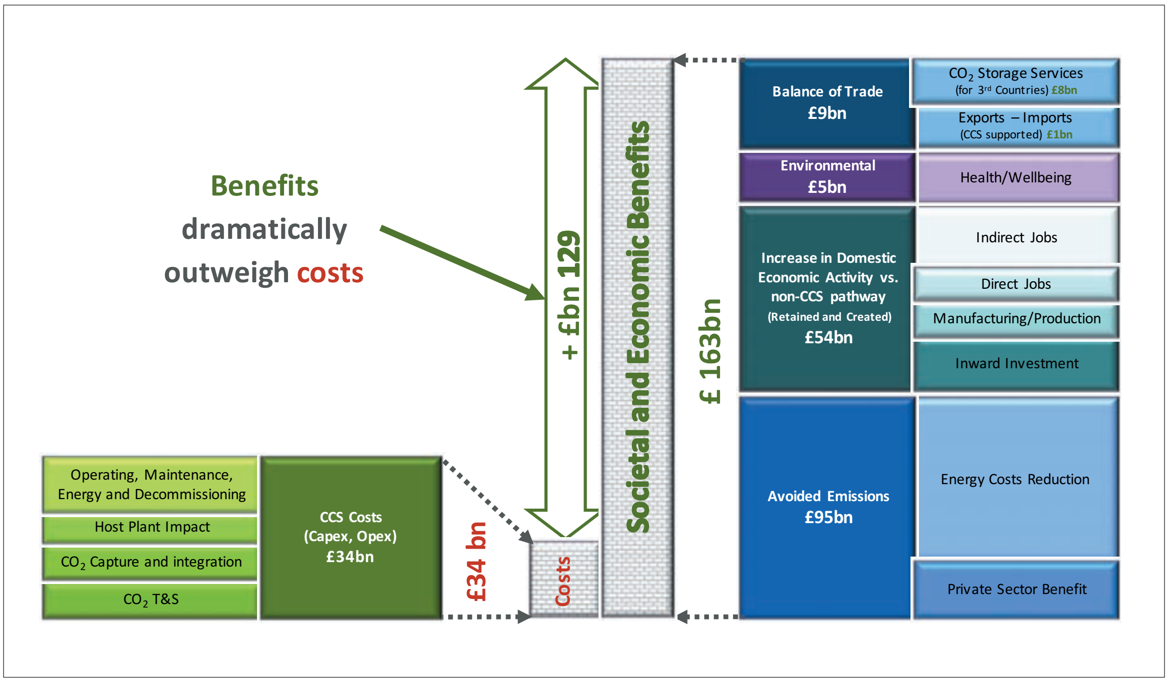
More information

www.sccs.org.uk

Study shows £129 billion net economic benefit of CCS to UK

Summit Power study shows that an East Coast CCS network could boost the UK economy by an estimated £160 billion between now and 2060. The report provides the first, quantified societal cost benefit analysis of a UK network of CCS investments and finds that the benefits of the scheme could outweigh costs by as much as £129 billion.

Under the proposed scheme, dedicated CO2 infrastructure would link clusters of major industry and power generation in Scotland, Teesside, the Humber region, and the South East, to CO2 transport and offshore storage infrastructure in the UK Continental Shelf. Importantly, the study shows that investments along the East Coast can be managed in steady and discrete phases to ensure each step is affordable and delivers the expected benefits.



How the Value of CCS Stacks-Up 2020 - 2060

Stephen Kerr, Project Director of the Caledonia Clean Energy Project, who led the study said, "This work reframes the understanding of how investing in infrastructure that cleans up industry, air quality, and even your gas boiler, can benefit all of us. The value to UK society is enormous: over £160 billion in added value to the economy and jobs numbers equivalent to the UK oil & gas sector. Summit Power's Caledonia Clean Energy Project is ready to deliver at Grangemouth, at the heart of an East Coast CCS Network."

"We've shown that for every £1 invested in Carbon Capture, the payback to the UK economy is almost £5. In the medium term, the strategic value to the UK in offering Europe-wide CO2 storage services is undeniable, and could more than double these numbers. We're already seeing Norway take a strategic lead in this area and its vital the UK isn't left behind. Strong leadership and a clear approach are now required to deliver carbon capture benefits in our economy, our industries and our climate"

The study was completed by Summit Power Caledonia, with industry and academic collaboration from Industria Mundum AG, Pale Blue Dot, Tees Valley Combined Authority and the University of Strathclyde.

Dr. Luke Warren, Chief Executive of the CCSA, commented, "This report is one of the most detailed cost benefit analysis of CCS carried out in the UK. The numbers – benefits of £163 billion versus costs of £34 billion – are staggering, and highlight the real value of CCS to the entire economy. "

"The benefits of CCS to multiple sectors such as industry, power, heat and transport demonstrate that CCS is integral to meeting the goals of the UK's industrial strategy, delivering sustainable regions and places that ensure a long-term future for vital industries.

""The value of CCS to the industrial regions of the UK is clearly understood and CCS projects have been proposed on the East Coast of England, Scotland and in the North West. It is critical that the Government sets out its new approach to developing CCS in the Clean Growth Plan in the next few weeks, and follows this up with concrete actions that enable 2 these projects to proceed, otherwise we risk losing out on the benefits of this vital technology."

More information

www.summitpower.com

www.ccsassociation.org

Turning waste CO2 into plastics

Econic Technologies has commercialised a catalyst developed at Imperial College London that enables manufacturers to use waste carbon dioxide to produce polyols, a key building block in polyurethane plastics, lowering CO2 emissions and saving money.
By Rowena Sellens, CEO, Econic Technologies

Much has been said and written about the global CO2 challenge and the levels of CO2 that need to be removed from the Earth's atmosphere to meet the Paris Agreement targets. Despite the breadth of opinion, what is evident is that there is no single or simple solution and almost certainly no one right answer to this obstacle in the foreseeable future. With the effects of CO2 already being felt by our atmosphere, we need to act – now.

At Econic Technologies, we are very excited to be commercialising technology that can contribute profitably, and in the near term, to the CO2 reduction agenda. It is our belief that being able to make money from an environmentally better process/product will contribute positively to the movement towards greener chemistry in general, and the capture and use of CO2 in particular. We also look ahead to further developments from our own catalyst technology platform that will unlock more opportunities to realise this potential.

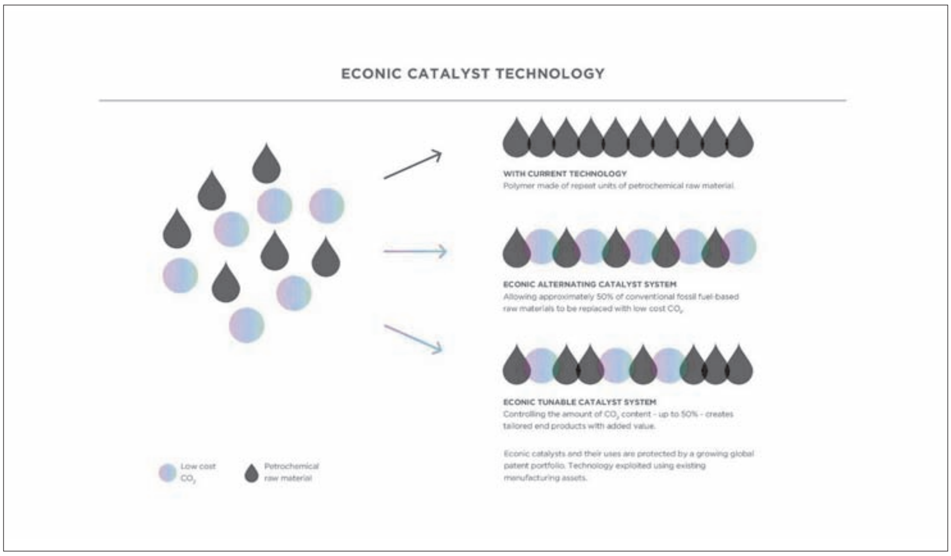


Fig. 1 - Schematic of Econic catalyst systems

Econic history

Founded in 2011 by Professor Charlotte Williams, who developed the basis of the patented catalyst technology invented whilst at Imperial College London (ICL), Econic was initially supported by Imperial Innovations (now Touchstone Innovations). In its six year life, the company has grown to include Jetstream Capital and Woodford Investment Management alongside Touchstone Innovations, all of whom are committed to remain invested throughout the company's journey to a profitable business that brings positive benefit to all. Expanding to over 25 employees, including 13 PhDs, the company is now based in a state-of-the-art laboratory facility at Alderley Park, just south of Manchester.

The technology has moved on over the past six years, which is reflected both in the growing company patent portfolio, and the breadth of our technical activities. As well as new catalyst research, our work covers all aspects of development that demonstrates the operational and commercial viability of the technology, providing evidence of its potential.

Econic catalyst technology's economic potential

Econic Technologies' pioneering catalyst systems enable manufacturers to use captured carbon dioxide emissions as a raw material feedstock, which reduces the requirement for environmentally demanding, oil-based feedstock. This enables producers to lower CO2 emissions and their feedstock costs significantly, creating potential economic and environmental benefits. In our first target market, the technology enables existing manufacturers to use waste carbon dioxide to produce polyols, a key building block in polyurethane plastics.

Polyurethanes are used widely. We encounter them every day: in the rigid insulation that keeps our homes warm and reduces our energy bills, in the flexible foams we sleep and sit on, in the plastics that support light-weighting of our cars to deliver improved fuel efficiency, and in the soles of our running shoes. In fact, this important material is vital in a range of applications that enhance our lives and improve our efficiency in terms of precious fuel and energy resources, so not having it at all, or having an inferior material, may have a net negative impact; there is a strong driver then to invest time and creativity into finding sustainable routes to its manufacture.

Uniquely, our tunable catalyst system allows polyol manufacturers to dictate the amount of CO2 to be incorporated, tailoring the polyol properties to match the final polyurethane application needs. The schematic in Figure 1 gives a simple illustration of Econic's technology, which, in contrast to current technology, facilitates the synthesis of polycarbonates (Econic Alternating Catalyst system) that contain 50% CO2 by molar weight, as well as polyethercarbonates (Econic Tunable Catalyst system) that allows for the bespoke incorporation of CO2 into the resulting polyol.

Econic is offering a technological solution to an interested market that has recently focused its attention on CO2 as a cheap raw material in the production of sustainable polyols. Indeed, it is important for the credibility and viability of this new technological direction and class of materials that key players in the industry have explored and endorsed their potential.

Reported alternative catalytic technologies can produce polyols that have either low or very high CO2 content (approaching the theoretical maximum of 50% molar content in a purely alternating polymer). In either case, the reported technologies typically operates at elevated CO2 pressures, which will necessitate new asset builds, rather than being deployable on existing production plants, thus creating a more challenging economic barrier to change within the established industry.

Figure 2 demonstrates the range of carbonate contents that can be accessed by Econic catalyst systems - enabling tunability across the entire range of CO2 contents at lower pressures than other typical catalyst systems. Econic's catalyst system opens the potential for the technology to be easily retrofitted to existing production assets, which would substantially lower the economic barrier to this process – by allowing for the incorporation of a reduction of oil-based feedstocks, the catalyst could save a typical production unit with an output of 50 kte/annum in excess of $10 million per year. We anticipate that this would pay back investment in the plant modifications within two years.

In order to turn the positive potential of CO2-based polymers into hard evidence of their viability, we are building a customer demonstration facility showcasing the catalyst producing pure polyols. The ability to access polyol materials on a larger scale will also facilitate our own, and our development partners', application programmes.

The company is fortunate to be the recipient of a Horizon2020 SME award, which funds market-creating innovation in disruptive small businesses that have significant growth potential and global ambitions. Only around 8% of applications are successful, so it is particularly encouraging to secure this additional support to bring the innovation to market.

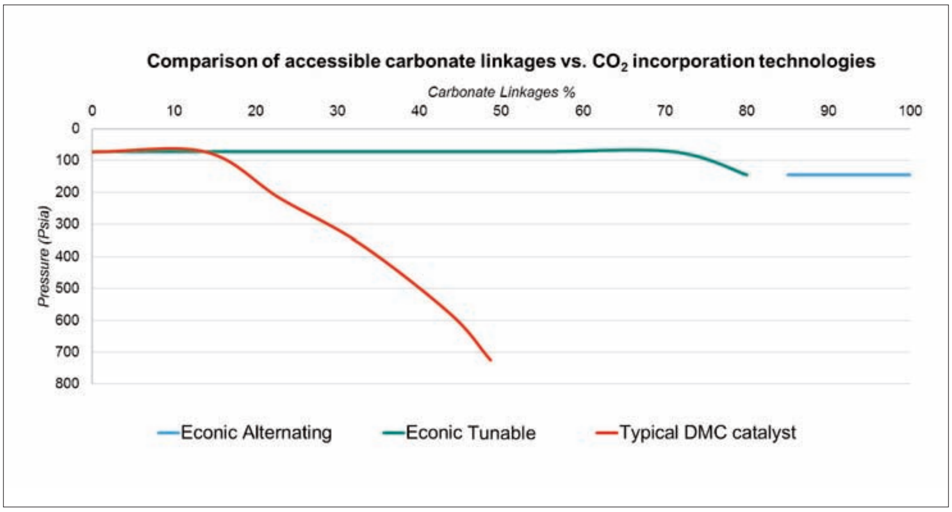


Figure 2: Comparison of incorporation of CO2 into polyol by catalyst technology and pressure where CO2 incorporation is expressed as % carbonate linkages – 100% carbonate linkages is equivalent of maximum 50% molar replacement of petrochemical raw materials

CO2 based polyols' product potential

The wide range of polyurethane applications, and their performance needs, creates a challenge for introducing any new material into this market. The chemical and physical properties of polyethercarbonate and polycarbonate polyols from CO2 are very dependent on the CO2 content. For example, a high CO2 content can increase viscosity, rigidity and Tg, but decrease thermal stability.

For some applications, such as flexible foams, a reduced CO2 content may be important to keep the viscosity within the range of equipment currently used in foam manufacture. In others, such as elastomers, a tunable CO2 content may be beneficial to tailor the rigidity and elasticity of the polyol to meet the needs of the corresponding polyurethane applications. The ability to tune the CO2 content of a polyol offers a powerful toolkit to designing new polyols for specific applications.

Along with this tunability comes the potential to exploit some of the product advantages accessible using this chemistry, thereby broadening the application reach and creating new opportunities for polyurethanes:

• Good rigidity, enabling lightweight foam products thanks to reduced material demands for the same strength.

• Improved chemical resistance, protecting elastomers and coated products from the harmful effects of chemical attack.

• Enhanced flame retardance, to better protect the buildings that use rigid foam insulation.

• Increased abrasion resistance, ideal for use in coatings that protect metal, wood and other surfaces from scratching.

• Better resistance to temperature changes, so coatings last longer and the time required between re-painting is extended.

• Good hydrolysis resistance, giving coated surfaces better protection against weathering and water damage.

Econic is a catalyst technology provider; we do not intend to manufacture polyols ourselves. We believe that partnerships with established manufacturing companies, who also hold deep experience in polyol application science, enable us to realise the benefits of our technology more quickly, and more widely, than trying to learn as we go.

Early adoption partners are already working with Econic Technologies to optimise processes and formulate products that will add value to their customers' products in the polyurethanes sector. These companies are manufacturers of rigid and flexible foams, elastomers (used in shoe soles and more) and high-performance coatings. Partners with a desire to realise the potential of such products in real time are key, and we are always open to discussing new ideas.

Realisable CO2 reduction potential

The environmental benefits of using CO2 in the production of polyols, or indeed other polymeric variants, is two-fold. There is the advantage of turning this waste product from an environmental burden to a useful raw material with the potential to generate profit. But that's just one third of the story. For every tonne of CO2 used in the manufacture of polyols, independent studies have shown that the partial displacement of oil-based feedstock results in a reduction of CO2 emissions by a further two tonnes. In other words, by not making the oil-based raw material that has been replaced by using one tonne of CO2, we avoid the creation of a further two tonnes of CO2 emissions.

Deploying this technology may not deal with CO2 mitigation on the gigaton scale, but it can have real impact, in real time. More CO2 could be incorporated into everyday products, turning waste into potential, while avoiding harmful emissions in the process. Additional CO2 emissions would be prevented as a result of a reduced reliance on fossil fuel-based raw materials, which themselves generate CO2 in their production. The net result? Turning CO2 into products that last longer and perform better, and reduce their carbon footprint on the planet.

If, by 2027, 30% of all polyol production took place using Econic's catalyst technology, 3.5 million tonnes of CO2 emissions could be saved each year – the equivalent to taking two million cars off the road. If we are ambitious and consider a scenario where uptake of CO2-based polyols within the PU market is at 90% by 2036, we could see CO2 mitigation on the order of 18 million tonnes per annum from solely this segment of the plastics industry.

Econic Technologies' Lab in Manchester, UK

A positive future

Econic's ambition doesn't rest with driving adoption of the technology to make CO2-based polyols. In line with our long-term vision, Econic will continue to develop catalyst technologies for other sustainable polymer processes, which will create the potential and flexibility to add real value for other plastics manufacturers. We envisage significant potential in markets far beyond polyols for our technology which, in the large and growing polymer sector, offers numerous areas in which CO2 containing products could find both technical benefits, market traction, and be economically attractive.

The next steps towards this are already being taken, as evidenced by the recent joint development agreement signed with SCG Chemicals, one of Southeast Asia's largest petrochemicals companies. Together we aim to develop processes to manufacture CO2-based high molecular weight polymers using Econic's catalyst technologies, and to assess application opportunities in this next target market.

Econic also has a role to play in developing and influencing the future successes of carbon impact technologies. There is an increasing recognition of the need to work together to tackle the technical, infrastructural and policy challenges of carbon capture and utilisation (CCU). Together with 28 other industrial and research partners, Econic has been heavily involved in the creation of a new European association that will address CO2 utilisation: CO2 Value Europe.

The purpose of the association is to coordinate the many different players in Europe involved in CO2 utilisation to integrate their efforts along the value chain, and to ultimately become the ambassador of the CO2 utilisation community towards policy makers and funders. Econic has invested its time and effort into this cause, because we strongly believe that the development of CO2 utilisation must be accelerated, and this goal requires better integration of the efforts of all interested stakeholders across sectors.

The founding members of the association have good representation from relevant CO2-emitting process industry sectors, renewable energy producers, and transformation technology and equipment providers, as well as the industrial gases sector. We are however, still seeking more members from the (petro)chemicals and polymers industries to cover the diversities of these sectors.

Fundamentally, we believe that bringing profitable carbon utilisation technology to market will help drive a value-adding carbon recycling economy that takes advantage of captured waste CO2 to deliver better products and true environmental benefit in real time. Our desire is to provide novel catalyst technology solutions and work with the right partners to bring those technologies and the products they create to market, thereby unlocking the potential of CO2.

With a clean technology that creates value and has a significant environmental impact, why would we think small…either as a business or for our planet?

More information

econic-technologies.com

The role of CCS in meeting climate policy targets

University College London has produced a report, commissioned by the Global CCS Institute, to further understanding of the potential contribution of CCS to a low carbon world, and the policies that may support that contribution.

CCS should be seen as an important component of a portfolio of mitigation technologies for meeting climate change targets, the report co-authored by UCL researchers finds.

The independent report examines policy issues in the deployment of CCS, in accordance with global commitments to limit temperature increases to below 2 and 1.5 degrees Celsius.

It outlines comprehensively the arguments made for and against CCS deployment, examines the experience of CCS deployment to date in a range of countries, draws lessons from other analogous technologies, and explores findings from integrated energy systems modelling.

The report finds that although CCS is not without risks or uncertainties, the available evidence suggests that the risks of CCS not being available as part of a portfolio of mitigation options to address climate targets, are greater than the risks of attempting to develop it.

As such, CCS should be considered a critically important part of any strategy for limiting temperature rise to 2˚C, and even more so for limiting temperature rise to 1.5˚C.

Recommendations

1. CCS is not without risks and uncertainties. However, it is our judgement that at the present time, the risks of not having CCS available – in terms of the impact that would have on the achievability of climate targets – appear to be greater than the risks that may be associated with attempting to develop it.

2. The development of CCS requires an innovation system perspective. This includes: long-term clarity through a high-level long-term carbon commitment, such as a legislated target; targeted research development and demonstration activities, including national test centres and cross-national research collaborations; long-term price incentives, or equivalent carbon disincentives; and a whole chain coordination approach, due to multi-actor supply chains, liabilities and shared infrastructures.

3. Legal and regulatory issues are also crucial, but CCS is an emerging area. As such the development of legislation and regulation should not been seen as a static exercise, but incorporate effective review procedures and adaptation mechanisms. Project specific regulation during periods where it is too early to commit to enduring regulatory frameworks, may be appropriate.

4. Transparent and ongoing scientific assessment of risks and uncertainties will be a crucial part of the long term sustainability and acceptability of CCS. Critical issues include transparently verifying that CO2 can be safely stored in any given project, and 135 demonstrating the full life cycle sustainability of biomass used in BECCS applications, including with appropriate certification processes. Broader risks of CCS not delivering to the extent envisaged in the scenarios discussed in this report may also be mitigated through strong increases in energy and material efficiency, which should be pursued as a no-regrets option.

Co-author Professor Paul Ekins, UKERC Co-Director, said the report found that pursuing CCS requires a whole-chain innovation systems approach, including coordination of actors and infrastructure, and attention to legislative and regulatory frameworks.

"Of course, there will be a need for technology `push' policies such as support for research and development, and market `pull' policies such as price support and carbon taxes."

"However, it's also important to recall that comparable large scale technological systems and infrastructures have historically benefitted from some kind of whole-chain coordination and support, with governments playing key enabling roles. We do not believe that CCS will succeed without similar whole-chain coordination and support."

UCL co-author, Dr Nick Hughes said report findings indicated that the non-availability of CCS appears to make climate mitigation scenarios "at best much higher cost, and at worst infeasible".

The report is intended to inform a wide variety of stakeholders on the relative importance of the full set of policy instruments available to promote CCS and emission reduction technologies more generally.

The report was led by authors Dr Nick Hughes and Professor Paul Ekins at the UCL Institute for Sustainable Resources, as part of a consortium that drew in other world-leading expertise from the UCL Energy Institute, UCL Faculty of Laws, University of Edinburgh and the UK Energy Research Centre. The project team brought together extensive experience on CCS technology, legal and regulatory issues connected to CCS, low-carbon energy policy-making, energy systems analysis and the governance of energy technologies.

More information

www.ucl.ac.uk

aCQurate project developing integrated CO2 storage monitoring

CMC Research Institutes in Canada has teamed up with SINTEF Petroleum Research in Norway to advance a new method for monitoring carbon dioxide geologically stored at onshore and offshore sites, such as the Norwegian Continental Shelf.

By Mark Lowey

The three-year, Cdn$4.4-million aCQurate project includes SINTEF testing its data integration method at CMC's new Containment and Monitoring Institute (CaMI) field research station in western Canada. The new approach integrates and correlates multiple datasets from various types of monitoring technologies, to improve monitoring of injected CO2.

"The goal of the project is to reduce the risk of geological storage of CO2 by increasing the ability to verify where the CO2 is in the geological reservoir," says Don Lawton, CaMI's director and professor of geophysics at the University of Calgary.

"To further develop and field-test its new approach, SINTEF requires different types of geophysical data that you can only get from an onshore CO2 storage project like the one we have at CaMI."

CaMI, developed and operated by CMC Research Institutes with operational funding from UCalgary, is located about 200 kilometres southeast of Calgary, in southern Alberta. The new facility began injecting CO2 this October into a geological storage reservoir at the site.

Other collaborating organizations and research groups in the aCQurate project are: Statoil in Norway; University of Calgary; Lawrence Berkeley National Laboratory in California; INRS (Institut national de la recherche scientifique) in Quebec; GFZ (German Research Centre for Geosciences) in Germany; Quad Geometrics in Norway and the Scripps Institution of Oceanography in California.

"It is a significant project in terms of international collaboration," Lawton says. "It shows that we are garnering high levels of international interest and participation in CaMI."

The kind teamwork taking place through this

Michael Nightingale, research scientist from the University of Calgary's Geoscience Department, works on a surface casing vent flow test at the Field Research Station project is key to reducing atmospheric levels of CO_2, says Sandra Odendahl, CMC Research Institutes' new president and CEO.

"Climate change is a global crisis and we need to act quickly and collaboratively to develop and commercialize research results," she says. "Because the field research station offers access to a variety of monitoring systems, it is ideal for bringing governments, industry and and academics together to accelerate the development of effective technologies for carbon storage."

CaMI "ideal" site for innovative R&D

The overall manager of the aCQurate project is SINTEF (Foundation for Scientific and Industrial Research) in Trondheim, Norway. SINTEF is the largest independent research organization in Scandinavia.

"What we've set out to do in the aCQurate project is to achieve accurate, quantitative and high-resolution monitoring of geological storage of CO_2, which can be applied to large-scale onshore and offshore storage sites," says Michael Jordan, senior research scientist at SINTEF.

The CaMI field research station has multiple surface and downhole monitoring technologies (see list at bottom of story) applicable to both onshore and offshore CO_2 storage, he says. "I don't know of any other sites where you have all these technologies co-located at the same time . . . it's a very big advantage."

Another advantage is that CaMI's geological storage reservoir is relatively shallow, which means it's not necessary to inject huge amounts of CO_2 in order to detect and monitor changes in the gaseous CO_2 plume and in the reservoir itself.

"It's an ideal testing ground for developing our integrated hybrid joint inversion method," Jordan says.

Getting the clearest picture of CO2 storage

Injecting CO_2 into a geological reservoir changes the fluids and pressure in the rock formations, which affects the reservoir's properties.

Seismic technology is widely used to monitor geologically stored CO_2. While this provides detailed information about subsurface structure, seismic data alone doesn't provide sufficient quantitative information.

For example, seismic data is insufficient for distinguishing pressure changes versus changes in the percentage of CO_2 saturation within the reservoir.

"That is important to make sure that the pressure is not exceeding the critical pressure in the reservoir, so that you don't damage your storage site," Jordan says.

CO_2 storage sites now employ multiple monitoring technologies, such as high-resolution seismic, electrical and gravity information. But often the data from these various methods are interpreted separately and look at only one aspect of the subsurface.

Since 2008, SINTEF has been developing its joint inversion approach for integrating various geophysical monitoring methods and datasets.

"The idea is to see the same subsurface from different viewpoints and make sure that the data we see from various monitoring methods, and the corresponding models of subsurface properties, are consistent with each other," Jordan says. "The more information you can integrate, the less the uncertainty becomes."

Ensuring effective and safe CO2 storage

Another driver of the aCQurate project is new regulations for CO_2 storage sites, which require both containment assurance and conformance assurance.

Containment means being able to demonstrate that the storage site is performing effectively and safely. This requires monitoring pore pressure and formation strain in the reservoir to ensure the injected CO_2 stays put, without migrating upward into another formation and potentially to the surface.

Conformance means the storage site is actually behaving as expected. "That means you have a consistency between what you predicted based on your models and what you observe," Jordan says. This also requires monitoring various reservoir parameters, such as the CO_2 saturation.

Measurement, monitoring and verification programs for CO_2 storage sites also require determining the reservoir structure with high-resolution images and reliably characterizing the fluids and rock properties.

Integrating multiple monitoring datasets provides "a more accurate picture of what's happening in the subsurface," Lawton says. "The aim is to increase certainty of CO_2 storage and verification of containment and conformance."

Helping Norway meet its CO2 storage challenges

Norway has extensive experience with storing CO_2 in geological structures, including two major projects operated by Statoil.

Since 1996, one million tonnes of CO_2 have been separated each year from natural gas production in the Sleipner field in the North Sea, and stored in a geological formation 1,000 metres below the seabed. And since 2008, CO_2 has been separated from the well-stream in the Snøhvit field at a liquefied natural gas facility on the island of Melkøya.

The Norwegian Continental Shelf has a significant storage potential that could be very valuable in a future European CO_2 storage market. However, the geological complexity of reservoirs is a major challenge for CO_2 monitoring strategies.

A particular challenge for Norway is the accumulation of CO_2 within thin layers like those at Statoil's Sleipner field.

Monitoring the subsurface of a large and deep CO_2 storage site offshore requires multiple high-resolution seismic data. Integrating several methods on such a large scale poses significant challenges, including the immense computational cost, Jordan says.

The aCQurate project will create a new hybrid structural-petrophysical joint inversion method that will help to answer accurately and quantitatively: Where is the CO_2? What is the pressure? What is the CO_2 saturation?

As part of the project, Quad Geometrics and the Scripps Institution of Oceanography plan to apply for U.S. Department of Energy funding to develop and test at the CaMI site novel, highly sensitive tilt meters, to measure very small changes in deformation at the surface induced by CO_2 injection.

Building international expertise

CLIMIT, Norway's national program for research, development and demonstration of CO2 capture and storage technology, is providing 53 per cent of the aCQurate project's total $4.4-million budget. Statoil is providing about $203,000, and the remainder is contributions-in-kind from the project partners.

More than 20 key personnel are participating among all the partners and collaborating organizations and research groups.

Key personnel include Jordan, Lawton and his UCalgary colleague Kris Innanen, associate professor of geoscience, and Amin Saeedfar, senior project lead at CMC Research Institutes, along with UCalgary graduate students and post-doctoral researchers. A post-doctoral researcher shared by SINTEF and GFZ also will be working at CaMI.

aCQurate is expected to lead to considerable development of expertise and technology in advanced geophysical monitoring of CO2 storage for the partnering countries of Canada, Norway, the United States and Germany. All the partners will have access to the integrated hybrid joint inversion approach.

If the new approach proves successful, it may become a preferred technology in new carbon capture and storage demonstration projects, which could be commercialized further with service companies.

In addition, there is an intensive program of geochemical and hydro-stratigraphic monitoring of the overburden rocks between the injection zone and the ground surface, to detect any changes in groundwater layers due to the injection of the CO2.

This program is being managed by Beth Parker, professor of engineering at the University of Guelph and her colleagues at the university, and by Bernhard Mayer, professor of geoscience, and his applied geochemistry research group at the University of Calgary.

By enhancing monitoring and evaluation of geologically stored CO2, the aCQurate project "may consequently help to increase public acceptance of large-scale geological storage and improve chances of reducing CO2 emission and meeting climate goals," the project partners say.

Extensive suite of geophysical monitoring technologies at CaMI

Researchers at the CaMI field station already have deployed or will deploy and test an extensive suite of surface and downhole monitoring technologies, including:

A crew laying seismic geophones at the Field Research Station in Alberta, Canada

• Seismic reflection surveys (bounce intense sound waves off underground rock structures to produce high-resolution seismic images of the geologic structure and reservoir properties);

• Controlled source electromagnetics (measures subsurface resistivity which can be used to quantify saturations changes in the storage reservoir due to the presence of CO2);

• Electrical resistivity tomography (measures electrical fields, or electrical resistivity. This is done either at the surface or with electrodes placed in well boreholes, to determine CO2 saturation levels in the reservoir);

• Gravity logs (Time-lapse gravity, which measures minute differences in the gravity field, is directly sensitive to the fluids in the pore-space, so it can be used to infer CO2 dissolution rates);

• Downhole gravimetry (measures the strength of a gravitational field, using instruments installed in well boreholes, to determine displacements in subsurface rock formations);

• Petrophysical data (measures the rock properties of the reservoir, such as pore pressure and strain);

• Distributed acoustic sensing fibre optics (uses distributed fibre optic cables as sensors to detect acoustic signals and measure strain in the reservoir);

• Magnetometric methods; (measures electrical resistivity changes to determine pore fluids and fluid chemistry due to injected CO2);

• Tilt meters (measures and analyzes very small changes in deformation at the surface induced by CO2 injection); and

• Microseismic monitoring stations (detect any small seismic events that might be caused by the CO2 injection, in collaboration with the University of Bristol in the U.K).

More information

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London Global CCS Institute meeting - UK now laggards?

Perhaps the UK can now be seen as as a global laggard in roll-out of carbon capture and storage, as we see renewed interest in the US, China, Australia, Japan and the Middle East, said Brad Page, CEO of the Global Carbon Capture and Storage Institute, at a London meeting in October.

By Karl Jeffery

In terms of which parts of the world are showing interest in carbon capture and storage at the moment, “this part of the world [the UK] are the laggards,” said Brad Page, CEO of the Global Carbon Capture and Storage Institute.

He was speaking at a London meeting to launch a report written by University College London (UCL) on the role of CCS in meeting climate policy targets.

Carbon capture is coming “back in the discussion again” in Australia, Mr Page said.

Also, “we have strong investment intent from Japan - gasifying coal to make hydrogen,” he said.

“Norway is very committed to those three projects - I’ve heard the noises [about funding cuts] are a distraction.

“The Middle East has its first steel plant with CCS. China is going to surprise everybody. The rest of the world will say, how did that happen.”

One continued problem with CCS investment is concerns from investors about an indefinite liability for storage of the CO_2. These concerns could be mitigated if CO_2 storage had a similar liability scheme to nuclear waste, where, in many countries, after a “proper period” of stewardship, the liability for waste is handed back to the “broader community” to be a custodian, he said.

Another point is that discussions about CCS continually compare the costs per ton of CO_2, but these comparisons are often inaccurate, because they come from the electricity sector, and compare CCS with renewables, without taking into account the total system cost such as the cost of having a back-up to renewables. “In Australia the real cost of a system based on renewables are starting to appear,” he said, a reference to the growing discussion about battery storage to complement renewables in Australia.

Delegates at the Global CCS Institute meeting in London in October

On the question of CO_2 utilisation, Mr Page said, “We're seeing good and relatively small-scale progress on that stuff. But there's a question of scale [can you ever utilise the volumes of CO_2 which people want to capture and store].

Lord Debden

Also at the meeting, John Gummer (Lord Debden), Chairman of the UK's independent Committee on Climate Change, questioned whether the fossil fuel industry is taking carbon capture seriously enough. “If I was running Shell I would be looking for a way out,” he said.

“We may not be taking it seriously now but we're taking it more seriously as each year goes by.”

Lord Debden emphasised that from his work with industry, he has seen that even when you prove to someone they have got a risk, they won’t spend anything. But “when things [actually] get very bad its surprising what people are able to do. When it goes wrong they find large quantities of money.”

So a similar logic perhaps applies with carbon capture today. People might be persuaded of the risk, but since they don’t yet actually see anything going wrong, money to solve the problem is not being found.

Another argument for carbon capture is “if we don't do what we need to do now, it becomes very much more expensive,” he said. “You try to say to companies, it is easier to do things in the course of business than when you are forced to do it." And government targets are likely to become tougher and not less tough."

There is also perhaps some complacency in government, because "we have been relatively successful until now at meeting targets," he said. "People believe it is automatic, it will keep on going on like that." But "we've done things that turned out to be the easier things."

Lord Debden had some harsh words for environmental groups, saying that they have "mistaken ends and means," continually promoting renewables as the solution to climate problems, without considering whether renewables alone are the right answer.

"NGOS .. are just like Donald Trump -they don't listen to the argument. We have got to get the whole thing concentrating on the ends."

Dr Julio Friedmann

Dr Julio Friedmann, principal deputy assistant secretary for fossil energy with the US Department of Energy, stressed that the money issue should be around financing (investment), not costs.

The costs will come down as investment goes on, he said. To illustrate, the first carbon capture plant being built in Texas is expected to cost $100 per ton of CO2 sequestered. But the engineers believe that the second will cost $80/ton and the third will cost $60/ton.

And getting the financing "is fundamentally a policy question" he said.

Dr Friedmann likens the last 50 years of climate discussions to telling children to clean their bedroom. First they tell you that the room is clean, analogous to people saying the climate does not need fixing. Then, they go to their room and start playing with their toys, rather than actually fixing the problem. This could be analogous to the way that climate professionals have been wasting time messing around with different schemes, but not actually getting the job done.

David Hone, Shell

David Hone, Chief Climate Change Adviser with Shell, emphasised that Shell can work together with governments to deliver a regulatory framework which can drive carbon capture investment, as it did in Canada.

"It can be an investible proposition through a market price on CO2. When that's there, we've been seen to respond to that," he said.

Mr Hone emphasised that the Paris agreement (United Nations) says that there should be net zero emissions by the second half of this century.

"They only way to do that is either to have no emission, or balance your emissions with sinks, and one of those is CCS," he said.

In other words, if you believe that we won't be able to get all of our energy from renewables, and so will continue to need hydrocarbon fuel, then we will need something like carbon capture to keep the CO2 out of the atmosphere.

Samantha McCulloch, IEA

Samantha McCulloch, analyst with the International Energy Agency (IEA), noted that only 0.1 per cent of the world's clean energy spend is going on carbon capture.

Environmental groups sometimes criticise CCS saying it is a distraction from what they really want to see (usually renewables). But with just 0.1 per cent of spend, "it is clearly not a distraction yet," she said.

There is some low hanging fruit for carbon capture, she said. You don't need to spend $6bn on a project. Norway's Sleipner project cost $100m in 1996, and captured 20m tonnes of CO2. There have been plans for coal chemical plants in China which could be equipped with CCS for under $20 a ton.

"We're seeing increased enthusiasm for CCS coming out of the US," she said.

Steel

One audience member from the steel industry noted that the European steel industry had once been keen on carbon capture, but then "our CEOs all ran for the hills when Chinese steel problem happened."

"The key to CCS is getting fairness in the costing – a level playing field," he said. [Perhaps some way that the same carbon costs would be levied both on domestic producers and steel importers].

GCCSI's Brad Page said he thought it was a lazy argument for companies to take a "most short-term view of your own survival."

Lord Debden noted that many steel industries do not have anywhere suitable nearby to store the CO2, such as the steel industry in South Wales, UK.

Other comments

Roger Harrabin, environment analyst with the British Broadcasting Corporation (BBC) and moderator of the event, began by stating that "I stand here as a CCS sceptic. It clearly works but I'm sceptical about it ever getting done."

Prof Paul Ekins, Professor of Resources and Environment Policy at the Faculty of the Built Environment at UCL, and a co-author of the report, said in that the "the non-availability of CCS makes climate mitigation scenarios at best high cost and at worst unfeasible. We're not really serious."

More information

www.globalccsinstitute.com

What to do with (industrial) CO2? Policies tailored to potentials

A new report co-authored by HeidelbergCement and Bellona Europa, on behalf of the Zero Emissions Platform, delves into the various options energy-intensive industries have to stay competitive in a low-carbon economy.

By Bellona Europa

The report highlights the options which are both realistic and offer substantial emissions reductions while noting the ones that have the potential to be the costly distractions that will derail Europe on the path to 2oC.

The current political context, more than ever, calls for decarbonisation technologies to be rigorously assessed and selected according to their GHG mitigation potential. With the low ambitions of the Low Carbon Economy Roadmaps for 2050 lagging behind the Paris Agreement, it is crucial to analyse the ways to achieve these reductions in energy intensive industries. The newly published report of the Zero Emissions Platform therefore evaluates the potentials of electrification, Carbon Capture and Utilisation (CCU) and Carbon Capture and Storage (CCS) as solutions for industrial decarbonisation.

Little renewables, lots of industry to decarbonise

More often than not, there is an impression that electrification can be the silver bullet that solves the industrial emissions conundrum. Whereas wind turbines and solar panels can certainly help decarbonise industries, an array of technologies will be needed to enable industries such as cement to become carbon neutral. When CO2 emissions are a product of production-specific chemical processes and not the combustion of fossil fuels, renewable energy sources can't do much to help.

There is more than one limit to electrification – the analysis of data published by the chemical industry association CEFIC shows that decarbonisation of Europe's chemical production – just one of the sectors in question – via electrification would require more than twice (+140%!) the EU's entire current electricity generation. With renewables sorely needed to decarbonise that current electricity production, the ZEP report concludes that electrification alone is not a viable pathway for decarbonising Europe's heavy industry within a timeframe relevant to the Paris Agreement goals.

Complementary solutions

The report concludes that, to achieve the lions share of emissions reductions in energy intensive industries, the CO2 produced must be stored (Carbon Capture and Storage – CCS). In addition to storing the CO2 permanently, there are some forms of Carbon Capture and Utilisation (CCU) that might (and some that might not) contribute to climate change mitigation.

CCU in particular has been gaining traction as a supposedly cost-effective way of addressing industrial carbon emissions in Europe. That potential, however, varies greatly across the broad spectrum of CCU technologies, ranging from the climatically useless to the useful. Whereas some CCU products only hold the CO2 stored for a few months and then release it back into the atmosphere, some can act as permanent storage within the relevant timeframe for halting dangerous climate change.

This broad range of emissions reduction potentials calls for a clarification, which the report provides by sorting through the various emerging markets for CO2 (re)use:

"There's a lot of misconceptions about the climate benefit of various technologies" says Jonas Helseth, the director of Bellona Europa.

"We hope that the report will contribute to the debate in a constructive manner and clarify some common misconceptions around CCU, as well as the prevailing assumption that there will be a vast oversupply of renewable electricity in the near term, that will solve all emission challenges'.

Such clarification is more than welcome at a time when some CCU products are already included in proposed future EU legislation without a robust (or any) life cycle assessment. Synthetic fuels produced from recycled fossil-derived CO2 as included in the revised Renewable Energy Directive could potentially, as our latest report emphasises, have serious detrimental impacts on efforts to reduce emissions – both in industry and transport.

Along with the lifecycle of the product and CO2 source of various CCU solutions, the report considers the potential market size for different CCU products and processes in Europe, concluding that the emerging markets for CO2 (re)use will only be able to address a minor portion of the emissions that will need to be abated to meet climate targets.

What we do with industrial CO2 now will make or break our prospects for a low carbon future – ultimately, we will have to pull it out of the atmosphere and store it for very long periods of time, in one way or another. As Dr. Graeme Sweeney, Chairman of ZEP emphasised, long lasting storage of that CO2 will be the key to achieving the goals we have set:

"If we are to have any hope of meeting the goals of the Paris Agreement, CCS is absolutely critical. Europe needs to urgently deliver the CO2 transport and storage infrastructure that will service a large number of sectors and create industrial CCS clusters. Such clusters open up opportunities to link to hydrogen networks, CCU and the provision of negative emissions and will enable the lowest cost route to sustainable growth in key regions across Europe."

More information

www.bellona.org

www.zeroemissionsplatform.eu

Climeworks combines CO2 direct air capture with storage

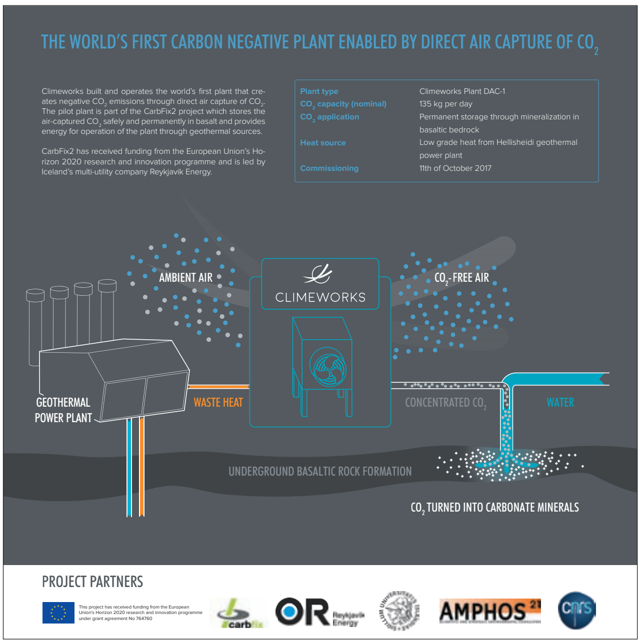
Swiss cleantech company Climeworks has partnered with Reykjavik Energy to combine direct air capture (DAC) technology for the first time with permanent geological storage.

As part of the CarbFix2 project Climeworks will demonstrate a safe, economically-viable and highly scalable carbon removal technology. This type of solution has been recognized as a crucial component in efforts to achieve global warming targets.

The EU-backed collaborative research project centers around one of the world's largest geothermal power plants in Hellisheidi, Iceland, where CO2 is currently injected and mineralized at an industrial scale. A Climeworks DAC module has been installed on-site to capture CO2 from ambient air for permanent storage underground, thus creating a carbon removal solution. Scientific studies have warned that the two-degree climate target is not achievable without carbon removal solutions. Carbon negative solutions are also likely to be a key theme at the UN Climate Conference COP 23 starting in Bonn next month.

Hellisheidi Power Plant - Photo by Arni Saeberg

A testing phase has started during which the CO2 is captured from ambient air, bound to water, and sent to more than 700 meters underground. There the CO2 reacts with the basaltic bedrock and forms solid minerals, creating a permanent storage solution. Climeworks' technology draws in ambient air and captures the CO2 with a patented filter. The filter is then heated with low-grade heat from the geothermal plant to release the pure CO2 which then can be stored underground.



During the trial Climeworks will test how its technology works with the specific weather conditions at the location in the South West of Iceland. The CarbFix2 project is a major step forward for DAC technology. Earlier this year the company made history with the world's first commercially-viable DAC plant near Zurich which filters 900 tons of CO2 from the atmosphere and supplies it to a local greenhouse.

Christoph Gebald, Founder and CEO at Climeworks, said, "The potential of scaling-up our technology in combination with CO2 storage, is enormous. Not only here in Iceland but also in numerous other regions which have similar rock formations. Our plan is to offer carbon removal to individuals, corporates and organizations as a means to reverse their non-avoidable carbon emissions."

Edda Sif Aradóttir, CarbFix project leader at Reykjavik Energy, said, "We have developed CarbFix at a unique location here in Iceland and proved that we can permanently turn this greenhouse gas into rock. By imitating natural processes this happens in less than two years. By integrating the Climeworks and CarbFix technologies we create a solution that is deployable where we have basalt but independent of the location of emissions. This is important to scale up the CarbFix approach on a global level."

More information

www.climeworks.com

Projects and policy news

Carbon capture critical to Europe's economic future

www.globalccsinstitute.com

Speaking at the Europe Middle East and Africa (EMEA) CCS Forum at the Port of Rotterdam, Global CCS Institute CEO, Brad Page, said CCS is the solution to a raft of climate, economic and social problems.

Climate change leaders meeting in Rotterdam have heard that carbon capture and storage (CCS) is instrumental in decarbonising European industry and creating a new energy economy across the continent.

"We are now at a critical juncture. CCS can no longer be a peripheral player in the climate change debate. To reach Parisclimate change targets, and create sustainable economic and social economies, CCS must be part of a mainstream, multi-lateral mix of 'must-have' clean technologies."

Mr Page, who leads the world authority on carbon capture, says CCS is tailor-made for Europe where myriad industrial hubs and clusters exist.

"It is the only technology capable of decarbonising major industrial sectors such as steel, cement, fertilisers, refining and petrochemicals and it is the conduit to a new energy economy of clean and sustainable energy across all forms including hydrogen, bioenergy and the raft of CO2 reuse applications."

Speaking to more than 100 attendees representing industry, government, academia and NGOs, Energy Future Initiative CEO, Dr Julio Friedmann, said CCS must be deployed swiftly and at scale if the world had any chance to make rapid reductions in greenhouse gas emissions.

"One key application is in heavy industry which produces 21 per cent of global emissions. Another is on the new, highly efficient coal plants built in Asia and Europe which will have long lives and eat up the carbon budget quickly, as well as natural gas plants which are becoming the mainstays of the power sector.

Dr Friedmann said the technology is proven, its commercial case is cogent and the climate science is unequivocal.

"We simply cannot reach a 2-degree world, let alone anything less, without it. The question is, are we really smart enough to do what we know needs to be done."

Also speaking at the Forum, Port of Rotterdam CEO, Allard Castelein, said calculations by the IPCC, IEA, and a recent Wuppertal Institute study commissioned by the Port, supports the fact that CCS will play an indispensable role in our climate change future.

"CCS is certainly necessary for Rotterdam. Our local industry is responsible for close to 20% of total CO2 emissions of the Netherlands. A large share of these industrial activities concern products that - at least for the time being - lack viable zero-emission alternatives. CCS and CCU form the most effective methods for swiftly scaling back CO2 emissions."

There are currently 17 large-scale CCS facilities in operation around the world, with four coming on stream within the next 12-18 months.

EU Commission recognises strategic importance of CCS projects

www.zeroemissionsplatform.eu

The EU has adopted a draft list of four projects of interest in cross-border CO2 transport.

The European Zero Emissions Technology & Innovation Platform (ZEP) welcomed the adoption of the draft list of four Projects of Common Interest (PCI) in the area of cross-border CO2 transport by the High-Level Decision Making Body, which includes the following projects:

• Statoil - CO2 cross border transport connections between a) emission sources in the Teesside industrial cluster; b) the Eemshaven area in the Netherlands and a storage site on the Norwegian Continental Shelf (NCS)

• Port of Rotterdam Authority – The Rotterdam Nucleus

• Tees Valley Combined Authority – Teesside CO2 Hub

• Pale Blue Dot. – CO2 Sapling Transport Infrastructure Project

The four projects represent a major step forward for CCS in Europe and could signal the birth of a number of strategic European CCS hubs.

The Norwegian project is particularly important for the following reasons:

• Norway is already a leader on CCS with the Sleipner project (that celebrated its 20th anniversary last year), the Snohvit project and the commitment to fund studies into developing CCS on three different industrial facilities. With the Statoil CO2 cross border transport project, Norway is developing a CCS portfolio that includes new and innovative CCS projects, which will generate vital knowledge that can be transferred between other sectors and other countries.

• The proposed storage for the Statoil project contains significant capacity and provides a strategic asset that, combined with the possibility of a shipping solution for CO2 transport from other countries, could open up the option to support a nascent North Sea CCS network. This would not only drive necessary cost reductions in CCS, but would also enable cost-effective CO2 reduction for the key countries bordering the North Sea; including the UK, the Netherlands, Belgium, and Germany.

• The Norwegian CCS portfolio with its broad application to industries such as cement, ammonia, waste-to-energy and power, demonstrates the importance of CCS to multiple industries. This is particularly relevant in light of the Paris Agreement goal to limit the global temperature increase to well below 2°C and the crucial role of CCS to meet this. For example, there are currently no cement or waste-to-energy CCS projects operating anywhere in the world, and the Norwegian projects would therefore represent internationally significant projects.

• There are currently 21 CCS projects in operation or construction around the world. However, if CCS is to fulfil its role in meeting the goals of the Paris Agreement, a step change in deployment is required. European countries that are considering the role that CCS can play in their decarbonisation strategies will look to countries such as Norway. It is therefore vital that the Norwegian projects are successfully deployed as this will help build confidence that CCS is a safe and effective CO2 reduction solution that must be developed urgently across Europe.

Decarbonising the global steel and cement sectors calls for more than zero carbon fuels

www.climateactiontracker.org

Deploying current technologies to decarbonise the steel and cement industries is likely not sufficient to meet the Paris Agreement's 1.5°C limit, according to a new Climate Action Tracker (CAT) study.versities including Cambridge and industry will further develop carbon capture and storage technology.

The steel and cement industries both have large emissions profiles. In 2015, around five percent of worldwide greenhouse gas emissions came from the steel industry—accounting for around 2.8 gigatonnes of CO2 equivalent (GtCO2e) per year. Cement-related emissions have nearly doubled their share of global greenhouse gas emissions—rising from 2.8 percent in 1990 to 5.5 percent in 2010, reaching more than 2.6 GtCO2e per year.

Decarbonisation of our energy system, (i.e., the transition towards net-zero CO2 emissions), can be achieved through higher energy efficiency, a zero-carbon electricity supply, electrification of residual demand, and zero-carbon fuels.

While these measures can set the buildings and transport sectors onto an emissions pathway compatible with the Paris Agreement's long-term temperature goal, this is not sufficient for industry, especially in steel and cement production.

The analysis finds that improvements in efficiency, decarbonisation of the energy supply for both steel and cement and a move towards circular value chains can lead to significant emissions reductions. CAT's latest study found that the combined effect is estimated to be an around 30%–50% reduction compared to current trends by 2050. This is a good start, but not the near-complete decarbonisation required for the Paris goal by around 2050.

"In short, emissions from these industrial processes are a difficult nut to crack, as large chunks of them are not related to conventional fossil fuel combustion," said Sebastian Sterl of NewClimate Institute, one of the lead authors of the study.

The CAT looked at three different scenarios for the steel and cement industries, using country case studies for the EU, China and Nigeria. One scenario follows current trends, one represents a shift towards decarbonisation of the energy supply, and one represents steps towards circular value chains.

"To reach the Paris Agreement's goal of net zero emissions by the second half of this century, we will need solutions for both of these industries, including increased R&D into innovative, low-emission production processes such as routes using carbon capture and storage (CCS) or renewables-based hydrogen," according to Lindee Wong of Ecofys, a Navigant company.

"It will also require a shift to using materials more efficiently, as well as substitution with lower emissions-intensive alternatives," added Dr. Ursula Fuentes of Climate Analytics.

University of Houston begins project with Oil India

www.uh.edu

Researchers from the University of Houston have begun a $1.4 million project to demonstrate using carbon dioxide captured from nearby petrochemical plants to boost oil recovery in a field in the Indian state of Assam.

The project is part of an ongoing partnership launched last year between the University and Oil India Limited, the Asian nation's national oil company.

The initial phase, funded by $500,000 from Oil India, included the calculation by UH researchers that the company's oil reserves are substantially higher than previously thought, as well as recommendations that increased production by 21 percent at one well alone, a first-year revenue increase of $4 million.

"This ambitious partnership has offered clear benefits for both Oil India and for the University of Houston," said UH President Renu Khator. "Finding a way to safely meet the growing demand for energy in India and other parts of the world is a fundamental challenge, and we appreciate the opportunity for our faculty and students to play a vital role in solving such important real-world problems."

The project is led by Ganesh Thakur, who was recruited by UH in 2016 as director of Energy Industrial Partnerships. A member of the National Academy of Engineering and a former executive at Chevron Corporation, Thakur also serves as Distinguished Professor of Petroleum Engineering.

He has overseen both Phase 1 of the partnership, cemented by a Memorandum of Understanding signed last year, and Phase 2, which focuses on demonstrating the effectiveness of flooding key oilfields in northeastern India with carbon dioxide, a technique that has been used to enhance oil recovery in the United States for 45 years.

Demand for energy is increasing in India, where the gross domestic product (GDP) is rising about seven percent a year, Thakur said. The country now imports more than 80 percent of its oil consumption, making it important to increase what it can produce domestically. The UH team is composed of a dozen people, from faculty members and post-doctoral researchers to graduate students, in disciplines including petroleum and chemical engineering and the geosciences.

Moreover, Thakur said the partnership also offers advantages for UH.

"It provides a good field research lab for us," he said. "It allows us to take the challenges the oil industry is facing and provide an integrated solution."

The carbon capture project will also include technical training for Oil India personnel on advanced enhanced oil recovery techniques and project design, along with a seismic study of the Makum-North Hapjan Field.

The initial project was completed in June with several key accomplishments:

UH research indicated the oil resources are about 20 percent higher in the key field of Oil India than previously thought.

Research-based production recommendations led to a production increase of 220 barrels per day from just one well, a 21 percent increase worth $4 million a year.

Fifty Oil India reservoirs were screened for enhanced oil recovery (EOR) opportunities; UH researchers also developed and patented a methodology to rank reservoirs and assess EOR potential. Researchers found the four top-ranked reservoirs have a potential for 17 million barrels of additional recovery.

UH field research discovered that drilling at a potential site would be uneconomic. The result was a savings of $4 million in drilling costs.

High-temperature CO_2 Sorption using Sintering-Resistant CaO/Saffil Fibres Sorbents Prepared by Precipitation Method

Sergio Ramirez-Solis, Valerie Dupont, Steven J. Milne
School of Chemical and Process Engineering (SCAPE), University of Leeds, Leeds LS2 9JT, UK.

Introduction

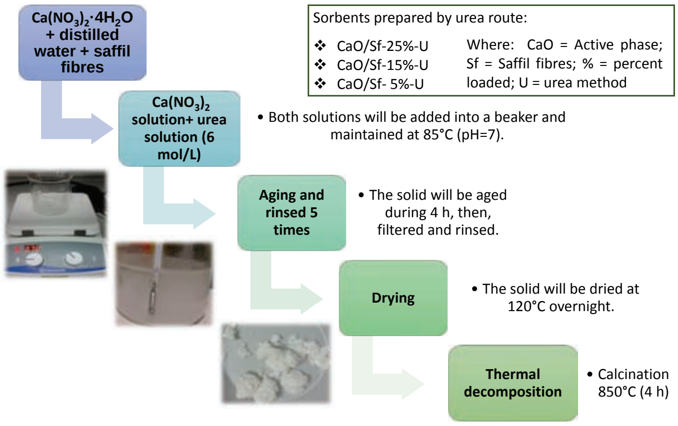
Carbon capture and storage (CCS) has emerged as a promising approach for reducing or mitigating anthropogenic CO_2 emissions into the atmosphere [1]. A classification of the carbon capture technologies positioned pre-combustion capture (PCC) as a potential solution for separating CO_2 from a gasification or reforming process [2]. CO_2 removal at high temperature is conducted through solid sorbents that have the ability to be carbonated and regenerated by a simple reversible reaction. CaO has been conceived as the most cost-effective CO_2 sorbent owing to its high carrying capacity in regards to other sorbents such as Li_2ZrO_3 and Li_4SiO_4, etc., thermodynamics and low production cost [3, 4]. However, the main drawback of natural or synthetic CaO is the drastic reactivity loss over the progress of the carbonation and calcination cycles caused by microstructural changes arisen through sintering [5]. In order to cope this effect, this research proposed the use of a refractory material such as the Saffil fibres (δ-Al_2O_3 catalytic grade) to enhance the thermal properties of CaO and thus inhibit or attenuate sintering.

Methodology

Ca/Sa-%-U sorbents were prepared by precipitation method using urea as precipitant agent. In order to conduct the synthesis method, Saffil fibres, calcium nitrate tetrahydrate ($Ca(NO_3)_2 \cdot 4H_2O$), urea and water were used as the raw materials. The procedure for loading CaO over the periphery of the Saffil fibres is described and schematized intuitively in the Figure shown below.

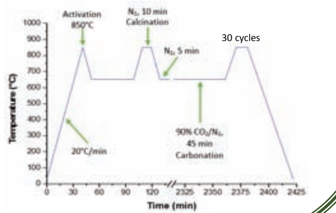
Sorbents prepared by urea route:
- CaO/Sf-25%-U
- CaO/Sf-15%-U
- CaO/Sf- 5%-U

Where: CaO = Active phase; Sf = Saffil fibres; % = percent loaded; U = urea method



Carrying Capacity Evaluation

A thermal profile that includes the operating parameters used for running 30 continuous carbonation-calcination cycles is presented. The conditions used in this program was settled up to evaluate the carrying capacity and thermal stability of the CaO/Sf-%-U sorbents at a harsh scenario.

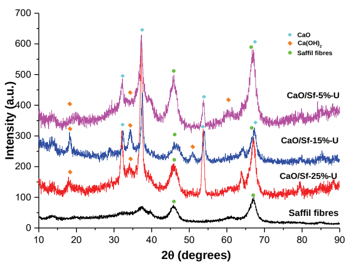


Results

Sorbents Characterization

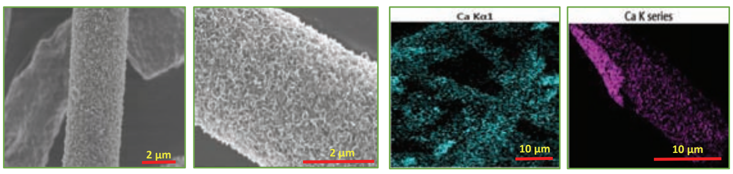
X-Ray Diffraction analysis

XRD patterns of the CaO/Sf-%-U sorbents registered in a 2θ range between 10 to 90°. The phase identification analysis elucidated that CaO and $Ca(OH)_2$ are the crystalline species obtained through the thermal decomposition of the CaO precursor .



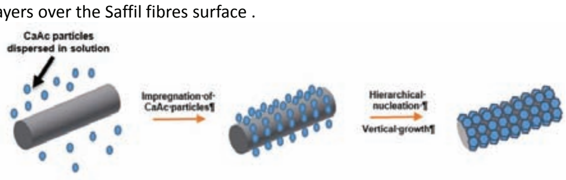
Scanning Electron Microscopy – Energy Dispersive X-ray Spectroscopy (SEM-EDS)

Morphological analysis of the CaO/SF-%-U sorbents loaded with 25% of CaO active phase and EDS mapping aimed to observe the distribution of CaO along the surface of the fibrous support.



Mechanism of Formation of the CaO over the Saffil Fibres

Apparent hierarchical crystallization process (nucleation and vertical growth) of CaO nano-layers over the Saffil fibres surface .

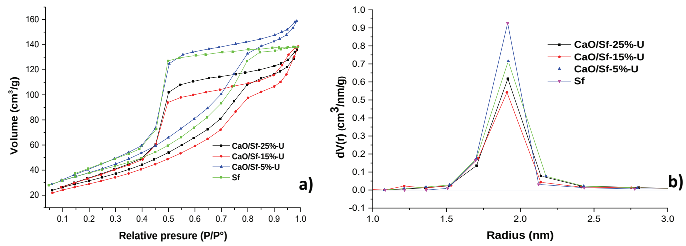


Surface Area and Pore Size Distribution

Specific surface area, pore volume and pore radius values obtained by BET and BJH methods in CaO/Sf-%-U sorbents prepared with different mass contents of CaO active phase.

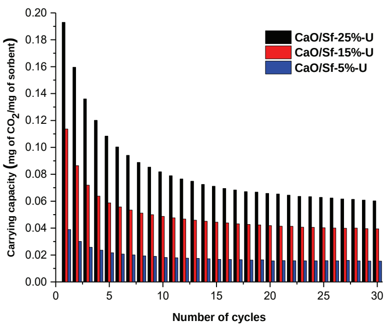
Sorbent	Surface area m^2/g	Pore volume cm^3/g	Pore radius nm
CaO/Sf-25%-U	96.2	0.223	1.909
CaO/Sf-15%-U	112.8	0.241	1.916
CaO/Sf-5%-U	123.2	0.285	1.919
Saffil fibres	138.5	0.249	1.915

Adsorption-desorption Isotherms and pore size distribution curves measured for CaO/Sf-%-U sorbents (**a)** and **c)**) by means of N_2 physisorption at 77 K.



Carrying Capacity Results

CO_2 carrying capacities measured in mg of CO_2/mg of sorbent in the CaO/Sf-%-U sorbents during repeated carbonation-calcination cycles.



Deactivation rate constants (k_1 and k_2) and residual reactivity values found by performing a non-linear curve fitting analysis.

Sorbent	Deactivation rate constant k_1	Deactivation rate constant k_2	Residual reactivity (mg CO_2/mg Sorbent)
CaO/Sf-25%-U	0.45724	0.105177	0.0647
CaO/Sf-15%-U	0.70448	0.10891	0.0411
CaO/Sf-5%-U	0.8600	0.14115	0.0160

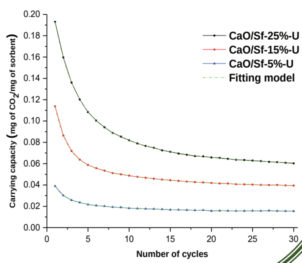
Semiempirical equation (1) proposed by Grasa et al. to predict the residual carrying capacity in CaO sorbents.

$$a_N = \frac{1 - a_\infty}{(1 + kN)^n} + a_\infty$$

Double exponential model used to forecast the residual reactivity of the CaO-based sorbents prepared by the precipitation method.

$$a_{cc,N} = A_1 * e^{-k_1 * N} + A_2 * e^{-k_2 * N} + a_r$$

Non-linear curve fitting for the determination of residual carbonation capacities in the CaO/Sf-%-U sorbents considering a long series of cycles.



Conclusions

- The preparation of the sorbents via urea allowed the nucleation and growth of structures with a peculiar morphology such as nanosheets.
- The highest CO_2 capture capacity was attained by the sorbent loaded with 25 wt. % of CaO.
- An enhancement in the thermal stability of CaO was not only accomplished by using Saffil fibres as a sintering inhibitor but also by the CaO morphology acquired by means of the nucleation-growth mechanism.

References

1. Metz, B., et al., *IPCC, 2005: IPCC special report on carbon dioxide capture and storage.* 2005.
2. Leung, D.Y.C., G. Caramanna, and M.M. Maroto-Valer, *An overview of current status of carbon dioxide capture and storage technologies.* Renewable and Sustainable Energy Reviews, 2014. **39**: p. 426-443.
3. Sreenivasulu, B., et al., *Development Trends in Porous Adsorbents for Carbon Capture.* Environ Sci Technol, 2015. **49**(21): p. 12641-61.
4. Kumar, S. and S.K. Saxena, *A comparative study of CO_2 sorption properties for different oxides.* Materials for Renewable and Sustainable Energy, 2014. **3**(3): p. 1-15.
5. Fennell, P.S., et al., *The effects of repeated cycles of calcination and carbonation on a variety of different limestones, as measured in a hot fluidized bed of sand.* Energy & Fuels, 2007. **21**(4): p. 2072-2081.

UKCCSRC Biannual Poster Prize winners

Three Early Career Researchers won prizes for their posters summarising research - Sergio Ramirez Solis, Revelation Samuel and Thomas Spitz.

By Adeola Awoyomi, Cranfield University

Delegates at UKCCSRC's Autumn Biannual meeting held in Sheffield in September

Sergio's poster was titled "High-temperature CO_2 sorption using sintering-resistant CaO/Saffil fibres Sorbents prepared by precipitation method" from the University of Leeds. His presentation enlightened the audience on his progress thus far in his studies including results and possible future work. He started from a brief introduction in his research, the materials and method used then the result obtained.

According to Sergio, CaO has been conceived as a better alternative to other sorbents like LI_2ZrO_3 and LI_4SIO_4 due to its high carrying capacity and low production cost. The major drawback in the use of CaO is the loss of reactivity over repeated cycles of carbonation and calcination caused by sintering. Sintering causes some microstructural changes that affect the thermal and mechanical stability of CaO. The use of Saffil fibres can enhance the thermal properties and inhibits sintering.

The sorbent was prepared by precipitation method with the following raw materials; Saffil fibres, calcium nitrate tetrahydrate, urea and water. Different sorbent loading was carried out and observed that the highest CO_2 capture capacity was attained when loaded with 25wt % of CaO. The carrying capacity of the sorbent was performed by using X-Ray Diffraction, thermogravimetric analysis, and scanning electron microscopy-energy dispersive X-ray spectroscopy.

The second presentation was made by Thomas Spitz, and his poster was titled "Operating flexibility of CO_2 injection wells", from the University of Edinburgh. According to Thomas, the electricity system dictates the operating regimes of CCS plants, and the CCS system is required to handle a large and regular amount of fluctuations in CO_2 feed flows depending on operating regimes.

He elaborated on different risks and possible solutions (operational and design) that could help injection wells cope better with the unstable flow rates. Some risks mentioned were hydrate formation, cracking of wellbore materials, hydrogen induced embrittlement, oscillations and vibrations.

Revelation Samuel gave the final presentation titled "Transient flow modelling of CO_2 injection into deep geological formations" from University College London. He presented well and eloquently and his message was understood well by the audience. Revelation's research studies are focused on modelling the transient flow behaviour of CO_2 and developing economical techniques for geological sequestration.

The head of the injection well to the reservoir is affected by several factors that could affect or change the temperature and pressure profiles along the well. Three steps were explained in the model development starting from the formulating the basic governing equations of the flow, implementing a method that simplifies the model equations and then to the model validation.

Results gotten from the model were validated with experimental data, and it proved to be accurate at the inlet temperature of 10 ˚C and 20 ˚C. Future work will be extended to dealing with various impurities combination in CO_2 stream. The acknowledgement was given to his sponsor in Nigeria (Petroleum Technology Development Fund - PTDF) and his supervisor Prof Haroun Mahgerefteh.

More information

Adeola Awoyomi's research is into CO_2 shipping particularly on the reduction of carbon and sulphur emissions when the ship is in motion, supervised by Dr Kumar Patchigolla at Cranfield University. She is considering the boil-off gas and carbon-dioxide emitted and liquefying them into the cargo tanks.

See two of the winning posters on the surrounding pages.

www.ukccsrc.ac.uk

Transient flow modelling of CO_2 injection into deep geological formations

Revelation Samuel* and Haroun Mahgerefteh

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UCL

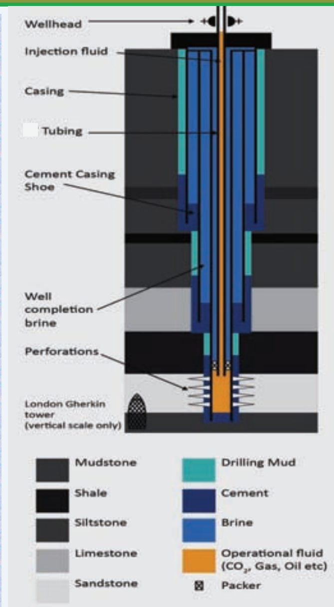
1. Objectives and problem statement

This study is focussed on modelling the transient flow behaviour of carbon dioxide (CO_2) during geological sequestration. Our objectives are:

- Develop and validate a transient flow model for the injection of pure CO_2.
- Demonstrate the usefulness of the model developed by applying data from a real CO_2 injection system as a test case.
- Employ the findings to predict optimum CO_2 injection strategies.

Injecting a highly-pressurised CO_2 into a formation with lower pressure will induce a rapid quasi-adiabatic Joule-Thomson expansion effect. As such, the resulting effect on the formation may be:

- ✓ Blockage due hydrate and ice formation with interstitial water around the wellbore and
- ✓ Thermal shocking of the wellbore casing steel, leading to its fracture and ultimately escape of CO_2.



Geological sequestration of CO_2 has been recognised as an important strategy for reducing the CO_2 concentration in the atmosphere .

From the head of the injection well to the reservoir the CO_2 is affected by several physical effects that contribute to the pressure and temperature profile along the well. Heat will be exchanged with the surrounding rocks along the well. This will not only affect the fluid properties of the CO_2 in the well but also the rock will be cooled or heated by the fluid flow.

Thus, this research is focused on developing economically viable techniques for geological sequestration of CO_2.

Fig 1: CO_2 injection well (UKCCS, 2016)

2. Model development

The development of a transient flow model for CO_2 geological sequestration comprises of three major steps:

i. Formulating the basic governing equations of the flow

ii. Selecting and implementing an efficient and accurate method that resolves or simplifies the model equations

iii. Validating the model against available field or experimental data.

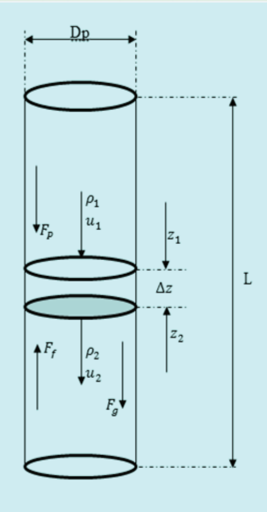


Fig 2: Schematic CO_2 injection process diagram

The system of four partial differential equations for the CO_2 liquid/gas mixture, to be solved in the well tubing, can be written in conservative form as follows:

$$\frac{\partial}{\partial t}U + \frac{\partial}{\partial z}F(U) = S_1 + S_2$$

where

$$U = \begin{pmatrix} \rho A \\ \rho u A \\ \rho E A \\ A \end{pmatrix}, \quad F(U) = \begin{pmatrix} \rho u A \\ \rho u^2 A + AP \\ \rho u H A \\ 0 \end{pmatrix},$$

$$S_1 = \begin{pmatrix} 0 \\ P\frac{\partial A}{\partial z} \\ 0 \\ 0 \end{pmatrix}, \quad S_2 = \begin{pmatrix} 0 \\ A(F + \rho\beta g) \\ A(Fu + \rho u\beta g + Q) \\ 0 \end{pmatrix}$$

A is the cross-sectional area, u and ρ are the mixture velocity and density, P is the mixture pressure, while E and H represent the specific total energy and total enthalpy of the mixture, respectively. z denotes the space coordinate, t the time, F the viscous friction force, Q the heat flux, and g the gravitational acceleration.

3. Initial and boundary conditions

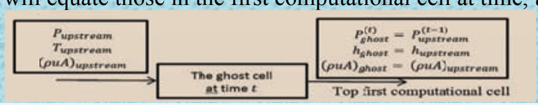
The model was validated using Ketzin pilot site Brandenburg, Germany CO_2 injection well initial and boundary conditions (Moller et al, 2014).

- Inlet pressure 57 bar, inlet temperatures are 10 °C and 20 °C, and injection mass flow rate 0.41 kg/s.
- Initial wellhead pressure 48 bar and temperature 10 °C,
- Total well depth 550m; 0.0889m internal diameter
- Initial bottom-hole pressure 68 bar and temperature 33 °C,

At the bottom of the well an empirical pressure-flow relationship derived from reservoir properties is employed:

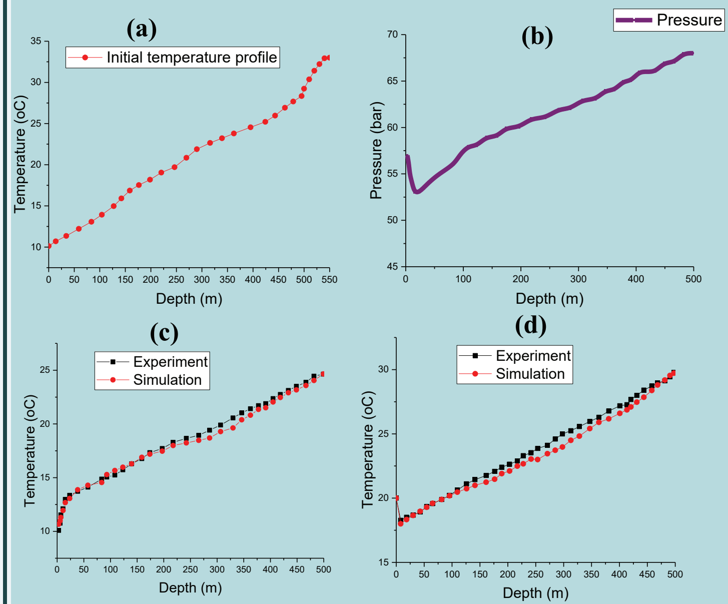
$$\tilde{A} + \tilde{B} \times M + \tilde{C} \times M^2 = P_{BHF}^2 - P_{res}^2$$

At the top of the well, the pressure, enthalpy and mass flowrate in the ghost cell will equate those in the first computational cell at time, $t - \Delta t$.



4. Results and conclusion

The flow and thermal behaviour of CO_2 in injection well is investigated using the above model and the corresponding results are plotted against experimental data. Fig 3 (a) shows the initial well temperature profile while Fig 3 (b) shows the pressure profile after injection. Fig 3 (c) and (d) show results of experiment versus simulation for 10 and 20 °C respectively.



- Injecting at an initial temperature of 10°C and 20°C our simulation results show perfect agreement with the experimental data.

References

1. Brown, S., Beck, J., Mahgerefteh, H., & Fraga, E. S. (2013). Global sensitivity analysis of the impact of impurities on CO_2 pipeline failure. Reliability Engineering and System Safety, 115, 43–54.

2. Vilarrasa, V., Silva, O., Carrera, J., & Olivella, S. (2013). Liquid CO_2 injection for geological storage in deep saline aquifers. *International Journal of Greenhouse Gas Control*, *14*, 84–96.

3. Moller et al, (2014) Injection of CO_2 at ambient temperature conditions –Pressure and temperature results of the "cold injection" experiment at the Ketzin pilot site. Energy Procedia, 63, 6289 – 6297

4. Toro EF. 2010. Riemann solvers and numerical methods for fluid dynamics: a practical introduction, pp. -624. London: Springer

Petroleum Technology Development Fund Scholarships

Distinct regions confirmed in carbon capture and synthesis solvent

Pacific Northwest National Laboratory research into ionic liquid solvents confirmed distinct regions in a popular carbon capture and synthesis solvent for the first time.

Imagine building a city with just two types of buildings: red homes and green offices. You spread the buildings out evenly, alternating red and green. Now, imagine that same city with neighborhoods and business districts. The 3-D map would have distinct areas of red and green. Dr. Xiao-Ying Yu at DOE's Pacific Northwest National Laboratory and her colleagues ended up with a similar map when they delved into a popular solvent, known as a switchable ionic liquid, or SWIL. The team drew the first chemical map of a SWIL.

"We saw something no one had seen before—chemistry that no one had seen before," said Yu, the PNNL chemist who led the team.

These switchable liquids capture carbon dioxide, serve as templates for tiny designer particles and extract desirable chemicals from biomass. SWILs are easier to control and produce less waste than conventional techniques. However, scientists didn't know exactly what happened inside the liquid. The team's research offers a detailed map of how SWILs work. The study gives scientists insights to better control existing SWILs and to design new, more effective liquids for green separation. In addition, SWILs may also serve as soft templates for creating extremely small structures.

"It gives us a deeper understanding of what the solvents are doing and how they behave," said Dr. David Heldebrant, a PNNL scientist studying the chemistry of carbon dioxide.

Used to capture carbon dioxide, synthesize nanoparticles and help turn biomass into biofuels, SWILs are a popular solvent. Sadly, these liquids are difficult to control and improve. Why? The inner workings of the liquids were a mystery. While many thought that SWILs were homogeneous when they were completely loaded with carbon dioxide, the team wasn't convinced. Working with theorists at PNNL, Yu and her colleagues examined computational simulations and calculations that showed distinct regions in the SWILs, even when the chemistry said it should be homogeneous.

The team took a two-pronged approach to drawing up a 3-D chemical map of a SWIL. One involved analyzing the liquid using instruments such as a time-of-flight secondary ion mass spectrometer (SIMS) at DOE's EMSL, a scientific user facility. "We are one of the few groups that can do SIMS analysis of liquids and liquid interfaces," said Yu. "Most places have to dry the sample up or use other bulk approaches. We don't."

Yu along with Juan Yao and Dr. Zihua Zhu analyzed the mass spectrometer data with insights from their synthesis colleagues.

They also conducted a series of experiments that combined the award-winning SALVI technology. SALVI, or System for Analysis at the Liquid Vacuum Interface, allows imaging instruments that require putting the air-sensitive ionic liquid sample under a vacuum to study liquids reacting in real time and in a realistic environment. SALVI, small enough to fit in the palm of a hand, requires as little as two drops of a liquid. The team used SALVI with a chemical dynamic photon beamline at DOE's Advanced Light Source, another scientific user facility. They found supporting evidence of the SWIL components, complementing the SIMS observations.

In analyzing the results from the two approaches and the earlier theoretical study, the team created a 3-D map for the fluid. "This research opened the flood gates," said Dr. Satish K. Nune, a PNNL chemist who worked on the study. "It gave a lot of people new ideas about SWIL chemistry."

More information

www.pnnl.gov

Green Technology of Carbon Dioxide Utilization

A new book, "Carbon Utilization: Applications for the Energy Industry", by Malti Goel and M. Sudhakar (Eds.), 2017 published by Springer highlights various options for CO2 utilization and promote research opportunity in energy intensive industry vital to address challenges towards low carbon growth strategy.

The book has an interesting coverage in environment and engineering disciplines on CO2 abatement & utilization, CO2 terrestrial sequestration and biotic options for reducing carbon footprints from coal use.

The 19 chapters of the book are grouped into four parts dealing with; policy dilemma, terrestrial options, low carbon growth strategies and current green technology research perspectives in industry.

Part 1 is exclusively devoted to power sector discussing policy perspectives, management of supercritical technology and green power production possibilities as well as the need for capacity development in carbon dioxide capture & removal processes, direct and indirect CO2 conversion technology.

The book is the outcome of the five days workshop on awareness and capacity building on Carbon Capture, Storage and Utilization: Towards low carbon growth Strategy held in New Delhi from July 27-31, 2015.

The workshop was organized by the Climate Change Research Institute (CCRI) through support from Ministry of Earth Sciences, Government of India and ONGC Energy Center.

More information

www.springer.com

Capture and utilisation news

NRL receives US patent for Carbon Capture Device

www.nrl.navy.mil

The Electrolytic-Cation Exchange Module (E-CEM) captures CO2 from seawater and produces synthetic fuel.

The world's oceans cover approximately 70 percent of Earth's surface and contain roughly 93 percent of the planet's carbon dioxide (CO2). With around 38,000 gigatons (Gt) of carbon, our world's oceans contain 16 times as much carbon as that found on land or in the atmosphere combined.

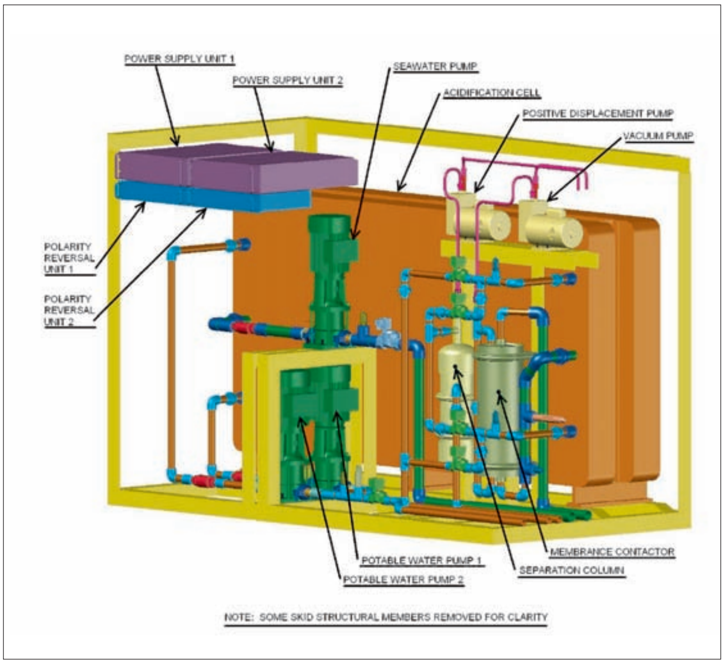
The Electrolytic-Cation Exchange Module (E-CEM), developed at the U.S. Naval Research Laboratory (NRL), provides the Navy the capability to produce the raw materials necessary to develop synthetic fuel stock.

"With greater attention being directed at mitigating the effects CO2 can have on the environment, an interesting and attractive alternative is to recycle the gas into energy-rich molecules," said Dr. Heather Willauer, research chemist, U.S. Naval Research Laboratory (NRL). "The process, based on Fischer–Tropsch technology, is CO2 neutral and eliminates the emission of sulfur and nitrogen compounds that are produced from the combustion of petroleum derived fossil fuels."

Building on the concept of capturing this natural resource, researchers at NRL have developed and received patent 9,719,178, issued Aug. 1 by the U.S. Patent and Trade Office (USPTO), for an electrolytic-cation exchange module (E-CEM). Under this design, the E-CEM is capable of both producing hydrogen (H2) and simultaneously extracting CO2 from seawater.

"In our previous work, the initial scale-up and integration of the E-CEM into a skid platform provided us the data needed to establish faster acidity equilibrium for future modules and improve energy efficiencies and production," said Willauer. "This technology provides the Navy the capability to produce fuel stock, at sea or in remote locations, for the production of synthetic LNG, CNG, F-76, and JP-5 petroleum products."

Located at NRL's Marine Corrosion Facility, Key West, Florida, the next generation, modified E-CEM, demonstrates the progressive steps forward toward integrating and commercializing these systems. The result, at present, is a 33 percent improvement in production time of CO2 and H2 with a feedstock production rate of a single E-CEM capable of producing more than one gallon of fuel per day — contributing to the removal of nearly five tons of CO2 per year.



The Electrolytic-Cation Exchange Module (E-CEM) developed by the U.S. Naval Research Laboratory (NRL) can produce synthetic fuel from CO2 in sea water

CO2 Solutions' first commercial project on track in Quebec

www.co2solutions.com

The project to capture CO2 from a pulp mill in Canada is on schedule.

The project with Fibrek General Partnership, a subsidiary of Resolute Forest Products Inc. and Serres Toundra Inc. entails the deployment of a 30-tonne per day (tpd) CO2 capture unit and ancillary equipment at a pulp mill in the Saint-Félicien region of Quebec (Canada) and the commercial reuse of the captured CO2 by the adjacent Serres Toundra greenhouse facility (the Project).

The Project is following its course as planned. In the spring of 2017, the preliminary engineering was finalized. Since then, the detailed engineering has been largely realized and will be completed in October 2017. The Resolute Forest Product's Saint-Félicien pulp mill completed its planned annual shutdown for maintenance which allowed the CO2Solutions' team to install the required connections from the Fibrek plant to route the flue gas to the future CO2 capture unit. This is an important milestone towards the completion of the unit which is expected to be commissioned in the fourth quarter of 2018.

The procurement of long-lead items has begun with the issuance of the first purchase order to ensure the receipt of the equipment in time for successful completion. Modules with key process equipment will be constructed over the coming winter months. Structural and foundation work is planned for the spring of 2018. It is anticipated that the modules will be assembled into the final configuration over the summer of 2018.

"We are very satisfied with the good working relationship achieved with our clients, Resolute Forest Products and Serres Toundra, as well as the project's engineering firm, BBA." stated Richard Surprenant, Chief Technology Officer for CO2Solutions. "Our objective since the beginning is to deliver a state-of-the-art project that surpasses expectations while meeting budget and schedule – and we remain confidently on this path."

DOE invests $36m in carbon capture projects

www.utwente.nl

U.S. Secretary of Energy Rick Perry has announced approximately $36 million in federally-funded financial assistance to advance carbon capture technologies.

Under the Department of Energy's (DOE's) Office Of Fossil Energy (FE), the Design and

Testing of Advanced Carbon Capture Technologies funding opportunity announcement (FOA) will support cost-shared research and development projects that will continue the development of carbon capture technologies to either the engineering scale or to a commercial design.

"Carbon capture technologies are one of the most effective ways we can continue to leverage the sustainability of our Nation's fossil fuel resources while advancing environmental stewardship," said Secretary Perry. "This funding opportunity will provide for further innovation on methods for capturing carbon emissions for storage and other utilization efforts, as well as underscore this Administration's commitment to both environmental and economic security."

Selected projects for this FOA will fall under two areas of interest:

• Scaling of Carbon Capture Technologies to Engineering Scales Using Existing Host Site Infrastructure—Up to four awards, with combined DOE funding up to $30 million.

• Initial Engineering, Testing, and Design for a Commercial-Scale, Post-Combustion CO2 Capture System—Up to two awards, with combined DOE funding up to $6 million.

These projects will undertake engineering-scale testing of transformational solvent - or membrane-based CO2 capture technologies, and will conduct design work for a commercial-scale, post-combustion CO2-capture system at an existing coal-fueled generating unit.

Imperial develops new porous material for more efficient carbon capture

www.imperial.ac.uk

Researchers at Imperial College London have successfully produced porous boron nitride with four times better adsorption properties than before.

Porous materials have high surface area due to their pore structure, which makes them perfect for a wide range of applications, for instance drug delivery, molecular separations, catalysis, gas storage, water or air treatment. Consequently, these materials are becoming increasingly important. Common types include: activated carbons, zeolites, metal-organic frameworks and – more recently – boron nitride. Despite having several exceptional properties (high chemical resistance, good thermal stability, high thermal conductivity and mechanical resistance), there has been very limited research into the properties and formation of porous boron nitride thus far.

Researchers from the Department of Chemical Engineering and Department of Materials at Imperial College London have now developed a new method to produce boron nitride with tunable surface area, micro- and meso-porosity. The template-free method, which involves multiple nitrogen-containing precursors, uses gradually released gases to create high surface areas and micropores in the structure.

As there are no additional materials involved in the precursors, a cleaning or washing step is not required after the decomposition of nitrogen.Therefore, this method presents a simple and straightforward way of producing porous boron nitride. After creating the structure, the team used 3D tomography and other analytical tools to visualize and characterize the pore network in terms of chemistry, structure, porosity and morphology.

They found that the newly developed porous boron nitride structure had up to four times higher carbon dioxide uptake compared to previously reported materials, even after compressing the powder samples into pellets. The results, published in ACS Nano, are highly relevant to industry as they show an important new method to produce boron nitride in a cost-effective and simple way, while enabling tunable total and microporosity. Crucially, in developing this new method, the researchers have also fully characterized the resulting boron nitride structure, which will help in applications such as carbon capture or catalysis.

Breakthrough in direct activation of CO2 and CH4 into liquid fuels and chemicals

www.liverpool.ac.uk

Researchers from the University of Liverpool have made a significant breakthrough in the direct conversion of carbon dioxide (CO2) and methane (CH4) into liquid fuels and chemicals which could help industry to reduce greenhouse gas emissions whilst producing valuable chemical feedstocks.

In a paper published in chemistry journal Angewandte Chemie they report a very unique plasma synthesis process for the direct, one-step activation of carbon dioxide and methane into higher value liquid fuels and chemicals (e.g. acetic acid, methanol, ethanol and formaldehyde) with high selectivity at ambient conditions (room temperature and atmospheric pressure).

This is the first time this process has been shown, as it is a significant challenge to directly convert these two stable and inert molecules into liquid fuels or chemicals using any single-step conventional (e.g. catalysis) processes bypassing high temperature, energy intensive syngas production process and high pressure syngas processing for chemical synthesis.

The one-step room-temperature synthesis of liquid fuels and chemicals from the direct reforming of CO2 with CH4 was achieved by using a novel atmospheric-pressure non-thermal plasma reactor with a water electrode and a low energy input.

Dr. Xin Tu, from the University's Department of Electrical Engineering and Electronics, said: "These results clearly show that non-thermal plasmas offer a promising solution to overcome the thermodynamic barrier for the direct transformation of CH4 and CO2 into a range of strategically important platform chemicals and synthetic fuels at ambient conditions. Introducing a catalyst into the plasma chemical process, known as plasma-catalysis, could tune the selectivity of target chemicals. "

"This is a major breakthrough technology that has great potential to deliver a step-change in future methane activation, CO2 conversion and utilisation and chemical energy storage, which is also of huge relevance to the energy & chemical industry and could help to tackle the challenges of global warming and greenhouse gas effect."

The highly attractive process could also provide a promising solution to end gas flaring from oil and gas wells through the conversion of flared methane into valuable liquid fuels and chemicals which can be easily stored and transported. Around 3.5% (~150 billion cubic meter gas) of the world's natural-gas supply was wastefully burned, or 'flared', at oil and gas fields, emitted more than 350 million tonnes of CO2.

The paper 'One-Step Reforming of CO2 and CH4 into High-Value Liquid Chemicals and Fuels at Room Temperature by Plasma-Driven Catalysis' is published in Angewandte Chemie International Edition

GPUSA seismic monitoring system tracks CO2 geological storage

A first-of-its kind permanent, continuous seismic monitoring system will be tested at a new facility in western Canada that develops and demonstrates technologies for secure underground storage of carbon dioxide.

By Mark Lowey

California-based GPUSA Inc. will install and test its automated orbital and linear vibrator seismic source technology this fall at CMC Research Institutes' $7-million Field Research Station in southern Alberta. The research station is operated by the Containment and Monitoring Institute (CaMI), a business unit of CMC Research Institutes in Calgary.

The Lawrence Berkeley National Laboratory in California, which has conducted initial field tests on GPUSA's system, will work in collaboration with CaMI and University of Calgary researchers to process the seismic data.

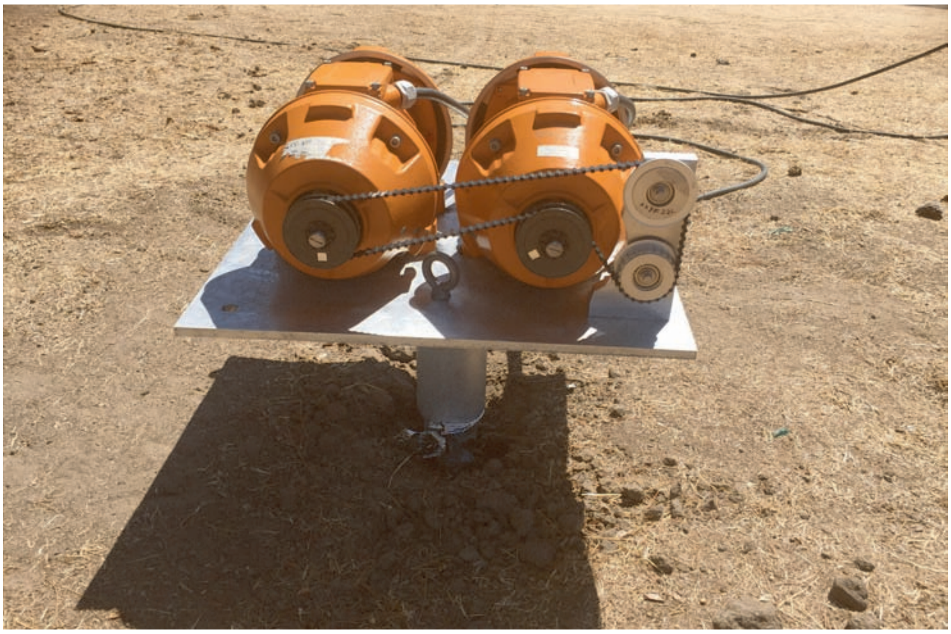
"CaMI enables the testing of this new technology, which is exactly what the Field Research Station was designed to do," says Don Lawton, CaMI's director and professor of geoscience at the University of Calgary.

"A lot of what we're developing and learning at the field station is directly applicable to Alberta's oilsands, including this new monitoring system," he says.

After testing is completed, the permanently installed system will remain at the field station, where it will be used to monitor carbon dioxide injected underground into a geological formation. The facility began injecting CO2 at the site in October this year.

The Field Research Station, operated with funding from the University of Calgary, is designed to play a pivotal role advancing the commercialization of carbon storage and helping industry better understand the movement of fluids underground.

"There couldn't have been a better site for us than the Field Research Station to test our system. It had everything we're looking for," says Jim Andersen, founder and CEO of GPUSA, and lead on the project.



GPUSA's new MicroVib Linear Vibrator atop a helical pile foundation, produces over 11000 pounds of force at 100Hz

The U.S. Department of Energy's National Energy Technology Laboratory last fall awarded GPUSA US$683,699 toward field validation of the company's system.

Andersen says permanently installed, continuous seismic monitoring is needed for safe and cost-effective geological sequestration of carbon dioxide. GPUSA's technology is designed to track and quantify the injected CO2 plume in the geological formation, and detect any migration through the overlying cap rock into shallower aquifers, or potential release at the surface.

The source that generates the seismic wave needs to be permanent, "because you want to be checking, if not once an hour, at least once a day to make sure nothing is shifting," he says. "If you had to bring in equipment every day to do this, it would be impractical."

For example, constantly deploying large vibroseis or 'thumper' trucks, which have a vehicle-mounted ground impact system to generate a seismic wave, is prohibitively expensive.

Also, if the trucks aren't positioned at the exact locations each time, the seismic images can be inconsistent. Moreover, the near-surface layer of the Earth attenuates the vibration the trucks produce, which can interfere with the quality of the seismic source and imaging. GPUSA's seismic sources are designed to bypass the attenuating near-surface layers.

"The beauty of a permanent source is that it stays in one location. Every time you use it there's no variation in where it is, and the output is constant," Andersen says. "It gives you a better picture."

Potential application in oilsands industry

Lawton says the technology developed by GPUSA can monitor any sort of activity in the subsurface, so it also has potential application in Alberta's oilsands industry.

Seismic monitoring is now used in steam assisted gravity drainage (SAGD) operations, which inject pressurized steam into the reservoir to heat and soften the bitumen so it can flow to wells and be pumped to the surface. The seismic surveys tell operators where the constantly changing steam chamber is in relation to the bitumen deposit.

However, these surveys are done on a "time-lapse" basis, typically every six months to once a year. During the time between the surveys, the steam chamber can shift and other changes can occur in the reservoir.

"Operators don't really know what has happened in between surveys," Lawton says

But with permanent, continuous reservoir surveillance, "you get immediate information about what's happening in the subsurface." SAGD operators would be able to quickly investigate sudden changes in the reservoir and make operational changes if necessary.

GPUSA's technology is an example of the trend in continuous reservoir surveillance using advanced geophysical monitoring that collects and manages huge amounts of data, Lawton says.

For example, the Field Research Station is equipped with fibre optic-based geophysical sensors instead of large arrays of seismic geophones. The advanced sensors, which will be used in conjunction with GPUSA's technology, are much easier and less expensive to install in wellbores at the site.

It would be difficult to test GPUSA's permanent system at an actual SAGD plant, where the complex bitumen-production environment doesn't lend itself to field research, Lawton says.

The Field Research Station, on the other hand, provides a unique, independent, controlled environment in which to do a proof of concept of new technologies. "The field station is a critical step between numerically modelling or benchtop experiments and a full-scale field pilot or a commercial-scale pilot," Lawton says.

The orbital vibrator, which is designed to work downhole, is built with corrosive-resistant material

New technology delivers powerful force

The tests of GPUSA's technology will be integrated with Lawrence Berkeley National Laboratory's (LBNL) fibre optic sensors and the conventional downhole seismic receiver array already installed at the CaMI site.

"We're very happy to be collaborating with CaMI, and to see GPUSA work towards commercialization of a permanent source technology that builds on earlier research efforts, including LBNL's," says Thomas Daley, head of geophysics and staff scientist in LBNL's Earth Sciences Division.

"Sites like CaMI's Field Research Station, designed to test and demonstrate subsurface monitoring technology, are very important to advancing monitoring science. We at Berkeley Lab are using the facility to develop and test our own technologies in electromagnetic imaging and fiber optic sensing," Daley says.

Three of GPUSA's units will be installed in one vertical well and two shallow wells at the field station, and tested for about 10 days. The units include two different types of orbital vibrator systems – one for high-resolution cross-well surveys and one for high-resolution vertical seismic profile surveys.

There are other commercially available seismic source technologies that can be placed downhole in wells. However, those sources, such as piezo-type devices, don't generate a powerful enough wave to produce seismic images at sufficient depths, says Andersen, who used to build sonar equipment for the U.S. Navy.

GPUSA's orbital vibrator systems are capable of generating thousands of pounds of vibratory force, or 10 to 50 times greater than traditional downhole piezo sources, he says.

The company's patented technology is based on cylindrical vibrating tools made by the construction industry for more than 40 years. These tools are used to shake poured concrete mixtures to remove any voids and ensure structural strength.

"We had to modify our system a little bit for what we needed to do, but the basic parts are made by the construction industry," Andersen says.

The orbital vibrator, which is designed to work downhole, is built with corrosive-resistant material. The system includes rugged, splash-proof, topside electronics control units for doing various types of seismic surveys.

"We want to make our system readily available at the right bandwidth, power level, size and cost, so it can be widely adopted by industry," Andersen says.

The fully automated wireless system is remotely accessible via the internet. Lawton, for example, could log in remotely any time from his Calgary office to run the system and check the CO_2 plume in the reservoir at the Field Research Station.

"When the tests are finished, we hope the researchers get good use out of the system," Andersen says.

More information

www.gpusa-ca.com

cmcghg.com

www.lbl.gov

www.ucalgary.ca

Statoil, Shell and Total enter CO2 storage partnership

The partners have signed a partnership agreement to mature the development of carbon storage on the Norwegian continental shelf (NCS).

The project is part of the Norwegian authorities' efforts to develop full-scale carbon capture and storage in Norway.

In June, Gassnova awarded Statoil the contract for the first phase of the project. Norske Shell and Total E&P Norge are now entering as equal partners while Statoil will lead the project. All the partners will contribute people, experience, and financial support.

The first phase of this CO2 project could reach a capacity of approximately 1.5 million ton per year. The project will be designed to accommodate additional CO2 volumes aiming to stimulate new commercial carbon capture projects in Norway, Europe and more globally across the world. In this way, the project has the potential to be the first storage project site in the world receiving CO2 from industrial sources in several countries.

"Statoil believes that without carbon capture and storage, it is not realistic to meet the global climate target as defined in the Paris Agreement. A massive scale up of number of CCS projects are needed and collaboration and sharing of knowledge are essential to accelerating the development. We are very pleased to have Shell and Total as partners and believe their experience and capabilities will further strengthen this project" says Irene Rummelhoff, Statoil's executive vice president for New Energy Solutions. "We trust that this robust partnership is well positioned to develop this first-of-a-kind project".

The three companies share a common vision of a carbon storage infrastructure.

"Shell sees CCS as a transformative technology that can significantly reduce emissions from those industrial sectors that will continue to rely on hydrocarbons for decades to come. Shell has significant experience of working with governments and other experts to support the development and wide-scale deployment of CCS and are pleased to be joining forces with our joint venture partners.", says Monika Hausenblas, Shell's executive vice president for Environment and Safety.

"Total is integrating the climate challenge into its strategy. Total's involvement in this first commercial-scale storage project, is thus fully aligned with our low carbon roadmap and our strategy to ultimately become a global CCUS leader" said Philippe Sauquet, President, Gas, Renewables & Power and President, Strategy-Innovation at Total. "The aim of this first integrated industrial-scale project, supported by the Norwegian Government, is to develop viable, reproducible commercial CCUS model in view of carrying out other major projects around the world."

The storage project will store CO2 captured from onshore industrial facilities in Eastern Norway. This CO2 will be transported by ship from the capture facilities to a receiving terminal located onshore on the west-coast of Norway. At the receiving terminal CO2 will be transferred from the ship to intermediate storage tanks, prior to being sent through a pipeline on the seabed to injection wells east of the Troll field on the NCS. There are three possible locations for the receiving terminal; a final selection will be made later this year.

The objective for the project, which is supported by Gassnova and other relevant governmental stakeholders, is to stimulate necessary development of CCS so the long-term climate targets in Norway and the EU can be reached. The collaboration will form basis for establishing a further partnership for the construction and operational phases.

More information

www.statoil.com

Transport and storage news

CO2 Capture Project report looks at CO2-EOR transition to CO2 storage

www.co2captureproject.org

The CCP (CO2 Capture Project) report provides an in-depth review of the regulatory pathways for transitioning a pure CO2 EOR (Enhanced Oil Recovery) project into a CO2 storage operation in two key jurisdictions – Texas, USA, and Alberta, Canada.

A CCP overview study of the subject in 2016 identified that although there are no technological barriers to be overcome, there are a number of legal, regulatory and economic challenges across jurisdictions which must be addressed to allow EOR projects to serve as CCS projects.

Alberta and Texas were chosen for specific focus in this new report as they are particularly favourable locations for potential CCS projects, resulting from a history of CO2 injection for EOR and/or existing CCS infrastructure.

The new report – CCP4: Review of CO2 EOR Transitioning to CCS in Texas and Alberta – looks at each of the jurisdictions through two lenses – firstly, the existing regulatory pathway for CCS permitting without EOR; and then, what is needed for a CO2-EOR scheme to gain credit as CCS and where regulation may be a barrier to that

transition. Each key project stage is covered, from planning and permitting, through to operation, decommissioning and closure. Case studies form each jurisdiction are also provided.

Arthur Lee, CCP Policy & Incentives Team Lead, commented, "This report takes the results from our work last year and moves them a stage further on, providing real detail in two key geographies. We find that, even in two relatively advanced EOR/CCS areas like Texas and Alberta, there are still gaps and uncertainties in the regulatory frameworks that need to be addressed for CO2 EOR projects to transition successfully to CCS."

Battelle completes 15 year CO2 Storage Project at Mountaineer Power Plant

www.battelle.org

One of the first tests for geologic storage of carbon dioxide at a commercial, coal-fired power plant has concluded, more than 15 years after it began, completing a journey from an initial exploratory well to successful operations and site closure.

Battelle started the carbon capture and storage (CCS) research project at the American Electric Power (AEP) Mountaineer Plant in New Haven, West Virginia in 2002 with research funding from the United States Department of Energy's (DOE) National Energy Technology Laboratory (NETL). Based on the positive findings from the exploratory well drilling and seismic survey, AEP decided in 2007 to proceed with a 20 MW pilot test facility, with on-site CO2 capture, compression, transport, and injection.

Battelle was hired by AEP to continue providing the geologic storage expertise. Carbon dioxide was injected from 2009 to 2011 into two injection zones. This was followed by a post-injection monitoring and site closeout phase ending in 2017.

"The geologic storage program was essential for proving the carbon dioxide storage capacity, injectivity, and safe containment at a working power plant," said Neeraj Gupta, Battelle Senior Research Leader. "It was the first CCS project at a working coal-fired power plant, it was funded primarily by private sources, it was a cradle-to-grave project, and we showed it could be done, especially in the Appalachian Basin region, which is so reliant on fossil fuels."

The Mountaineer project helped establish the technical viability of CCS to reduce greenhouse gas emissions from coal-fired power plants, and to store carbon dioxide in geologic layers with limited prior data. It addressed the science and field operation aspects, which are crucial for future deployment of the CCS technologies.

The combination of field monitoring and modeling proved that the injected carbon dioxide stayed in a small region near the injection wells, as predicted by the models. This was instrumental in obtaining regulatory approvals to plug the wells and achieve site closure, following six years of post-injection monitoring. It also expanded the storage resource estimates of the Appalachian Basin region, with identification of new regional targets zones for geologic storage.

The collaboration between Battelle, AEP and others led to many other geologic, engineering, field implementation, and regulatory lessons learned, with regional and global impact for CCS technology development and new knowledge for America's carbon sequestration partnerships, such as the Midwest Regional Carbon Sequestration Partnership.

The project demonstrated the full life-cycle, from inception, characterization well-drilling to find suitable storage zones, reservoir analysis, integration with pilot-scale system for a CO2 supply, injection, storage assessment, monitoring and final close-out. There were more than 200,000 hours of safe operations by Battelle staff and dozens of contractors.

Battelle also served as lead geologic storage contractor for the assessment of commercial scale-up, after a competitive selection process. As a part of this effort, Battelle drilled a new well two miles from the plant to confirm the continuity of storage horizons.

DOE supported CO2 Capture Project reaches 4M tonne milestone

www.netl.doe.gov

A large-scale carbon dioxide (CO2) capture technology made possible through support from the Department of Energy's Office of Fossil Energy and National Energy Technology Laboratory has captured and transported its 4-millionth metric ton of CO2.

Air Products and Chemicals designed, built, and is operating the state-of-the-art CO2-capture and storage system at their hydrogen-production facility located at the Valero Port Arthur Refinery in Port Arthur, Texas.

The project uses a gas-separation technology called vacuum swing adsorption to capture more than 90 percent of the CO2 from the product streams of two commercial-scale steam methane reformers, preventing its release into the atmosphere.

In addition to demonstrating the integration of Air Products' vacuum swing adsorption technology, the project is also helping to verify that CO2-enhanced oil recovery (CO2-EOR) is an effective method for permanently storing CO2. CO2-EOR allows CO2 to be stored safely and permanently in geologic formations, while increasing oil production from fields once thought to be exhausted.

The CO2 captured from the Port Arthur facility is being used for EOR at the West Hastings Unit oil field in southeast Texas. Injected CO2 can dissolve and displace oil residue that is trapped in rock pores. The demonstrated technology can also enhance the U.S. hydrogen market for refinery use, which is estimated to be almost 4 million tons annually.

DOE invests $4m in safe geological storage projects

www.netl.doe.gov

The U.S. Department of Energy's (DOE) Office of Fossil Energy has selected two projects to receive approximately $4 million in federal funding for cost-shared research and development for the safe storage of CO2 in geologic formations.

The selected projects are supported through funding opportunity announcement (FOA) DE-FOA-0001725, Technology Development to Ensure Environmentally Sustainable CO2 Injection Operations. This FOA focuses on developing modeling and monitoring methods, technologies, and tools that help assess the position of CO2 plume over time within various geologic formations and sedimentary environments.

DOE's Carbon Storage Program advances the development and validation of technologies that enable safe, cost-effective, and permanent geologic storage of CO2. The projects will support the program by increasing understanding of subsurface behavior and by enabling scientists to more precisely assess CO2plumes to verify their conformity, stability, and containment.

The National Energy Technology Laboratory (NETL) will manage the projects.