Carbon Capture Journal

CCS in Canada

CCS Knowledge Centre: large scale CCS ready for 2nd generation

New heat integration strategy to improve efficiency of a CCS facility

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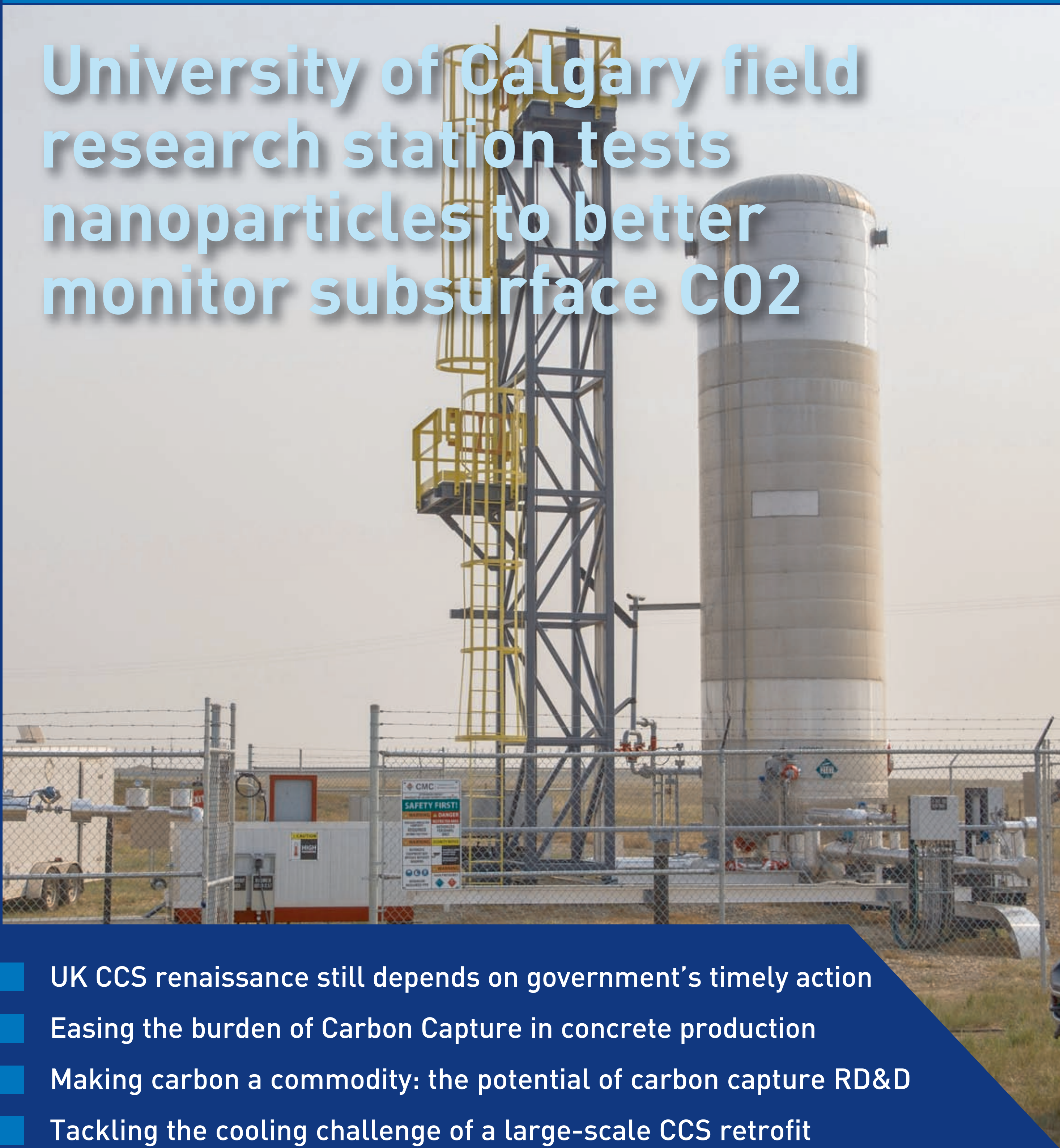
University of Calgary field research station tests nanoparticles to better monitor subsurface CO2



UK CCS renaissance still depends on government's timely action

Easing the burden of Carbon Capture in concrete production

Making carbon a commodity: the potential of carbon capture RD&D

Tackling the cooling challenge of a large-scale CCS retrofit

Fully decarbonising Europe's energy system by 2050

Pöyry has produced a point of view on how Europe's energy system can be fully decarbonised by 2050 in line with the Paris Agreement objectives. The study investigates the key question: "How can a fully decarbonised energy sector be achieved and what are the risks of precluding options in favour of certain technologies?"

Pöyry developed an analytical framework for the power, heat and transport sectors to quantify the risk in not allowing some technologies to participate in the decarbonisation challenge, through implicit or explicit policy actions.

It compares a balanced 'Zero Carbon Gas' pathway where hydrogen, biomethane and carbon capture and storage (CCS) compete with renewables, biomass and nuclear in all sectors to a forced 'All-Electric' pathway where gas infrastructure and gas technologies are excluded, meaning no CCS.

The report recognises that other pathways are possible but comparing these two pathways is instructive for understanding the risks and challenges. Pöyry used assumptions from external sources reflecting their best view of the technology costs and capabilities.

The 'Zero Carbon Gas' pathway represents a future where economics determine which technologies are deployed in order to fully decarbonise the energy sector. The gas industry is allowed to adapt to the requirements of a decarbonised system and provides zero carbon energy in all sectors.

For the purposes of the report 'zero carbon gas' refers to all gaseous fuels that can have a zero carbon footprint across their production chain.

The 'All-Electric' pathway builds upon the assumption that only electrification can achieve decarbonisation and policies are put in place to prevent the development of 'Zero Carbon Gas' alternatives, resulting in new nuclear and biomass build.

The study finds that there are ways to fully decarbonise the European energy system. However, in order for any of these pathways to be achievable, there are certain prerequisites that need to be met.

CCS is integral to the 'Zero Carbon Gas' pathway which can only be achieved if CCS is available and accepted.

CCS allows gas to be used in a wide range of sectors (power generation, heat production, hydrogen production and industrial process output). Pipeline infrastructure needs to be built and adapted to transport the CO2 to the storage sites.

It also relies on hydrogen being produced on a large scale for heat and transport: In order for hydrogen to be competitive, large quantities of methane reformers need to be deployed in all countries.

The 'All-Electric' pathway relies on a significant contribution from nuclear power. Biomass has to be considered sustainable and is available: The absence of CCS or any other alternatives leaves biomass as the only option to decarbonise heat for industrial processes that cannot be provided by electric solutions.

Industry must be decarbonised without CCS. While the study only considers decarbonisation of the energy sector, not allowing CCS has wide-ranging consequences for the industrial sector.

Without CCS, other more expensive solutions in industrial processes need to be found to avoid emissions – or operations need to scale down or relocate away from Europe.

The report concludes that delivering decarbonisation will require significant investment (almost €1 trillion in new power generation alone) and delivering zero carbon solutions is not without risk. A pathway that precludes options, e.g. CCS, could lead to higher investment costs than necessary (e.g. in power generation or networks) and increased risks. Accordingly, it is prudent to keep as much flexibility in the technology options available.

Allowing competition between all energy sources leads to a more integrated and lower cost solution. A more restricted pathway, such as the 'All-Electric', prohibits this competition and leads to a world with much higher costs. In transport, fuel cells appear to be more efficient than batteries in heavy duty vehicles; in heat, hydrogen offers a cost-effective solution; in power, the resulting system is more flexible and relies significantly less on nuclear generation.

In the fully decarbonised future of 2050, unabated natural gas does not have a role. For the gas industry it is therefore vital to develop and demonstrate the benefits of zero carbon gas options, such as biomethane, CCS and hydrogen. It is crucial that policies are put in place to support these adaptations, especially where regulated industries are concerned.

Hydrogen can contribute across transport, heat and power sectors. The assumed capabilities of EVs in providing system flexibility significantly reduce the potential of electrolysis in power-to-gas so the industry must develop a hydrogen supply system using methane reforming.

CCS is the key enabling technology for a 'Zero Carbon Gas' pathway as a cheaper and more resilient route towards decarbonisation. It is the most economic option for abating emissions from industrial heat and facilitates large scale hydrogen production. If alternative carbon usage technologies are developed during this time then this will assist with limiting the volumes that need to be stored.

More information

www.poyry.com

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Front cover:

The Containment and Monitoring Institute (CaMI) boasts a unique field research station for in-field testing of technologies to accelerate the development and deployment of technologies to measure, monitor and verify underground storage of CO2 (pg. 5)

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Large Scale CCS ready for 2nd Generation

A team of engineers at the International CCS Knowledge Centre have uncovered a game-changer for large scale CCS – catapulting it to second generation. Bringing together over 20 years of combined CCS experience from SaskPower's Boundary Dam 3 CCS Facility (BD3), the team is spearheading a feasibility study to retrofit the Shand Power Station with impressive outcomes.

"We are excited about it because many of the common hurdles for large scale CCS are being addressed and results show that next generation CCS technology will be significantly cheaper, more efficient, and integrate well with renewable energy," says Mike Monea, President and CEO of the Knowledge Centre.

Maximizing efficiency and responding to integration from wind or solar, all whilst capturing the most CO2 possible by using an affordable technology is key for CCS to be considered a major climate change mitigation option. The International Energy Agency says that CCS must be able to mitigate 94 (gigatons (GT)) of carbon before 2050 to limit the global temperature rise to 2°C.

The Knowledge Centre's feasibility study examines a business case for a post-combustion capture retrofit on SaskPower's Shand Power Station – located near the famed BD3 in Estevan, Saskatchewan, Canada. The Shand facility however is a 300-MW, single unit, coal-fired power plant – double the capacity of BD3.

A feasibility study is being conducted on retrofitting SaskPowers's Shand Power Station for post combustion carbon capture

Evolution to Success

With operations commencing in 2014, BD3 was the world's first carbon capture facility fully-integrated with a coal-fired power plant and a pioneer for large-scale capture. It is also renowned for its full-chain CCS including capture, transport to enhanced oil recovery (EOR), as well as to onsite geological storage to a depth of 3400M at the Aquistore site.

Motivated to see sizeable impact on CO2 reductions to support global climate change goals, the Knowledge Centre was established - as a non-profit by BHP and SaskPower - to share the learnings garnered from BD3 to accelerate world-wide development of CCS.

The leaps in technology from first generation to second, contemplated in the Knowledge Centre's study, build on the achievements and lessons learned at BD3. Like all first-out-of-the-gate innovation, it has had its challenges. Yet the CCS story at BD3 is one of an evolution to success. In the spring, the facility celebrated a milestone of two-million tonnes of CO2 captured. As well, it recently had a successful operating run at 99% reliability for a period of six months.

"In the early days, the focus was really on learning - with the best of those lessons stemming from unforeseen events in operation. We know what works - just as vital, we know what doesn't work. We know how to prevent detours, delays, and miscalculations because we've backtracked, and retooled to fix and adapt," says Corwyn Bruce, Head of Technical Services for the Knowledge Centre. The focus now for BD3 is on optimizing the facility.

Thermal Energy Source Optimized

Optimization is fundamental when looking to second generation. The Shand Feasibility Study – produced to be consistent with the American Association of Costing Engineers

(AACE) Class 3 / 4 Estimates – sees positive impacts on both economics and design.

One of the key challenges in post-combustion capture is to minimize the extra energy required by the host facility (parasitic load) to regenerate the solvent and release CO2. The source of this thermal energy is critical to how efficient and flexible the plant will operate.

Most studies to date -that look at derate mitigation options - have focused on the full load performance of a plant with thermal energy coming from the coal plant's steam turbine versus the combined performance of coal and gas plants in a combined heat and power arrangement. However, these studies haven't considered the realities and limits that are then imposed on the gas turbine cycle. In the Shand Feasibility Study, the Knowledge Centre details the contrast between the new gas-fired steam source and steam extraction from the coal plant.

In the scenario of when a coal-fired capture plant is integrated with a gas plant, it becomes more difficult to dispatch the two generation sources independently. In the examination of steam extraction from a coal plant, the feasibility study replaced portions of the steam path to optimize the steam extraction pressure without imposing throttling losses or adding additional equipment.

"This provides the opportunity to apply upgraded blade technology and recover accumulated degradation in turbine components, describes Mr. Bruce.

"It also provides the best environment for the plant to operate with maximum flexibility to ebb and flow with the variables that impact power plants on a daily basis." If the steam is coming from the coal plant, the quantity of steam available will follow the amount of CO2 to capture, as the load on the coal plant changes.

The study shows that extracting steam from the existing coal plant has the lowest impact and provides the most flexible and economic option.

Work on SaskPower's Boundary Dam 3 CCS Facility (BD3) is now focussed on optimising the facility and knowledge gained will be used to inform the Shand feasibility study

Cooling Technology Ensures Water Conservation

An additional benefit is water conservation. This design tackles barriers of: 1) water availability generally being a limiting factor for most thermal plants; and 2) that the integration of CCS increases the amount of cooling required. In the feasibility study, the design works with the existing water allotment of the site augmented by water condensed from the flue gas and a portion of dry cooling such that the facility can be economically cooled without requiring additional cooling water.

Increased Flexibility to Integrate with Renewables

In rendering cost effective and efficient large-scale CCS plants, there are many variables and operating constraints that all force a need for flexibility, such as: the value of electricity, markets for CO2, taxes, regulations, etc. One such example of retooling addressed in the feasibility study is the ability to adapt to a plant's operating variability. In the first-generation design and operation of BD3, it is optimized to capture carbon when the unit is running at full load.

However, units often run at decreased loads. With the increased need to incorporate more energy options, such as renewables, it is important that coal plants be able to decrease their load as required - to allow for these alternate sources of electricity production into the grid.

As such, it is important that a capture facility must be able to continue to capture CO2 even when the unit that it is serving is running below full capacity. The Shand Feasibility Study takes advantage of the plant's ability to vary its output, and to increase the capture rate at lower loads beyond 90%, while supporting the integration of additional renewable energy from wind and solar.

The need for flexibility is key. In this study at Shand, the aim is to maximize the efficiency of the thermal plant as well as ensure that the design is nimble enough to not disrupt existing operation - creating a reliable, clean coal energy system that allows CCS to integrate well with renewable energy sources.

Scale Matters

The Knowledge Centre has examined the feasibility of CCS on potential capture facilities of numerous sizes.

In the Shand Feasibility Study, the scale increases from BD3's 150 megawatts (MW) to Shand's 300 MWs. With Shand producing approximately 1,100 kg of C02 per MW hour, the application of CCS on the plant would see the capture of as much as two million tonnes of CO2 per year.

Increasing the size of the facility, increases the impact on emissions while decreasing the cost per tonne of CO2 captured.

Significant Savings for 2nd Gen.

As with any second-generation technology, efficiencies are generated through what was learned, then design and approach are adapted – both of which positively impact the economics of a project. Early projections on how much would be saved to build the next large-scale CCS facility were anticipated at 30%.

However, findings from the Knowledge Centre's feasibility study indicate the potential for significantly deeper cost reductions with a greater amount of CO2 being mitigated.

This is good news, especially for the climate – as the CCS field has often been hindered by the perception of a hefty price tag. Several global energy research organizations including the International Energy Agency, and the UN International Panel on Climate Change (IPCC) recognize that much of the world cannot meet their emission reduction targets without large-scale CCS. Research affirms that without CCS, the median increase in mitigation cost is 138%.

The cost of CCS will continue to decline as more plants are built.

Global & Industrial Application

To advance global climate change goals, an intentional and tactical approach is needed for commercial scale CCS. Many developing countries have a growing middle class and demand energy security. Implementation of CCS could meaningfully aid in decarbonizing electrical grids and even other industrial emissions.

"Globally, we have had numerous enquiries from people interested in maintaining value in existing generating assets, a diverse fuel mix or securing a low cost fuel, such as coal, all while lowering GHG emissions in response to various policy signals and pressures specific to each region," says Beth Hardy, the Knowledge Centre's Vice President of Strategy and Stakeholder Relations.

CCS is applicable beyond the energy sectors and can be applied to industrial sources of emissions which have limited abatement options such as iron, steel, concrete, and agriculture. For example, during the production of cement which is 8% of the worlds CO2, two-thirds of the emissions are from the process and are independent of the fuel burned. Interestingly, the flue gas from a cement plant is very similar to the flue gas stream from a coal fired power plant like BD3, and as such the learning from BD3 can help de-risk that process.

The Knowledge Centre will apply the principles of the Shand Feasibility Study to other feasibility studies as well as front-end engineering design studies throughout the world in a variety of industrial applications, including cement, waste-to-energy, as well as coal power.

Our job is to improve the delivery and performance of large-scale CCS so that it can be effectively utilized around the globe," says Mr. Monea. "We've got the expertise, the hands-on experience, and we want to share it with the world."

Public release of the Shand Feasibility Study is anticipated in the autumn of 2018. For more information, see the International CCS Knowledge Centre's detailed abstracts for eight papers accepted to GHGT-14 conference, upcoming in Melbourne Australia, October 21-26, 2018.

More information

www.ccsknowledge.com

University of Calgary field research station to test nanoparticles to better monitor subsurface CO2

More than a dozen PhD students and postdocs from Norway have been learning about techniques being developed at the University of Calgary to use nanoparticles to monitor CO2 in the subsurface. By Jennifer Allford, for the Office of the Vice-President (Research)

University of Calgary researchers and their Norwegian University of Science and Technology counterparts spent a week together in UCalgary labs and at the Containment and Monitoring Institute (CaMI) near Brooks, as part of a research collaboration on carbon storage and enhanced oil recovery. Photos by Adrian Shellard, for the University of Calgary

The students from Norwegian University of Science and Technology (NTNU) were in Alberta as part of CARBEOR, a partnership to advance research and education on carbon storage and enhanced oil recovery. They spent time in laboratories, classrooms and in workshops at UCalgary, followed by field studies at the Containment and Monitoring Institute (CaMI) in Newell County, a geophysical monitoring site that is unique in the world.

“The ability to do experiments in the field in real rocks at real scale is incredibly powerful,” says Dr. Steven Bryant, PhD, UCalgary’s co-manager of CARBEOR and Canada Excellence Research Chair in Materials Engineering for Unconventional Oil Reservoirs. “You can do lots of stuff in the lab and you can do anything you like on the computer but getting things into the real world is when you really find out how it’s going to work.”

The NTNU scholars spent two days at CaMI, learning about advanced geophysical monitoring techniques, including using nanoparticles to get better images of CO2 in the subsurface — research that could lead to better monitoring of sequestered greenhouse gases and enhanced oil recovery.

“No matter what you’re doing it’s always helpful if you can turn up the image contrast, whether it’s something medical or in the subsurface," says Bryant. "We know nanoparticles can give us another tool that we can deploy to, in effect, brighten up the images."

While NTNU has geophysical monitoring labs, researchers at the Norwegian university aren't able to do real-life experiments in their oilfields. "We don't have the rocks on land," says Dr. Ole Torsæter, a NTNU professor in reservoir engineering, "Everything for us is offshore and then everything becomes so expensive." Visiting CaMI offers the NTNU researchers "unique possibilities" as well as opportunities for collaboration on carbon capture and storage and other research projects, he says.

"In Norway I'm doing rock physics and although we try to make experiments valid for the large scale, it's hard because you have this upscaling issue," says Stian Roerheim, a PhD student in engineering at NTNU. "That's why it's important to go to the field because things tend to not be exactly the same in the lab as it is in practice in the field."

University of Calgary and NTNU researchers at the CaMI field research station near Brooks, Alta.

Olga Ibragimova, a postdoc at NTNU, focuses on the potential for improving properties of tailings through novel approaches, studying adsorption and desorption of chemicals in order to recycle them prior to submarine tailings deposition. "My task is to validate the analytical methods and measure the concentration of chemicals in tailings-seawater systems to be very sure that they are as non-toxic as possible. This knowledge, especially the study of nanoparticle properties, is a new technique for me and I believe that this training can be very useful in my future studies. I would like to develop my skills and explore the effect of nanoparticles properties on their performance for better understanding of the mechanism."

UCalgary researchers and students have visited Europe twice as part of the three-year CARBEOR project, which also includes a graduate student exchange program. "One of the main objectives of CARBEOR is to give graduate students and researchers from both universities training opportunities and experiences in different environments," says Dr. Don Lawton, PhD, director of CaMI, UCalgary's co-manager of CARBEOR, and professor of geophysics in the Faculty of Science.

"Collaborating with researchers in Norway and elsewhere will help us all reach the end goal of more efficient energy production and reduced environmental impacts."

CaMI, a partnership between the university and non-profit CMC Research Institutes, is supported in part by the Canada First Excellence Research Fund (CFREF) initiative, Global Research Initiative in Sustainable Low Carbon Unconventional Resources. The $850,000 CARBEOR partnership is funded by the Research Council of Norway and through in-kind funding from the Canada Excellence Research Chairs program.

Don Lawton, left, explains the results of seismic waves to UCalgary and NTNU researchers at the CaMI field research station

More information

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UK CCS renaissance still depends on government's timely action

Industry is ready to put money into deploying CCS but needs to know that the policies will be in place to make it a viable investment.

By Rebecca Bell, Indira Mann and Philippa Parmiter, Scottish Carbon Capture & Storage

When tackling what seems an overwhelming challenge, such as climate change, it can be useful to repeat the following phrase: Start at the beginning.

The UK's Energy Minister, Claire Perry, said something similar when welcoming the findings of the Carbon Capture Utilisation and Storage (CCUS) Cost Challenge Task Force in July, although more along the lines of "starting from where we are now".

So where is "now" when it comes to meeting the UK's climate targets through a commercially viable carbon capture and storage (CCS) industry, and do we have what it takes to get on with the job?

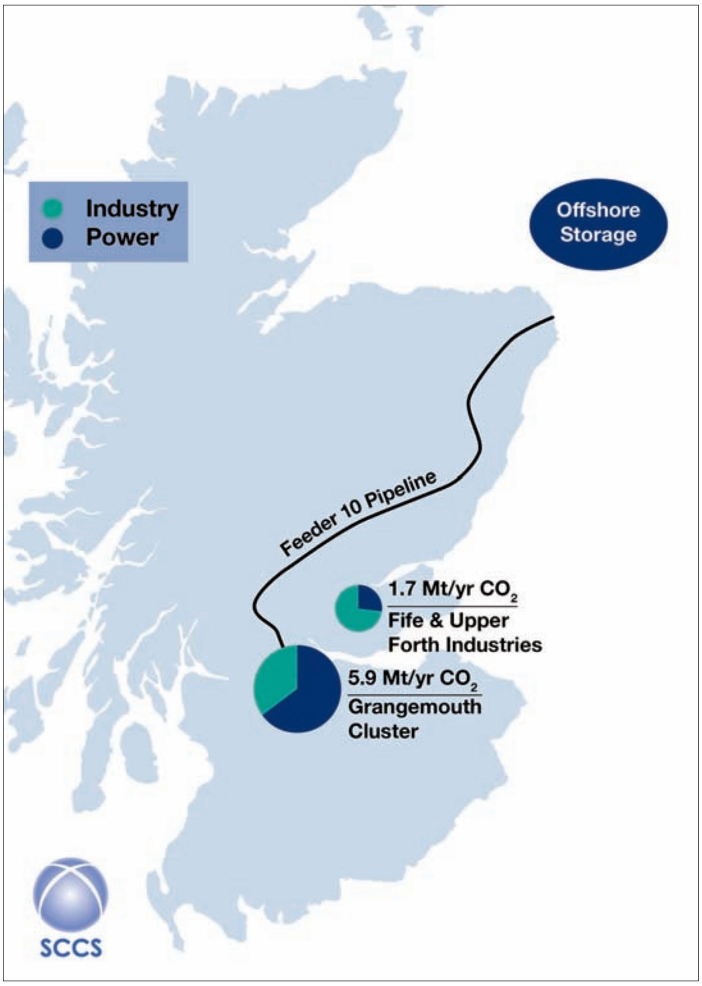
Billions of tonnes of carbon dioxide (CO2), the main culprit in our planet's escalating temperatures and extreme weather events, have been vented to the skies since government and industry first began exploring the potential of CCS.

Valuable lessons have been learned from previous attempts to get the ball rolling in the UK (let's not harbour any bitterness here). A handful of promising CCS projects – though not nearly enough – are making slow but steady progress. And Scotland, with its geology and other assets, is still uniquely placed to lead the UK towards a carbon-neutral society by 2050.

The argument for CCS has evolved, and it is now recognised as a means of decarbonising not just industrial processes and electricity generation but also heat and transport when used as part of hydrogen production. Used wisely and strategically, CCS reaches across our entire economy, future-proofing industry from a rising carbon price and bringing other benefits that it would be foolish to ignore.

The UK Government's Industrial Strategy and Clean Growth Strategy underline the role of CCS in supporting industrial growth. A study last year – Clean Air, Clean Industry, Clean Growth: How Carbon Capture Will Boost the UK Economy by Summit Power – concluded that CCUS could boost the UK economy by around £163 billion between now and 2060, outweighing investment costs by a factor of five.

The past year has seen CCS enjoying something of a renaissance, with a number of new projects under way, courtesy of European Union and UK funding, and further support from the Scottish and UK governments for existing projects. The case for CCS is made. What the UK Government must now do is act on the advice of the CCUS Task Force without further delay.



The Feeder 10 onshore pipeline is one big piece of the jigsaw, with nearly three quarters of Scotland's large point source emitters located within 40km of its route from the central belt towards North Sea CO2 storage sites

One headline recommendation from the Task Force is to focus on regional clusters of industry, power generation and hydrogen production. Tie these into shared infrastructure for transporting CO2 to offshore storage sites and you have a cost-effective solution to building a CCS network. As the impact on the public purse is a key factor in the delivery of CCS, this is good advice for all concerned.

The east of Scotland has an enviable set of advantages for any CCS project developer. These range from an experienced workforce, which has honed its skills in the oil and gas industry, to commercially ready offshore CO_2 storage sites and legacy oil and gas infrastructure that can be repurposed for CO2 transport.

The Feeder 10 onshore pipeline is one big piece of the jigsaw, with nearly three quarters of Scotland's large point source emitters located within 40km of its route from the central belt towards North Sea CO_2 storage sites.

There are also two high-profile CCS projects being developed here – Acorn in north-east Scotland and the Caledonia Clean Energy Project at Grangemouth – which are poised to kickstart a UK North Sea CCS industry that can also offer a carbon storage service to the rest of Europe.

The re-use of infrastructure will dramatically reduce the capital costs of these projects; by £750 million for the Acorn project and £440 million for Caledonia, respectively. These potential savings can only be realised if the infrastructure in question is protected from the decommissioning axe.

That means Ms Perry's Department for Business, Energy and Industrial Strategy working strategically, and urgently, with the Oil and Gas Authority (OGA) to join the dots and review the decommissioning process. The UK and Scottish governments also need to work with the oil and gas industry to secure these assets and keep them in good condition until they can be re-used.

Given that our leaders now appear to be convinced of the need for CCS, and the physical requirements seem to be in place, things are looking quite positive for the delivery of a CCS industry. Aren't they?

We are agonisingly close but, while UK policy and legislation does in theory support the roll-out of CCS, there just isn't enough certainty to convince businesses and other potential investors to back this particular horse. Industry is ready to put money on the table to deploy CCS, but it needs to know that the policies will be in place that make this a viable investment. Primary legislation could provide that reassurance, but the clock is ticking and new laws are a time-consuming business.

In addition, there are already worrying signs that legislative opportunities have been missed, such as a failure to provide market signals in the UK's Energy Bill that would have provided the confidence private investors are waiting for.

The OGA has also failed to take on board the potential for developing CO_2 enhanced oil recovery in the UK North Sea, or act to avoid the risk of rapid decommissioning of the infrastructure that can bring significant savings to CCS development.

So, what can be done to take the renewed momentum for CCS to its necessary conclusion? We are posing that question to industry partners in Scotland by forming the Scottish Low Carbon Industry Leadership Group, with members who want to future-proof their business and identify market advantages from a global imperative to decarbonise their operations.

We will work closely with the group to explore market opportunities, such as CO_2 utilisation and hydrogen production. There are many options for industries, such as oil refining, chemicals, cement, and even distilleries, to deeply decarbonise their operations and we will be investigating innovative solutions, from fuel cells and hydrogen to bioenergy.

The group will also benefit from being kept aware of current government thinking and from knowledge exchange between Scottish industries, sharing best practice for reducing carbon emissions. Perhaps most importantly, we will steer industries towards funding opportunities, such as the UK Government's anticipated support in 2019 for CCUS clusters.

The Task Force's proposed criteria for a CCUS cluster include, among other assets, an existing industrial base, a well-developed project with strong commercial sponsorship, good access to CO_2 storage capacity and strong local and regional support.

That sounds a lot like the Caledonia and Acorn projects, which will make use of North Sea infrastructure for CO_2 transport and storage and consider the opportunities to maximise future inward investment, fulfilling another two of the Task Force's criteria.

A world-leading climate scientist in America recently called the extreme weather wreaking havoc across the globe the "face of climate change". In the UK, we have the capability coupled with the opportunity to take climate action and share that knowledge and expertise with other nations. We know where we stand on CCS; the time to deliver is now.

Scottish Carbon Capture & Storage (SCCS) is the largest CCS research partnership in the UK with its partner institutes engaged in innovative research and development. Its world-class scientists are spearheading moves to improve the efficiency and economics of CCS alongside other work, such as policy and public engagement, to support its deployment worldwide.

More information

www.sccs.org.uk

From a 'waste disposal' problem to a 'CO2 industry' opportunity

Politicians, industry, academia and NGOs all gathered for the annual week of discussions and political events in Arendal, Norway earlier this month. Bellona, Fortum Oslo Varme and Oslo City Climate Agency gathered important stakeholders for an event on the potential for a CO2 industry linked to waste incineration.

Waste disposal is a major, global concern, stated Liv Monica Stubholt from Oslo Fortum Varme, Norway's largest supplier of district heating. In Norway, we can use organic waste for biogas production and we recycle materials such as plastic, glass and metals. What is left is sent to waste incineration plants such as Klemetsrud in Oslo, and used for the generation of district heating. However, such waste incineration plants account for large, local CO2 emissions in cities.

More waste incineration in the EU

There are 450 waste incineration plants across Europe, which account for large amounts of CO2 emissions. Moreover, 60% of waste in the EU is still being sent to landfills, with detrimental consequences for both climate and environment. "Restricting regulations for reducing landfill waste to a minimum will only increase the need for waste incineration plants and tackling emissions from these", said Heidi Sørensen, director of Climate Agency in Oslo.

While waste disposal is a growing global problem, there is also an emerging industrial opportunity to solve the problem, which offers to create new jobs and enhance international collaboration, several speakers agreed.

On August 10th, the Norwegian government confirmed its commitment for the detailed engineering design of a CO2 capture project at the waste incineration plant at Klemetsrud in Oslo, Norway. The government will then appraise investment in building the plant in 2020 or 2021.

Creating a value chain

Even though Norway is to take first steps towards investment in the new technology and sees it as an industrial opportunity, it is important that a commercial value chain is in place to decrease costs which are covered by the state.

Norway has the knowledge and competence in this area and combines industrial and climate policies to achieve the results. Now it is more important than ever that the planned CCS plants be accomplished within the set timeframe and to avoid any further delay.

CO2 capture in Oslo of national importance

The Vice Mayor for Business Development and Public Ownership in Oslo, Kjetil Lund, confirmed Oslo's ambitions to be a leader on the climate action front, which in turn will necessitate the deployment of CCS technology at the Klemetsrud plant. The plant's emissions are not only a significant share of Oslo's greenhouse gas emissions, but are also an important contributor to total national emissions.

A subsequent debate among leading climate and energy politicians, including the minister for oil and energy, focused on the public support for such an investment, with benefits such as industrial competitiveness, job creation and support towards meeting climate goals. Developing carbon capture plants still entails a large investment in the state budget and public acceptance will be key to making it a successful win-win outcome for all stakeholders.

Minister of Oil and Energy Terje Søviknes came on board Bellona's boat Kallinika to celebrate the Norwegian government's commitment to the detailed engineering design of a CO2 capture project at the waste incineration plant at Klemetsrud in Oslo, Norway

More information

www.bellona.org

Easing the Burden of Carbon Capture in Concrete Production

Dr. Geoff J. Nesbitt, CEO, Verditek looks at how Regenerative Froth Contactor (RFC) technology can reduce emissions in cement production, easing the burden commonly associated with mandatory carbon footprint reduction. www.verditek.com

Usually, associating the words ‘concrete’ and ‘footprint’ will conjure up images of perfectly preserved footprints pressed into setting concrete by small children or animals – a common fixture in many municipalities. However, as the most abundant man-made material on earth, conventional concrete comes with a significant emissions problem. As concrete’s main by-product, CO2 emission from cement production has a huge carbon footprint.

Seven percent of global man-made greenhouse emissions come from cement and in 2017 alone global cement production was responsible for around 4 billion pounds of CO2 emissions. Dwindling CO2 supplies recently impacted various industries in the UK, sparking conversations around the potential re-use of CO2 captured in other industries. While this could become a longer-term goal, cement producers should have already begun to explore carbon capture solutions in reaction to intensifying pressure to reduce greenhouse gas emissions on a global scale.

Pressure Rising

Carbon capture technology will essentially provide cement producers in any country that is applying the COP21-Paris accord rules with a renewed license to operate. The 195 governments that signed the Paris Agreement in 2016 (possibly excluding America) will be implementing COP21 as a regulation that forces their industries to take action. From the cement industry to oil, gas, manufacturing and beyond, industries must recognise COP21 as the official prompt to start budgeting for adjustments they must make to meet the moving climate change targets and to explore solutions that will realistically aid them in meeting those targets.

It’s not just governments that are demanding change. There is mounting demand for sustainability from the general public too. One survey conducted by YouGov on behalf of the Carbon Trust found that 55 percent of UK consumers would feel “much more than positive” about a company that has reduced the carbon footprint of its products. Moreover, two thirds of consumers across the UK, France and Germany would now like to see a recognisable carbon footprint label on goods. But it’s not all about everyday products. This growing demand for sustainability is likely to extend to every aspect of the world that surrounds us, from eco-friendly materials to greener energy generation in housing, commercial buildings, infrastructure and public spaces.

National Geographic reports that nearly 70 percent of the world’s population will live in cities by 2050. That’s a 55 percent increase on today’s figure. While cities cover just 2 percent of the world’s land surface, they account for 70 percent of greenhouse-gas emissions. Thirty percent of those emissions are generated by buildings alone. While there are viable alternatives to cement in residential construction with sections such as roofs, walls and floors prefabricated from either wood or MgO materials, commercial and industrial structures which are subject to higher stresses and loads will continue to rely on cement.

Some producers have successfully introduced recycled aggregates into the cement mix, yet only up to 10 percent can realistically be used in a mix before the strength of the cement is compromised. As the sustainability movement continues to develop, the pressure to reduce carbon emissions will continue to rise for cement producers.

A Matter of Cost

Given the costs associated with implementing carbon capture technology, it’s hardly surprising that the global cement industry has been seeking subsidisation or some form of financial relief from governments pressuring them to take on the burden of reducing the carbon output. While there is currently no offer of subsidies, some governments have introduced carbon credit schemes. These however have been criticized for falling short of making a significant impact, and in some quarters are seen as a means for governments to capitalise on carbon production.

The cement industry would prefer not to be confronted with the expense of implementing any solution, but it cannot continue to vent CO2 into the atmosphere without consequence. The only viable option for cement producers is to seek out emerging solutions that can achieve the same results as conventional contractors in a more affordable way.

RFC technology is a relatively compact cost-effective technology for mixing gas with solvents, which is the primary method for washing CO2 from flue gas. RFC technology has the potential to offer a more affordable method to strip the CO2 from the kiln exhaust thanks to the equipment’s lower cost per tonnage. An RFC unit can be placed next to the exhaust chimney with the exhaust routed to the contactor where the amine solvent will react with the CO2. The use of these solvents is established and well known to cement producers, however, the latest innovations in RFC technology is less known and the advantages it can offer in a smaller operating burden.

A Step in the Right Direction

Compared to conventional contractors, RFC is more robust and has the advantage of working with precipitating solvents. It could even be possible for producers to lease the technology instead of buying it outright, shifting the proposition to an operating budget instead of a major capital purchase.

While the captured CO2 will still need to be sequestrated or put to use elsewhere – perhaps in some of those industries experiencing a CO2 shortage – RFC provides the first step towards this by enabling the cement producer to reduce the cost of meeting stringent regulations and intensifying demand for carbon footprint reduction from all directions.

UK CCUS Cost Challenge Taskforce report: delivering clean growth

An independent report to government on progressing carbon capture, usage and storage in the UK has proposed a viable business plan but urgency is needed.

The Clean Growth Strategy sets out the UK Government's new approach to carbon capture usage and storage and recognises the potential importance of CCUS to support the decarbonisation of the UK's economy.

The CCUS Cost Challenge Taskforce was established in January 2018 with the remit of informing and proposing a strategic plan to Government for supporting the development of CCUS in the UK, in order to meet Government's stated ambition of "having the option to deploy CCUS at scale during the 2030s, subject to costs coming down sufficiently."

The Taskforce proposes a range of measures and actions to inform a new approach to CCUS deployment that will enable cost reductions to be secured. By demonstrating that CCUS can deliver decarbonisation across industry, power, and provide solutions for heat and transport, the report focuses on building a long term, commercially sustainable and cost-effective decarbonisation service industry for the UK. This, in turn, can bring new industrial opportunities, secure long term jobs, deliver new economic development across our industrial heartlands and secure international competitiveness through new decarbonised products and services.

The report identified viable business models, funding mechanisms, and an innovation pathway, as well as suggesting options to support the lowest cost delivery of a potentially transformative technology, underpinned by a series of short, medium and longer term recommendations.

Key messages for Government

• We need to recognise the CCUS opportunity and the urgency of acting now in order to deliver CCUS at scale, at lowest cost. Project lead times are long, and time is limited if we are to deliver CCUS on the scale which may be necessary by 2050, with potentially well over 100 million tonnes of carbon dioxide per year needing to be stored. This can be achieved with joint industry and Government vision, supported by the first projects becoming operational from the mid-2020s and an industry pipeline of financeable projects.

• CCUS can unlock value across the economy to enable low carbon industrial products, decarbonised electricity and gas, a hydrogen economy, greenhouse gas removal, and new industries based around utilising CO2.

• We need viable business models to move the technology to a sustainable commercial footing.

• We believe that CCUS can already be deployed at a competitive cost. Project concepts being proposed are comparable on cost with other first of a kind low carbon technologies. Our approach is to focus on deploying CCUS in clusters, with the cluster stakeholders identifying how the value of CCUS can best be secured to benefit their local economies and needs.

CCUS meets the three tests of the UK Clean Growth Strategy

Developing and deploying CCUS in the UK is consistent with all three tests set out by the Minister of State for Energy and Clean Growth in launching the Clean Growth Strategy:

• Delivering maximum carbon emissions reduction: CCUS can support cost-effective decarbonisation across a wide range of sectors, while simultaneously supporting clean growth across the economy. CCUS is a key technology which can enable decarbonisation in some high value industrial sectors, retaining and creating key jobs as part of a modern industrial strategy.

• Following a clear cost reduction pathway: Cost-effective CCUS can be achieved through industry and Government working together to:

- Unlock early investment: Industry and Government working together to create a stable, long term, supportive policy environment to unlock development of at least two CCUS clusters to be operational from the mid-2020s, anchored by "catalyst" projects to enable learning by doing, to pull through innovation and reduce the cost of capital, meaning future projects cost less.

- A new business model for CO2 transport and storage infrastructure: Separating the business model for CO2 transport and storage ("T&S") infrastructure from the business models for CO2 capture projects can reduce overall commercial risks and costs, by reaching cost-effective public-private risk sharing arrangements. Developing viable business models, as well as sharing of T&S infrastructure, and the strategic re-use of existing oil and gas assets are considered important steps that can enable potential cost reduction in CCUS.

- Create CCUS clusters: The development of clusters (i.e. regional groupings where several CCUS facilities share infrastructure and knowledge) and associated Clean Growth Regeneration ("CGR") Zones can help drive lower cost CCUS, unlock value for local economies, and foster continuous technical innovation. Early progress is required to develop these clusters.

• Making the UK a global technology leader: By acting now, the UK will be able to make the most of its current engineering, geological, and commercial advantages to build a strategic supply chain, and grasp the opportunity to develop a large export market share of a potential globally significant sector.

Industry Comment

The **Carbon Capture & Storage Association** (CCSA) said the report sets out the enormous opportunity and value that CCUS delivers across the UK economy and emphasises the need for urgency to enable CCUS to fulfil its role in achieving the lowest-cost route to meeting the UK's statutory climate change targets.

The overall conclusion of the Taskforce is that CCUS meets the three commitments set out in the Clean Growth Strategy; reducing emissions in the most cost-effective way, maximising innovation and making the UK a global technology leader. The UK is uniquely placed to grasp the CCUS opportunity, with the potential to develop a large export market delivering significant economic benefits for the UK.

The report recommends a number of key actions and messages, including:

• A minimum of two CCUS clusters (incorporating capture plants and CO2 stores) operational from the mid-2020s.

• The development of CCUS clusters delivers value across the UK economy by enabling low-carbon industries and electricity as well as unlocking other benefits such as decarbonised hydrogen for heating, greenhouse gas removal and carbon dioxide utilisation.

• The development of a new business model for CO2 transport and storage, separate from that which is used for the capture plant.

Dr. Luke Warren, Chief Executive of the CCSA, commented, "After six months of intense discussions between a number of key CCUS stakeholders, the message from today's report is clear: CCUS can already be deployed at a competitive cost, through the development of CCUS clusters in key UK regions. These clusters could support clean growth across the UK economy whilst retaining and creating high-value jobs in some of the UK's most important industries."

"The Government has committed to publishing a CCUS Deployment Pathway by the end of 2018. The next five – six months therefore represent a crucial period for CCUS. It is imperative that industry and Government now work together to ensure that the recommendations set out in today's report are taken forward and reflected in a strong and ambitious new approach to CCUS."

Scottish Carbon Capture & Storage (SCCS) said that CCUS reaches across the whole economy, for example in the retention and growth of high-value jobs in industrial production and the oil and gas industry; and the production of low-cost hydrogen with CCUS to decarbonise heat and transport said Scottish Carbon Capture & Storage. CCUS is vital to the aspirations of industrial growth as defined in the government's Industrial Strategy and Clean Growth Strategy. A study last year, Clean Air, Clean Industry, Clean Growth: How Carbon Capture Will Boost the UK Economy, concluded that CCUS could boost the UK economy by an estimated £163 billion between now and 2060, outweighing the investment costs of £34 billion by a factor of five times.

The Task Force report recommends focusing on regional clusters around industry, power production and hydrogen production; gathering CO2 and transporting through separately managed, shared infrastructure to offshore storage rather than the end-to-end, single large power plant projects of the past.

The report finds that large cost reductions are possible through this sharing of infrastructure and additionally through the reuse of existing oil and gas infrastructure, both onshore and offshore. Several existing pipelines connected to well-characterised stores are suitable for conversion to CO2 transport, leading to reductions in capital costs of £750 million for the Acorn project and £440 million for the Caledonian Clean Energy Project. These large potential savings can only be achieved if we make sure that the pipelines we need aren't swept up in the rush for decommissioning. The Oil and Gas Authority and BEIS need to urgently review the decommissioning process and the implementation of the Maximising Economic Recovery Strategy in the next few months.

If government wishes to have the option to deploy at scale in the 2030s the building and operating of CCUS networks must begin in the 2020s, but before construction decisions can be taken early action is needed on legislation, risk management and financial structures. Two such actions include changes to the gas safety management regulations (GSMR) and managing the long-term liability for storage. Regional gas companies will be making investment decisions during 2019 for the period 2021 to 2026 so it is urgent that a commitment is indicated to change the GSMR to allow some hydrogen content in our existing gas networks; and unless the government caps liability or takes some of the burden of risk then storage projects will remain difficult to insure.

Stuart Haszeldine, SCCS Director, said, ""This comprehensive report compiles an integrated examination of industrial need, technical capability and financial investability. The report proposes a very welcome reset of CCUS strategy, which recognises for the first time that CCUS has value across the entire UK economy and enables clean industrial growth."

"East Scotland is extremely well placed as a region of the UK with unique access to commercially-ready very secure CO2 storage sites offshore. We have two leading CCS projects - Acorn and the Caledonia Clean Energy Project – which are ready to bring costs down further by re-using oil and gas industry legacy pipelines.

"CCUS will enable the retention of tens of thousands high value skilled jobs in the oil and gas industry and is a significant part of the North Sea oil and gas industry's transition to a low-carbon future. It is positive that the task force has recommended that government and industry undertake a strategic review of the oil and gas assets that could be repurposed for carbon dioxide transport. However, this needs to go further – UK and Scottish governments and industry need to work together to ensure that these strategic assets are protected and kept in good condition until they can be re-used. They also need to make sure that decommissioning is paused until this review is completed, otherwise we run the risk of throwing our infrastructure investment away."

"We now call on the government, and particularly Minister of State for Energy and Clean Growth, Claire Perry to take these recommendations on board, and start taking the action we need to make CCUS a reality."

More information

www.gov.uk

www.ccsassociation.org

www.sccs.org.uk

Why do public responses to CCUS matter if CO2 is stored offshore?

Social scientists working on public perceptions and acceptability in the CCUS field often get asked this question.

By Christine Boomsma, Senior Researcher and Emma ter Mors, Assistant Professor Leiden University, who are both working on societal support for the Align CCUS project.

When CO2 storage takes place offshore, rather than onshore, perhaps making use of existing infrastructures from the oil and gas industry; do we still need to be concerned with public responses to CCUS? After all, in the case of offshore CO2 storage there seems to be no obvious local community directly near the storage site, and the CO2 injection wells are often far enough from land that they are largely out of public view. So, assuming that out of sight will mean out of mind - why are public responses to offshore CO2 storage worth studying?

To answer this question we can look at a recent CCS project taking place in Victoria, Australia which is currently in the project development phase (the CarbonNet Project[1]). Here the government is looking into storing CO2 offshore. In response, community members along the coastline have set up the Ninety Mile Beach Action Group Against Carbon Storage[2]. Clearly, these communities feel affected by the offshore CCS plans, even though they do not live directly next to the storage site. Offshore CO2 storage is not 'out of mind' for them – instead, locals have voiced concerns about the effects that CO2 storage will have on the 'pristine' environment, and unhappiness about the level of information communicated by the government.

It is not difficult to imagine that an offshore industrial development, such as a CCUS project, can lead to strong public reactions when the development is seen as destroying those qualities that make the sea a special place for many

Photo: https://beeldbank.rws.nl, Rijkswaterstaat / Harry van Reeken.png

This is only one example of public responses to offshore CC(U)S but there is evidence to suggest that this is not an unique story. Most of the environmental social science research on comparing public responses towards offshore and onshore developments has been done in the wind energy sector. Similar to offshore CCUS, offshore wind is often posed as a less problematic, more acceptable alternative to onshore wind by academics, policy makers and developers[3]. However, research in this field has shown that this isn't necessarily the case, which is also relevant for offshore CCUS; in fact:

There is no evidence for an universal preference for offshore developments over onshore developments[4]

Instead, public responses depend on the local context of a development. Although there are examples of offshore developments which have led to little public resistance, acceptability isn't a given when developments are placed offshore rather than onshore. In a recent study on CCS storage options among the German public, the majority of respondents said that they would prefer CO2 to be stored nowhere at all when asked whether they preferred onshore or offshore storage. Also, although offshore CO2 storage was seen as a slightly better option than onshore storage among the general public, citizens of coastal regions were equally negative about both storage options[5].

So, what do we know about the factors that are important when it comes to public responses to offshore developments? In the case of wind energy, studies have shown that the factors that influence public responses to offshore wind are largely the same as those that influence public responses to onshore wind energy. Importantly, this includes factors related to the decision-making process around a project: e.g. does the (local) public have a voice within this process, does the (local) public trust the stakeholders involved in this process?

For onshore CC(U)S projects we know that when there is a lack of trust between local communities and stakeholders (such as the project developer or local authorities), and/or communities aren't given a meaningful voice as part of the decision-making process this can give rise to public resistance and can cause delays for a project[6]. These factors are also likely to play an important role in public responses to offshore CCUS projects.

Thus, as is the case for onshore developments, spending time to understand the local context, identifying relevant (on-and offshore) stakeholders and local needs and concerns will be crucial for public support. This awareness already exists within some offshore CCUS projects that are currently being planned, but identifying who the relevant community is may be more complex and time-consuming for offshore developments compared to onshore developments.

Nevertheless, it should be an important step in the project development phase especially since the general public and local communities may have very different ideas about what the sea represents and what it can be used for, compared to developers and policy makers[7].

The sea, for many people, is a place of 'openness' and 'wilderness' where human structures do not belong and which isn't owned by anyone. It is not difficult to imagine that an offshore industrial development, such as a CCUS project, can lead to strong public reactions when the development is seen as destroying those qualities that make the sea a special place for many.

We saw this in the Australian CCS project, which we started with, where locals felts that their 'pristine part of the world' was being threatened. Also, when it comes to identifying the relevant communities and their concerns an often overlooked factor with offshore developments is that there will always be an onshore element as well.

In the case of CCUS, this will most likely be in the form of transport pipelines. There is little research available on public responses to onshore pipelines (or offshore pipelines for that matter), as social science research has mainly focused on societal perceptions of CO2 storage sites.

What we do know suggests that these pipelines could be a safety concern for local communities and are likely to have a negative influence on public responses to offshore CCUS if these concerns are not taken seriously and addressed[8].

What is the ALIGN CCUS project doing to contribute to our knowledge about public responses to offshore CCUS?

From the research and examples discussed so far it is clear that studying public responses to CCUS is important, even when storing CO2 offshore. Research gaps remain, for instance around successfully engaging communities with offshore CCUS and public responses towards onshore and offshore pipelines. Within ALIGN CCUS WP6 'Implementing CCUS in Society' contributes to this timely and relevant research area by examining the factors influencing societal support of industrial CCUS using various methods:

1) An important part of the work within WP6 involves a large-scale survey of public perceptions towards various aspects of industrial CCUS, including views towards transport and storage. This survey will offer an opportunity to examine public perceptions, and importantly – the key factors underlying these perceptions.

2) Literature reviews, media analyses and stakeholder interviews will delve deeper into current debates around public responses to industrial CCUS. This work will provide novel insights into the experiences that stakeholders have with regards to engaging the public with CCUS, the knowledge gaps that still exist, and the role of the offshore context.

Overall, through innovative basic and applied research WP6 will provide tools that CCUS stakeholders can use to understand and engage with local communities and the wider public, thereby helping to reduce nontechnical risk of offshore industrial CCUS implementation.

References

[1] http://earthresources.vic.gov.au/earth-resources/victorias-earth-resources/carbon-storage/the-carbonnet-project

[2] http://www.abc.net.au/news/2018-05-13/tiny-victorian-beach-community-fights-ccs-plans/9738480

[3] Haggett, C. (2008). Over the sea and far away? A consideration of the planning, politics and public perception of offshore wind farms. Journal of Environmental Policy & Planning, 10(3), 289-306. Haggett, C. (2011). Understanding public responses to offshore wind power. Energy Policy, 39(2), 503-510.

[4] Wiersma, B. & Devine-Wright, P. (2014). Public engagement with offshore renewable energy: a critical review. WIREs Climate Change, 5(4), 493–507.

[5] Schumann, D., Duetschke, E., & Pietzner, K. (2014). Public perception of CO2 offshore storage in Germany: regional differences and determinants. Energy Procedia, 63, 7096-7112.

[6] Terwel, B. W., Koudenburg, F. A., & Ter Mors, E. (2014). Public responses to community compensation: the importance of prior consultations with local residents. Journal of Community & Applied Social Psychology, 24(6), 479-490. Terwel, B. W., Ter Mors, E., & Daamen, D. D. (2012). It's not only about safety: Beliefs and attitudes of 811 local residents regarding a CCS project in Barendrecht. International Journal of Greenhouse Gas Control, 9, 41-51.

[7] Gee, K. (2010). Offshore wind power development as affected by seascape values on the German North Sea coast. Land Use Policy, 27(2), 185-194. Kempton, W., Firestone, J., Lilley, J., Rouleau, T., & Whitaker, P. (2005). The offshore wind power debate: views from Cape Cod. Coastal Management, 33(2), 119-149.

[8] Shackley, S., Reiner, D., Upham, P., de Coninck, H., Sigurthorsson, G., & Anderson, J. (2009). The acceptability of CO2 capture and storage (CCS) in Europe: An assessment of the key determining factors: Part 2. The social acceptability of CCS and the wider impacts and repercussions of its implementation. International Journal of Greenhouse Gas Control, 3(3), 344-356.

More information

This article was originally published as a blog on the Align CCUS website:

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ZEP report on role of CCUS in a below 2 degrees scenario

The report concludes that CCS is available today, constitutes an essential part of the lowest cost solution, and is particularly necessary for reducing emissions from 'hard to mitigate' sectors such as industrial processes and distributed heating.

The European Zero Emissions Technology & Innovation Platform (ZEP) report also states that as part of the lowest cost pathway to delivering long-term EU greenhouse gas emissions reductions, CCUS enables a 'just transition'. This is one that is perceived as not unduly costly to people locally and globally.

The report argues that European industry in particular needs to deploy low-carbon solutions that are available today, and CCUS represents one of the few technologies that is available, scalable and costeffective. CCUS therefore enables a transition that is 'just' both locally and globally, sustaining the economic contribution of the industries in which Europe has already invested.

Commenting on the report, Dr. Graeme Sweeney, Chairman of ZEP, said: "The European Commission has just published its consultation on the strategy for long-term EU greenhouse gas emissions reduction and how to deliver net-zero emissions by 2050. There is no doubt that reaching this target will be incredibly challenging and we will need all tools at our disposal. Our report published today is clear: CCUS is not an and/or technology, it is a must-have."

"CCUS technologies are available now and their urgent deployment therefore represents the lowestcost solution with minimal disruption to industry, consumers and infrastructure. By comparing CCUS deployment to delivery of historical public services, such as the provision of clean water or transport infrastructure, we begin to see CCUS in a different light; as part of a 'just transition' that delivers benefits to various sectors and national economies across Europe. It preserves jobs in vital industries and creates new ones, thereby delivering economic prosperity for Europe whilst establishing our industrial heartlands as the go-to place for low-carbon products on the international scene."

"In the last year, we have seen much-needed action and progress on delivering CCUS in countries such as Norway, The Netherlands and UK. What is needed now is coordinated action between the Commission, Member State Governments and the private sector to put in place the necessary mechanisms to enable investment in CO2 transport and storage infrastructure. This will create industrial CCS clusters that are able to reconcile continued growth with reducing emissions, thereby ensuring a sustainable future for key European regions".

Conclusions

The paper proposes that among the many other actions on going, CCUS (and ultimately also hydrogen) have a crucial role in reducing real emissions at current source in a manner that does not lead to the transfer of emissions and economic benefits of industry to other regions. This will enable CCUS infrastructure to be developed as both a national and global common public resource, incentivising the type of cooperative public-private action that has been observed in the past, for example in the case of water treatment and storage.

In this regard, it proposes that the EU strategy for long-term emissions reductions assesses how CCUS, along with other solutions such as hydrogen will enable a truly just transition toward the 2c target, and to involve a wider stakeholder audience in this discussion. As discussed, this will require that the economic narrative set out here is further developed based on fuller development of the type of transparent evidence-based metrics presented in this study.

It will also require a fuller set of the economy-wide modelling methods to generate them. At this stage, our review shows that both CCUS and hydrogen are part of the least cost portfolio for 2050. Without CCUS in 2050 and all along the timeline to 2050, the local, national and global economic and environmental costs of achieving the 2c Paris targets will be much higher. Worse, the likelihood of achieving the targets much reduced. There is a positive business case for CCUS across the EU Member States, if they are to achieve their commitments.

Achieving the required CO2 emissions reduction will require local solutions at industrial cluster level. It will also require regional infrastructure solutions so that a transport and storage service provided for CO2 captured. This reflects the need for incentives for CCUS to be established by Member States to provide certainty for investors.

This constitutes the key role for government actors. CCUS should be implemented on a country and regional basis to the level and extent of cooperation required across an integrated European economy. In the case of CCS, the key point is making best use of the CO2 storage resources that will be developed to address the real current emissions where they occur in their currently locations.

In the case of hydrogen production involving CCS, the crucial point is bringing fuel production closer to its point of distribution and use. Only by using all available and cost-effective funding and policy mechanisms – which may involve approaches such as developing a 'market maker' – can the EU meet its commitments to the Paris Agreement, including any increase in ambition to reach net-zero emissions within the EU by 2050.

More information

Download the report here:

zeroemissionsplatform.eu

IEA bioenergy report: implementing bio-CCS in biofuels production

The report looks at two example cases selected to cover a representative range of gasification technologies, biofuel products and possibilities for CCS infrastructure.

In combination with other climate change mitigation options (renewable energy and energy efficiency), the implementation of carbon capture and storage (CCS) will be necessary to reach climate targets. If the CO2 released by bio-based processes is captured and stored in geological formation or other storage options, negative CO2 emissions can be potentially achieved.

With this background, the report provides an initial overview of the potential of biomass and waste gasification to contribute to CCS through the assessment of two example cases set in Norway and The Netherlands. A description of these possible biofuel routes based on gasification, together with an estimation of the overall costs and potential impact of bio-CCS on greenhouse gas balances, has been presented. The study cases (600 MWth thermal input) have been selected to cover a representative range of gasification technologies, biofuel products and possibilities for CCS infrastructure in countries which offer particularly good opportunities for the implementation of this technology:

• Case 1: production of Fischer-Tropsch syncrude from high-temperature, entrained-flow gasification in Norway.

• Case 2: bio-SNG production from indirect gasification in The Netherlands.

The results have shown that the application of CCS in biofuel production processes can have a considerable impact on the reduction of greenhouse emissions. In both scenarios considered, the addition of CCS to a biofuel production value chain doubles the amount of avoided CO2 from 0.6 to 1.1 Mton/y.

This positive impact on the reduction of CO2 emissions comes at a cost: the biofuel production price increases by 10-14%, as shown in Figure 1. Given the significant role of bioenergy expected in the future energy system, we conclude that with the right incentives, biofuel production coupled to CCS can be a powerful tool for CO2 mitigation to reach the global climate targets. The analysis also reveals that it is necessary to modify the current CO2 emission system in order to reward the negative emissions achieved by bio-CCS. If there is an economic value for negative CO2 emissions, bio-CCS can significantly improve the business case with respect to the base case.

The results of Case 1 show that under the conditions assumed, the cost of production of FT syncrude from woody biomass increases from 24.0 to 26.4 €/GJ, if the costs of CO2 compression and cooling, transport and storage are included in the overall value chain. The analysis also shows that the economic impact of including CCS is very sensitive to the CO2 transport cost, the overall FT syncrude production cost increased from 26.4 to 30.8 €/GJ (by 17%) when CO2 transport cost increased from 0.09 to 0.36 €/ton/km. Possible compensation measures of the higher FT syncrude production costs resulting from the implementation of CCS include the reduction of feedstock supply costs, or the increase in the market value for bio-based LNG (which is a by-product, thus a revenue in the process), or the increase in the credits for CO2 capture.

The following assessments are presented: 1) 25 wt.% of the input woody biomass is replaced by sewage sludge with a gate fee of 10 €/ton; 2) the price of bio-based LNG is increased by 25%(from 20 to 25 €/GJ); or 3) the CO2 credits are increased by 100% (50-100 €/ton). The results show that substitution of the wood with sewage sludge or increase of the CO2 price will not improve the overall economic viability significantly, and also the price of the natural gas or CO2 credits had only a minor effect on the FT syncrude costs.

As for Case 2, the results show that under the conditions assumed, the production cost of bio-SNG increases by approximately 14%, from 19.6 €/GJ to 22.3 €/GJ, when adding CCS to the bio-SNG process. Transport and storage of CO2 contribute with 5.3% to the total SNG production cost. By applying pre-combustion technology (amine scrubbing in this case) to indirect gasification, approximately 1/3 of the initial carbon contained in the biomass can be captured (the rest ending up in the flue gas side of the indirect gasifier).

The cost (and thus the origin) of biomass has an important effect on the production cost. Under the assumptions of this work, the threshold biomass price for the project to become financially feasible is around 8 €/GJ. Under the reference conditions considered in this study, a breakeven CO2 price of approximately 30 €/ton has been determined, which indicates the need for the modification of the current CO2 emission system to account for the negative emissions achieved by bio-CCS.

The economic feasibility of bio-SNG + CCS is also very sensitive to the price of the bio-SNG product. The breakeven cost of bio-SNG is 17.8 €/GJ according to the assumptions taken. The investment cost has a dramatic effect on both the bio-SNG production cost and the ecomomic feasibility of the project. Under the conditions assumed, it would be necessary to reduce the investment costs below 1180 €/kW input for the project to become profitable. Thus, a significant effort needs still to be performed in the coming years for the demonstration of bio-SNG at large scale in order to reduce the capital costs.

The results of this preliminary assessment study have identified opportunities and challenges for the implementation of bio-CCS schemes. Detailed cost analyses, other locations and technological solutions other than mentioned in this exploratory study, as well as extrapolation of the results to a more global perspective and the study of the integration of the produced CO2 in power to fuel/chemicals schemes (carbon utilization), are topics beyond the scope of this project which should be addressed in more detail in future work.

More information

ieabioenergy.com

Making carbon a commodity: the potential of carbon capture RD&D

A report from the Carbon Utilization Research Council and ClearPath Foundation examines the potential for market-driven deployment of carbon capture, utilization and storage (CCUS) technologies for coal and natural gas power plants.

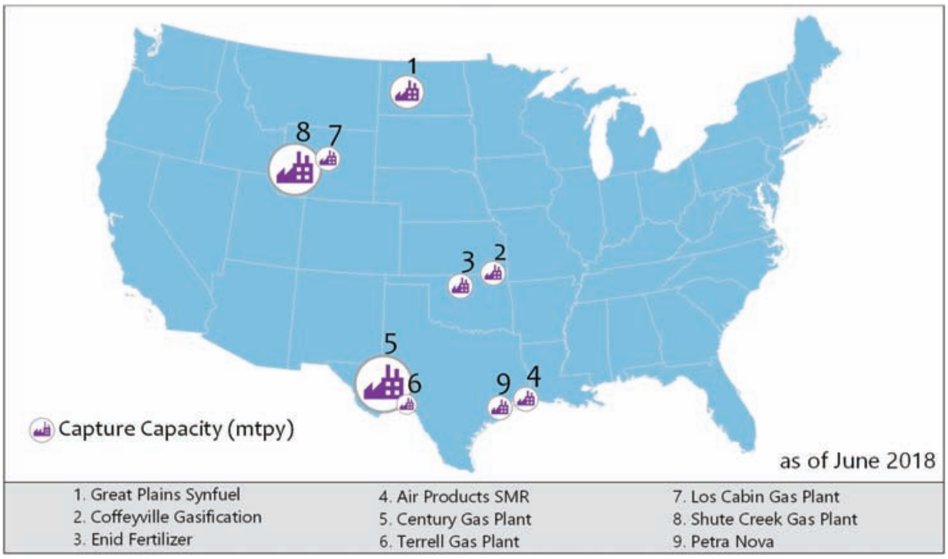
In particular, it examines how reducing the cost of carbon capture via a rigorous research, development and deployment (RD&D) program can enable new coal and natural gas power projects with carbon capture for enhanced oil recovery (EOR), and quantifies the resulting economic and employment benefits to the United States.

Under evaluated scenarios, an accelerated RD&D program would enable market-driven deployment of 62 to 87 GW with carbon capture technologies without any additional environmental regulations or mandates. By 2040, power-sector carbon capture could enable over 920 million barrels of additional domestic oil production each year, with the increased oil activity supporting up to 780,000 jobs and a $190 billion increase in gross domestic product (GDP).

Lower-cost power produced via the RD&D effort could reduce the national retail cost of electricity up to 2.0% by 2040, which is expected to increase GDP an approximate $55 billion and create another 380,000 jobs economy-wide. Projections vary based on key input assumptions, such as power demand growth and fuel prices.

"This study reinforces the importance of robust RD&D funding," CURC Executive Director Shannon Angielski said. "If we look at past success stories, especially with the development of scrubber technologies and increased efficiency in the use of our fossil energy resources, it is clear that public-private sector partnerships have been a driving force in the commercial deployment of energy technologies that have meaningful economic and environmental impacts."

"Carbon capture isn't just a vital tool to decarbonize our economy, it can also dramatically grow U.S. jobs, energy production, clean baseload power and the overall economy," ClearPath Executive Director Rich Powell said.



Map of Large U.S. Carbon-Capture Projects for EOR (Based on data from Global CCS Institute)

Importantly, the study found these benefits over the next two decades would be lower under less aggressive RD&D scenarios. With less aggressive rates of RD&D, the analysis found significantly less deployment of carbon capture technology by 2040. Under scenarios with higher technology costs, the study forecasted a roughly two-thirds reduction in new coal and natural gas with carbon capture.

In all scenarios, carbon capture power projects were driven by market decisions and only built when it was the lowest lifetime cost option and associated enhanced oil recovery regions did not exceed production limits. High rates of economic growth and high oil prices were other factors that resulted in more robust carbon capture deployment in the tested scenarios.

Released with the study is the 2018 CURC-EPRI Roadmap, a technical report that describes enabling technology pathways and resources needed to achieve the cost reductions envisioned in the study.

Realising the benefits

Power sector modeling analysis in the report showed that a rapid reduction in carbon capture costs can lead to theoretical market deployment for EOR, but translating these benefits into the real-world depends strongly on:

• A public-private partnership across the entire RD&D cycle. Dedicated public-private partnerships are needed across the development cycle, from bench-scale research to commercial projects. The large capital requirements and first-of-a-kind risks associated with transformative carbon capture projects make it uniquely challenging for the highly regulated power-sector industry to invest in the initial wave of projects. On first-of-a-kind commercial projects in particular, where new technologies have not been previously demonstrated, warranties and other forms of insurance are difficult to procure in the marketplace without initial government support. Bipartisan legislation authorizing public-private partnerships across the entire RD&D spectrum has been introduced in both the House and Senate that would accomplish this.

• An aggressive commitment to the carbon capture and power systems program. By 2035, the U.S. Department of Energy (DOE) aims for a new coal plant with carbon capture to cost 40% less than it would cost to build a plant using today's technology. While the DOE's Carbon Capture & Power Systems budget in support of this goal has been steadily climbing, annual funding levels remain, on average, 45% below recommended levels by the power-sector and associated industries. Echoing previous reports from the National Coal Council, the Carbon Utilization Research Council (CURC) and the Electric Power Research Institute (EPRI), funding for basic research, large-scale pilots, and commercial-scale demonstrations is needed.

The most recent industry report recommends a $760 million average annual budget for the equivalent activities in the DOE Carbon Capture & Power Systems RD&D program through 2035, including significantly more funding in the next decade needed for commercial-scale demonstrations. Technologies should be tested on natural gas as well as the three major U.S. coal types to benefit the existing coal and natural gas fleets, maximize domestic natural resources, and accelerate the development of advanced new power cycles. After increasing levels to this amount, the DOE annual Fossil Energy RD&D budget would still be less than current allocations to the DOE's renewable energy equivalent.

• Streamlined rules and regulations. Certain environmental regulations discourage industry's adoption of carbon capture technologies. Interstate and intrastate carbon dioxide pipeline permitting processes have been identified as potential barriers. Congress has signaled it will tackle these issues, such as through the USE IT Act sponsored by Senators Barrasso (R-WY), Capito (R-WV), Heitkamp (D-ND), and Whitehouse (D-RI) that would make large carbon dioxide pipeline projects eligible for a streamlined permitting process.

Another issue to be tackled is the subsurface reporting and regulatory requirements for EOR projects that capture carbon dioxide from power plants for use in their operations for compliance with the Clean Air Act, relevant state-based regulations, and potentially, the Section 45Q tax credit. Some entities within the EOR industry have stated they will not enter into commercial offtake agreements for captured power-sector carbon dioxide with owners and operators because of potentially significant cost, liability, and legal issues associated with these reporting requirements. These policies should be re-evaluated to address these challenges and encourage the utilization of power-sector carbon dioxide in EOR operations.

• Internal Revenue Service (IRS) interpretation of the revamped carbon capture tax credit. In 2018, Congress enacted sweeping reforms to the Section 45Q tax credit for the capture and storage of carbon dioxide in secure geologic storage. Section 45Q provides separate credit levels for EOR and pure sequestration projects. Included among the recent changes: the credit level for EOR projects is to increase from \$10 to \$35 per metric ton of carbon dioxide stored and a total cap on credits was replaced with a January 2024 commence-construction deadline. IRS interpretation of the new language, e.g., what it means to "commence construction" on a carbon capture project, will have a significant influence on short- and medium-term development and important project finance decisions. Early clarification of these critical ambiguities will facilitate carbon capture project development utilizing this credit.

2018 CURC-EPRI Roadmap

The Roadmap focuses on the technologies and partnerships needed to improve the environmental performance of fossil-fuel power generation and to support the continued delivery of low-cost and low-emissions electricity.

The CURC-EPRI Roadmap presents a plan for delivering low- or zero-carbon emission, fossilfueled power plant technologies between 2025 and 2035 that can be cost-competitive with other sources of electricity under projected future market conditions. The 2018 Roadmap builds on prior CURC-EPRI Roadmaps by identifying the technology developments needed to costeffectively implement technologies that will result in a reduced carbon footprint from the use of coal and natural gas resources in power generation.

The Roadmap:

• evaluates development needs for the existing fossil-fuel fleet;

• updates efforts to accelerate development of "transformational" technologies that can deliver significantly higher value in terms of cost, efficiency, flexibility and environmental performance from the use of fossil fuels

• promotes continued support of large-scale pilots and demonstrations of new technologies.

"To understand the value of innovative fossil-fuel technologies, we need only to look to the future; coal and natural gas will provide 56 percent of the total U.S. net electricity generation by 2040, demonstrating the importance of an all of the above resource portfolio", stated Shannon Angielski, Executive Director of the Carbon Utilization Research Council. "The CURC-EPRI Roadmap embraces this reality while providing a clear pathway to capitalizing investments that will cover the developmental needs for commercializing new technologies."

"The benefits of investing in the U.S. fossil fleet are clear. Historically, we've seen the positive results from such investment. One important example is the development and deployment of SO2 scrubbing technology, which evolved from a public-private partnership development process. The same type of partnership and investment in innovation will provide us with the next generation of emission reducing technologies. The Roadmap covers today's as well as the tomorrow's innovation needs for our fossil fuel fleet," said Holly Krutka, Vice President of Coal Generation and Emissions Technologies for Peabody and CURC Co-Chair.

"Research, development, and deployment of technologies that enhance the viability of existing and future fossil plants is an important part of EPRI's work in supporting a diverse energy portfolio," said EPRI Generation Vice President Tom Alley. "The updated 2018 Roadmap will help to provide the industry, stakeholders and public a clear line of sight on a potential path forward."

More information

Download the reports at:

www.curc.net

clearpath.org

www.epri.com

Projects and policy news

Climeworks raises USD 30.8 million to commercialize carbon dioxide removal technology

www.climeworks.com

Climeworks raises $30.8 million to commercialize carbon dioxide removal technology.

The funds will be used to further industrialize our Direct Air Capture (DAC) technology, significantly reduce its costs and prepare for mass production. To date the company has built nine direct air capture plants in six countries, operating in three different market segments.

“Our direct air capture plants serve markets ranging from Food, Beverage and Agriculture, through Renewable Fuels and Materials to Carbon Dioxide Removal. In the latter, companies and individuals can reverse their unavoidable emissions via Climeworks. All three markets are set to grow, and with this latest investment Climeworks is well-positioned with a strong base for further growth”, said Climeworks co-founder and co-CEO Jan Wurzbacher.

"Two of the plant launches marked milestones in the DAC industry last year: in 2017 we opened the world’s first commercially operational CO2 capture plant in Switzerland. Later that year in November, we launched the world’s first DAC plant in combination with underground sequestration of CO2 in Iceland. Since 2017 we have doubled our staff, and our team now comprises 60 employees".

“Besides assembling an exceptional team, we are happy and thankful that we were able to establish an excellent shareholder structure over the last years, supporting us to pioneer the creation of a new, timely and relevant industry”, said Climeworks co-founder and co-CEO Christoph Gebald.

Malaysian and Austrian research institutes collaborate on BECCS

www.itb.ac.id
www.iiasa.ac.at

Institut Teknologi Bandung (ITB) has signed a cooperation agreement with International Institute for Applied System Analysis (IIASA) to work on bio-energy CCS.

The collaboration will include scientists and experts from both parties developing and implementing joint research projects with third party funding, post-graduate student exchanges, information exchange, including access to relevant databases, joint scientific publications and participation of research and academic staffs in seminars and conferences.

ITB had been seeking an international research project as part of a move from a research institute to an entrepreneurial university.

Dr. Mohammad Rachmat Sule, Center Manager of CoE CCS/CCUS said that ITB is currently preparing the first CCS Pilot Project in South East Asia and South Asia, where the CO2 source for the pilot project is obtained from oil and petroleum industries. This pilot project will contribute to reduction of carbon emissions regionally and globally.

However, since IIASA also invites ITB to develop BECCS, this will be very important for Indonesia as one of the forest centers in the world, especially if energy generated from bio-energy can be utilized broadly in the future. “Bio-energy is classified as a type of energy characterized by zero carbon emission. Combined with CCS, bio-energy will be contributor for negative emission”, Rachmat concluded.

U.S. DOE awards funding to five more project

energy.mit.edu/lcec

The U.S. Department of Energy’s (DOE) Office of Fossil Energy (FE) has selected five additional projects to receive approximately $11.3 million in federal funding for cost-shared research and development.

Selected projects will support DOE’s Carbon Capture Program, which is developing transformational, step-change, low-cost capture processes and enabling technologies that will maximize the efficiency of our nation's fossil-based power generation infrastructure. The selected projects will join six other projects under this FOA chosen by FE to receive approximately $17.6 million in February 2018.

The National Energy Technology Laboratory will manage these additional projects, and descriptions follow.

ROTA-CAP: An Intensified Carbon Capture System Using Rotating Packed Beds – Gas Technology Institute(Des Plaines, IL) will develop and validate a transformational carbon capture technology using novel integrated hardware and advanced solvents. The project aims to provide an economically viable carbon capture system for flue gas sources.

Universal Solvent Viscosity Reduction via Hydrogen Bonding Disruptors – Liquid Ion Solutions(Pittsburgh, PA) plans to achieve lab-scale demonstrations of an additive system capable of decreasing the viscosity of any non-aqueous chemical solvent for post-combustion carbon capture. All data generated in the project will be used to update a cost-benefit analysis and demonstrate the feasibility of the technology.

Inexpensive and Sustainable Anti-Corrosion Coating for Power Generation Applications – LumiShield Technologies, Inc. (Pittsburgh, PA) aims to achieve lab-scale demonstration of a corrosion-prevention technology that will facilitate the capture of carbon dioxide (CO2) from coal- and natural gas-fired power generation by reducing the cost of construction materials and maintenance.

Emissions Mitigation Technology for Advanced Water-Lean Solvent Based CO2 Capture Processes – Research Triangle Institute (Raleigh, NC) seeks to reduce solvent and aerosol emissions for transformational CO2 capture technology based on water-lean solvent systems. These water-lean solvents have the potential to become next-generation systems due to their low energy requirement for regeneration, low viscosity, and low equipment corrosion.

Advancing Post-Combustion CO2 Capture through Increased Mass Transfer and Lower Degradation – University of Kentucky Research Foundation (Lexington, KY) proposes to significantly advance deployment of CO2 capture through enabling technologies that increase CO2 mass transfer and reduce solvent loss. Successful development of these technologies will result in a reduced cost approach that can extend over a broad spectrum of CO2 capture systems.

New Heat Integration Strategy Improves Efficiency of a CCS Facility

The aim is to minimize the impact that capturing carbon has on a power plant's ability to produce electricity by being more efficient in how we reduce, reuse and recycle heat.
By Stavroula Giannaris, MSc

This article is based on a recent abstract and is part of a feasibility study to optimize the steam cycle heat integration process, and in particular, the use of condensate preheating (CPH) to lower the energy penalty experienced with a fully integrated CCS, scale-up retrofit.

CCS technology requires steam for amine regeneration. This steam can come from within the power plant (integrated design resulting in an electricity output penalty) or from an external dedicated steam supply (increased capital costs). The integrated approach was used in SaskPower's Boundary Dam 3 Carbon Capture and Storage Facility (BD3), the world's first fully integrated CCS retrofit of a coal-fired power plant.

BD3 is unique in design and has heavily informed our work at the International CCS Knowledge Centre. Learnings from BD3 have provided the foundation for our feasibility study of SaskPower's Shand Power Station – a second-generation CCS project that will be more efficient and more economical.

SaskPower's Shand facility is a 300 MW, single unit, coal-fired power plant producing approximately 1,100 kg of CO2/MW-h. Shand's capacity is twice that of BD3's – making it an ideal candidate for a large-scale, CCS retrofit.

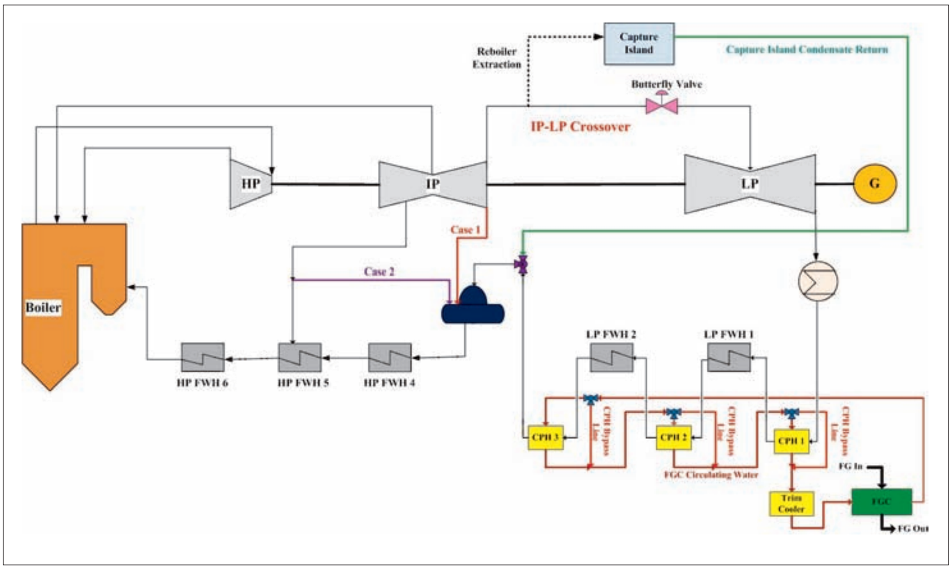


Figure 1. Steam Cycle Configurations with the CPH arranged in a series with the low-pressure fee water heaters. This alignment reduces stress on the DEA and lowers the overall energy penalty

How a Power Plant Works

Before we dive into our findings, let's take a look at the regular workings of a power plant. In simple terms, steam exits the boiler, passes through the turbines, expands, loses heat, and then enters the condenser. At this point the steam is essentially water and is referred to as condensate. This condensate passes through a series of feed water heaters, which use steam extracted from the turbine to warm up the "cold" condensate before it re-enters the boiler. Having the condensate re-enter the boiler "preheated" and in a "warm" state is optimum because the boiler doesn't have to work as hard, making it function more efficiently.

What Happens When We Add a Carbon Capture Facility?

Things change when the power plant must function with the added relationship of a carbon capture facility that draws on the power plant for steam as part of the capture process. The flue gas that exits the power plant is very hot and must be cooled before entering the capture facility to work properly with the amine (the solvent used to capture the CO2).

The heat that is rejected from the flue gas via the flue gas cooler (FGC) is essentially transferred to water, producing a hot circulating stream. This hot circulating stream flows to three Condensate Pre-Heaters (CPH 1,2 and 3).

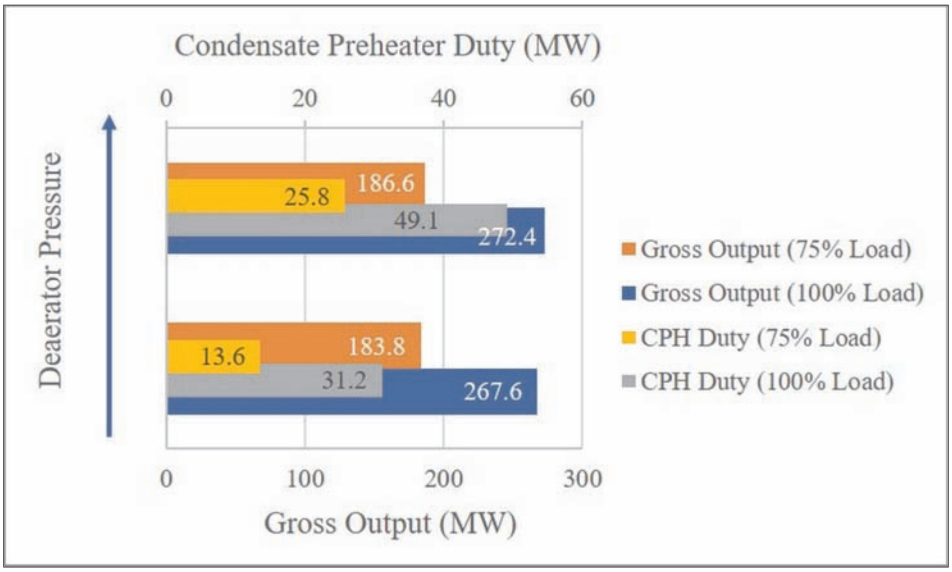
The difference between BD3 and Shand is that in BD3 there is one large CPH that is in parallel with the LP (low-pressure) heaters, as opposed to the 3 CPHs that are in series orientation with low-pressure feed water heaters 1 and 2 (LP FWH 1 and 2). This means that LP FWH 1 and 2 are completely by-passed during capture operations (i.e. the condensate does not flow through them at all). In this case, if the FGC suddenly goes off line, the stream of hot water flowing to the CPHs becomes cold and no longer supplies heat to "warm up" the condensate. The condensate then enters the deaerator (DEA) in a "cold" state, forcing the DEA to extract a larger amount of steam to warm it up. This scenario continues until LP FWH 1 and 2 can be put back into service – causing stress on the system.

Reusing Heat and Reducing the Output Penalty via Condensate Preheating Flexibility

In our Shand model, we proposed that these

CPH be arranged in series with the LP FWH 1 and 2, see Figure 1. The five of them together, (LP FWH 1 & 2 and CPH 1,2, and 3) work to "warm up" the condensate by primarily using the rejected heat from the flue gas.

FWH 1 and 2 remain in service during capture operations, but only function at a 5% capacity in order to ensure the steam is flowing in the correct direction, and that the heaters are warm and ready for service, if required. In other words, the amount of steam they continue to extract from the LP turbine for "pre-heating" purposes is minimal. This way, if the FGC shuts down, the loss in heat that was being supplied by CHP 1,2 and 3, will be easily compensated by LP FHW 1 and 2, since the condensate is already flowing through them. LP FHW 1 and 2 will recognize the colder condensate stream entering the system and will revert to extracting the usual amount of steam from the turbine to warm up this suddenly "colder" stream.



Effects on the Steam Cycle with Increasing Deaerator Pressure

This new heat integration method eliminates any stress that may be experienced by the DEA. Overall, this new configuration of the CPH train lowers the energy penalty by reusing the maximum amount of rejected flue gas heat and limiting the amount of steam extracted. More importantly, this configuration continually adapts to changing amounts of unit load, which is one of the features that allows this carbon capture plant to integrate with variable renewable energy sources like wind and solar.

It has been exciting to be part of this International CCS Knowledge Centre study to demonstrate that the second generation of CCS technology can be more efficient, cost effective and flexible.

More information

www.ccsknowledge.com

Tackling the Cooling Challenge of a Large-Scale CCS Retrofit

A new hybrid design cooling system study provides a solution to the cooling challenge for new CCS facilities, and demonstrates how to maintain a zero liquid discharge facility.
By Wayuta Srisang, PhD.

In a hybrid car, electricity and fuel combustion are two different processes that are combined in a complimentary way to reduce the emissions profile of a car. With a hybrid cooling system, both dry and evaporative cooling can be implemented in a complimentary manner to offer a solution to reduce the water intake and its consumption for the power plant's cooling system.

On it's own, a coal-fired power plant is designed to continuously recycle and cool water and steam internally. When we add a large-scale carbon capture facility, the combined systems generate a volume of heat and water that the existing cooling system of the power plant is incapable of rejecting on its own.

At the International CCS Knowledge Centre, we are committed to eliminating barriers, either real or perceived, that inhibit large-scale, CCS development. Since the availability of cooling is generally one of the first design concerns for siting a thermal power facility, and quite often ends up being the limiting factor for further expansion at a given site, we anticipate that the availability of cooling capacity can often impede the addition of CCS to a facility.

This cooling challenge formed the basis of a study we conducted which sought to design an additional cooling system for a CCS retrofit of SaskPower's Shand Power Station (Shand). Shand is a 305 MW, single unit, coal-fired power plant producing approximately 1,100 kg of CO2/MWh. Shand's capacity makes it an ideal candidate for a large-scale, CCS retrofit.

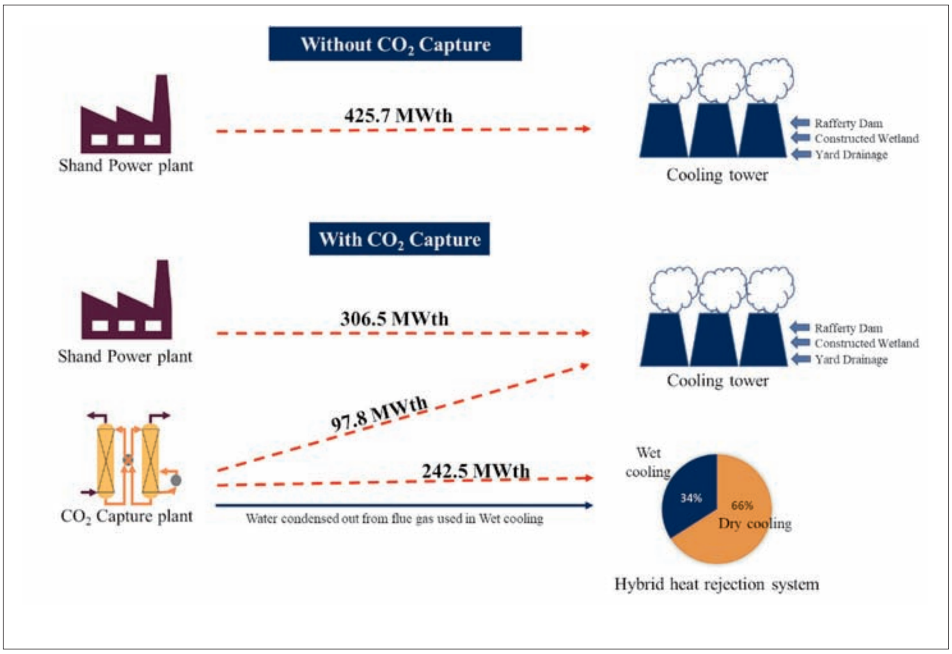


Figure 1 - the source and amount of heat that must be rejected from the power plant with and without a CO2 capture facility

Shand draws water from three main sources: the Rafferty Dam, a secondary treated sewage water stream from the nearby city of Estevan (after passage through a Constructed Wetland) and a yard drainage system that collects melted snow, rain and runoff.

These water supplies are used in the plants cooling tower to reject 425.7 megawatts thermal (MWth) of heat. There is limited water in the area, and a draw on additional water (for increased heat rejection capacity) is not anticipated to be possible and is likely a consideration for many power plants around the world.

So how does CCS change the heat rejection profile of a power plant? The addition of an integrated capture plant actually reduces the amount of heat rejected by the power plant, because some of the steam is being drawn to the CCS facility for its use.

Figure 1 illustrates a drop in the heat to be rejected from the power plant from 425.7MWth to 306.5MWth. Since there is less heat from the power plant, the carbon capture facility can reject some of its excess heat to the cooling tower, but the cooling tower doesn't have the capacity to manage the entire volume coming from both systems.

Figure 1 indicates that after the capture plant rejects 97.8 MWth to the power plants cooling tower 242.5 MWth is still left.

This quantity of heat is approximately a 50% overall increase in the amount of heat that the existing power plant must reject.

During capture operations, flue gas must be cooled prior to the CO2 capture reaction. This cooling condenses water out of the flue gas at a rate of approximately 97.5 tonnes/hr. In order to maintain zero liquid discharge (ZLD) of the plant, this water can be used for cooling but it isn't nearly enough as this stream of condensed water can only reject 40% of the excess heat, leaving 60% that still needs rejecting. This problem inspired the design of a hybrid cooling system consisting of dry air coolers and wet surface air coolers (WSAC) connected in series as a solution.

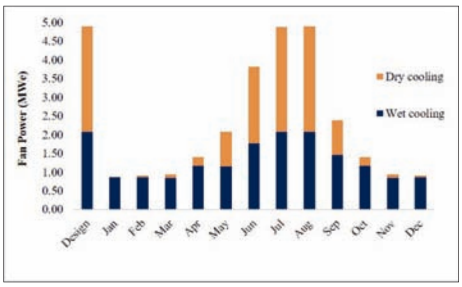


Figure 2 - the effect that the outside temperature throughout the year has on the amount of fan power required for the hybrid cooling system

The new hybrid system's design is based on 18deg C dry bulb and 13.7deg C wet bulb temperatures, which is the 85th percentile of the historical temperature from 1991 to 2005 in the Estevan area (Environment Canada Data). Though more CO2 can be captured at low ambient temperatures, de-rates of the CCS facility are viewed as still being acceptable at high ambient temperatures.

Setting the design case at the 85th percentile decreases design margins, avoids oversizing the system and saves costs. Overall, the heat load on the dry air cooler and WSAC is 66% and 34% MWth, respectively. The power consumption at the design condition is 3.91 megawatts electric (MWe) for dry air cooler and 1.01 MWe for WSAC.

A major challenge in western Canada is that ambient temperatures can range from +40deg C to -40deg C. To compensate for this range, we designed the system so that both the dry air cooler and WSAC have variable frequency drives which allows them to adjust the relative amount of overall cooling to match ambient conditions. This allows the heat rejection to be shifted between wet and dry cooling, so that the system can adjust the amount of cooling that is evaporative in order to maintain the water balance on the site.

We were curious about the effect that the varying temperatures, over a calendar year, might have on fan power consumption. It turns out that the consumption is only 40% of the design case, which is a bonus because this low energy cooling results in more power being able to be sold from the plant.

Our new hybrid design cooling system study provides a solution to the cooling challenge for new CCS facilities, and demonstrates how to maintain a zero liquid discharge facility. The International CCS Knowledge Centre will continue to champion solutions to advance the development of large-scale CCS facilities to reduce greenhouse gas emissions for our planet.

More information

Download full abstracts at:

www.ccsknowledge.com

Capture and utilisation news

CO2 separating membranes developed at Imperial could make carbon capture more efficient

www.imperial.ac.uk

The membrane, developed by researchers at Imperial College London performs better than traditional materials when used for carbon dioxide capture from power plants.

The membrane is made of a UV-responsive material and a polymer, which can absorb and release CO2 with the application of UV light. This is a less energy-intensive way to release the CO2, which would otherwise require the application of heat or pressure.

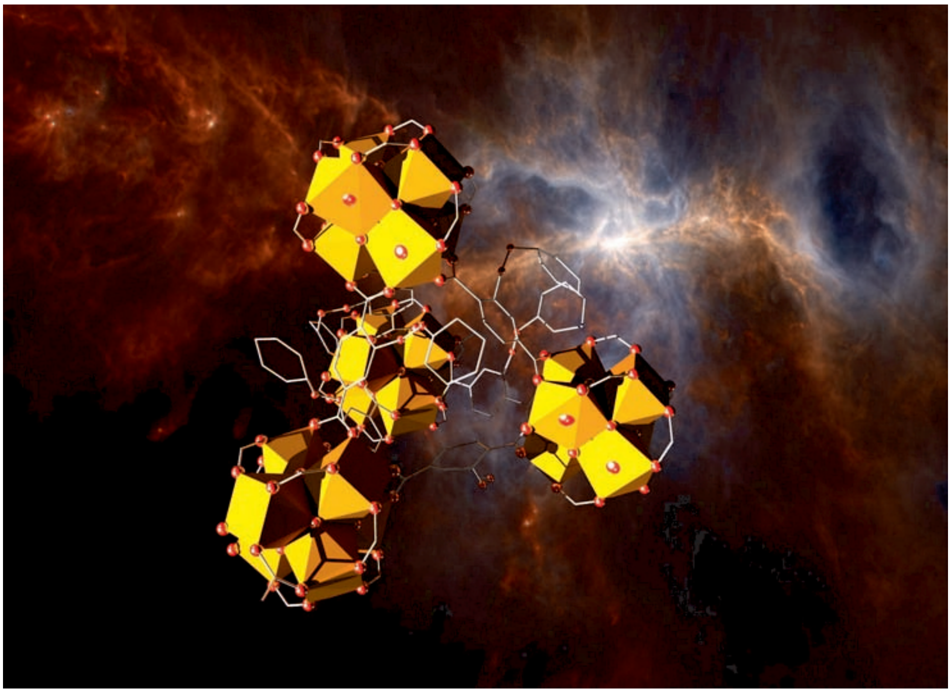
The composite material, developed by PhD student Nicholaus Prasetya and Dr Bradley Ladewig from the Department of Chemical Engineering at Imperial is the first of its kind. Initial research shows its ability to effectively separate carbon dioxide and nitrogen in post-combustion processes; for example treating flue gas from a power plant.

Dr Ladewig said: “Our previous work already showed that photo-responsive materials can be used as carbon dioxide sorbents, but this is really innovative - we have shown that it’s possible to make photo-responsive carbon dioxide separation membranes.”

This research has opened the door for further exploration of innovative applications for UV-responsive materials in the carbon capture and post-combustion stage of carbon capture and storage processes. When CO2 is filtered more efficiently in these processes, the result is that less CO2 is released into the atmosphere and more can be stored for further use in other industries that have a demand for it.

As an emerging area of research, further experimentation is required, but initial results are promising. An important element of the carbon capture and storage process, this work could lead to a new generation of more efficient, longer lasting, and cheaper to develop membranes.

The research is published here: A new and highly robust light-responsive Azo-UiO-66 for highly selective and low energy post-combustion CO2 capture and its application in a mixed matrix membrane for CO2/N2 separation, Journal of Materials Chemistry A (2018)



A photo-responsive CO2 separation membrane could make carbon capture more efficient. Image reproduced by permission of B. Ladewig from Prasetya et al., J. Mater. Chem. A, (2018)

Inventys raises $11m

www.inventysinc.com
www.oilandgasclimateinitiative.com

Inventys, has secured US$11M with lead investment from OGCI Climate Investments, alongside existing investors The Roda Group and Chevron Technology Ventures, as part of a planned US$21M Series C Financing Round.

The US$11M will fund the 30-tonne per day (TPD) CO2 capture pilot plant demonstration program with Husky Energy scheduled to be in operation in Q1-2019, as well as support Inventys’ aggressive time-to-market strategy for 2020.

Dr. Pratima Rangarajan, CEO of OGCI Climate Investments, said, “As we address climate change, we must develop economic ways to capture, utilize, and store CO2. Inventys’ technology can cause a step change in the economics of CO2 capture.”

“At Inventys, we see it as an opportunity to put CO2 to work. Some say it’s too costly and difficult to capture and use or store CO2 using a distributed supply model. We believe Inventys’ technology will prove them wrong,” said Inventys President & CEO Claude Letourneau.

“We’ve built a world-class team of scientists, engineers, technicians, specialists, strategists, project developers and entrepreneurs dedicated to creating a global CO2 marketplace using our breakthrough next-generation carbon capture technology.”

A key building block for unlocking the growth of the CO2 marketplace is shifting the carbon capture cost curve down by at least a factor of two from conventional technology (chemical solvents). Inventys found a way to do this with advanced solid adsorbent nanomaterials, combined with a novel modular compact contactor, to capture CO2 from very dilute post-combustion flue gases (from industrial processes and gas-fired power plants).

Dr. Steven Chu, former US Secretary of Energy and a member of Inventys’ board of directors, said “Carbon capture, utilization, and sequestration from point sources such as power, cement, and steel plants is essential to minimize the risks of climate change.”

“After completing an extensive due diligence process, OGCI Climate Investments recognized that Inventys has a leadership position in dramatically lowering the cost of carbon capture needed to develop this multibillion-dollar market opportunity.”

Transport and storage news

Alberta Carbon Trunk Line finance and construction agreement

www.wolfmidstream.com

www.enhanceenergy.com

Enhance Energy and Wolf Carbon Solutions have entered into a project development and coordination agreement for the construction and operation of the Alberta Carbon Trunk Line.

The ACTL is a 240-kilometre pipeline that will collect carbon dioxide from industrial emitters in and round Alberta's Industrial Heartland and transport it to aging reservoirs throughout central and southern Alberta for secure storage and enhanced oil recovery projects.

Subject to closing under this agreement, Wolf will construct, own, and operate the CO2 capture and pipeline transportation assets. Enhance will continue to be the owner and operator of the CO2 utilization and sequestration portion of the ACTL project through its EOR operations.

Upon closing of this agreement, anticipated to be within 60 days, the parties will enter into a long-term service agreement and construction activities related to the ACTL project will commence. Initial CO2 flow rates are expected to start at 800 tonnes per day in the fourth quarter of 2019 and increase to 4,400 tonnes per day by the end of 2019.

CO2 will be supplied to the ACTL project by the Sturgeon Refinery (operated by the Northwest Redwater Partnership) and the Redwater Fertilizer facility (owned and operated by Nutrien, the world's largest crop nutrient company) and delivered to Enhance's EOR project in Clive, Alberta. Initially, Wolf will provide midstream services only to Enhance, with other suppliers and users of CO2 having future access to Wolf's capture, compression, and transportation services.

"Carbon capture and storage is already established as a viable emission reduction strategy for Alberta industries and we believe it has great potential to become much more widely applied," said Gord Salahor, Wolf's Chief Executive Officer.

"The ACTL is a desirable infrastructure asset for Wolf because it represents the core of an expandable network capable of facilitating many carbon mitigation options for emitters over the long term."

The construction of ACTL will be funded by Wolf in part through investments made by Canada Pension Plan Investment Board ("CPPIB") of up to $305 million. Additional public funding for the ACTL project of $63 million has been provided by the Government of Canada under the Federal EcoETI Program and the Federal Clean Energy Fund Program, and $223 million in construction funding has been approved under the Province of Alberta's Carbon Capture and Storage Funding Act (2009). Enhance also expects to invest over $1 billion in capital costs related to CO2 storage and EOR development over the life of the ACTL.

U.S. DOE awards $10.7m for carbon storage research

www.energy.gov/fe

The projects will advance tools and methods for assessing the state of stress and geomechanical impacts within the subsurface associated with underground carbon storage.

The projects are supported through the funding opportunity announcement (FOA) DE-FOA-0001826, Developing Technologies to Advance the Understanding of State of Stress and Geomechanical Impacts within the Subsurface.

The National Energy Technology Laboratory (NETL) will manage the selected projects, which are summarized below:

Area of Interest 1: Tools and Methods for Determining Maximum Principal Stress in the Deep Subsurface

1. Refining Principal Stress Measurements in Reservoir Underburden in Regions of Induced Seismicity through Seismological Tools, Laboratory Experiments, and Theory – Electric Power Research Institute, Inc. (Palo Alto, CA) will develop methodologies to measure in-situ principal stress in the deep subsurface through use of multiple independent seismic methods, laboratory verification, and theoretical framework.

2. A Non-Invasive Approach for Elucidating the Spatial Distribution of In-Situ Stress in Deep Subsurface Geologic Formation Considered for CO2 Storage – Battelle Memorial Institute (Columbus, OH) will develop and demonstrate a method that improves the measurement of in-situ principle stresses in the deep subsurface.

The methodology will determine the spatial distribution of the magnitude and orientation of principle in-situ stresses in the deep subsurface, including near and far from the wellbore; test the method at one or more field sites considered for hosting CO2 sequestration and defining performance limits on uncertainty and spatial resolution that can be achieved with the method; and improve state-of-the-art methods for determining in-situ stresses.

3. Development of Thermal Breakout Technology for Determining In-Situ Stress – RE/SPEC Inc. (Rapid City, SD) will develop a thermally induced borehole breakout technology to improve in-situ stress measurements. The tool will include acoustic emission sensors to determine the onset of breakout behavior and locate the source of emissions around the hole

Area of Interest 2: Methods for Understanding Impact of Vertical Pressure Migration Due to Injection on State of Subsurface Stress

4. Identification of Faults Susceptible to Induced Seismicity:Integration of Forward and Joint Inversion Modeling, Machine Learning, and Field-Calibrated Geologic Models – Board of Trustees of the University of Illinois (Urbana, IL) will apply advances in seismic modeling and fault detection to the Illinois Basin Decatur Project dataset to gain a better understanding of the causes of induced seismicity and will advance the development of a methodology to evaluate comparable sites for potential induced seismicity.

5. Boosting Reliability of the State of Stress Characterization and Prediction in CO2 Storage Reservoirs Using Machine Learning and Integrated Geomechanics and Geophysical Methods – New Mexico Institute of Mining and Technology (Socorro, NM) will develop a framework to boost the reliability of characterization and prediction of the state of stress in the overburden and underburden in CO2storage reservoirs using machine learning, as well as integrated geomechanics and geophysical methods.

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