Carbon Capture Journal

CCS in the UK

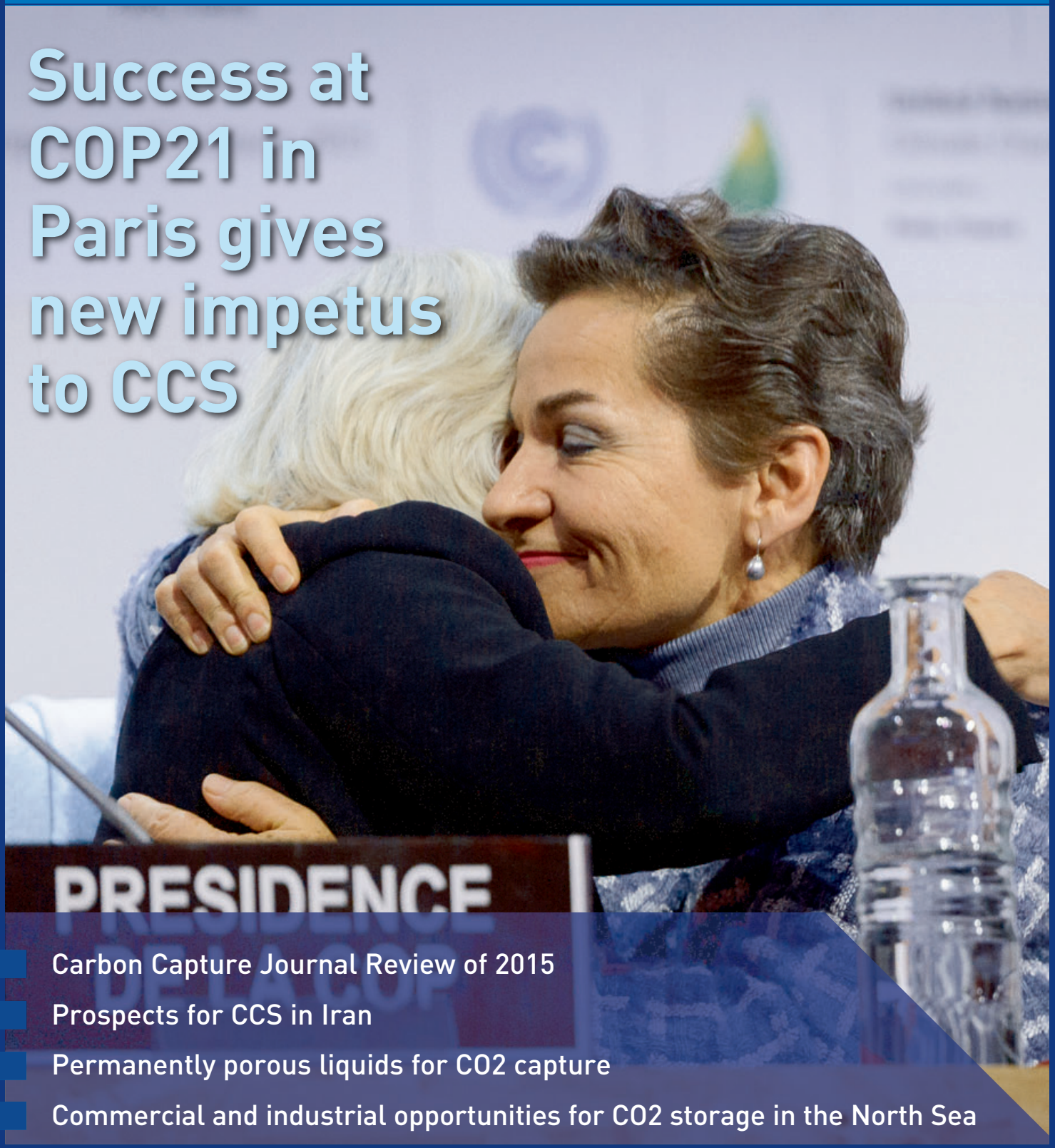
COP21 - what it means for the UK

George Osborne - the climate villain missing from Paris

Are CfDs the answer?

Jan / Feb 2016 Issue 49

Success at COP21 in Paris gives new impetus to CCS



Carbon Capture Journal Review of 2015

Prospects for CCS in Iran

Permanently porous liquids for CO2 capture

Commercial and industrial opportunities for CO2 storage in the North Sea

Carbon capture and storage – should we be telling a better story?

Carbon Capture Journal is interested in running a conference in Teesside or York later this year to explore the hydrogen industry, telling a better story and carbon capture. If you think this might be of interest please contact Karl Jeffery, publisher of Carbon Capture Journal on jeffery@carboncapturejournal.com

When the UK government cancelled that £1bn carbon capture and storage competition last December, one of the reasons provided by the UK's Conservative government's two most senior people (David Cameron, Prime Minister, and George Osborne, Chancellor of the Exchequer) was that the cost benefit analysis did not add up.

Or more specifically – George Osborne said that the government had to make difficult decisions about where to spend the money and decided it was better spent elsewhere. David Cameron said that the government had to make 'tough choices', about 'technology that works and technology that doesn't work'.

Carbon capture people could happily share many strong arguments and facts about why the cost benefit analysis of carbon capture does work and why the technology works – and we have been doing this.

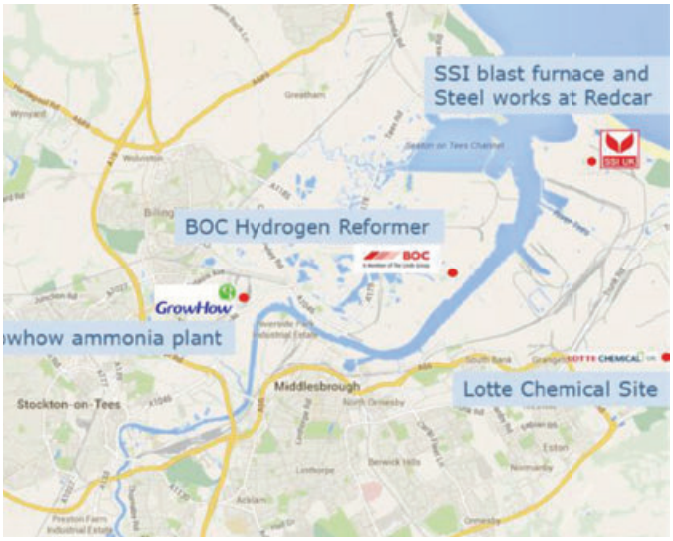
But how about this idea - what Mr Osborne and Mr Cameron may have actually meant was, the 'cost vote' analysis did not add up – the party is looking for ways to spend money which would lead to more votes, and there's no votes from Peterhead and White Rose carbon capture and storage?

Whether or not the government would allocate spending on climate change according to where it gets the most votes, it might well be worth the UK 'carbon capture industry' thinking hard about how the cost vote analysis of carbon capture could be improved.

And there is a very good idea – in Teesside.

In Teesside, there is a group of process industry plants, with operators including BOC and Lotte Chemical, which have been talking about getting a carbon capture plant running for a few years.

Most of the plants run on methane. A new suggestion is that Teesside could build a steam methane reformer plant upstream, which would convert the methane to hydrogen and carbon dioxide. The hydrogen would be fed to the Teesside plants as a source fuel (where it could reasonably easily replace methane) and the CO2 could be piped up to Aberdeen and out to the Goldeneye field (which was going to be connected to Peterhead).



Teesside Collective locations (Image: Teesside Collective Blueprint for Industrial CCS in the UK)

Where's the votes here?

First of all, we are in the industrial sector, not the electricity sector. In the electricity sector, like it or not, there is a wind vs carbon capture debate going on – many wind enthusiasts see carbon capture as a means of stopping renewables or prolonging the use of wind. So if the government spends money on carbon capture for electricity, it risks losing the votes of wind power enthusiasts, as well as having to face a lot of noise that they make.In the industrial sector, most environmentalists can see that you can't run a chemical plant on wind power – so carbon capture is the only option for avoiding CO2 emissions (or otherwise shutting the plant down).

Secondly, there are around 20,000 people employed in process industries in the Tees Valley. The recent closure of Teesside Steelworks has got the message home (if it wasn't already) that jobs can be easily threatened. This closure wasn't directly due to anything related to carbon, but there are increasing noises of concern that carbon emission costs are making industries uncompetitive with parts of the world which don't pay these costs.

A possible source of votes is people who might get excited about hydrogen. There has been a lot of excitement about hydrogen cars, trains, motorbikes and more over the past few years – and the business case often leads much to be desired (if it didn't, hydrogen cars would be on the roads by now). But we are not talking about business cases here, we are talking about stories and getting people excited.

Another advantage of this scheme is that there is no untested technology involved – steam methane reforming is an established technology.

And it is possible that some real new industries could be developed from the source of hydrogen – for example making methanol, which is a liquid and so easier to handle. There is already a methanol-fuelled ferry in operation, the 240m long, 51,837 GT (gross tonnage) Stena Germanica, running between Kiel (Germany) and Gothenburg (Sweden).

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Front cover:

'Accord' in Paris gives new impetus to the deployment of CCS (Image: COP21)

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Leaders - CCS in the United Kingdom

Projects and policy

Special section on COP21 in Paris

Capture and utilisation

Transport and storage

Carbon Capture Journal review of 2015

Undoubtedly the highlight of the year was the Paris Climate Agreement which puts CCS centre stage as the best and most cost effective mitigation technology for power and industry. There was progress on Quest in Canada, Uthmaniyah CO2-EOR project in Saudi Arabia and the Texas Clean Energy Project. However the UK inexplicably went into reverse by cancelling its flagship CCS Commercialisation competition just weeks before its expected conclusion.

January

A report by Scottish Carbon Capture and Storage (SCCS) urgently calls for specific policy support and wider political ambition within the European Union.

Researchers in the Department of Earth, Atmospheric and Planetary Sciences at MIT find that once injected into the ground, less carbon dioxide is converted to rock than previously imagined.

EURELECTRIC, the EU electricity trade body, urges EU policymakers to push ahead with CCS demonstration as part of Europe's decarbonisation strategy.

A California Council on Science and Technology paper finds that the state needs to resolve regulatory uncertainties surrounding CCS.

Pilot scale testing of a Linde-BASF CO2-capture technology begins at the National Carbon Capture Center in Alabama.

The Illinois Basin-Decatur Project successfully captures and stores one million metric tons of carbon dioxide and injected it into a deep saline formation.

Research from the University of Cambridge shows that aquifers rich in silicate minerals may delay, or even prevent, CO2 from being carried to greater depths where it may be less likely to escape.

February

The Department of Energy and Shell Canada collaborate on field tests to validate monitoring, verification, and accounting technologies for underground storage of CO2.

The Australian Government grants AUS $25 million over five years to the Otway CCS research project based in Victoria.

CO2 being delivered from the Callide Oxyfuel Project to CO2CRC's Otway project site. The Callide project was successfully completed in March

The UK CCS Research Centre's PACT Facilities joins the CC Test Centre Network founded by TCM Mongstad.

The UK can implement an affordable transition to a low carbon energy system by 2050 but decisions taken in the next decade will be critical says areport by the Energy Technologies Institute (ETI).

CMC Research Institutes will establish a Field Research Station (FRS) to commercialise instruments associated with CO2 underground storage.

A team of researchers at Harvard and LLNL develop a novel class of materials that could enable a safer, cheaper, and more energy-efficient process for carbon capture.

The U.S. Department of Energy suspends the FutureGen clean-coal project in western Illinois because it could not meet a spending deadline.

The U.S. President's Financial Year 2016 budget requests $560 million for the fossil energy research and development portfolio.

CO2 Solutions' pilot plant begins construction at Husky Energy's Pikes Peak South heavy oil site in Saskatchewan.

March

The successful collaboration between CO2CRC's Otway Project in Victoria and the Callide Oxyfuel Project in central Queensland comes to the end of a key stage with the completion of the Queensland project.

New analysis from think tank Green Alliance highlights that CCS is the only technology available to decarbonise heavy industry to the extent needed to meet carbon targets and protect the UK from climate change.

The UK and Scottish Governments give £4.2

million in-principle funding to support Summit Power's proposed CCS coal-gasification power station located in Grangemouth.

An Energy Technologies Institute report shows that Building a 10 GW scale Carbon Capture and Storage sector by 2030 in the UK is feasible and affordable.

UC Berkeley chemists develop a material that can efficiently remove carbon from the ambient air of a submarine as readily as from a coal-fired power plant.

April

In a landmark accomplishment, the U.S. Department of Energy announces that a group of carbon capture and storage projects supported by the Department have safely captured 10 million metric tons of carbon dioxide.

The Aquistore Project begins injecting carbon dioxide 3.4 km underground in Canada's first deep saline CO2 storage project.

Taiwan's largest integrated steel maker, China Steel Corporation (CSC), approves a 1400M TWD ($46M USD) capital investment in a LanzaTech commercial ethanol facility.

The CCP (CO2 Capture Project) is now in its fourth phase, having officially extended its program by a further four years, beginning February 2015 and concluding at the end of 2018.

CO2 Solutions announces the results of the pilot testing of CO2 Solutions' carbon capture process, completed in January 2015.

May

A federal grant for the CREATE student training program at the University of Calgary will provide a comprehensive training opportunity for students working on CCS.

Chris Davies, former EU MEP and rapporteur for carbon capture and storage, believes that European countries will support carbon capture once they realise they need it to meet their targets

Gassnova delivers a study on potential full-scale CCS projects in Norway to the Ministry of Petroleum and Energy.

Four potential new companies, including GE and Alstom, could test their capture technology at TCM Mongstad

Research Project ECO2 presents approach for a sound environmental risk assessment of sub-seabed CO2 storage.

Mott MacDonald is awarded a contract by Shell UK Limited to provide project management organisation services during the FEED phase of the Peterhead CCS project in north east Scotland.

June

The Energy Technologies Institute (ETI) seeks co-venturers to develop an investable concept for major new power generation capacity fitted with carbon capture and storage.

An IEA Clean Coal Centre report looks at whether microalgae can be used to remove CO2 from the flue gas of coal-fired power plant.

CCS TLM and Fabricom form a strategic alliance to deliver integrated, full value chain services and solutions to the CCS sector.

BG Group, BP, Eni, Royal Dutch Shell, Statoil and Total call on governments around the world and to the United Nations Framework Convention on Climate Change (UNFCCC) to introduce carbon pricing systems.

The DNV GL led CO2PIPETRANS joint industry project (JIP) releases a third batch of experimental data that will greatly assist in the design process of CO2 pipelines.

July

Saudi Aramco announces the launch of its Uthmaniyah CO2-EOR Demonstration Project, the Middle East's first operational large-scale CCS facility

CO2 Solutions reports initial results from its pilot where enzyme-based CO2 capture technology has performed in line with expectations.

Rice University scientists publish a new study that shows how chemical changes affect the abilities of enhanced buckyballs to confine greenhouse gases.

The final phase of a project on the geological storage of carbon dioxide at Ketzin/Havel in Germany starts with the abandonment of the first of five wellbores.

Teesside Collective in the UK publishes a viable end-to-end plan for Europe's first Industrial Carbon Capture and Storage network.

National Oceanography Centre releases results from a submarine CO2 leak study into the realistic simulation of the potential envi-

ronmental impact of a submarine CO2 leak.

August

Toshiba publishes a feasibility report on applying Carbon Capture and Storage to a major steel plant in China.

The U.S. National Energy Technology Laboratory (NETL) selects eight projects to receive funding to construct small- and large-scale pilots for reducing the cost of CO2 capture and compression.

The Australian Government invests in the advancement of carbon capture and storage technologies through a research fund designed to facilitate industry investment and research,

The Crown Estate and the British Geological Survey offer free, licenced access to the CO2 Stored database for subscribers via a more user-friendly website.

The Energy Technologies Institute seeks partners for a project to study the impact of removing brine from under-sea stores that could be used to store captured carbon.

An IEAGHG study aims to characterise key countries and regions worldwide where CCS could play an important part of mitigation efforts, based on national circumstances and priorities.

September

The National Energy Technology Laboratory (NETL) releases the fifth edition of the Carbon Storage Atlas, which shows increased storage potential.

Drax will complete FEED studies but not invest further in the UK White Rose CCS project because of reduced renewable subsidies.

Four new CO2 capture vendors, including GE and Alstom, will test their technology at Technology Centre Mongstad (TCM) in Norway.

The Department of Energy selects five projects that will study the feasibility of using salty water from carbon dioxide storage sites to produce fresh water.

Michigan State University and PHYCO2 partner to develop algae technologies that capture carbon dioxide from power plant emissions.

Solidia Technologies is awarded the patent for a method of curing concrete with CO2 instead of water.

The Goldeneye reservoir in the UK North Sea is independently verified as suitable for the safe storage of carbon dioxide from an Aberdeenshire power station.

Researchers at Aalto University open a pilot plant that converts CO2 and slag, the by-product of steel manufacturing, into a valuable mineral product.

The Alberta-based Climate Change and Emissions Management Corporation invites submissions for the second round of the $35 million international CCEMC Grand Challenge: Innovative Carbon Uses.

October

Southern Company subsidiary Southern Company Services and Korea Electric Power Corporation (KEPCO) join forces on CCS technologies.

An Energy Research Partnership report concludes there is a narrow window of opportunity to deploy CO2-EOR in the UK North Sea.

ION Engineering completes pilot scale testing of its solvent for CO2 capture from large point sources at the National Carbon Capture Center.

The $20M NRG COSIA Carbon XPRIZE ilaunches - a competition to address CO2 emissions from fossil fuels.

The secure and permanent storage of carbon dioxide within a single geological storage formation can be optimised by injecting CO2 at more than one point simultaneously, according to results from an innovative study of rocks beneath the UK North Sea.

November

Shell officially opens the Quest carbon capture and storage (CCS) project in Alberta, Canada, and begins commercial operations there.

The UK Government axes the funding for its CCS competition as part of a spending review, just weeks before it is due to conclude.

DNV GL will conduct the oil and gas industry's largest ever controlled release of carbon dioxide from an underwater pipeline at its Testing and Research Centre in the UK.

Carbon Clean Solutions starts testing its solvent technology at Technology Centre Mongstad (TCM), and aims to commercialize a technology with the potential to halve the current energy demand.

A National Coal Council white paper focuses on incentives and policies that can be employed to level the playing field for deploying CCS technologies in the U.S..

UK Energy and Climate Change Secretary Amber Rudd begins a consultation on ending unabated coal-fired power stations by 2025.

Aker Solutions will conduct a feasibility study on the development of the world's first commercial-scale carbon capture facility for use in cement production.

A Zero Emissions Platform (ZEP) report concludes that reducing EU power sector emissions without CCS would cost €1.2 trillion more.

Air Liquide launches Cryocap™, a unique industrial installation that enables the capture of CO2 released during hydrogen production via a cryogenic process.

U.S. Energy Secretary Ernest Moniz announces an international initiative to facilitate collaborative testing of CCS technologies at real-world saline storage sites.

December

COP 21 concludes with agreement in Paris, giving a new impetus to CCS deployment - the technology is recognised as vital to meeting the climate change pledges.

Summit Power Group signs a contract with Chinese and Canadian heavy industrial firms at an event in Beijing to build the Texas Clean Energy Project.

The Asian Development Bank (ADB) and the People's Republic of China (PRC) work together on emissions reduction with a Roadmap for CCS in the PRC.

More information

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The climate villain missing from Paris

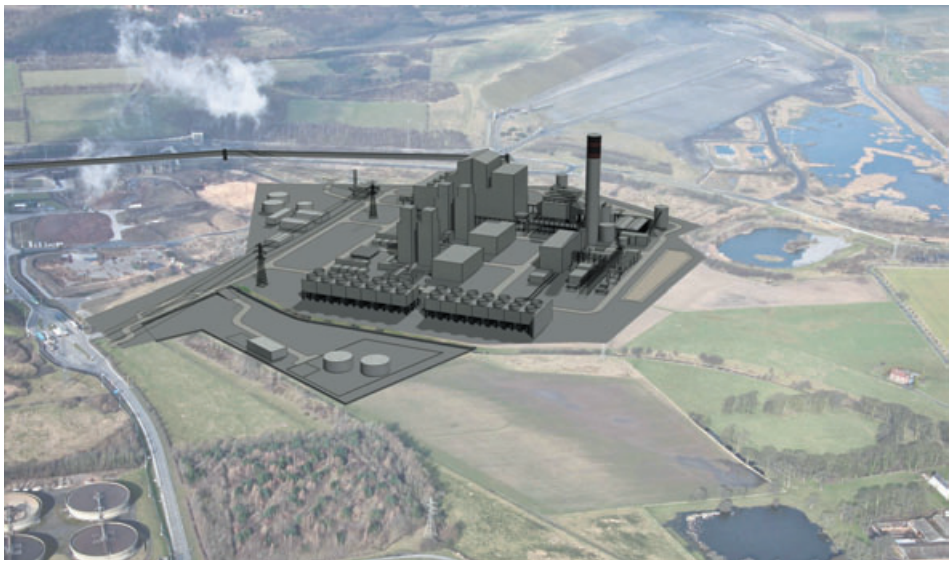
At the conclusion of COP21 more people are starting to realise that the political ambitions of one man are likely to have increased the cost of dealing with climate change by billions of euros. Yet the government to which he belongs is still trying to portray itself as a world leader in the achievement of CO2 reductions.

By Chris Davies, former MEP and rapporteur to CCS in the European Parliament

In reality, his actions have set back, and perhaps killed, the development of a technology that is vital if Europe is to achieve its 2050 objective of reducing emissions by 80-95%. He is a man who should be vilified by climate change campaigners but, with few people appreciating the scale of damage he has done, his name is still escaping virtually unspoken in Paris.

The climate villain is George Osborne, the British chancellor of the exchequer (finance minister). With much fanfare he revealed to the House of Commons his plans to balance the UK's budget.

Surreptitiously, he also sneaked out a written statement announcing, just days before the start of the climate talks in Paris, the cancellation of a £1 billion allocation intended to support the capital costs of developing carbon capture and storage (CCS) projects.



The European Commission had already offered €300m from its NER300 programme to support White Rose when the UK Government scrapped its £1bn prize, meaning the project is unlikely to go ahead

Never has the promise of spending £1 billion been proclaimed so often. For five years and more a succession of government ministers have used it to demonstrate their commitment to reducing CO2 emissions. In a speech to the United Nations plenary, prime minister David Cameron even went so far as to claim that Britain had already spent the money on developing CCS. Now the promise is broken.

Delegates at COP21 know that the Intergovernmental Panel on Climate Change (IPCC) has warned that the cost of reducing CO2 emissions will more than double unless CCS technology is deployed. The Zero Emissions Platform, advisor to the European Commission, claims that CCS can save the EU an estimated €2-4 trillion up to 2050 for the energy sector alone. Such estimates of financial savings are based on assumptions that the cost of CCS deployment will be reduced as experience is gained from early demonstration projects.

Although there are 22 CCS facilities in operation or under construction across the world, hopes for a European development strategy rested until last month on just three projects, principal amongst them being Peterhead and White Rose in the UK.

The former was promoted by Shell and SSE to capture CO2 from a gas fired power station and transport it along existing pipelines to a platform in the North Sea, from which it was to be injected into rock that previously contained methane. The latter project, supported by GE, BOC and National Grid. had planned a state-of-the-art coal power plant on the Drax power station site in Yorkshire that would capture 90% of the CO2 produced, transporting it to a North Sea storage site by a pipeline that would also serve industrial installations across the region.

Peterhead and White Rose were hardly speculative projects. The previous government handed them £100m to help them reach the point of final investment decisions. The European Commission had offered €300m from its NER300 programme to support White Rose (and discourteously was given no advance warning of the Osborne announcement).

Consequences

Commentators are only now starting to realise the full consequences of Osborne's catastrophic decision:

• He has cancelled support for the first CCS project in the world at a gas power station, doing this just one week after his government announced that gas would replace coal as the UK's principal source of fossil fuel electricity generation;

• He has curtailed development of CO2 storage beneath the North Sea, despite its potential to meet all the likely needs of Europe for a century or more with huge opportunities to generate income and employment;

• He has turned his back on the use of CO2 to enhance North Sea oil and gas recovery, and so robbed his own Treasury of a major potential source of future revenue;

• He has deprived British industry of the opportunity to become a European and world leader in the development of CCS technology, and to demonstrate its application not only for the decarbonisation of industry but also for power generation.

Did Osborne give a thought to the implications for climate change or business when he made his decision, or did personal ambition outweigh all other considerations? It's no secret that he wants to become prime minister when David Cameron steps down in three or four year's time. Failure to address the government's budget deficit would certainly count against him.

With the stroke of a pen he secured a short term gain in financial presentation but at the cost of very negative long term economic consequences.

Ironically, the UK will for years be able to boast of its success in reducing CO2 emissions even in the absence of CCS, a fact that a political tactician like Osborne will have appreciated fully. The country's coal power stations, which only last year provided up to 40% of its electricity, are being closed rather than upgraded to meet the requirements of the EU's Industrial Emission Directive.

In the absence of sufficient low carbon generating capacity plentiful use will instead be made of the new interconnectors from France, the Netherlands and Ireland. The country's deindustrialisation will continue, with the lights being kept on by electricity bought from other countries.

Has Osborne killed CCS in Britain entirely? We don't yet know, and nor do the government officials in the UK's Department for Energy and Climate Change (DECC) who have to pretend that Britain still has a long term climate and energy policy but who now don't actually know what it is.

There could yet be a Plan B; capital grants for CCS may have gone but revenue support could still be made available. Operators of the proposed Hinckley C nuclear power station have been promised that electricity generated will be bought at the rate of at least 92.5p/MWh. CCS developers would be queuing up if a similar offer was made to them.

Climate campaigners who criticise world leaders for want of foresight and vision should point directly at the example set by George Osborne, a villain who has put politics before the planet and his own future before that of his country. His government colleague, climate and energy secretary Amber Rudd, who has consistently praised the virtues of CCS now stands humiliated.

She has been forced to dance like a puppet on a string pulled by Treasury officials, with everyone knowing that she had no hand in this decision and was told of it only hours before the announcement. If anyone at the Paris talks suggests the burning of an Osborne effigy she might be first to offer a match.

More information

See Chris Davies' talk on the business case for investing in carbon capture and storage based on EU's planned emission limits in our report on Finding Petroleum's conference, "Investing in Petroleum under a Carbon Cloud".

COP21 - what it means for CCS in the UK

Ciara O'Connor, Research Manager, UKCCSRC, wrote a series of blogs from the Paris Climate Change Conference - this is her round-up of the result and what it means for the UK.

As at previous COPs, the distribution of the final text, which had been through two weeks of negotiations, and the convening of the final plenary session was delayed…and delayed… BUT on the evening of the 12 December 2015, Laurent Fabius, the French Minister for Foreign Affairs and the COP21 President, brought down his gavel to announce the Paris Agreement had been adopted.

This was a truly historic moment and although, two weeks on, we know the agreement isn't perfect, it is significant that over 180 countries have made this commitment to fight climate change.

So what does the Paris Agreement say? And why is it important for the UK CCS community?

The agreement includes a target to 'hold the increase in the global average temperature to well below 2°C above pre-industrial levels' and 'to pursue efforts to limit the temperature increase to 1.5°C'.

It also underlines, in Article 4, the need to 'reach global peaking of greenhouse gas emissions as soon as possible, recognizing that peaking will take longer for developing country Parties, and to undertake rapid reductions thereafter in accordance with best available science, so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century.'

It is significant that the agreement includes an ambition to get to 1.5°C but some Parties may not feel it's ambitious enough – such as vulnerable island states that were pushing for 1.5°C to be the goal.

In addition, the wording in Article 4 of the agreement, which was preceded in earlier versions of the text by language around 'greenhouse gas emission neutrality', reduction targets and timelines, is disappointing and has been criticised by some delegates and observers.

It is clear that transformative action is needed at the national level to enable countries to meet the targets and commitments they made in Paris as they will now need to, under the agreement, submit action plans outlining how they will curb global emissions, with a five-yearly system of reviewing and ratcheting-up of ambition

As we know, Carbon Capture and Storage is a technology that is key to decoupling greenhouse gas emissions from fossil fuel consumption and so will be of vital importance in a future where the global community strives to limit temperature increase to 1.5°C and meet greenhouse gas emission neutrality in the second half of this century.

How does the Paris agreement affect UK CCS?

At an evidence hearing on the outcomes of COP21, convened by the Energy and Climate Change Committee (ECCC) on the 16 December 2015, the Rt Hon Amber Rudd MP, Secretary of State, Department of Energy and Climate Change, was asked how the UK will meet the 1.5°C target and whether there would be retrospective adjustments to recent changes in UK energy policy in light of the Paris Agreement.

Secretary of State Rudd said the 1.5°C target was aspirational, that moving from the current trajectory of 2.7°C to 2°C takes priority and that the UK's 2°C target, enshrined in the Climate Change Act, is operational. She also stated that she had set out a 'clear direction of travel' in her 'New Direction for UK Energy Policy' speech on the 18 November 2015 and that the future is going to be 'low carbon and value for money'.

This did not prevent the Committee from criticising recent Government decisions to remove subsidies for renewable energy and the announcement on the day of the Spending Review to cut the £1 billion ring-fenced for the CCS commercialisation programme – a move that was branded by the Chair of the Committee, Angus MacNeil MP, as 'penny wise pound foolish' as he called on Ministers to 'resist short term political pressures that seek to slow down low carbon transformation'.

It is difficult to know what the future holds for CCS in the UK but Secretary of State Rudd did state in the ECCC evidence hearing on COP21 that CCS will be necessary in long term plans (2060s and later) to meet ambition and will be important for dealing with industrial sources of CO2.

The question I have is whether any of this will be soon enough to enable the UK to meet the commitments it made in Paris. To quote Lord Deben, Chairman of the UK's independent Committee on Climate Change, 'the UK will have an issue meeting its 2030 target without CCS'.

And so for now, I look forward to the Secretary of State's response to Mr MacNeil MP's request for information on the reason behind the decision to cancel the CCS competition and will watch with interest the one-off session the ECCC is convening on the CCS announcement, on the 12 January 2016.

More information

View Ciara O'Connor's other blog posts:
www.ukccsrc.ac.uk/blog

Do CfDs hold the future for the UK's CCS industry?

The UK Department of Energy and Climate Change controversially scrapped the £1bn Commercialisation Programme last year. Could the consultation on CfDs give a welcome indication of the Government's new intentions for the future of the industry.

By Matthew Billson, Programme Director, Energy2050, University of Sheffield; formerly Head of CCS Strategy & Innovation, DECC 2010-2014

In November 2015, DECC published a short, slightly obscure consultation[1] on Contracts for Difference. The detail of the consultation was on whether to make small legislative changes so as to ensure CfDs could be paid to CCS projects which had been retrofitted to existing power stations.

The consultation closed in December – days after the Government shocked the CCS industry by scrapping the £1bn Commercialisation Programme. How the Government takes forward the consultation could be one of the first indications of its intentions for the future of the industry.

The changes proposed in the consultation were to correct a legislative quirk on how exactly an "eligible generator" is defined – which as currently drafted would exclude power stations from qualifying for a CfD to retrofit a CCS project.

The legislative changes would be relatively straightforward and pain free, but would require some time and resource from the civil servants ensconced in DECC. A commitment to make those changes would provide some reassurance that the Conservative government still foresees CCS as part of the future energy mix.

The new dash for gas as hinted by Amber Rudd's policy reset speech in November, indicated a new fleet of gas power stations. However, as the Committee on Climate Change has pointed out, if many of those new stations are not subsequently fitted with CCS by around 2035 they would likely be obsolete due to tightening climate targets. So making the small legislative tweaks now will play a part in ensuring possible future CCS projects.

Peterhead Power Station in Scotland. The project could proceed without the £1bn capital support, but statements by the consortium involved suggest that could be unlikely (Image ©Shell)

It would also allow the Government to sensibly award the possible funding in the Levy Control Framework which may have been freed up by cancelling the Commercialisation Programme. Whilst in theory both Peterhead and White Rose could proceed without the £1bn capital support, statements by the consortia involved suggest that could be unlikely. So if they are mothballed, there could be several hundred million of pounds available to fund CfDs for future projects – although that may be soaked up by the reported "overspend" in the current LCF period.

Another key awaited announcement which will affect future CCS projects is the size of the Levy Control Framework beyond the current 2020/21 period. It is likely that any so-called "Phase 2" CCS projects – which perhaps now should include the new Phase 1 – will be commissioned in that new LCF period. So whilst legislative tweaks are welcome and necessary, the far more important policy announcement is also still yet to come.

More information

Energy2050 is one of the UK's largest energy research institutes. Based at the University of Sheffield, it has over 120 academics and more than 250 PhD students undertaking energy research and innovation.

energy2050.ac.uk

1 Consultation on a proposed amendment to the Contracts for Difference (Definition of Eligible Generator) Regulation, Nov 2015.
https://www.gov.uk/government/consultations/consultation-on-a-proposed-amendment-to-the-contracts-for-difference-definition-of-eligible-generator-regulations

UK Committee on Climate Change fifth Carbon Budget

The UK Government should continue on the lowest-cost path towards the legal requirement to reduce UK emissions by at least 80% in 2050 on 1990 levels. It should commit to an emissions reduction of 57% by 2028-2032, the Committee on Climate Change says in its fifth Carbon Budget.

Lord Deben, Chairman of the Committee on Climate Change,said, "The UK has been at the forefront of global action on climate change. As a nation, we have begun the transition towards a low-carbon economy.

By legislating the fifth carbon budget at the recommended level, the Government will take the next important step. That will build on its commitment to the UK's existing climate targets and send a clear signal to businesses and consumers that UK climate ambition remains on track through the 2020s and into the 2030s."

The fifth carbon budget marks the half-way point from the first carbon budget period (2008-2012) to 2050. The scientific evidence confirms that without action to limit warming to the globally agreed level of 2°C, climate change will pose serious risks to the UK and around the world. The UK's contribution – as set by the 2050 target – is in keeping with, and helps to promote, wider international climate action.

The UK has made good progress to date, the Committee said. Emissions have reduced by 36% on 1990 levels and if current policies are effective will be down by 43-46% in 2020. In order to meet the legislated fourth carbon budget (2023-2027) emissions must fall by 52%.

The proposed fifth carbon budget continues along that trajectory, and would continue to cut emissions at lowest-cost to UK businesses and households. These are steady emissions reductions equivalent to 2% per year from 1990-2014, 3% per year from 2014-2030 and 4% per year from 2030-2050.

However, to keep within the emissions limits set by the fourth and fifth carbon budgets, and to stay on track to 2050, a number of new policies and clear long-term signals to investors are urgently required.

Scenarios for the fith carbon budget

By 2030, the Committee's scenarios to meet the fifth carbon budget involve:

• By the 2030s around 1 in 7 UK homes are heated using low-carbon sources of energy, helping to reduce emissions significantly and drive further innovation in delivering sources of low-carbon heat.

• By the 2030s, the majority of new cars and vans bought in the UKare fully or partially electric, removing a significant proportion of emissions from transport, improving UK air quality and potentially boosting UK manufacturing.

• By the 2030s, the UK is largely powered by low-carbon sources of electricity, delivering power with emissions of below 100 grammes of CO_2 per kilowatt-hour (compared to 450g today). Low-carbon options in the power sector are important to support emissions reduction in other sectors, such as transport and heating, as well as to reduce emissions from the power sector itself.

• By the 2030s, insulation is installed in nearly all UK homes where it is cost-effective, reducing the cost of energy to households.

The Committee's advice balances a range of statutory duties required by the Climate Change Act. This includes ensuring that carbon budgets are affordable, do not adversely affect the UK's competitiveness, are consistent with energy policy, particularly security of supply, and ensure that potential impacts on fuel poverty are manageable.

The advice also considers the implications of particular circumstances in England, Scotland, Wales and Northern Ireland. The fifth carbon budget delivers on all counts.

The advice is based on a thorough, independent assessment of the evidence. This includes an open call for evidence, roundtable discussions with industry and other stakeholders, and considerable new analysis.

As well as representing the lowest-cost path to meeting the UK's 2050 legal commitment to reduce emissions, action required to meet the budget would also deliver a range of benefits in the areas of health and innovation, the Committee says

More information

The Fifth Carbon Budget can be downloaded here:

www.theccc.org.uk

Prospects for CCS and CCUS projects in the Islamic Republic of Iran

Iran is looking to implement CCS and CCUS projects, beginning with matching sources with nearby storage reservoirs and using CO2 to enhance oil recovery at its major oil fields.

By Amir Mohammad Eslami, CEO Rahbord Energy Alborz Ltd.

In recent years, Iran has increasingly seen problems caused by the effects of global warming inside its borders, such as increases in temperature, disorderly rainfall regime, long droughts and decrease in lake levels. Although these problems have been affected by mismanagement for some time, it is undeniable that global warming is the principle cause, as in the rest of the world.

Port Mahshahr, located in south west Iran, north of the Persian Gulf, saw one of the highest temperatures ever reported on earth last summer.

A letter was published this Oct, predicting that on current trends, future temperatures in southwest Asia are projected to exceed the threshold for human habitation. High-resolution regional climate model simulations show that extremes of temperature in the region around the Persian Gulf are likely to approach and exceed this critical threshold under the business-as-usual scenario of future greenhouse gas concentrations.

In 23 November 2015 The Islamic Republic of Iran submitted its new climate action plan to the UN Framework Convention on Climate change.

I.R. Iran mitigation action includes several parts and CCS has been considered as an essential action. Work on CCS in Iran was started several years ago, by Government alongside the National Iran Oil Company NIOC and in the private sector by Rahbord Energy Alborz ltd, known as a leading Iranian company in CCS and CO2 utilization.

Iran statutes on CO2 emission

In 2012, Iran showed a record 556 Million tons CO2 emissions related to fossil fuel consumption, the highest in the Middle East. At the same time Iran has the largest installed power generation capacity in the region, rising to 72000 MW in 2014 including 25 steam cycle, 78 gas turbine and 15 combined cycle power plants.

"The sleeping lion is awaking in Iran" - Amir Mohammad Eslami, CEO of Rahbord Energy Alborz ltd

In 2012, the power sector emitted 174 Million Tons and industry emitted 94.95 million tones CO2 respectively. By this trend, CO2 emissions from the energy sector will rise to at least 800 million tones by 2035. Such increase in emissions brings global environmental challenges that could be avoided by Carbon Capture and Storage (CCS) projects.

At the same time there is huge capacity for storage in the country : 70 Gt CO2 storage capacity may be present in saline aquifers, approximately 19 Gt CO2 storage capacity could result from enhanced oil recovery (EOR), and 1.1 Gt capacity could result from enhanced gas recovery, indicating great potential for CO2 storage in Iran.[1]

However this estimation just represents a maximum theoretic storage capacity and for example the practical capacity through EOR does not exceed more than 6 Gt. Also point sources are widely distributed in all parts of country, and there is good match between sinks and sources in Iran.

On the other hand, Iran, with a record of over one century of oil production, is currently one of the major oil producing countries of the world .

According to the I.R. Iran oil ministry's 20 year plan, crude and condensate production will achieve 5.7 million barrel per day in 2017 and will rise to 7 million barrel per day in 2035, however several of the old fields have been depleted to an uneconomical level of production and annual reductions in production are reported in these fields, which requires effective Improved Oil Recovery (IOR) and EOR methods.

Currently over 100 million cubic meters of natural gas is re-injected daily to maintain oil production to an economical level. It is estimated that in order to maintain and increase pressure, over 200 million cubic meters per day of natural gas will be needed daily by 2025. A huge amount of suitable fluids must be allocated for miscible EOR in addition to pressure maintenance.

More than 20 million tones per year of CO2 is emitted from power plants and the same amount is emitted from industries located in 4 southern states and provinces of Iran: Kouzestan, Booshehr, Pars and Hormozgan. At the same time, the main share of petroleum and gas production belongs to these 4 states. In some cases, power plants are located just above the oil fields which are suitable for CO2 EOR. Also, these 4 states all are faced with sweet water shortage. Rahbord Energy Alborz studied the possibility of multilateral utilization of southern power plants' flue gas: utilizing heat for water treatment and capturing CO2 for EOR.

Rahbord Energy Alborz and CCS in Iran

Rahbord Energy Alborz ltd is a pioneering Iranian company in CCS and CO2 utilization. Besides CO2 EOR as well as CO2 EGR and deep saline formation storage, Rahbord Energy Alborz works on production of Dimethyl Ether from Hydrogenation of CO2 as a chemical capturing method. Also the company conducts some research programs on CO2 utilization by bio diesel production from micro algae .

Up to now, several projects have been awarded by governmental or private sector clients to Rahbord Energy Alborz ltd. One of the most important clients of Rahbord Energy, is NIOC national Iran oil company. In addition to projects awarded by clients, several studies and technologies have been developed by Rahbord itself according to the company's vision and mission.

Ramin: Capture of 5 Million Tonnes CO2 and its Injection in Khouzestan Oil Fields

Khuzestan state located in south west Iran is the most important petroleum producer state in Iran.

Many of the famous giant and super giant fields such as Aghajari, Maroon, Ahvaz, Parsi, Ramshir, Mansoori, Karanj, Abteymoor and Koupal are located in Khouzestan.

There are several large stationary CO2 sources in Khouzestan including 3 power plants emitting at least 6 million tonnes CO2. Ramin power plant located 25 kilometres north-east of the city of Ahwaz was selected as the source of CO2. Ramin power plant contains 6 units of 315 MW steam turbines with the total nominal capacity of 1890 MW and the actual production capacity of 1748 MW.

Rahbord Energy Alborz ltd investigated and provided conceptual, feed and basic engineering of a CO2 capturing plant with average capacity of 5.2 million tones per year for this huge power plant. All near by oil reservoirs have been screened and evaluated for CO2 EOR.

Ramin power plant 25 kilometres north-east of the city of Ahwaz was selected as the source of CO2 for a full chain CCS project

A complete chain of CO2 capture, boosting, transfer, injection and re-injection facilities in different scenarios according to different reservoirs has been designed by Rahbord Energy Alborz ltd. At this time lab tests of CO2 flooding are going forward and after all economical evaluations and investigations, Rahbord is looking forward to start a pilot test and full scale project.

CO2 Capture from industrial sources

Besides Iran's power sector, a considerable amount of CO2 is emitted from the industrial sector of Iran; many cement factories, steel factories and natural gas refineries are located near oil fields. Rahbord Energy Alborz ltd investigated all non power plant sources in order to supply CO2 required for EOR in addition to low cost CO2 that could be allocated for deep aquifer or saline formation storage.

Rahbord Energy Alborz identified and allocated 5.5 million tonnes per year of high purity CO2 in different industries, in addition to 16 million tonnes per year of CO2 with concentration of 5% to 50%.

Several sources including Ammonia plants, Ethylene Oxide plants, natural gas refineries, cement factories and steel factories were studied and conceptual, feed engineering was performed for most of them as well as starting basic plant design for some of them.

In fact, some of the sources already could be assumed as “Capture Ready” plants and according to Rahbord works, others have capturing plans now.

After selecting and evaluating suitable reservoirs, two different main pipelines will transfer CO2 from sources to nominated reservoirs.

Oxy fuel power plant and combined nitrogen and CO2 injection

In addition to CO2 miscible EOR which is one of the best methods for appropriate reservoirs, nitrogen could be used for pressure maintenance, pressure boosting and even miscible injection if the reservoir pressure is high enough. In addition, according to economical reasons, nitrogen could be used to follow miscible injection in CO2 EOR projects also.

Therefore, a combined power system which can provide CO2 and nitrogen at the same time could be considered as a new solution.

A full study for nitrogen injection has been performed by Rahbord Energy Alborz ltd.

The company prepared a master development plan to develop a giant natural nitrogen reservoir located at the Zagros plant and also designed a centralized air separation unit (ASU) plant as well as distirbuted ASU plants.

Nitrogen injection was studied both for increasing pressure and miscible EOR, in several reservoirs. 3D simulation, well engineering, production unit and surface facility design were included also.

Nitrogen and CO2 production requires oxy fuel power plant installation or oxidizer enrichment in current steam cycle power plants.

Rahbord Energy Alborz completed a variety of studies including ASU design, boosting station, nitrogen & CO2 pipe lines, injection facilities and production facilities .

Site selection, screening and evaluation reservoirs for CO2 EOR

In 2013 Central Oil Production Company (ICOFC) asked Rahbord Energy Alborz to screen and select suitable reservoirs for CO2 EOR. To this purpose, Rahbord Energy Alborz ltd used its own screening software.

Not only Central Oil Production Company reservoirs were considered, Iran offshore reservoirs were also evaluated for CO2 EOR. IOOC works in the offshore region located in the Persian Gulf including 4 regions: Bahregan,Siri, Lavan and Khark, which have 19 productive oil fields.

Due to long time production, water and gas are already injected into several reservoirs offshore. IOOC planned increased production from its field, already 350000 barrels per day is injected to oil fields beside considerable natural gas as secondary recovery.

Develop Technical Software for CO2 EOR and CCS

Selection of the most suitable sites is one of most important factors for successful CO2 storage. This fact as well as limited access to reservoir models by national or international oil companies, motivated Rahbord Energy Alborz to develop a new software for screening suitable reservoirs, short cutting some injection simulations and giving preliminary predictions.

MEC (Miscible EOR Consultant) is a new smart tool for screening suitable reservoirs and selecting the best miscible gas injection process, developed in 2013-2014 to classify the most effective method for miscible EOR.

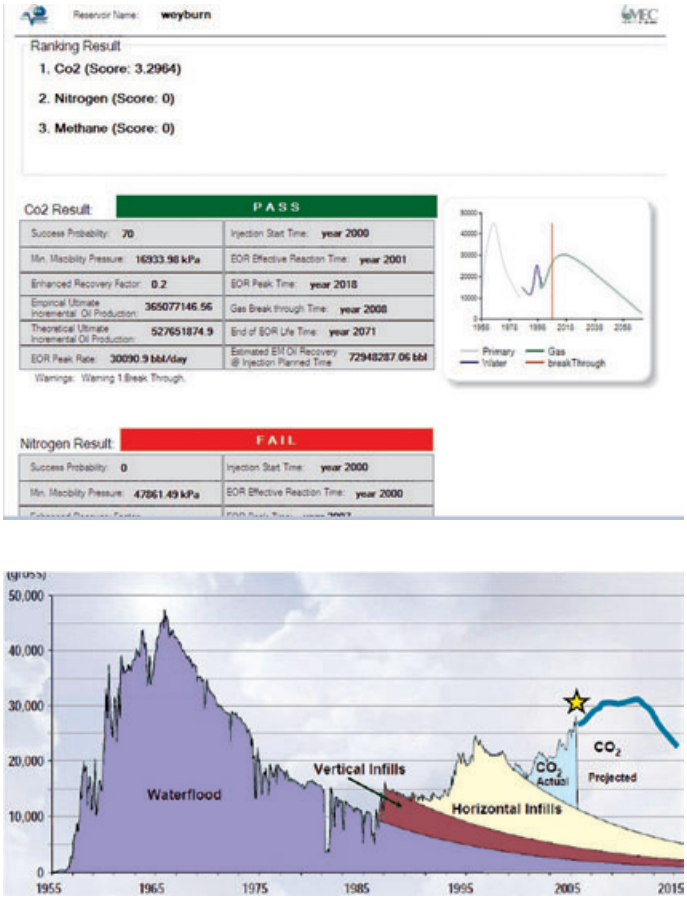
MEC also can sort Miscible EOR methods according to efficiency. It reports oil recovery, breakthrough time, and forecasts operation problems.

The MEC is more flexible about parameter criteria with the ability to update CO2 EOR criteria according to new successful CO2 EOR experiences. Another advantage of MEC in comparison to traditional screening tools is the ability of this software for calculation and prediction of probability of CO2 EOR success. in addition a preliminary production curve prediction could be presented by this software.

CCS adviser is another software originating from modification and basic upgrading in MEC to apply to all CCS project screening. CO2 EOR, EGR, coal bed methane and saline formation, all types of important stationary sources, power plants, iron & steel, cement factory and also petrochemical plants are considered by CCS adviser.

All the necessary correlations and calculations are performed by the software automatically. By performing more applied and analytical assessments, CCS Adviser overcomes problems resulting from uncertainty of binary value of reservoirs and reports more detailed results which allow operators to make better decisions.

This new tool covers the full chain of CCS projects, capturing methods, capturing costs, transportation costs, site selection, revenue, storage capacity and operation problems which can be matched together.



MEC (Miscible EOR Consultant) is a new smart tool for screening suitable reservoirs and selecting the best miscible gas injection process for EOR. The chart shows a prediction for the Weyburn project (above) and how the prediction fits with actual data

CO2 utilization from Ethylene Oxide plant

Another ongoing CO2 utilization project is CO2 recovery from an Ethylene Oxide plant in southern Iran.

In this project, 50000 Tonnes per day CO2 will convert to food grade CO2 and dry Ice and a remaining 100000 Tonnes per year will be transferred to another petrochemical plant and the CO2 consumed as a feed stock.

Rahbord Energy Alborz ltd completed all marketing plans, feasibility, conceptual and feed engineering, executing the project, which will be started May 2016 and before the end of 2016 a recovery plant will be installed and operating.

Other Activities on CCS in Iran

The first CO2 capture from a power plant was installed in 2010 in the Besat plant located south of Tehran. A small capturing plant

150000 tonnes per day of CO2 will be recovered and reused from an Ethylene Oxide plant in southern Iran

with capacity of 18000 tones per year was installed to recover industrial and food grade CO2 from the 225 MW old steam cycle power plant .

Some legal problems occurred in the Besat contract because of transparency which affected this project, also selection of this power plant was not careful and correct.

In 2015, NIGC presented PARSISOL, a customized amine based solvent appropriate for H2S removal from a natural gas refinary in Iran. RIPI claims that this solvent could be used for CO2 capture process too but there is still not a record or report on application of PARSISOL for CO2 capture.

Readiness for Demonstration and large Scale Project in 2016

Now, Rahbord Energy Alborz ltd has finished a considerable part of studies, tests and engineering works for CO2 capture and Storage as well as utilization. All CO2 sources in Iran have been identified, suitable sources ranked and nominated, suitable reservoirs which can meet CO2 EOR criteria have been selected, production history of selected fields was considered, CO2 injection has been simulated and studied in several and production scenarios were extracted.

This successful completion coincides with Iran and western countries agreeing to remove sanctions.

The most recent model of Iran oil field development contract is called IPC, providing better conditions and a framework for CO2 EOR and more motivation.

Rahbord Energy Alborz prepared a long term 30 years plan and road map, along the IEA 450 ppm scenario and new policy scenario. Execution of the road map however depends on government policy, post Kyoto regime and COP decision and will be affected by energy or oil price, but it is clear that it won't be stopped.

According to this plan, up to 150 Million tonnes CO2 yearly could be captured long term and could be stored in saline formations in Iran, used for EOR and EGR and a small share could be used in chemical plants and bio diesel production.

Kermanshah Urea Plant: CO2 is recovered from a gas turbine stack and used to supply a feed stock to manufactur urea, the plant was designed and installed by an Iranian manufacturer

This huge long term plan needs huge engineering potential and financial resources of course but it is clear and relies on several practical economic projects in the short term with good source sink match.

The main focus concentrated on low cost CO2 from high purity streams and power plants close to the oil fields which allows CO2 EOR despite the decrease in oil price.

Rahbord Energy Alborz is going to make more synergy and generate a consortium by other Iranian EPC contractors and upstream companies. Up to now, several agreement have been signed but Rahbord Energy Alborz ltd welcomes any foreign qualified company to start pilot tests and full scale projects.

Up to now, several up stream service companies, consultants and suppliers from different European countries, announced their interest for collaborations dependent on legal regulations between the European Union and Iran.

In any case, the first CO2 capture and storage project and CO2 utilization will be conducted soon.

More information

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National Coal Council paper calls for policy parity for U.S. CCS

U.S. Secretary of Energy Ernest Moniz requested that the National Coal Council develop a white paper that focuses on incentives and policies that can be employed to level the playing field for deploying CCS technologies.

The report, "Leveling the Playing Field for Carbon Capture and Storage Technology", calls for legislators to create a level playing field to deploy carbon capture and storage technologies (CCS) used for coal, natural gas and industrial sectors at commercial scale.

The white paper offers recommendations to create "policy parity" for CCS to achieve diverse energy policy objectives and examines the state of play for clean energy development including coal. Authors have provided a gap analysis defining the difference between the current trajectory of CCS and what is needed to propel its progress.

The white paper was requested by U.S. Secretary of Energy Ernest Moniz in advance of the U.N. Conference of Parties in Paris late this month. The NCC was chartered in 1984 under the Federal Advisory Committee Act (FACA) to advise, inform and make recommendations to the U.S. Secretary of Energy on matters related to coal policy and technology.

"Coal will continue to be a major source of electricity in the United States and globally for decades to come," said NCC Chair Jeff Wallace, retired Vice President of Fuel Services for Southern Company. "The world needs CCS to achieve its environmental goals, and CCS offers the greatest opportunity to capture, use and store significant volumes of carbon dioxide from fossil fuels."

Some 87 percent of global energy is supplied by fossil fuels, and coal is by far the most abundant fossil fuel by reserves. Coal provides 44 percent of the world's electricity. Coal will remain the dominant fuel for power in 2035, accounting for approximately one-third of electricity, according to the BP Energy Outlook 2035. Currently there are more than 2,200 coal units in construction and planned globally.

NCC Report Chair Glenn Kellow, Peabody Energy's President and Chief Executive Officer, explained that the U.S. Department of Energy has stewarded a successful research and development program to spur early development of CCS technologies, though greater support is needed to bring CCS to commercial scale.

"We believe the recommendations in this report will bring much needed advances to commercialize this vital technology and will help guide decisions on global facilities that will operate for years to come," said Kellow. "This report addresses the path to near-zero emissions, which is recognized by global leaders as essential to carbon goals," Kellow said.

In assessing policy parity for CCS, the NCC noted U.S. renewables received 12 times the federal subsidies compared with coal in 2013 even though fossil fuels produced 79 percent of U.S. energy, and renewables 11 percent.

Principle recommendations

• Financial Incentives: Financial incentives for CCS must be substantially increased and broadened to include incentives available to other clean energy sources. Incentives should be emphasized and designed recognizing, as with wind and solar in the 1990s, that CCS is an immature technology with upfront risks and high capital costs. Risk to capital must be reduced, and operating incentives are important to assure a steady long-term revenue stream and lessen direct costs to consumers.

• Regulatory Improvements: A first-of-its-kind regulatory blueprint is needed to remove barriers to construction and development of CCS projects. This blueprint would be applicable to power plants and carbon capture facilities and would apply to transportation and injection.

• Research, Development and Demonstration: The U.S. Department of Energy must be a catalyst for additional commercial-scale demonstration projects, and such projects must commence immediately. The NCC believes that the United States should set a goal of bringing online 5 to 10 gigawatts of commercial-scale projects by 2025, and development must begin now.

• Communication and Collaboration: The U.S. Department of Energy must assure U.S. and global policymakers and other stakeholders that fossil fuels will be used in coming decades to a greater extent than today, and there is a resulting need for CCS. The U.S. Department of Energy should initiate international collaboration to support the prompt deployment of 5 to 10 GW of commercial scale demonstrations in addition to U.S. projects.

More information

The report can be downloaded here:
www.nationalcoalcouncil.org

CCS vital to meeting climate change pledges say environmental NGOs

CCS is an essential and viable part of the solution to climate change, but government policies are urgently needed if it is to be deployed widely, reiterates a report by the ENGO network.

"Closing the Gap on Climate: Why CCS is a Vital Part of the Solution" was released by members of the ENGO Network on CCS at the international conference on climate change in Paris. The report updates a 2012 report, and chronicles CCS development since the 2005 Intergovernmental Panel on Climate Change Special Report on Carbon Capture and Storage, which called for targeted governmental support at the local and international levels to foster the deployment of CCS.

"New government policies, without question, are the missing ingredient today, and the key to enabling substantial and faster adoption of CCS technology, alongside other climate-protection technologies that enable further reductions in CO2 emissions," said David Hawkins, director of the climate program at the Natural Resources Defense Council, a New York-based environmental advocacy organization.

"With each year passing year, the need grows for more rapid deployment of all climate mitigation solutions." "Our new report is a fresh reminder that CCS is not just about coal," Hawkins said. "It is also applicable to natural gas-fired power generation and to key industrial sectors, such as cement, steel and chemicals. What is more, CCS combined with sustainable biomass feedstocks could help us achieve 'negative emissions,' which are increasingly being considered in climate models as a route to limiting global warming to 2°C."

Key report conclusions include:

• With a host of operating projects as living proof, CCS technology is a reality now and not a theoretical future prospect.

• Large-scale CCS deployment that will meaningfully accelerate global decarbonization efforts depends on political will to address the delaying tactics of fossil fuel interests over the past decade.

Summary

The new report re-examine the role of CCS as a technology traditionally perceived as specific to coal-fired power generation, but whose value is now widely recognized as much broader: in the decarbonization of power generation fuelled by natural gas, in the industrial sector, and in the increased focus on removing carbon from the atmosphere through Bio-CCS.

It also assesses the extent to which governments have made progress in instituting laws, regulations and policies that can lead to the meaningful deployment of CCS technology, presenting detailed regional and country perspectives for the European Union, Norway, Canada, the U.S., Australia and China.

The report concludes that, globally, the pace of CCS deployment has proved slower than anticipated, but significant technological and technical progress has been made in recent years, as witnessed by the numerous large demonstration projects now in operation.

These are likely to triple by 2017 compared to the beginning of the decade. Government action and supporting policies remain the missing ingredient, and the key to unlocking more substantial and faster adoption of CCS technology.

Concerted policy efforts will be needed at the regional, national and international levels to overcome this.

- For CCS to deliver on its significant potential, concerted government action at the regional, national and international levels is needed in order to provide a stable market signal and investor certainty.

• More large-scale integrated projects need to be deployed to a degree that will enable movement beyond the initial high-cost phase inherent to any technology that has not yet achieved widespread use. Regulatory, policy and market conditions need to drive widespread CCS investment and cost-reductions through learning and economies of scale.

Network members urged that the Paris agreements also focus on ensuring sufficient funding for CCS deployment globally, and on a mechanism for the transfer of relevant knowledge and know-how from industrialized to developing countries.

Members of the international ENGO Network on CCS are: The Bellona Foundation, Clean Air Task Force, The Climate Institute, E3G, Environmental Defense Fund, Green Alliance, Natural Resources Defense Council, The Pembina Institute, Sandbag, World Resources Institute, and Zero Emission Resource Organisation.

More information

The mission of the ENGO Network on CCS (aka Environmental NGO Network on Carbon Capture & Storage), is to pursue domestic and international policies, regulations and initiatives that enable CCS to deliver on its emissions reduction potential safely and effectively.

www.engonetwork.org

Investing in petroleum under a carbon cloud - oil & gas companies and CCS

Finding Petroleum's conference in London on November 19 2015, supported by Carbon Capture Journal, had a range of talks looking at how oil and gas companies can respond to climate change

Summary

Finding Petroleum's London forum on November 19 2015, "Investing in Petroleum under a Carbon Cloud", covered topics including whether oil and gas companies have to worry about 'stranded assets', which oil companies will be hit hardest by carbon taxes, and will the industry all be shut down by renewables.

Also, how can investors steer companies to reduce emissions, how the industry can get carbon capture projects going, what institutional investors are thinking, and the threat of lithium ion batteries.

There wasn't any conclusion from the conference, except perhaps to say, oil companies are under increasing pressure to 'do something' about the climate, and perhaps getting involved in carbon capture is the best way they can respond to this pressure.

Good guys and bad guys - Belinda Perriman, Teesside Collective

It's the oldest story in the world: the good guys fight the bad guys. Many have cast fossil fuel companies in the climate change story as the 'bad guys' and the renewables companies are naturally the 'good guys'. We need then to be at war with the fossi fuel companies, so goes the narrative. Belinda Perriman asked, "Is there wasa more helful alternative narrative?"

As a society, "we've arrived where we have good guys and bad guys in the climate change story," said Belinda Perriman, Commercialisation Manager at Tees Valley Unlimited, formerly Senior Commercial Advisor, CCS and Oil & Gas with Shell.

The moves to push investors to divest from fossil fuels is like saying, "kill the monster", then life would be great, because the good guys would have won the battle," she said. "It's a dramatic script, slaying the dragon.

"Much as I love windmills, solar panels and my Tesla car, I haven't seen a single forecast from any Advising Body or NGO that shows we can meet the energy needs (even with increased energy efficiency) of a growing population based only on renewables in the next few deacdes. That growth in demand comes from very reasonable requirements for a washing machine, a refrigerator, or for transport that gets us further than a bicycle."

Also, "Energy systems take decades to develop. That unfortunately, doesn't fit the ohter script that someone charges in and saves everyone/the planet just in the nick of time."

Should supporters of carbon capture be telling the story in a different way, she asked, or find a way for the public to accept a more complicated story?

That the 'monster' in the story, climate change, is not something caused by some nasty people who need to be killed, but something caused by ourselves, by society as a whole and our thirst for energy.

"Like so many deeper stories, the bad guy is sometimes within ourselves," she said.

"By meeting the energy needs and ignoring rules of physics that we understood as the industrial revolution kicked off, we have all created much of the problem of climate change."

The October 2015 announcement by 10 oil and gas industry CEOs, saying that they wanted to be part of the climate solution, was encouraging, Belinda felt. Not exactly the story of total reformation of character, but they did express a desire to change and to be working with society in fighting the climate change 'monster'.

The CEOs may have been thinking of the skills their companies have, which could contribute to the climate solution by storing carbon back underground, where it came from, she said.

Sadly, many people just slotted their announcement in the existing 'good guy bad guy' story, she said.

Storage

One way to change the story would be if oil companies work with governemnts for a new business model around garbage collection, helping take society's waste product, carbon dioxide, for a fee.

Oil companies need an incentive to do work on complex projects, that take a lot of time and effort to deliver.

One incentive could be for a government to reduce or have no taxes on CO2 + EOR projects, she said. Having millions of tonnes of CO2 stored at no cost to society is better 'value for money' than paying all the costs.The alternative means of dramatically reducing CO2 emissions into the atmosphere could be significantly more expensive.

A high carbon price would also serve as a good incentive for oil companies to develop

CO2 storage projects, she said.

A carbon capture and storage industry, whether or not combined with EOR, could bring a new generation of people into the oil and gas industry.

Many people are still expecting carbon capture and storage to pay for itself or be 'economically viable' without subsidy. So it is important to note that it is still basically garbage collection, taking away huge volumes of unwanted waste. Even with small volumes being used, it is as likely to be economically viable by itself as your council garbage collection is likely to survive without funding.

Teeside

Ms Perriman currently serves as commercialisation manager for Teesside Collective, a group of heavy industrial plants in Teeside (North of England) that want to cut their emissions by over 90%, tranporting and storing CO2 to geological stores deep below the North Sea.

The project is regrouping after the closure of SSI's Steelworks on Teesside earlier this year, with new members joining the Collective, and new solutions being explored. Emissions from Teesside are still some 7 million tonnes a year.

And a novel idea is being explored: carbon could be separated upstream of the industrial plants. This could use well known technology of steam methane reforming (SMR) of natural gas to form hydrogen, a clean burning fuel, and pure CO2. The hydrogen could then be supplied to the plants as a clean burning fuel, instead of natural gas. This would require different burners, but the existing pipeline distribution network could be used. Teeside already has hydrogen production and hydrogen storage caverns, studied recently by ETI.

And so Teesside Collective are leading the charge, as part of the solution to reduce emissions from heavy industry, in what is perhaps the most dramatic story of our time.

Chris Davies – carbon capture needs industry cheerleaders

The carbon capture industry needs industry cheerleaders to come forward with proposals for taking CCS forward – perhaps starting with the 10 CEOs who signed up to the 'oil and gas climate initiative', said Chris Davies

In October 2015, 10 chief executives of major oil and gas companies signed up to the 'oil and gas climate initiative', with a short report devoting much attention to CCS.

"For people like me that's encouraging. Good stuff," said Chris Davies, the former leader ('rapporteur') for carbon capture and storage in the European Parliament and former MEP for North West England (1999 to 2014).

"But where's the beef? I've seen nothing yet. I don't think there is anything."

"We need cheerleaders. We need companies to come forward with proposals for taking CCS forward."

"I'm not asking them to part with money. I'm not here asking you to shove 500m euros in a black hole. I'm asking you to push the case to governments why they should find the money through levies on fossil fuels."

"We need oil and gas chief executives to start saying very loudly to the European Commission that they need the business case developing, in order to make the investments."

"If there's one overriding objective, it is to promote and encourage political will for carbon capture across Europe."

"It has been political will which has taken forward renewables, it has been political will which will take forward carbon capture."

Government and industry

Carbon capture and storage needs both industry and government to work, because without government support, "there is no business case for investing in CCS."

But also, "there is no business case for investing in renewables if you take away the subsidies."

"There's no business case for investing in gas fired power stations at the moment, which is why they are closing."

"If you want a business case, we know the mechanisms. First of all it's subsidy. Second, you put a price on carbon one way or another."

Download a full report from the conference at ***www.findingpetroleum.com***

"Third, a mechanism which gives the certainty to investors."

"CCS has no purpose whatsoever apart from fighting climate change. It is up to politicians to create the business case which justifies the investment."

EU targets

The European Union set a target to reduce emissions by 40 per cent by 2030, building on a previous target to reduce emissions by 20 per cent by 2020. "That 2030 goal should be perfectly possible," he said.

It is important that the goal isn't achieved by moving heavy industry from Europe to China, which will lead to no benefit to the climate.

It may be possible to achieve even the 40 per cent emission reduction without using carbon capture and storage, he said. But to reduce emissions more than 40 per cent, we will have to find a way to handle emissions from gas power stations, cement plants, oil refineries and large energy intensive industry. "CCS is not going to be the whole answer but it is part of the answer."

"The Intergovernmental Panel on Climate Change (IPCC) and International Energy

Agency (IEA) repeatedly say, if you want to achieve these things at lowest cost you're going to have to apply CCS," he said.

But so far very little progress has been made.

In March 2007, the European Council (a council of European Prime Ministers) set a goal of Europe having 12 CCS demonstration projects by 2015.

"It was European governance by press release. Prime ministers go into a room, they've got to say something, someone says, 'say something about CCS' They write it into the press statement and issue it, without any idea at all how they are going to promote construction of the CCS plants," he said.

"They relied solely on the Emission Trading Scheme driving up the carbon price to provide sufficient incentive, and meanwhile just threw money at renewables."

Now it's 2015, "we don't have a single demonstration plant in operation, and none approved. There are two in Europe, outside the EU in Norway, Sleipner and Snøvhit, which have now stored 20m tonnes of CO2 underground, perfectly safely and well measured and monitored."

In the US, 65m tonnes of CO2 are being stored every year entirely through EOR schemes, compared to 1m tonnes a year in the whole of Europe.

"At the moment many across Europe people are unaware of CCS technology.

There's outright hostility from some member state governments."

Renewables

Supporters of renewables have compared carbon capture with giving an alcoholic a bottle of port instead of whisky, in that it doesn't deal with the problem, it just pushes it back.

"I'm going to point to a little frustration with the renewable sector," he said. "I like renewables, they have a huge role to play, but I wish they would tell the whole story."

A 2013 German study looked at the costs of renewables per ton of CO2 mitigated. It found that onshore wind required a subsidy equivalent to a CO2 cost of €40/tonne (compared to the current €8 price of allowances). But solar power subsidies could amount to the equivalent of a CO2 cost of €500 a tonne.

"You can see why subsidies are being curtailed. Carbon capture and storage could be developed for a fraction of that price," he said.

Also, "I wish the renewable sector would point to the advantage they have with preferential access to the grid," he said.

A carbon capture and storage plant would, similarly, "need guaranteed access to grid to ensure the investment was properly justified," he said.

Tree

Mr Davies' vision for how carbon capture can grow is like the way a tree grows.

Consider that the Dutch ROAD carbon capture project could (if approved) build a pipeline feeding CO2 from a power station into the North Sea.

It would be possible to connect many different Rotterdam industrial plants to this pipeline, also sending CO2 to the North Sea, where there is space for centuries of CO2 storage.

"Before long that pipeline becomes the trunk of a tree, with branches going down to Antwerp and the industrial complexes there, and up toward north Rhine Westphalia and industrial complexes of Germany," he said.

The US has already done it, with 4000km of CO2 pipeline. "You have the basis for all sorts of industries currently emitting CO2 to atmosphere, to store that CO2 permanently in the ground."

"The hard part is getting started, getting from here to there. That's where the political will comes in, the need for some vision, determination to win arguments, insist that progress is made, press for sufficient financial resources.

"At the moment that vision is missing. CCS is too often dismissed."

"If we were to secure some of the reductions in CO2 emission that are absolutely essential to stop temperatures rising, that will has got to be found."

Teeside

From a political point of view, the Teeside carbon capture project, collecting CO2 from heavy industry rather than power generation, could be much easier to sell to the 'green lobby', he said.

"Almost all environmentalists recognise you can't decarbonise industry without CCS because the CO2 is not caused by fossil fuels but with the processes of developing the product," he said.

"Teeside and Rotterdam are the two leaders in terms of developing a case for industrial CCS," he said.

But Teeside carbon capture also does not have any business case at the moment without government support. "It is very attractive but comes down to the need for governments to say, we're going to make this happen."

Enhanced oil recovery

A carbon capture plant in Aberdeen could be the start of a CO2 supply which could be used for enhanced oil recovery (EOR).

"I asked Shell, why have we never developed EOR in the North Sea. They say, 'because we haven't got a source of supply.' It's chicken and egg," Mr Davies said.

"At the moment oil prices don't encourage investment of that kind, but it's there for the future."

Prices

It is fair to expect carbon capture prices to come down. Consider that the team behind the Boundary Dam carbon capture project, in Canada, say they could build the next plant for 30 per cent less cost.

"They find the energy demand is lower than expected. The plant was also designed with methods to capture different trace chemicals, which are not proving a problem. The plant was also built bigger than it needed to be," he said.

"It's a classic case of learning by doing. In renewables everyone says the price will come down, and it will be the same with CCS."

More information

All the talks can be viewed here:

www.findingpetroleum.com

Projects and policy news

Summit signs contracts for Texas Clean Energy Project

www.texascleanenergyproject.com

Summit Power Group has signed a contract with Chinese and Canadian heavy industrial firms at an event in Beijing to build the Texas Clean Energy Project.

The contract is for engineering, procurement and construction, or EPC work, for the more than $2.5 billion plant. Summit is still trying to raise money, but described it as a "major step toward financing and construction".

The contract represented a major hurdle cleared by Summit toward building the Texas Clean Energy Project, a 400 mega-watt coal plant that will capture more than 90 percent of CO2 emissions at its 600-acre site near Penwell and will then sell that carbon to oilfield customers.

"Without this EPC contract being signed, we would not have been able to move forward," Miller said in an email. "The significance of the EPC contract is that (it) gives the equity investors the construction costs and the construction timetable. That's why we had to wait for the EPC to be signed before we could move to the next step, which is getting the equity, firming up the debt, and committing all of that at a financial closing."

The contract covers "the bulk of construction," Miller said. Specifically, it covers engineering, construction, commissioning and operational demonstration of the chemical and carbon capture block for the project.

That work will be integrated with a combined cycle power block from Siemens, which is a series of engines used for generating power. Siemens will also supply coal gasification equipment for the chemical block.

Summit officials expect to finalize a contract with Siemens later this month, Miller said.

One of the firms to sign on Monday was China Huanqiu Contracting and Engineering Corp., also called HQC. The other firm was Montreal-based SNC-Lavalin Engineers and Constructors, whose major responsibilities include construction, construction management and procurement of bulk materials.

The companies, which operate internationally, entered a consortium agreement on the Summit project.

"The U.S. and China have a shared opportunity and responsibility to develop and deploy solutions that help the world transition to lower carbon energy," Summit CEO Jason Crew said in a prepared statement. "TCEP will demonstrate that through thoughtful design, proven technologies, and best practices, Sino-U.S. cooperation can not only deliver low carbon power and chemicals but also support economic growth and thousands of jobs in both countries."

Besides CO2 and power, the plant would produce urea and, to a lesser degree, sulfuric acid. Summit renewed an agreement in October 2014 with CPS Energy in San Antonio to sell electric power to the utility.

Construction contracts represented the greatest challenge for the project, and having them will allow Summit officials to raise debt and whatever remaining equity needed to fund the project, said Jim Wood, a former deputy assistant secretary of energy who specialized in clean coal from 2009 to 2012 and the current director of the U.S.-China Clean Energy Research Center at West Virginia University, who is not a part of the Summit project.

UK cancels £1bn for CCS competition

decc.gov.uk

The UK Government has axed the funding for its CCS competition as part of a spending review.

In a statement released as a regulatory announcement (RNS) on the London Stock Exchange, the Government said, "Today, following the Chancellor's Autumn Statement, HM Government confirms that the £1 billion ring-fenced capital budget for the Carbon Capture and Storage (CCS) Competition is no longer available."

"This decision means that the CCS Competition cannot proceed on its current basis. We will engage closely with the bidders on the implications of this decision for them."

The Carbon Capture and Storage Association called it a dark day for CCS.

Dr Luke Warren, Chief Executive of the CCSA, commented: "Today's announcement that the funding for CCS will be cut is devastating. Only six months ago the Government's manifesto committed £1 billion of funding for CCS. Moving the goalposts just at the time when a four year competition is about to conclude is an appalling way to do business."

"This announcement is a real blow to confidence for companies investing in CCS. We call on the Government to come forward - as a matter of urgency – with their plans for CCS as this technology is critical for the UK's economic, industrial and climate policies."

"Without concrete Government support for CCS the UK will lose the opportunity for cost-effective decarbonisation."

Added to this, Scottish Carbon Capture and Storage reports that DECC may be disbanded altogether, with no climate function retained.

"Well-placed sources at Westminster and in the Department of Energy and Climate Change (DECC) state that DECC will be disbanded after the COP21 Paris climate change talks are over," it said.

UK to end coal power stations without CCS by 2025

decc.gov.uk

UK Energy and Climate Change Secretary Amber Rudd has begun a consultation on ending unabated coal-fired power stations by 2025.

A consultation will be published in the spring of 2016 on when to close all unabated coal-fired power stations and will set out proposals to close coal by 2025 and restrict its use from 2023.

In a new direction for UK Energy Policy, the consultation will look at replacing coal power plants without CCS with gas plants. Renewables and nuclear will also play an increasing role. However the issue of carbon capture for new gas plants was not addressed.

"We now have an electricity system where no form of power generation, not even gas-fired

power stations, can be built without government intervention. And a legacy of ageing, often unreliable plant," she said.

"Perversely, even with the huge growth in renewables, our dependence on coal - the dirtiest fossil fuel – hasn't been reduced. Indeed a higher proportion of our electricity came from coal in 2014 than in 1999.

"So despite intervention we still haven't found the right balance."

"One of the greatest and most cost-effective contributions we can make to emission reductions in electricity is by replacing coal fired power stations with gas.

"I am pleased to announce that we will be launching a consultation in the spring on when to close all unabated coal-fired power stations. "Our consultation will set out proposals to close coal by 2025 - and restrict its use from 2023. If we take this step, we will be one of the first developed countries to deliver on a commitment to take coal off the system.

"But let me be clear, we'll only proceed if we're confident that the shift to new gas can be achieved within these timescales.

Dr David Clarke, Chief Executive of the Energy Technologies Institute, commented, "Stable and clear government policy is critical to engaging industry and investors in development of the UK energy system.

"Whilst today's announcement recognises the need for urgent action to address near-term energy security needs these actions need to be linked to critical longer term strategic decisions – particularly the requirement for any new gas plant to be capable of being fitted with Carbon Capture and Storage (CCS) technology at a future date.

"This also means new gas power stations should be preferentially sited close to the east and west coasts to allow ready, economic connection to a future CCS pipe and storage network.

"CCS is the key economic game changer in a move to a UK low carbon energy system, particularly one based heavily on natural gas, and can halve the cost of meeting UK climate change targets.

"The Government has set out a plan to demonstrate CCS by building the initial pipeline and storage infrastructure and this needs to be sustained as a key example of industry and government working together to deliver secure, sustainable, affordable energy to consumers."

The IEA Clean Coal Centre also pointed to the failure to mention CCS in the speech.

"The IEA Clean Coal Centre has consistently argued that old, unabated coal-fired power plants should be phased out worldwide to lower CO2 emissions. So the plan for this to be part of the process for the UK to meet its climate change commitment of reducing emissions of greenhouse gases by 80% by 2050 is understandable. However, we are concerned that Amber Rudd made no overt mention of carbon capture and storage (CCS), as a way to reduce emissions from any fossil-fuel fired power plant."

"The Centre would like to see the construction of CCS demonstration plants proceed promptly in the UK. For example, if the White Rose project in Yorkshire were to go-ahead it could give an opportunity to provide very low CO2 emitting coal-fired power and provide the basis for a CCS hub so that neighbouring industries could also capture and store their CO2, using the White Rose pipeline.

At one time the UK was a leader in the development of CCS and we know the government has recently given its support for CCS projects, such as £4.2 million for research and feasibility work for a proposed 570 MW CCS coal-gasification power station in Grangemouth, Scotland, awarded in March this year. However, it will certainly be hard to promote and sell the technology abroad if there is no commercial deployment in the UK."

"It is generally accepted that gas-fired power stations emit less CO2 than coal-fired. However, emissions from gas are comparable to those from new top-of-the-range ultra-supercritical (USC) coal-fired plant and would be higher than those from USC coal with CCS. Building unabated gas-fired power stations locks the UK in to substantial emissions from fossil fuels for possibly the next 40 years.

The IEA CCC published a report this year comparing the greenhouse impact of coal and gas. It found that if the rate of methane leakage is more than 3% during the upstream sourcing and processing of natural gas, then the climatic benefit of substituting gas for coal is negated."

"Finally, there was no mention of biomass, which can have a significant impact on CO2 emissions when cofired with coal.

The conversions at Drax have cut emissions of CO2 by 12 mt/y for example. Biomass also has the advantage over other renewables in that it is not intermittent and can use the massive grid infrastructure that is already in place for coal-fired power plants."

"So, the hopes of the CCC rest on Ms Rudd's inclusion of the word 'unabated'. We trust this means that there will be CCS fitted to both coal and gas-fired power plants within the decade."

Southern Company and Korea Electric collaborate on CCS

www.southerncompany.com

www.kepco.co.kr

Southern Company subsidiary Southern Company Services and Korea Electric Power Corporation (KEPCO) will jointly market CCS technologies.

Through the agreement, the companies will jointly explore opportunities for these and other technologies in the U.S., the Republic of Korea and in developing nations.

Among the technologies to be evaluated is Transport Integrated Gasification (TRIG™), developed at Mississippi Power's Kemper County energy facility and marketed by Southern Company and KBR.

The Kemper facility is designed to generate electricity using low-rank coal with resulting carbon emissions better than a similarly sized natural gas plant. At least 65 percent of the plant's carbon emissions are expected to be captured and repurposed through enhanced oil recovery.

The agreement also provides for the testing of KEPCO's carbon capture technologies at the U.S. Department of Energy's National Carbon Capture Center (NCCC) in Alabama, which is operated by Southern Company Services.

Aligned with efforts by the U.S. and Korea to cost-effectively reduce greenhouse gas emissions, the NCCC conducts research and development (R&D) to evaluate and advance emerging carbon capture technologies through integration with a coal-fired power plant and a pilot gasification facility.

Comprehensive review of renewable energy

www.unep.org

A new report presents the environmental costs and benefits linked to different renewable energy sources, and makes one thing abundantly clear: anything is better than coal.

Policymakers, industry and government officials will have to invest US $2.5 trillion for electricity generation over the next 20 years, says a report by the International Resource Panel, hosted by the United Nations Environment Programme (UNEP), and environmentally any alternative is better than coal.

The report, "Green Energy Choices: The Benefits, Risks and Trade-Offs of Low-Carbon Technologies for Electricity Production," takes a cradle-to-grave look at the environmental and health pros-and-cons of nine different renewable sources of energy. It is the first such comprehensive international report to do so.

While the report is filled with important details of the benefits and impacts of different energy choices, the bottom line is clear, says report co-author Thomas Gibon, a PhD candidate at the Norwegian University of Science and Technology's (NTNU) Industrial Ecology Programme.

"Moving away from fossil fuels and coal will help us avoid a lot of environmental impacts, particularly from air pollution and greenhouse gases," Gibon says.

And the difference is considerable, the report says: electricity from renewable sources emits between 90-99 percent less greenhouse gases than coal-fired plants, and causes 70-90 percent less pollution.

Gibon's PhD research formed the underpinnings for the report's analyses.

Pointing out problems to avoid them

Perhaps the most important message in the report is the most obvious: continuing with business as usual and without renewable energy use will double greenhouse gas emissions by 2050, "with serious impacts on human health and the environment," the report says.

Nevertheless, all forms of electricity generation have their impacts, which is where the new report offers important insights for decision makers contemplating a low-carbon future.

One is that building different kinds of renewable energy installations will increase the need for materials such as steel, aluminum, copper, concrete and a variety of rare earth metals compared to "business as usual."

There are two reasons for this, Gibon says. The first is that because most renewable energy sources run only intermittently --a wind farm may generate electricity just 20-25 per cent of the time, for example. That means each kilowatt-hour of electricity requires more infrastructure than conventional sources.

A second challenge is that at least some renewable energy installations have shorter lifespans than their conventional counterparts.

"A wind turbine may have a lifespan of 20-25 years," Gibon said. "So all the material investments you make last 20 years, and then you have to rebuild."

CCS works, but consumes energy

Although it is not a renewable energy source, the researchers looked at the benefits and impacts of retrofitting coal and natural gas fired power plants with carbon capture and storage (CCS).

The good news is that CCS does cut greenhouse gas emissions from fossil fuel plants, with cuts in emissions from modern coal-fired plants of between 74-78 percent compared to plants without emissions controls.

These cuts come at a cost, however. For one, controlling greenhouse gas emissions from coal-fired plants reduces their efficiency, because the emissions capture process requires energy.

"Running CO2 capture facilities requires an increase in energy demand of up to 10 per cent more per kilowatt hour," Gibon said. "It's the energy penalty problem."

CCS also can involve the use of toxic compounds to capture CO2, which have their own impacts. Other environmental impacts include an increase in particulate matter and the emission of pollutants that can overfertilize lakes and the marine environment.

All told, coal- or gas-fired systems increase pollution harmful to the environment and human health by 5-80 per cent compared to the global electricity generation mix in the year 2010, the report says.

Apples to apples

Gibon has been working on the underpinnings for the report for almost 4 years, the entire length of his doctoral research at NTNU.

One of the reasons for this is the enormous complexity involved in compiling available information and making it comparable. The report relies on something called life-cycle assessments, in which all of the impacts of the technology--starting with its construction or manufacture, extending through its useful life and ending with its decommissioning--are considered so that the true environmental costs of the technology can be estimated.

The problem is that these assessments, called LCA, may not be comparable because they are often for different areas of the globe, or span different time periods, Gibon said. Many studies were also focused on greenhouse gas emissions, but the authors of the report also wanted to look at other environmental and human health effects, he said.

In the end, Gibon and his colleagues were able to make all of the results from the different studies of renewable energy consistent, so the report does compare "apples to apples."

Commenting on the study's release, Achim Steiner, Executive Director of UNEP, said it was important for policymakers to have access to this comparative analysis.

"These technologies will be critical to keeping global warming under 2 degrees C, but we need to remain cognizant of their effects on the environment, such as their higher use of metals like steel and copper in manufacturing.

As countries look to meet their energy needs while combatting climate change, this report can help identify the most sustainable mix of energy technologies to accomplish that goal," Steiner said.

COP21 reaches agreement in Paris

After a successfull conclusion of the Paris Climate Change Conference, and the recognition that CCS is an essential and viable mitigation solution for countries to achieve their 'Intended Nationally Determined Contributions' there is renewed opptimism and urgency to move ahead with deploying the technology.

Below are summaries of some of the key CCS-related events and reports at COP21. Meade Harris from the Global CCS Institute provides an overview of their side event on financing of CCS in developing countries. One of the key points of the agreement was Article 6 which could provide the basis of a new Clean Development Mechanism for 'internationally transferred mitigation outcomes' (see Shell Climate Change Advisor David Hone's blog for more on this - **blogs.shell.com**).

Bellona Europa director Jonas Helseth talks about the sub-optimal pace of development in Europe and the key obstacles remaining.

A Roadmap for CCS in China was released at the conference and a report from Biofuelwatch warns of relying on bioenergy with CCS to deliver zero or negative emissions.

'Accord' at the end of the Paris Climate Change Conference in Paris (Image: COP21)

Global CCS Institute side event - financing CCS in developing countries

On Tuesday 8 December the Institute hosted a high profile side event featuring speakers from the Grantham Institute, International Energy Agency and World Bank to discuss the key issues. The Institute's Senior Advisor, Capacity Building & Public Engagement for The Americas, Meade Goodwin, provides a summary of the event.

On Tuesday 8 December, in front of a room full of attendees located within the official 'blue zone' of the UN Climate Talks in Paris, the Institute's CEO Brad Page moderated an event on financing the demonstration and deployment of CCS in developing countries.

Meeting the 2°C goal requires the long-term global decarbonisation of the energy and industrial sectors in a cost-effective manner, and this means significant deployment of CCS is needed in both developed and developing countries over the coming decades. The Institute's side-event discussed ways and means of financing CCS in the energy and industrial sectors, with a focus on developing countries.

The distinguished panel included speakers:

Philippe Benoit – Head of Energy Efficiency and Environment Division, International Energy Agency (IEA)

Anita George – Senior Director Global Practice on Energy and Extractive Industries, World Bank

Lord Nick Stern – IG Patel Chair of Economics and Government, Grantham Institute (LSE)

Rodolfo Lacy Tamayo – Mexico's Undersecretary of Planning and Environmental Policy

Takeshi Nagasawa – Director, Global Envi-

ronment Partnership Office, METI

Abyd Karmali – Managing Director, Climate Finance at Bank of America Merrill Lynch; and GCF private sector representative

Ashok Bhargava – Chair of the Energy Sector Committee and Director, Energy Division - East Asia Department, Asian Development Bank (ADB)

Mr Page provided an overview on the necessary role for developing countries when it comes to CCS development and deployment, stating that to be on track with the 2°C trajectory, CCS will need to be scaled up some 100 times from its current capture capacity.

Lord Stern explained that the most cost effective way you can hold global average temperature rises to 2°C must include CCS. He reflected that while the world is currently capturing some 28 million tonnes (Mt) CO2 per annum from 15 operational projects, much more still needs to be done. He said that "20 projects is not enough. We need 100 or 150 projects. We need to push very hard to get more projects" and in order to get more projects, especially in developing countries, governments must implement strong policies and/or commit to much more public investment in CCS.

Lord Stern closed by identifying the so-called "elephant in the room"; the fact that over 2,700 new coal fired power plants will be built over the next few decades - in addition to about 1,000 existing coal fired plants the IEA believes will still be operational in 2040. In the context of the greenhouse gas stock issue and ever dwindling and finite carbon budget available, Lord Stern said that the world needs a way to keep the associated emissions embedded in the global coal fleet out of the atmosphere. Further, he added that for some industrial processes like steel, aluminium and iron there is no alternative other than CCS.

Philippe Benoit identified 3 core points on CCS:

The IEA's climate analysis indicates that CCS needs to contribute about 13% or 100 billion tonnes (Gt) CO2 of the global cumulative emission reductions required by 2050 to maintain a least-cost track to meeting the 2°C goal.

While there's a lot of discussion on supporting CCS pilot projects, Philippe thinks the discussion should focus on supporting a full scale demonstration project in a developing country by securing "real money". He said that the IEA's analysis indicates that a commercial scale CCS project might require about US$400 million (perhaps grant funding) from, for example, multi-lateral development banks - who are used to this scale of investment; and US$600 million in loans.

Philippe re-enforced the point that this is not an "either/or" for CCS, renewables or energy efficiency; but rather, we need to have all of these technologies if we are to keep below 2°C of warming.

Philippe reiterated that the IEA considers critical the support of CCS projects in developing countries and reaffirmed commitment to working with other international partners such as the Institute to explore appropriate financing models.

Anita George gave an overview of the World Bank's commitment to CCS in developing countries and reflected on how resources might be mobilised to support such projects. She emphasised the work the bank is doing in South Africa, Mexico, Indonesia and China. The World Bank has a dedicated CCS Trust Fund, which provides a forum for all of these counties to compete for capacity development work, studies and pilot projects.

One of her key points was that localised capacity development is critical to develop and deploy CCS. This is why the World Bank is focused on building the capacity upfront - so that pilot CCS projects can be up-scaled to commercial scale.

Ashok Bhargava stated that the ADB is committed to CCS and has a dedicated Trust Fund much like the World Bank (co-funded by the Institute). He observed that developing countries seem to have a primary focus on developing renewables and energy efficiency. But like Lord Stern, he identified the core issue as the demand for coal fired power and industrial products such as iron and steel. He also indicated the ADB's focus is predominately CCUS in China, and last week they launched a CCS China roadmap here at COP21.

Abyd Karmali provided some private sector views on financing CCS investments in developing countries. He said that the Bank of America-Merril Lynch alone managed some US$90 trillion dollars; and so financing CCS it is not a liquidity issue but it is a rate of return issue (noting that it's still in a demonstration phase and not a commercial deployment phase yet).

He also indicated that there needs to be adequate risk sharing in any finance package, scale and aggregation, and liquidity. Financiers tend to hold concerns over a lack of cost-reduction curves for specific CCS technologies and/or learning curves which are available for most renewables. He also suggested that additional concerns exist around emerging markets.

Finally, Rodolfo Lacy discussed Mexico's 15 year history in CCUS. Mr Lacy described the process that his Government has gone through in regard to current energy reform efforts as well as the North American and Mexican Carbon Storage Atlas that was first released in 2014. Mexico has two pilot projects planned that should be up and running by 2017.

Mexico has been focused on three main issues over the past two years as the Government has been working with the Global CCS Institute and the World Bank on capacity development:

• Gas on CCUS: As Mexico does not use much coal the main issue is the application of CCUS to natural gas plants

• Regulations on the life-cycle analysis

• Review of the legal and financial regulations to ensure that CCUS has fair treatment.

Takeshi Nagasawa spoke on Japan's Joint Crediting Mechanism (JCM) which he describes as a bottom-up approach to implementing a market mechanism. He confirmed that METI was interested in including CCS in the portfolio of JCM projects. They have been conducting scoping studies and are hoping that the first JCM project on CCS will be in Mexico and then the next one in Indonesia.

More information

The Institute attended COP21 as an accredited observer advocating for the vital role CCS must play in a broad portfolio of low-carbon technologies needed to decarbonise the global economy.

A range of publications, fact sheets and videos are available here:

cop21.globalccsinstitute.com

www.globalccsinstitute.com

Bellona tells the truth behind CCS's suboptimal pace of deployment

At a Sheffield University-hosted event on Friday, 11 December 2015, themed 'Can carbon capture technologies really deliver on the aims of the UNFCCC?' Bellona Europa's Director, Jonas Helseth, who featured as a panelist during the event, took the opportunity to point out the key obstacles in the way of CCS.

By securing the agreement of nearly 200 countries to limit global temperature rise to 1.5°C above pre-industrial levels, the two-week climate conference in Paris, COP21, set a historic milestone in the UN climate process. Importantly, the attainment of this goal would necessitate the large-scale deployment of deep decarbonisation technologies, such as CCS.

While Bellona hosted a series of events in the blue zone of Le Bourget conference center with the aim of bringing attention to the importance of CCS and Bio-CCS technologies in the climate mitigation portfolio, the only CCS event hosted within the publically accessible climate generations area was the Sheffield University event of last Friday 11 December. Among the panelists featured Bellona Europa's Director Jonas Helseth and representatives from the International Energy Agency (IEA) and the Global CCS Institute (GCCSI).

The inconvenient truths about CCS

Speaking to a full room of new, but curious faces, Helseth took the opportunity of sharing Bellona's views on the reasons behind the current status and sub-optimal pace of CCS deployment in Europe. "The EU is an interesting example of how not to do CCS" noted Helseth while pointing out that the carbon price observed in the EU's Emission Trading System (EU ETS) has been too low and volatile to provide the commercial incentive to drive CCS deployment.

In addition to being failed by the EU ETS and its related funding mechanism, the NER300, CCS has been hindered by major utility companies, the very actors who had the power in their hands to drive the technology's deployment forward. "Major utility companies who failed to adapt to changes in the energy market early on are now experiencing revenue losses and bankruptcy. Interestingly, many of these companies have been riding two horses: in other words, sporadic attempts to develop CCS alongside moves aimed at undermining these very attempts".

Helseth also pointed out that many oil and gas producing companies have a stake in CCS but at best see it as an insurance strategy for their assets, and at worst as a threat to their bottom lines. "The CCS story is largely being told by people who have little credibility in the broader public and notably in civil society" Helseth added. Many of the institutions promoting CCS today have membership consisting of the above-mentioned companies, which provokes suspicion and undermines their ability to reach out beyond those already convinced of the need for the technology.

Bellona Europa Director Jonas Helseth speaking at the event

Building a societal case for CCS

Helseth emphasised that CCS is the only available option to attain deep decarbonisation of heavy industry sectors, such as cement and steel, which account for roughly 30% of global emissions and which have no renewable alternatives. Further to being the sole deep decarbonisation tool for heavy industries, CCS holds enormous employment potential and can help us in ensuring that climate policies do not become incompatible with having a strong industrial base in Europe, as this would undermine the political capital and will to take action.

"The problem is that these heavy industries are not in the room today when the future of CCS is being discussed" – noted Helseth. While the 5th Assessment Report of the IPCC, along with a number of other recent studies, confirms the need for CCS technology in keeping below the 2°C threshold, public acceptance issues have persisted. These, in turn, will not be overcome until we successfully build a societal case for CCS and reach out to a broader audience: "It is not what is being said that people feel uncomfortable with, but rather who is saying it. Conversation with the same people isn't helping" argued Helseth.

It is critical that new voices enter the debate in favor of CCS, lest we fail to instigate the action now that will enable us to deliver full decarbonisation in coming decades.

www.bellona.org

CCS Roadmap for China

On the sidelines of COP21 the Asian Development Bank (ADB) and the National Development Reform Commission (NDRC) of the People's Republic of China (PRC) launched a Roadmap for Carbon Capture and Storage demonstration and deployment in the PRC.

ADB President Takehiko Nakao said he appreciated the PRC's ambitious targets to reduce CO2 emissions per unit of gross domestic product by 40-45% from 2005 levels by 2020, and 60-65% by 2030, peaking out its greenhouse gas emissions around 2030. He commended the PRC for its efforts to establish a nationwide emission trading scheme from 2017.

"Together with the government, we are now selecting a few pilot cities to develop clear pathways to peak out CO2 emissions much earlier for those cities," Mr. Nakao said. "Lessons learned from these cities can be widely disseminated to other areas within the PRC to reinforce city and local level actions."

To date, ADB has provided nearly $4 billion to the PRC for energy efficiency, emission reduction, and renewable energy projects. Out of these, projects approved between 2011 and 2014 amounting to $2 billion will reduce annual CO2 emissions by 25 million tons.

To intensify the partnership, Mr. Nakao and Minister Xie signed a Memorandum of Understanding in January 2014 for cooperation on climate change related issues. For the PRC's 13th Five Year Plan Period of 2016-2020, ADB is recommending even more ambitious mitigation targets for the whole country to peak out emissions earlier than around 2030. This can be achieved through a nationwide emission trading system, more climate investment, and innovative technologies such as carbon capture and storage (CCS).

There are already nine small CCS pilot projects in operation in the PRC. The challenge is to scale up and commercialize. ADB has been assisting CCS in the PRC through technical assistance since 2009.

At the joint event, a roadmap for the PRC to mainstream the use of CCS was launched. It recommends a dual approach. One is to demonstrate low-cost CO2 capture in coal-chemical plants and at one or two coal-fired power plants. The other is to carry out intensive research to overcome high costs and other hurdles in coal-fired power plants.

Wider deployment of CCS would enable the PRC to cut up to 90% of CO2 emissions from its fossil fuel-based power and industrial plants, according to the roadmap. The accumulated CO2 reductions would amount to 10 million–20 million tons by 2020, 160 million tons by 2030, and 15 billion tons by 2050.

Regarding CCS technology, in 2009 ADB set up a CCS Fund with contributions from the Global CCS Institute in Australia, and Department of Energy and Climate Change, United Kingdom to address capacity, knowledge and analytical gaps associated with early stage CCS projects and help prepare large-scale demonstration projects in ADB's developing member countries. Currently, a new technical assistance from this CCS fund is being prepared to assess feasibility of a large-scale CCS demonstration project in the PRC.

Summary

The Roadmap is an assessment of the potential, the barriers and the challenges in demonstrating and deploying CCS in the People's Republic of China. It identifies unique low cost opportunities, recommends a gradual two phase approach to CCS deployment in the country and, provides complementary suite of policy actions to enable it.

Among the report's key messages are:

- CCS demonstration and deployment is essential for cost-effective climate change mitigation
- The PRC can benefit from international experiences
- Unique low-cost CCS demonstration opportunities exist in the PRC
- CCS demonstration faces formidable challenges in the absence of targeted support
- Current low oil prices may have temporarily reduced incentives for CO2
- A phased approach to CCS demonstration and deployment is needed

Can we rely on bioenergy with CCS for emissions reductions?

Biofuelwatch has published a critical analysis of Bioenergy with Carbon Capture and Storage (BECCS), warning against reliance on the technology to achieve net zero emissions.

The report, "Last-ditch option or wishful thinking – Bioenergy with Carbon Capture and Storage" was launched by Biofuelwatch at at COP21 in Paris.

In a press release, Biofuelwatch said that the negotiating text for Paris included references to 'net zero emissions', implying that it is possible to neutralise fossil fuel burning by sucking emitted carbon back out of the atmosphere, and that BECCS is widely promoted as the most 'feasible' and 'near term available' way of removing carbon from the atmosphere. "Biofuelwatch's report demonstrates that relying on BECCS to deliver 'net zero emissions' is no more credible than expecting carbon-sucking extra-terrestrials to do the job," the organisation said.

Report co-author Almuth Ernsting added, "Industry and even spokespersons of the International Panel on Climate Change are speaking about BECCS as if it was a saviour technology, a climate quick-fix that will allow us to continue burning fossil fuels and still avoid catastrophic climate change in the future. Our new report shows that BECCS is nothing more than smoke and mirrors."

BECCS is the combination of bioenergy with Carbon Capture and Storage and, if implemented, would involve capturing CO2 from biomass-burning power stations or biofuel refineries, and pumping it underground. The concept is based on the assumptions that large-scale bioenergy can be carbon neutral, or at least low carbon, and that burying some or all of the CO2 emitted will render it carbon-negative.

It also assumes that CO2, once pumped underground, will definitely stay there forever, and that the technologies required for BECCS are technically and economically viable. Biofuelwatch says its report shows that each of those assumptions is based on wishful thinking rather than solid evidence.

"BECCS proponents claim that the technology could in future remove as much as 10 billion tonnes of CO2 every year, more than a quarter of current global CO2 emissions. This idea has risen to prominence since the International Panel on Climate Change (IPCC), published its most recent Assessment Report in 2014.

Most of the models considered by the IPCC suggest that keeping global temperature rises to within 2 degrees will require BECCS in combination with reductions in greenhouse gas emissions. Now campaigners fear that that policy-makers will be tricked into thinking that so-called 'negative emissions' technologies can contribute to reducing global carbon emissions."

Does the concept of large-scale carbon-negative bioenergy make sense?

Virtually all peer-reviewed studies about BECCS rely on the assumption that, subject to sustainability standards being in place, large-scale bioenergy will be at least close to carbon neutral. None of them discuss the large and growing volume of studies about the direct and indirect greenhouse gas emissions associated with bioenergy.

Evidence shows that existing policies which promote increased use of biofuels and wood-based bioenergy have had serious negative impacts, including on the climate. This is true for EU biofuels, too, despite the fact that sustainability and greenhouse gas standards are written into legislation.

Direct and indirect emissions from land use change for biofuels are so high, that biofuels are commonly worse for the climate than the oil they replace.Wood-based bioenergy has led to increased forest degradation and destruction, and higher carbon emissions from land-use change associated with the expansion of industrial tree plantations. Large-scale removal of 'residues' from forests and agriculture depletes soil carbon and nutrients and harms future plant growth.

For carbon negative bioenergy to be possible, it would not be enough to keep bioenergy-related emissions down: Land-based ecosystems remove 23% of all the CO2 emitted through fossil fuel burning and cement production. Damaging natural carbon sinks for the sake of trying to create a new, unproven artificial one through BECCS would be highly dangerous. Experience with bioenergy so far clearly demonstrates that the basic concept of carbon negative BECCS is a myth.

Are BECCS technologies viable and scalable?

Biofuelwatch's report looks at each of the proposed BECCS technologies in detail. Only one of them has ever been demonstrated: this involves capturing the highly pure stream of CO2 from ethanol fermentation. It is highly unlikely to become commercially viable unless the CO2 is sold for Enhanced Oil Recovery (EOR), i.e. to exploit otherwise unrecoverable oil reserves.

One highly subsidised project involves pumping CO2 from an ethanol plant into a sandstone formation, rather than using it for EOR. However, the CO2 emissions from the fossil fuels which power the refinery, are higher than the amount of CO2 captured and not even the owners of the ethanol plant call it 'carbon negative'.

"Advanced biofuel" production presents a significant opportunity for BECCS, according to the IEA, because it yields pure CO2, which is much cheaper and easier to capture than the diluted CO2 in power station flue gases. Yet the "advanced biofuels" technologies considered by the IEA are not, and might never become viable: nobody has found any way of producing net energy with them.

Capturing CO2 from power stations that burn biomass has never been attempted. This report therefore examines the experience with capturing carbon from coal power plants. Only one commercial scale power plant project exists and it uses post-combustion capture.

An economic analysis shows that if the scheme was operating as intended, with CO2 being sold to an oil company for EOR, it could still not break even financially over its lifetime. A Freedom of Information request revealed that the plant has been beset with serious problems: so little CO2 has been captured that the operators have had to pay fines to the oil company for breach of their CO2 supply contract. Two other technologies exist: oxyfuel-combustion and Integrated Gas Combined Cycle (IGCC) plants with carbon capture.

Oxyfuel combustion with carbon capture has been tested in pilot scheme and found to be highly costly and inefficient with current technical knowledge. IGCC plants are extremely expensive, complex, and failure prone. One IGCC plant with carbon capture is under construction but costs have spiralled from $1.8 billion to $6.4 billion, amidst long delays.

Studies about Carbon Capture and Storage (CCS) tend to assume that prices will come down over time. This is based on the belief in a natural 'learning curve' for all new technologies which inevitably reduces prices, provided enough initial funding is allowed. In reality, such 'learning curves' exist for some technologies but not for others and there is no evidence to suggest that CCS will ever become commercially viable.

The report concludes with an examination of the reliability of carbon storage. All existing commercial CCS projects, (apart from the one malfunctioning power station project), involve capturing pure CO2 streams from industrial processes and using them for EOR. During EOR, around 30% of the CO2 is directly emitted again. Once carbon emissions from the additional oil that is exploited are counted, EOR projects generally result in net carbon emissions – even if 70% of the captured CO2 was to remain securely locked up.

There is a strong industry bias in many studies looking at how securely CO2 can be stored underground, with much of the monitoring being conducted or financed by oil companies. There is now an increasing body of evidence that underground storage is far less reliable than CCS proponents hope.

The argument that we need BECCS seems no more convincing than an argument that we need carbonsucking extra-terrestrials. The availability of largescale carbon-negative BECCS appears no more credible than the existence of such extra-terrestrials. The only proven ways of removing carbon from the atmosphere involve working with nature, i.e. agro-ecology and the regeneration of natural ecosystems.

The pseudo-science about BECCS

Biofuelwatch's research into bioenergy and BECCS raises serious questions about the prevalent discourse on climate change mitigation, not just amongst policymakers but also amongst leading scientific institutions, including the IPCC.

Why is the underlying premise of a large potential for sustainable, low or zero carbon bioenergy not being questioned when there is so much evidence that bioenergy policies meant to realise this assumed potential are contributing to environmental destruction and increased carbon emissions including, at least indirectly, from Indonesia's burning forests and peatlands?

Why do so many studies about the potential for 'sustainable bioenergy' (including for the purpose of BECCS) rely on sustainability standards as a supposedly credible key tool? Why could we not find a single study which attempts to test the hypothesis that sustainability standards can be effective against real-world evidence, in particular against the EU's mandatory biofuel sustainability and greenhouse gas standards, introduced in 2010? Robust testing of hypothesis against evidence lies at the heart of what is known as the 'scientific method' after all.

As the report shows, many other claims made about BECCS and other agencies, such as the IEA, appear far removed from any 'real world evidence' and critical examination.

For example, various studies state that BECCS is a costeffective way of mitigating climate change, as if this was a fact, even though none of the proposed BECCS technologies (except for a small amount of CO2 capture from ethanol refining for sequestration and Enhanced Oil Recovery purposes) have ever been implemented, not even on a very small scale.

Policy makers are being misled about the 'potential' for using bioenergy to scrub CO2 from the atmosphere – and thus into believing that we can continue to burn fossil fuels, continue to achieve economic growth and yet still avoid the worst impacts of climate change. Some of those creating false hopes about BECCS are, predictably, fossil fuel companies such as Shell.

However, the IPCC, the IEA and various academic institutes share some of the responsibility for such poor advice being given to governments and anybody else involved in developing climate-mitigation policies.

The IPCC's conclusion on BECCS and climate change mitigation are particularly disappointing in this context: The IPCC has for years played a vital role in defending the scientific consensus on climate change, by demonstrating that that this is a real scientific consensus based on a wealth of empirical evidence against which models have been tested again and again.

Studies which portent to 'prove' that we can draw carbon out of the air with BECCS or other 'negative emissions technologies', by comparison, generally rely on computer-based models and untested assumptions rather than solid empirical data.

Questions as to whether different BECCS technologies are feasible are rarely explored in studies, and research into the safety of CO2 storage is so closely linked to industry interests that much of it cannot be regarded as remotely independent.

In short, it appears that claims about BECCS – like other 'negative emissions technologies' are based on pseudo-science, coupled with corporate lobbying.

Even if BECCS may never become a reality, the claims about it are highly dangerous:Whether before or after the Climate Conference in Paris, we can ill afford false assurances about ways of removing carbon from the atmosphere – and we can ill-afford false assurances about the possibility of very large-scale industrial bioenergy either.

More information

Download the report at:
www.biofuelwatch.org

Permanently porous liquids for carbon capture

Scientists at Queen's University Belfast have made a porous liquid with the potential for a range of applications including carbon capture.

Researchers in the School of Chemistry and Chemical Engineering at Queen's, along with colleagues at the University of Liverpool, UK, and other international partners, developed the new liquid and found that it can dissolve unusually large amounts of gas, which are absorbed into the 'holes' in the liquid. The results of their research are published in the journal Nature.

The three-year research project could pave the way for more efficient and greener chemical processes, including carbon capture.

The results provide the basis for development of a new class of functional porous materials for chemical processes that could be prepared in commercial quantities from a mixture of readily available reagents.

Although this type of porous liquids might not be competitive with porous solids for gas storage, the researchers envisage other applications, such as gas separation, which would utilize the high concentration of prefabricated cavities in the liquid.

Professor Stuart James of Queen's School of Chemistry and Chemical Engineering said, "Materials which contain permanent holes, or pores, are technologically important. They are used for manufacturing a range of products from plastic bottles to petrol. However, until recently, these porous materials have been solids. What we have done is to design a special liquid from the 'bottom-up' - we designed the shapes of the molecules which make up the liquid so that the liquid could not fill up all the space. Because of the empty holes we then had in the liquid, we found that it was able to dissolve unusually large amounts of gas. These first experiments are what is needed to understand this new type of material, and the results point to interesting long-term applications which rely on dissolution of gases."

"A few more years' research will be needed, but if we can find applications for these porous liquids they could result in new or improved chemical processes. At the very least, we have managed to demonstrate a very new principle - that by creating holes in liquids we can dramatically increase the amount of gas they can dissolve. These remarkable properties suggest interesting applications in the long term."

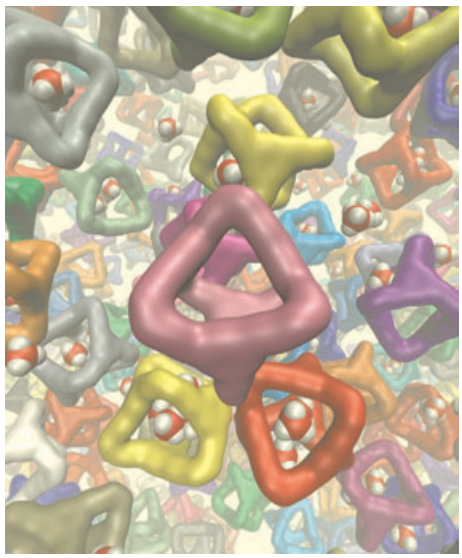
Queen's University Belfast led the research which also involved the University of Liverpool and universities in France, Germany and Argentina. The study was mainly funded by the Leverhulme Trust and the Engineering Physical Science Research Council (EPSRC).

Liquids versus solids

The structural rigidity and robustness of solids allows them to contain permanent, uniform cavities of precise size and shape. By contrast, liquids have fluid structures, and any 'porosity' is limited to poorly defined and transient intermolecular cavities, most of which are smaller than typical molecules.

Porous solids such as zeolites and metal organic frameworks offer major benefits in gas separation processes such as carbon capture, such as lower energy penalties in adsorption desorption cycles, but their solid nature can impose limitations. Liquid solvents, rather than porous solids, are the most mature technology for post-combustion capture of carbon dioxide because liquid circulation systems are more easily retrofitted to existing plants.

Materials that combine the properties of fluidity and permanent porosity could therefore offer technological advantages, but permanent porosity is not associated with conventional liquids. The Nature paper describes free-flowing liquids whose bulk properties are determined by their permanent porosity. To achieve this, cage molecules were designed that provide a well-defined pore space and are highly soluble in solvents whose molecules are too large to enter the pores. The concentration of unoccupied cages can thus be around 500 times greater than in other molecular solutions that contain cavities, resulting in a marked change in bulk properties, such as an eightfold increase in the solubility of methane gas.



'Cages' that can trap gases such as carbon dioxide can be dissolved in a solvent whose moelcules are too large to fit into the cage

To use the 'cage' concept for commercial applications, a manufacturing process using readily available diamine chemicals was developed which results in a liquid containing 'scrambled' cages that have the same properties as the test liquid.

The resulting mixture of scrambled cage molecules has much higher solubility in common organic solvents than similar cages prepared from a single diamine because of increased structural disorder.

Gases such as methane, nitrogen, carbon dioxide and xenon showed enhanced solubilities in the scrambled-cage-based porous liquid.

More information

Read more at:

www.qub.ac.uk

Capture and utilisation news

Aker Solutions CO2 capture for Norcem

www.akersolutions.com

Aker Solutions will conduct a feasibility study on the development of the world's first commercial-scale carbon capture facility for use in cement production.

The company will look at capturing as much as 400,000 tons of carbon dioxide (CO2) a year at Norcem's cement plant in Brevik, Norway, using Aker Solutions' technology. The extended feasibility study will contain an overall design for the facility, including its utility systems, CO2 liquefaction and ship offloading as well as integration with the cement plant.

Aker Solutions' carbon capture technology has been successfully tested for 18 months at the cement plant using a mobile test unit. The tests show that the technology is cost-efficient, robust and flexible during various operating conditions at the plant.

"The promising results of this pioneering project show that our technology can be used to substantially reduce CO2 emissions," said Per Harald Kongelf, head of Aker Solutions in Norway. "We are very pleased that our technology has proven to be the most efficient for further developments in Brevik and we look forward to a continued collaboration with Norcem."

The work for Norcem is part of a feasibility study that will be submitted to Gassnova and the Norwegian Ministry of Petroleum and Energy by the end of May 2016. The Brevik plant has been nominated to become a national carbon capture and storage demonstration project in Norway by 2020.

"The collaboration with Aker Solutions will take Norcem an important step forward in the development of a commercial-scale capture plant in Norway," said Per Brevik, director of sustainability and alternative fuels at Norcem.

Aker Solutions' Mobile Test Unit (MTU) which was operated for eighteen months in a test campaign at Norcem

Underwater solar cells to convert CO2 to fuel

www.stanford.edu

Stanford engineers have developed solar cells that can function under water and convert CO2 to methane.

The research, published in Nature Materials, was led by Stanford materials scientist Paul McIntyre, whose lab has been a pioneer in artificial photosynthesis.

In plants, photosynthesis uses the sun's energy to combine water and carbon dioxide to create sugar, the fuel on which they live. Artificial photosynthesis would use the energy from specialized solar cells to combine water with captured carbon dioxide to produce industrial fuels, such as natural gas.

Until now, artificial photosynthesis has faced two challenges: ordinary silicon solar cells corrode under water, and even corrosion-proof solar cells had been unable to capture enough sunlight under water to drive the envisioned chemical reactions.

Four years ago, McIntyre's lab made solar cells resistant to corrosion in water. In the new paper, working with doctoral student Andrew Scheuermann, the researchers have shown how to increase the power of corrosion-resistant solar cells, setting a record for solar energy output under water.

"The results reported in this paper are significant because they represent not only an advance in performance of silicon artificial photosynthesis cells, but also establish the design rules needed to achieve high performance for a wide array of different semiconductors, corrosion protection layers and catalysts," McIntyre said.

Such solar cells would be part of a larger system to fight climate change. The vision is to funnel greenhouse gases from smokestacks or the atmosphere into giant, transparent chemical tanks. Solar cells inside the tanks would spur chemical reactions to turn the greenhouse gases and water into what are sometimes called "solar fuels."

"We have now achieved the corrosion resistance and the energy output required for viable systems," Scheuermann said. "Within five years, we will have complete artificial photosynthesis systems that convert greenhouse gases into fuel."

Years of work have gone into developing solar cells that could operate in water permeated by corrosive greenhouse gases. McIntyre's lab solved the corrosion problem in 2011, by coating the electrodes in these special cells with a protective layer of transparent titanium dioxide.

This coating is so thin that it would take 25,000 layers to stack up to the thickness of a single sheet of paper. But those first-generation, corrosion-proof cells still couldn't extract enough voltage from the sunlight as it filtered though the water.

Scheuermann has shown how to make the corrosion-resistant solar cells more powerful by adding a layer of charged silicon between the titanium oxide and the basic silicon cell.

The resulting device consists of several layers with different electronic functions. The active silicon layer rests at the bottom, absorbing

sunlight and exciting electrons. Above that active layer sits the new silicon dioxide booster, which increases the voltage. On top of the booster the transparent titanium dioxide seals the system and prevents corrosion, and also serves as a conductor.

These three layers are coated with iridium, which serves as the catalyst that allows CO2 and H2O molecules to meet. The electricity conducted from below breaks the chemical bond on these two molecules and recombines the elements to produce pure oxygen and the natural gas methane (CH4).

This system for artificial photosynthesis works like a battery, but in reverse. In the paper, McIntyre and Scheuermann worked on the positive electrode component of solar cells, called anodes. Other researchers have been working on the complementary cathodes. The record performance of this new anode, combined with current cathode technology, makes the entire system feasible.

Carbon Clean Solutions starts testing at TCM

www.carboncleansolutions.com

Carbon Clean Solutions Limited (CCSL) has started to test its solvent technology at Technology Centre Mongstad (TCM), and aims to commercialize a technology with the potential to halve the energy demand.

CCSL, which was recently included in the World Economic Forum's list of the most promising global Technology Pioneers of 2015, is now demonstrating its technology at TCM to generate long-term testing data at full scale carbon capture.

The test is part of CCSL's plans to further develop its patented APBS chemical solvent, which has the potential of removing up to 50% more CO2 with the same energy requirement, thereby reducing the size of equipment and energy demand. The test campaign will continue until March 2016.

"Our drop-in solvent technology has the potential to dramatically reduce high corrosion, high energy demand and solvent loss. Having demonstrated the technology at pilot scale at the National Carbon Capture Centre, USA, we believe that this new demonstration with TCM can bring the technology to commercial readiness benefiting generations to come," said Aniruddha Sharma, Chief Executive Officer at CCSL.

CO2 Solutions receives further Government funding

www.co2solutions.com

CO2 Solutions has received an additional CAD$350,000 funding from the Government of Canada.

The funding was received from Natural Resources Canada's ecoENERGY Innovation Initiative for CO2 Solutions current carbon capture demonstration project, which is to test a rotating packed bed ("RPB") technology configuration, with the potential of achieving a further reduction of operating and capital costs.

The company had previously entered into a collaboration agreement with GasTran Systems (GTS), giving CO2 Solutions exclusive use of GTS's rotating packed bed technology for CO2 capture. Initial joint testing at CO2 Solutions at a scale of 0.5 tonnes per day (tpd) of CO2 captured showed that using the GTS RPB equipment can potentially lead to a 20 fold reduction in the size of capture equipment as compared to a conventional packed tower approach.

This would significantly reduce capital costs associated with the application of carbon capture technology, as well as increase the applicability of CO2 capture at many emitter locations where space and footprint considerations are as important as cost, such as power plants and refineries.

The additional funding will go towards testing a larger-scale RPB-based system. The test unit, to be built and assembled in Quebec, will be shipped for testing at a premium independent US based facility for research into carbon capture and other environmental technologies.

Work is intended to determine design and costing parameters for commercial application of the new technology. Total cost towards completion of the "add-on" project are estimated at $640,000, which would result in a net expense to the Corporation of $290,000. The project will run until March 2016.

$2.5m for Notre Dame study into ionic liquids

www.nd.edu

Joan Brennecke, Keating-Crawford Professor of Chemical and Biomolecular Engineering at the University of Notre Dame, is the recipient of a $2 million U.S. Department of Energy (DOE) grant.

Brennecke received the grant from the DOE's Office of Fossil Energy, National Energy Technology Laboratory (NETL) to study how ionic liquids, or salt in a liquid state, can improve the efficiency and economics of the carbon dioxide (CO2) capture process. Ionic liquids require less energy than today's approaches to capturing CO2. Brennecke will study the encapsulation of solid compounds that turn into an ionic liquid when they react with CO2 and turn back into a solid when the CO2 is released.

Ionic liquids, Brennecke believes, are a potentially pivotal component of an integrated system that can safely and economically sequester combustion-generated CO2, thereby mitigating its impact on climate change. The liquids have the potential to efficiently capture CO2 from the flue gas of coal-fired plants, as demonstrated in 2004 by a research team led by Brennecke and Edward J. Maginn, Dorini Family Professor of Energy Studies and department chair of chemical and biomolecular engineering, as part of a project sponsored by the DOE's National Energy Technology Laboratory.

Transport and storage news

DNV GL to conduct controlled subsea release of CO2

www.dnvgl.com

DNV GL will conduct the oil and gas industry's largest ever controlled release of carbon dioxide from an underwater pipeline at its full-scale Spadeadam Testing and Research Centre in Cumbria, UK.

The planned underwater release, scheduled to start in January, is part of an international Joint Industry Project (JIP) 'Sub-C-O2' to develop safety guidelines on the use of offshore CO2 pipelines. Companies participating in the JIP are Norway's Gassnova, Brazil's Petrobras, the UK government's Department of Energy and Climate Change, the UK's National Grid and DNV GL. Italy's ENI is expected to join the JIP in early 2016.

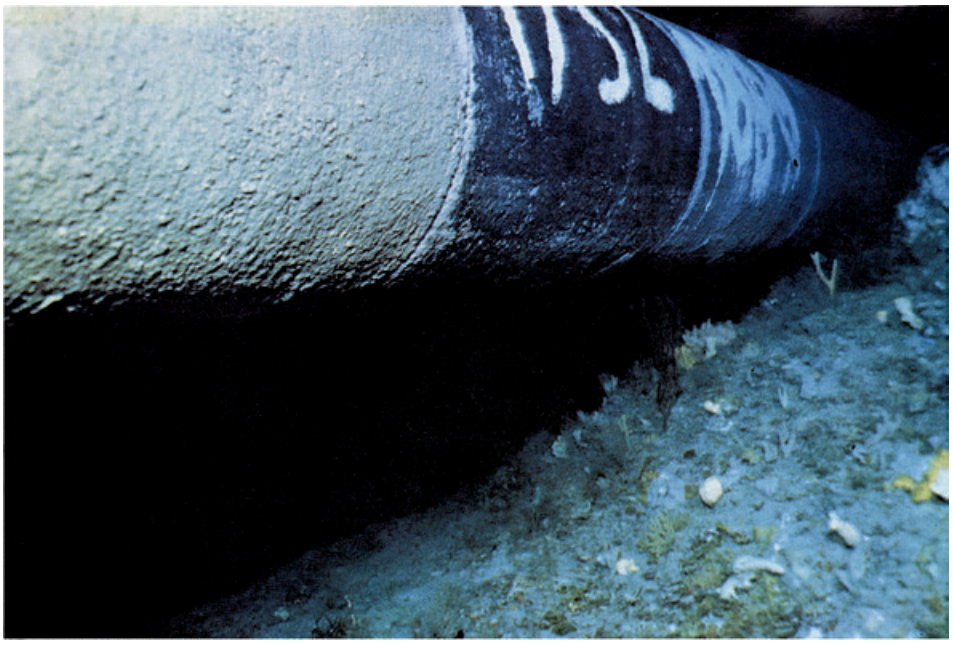
This is the second experimental phase which will run for three months and will involve releases in a 40-metre diameter, 12-metre deep pond at the Spadeadam Testing and Research Centre, which is located in Cumbria, UK.

Experimental findings will be shared periodically with JIP participants so that next steps can be refined. CO2 testing at Spadeadam will conclude by June 2016.

"This is the largest experimental investigation to date of underwater CO2 releases which will study the effects of depth on measured and observed parameters," said Gary Tomlin, VP Safety and Risk, with DNV GL at Spadeadam.

"The testing is designed around what is already known about underwater natural gas (methane) leaks and the possible occurrence of CO2 hydrates collecting on pipework. By using high-speed, underwater cameras and other measurement techniques, we can examine the configuration and characteristics of the released gas. It will allow us to see whether it reaches the surface and analyse what happens."

The first phase of experiments are currently underway at Spadeadam and involves small-scale, controlled CO2 releases from a three inch nominal bore pipeline in a 8.5 metre diameter, three metre deep water tank and are expected to be completed by December.



DNV GL will conduct a controlled release of CO2 from a subsea pipeline to further develop safety guidelines

Statoil to conduct CO2 storage feasibility study

www.statoil.com

The Norwegian Government has tasked Statoil to conduct a feasibility study regarding CO2 storage on the Norwegian Continental Shelf (NCS).

The study will include various development concepts for storing CO2 at three different subsea locations, Utsira, Heimdal and Smeaheia and is to be completed by 1 June 2016 at a budget of NOK 35 million.

The Norwegian Government said its strategy on CCS contains a broad range of activities aimed at developing technologies for capturing, transporting and storing CO2 and this feasibility study is an important step in the strategy's actions aimed at developing full-scale CCS.

Aquistore receives $2.5M in DOE funding for monitoring

aquistore.ca

The funds will be used to develop an intelligent CO2 monitoring system.

The Petroleum Technology Research Centre (PTRC) and the Energy & Environmental Research Center (EERC) at the University of North Dakota have received $2.5 million in U.S. Department of Energy (US DOE) funding awarded through the National Energy Technology Laboratory (NETL).

The project will develop an 'intelligent monitoring system' (IMS) utilizing data acquired through PTRC's Aquistore project. The newly developed IMS will allow future CO2 storage site operators to more efficiently manage operations, data management, and monitoring.

The EERC will work to develop the IMS through real-time, data-capable workflows, algorithms, and a user interface to automate the integration of carbon dioxide (CO2) monitoring and simulation data from Aquistore. Current monitoring technologies require various project teams to acquire and process data to manually combine multiple forms of data in order to manage the program. The IMS will automate many of these steps and substantially streamline the process. By providing a more efficient and cost-effective measurement, monitoring, and verification system, Aquistore and other CO2 storage projects will optimize storage efficiency and costs while minimizing risk.

Managed by the Regina-based PTRC, Aquistore is the storage component of SaskPower's first-in-the-world Boundary Dam CCS Integrated Demonstration project,

North Sea to the Rescue: the commercial and industrial opportunities for CO2 storage in the North Sea

CCS is an indispensable component of national and global decarbonisation pathways as recognised by the IPCC, the IEA, and the European Commission. Using estimates of the CO2 required to be stored in the North Sea for Europe to reach its 2050 decarbonisation objectives, Bellona has estimated the size of the future North Sea CO2 storage sector.

The CO2 storage sector has the potential to become a major North Sea enterprise, employing 22,000 people by 2030. Countries surrounding the North Sea basin must act to encourage the sectors development and to enable Europe to decarbonise effectively.

The key findings of the report were launched at Bellona's COP 21 side event themed 'From extraction to injection: North Sea CO2 storage and the CCS business case'.

Carbon Capture and Storage delivers very substantial CO2 reductions from large industrial and energy facilities that currently pollute. CCS is not a peripheral decarbonisation technology. CCS is an indispensable component of national and global decarbonisation pathways as recognised by the IPCC, the IEA, and the European Commission.

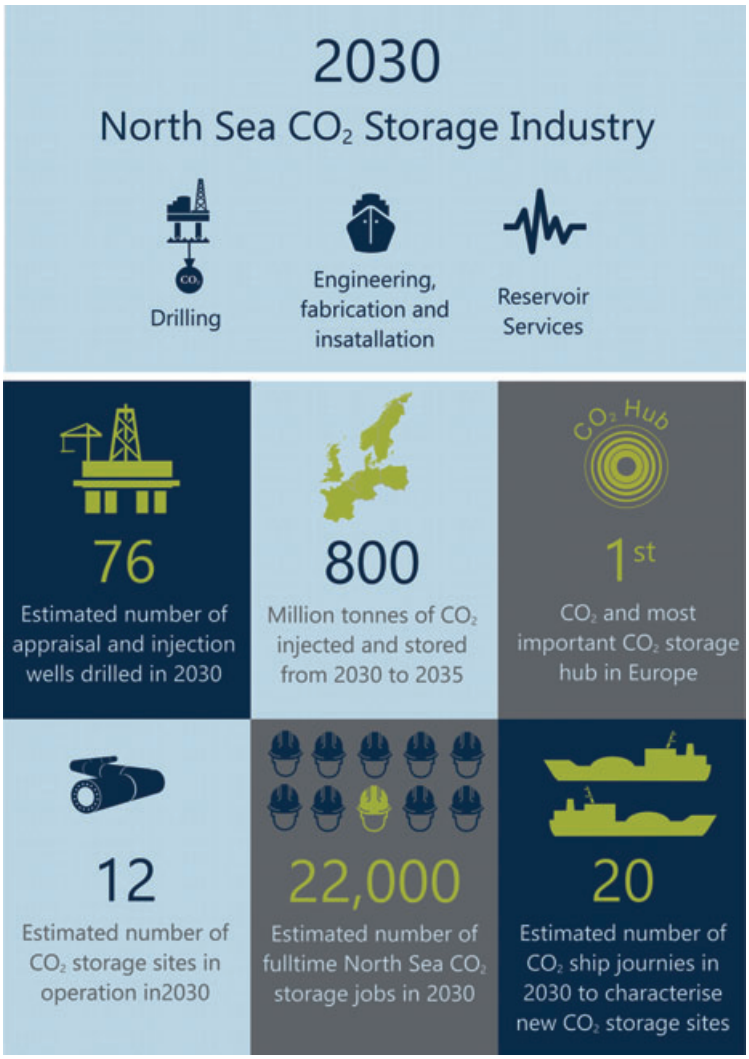
The EU 2050 Energy Roadmap relies heavily on the deployment of CCS to meet EU wide decarbonisation goals (European Commission, 2011). CCS deployment provides a huge opportunity for Europe to meet its energy, climate and societal goals, in particular to achieve its GHG emissions reduction targets at lower cost while satisfying energy security.

The North Sea has a critical role in the permanent storage of CO2 from many of Europe's emitters. The North Sea has immense secure CO2 storage capacity and indigenous offshore industries with the capability to develop and operate CO2 storage complexes.

The development and operation of transport and storage infrastructure has the potential to become a new industry for the North Sea, eclipsing declining hydrocarbon production. Countries that act now to remove commercial barriers and incentivise the sectors development will foster highly skilled employment attract industrial activity and enable the development of technology and service sectors.

Using estimates of the CO2 required to be stored in the North Sea for Europe to reach its 2050 decarbonisation objectives, Bellona has estimated the size of the future North Sea CO2 storage sector.

CO2 storage will require the characterisation of storage sites, the drilling of appraisal and injection wells, the emplacement of CO2 platforms, along with engineering, fabrication and logistics. CO2 storage requires many of the same skills and infrastructure now underemployed or to be decommissioned.



Infographic looking at a potential CO2 storage industry in the North Sea in 2030 (Source: Bellona)

The CO2 storage sector has the potential to become a major North Sea enterprise, employing 22,000 people by 2030. Countries surrounding the North Sea basin must act to encourage the sectors development and to enable Europe to decarbonise effectively.

More information

The report can be downloaded here:
www.bellona.org

Carbon Capture Journal

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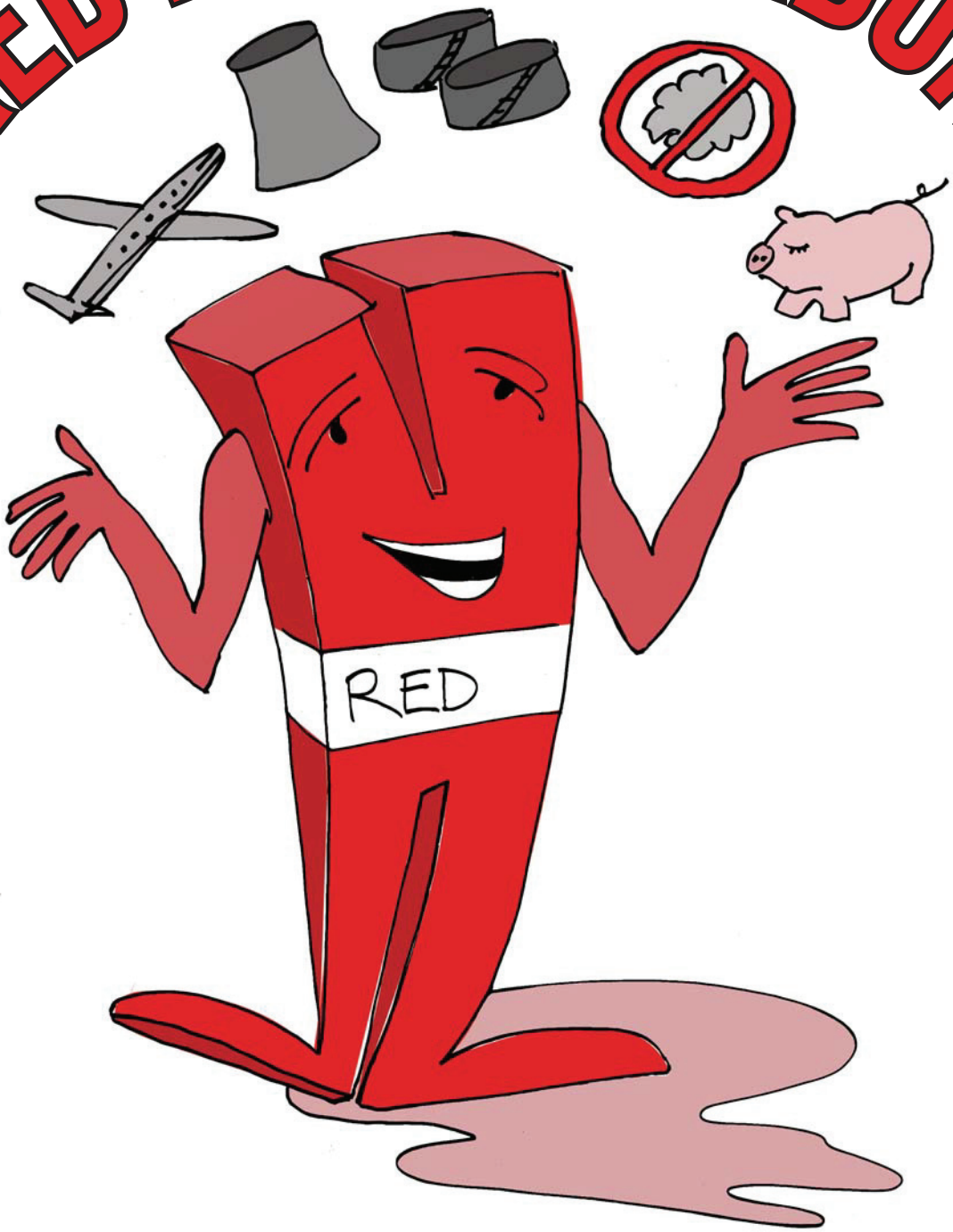

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